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Moss Landing Community

Coastal Climate Change Vulnerability Report


Photo: Don Debold

JUNE 2017

CENTRAL COAST WETLANDS GROUP

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Monterey County and the Community of Moss Landing

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Summary of Findings

This hazard evaluation is intended to provide a predictive chronology of future risks to benefit local coastal planning and foster discussions with state regulatory and funding agencies. Estimates of the extent of assets at risk of various climate hazards were made using best available regional data. 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. The hazard maps provide projected hazard zones for each climate scenario for each of the three planning horizons. For clarity, this report focuses the hazard analysis on a subset of those scenarios, recommended by local and state experts.

- Most of the buildings (15) on the Moss Landing island, some buildings (8) within the Moss Landing Harbor, 3,896 acres of farm land, and 85,798 feet of road are located within the FEMA 100-year flood zone.
- The 2010 ESA Sea Level Rise risk models (excluding wave derived coastal flooding behind tide gates) project that 15 residential and 23 commercial properties and 12,483 feet of road are presently vulnerable to the hazards associated with Coastal Climate Change.
- The most critical protective structures within the Moss Landing area are the two tide gates that control tidal range within the lower Salinas Valley along the Old Salinas River and Tembladero Slough (Potrero Road tide gates) and Moro Cojo Slough (Moss Landing Road tide gates).
- By 2030, a total of 96 buildings are vulnerable to coastal climate impacts (excluding Coastal flooding behind tide gates, and erosion behind seawalls), 60 more than currently at risk (2010 vulnerability assessment).
- Ten buildings within the 2030 hazard area are located on Moss Landing Island, approximately 20 are located in the commercial district, and10 in the residential neighborhood off Potrero Road.
- The beach along the Moss Landing Island is projected to erode inland up to 70ft by 2030, placing the existing structures within the active wave impact zone.
- By 2030, erosion of the dunes south of Sandholdt Bridge will reduce the dune width to less than 200ft, decreasing the ability of the dunes to mitigate coastal flooding risks inland of the Potrero tide gate.
- There is a significant increase in the number of properties at risk of coastal climate change by 2060 and an almost complete loss of services on the island.

- Almost all the commercial district buildings and approximately half of the residences within the Monterey Dunes Colony fall within the 2060 combined hazard zone.
- By 2060 erosion of the dunes near Potrero road and near the Salinas River mouth are at risk of wave overtopping during storms, leading to ocean waves flowing into the Old Salinas River channel, bypassing the coastal flood protections provided by the tide gates.
- By 2100 the increased height of monthly tides becomes the driving hazard for Moss Landing adaptation planning.
- By 2100 much of the agriculture lands south of Moss Landing and west of Highway One will be vulnerable to frequent flooding due to further dune erosion and loss of water control structure functions.

1. Introduction

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[1] 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.

1.1 Project Goals

This project will achieve three key objectives to further regional planning for the inevitable impacts associated with sea-level rise (SLR) and the confounding effects of SLR on fluvial processes within the Moss Landing community. This project will:

1. Identify what critical coastal infrastructure may be compromised due to SLR and estimate when those risks may occur;
2. Identify how fluvial processes may increase flooding risk to coastal communities in the face of rising seas; and
3. Define appropriate response strategies for these risks and discuss with regional partners the programmatic and policy options that can be adopted within Community Plans, Hazard Mitigation Plans, and LCP updates.

The County of Monterey developed and adopted a Local Hazard Mitigation Plan in 2014. This plan works to "identify and profile natural hazards [storm surge, coastal erosion, earthquake, expansive soils, flood, and tsunami] and to lesser extent manmade hazards; assess vulnerability; set local hazard mitigation goals and strategy; and plan for future maintenance of the Local Hazard Mitigation Plan."[2] Sea level rise is not explicitly addressed by the plan, though increased intensity of coastal erosion and storm flooding due to sea level rise are discussed. The plan explores integrated mitigation strategies, which include actions to reduce vulnerability from erosion, flooding, and other natural and human hazards.

The Moss Landing Community Plan[3] discusses sea level rise and the importance of armoring the coastline in order to protect the harbor and its related coastal uses. This vulnerability report is intended to aid future planning to increase resiliency and provide greater detail on the risks to the Moss Landing

[1] State of California. *California Coastal Act of 1976*. http://www.coastal.ca.gov/coastact.pdf

[2] Monterey Multi-Jurisdictional Hazard Mitigation Plan, 2014, ch 2, pg 3

[3] Moss Landing Community Plan, Revised Draft 2014

area 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[4] layers developed in 2014 using funding from the California Coastal Conservancy.

1.2 Study Area

Moss Landing is located on California's Central Coast along the Monterey Bay, in the Northern part of Monterey County. The study focuses within the residential, commercial and harbor district of the Moss Landing Community Plan Area and the surrounding low-lying agriculture and wetland areas, extending from the beaches, harbor and estuaries inland to the boundaries of the Coastal Zone (Figure 1). Specific neighborhoods discussed within this assessment are outlined in Section 2 and shown in Figure 2.

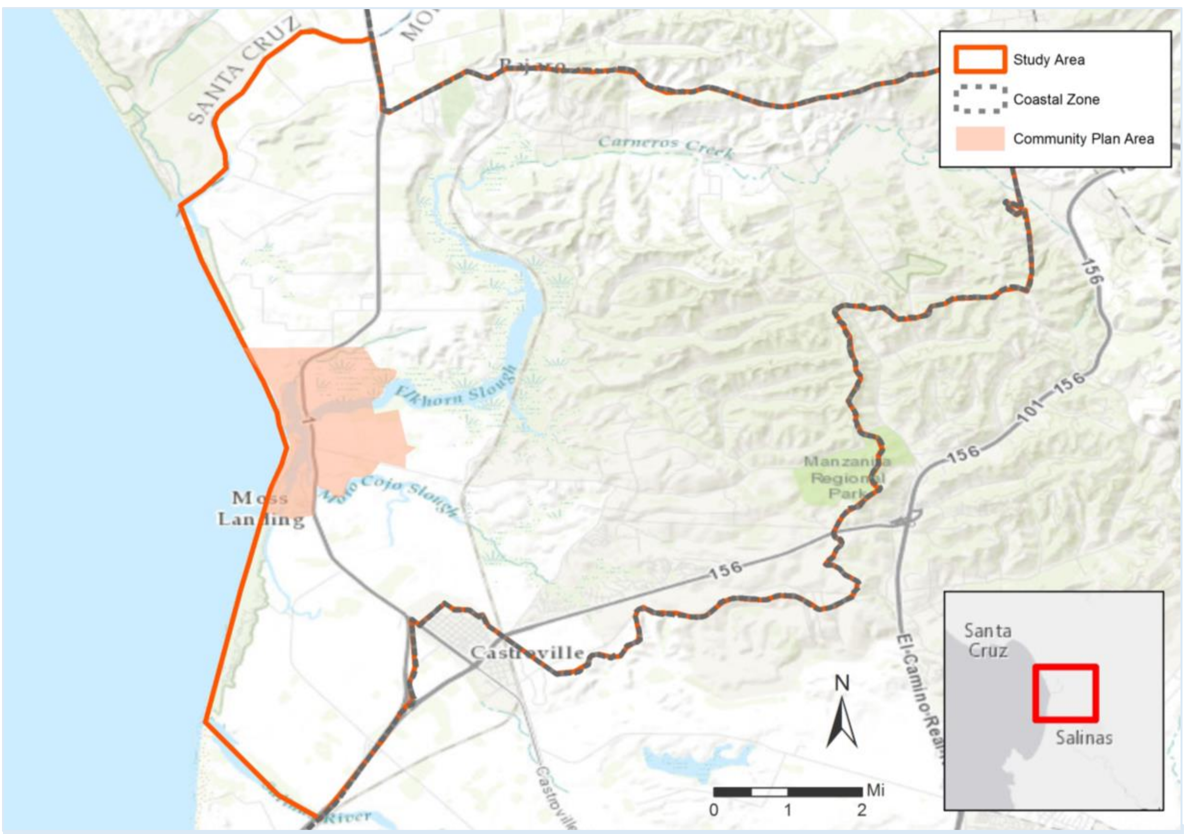

Figure 1. Moss Landing Study Area

[4] 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

2. Community Profile

2.1 Local Setting and Climate

Moss Landing has a mild climate, with average monthly high temperatures ranging from low 60s to low 70s, and average monthly lows ranging from high 30s to low 50s. Moss Landing is often foggy in the summertime, due to the temperature differential between land and sea.

The Moss Landing community is surrounded by water—the ocean, Elkhorn Slough, Moro Cojo Slough, and the nearby Salinas River encircle this historical fishing community. This proximity to the ocean leaves Moss Landing vulnerable to periodic flooding, now and due to climate change, more so in the future. Storm events have impacted the community in the past; including the 1995 flood and the 1982 and 1998 el Nino events. Each of these climatic events has damage infrastructure and properties.

Moss Landing is a small fishing village with restaurants, antique stores, and galleries, best known for its working harbor and proximity to Elkhorn Slough and the productive farmlands of the Salinas Valley. Moss Landing hosts the annual Antique Street Fair and other cultural events and supports the research and educational endeavors of the Monterey Bay Aquarium Research Institute and Moss Landing Marine Laboratories. The seven neighborhoods defined within the Moss landing Community Plan along with the one additonal neighborhood outside of the Community Planning Area (Moss Landing Dunes Colony) are described below.

Island

This mixed-use district is located along the Sandholdt Road separated from the rest of Moss landing by the Old Salinas River Channel. The Sandholdt Bridge connects the harbor to the Island. This area includes the Monterey Bay Aquarium Research Institute (MBARI), the Moss Landing Marine Labs (MLML) Shore Lab, Del Norte Building and Marine Operations, and Phil's Fish Market. Along the east side of this sand spit are numerous harbor facilities.

Village

The Moss Landing Village neighborhood parallels Moss Landing Rd and is Moss Landing's main commercial area. A number of restaurants, antique shops, and other small businesses are located here, as well as the post office and North Monterey County Unified School District. Moss Landing Marine Labs main campus is also located in this area.

Harbor North and South

The Moss Landing Harbor has parking and other harbor and beach access facilities. The harbor supports commercial fishing and recreational boating as well as restaurants. The Jetty Road sand spit is located in along the northeast side of the harbor.

Heights

This residential neighborhood is located along Potrero Road and Pieri Court on the south side of the Moss Landing Community Plan Area.

Elkhorn

This area is primarily wetland habitat that borders Elkhorn Slough and encompasses the Moss Landing State Wildlife Area.

Dolan

This area is primarily zoned for heavy industry and contains the Moss Landing Power Plant.

Dunes Colony

The Monterey Dunes Colony is a residential community located off Monterey Dunes Way south of Moss Landing. This neighborhood falls outside of the Moss Landing Community Plan Area, however.

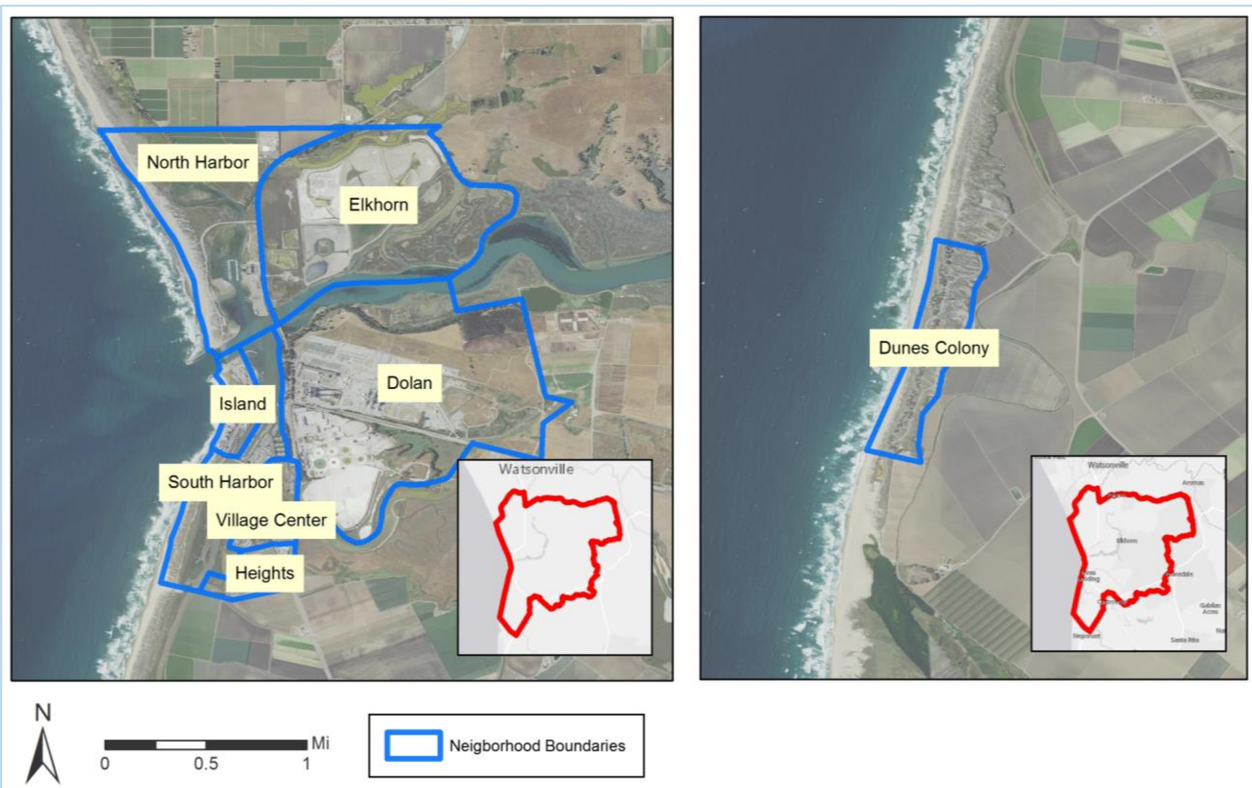

Figure 2. Moss Landing Neighborhoods

2.2 Demographics

The census-designated place of Moss Landing has a population of 200 people (ACS 2014 estimate). Of the 200 people, 145 identify as white and 55 identify their race as other; 163 identify as Hispanic or Latino. The median household income is $30,500, the mean household income is $47,653, and 34.5% of the civilian workforce is unemployed, with 12.5% of people under the poverty line. 80% of people have a high school diploma, and 4.5% have a bachelor's degree or higher.[5]

2.3 Community Resources and Assets

Land Use

Important Facilities: Moss Landing features two important research facilities, Monterey Bay Aquarium Research Institute (MBARI) and Moss Landing Marine Laboratories (MLML), both focused on oceanographic and marine research and education. Moss Landing is also home to a natural gas-powered electric generation plant, which provides electrical power to the Central Coast.[6] The Moss Landing Post Office is located in Moss Landing village.

Monterey Dunes Colony*:* The Dunes Colony features 120 two, three, and four-bedroom vacation homes stretched out over a mile of beach front property. The Dunes Colony is bordered by Salinas River State Beach to the north and south.

Accommodations, Food, and Shopping*:* Moss Landing has one Bed & Breakfast, Captain's Inn, as well as 4 private vacation rentals and a campground. There are 14 shops, and 15 restaurants, cafes, and markets.[7]

Emergency Services: Moss Landing Harbor provides berths for Coast Guard and California Dept. of Fish and Wildlife boats.

Farmland*:* Moss Landing community is surrounded by thousands of acres of productive farmland, growing artichokes, cauliflower, broccoli, turnips, squash and brussel sprouts.

Recreation and Public Access

Beaches, Parks, and Reserves: Moss Landing State Beach, Salinas River State Beach (part of which is designated as the Salinas River Dunes Natural Preserve), and Zmudowski State Beach Park offer great places for surfing, horseback riding, surf fishing, windsurfing, hiking, and wildlife-watching.
The Elkhorn Slough National Estuarine Research Reserve, the Elkhorn Slough State Marine Reserve, and the Moss Landing State Wildlife Area (limited recreation access), encapsulate Elkhorn Slough and its many surrounding wetlands, while also providing more than five miles of hiking and boardwalk trails,

[5] United States Census Bureau, http://factfinder2.census.gov
[6] Moss Landing Community Plan, Revised Draft 2014
[7] Moss Landing Chamber of Commerce, http://www.mosslandingchamber.com/directory.html

and a visitor center with restrooms and a paved overlook road. The slough is also accessible by kayak or small boat from the harbor, allowing up-close viewing of the incredible biodiversity.

The Monterey Bay Marine Sanctuary Scenic Trail runs through Moss Landing, helping link Santa Cruz and Monterey County coastal access infrastructure.

Moss Landing Harbor*:* The Moss Landing Harbor is the number one commercial fishing harbor in the Monterey Bay with 600+ slips for recreational boaters and commercial vessels. Partnering with marine research and education, the Moss Landing Harbor District (MLHD) provides full public access to the environment. Designated as a year-round port of safe refuge, Moss Landing Harbor provides safe, reliable marine refuge and services to boating members of this community.

Coastal Access and Public Parking: Boats within the harbor offer tours of Elkhorn Slough and the Monterey Bay National Marine Sanctuary to observe local wildlife. There are public parking lots and street parking on Jetty Road, just off of Highway 1, to provide easy access to the beach. There are parking lots near Kayak Connections for kayakers, and there are parking lots around the harbor providing access to the Slough and the ocean. Access and parking to Salinas River State Beach is provided at the ends of Sandholdt, Potrero and Molera roads.

Transportation

Highway 1*:* Highway 1 runs through Moss Landing with a bridge crossing Elkhorn Slough.

Rail: The rail line transects the Moss Landing study area passing through Elkhorn and Moro Cojo sloughs. The rail line is operated daily by Southern Pacific for both commercial and passenger service.

Bridges: There are a number of bridges and roads that overpass the complex network of creek and wetland features within Moss Landing.

Natural Resources

Wetlands: Elkhorn Slough's tidal salt marsh provides critical habitats for many species, including more than 135 species of aquatic birds, 550 species of marine invertebrates, and 102 fish species, as well as sea otters, sea lions, and harbor seals. Surrounding wetlands including the Moro Cojo Slough and Old Salinas River provide important habitats for threatened species and flood attenuation during winter storms.

Dunes*:* The beach dunes along Moss Landing State Beach and Salinas River State Beach provide important habitat for many native plants and animals, including the western snowy plover, the white-tailed kite, western fence lizard, beach wild rye, beach bur, yellow sand verbena, and many more species.

Protected Habitats: Monterey Bay National Marine Sanctuary, Elkhorn Slough State Marine Conservation Area, Elkhorn Slough State Marine Reserve, Elkhorn Slough National Estuarine Research

Reserve, Moss Landing State Wildlife Area, Moro Cojo State Marine Reserve, Salinas River Dunes Natural Preserve, and California State Beaches support special status species and their habitats.

Water and Utility Infrastructure

Tide Gates: There are two tide gates in place to help reduce tidal range within the Old Salinas and Moro Cojo sloughs. These structures restrict tidal flooding to large areas of the southern Moss Landing study area but also inadvertently restrict river discharge during large winter storms.

Pump Station*:* There is a wastewater pump station located along Moss Landing Road across the street from the North Monterey County School District office.

2.4 Historical Events

Moss Landing and nearby farmlands are vulnerable to both river and ocean flooding. Monterey County Water Resources Agency describes recent flooding on their website[8] and outlined below in Table 1. The 1995 March floods resulted in County-wide flooding to private property resulting in damage to 1,500 homes and 110 businesses. In Castroville 312 residences and 38 businesses were damaged and 1,320 residents were evacuated. The County describes a second flood event in February 1998 events as;

> *"a series of El Niño winter storms which hit various parts of California, and particularly Monterey County. Close timing of the rainfall events contributed to intense flooding, in that heavy rain would continually hit ground that was still saturated from the previous rain. An estimated 50 roads and highways were closed or restricted, in most cases due to washouts, landslides, and mudslides. Several communities were evacuated, particularly the entire town of Pajaro near Watsonville, all residents of the Sherwood Lake Mobile Home Park near Carr Lake in Salinas, and portions of Bolsa Knolls and Toro Estates. Drinking water quality warnings remained in effect for certain areas for some time afterward. By the end of the first week of February, at least 6,600 homes and businesses had been without power for varying periods of time."*

County-wide, losses resulting from the 1998 event are estimated at over $38 million, with agriculture-related losses totaling over $7 million and damaging 29,000 acres of crops. A similar increase in tidal flooding occurred in 2014 after the failure of the Moro Cojo tide gates which allowed the estuary to fill slowly over numerous months with saltwater (tidal range did not appear to increase). Portions of the Moro Cojo Slough were inundated with salt water above the habitats normal range, leading to the dieback of fringing brackish and freshwater plant communities.

[8] Monterey County Water Resources Agency. Historical Flooding. http://www.mcwra.co.monterey.ca.us/floodplain_management/historical_flooding.php

Table 1. Major Floods in Moss Landing and Northern Monterey County, 1911 to Present
(Sources: Monterey County and California Dept. Water Resources)

DATE	DESCRIPTION OF DAMAGE
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.
February 1938	Salinas River flooded, damaged bridges, crops, and roads.
Winter 1940-41	Closed roads, washed out piers and foundations, flooded streets, most rainfall for any season since 1890.
February 1945	Lots of rain over 36 hours during an extreme dry spell, little damage.
January 1966	32,000 acres of farmland inundated along the Salinas River, estimated $6,572,000 in damage.
January & February 1969	2 successive floods of the Salinas River, lots of damage throughout the county
March 1995	Damage all over the county, mass evacuations throughout, including Moss Landing
February 1998	El Niño winter storms hit, rain and saturated ground, land and mudslides
March 2011	Tsunami, maximum amplitude of 2 meters in the area, Moss Landing damages: $1,020,000
December 2014	Flooding in lower Salinas Valley due to localized rain and flooding in the Gabilan Watershed. Costs to the agriculture industry estimated at more than $1,500,000
Winter 2017	Numerous winter storms hit, dune erosion, rain, saturated ground and flooding, land and mudslides

2.5 Coastal Protection Infrastructure and Management

There are a number of coastal protection structures in Moss Landing that reduce risks of coastal and fluvial erosion as well as tidal, storm, and fluvial flooding (Table 2). Unlike much of the Monterey Bay coastline, most coastal protective structures within Moss Landing are designed to maintain harbor functions and limit inland tidal flooding of agricultural areas.

Table 2. Inventory of Existing Coastal Protection and Water Control Structures in Moss Landing

STRUCTURE LOCATION	TYPE OF STRUCTURE
Rip-rap in front of MLML Aquaculture Center	Rip-rap seawall
Wall in front of MBARI Building	Concrete wall and building wave barrier
Wall in front of MBARI Office Building	Concrete wall and building wave barrier
Hip Wall in front of Phil's Fish Market	Concrete wall
Hip Wall in front of Del Norte	Concrete wall
Moss Landing Harbor Jetties	Rip-rap jetties
Highway 1 Bridge over Elkhorn Slough	Bridge on pilings
Highway 1 overpass above Moro Cojo Slough	Box culvert
Elkhorn road overpass above Elkhorn Slough	Multiple box culverts
Rail road bridge over Elkhorn slough	Wooden Rail bridge
Rail road bridge over Moro Cojo slough	Wooden Rail bridge
Moss Landing Road Culverts	Cylindrical culverts with tide gates
Sandholdt Bridge	Concrete bridge with pilings
Potrero Tide Gates	Cylindrical and box culverts with tide gates
Molera Road Bridge over Tembladero Slough	Concrete bridge with pilings
Dunes Colony Road culverts	Cylindrical culverts
Highway 1 Bridge over Tembladero Slough	Concrete bridge with pilings
Rip-rap in front of ag field at Salinas River Mouth	Rip-rap pile along river channel
Culverts under Castroville Blvd	Multiple box culverts

Rip rap in front of the MLML Shorelab

Remnant concrete structure in front of MLML Shorelab

Hip wall in front of MBARI

Figure 3. Coastal armoring structures of various conditions along Moss Landing shoreline
(Photos: Sarah Stoner-Duncan)

Moss Landing Shoreline Protection Structures

Approximately 1,300 feet of coastal armoring including hip-walls, rip rap, and dune building/restoration, have been constructed along the beach south of the harbor entrance (on Moss Landing "Island") to protect adjacent buildings including the Moss Landing Marine Labs (MLML) Shore Lab and Monterey Bay Aquarium Research Institute (MBARI) (Figure 3). These structures are of various ages, conditions and levels of service. The MBARI sea wall is in excellent condition and the building is designed to be resilient to wave run-up damage that may occur during large storms. The northern MBARI building is protected by a dune enhancement and restoration project that has increased the height of the dunes between the ocean edge and the property. MBARI and MLML Del Norte are further protected by hip-walls that run between the back edge of the dunes and the parking lots of these properties. The Del Norte property is also protected by a dune enhancement and restoration project that has elevated the dunes in front of this property by approximately four feet. The Moss Landing Marine Labs Shore Lab is located directly south of the MBARI facility. This property's seaward edge is maintained by a remnant concrete and steel pad from an old pier that has been destroyed. Rip-rap and concrete rubble of poor condition further protects this property from erosion. As much as 25 feet of the property behind the rip-rap is no longer in use.

Harbor Shoreline Structures

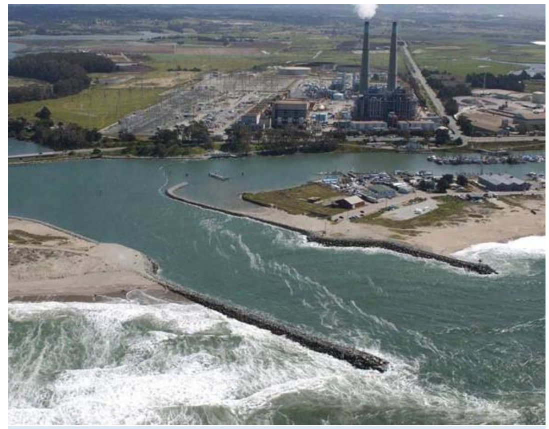

Figure 4. Moss Landing Harbor levees
(Image: Coastal Records Project)

Much of the Moss Landing Harbor is developed for commercial and recreational boating and is comprised of a mix of rip-rap and concrete sea walls. A large amount of harbor related infrastructure was built within the footprint of the historical Old Salinas River. The Harbor entrance is maintained by two large rock jetties that reach more than 1,500 feet out from the main harbor channel into the open Monterey Bay (Figure 4). The harbor mouth and main harbor channel are dredged periodically to maintain operational depth. While the jetties remain in good condition, the sand behind the inland end of structures has eroded by tidal eddies that scour sand and deposit those sediments elsewhere (in the north harbor area). Most of the 2.5 km of the south harbor waterfront is man-made and or hardened with rip-rap or concrete. Only one quarter (0.5km) of the north harbor waterfront is protected or hardened.

Water Control Structures

There are 3 tide gates and 26 culverts that manage river discharges and tidal exchange within this area (Figure 5). Many of these structures are in disrepair, often exacerbated by a complex network of agency ownership and management agreements. Much of this infrastructure was designed to function under static sea level, rain fall and river discharge conditions and may be undersized or unable to function properly under predicted future conditions. Two of the tide gates (Moss Landing Road and Potrero Road) protect the Salinas Valley, South of the harbor from flooding during high tides and ocean storms.

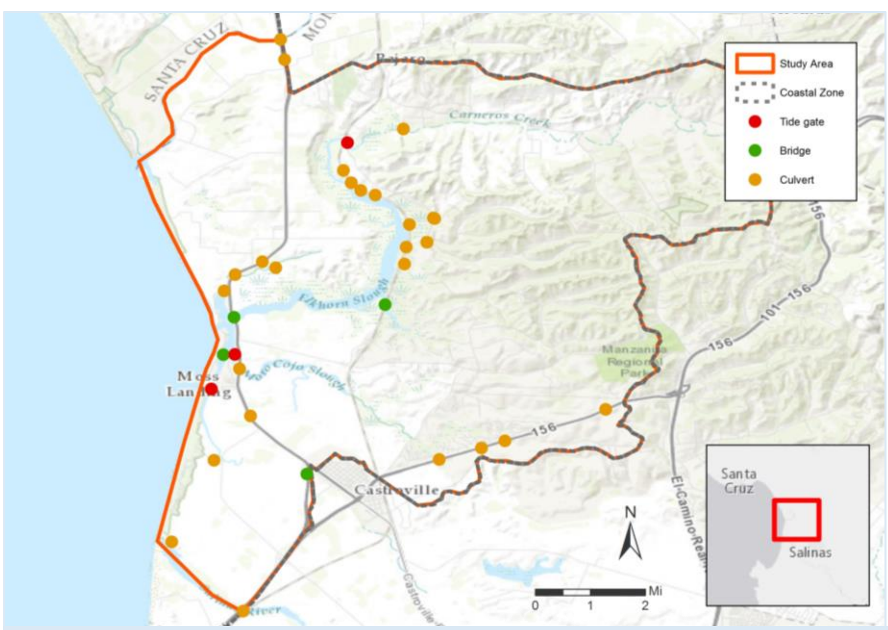

Figure 5. Moss Landing Area water control infrastructure and bridges

Sand Dunes

To the south, the residential properties within the Monterey Dunes Colony rely on native dune restoration and erosion management to protect structures from wave impacts. The dunes also protect the low-lying Salinas Valley from wave induced flooding.

Active Management

Much of the vast historical Salinas River estuary has been "reclaimed" for grazing, agriculture, development, the harbor and other uses. Reclamation efforts frequently included digging drainage ditches to drain flood waters from the marsh edges and the construction of berms along the main channels to keep tide and flood waters from once again flooding these properties. Large portions of these reclaimed lands are no longer useful for agriculture or other purposes because of high ground water and salt accumulation in the soils. The berms that protected these properties have fallen into disrepair and in many locations, have been removed or compromised leading to restored flooding of these properties. The farming lands along the Old Salinas River (OSR) and Tembladero Slough/Gabilan drainage have remained as farmland because of their high productivity, lower (but still significant) salt accumulation within the soils, and relative protections provided by the tide gates. The tide gates at Potrero and Moss Landing roads restrict tidal flooding and salt water intrusion. The OSR/Tembladero has not been flooded (because of the tide gates) by the increased tidal range associated with the opening of the harbor mouth. Much of the Reclamation Ditch is hardened with rip-rap or concrete spoils to reduce channel bank erosion.[9]

[9] The Elkhorn Slough National Estuary Research Reserve has completed a nine-year planning process to prioritize future management of the Elkhorn Slough including the future threats of SLR and climate change, and therefore was not a focus for this vulnerability assessment. Elkhorn Slough Tidal Wetland Project (TWP) characterized four large-scale alternatives designed to decrease tidal scour and associated negative impacts resulting from this artificial mouth. The future implications of Sea Level Rise were reviewed extensively within this planning process. Specific long-term management and SLR adaptation recommendations for the Elkhorn Slough are available within the documents produced by the TWP http://www.elkhornslough.org/tidalwetlandproject/.

3. Projecting Impacts

3.1 Disclaimer: Hazard Mapping and Vulnerability Assessment

Funding Agencies

The hazard GIS layers used in this analysis were created with funding from The State Coastal Conservancy and this Vulnerability Analysis was prepared with funding from the Ocean Protection Council. The results and recommendations within this planning document does 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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3.2 Coastal Hazard Processes

The ESA coastal hazard modeling and mapping effort[10] led to a set of common maps that integrate the multiple coastal hazards projected for each community (i.e. hazards of coastal climate change). There is however a benefit to evaluating each hazard (or coastal process) separately and presented below. Two important limitations of the original hazard maps were addressed within this focus effort for Moss Landing. ESA was contracted for this project to model the impacts of flooding from the combined effects of rising seas and changes in rainfall leading to an increase in winter stream flows. CCWG staff post processed 2030 hazard layers to account for reductions in potential hazards provided by current coastal protection infrastructure (see section 3.3). This refinement of coastal hazard mapping helped to better understand the future risks Moss Landing may face for each coastal hazard process.

It is understood that each modeled coastal process will impact various coastal resources and structures differently. This report evaluates the risks to infrastructure from each coastal hazard for each time horizon. This analysis helps to link risks with 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 Methods Report.[10]

FEMA

FEMA flood hazard maps are used by the National Flood Insurance Program and present coastal and fluvial flood hazards. These maps only assess existing hazards and do not consider future erosion or projected sea level rise and therefore, are believed to underestimate future coastal flood hazards. A recent enhancement of FEMA flood maps has been underway for the California Coastline. FEMA describes the effort as, "Region IX is initiating flood studies/mapping projects in coastal areas as a result of Congressional appropriations for Flood Hazard Mapping under Risk MAP . These efforts will address

[10] ESA PWA. 2014. *Monterey Bay Sea Level Rise Vulnerability Assessment Technical Methods Report*

gaps in required engineering and mapping for high flood risk areas impacted by coastal flooding. Cumulatively, these flood studies/mapping projects are being referred to as the California Coastal Analysis and Mapping Project (CCAMP)." Our review of initial map outputs suggests that the new analysis does account for coastal storm flooding impacts to the Salinas Valley. Once these maps are finalized, overlay of these hazard areas with the hazard layers used for this Moss Landing study would aid local agency understanding of how various hazards are interpreted and how current protective infrastructures are accounted for within the FEMA coastal flood maps.

Combined Hazards

CCWG merged the coastal hazard layers (for the specific scenarios[11] as modified to account for structures) to create a new combined hazard layer for each planning horizon (2030, 2060 and 2100). These merged layers represent the combined vulnerability zone for "Coastal Climate Change" for each time horizon. Projections 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. Therefore, this study also evaluates the risks associated with each individual coastal hazard.

Rising Tides

These hazard zones show the area and depth 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. There are two types of inundation areas: (1) areas that are clearly connected over the existing digital elevation through low topography, (2) and other low-lying areas that don't have an apparent connection, as indicated by the digital elevation model, but are low-lying and flood prone from groundwater levels and any connections (culverts, storm drains and underpasses) that are not captured by the digital elevation model. This difference is captured in the "Connection" attribute (either "connected to ocean over topography" or "connectivity uncertain") in each Rising Tides dataset. 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. Projected risks from rising tides lead to reoccurring flooding hazards during monthly high tide events.

Coastal Storm Flooding

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 predicted wave conditions), and (3) additional flooding caused when rising sea level exacerbate storm surge and wave overtopping. These hazard zones also take into account areas that are projected to erode, sometimes leading to additional flooding through new hydraulic connections between the ocean and low-lying areas. Storm flood risks represent

[11] See the 2017 Santa Cruz County Coastal Climate Change Vulnerability Report for the discussion on scenario selection

periodic wave impact and flooding. These hazard zones DO NOT consider upland fluvial (river) flooding and local rain/run-off drainage, which likely play a large part in coastal flooding, especially around coastal confluences where creeks meet the ocean (analyzed separately for the Moss Landing area).

Dune Erosion

These layers represent future 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.

Fluvial Flooding

A river flooding vulnerability analysis was completed specifically for this study to evaluate the cumulative impacts of rising seas and future changes in fluvial discharge within the Gabilan Watershed. The ESA modeling team expanded hydrologic models of the Gabilan watershed provided by the County to estimate discharge rates under future climate scenarios. The fluvial model estimates localized flooding along the Reclamation Ditch/Gabilan Creek when discharge is restricted behind the Potrero tide gates during high tides. The model results are presented here and the methodology is described within the separate Fluvial Report by ESA[12].

3.3 Scenario Selection and Hazards

The California Coastal Commission guidance document[13] 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 the 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

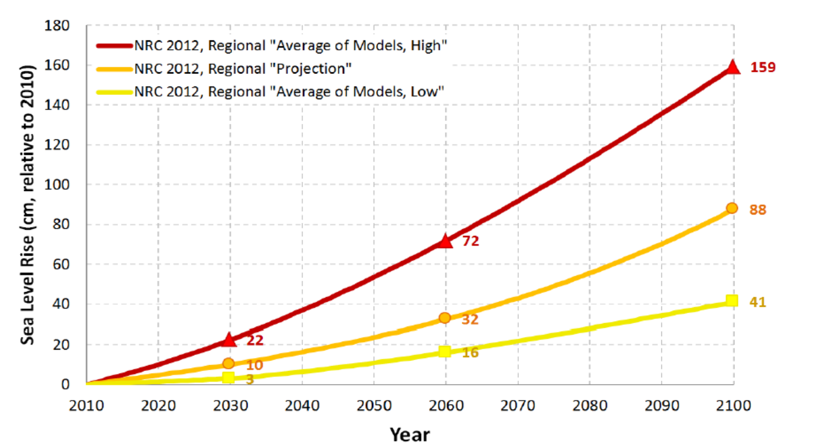


Figure 6. SLR Scenarios Sea Level Rise scenarios for each time horizon. (Figure source: ESA 2014)

[12] ESA. 2016. *Climate Change Impacts to Combined Fluvial and Coastal Hazards*. May 13, 2016.

[13] 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.

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*[14] (Figure 6). 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 developed and natural areas. 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. The climate vulnerability maps used for this study identify hazard zones for each climate scenario for each of the three planning horizons. For clarity, this report focuses the hazard analysis on a subset of those scenarios, recommended by local and state experts (Table 3).

The Coastal Commission recommends all 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. In addition to evaluating the worst-case scenario, planners need to understand the minimum amount of sea level rise that may cause impacts for their community, and how these impacts may change over time, with different amounts of sea level rise.

Table 3. Coastal Hazard 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)

[14] 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.

3.4 Assumptions and Modifications to ESA Hazard models

Coastal Armoring and Tide Gates

The ESA coastal hazard projections do not account for the protections that existing water control structures and coastal armoring provide to reduce coastal erosion and coastal flooding (both storm flooding and rising tides). Because existing armoring and tide gate functions are not accounted for, the areas identified as vulnerable by the original coastal erosion ESA GIS layers overestimate future erosion, coastal storm flooding, and rising tides hazard zones (as recognized within the ESA supporting documentation). To address this issue, a GIS layer of existing coastal armoring was referenced to identify areas where some level of protection currently exists.[15]

To account for the protections provided by coastal armor and tide gates, assets located behind those structures were removed from the 2010 and 2030 erosion, coastal storm flooding and rising tides vulnerability analysis. In many cases, properties were reclassified as “protected” from coastal hazards by recognizing the protections those structures provided. Coastal flooding layers accounted for the height of coastal structures (hip walls etc.) and predicted the potential for wave overtopping and flooding that may occur with those structures in place. Some structures were therefore identified as protected from coastal erosion and vulnerable to coastal flooding.

Because the life span of coastal infrastructure is limited, this vulnerability analysis assumes that all existing coastal protection and tide gate infrastructure will fail and need to be removed, replaced or significantly redesigned at some point between 2030 and 2060. Once these structures fail, erosion will accelerate and quickly meet projected inland migration rates (as documented at Stilwell Hall, Fort Ord) unless protective measures are implemented. Therefore, the vulnerability analysis for the 2060 and 2100 planning horizons assumes that current coastal armoring and tide gates will no longer function and that the modeled hazard zone layers provided by the ESA technical team fully represent future hazards for these time horizons.

3.5 Assets Used in 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 Central Coast Wetlands Group. Assets that fell outside of the planning area were not included in this report. Several data layers that were intended to be used in this analysis were not available (Table 4).

[15] California Coastal Commission. 2014. *GIS layer of existing coastal armor structures in Santa Cruz County.*

Table 4. 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[16]
	Farmland	Analyzed
	Military	None in Planning Area
	Historical and Cultural Buildings	Not used in analysis[17]
Water and Utilities Infrastructure	Sewer Structures & Conduits	Unable to obtain data
	Water Main Lines	Unable to obtain for analysis
	Gas	Unable to obtain for analysis
	Storm Drain Structures & Conduits	Analyzed (partial data set)
	Tide gates and Culverts	Analyzed
Parks, Recreation, and Public Access	Coastal Access Points	Analyzed
	Parks	Analyzed
	Beaches	Analyzed
	Coastal Trail	Analyzed
	Coastal Access Parking	Analyzed
Transportation	Roads	Analyzed
	Rail	Analyzed
	Bridges	Not used in analysis
	Tunnels	None in Planning Area
Natural Resources	Wetlands	Analyzed
	Critical Habitat	Analyzed
	Dunes	Analyzed

[16] Building foot print layers were used instead of parcels maps to better project future structural vulnerabilities.
[17] The data are available but not reported within this document.

4. Combined Impacts of Coastal Climate Change

4.1 Background

Previous storm driven damage to the Moss Landing shoreline and low-lying areas was derived from the combination of several different types of impact. Waves damage buildings through blunt force impact. Waves overtop dunes and sea walls leading to localized or extensive flooding of low lying areas. Flooding is often exacerbated by storm drains and tide gates that impede drainage of those waters to the ocean. Future risks of flooding and wave impact damage will be magnified as higher local sea levels and greater wave heights combine during winter storms with higher river discharges. Greater wave impact intensity will cause greater damage to coastal structures and wave heights will extend risks of damage further inland as waves overtop coastal structures more intensively and propagate further up the Moss Landing Harbor, Elkhorn Slough and Old Salinas River. These cumulative threats are termed within this document as the risks of “Coastal Climate Change.”[18]

4.2 Existing Vulnerabilities

FEMA

Federal Emergency Management Agency (FEMA) has produced flood hazard maps that identify several portions of the Moss Landing Community as vulnerable to river flooding during a 100-year flood event (based on historical rainfall data, new maps are expected to be available soon). FEMA identifies most of the buildings (15) on the Moss Landing Island, some buildings (8) within the Moss Landing Harbor, 3,896 acres of farm land, and 85,798 feet of road located within this 100-year flood zone. Most residential development is located outside of the FEMA flood zone.

Recent flooding events resembled that projected by the FEMA Flood Hazard maps. On December 11, 2014, localized rainfall within the Gabilan hills caused discharges of almost 700cfs within the Reclamation Ditch (Gabilan Creek) while, during that same period, the Salinas River flow did not surpass 10cfs (Figure 7). River flows increased during winter king tides, reducing discharge capacity through the Potrero and Moss Landing tide gates, causing significant flooding of agriculture lands within the lower Salinas Valley. Flood damage was estimated at more than two million in crop losses.

[18] This study did not investigate the risks from increased heat, decreases in water supply or increases in threats from fire that are also predicted due to climate change.

Flooding as projected within the FEMA 100-year hazard maps is expected to become more frequent (i.e. 10–20 year intervals) due to changing rainfall patterns associated with climate change. The Monterey County Hazard Mitigation Plan suggests that, "Based on previous occurrences, Monterey County can generally expect a serious flood event to occur every 4 years." The future threats from increases in river flows during less frequent but more intense rain events were investigated within this project and are reported in Section 5.3.

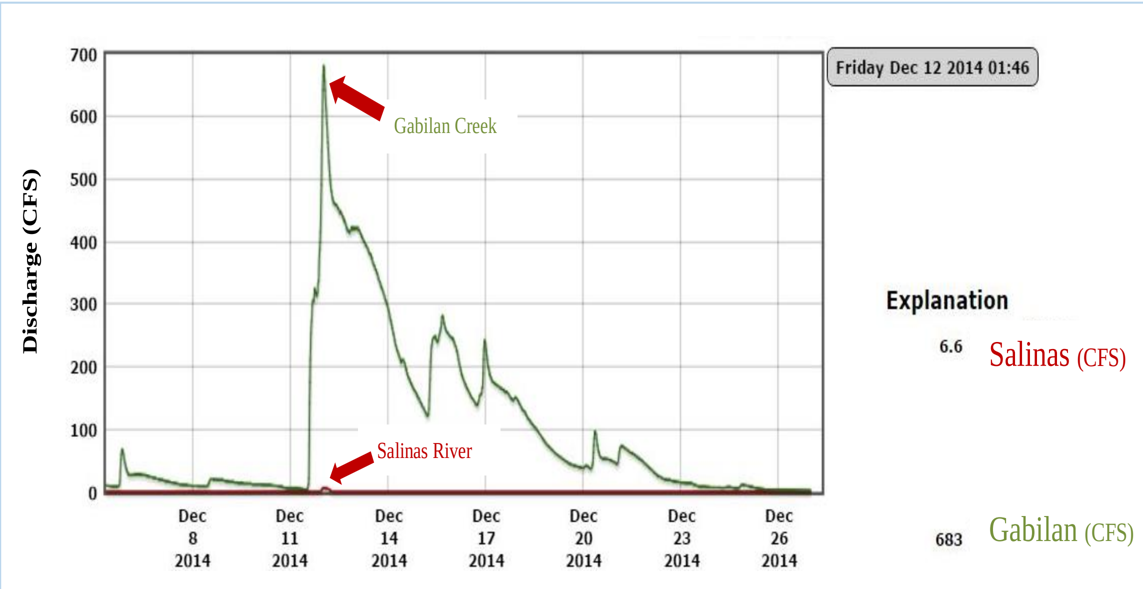


Figure 7. Discharge Rate at Gabilan Creek and Salinas River in December 2014
(Figure source: ESA 2016)

ESA Existing Hazards (2010)

The combined risks from current climatic conditions (2010 model years[19]) were evaluated for the Moss Landing Community and are listed in Table 5. The Existing hazard zone is shown in Figure 8. Much of the vast wetland and creek habitat within the Moss Landing area can flood during high tides except where those resources are managed behind tide gates. Most properties below high tide elevation within the Elkhorn, Bennett and the lower Moro Cojo Slough (except along the Moss Landing Road commercial district) have been purchased for habitat restoration or conservation (one last parcel within the Moro Cojo is currently targeted for acquisition). Low lying areas adjacent to the Old Salinas River, Tembladero Slough/Gabilan drainage and Castroville Slough are located behind tide gates that limit tidal range within these drainages or are behind pump stations that actively pump water from low lying areas. These management strategies allow these areas to be productive farm land (some of these parcels are only farmed during dry summer months) even though many are below sea level.

The 2010 ESA Sea Level Rise risk models correlate well with the FEMA flood maps (FEMA flooding extends further inland) within the Elkhorn and Moro Cojo Slough areas but differ greatly within the OSR

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

and Tembladero areas (Figure 8). The discrepancies within the lower Salinas Valley are likely do to small differences in DEM elevation base layers and drainage network maps within this flat low-lying valley. A combination of the two hazard maps most likely best reflects current flooding vulnerabilities within this area. The 1995, 1998, 2014 and 2017 flood events can be used to corroborate the flood risk vulnerabilities within this drainage[20].

The 2010 ESA Sea Level Rise risk models (excluding wave derived coastal flooding behind tide gates) project that 15 residential and 23 commercial properties and 12,483 feet of road (including parts of Hwy 1 south and north of the Elkhorn Slough Bridge) are presently vulnerable to the impacts of Coastal Climate Change (Table 5). Most of this same infrastructure was impacted during the 1998 flood.

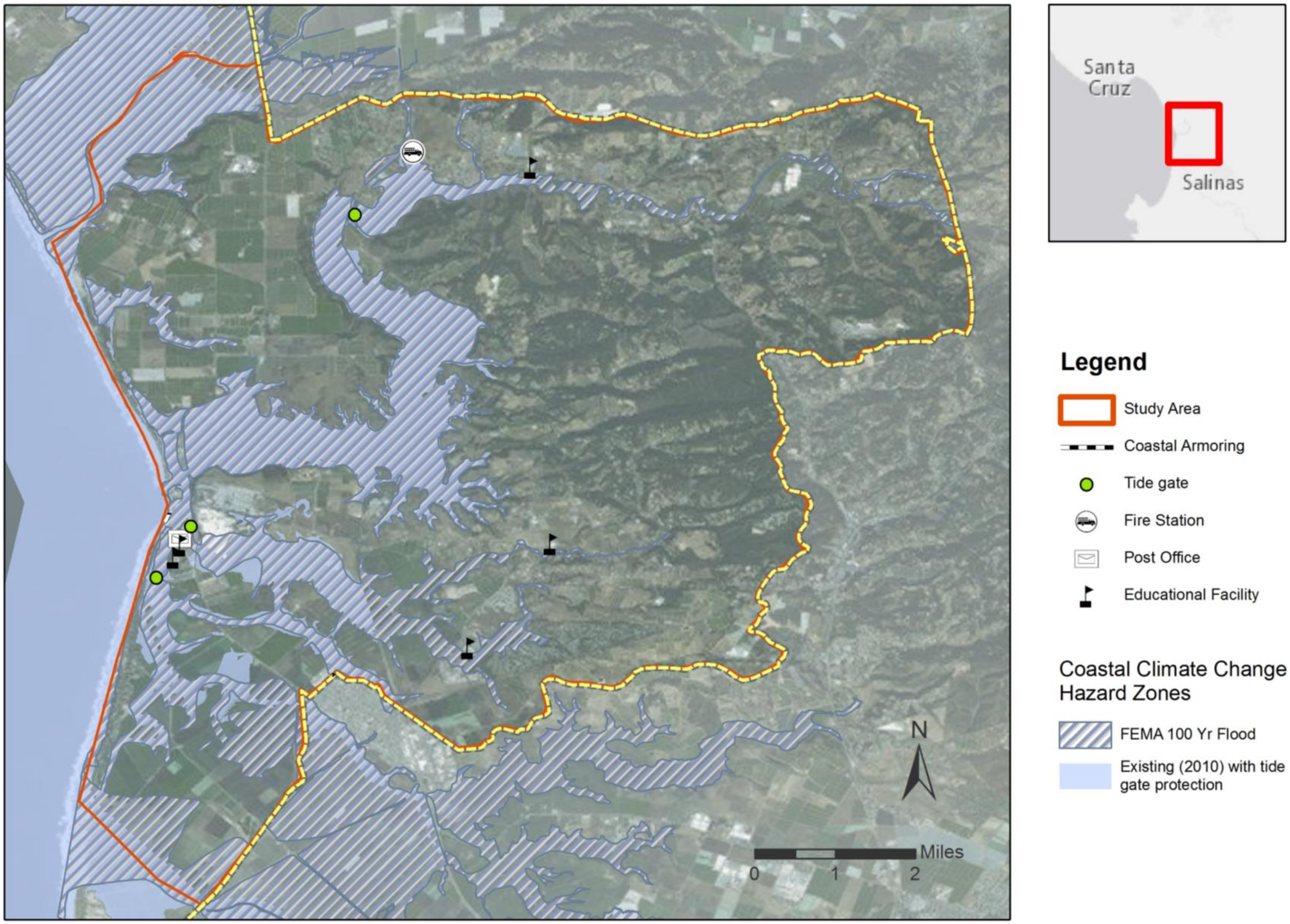
Additional residents and businesses within the 2010 hazard zone are located within the Castroville community further inland from the Coastal Zone along the Gabilan/Reclamation Ditch drainage (outside the study area of this report).

[20] Watershed Education Outreach Program. 1995. *Salinas Valley Flood Report*

Table 5. Comparison of FEMA and ESA Existing (2010) Hazard Zones

ASSET	UNITS	TOTAL	FEMA	2010 (WITH ARMOR)
Land Use and Buildings				
Total Buildings	Count	6,642	327	88
Residential	Count	5,815	219	15
Commercial	Count	71	13	23
Public	Count	52	14	3
Visitor Serving	Count	3	0	2
Other	Count	701	81	45
Educational Facilities	Count	5	0	0
Post Offices	Count	1	0	1
Emergency Services	Count	1	0	0
Farmland	Acres	15,393	3,896	1,951
Transportation				
Roads	Feet	687,784	62,175	12,483
Rail	Feet	45,730	24,438	7,123
Highway 1	Feet	62,949	15,050	3,324
Parks, Recreation, and Public Access				
Parks	Acres	6,513	2,274	2,536
Beaches	Acres	161	80	143
Coastal Access Points	Count	17	5	3
Parking Lots	Acres	9	3	1.5
Water and Utility Infrastructure				
Storm Drains	Feet	29,201	4,336	0
Culverts and Tide Gates	Count	29	23	21
Natural Resources				
Dunes	Acres	1,227	565	607
Critical Habitat	Acres	2,306	925	389
National Wetlands	Acres	5,889	4,669	1,526

Figure 8. Existing (2010) Flood Modeled Hazard Zone Compared to FEMA 100-Year Flood zone



4.3 Summary of Future Vulnerabilities by Planning Horizon

Due to climate change, the cumulative number of Moss Landing properties and infrastructure at risk will increase between 2010 and 2100 as projected ocean water elevation and storm intensity increase. Impacts during early time horizons (2030) will most commonly result from infrequent storm induced flooding and erosion. Hazards associated with fluvial and tidal flooding will increase during future time horizons (2060 and 2100). The assets at risk from the combined effects of “coastal climate change” are presented in tables below for each time horizon (Table 6).

Secondly, the technical team determined that it is likely that all coastal protection infrastructure (sea walls, rip-rap, and groins) will need to be replaced or significantly improved at some point before 2060, and therefore the 2060 and 2100 coastal erosion analyses do not account for the protections provided by existing structures. Rather, the analysis accounts for the expected lifespan of coastal structures and assumes that future actions must be taken to replace structures if the community intends to mitigate these projected hazards. This approach to future hazard analysis recognizes that current coastal armoring may continue to provide protection from wave impacts through 2030 but may fail prior to 2060. The map at the end of this section documents the combined coastal climate change hazard zones for 2030, 2060, and 2100 which includes dune erosion, frequent to annual wave damage and storm related flooding, and areas where increases in sea level will lead to monthly inundation during high tides Figure 9).

2030

For 2030, the vulnerability analysis assumed that current coastal protective structures will still be present and functioning. The most critical protective structures within the Moss Landing area are the two tide gates that control tidal range flooding within the lower Salinas Valley along the Old Salinas River and Tembladero Slough (Potrero Road tide gates) and Moro Cojo Slough (Moss Landing Road tide gates). The 2030 analysis accounts for the reduction of inland flooding that these structures provide. River flooding, however, remains a hazard.

Buildings and Land Use: The list of properties at risk from the combined effects of coastal climate change for 2030 (excluding flooding behind tide structures) is similar to those projected at risk within the 2010 initial condition evaluation. FEMA flood maps extend the hazard zone within the lower Salinas Valley past that projected by the ESA 2030 fluvial evaluation. For 2030, a total of 96 buildings are vulnerable to coastal climate impacts (other than areas protected from coastal flooding behind tide gates), only 8 more than currently at risk (2010 vulnerability assessment). Ten of these buildings are located on Moss Landing Island, approximately 20 are located in the commercial district, and 10 in the Potrero Road Residential Neighborhood.

Transportation: 20,279 feet of road including parts of Potrero Road, Moss Landing Road, and Hwy 1 (3,894 feet) fall within the combined 2030 hazard zone.

Recreation and Public Access: The beach along the Moss Landing Island is projected to erode inland up to 70ft, placing the current structures within the active wave impact zone. Lateral coastal access in front of these structures will be impacted or eliminated. Erosion of the dunes south of Sandholdt Bridge will reduce the dune width to less than 200ft, decreasing the resiliency of the dunes to mitigate coastal flooding risks to properties inland of the Potrero tide gate.

Natural Resources: Much of the wetland habitat within the Moss Landing/Lower Salinas Valley is within the boundaries of the coastal hazard layers for 2030. However, many of these resources are "protected" from full tidal flooding by the Moss Landing and Potrero road tide gates. A study has begun by researchers at Moss Landing Marine Labs to estimate the adaptive capacity of these wetland resources if tidal ranges increase.

Water Control Structures: Although many of the water control structures (culverts and tide gates) fall within the flood hazard zone, we assume that inundation levels are at a height in which these structures will still function as intended. The fluvial analysis for the Old Salinas River estimates the flow restriction posed by these tide gates based on future projected discharge rates.

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 (tide gates and coastal armoring).

Buildings and Land Use: There is a significant increase in the number of properties at risk of coastal climate change by 2060. The 2060 hazard zone (Figure 9) projects almost complete loss of services on the island during storms by the combined effects of coastal climate change unless protective structures are upgraded or beach nourishment and sand dune enhancement efforts are increased significantly. Almost all the buildings within the commercial district and approximately half the homes within the Monterey Dunes Colony fall within the 2060 combined hazard zone.

Transportation: Erosion and wave overtopping risks are projected to impact the north harbor along Jetty Road. Storm surge and larger river discharges into the Moss Landing Harbor are projected to cause flooding of the Moss Landing Road area. The flood protection provided by the Moss Landing Road tide gates for the Moro Cojo watershed is assumed to be compromised. Much of the Hwy 1 corridor within the planning area is projected to be vulnerable to flooding.

Water Control Structures: By 2060 many of the existing tide gates and culverts will not have the capacity to address the combined impacts of coastal storm flooding and rising tides.

Natural Resources: Coastal erosion compromises sand dune's ability to restrict wave overtopping and flooding within the lower Salinas Valley. By 2060 erosion of the dunes near Potrero road and near the Salinas River mouth are at risk of storm wave overtopping, leading to waves flowing into the Old Salinas River channel, bypassing the coastal flood protections provided by the tide gates and river levees. This inland migration of beach along this portion of the coast poses a significant risk to the Salinas Valley if the dunes are not encouraged to migrate inland with the coastline. Such migration will of course lead to serious conflicts with adjacent agriculture and the current alignment of the Old Salinas River.

2100

By 2100 the increased height of monthly tides becomes the driving hazard for Moss Landing adaptation planning.

Buildings and Land Use*:* Monthly high water is projected to flood much of the Moss Landing Road commercial district and portions of the Moss Landing Island/Sandholdt Road mixed use district. Winter wave overtopping and dune erosion will become significant hazards for land uses within the harbor as the sand spits along Sandholdt and Jetty road are reduced in width by erosion. By 2100, 272 buildings are located within the projected hazard zone.

By 2100, wave run-up energy will be greater during most storms causing flood and wave damage within the harbor. River flooding is projected to be significant and more frequent. Much of the agriculture lands south of Moss Landing and west of Highway One will be vulnerable to flooding due to further dune erosion and loss of water control structure functions.

Water Control Structures: In 2100, many of the passive water control structures located throughout the Moss Landing area will fail to work as designed leading to inland flooding.

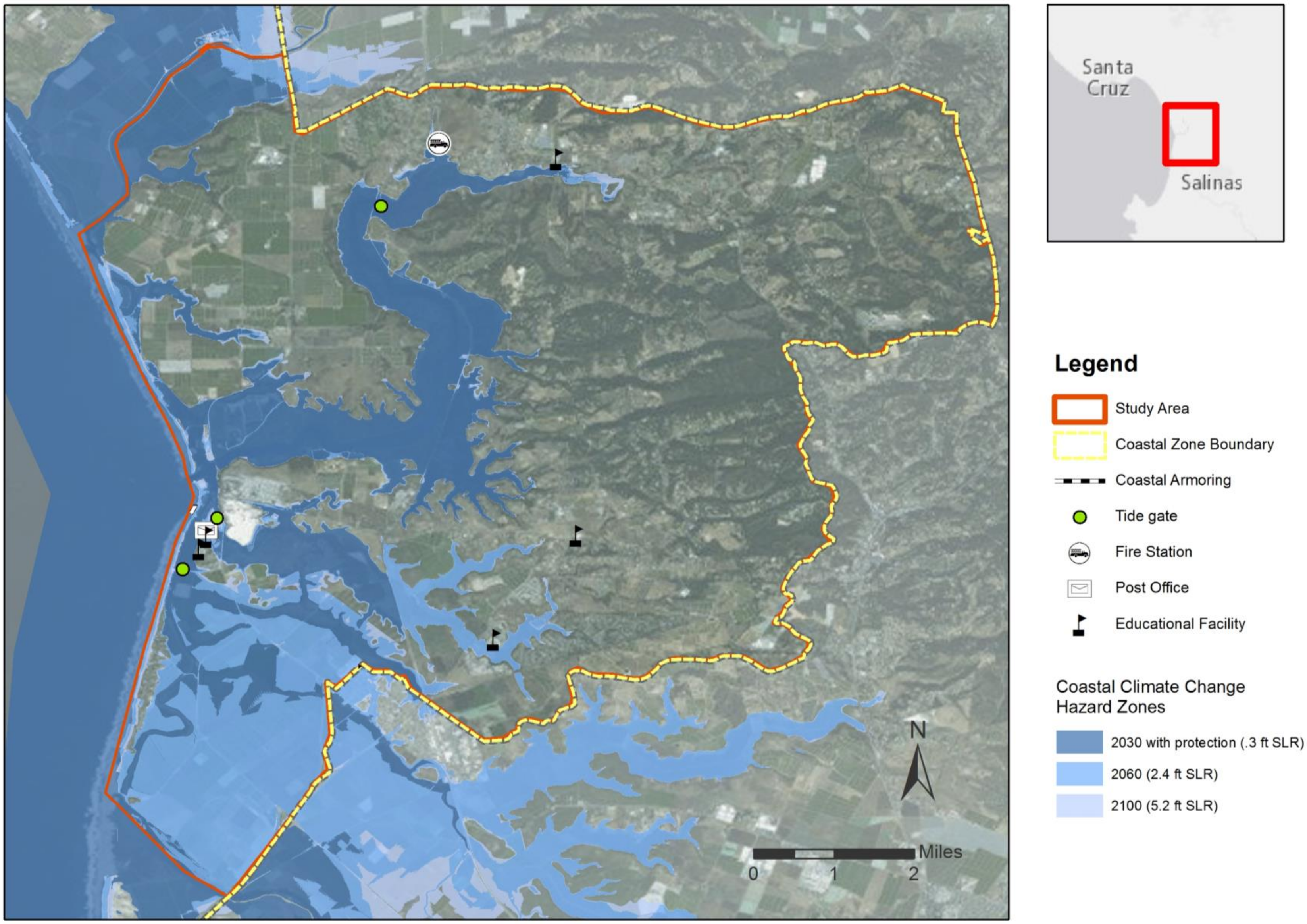
Transportation*:* By 2100, 73,286 feet of road (including Hwy 1) fall within the combined hazard zone. Much of the transportation infrastructure will need to be raised, moved, or allowed to flood as tidal height increases and the functionality of current water control structures is reduced.

Natural Resources: The Old Salinas River channel and Harbor main channel are vulnerable to coastal wave processes as the dunes along this stretch of coast experience the effects of “coastal squeeze.” Within these areas the dune faces are projected to erode inland while the location of inland development remains static. Three sections of the coastal sand spit are vulnerable to loss from coastal erosion. The failure of these dunes will likely lead to significant changes in how (or if) the harbor and Sandholdt sand spit development continues to function. Additionally, many of the surrounding freshwater wetlands resources may be negatively impacted by the increased tidal range.

Table 6. Vulnerability of Assets due to Combined Effects of Coastal Climate Change

ASSET	UNITS	TOTAL	2030 (WITH ARMOR)	2030 (NOARMOR)	2060 (NO ARMOR)	2100 (NO ARMOR)
Land Use and Buildings						
Total Buildings	Count	6,642	96	139	198	272
Residential	Count	5,815	17	21	59	113
Commercial	Count	71	25	25	28	32
Public	Count	52	3	3	6	8
Visitor Serving	Count	3	3	3	3	3
Other	Count	701	48	87	102	116
Schools	Count	5	0	1	1	1
Post Offices	Count	1	1	1	1	1
Emergency Services	Count	1	0	0	0	0
Farmland	Acres	15,393	1,991	4,731	5,290	5,532
Transportation						
Roads	Feet	687,784	20,279	50,746	73,286	95,284
Rail	Feet	45,730	7,855	11,280	15,901	24,728
Highway 1	Feet	62,949	3,894	14,464	22,780	29,040
Parks, Recreation, and Public Access						
Parks	Acres	6,513	2,547	2,584	2,746	2,834
Beaches	Acres	161	143	143	160	161
Coastal Access Points	Count	17	5	5	11	13
Parking Lots	Acres	9	2	2	5	9
Water and Utility Infrastructure						
Storm Drains	Feet	29,201	0	80	100	172
Culverts and Tide Gates	Count	29	19	20	22	24
Natural Resources						
Dunes	Acres	1,227	636	736	894	969
Critical Habitat	Acres	2,306	1,048	1,126	1,361	1,629
National Wetlands	Acres	5,889	3,382	4,074	4,387	4,495

Figure 9. Hazard Zones for the combined effects of future coastal climate change
(Excludes flooding behind existing tide gates from rising tides and coastal storms for planning horizon 2030)



5. Vulnerability by Coastal Hazard

The hazards associated with each of the modeled coastal processes (coastal storm flooding, coastal erosion, rising tides and fluvial flooding) threaten various types of coastal infrastructure differently. Wave and fluvial flooding can damage buildings, and temporarily restrict use of public amenities, make storm drains and tide gates ineffective and limit the use of roads and walkways. Many of these impacts are temporary and repairs can be made. Dune erosion and monthly high tide flooding, however, are permanent impacts that will lead to extensive rebuilding, a change in use or abandonment of the property. By analyzing the impacts due to separate coastal hazards, coastal resource managers can begin to plan adaptation strategies accordingly (see Section 7 for a discussion on adaptation strategies).

5.1 Rising Tides

Though the projected hazard extent for rising tides is less than for coastal storm and river flooding, the impact is more frequent. Tidal range is projected to increase by 0.3 feet by 2030, 2.4 feet by 2060 and 5.2 feet by 2100 (Table 7). The projected extent of the rising tides hazard zones within the study area are shown in Figure 10. Buildings projected to be impacted within the Moss Landing Community Plan Area are shown in Figure 11.

Table 7. Extreme Tide Conditions for Reclamation Ditch System

TIME PERIOD	SEA LEVEL RISE (FT)		10- YEAR TIDE LEVEL + SLR (FT NAVD)	
	Medium	**High**	**Medium SLR**	**High SLR**
2030	0.3	0.7	8.0	8.4
2060	1.1	2.4	8.8	11.0
2100	2.9	5.2	10.6	12.9

By 2030, the tidal estuary habitat of the Old Salinas River, Bennet Slough and Elkhorn Slough will be flooded during normal high tides. Unless rapid marsh plain accretion occurs, this tidal flooding will risk further marsh plain die back and a transition to mud flat. An increase in tidal flooding occurred in 2014 after the failure of the Moro Cojo tide gates which allowed the estuary to fill slowly over numerous months with saltwater (tidal range did not appear to increase). Portions of the Moro Cojo Slough were inundated with salt water above the habitats normal range, leading to the dieback of fringing brackish and freshwater plant communities.

No buildings are within the projected 2030 tidal flood extent. However, by 2060, 18 structures within the commercial district are vulnerable to high tides if the Moss Landing Road tide gates do not continue to regulate tidal exchange within the Moro Cojo Slough. By 2060 most parking areas around the harbor are vulnerable to monthly flooding and most of the properties along Moss Landing Road are projected to be flooded every month. Portions of Moss Landing and Jetty roads will be flooded by 2060 as well as a number of buildings on the Moss Landing Island adjacent to the harbor. Coastal Access along the harbor and Potrero Road will also be flooded more frequently (Table 8).

By 2100 most of the development within the Moss Landing Commercial and harbor areas will be flooded monthly during high tides. Only limited flooding risk is projected for the residential area along Potrero Road. A total of 1,170 feet of roads are vulnerable to monthly high tides at 2030 within the Moss Landing Community; rising to 12,278 by 2060 and 30,834 ft. by 2100. Tides will flood more than 11,000 feet of Highway 1 within the Moss Landing Study Area by 2100.

Some farmland in the lower Salinas Valley is already vulnerable to flooding during high tides. However, this risk is reduced significantly by the Potrero and Moro Cojo tide gates. The proper function of these tide gates is dependent on water elevations within the harbor. As ocean levels rise, these gates will be less able to maintain current inland water levels and flooding is expected to increase within Salinas Valley agriculture fields. By 2100, 3,168 acres of farmland within the Moss Landin Study Area are projected to flood monthly.

Table 8. Assets Vulnerable to Rising Tides

ASSET	UNITS	TOTAL	2030 (WITH PROTECTION)	2060 (NO PROTECTION)	2100 (NO PROTECTION)
Land Use and Buildings					
Total Buildings	Count	6,642	7	58	106
Residential	Count	5,815	2	8	19
Commercial	Count	71	2	25	31
Public	Count	52	0	3	8
Visitor Serving	Count	3	0	3	3
Other	Count	701	3	19	45
Education Facilities	Count	5	0	1	1
Post Offices	Count	1	0	1	1
Emergency Services	Count	1	0	0	0
Farmland	Acres	15,392	92	1,572	3,168
Transportation					
Roads	Feet	687,784	1,170	12,278	30,834
Rail	Feet	45,730	3,313	12,636	21,072
Highway 1	Feet	62,949	1,095	4,850	11,691
Parks, Recreation, and Public Access					
Parks	Acres	6,513	1,946	2,480	2,552
Beaches	Acres	161	15	43	63
Coastal Access Points	Count	17	1	3	8
Parking Lots	Acres	9	0	2	8
Water and Utility Infrastructure					
Storm Drains	Feet	29,201	0	56	139
Culverts and Tide Gates	Count	29	9	22	24
Natural Resources					
Dunes	Acres	1,227	200	574	688
Critical Habitat	Acres	2,306	803	975	1,254
National Wetlands	Acres	5,889	2,524	3,961	4,322

Figure 10. Rising Tides (Extreme Monthly High Water) Hazard Zones within Study Area

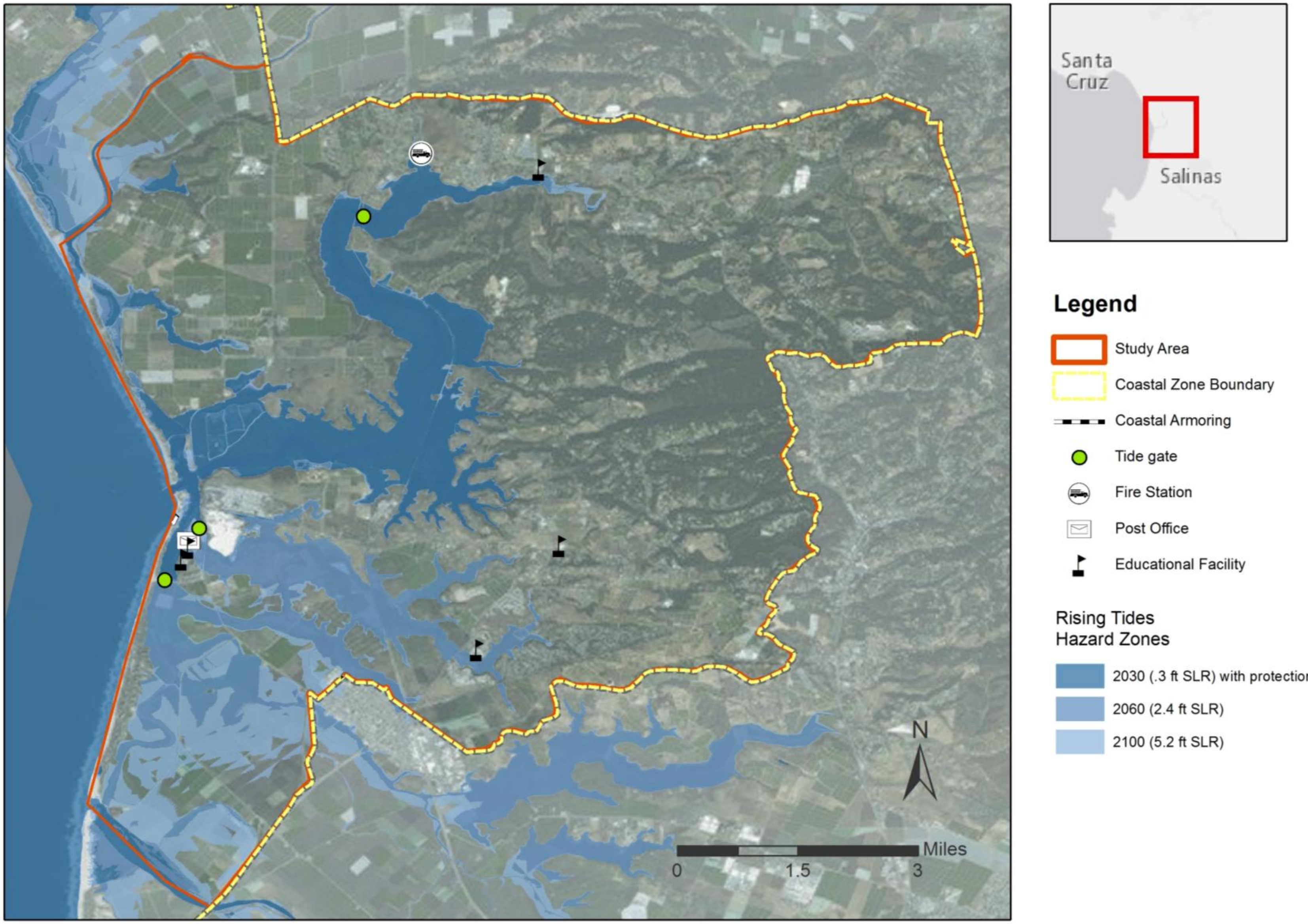
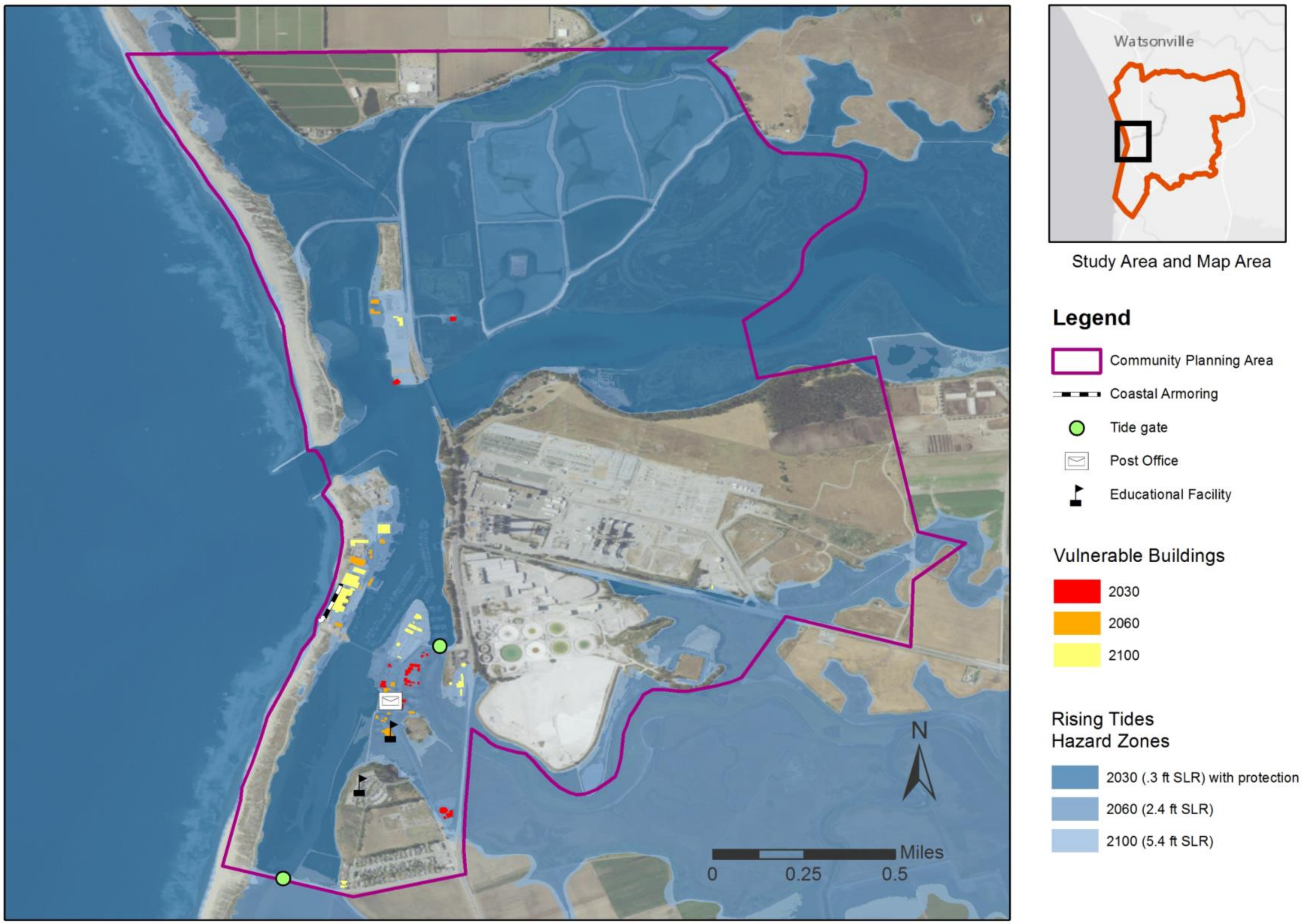


Figure 11. Buildings within the Moss Landing Community Plan Area vulnerable to Rising Tides (Extreme Monthly High Water)



5.2 Coastal Storm Flooding and Wave Impacts

Due to climate change, the cumulative number of Moss Landing properties and infrastructure at risk increases as projected ocean water elevation and storm intensity increase (i.e. Coastal Storm Flooding). Coastal Flooding risks arise during winter storms with increased local sea level (exacerbated by off shore high pressure systems) and increases in wave height and energy (due to storm related winds) leading to wave impacts and localized flooding from water overtopping dunes and other coastal structures. The ESA risk models estimated both wave run-up extent and height of water for the Moss Landing coastline and harbor areas. The projected coastal storm flood hazard zones, within the study area for time horizons 2030, 2060, and 2100, are shown in Figure 12.

For 2030, the coastal flooding vulnerability analysis assumes that current tide gate and coastal protective structures will remain functioning. Regardless, coastal flooding will be a significant threat for Moss Landing by 2030. Coastal dunes that protect inland wetland habitat, agriculture, urban development and the Moss Landing Harbor all will be impacted by the increased force of wave energy, leading to the loss of dune habitat and the possible overtopping of the dunes near the Salinas River mouth, risking inland flooding. Brackish water resources and agriculture lands further inland are vulnerable to saltwater inundation if the dunes and/or tide gates fail to restrict connectivity between coast and creek.

Structures on Moss Landing Island adjacent to the shore will see more frequent and severe wave damage due to coastline migration (water line migration and wave run-up encroachment inland while infrastructure locations remain static). Figure 13 identifies properties in the Moss Landing Community Plan Area that will be impacted by coastal storm flooding. Due to the Moss Landing Harbor deep water channel, storm surge and flooding can migrate up the channel into the heart of the Moss Landing community, increasing flood hazards to much of the community. The assets vulnerable to coastal storm flooding in each planning horizon for the entire study area are presented in Table 9.

This study assumes that tide gates that protect southern Moss Landing, Castroville and the Salinas Valley from flooding during current high tide events will fail to provide flood protection from the projected hazards of 2060 ocean derived storms. Rather, this analysis assumes that future actions must be taken to mitigate these projected hazards. Therefore, this analysis identifies the infrastructure vulnerable to future coastal flooding if these structures are not replaced or upgraded.

By 2060, coastal flooding is projected to circumvent the Moro Cojo tidal structure unless new structures are built to restrict storm surge from passing over Moss Landing Road. Cost considerations, feasibility constraints and the secondary implications of tide gate upgrades on coastal resources (water quality, wetland habitat, fish migration) will likely be significant (see Section 6). Depending on construction and operational costs, construction feasibility and legality of replacing current tide gates, land uses behind these structures may need to adapt to the projected flood hazards or be lost.

Projected impacts from coastal flooding (wave overtopping dunes and levees causing inland flooding) demonstrate the dire vulnerabilities that agricultural lands, Moss Landing's coastline, and the surrounding area face in the future. By 2100 several portions of the protective dunes complex are projected to no longer restrict ocean waves, leading to significant flooding within the lower Salinas Valley (69 additional buildings). The long-term preservation of the Salinas State Beach dunes complex and the effective restriction of storm surge inland of Potrero road are critical to the future viability of the southern Moss Landing region. The potential for inward migration of these dunes is likely but will come in conflict with present land use of those properties.

Table 9. Assets Vulnerable to Coastal Storm Flooding and Wave Impacts within Study Area

ASSET	UNITS	TOTAL	2030 (WITH PROTECTION)	2060 (NO PROTECTION)	2100 (NO PROTECTION)
Land Use and Buildings					
Total Buildings	Count	6,642	66	183	259
Residential	Count	5,815	16	44	101
Commercial	Count	71	1	28	32
Public	Count	52	2	6	8
Visitor Serving	Count	3	0	3	3
Other	Count	701	47	102	115
Schools	Count	5	0	1	1
Post Offices	Count	1	0	1	1
Emergency Services	Count	1	0	0	0
Farmland	Acres	15,393	879	5,290	5,532
Transportation					
Roads	Feet	687,784	20,101	72,261	93,486
Rail	Feet	45,730	7,855	15,901	24,729
Highway 1	Feet	62,949	3,903	22,780	29,041
Parks, Recreation, and Public Access					
Parks	Acres	6,513	2,134	2,710	2,808
Beaches	Acres	161	143	149	161
Coastal Access Points	Count	17	4	10	12
Parking Lots	Acres	9	2	5	9
Water and Utility Infrastructure					
Storm Drains	Feet	29,201	0	100	172
Culverts and Tide Gates	Count	29	16	22	24
Natural Resources					
Dunes	Acres	1,227	394	842	945
Critical Habitat	Acres	2,306	1,122	1,346	1,629
National Wetlands	Acres	5,889	2,750	4,387	4,494

Figure 12. Coastal Storm Flood Hazard Zones within Study Area

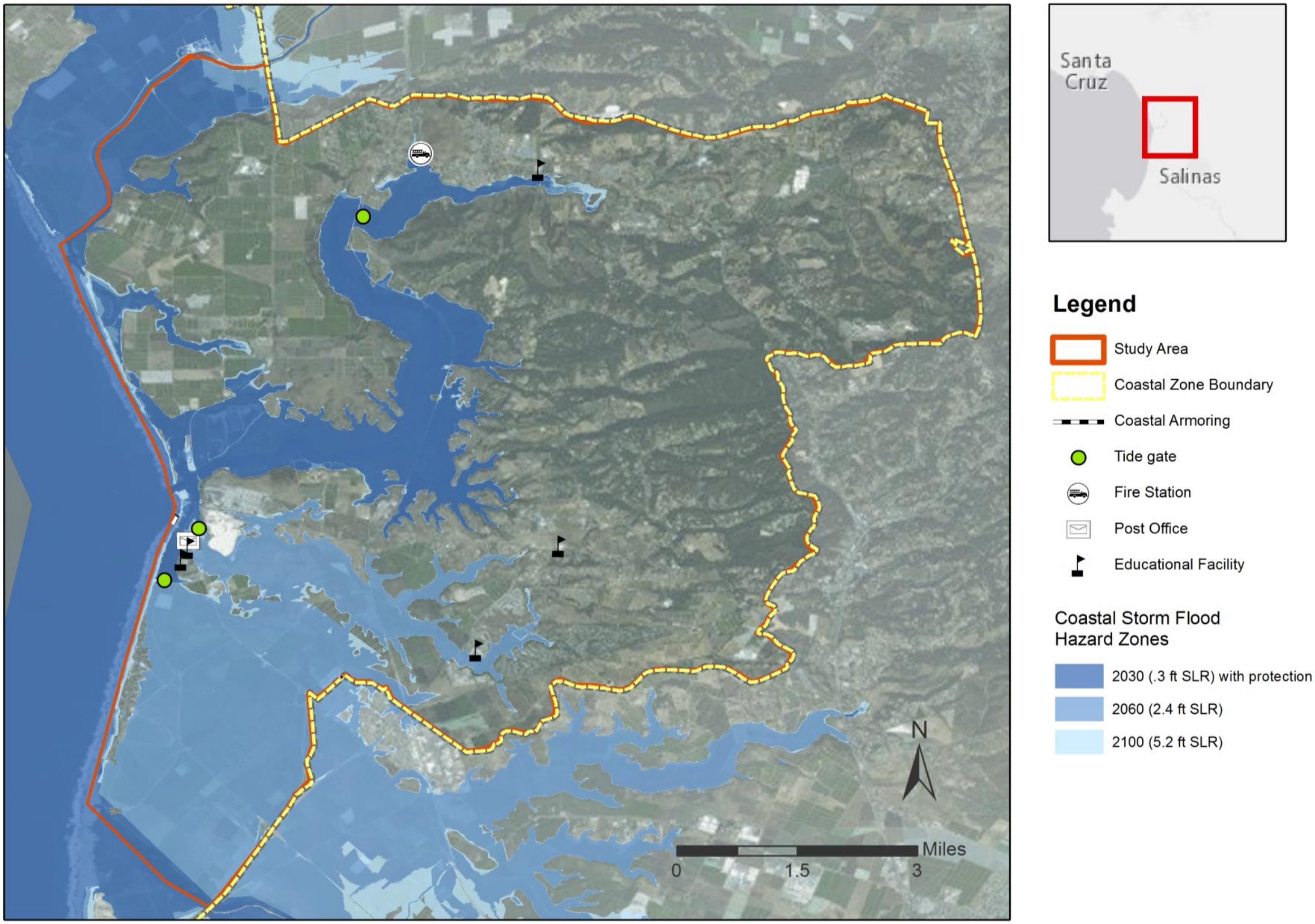
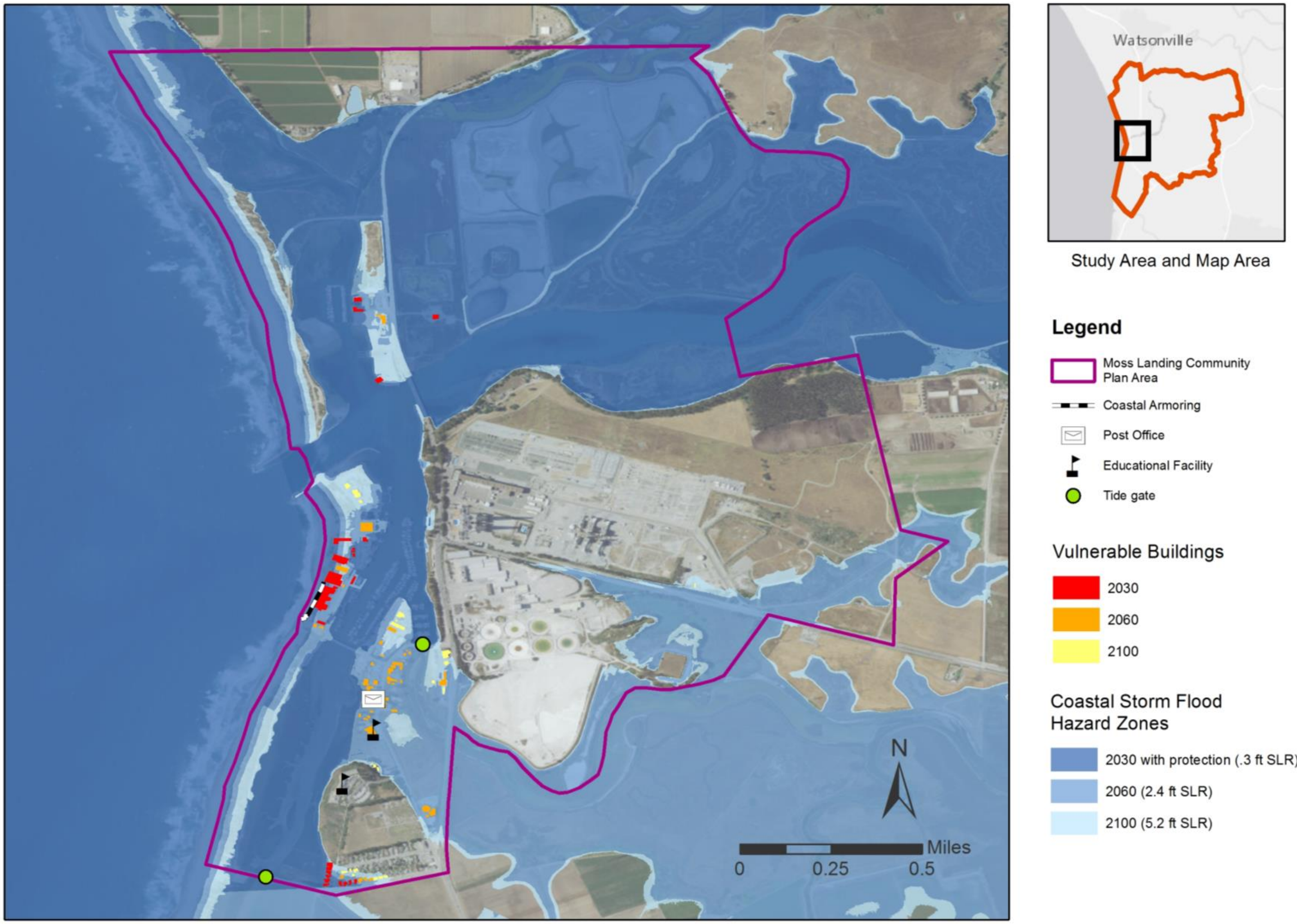


Figure 13. Buildings within the Moss Landing Community Plan Area vulnerable to Coastal Storm flooding



5.3 Fluvial Impacts

The December 11, 2014 storm event in the Salinas hills caused waters to flow down through the Gabilan watershed causing significant flooding within the Moss Landing agriculture fields. Flow within the Gabilan Reclamation Ditch was estimated to be 700 CFS (50-100 times normal flows) while the Salinas River directly south of the Gabilan saw no increase in flow rates (6cfs - demonstrating the local intensity of this rain event). This flooding was exacerbated when the draining capacity of the gates was compromised by high "king" tides causing river floodwaters to back up behind the tide gate structure. The future hazards of river flooding due to the predicted increase in fluvial discharge, higher ocean elevations during storms and higher sea level elevations were evaluated for Moss Landing and the Lower Salinas Valley[21]. The predicted increase in fluvial discharge within the Gabilan/Rec Ditch due to more intense rainfall during storms used for this analysis is outlined in Table 10.

Table 10. Increases in 100-year Discharge for the Reclamation Ditch System Relative to Historic Period (1950-2000)

EMMISIONS SCENARIO	2030	2060	2100
Medium (RCP[22] 4.5 5th percentile)	20% Increase	40% Increase	60% Increase
High (RCP 8.5 90th percentile)	140% Increase	210% Increase	275% Increase

The project team documented flows that occurred during the December 2014 flooding event to test the accuracy of the expanded Gabilan fluvial model. The model accurately projected the back watering within the Old Salinas River and the rerouting of the floodwaters under the Highway 1 into the Moro Cojo Slough (Figure 14). Future revisions to this fluvial model will be made as part of the 2017 Greater Monterey IRWMP storm water planning effort to provide additional information on the potential flood reduction potential if the Old Salinas River, the Salinas River lagoon and the Moro Cojo estuaries were strategically managed.

[21] ESA. 2016. *Climate Change Impacts to Combined Fluvial and Coastal Hazards*. May 13, 2016.

[22] The World Climate Research Programme under the Coupled Model Intercomparison Project Phase 5 uses emissions scenarios referred to as Representative Concentration Pathways (RCPs). The highest scenario, RCP 8.5, reflects a track with little mitigative measures to reduce greenhouse gas emissions resulting in a net increase in radiative forcing of 8.5 W/m2 by 2100 relative to pre-industrial conditions. A medium level emissions scenario, RCP 4.5, reflects a future wherein changes in technology and energy usage stabilize the increase in net radiative forcing to 4.5 W/m2 by 2100. These emissions scenarios, RCP 4.5 and RCP 8.5, were used to reflect respectively medium and high emissions trajectories for this study

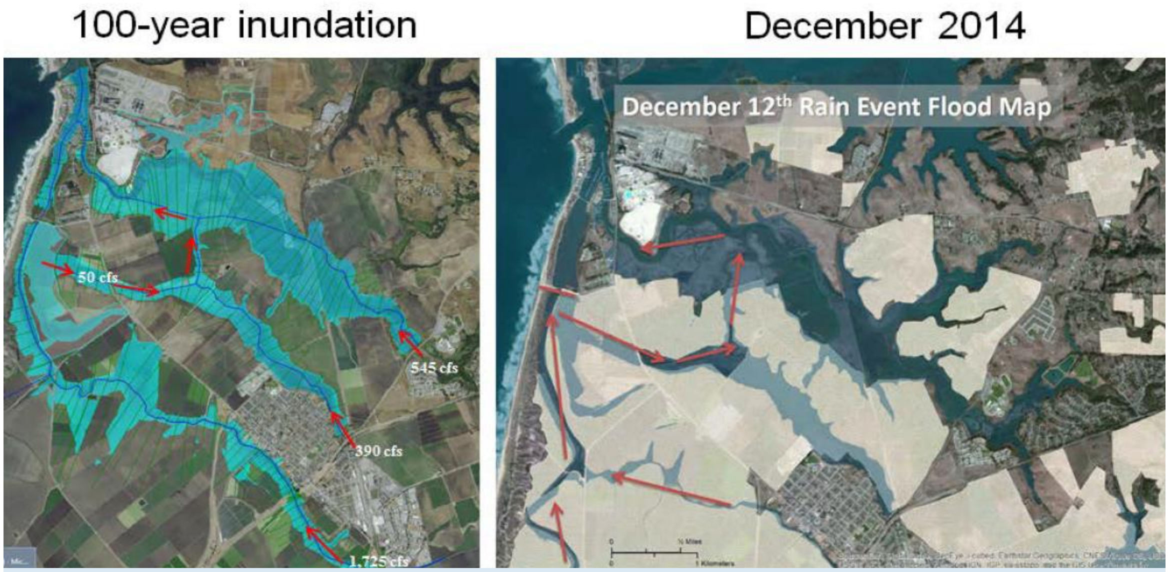


Figure 14. Comparison of Modeled 100-year flow paths and observed flow paths during Dec 2014 flood (Figure source: ESA 2014)

Currently, residential and business properties in Moss Landing have been build adjacent to, but above the FEMA flood plain. A significant area of the lower Salinas Valley agriculture fields, however, is currently vulnerable to flooding from the Gabilan Watershed and Old Salinas River (Image 1). Many of the farm fields vulnerable to flooding within the Moro Cojo Slough have been purchased for wetland restoration or conservation. Other historical wetland areas within the Gabilan drainage between Castroville and Salinas remain in agriculture production through the aid of water lift stations that pump water from drainage systems in the low-lying areas. Water elevation within these basins can be more than 8ft below sea level. Obviously, these areas are vulnerable to flooding in the winter and have (inadvertently) provided flood attenuation service to downstream resources during flood events.

Image 1. February 20th, 2017 flooding of lower Salinas Valley (note similarities with hazard map Fig. 14) (Photo: KSBW drone footage)

Flooding risks projected within the ESA climate change models identify only small additional areas of agriculture land vulnerable to fluvial flooding by 2030. The area of flooding however increases significantly within the lower Salinas Valley (west of Hwy 1) by 2060 and 2100 as the combined effects of SLR and changing rainfall patterns increase significantly (Figure 15).

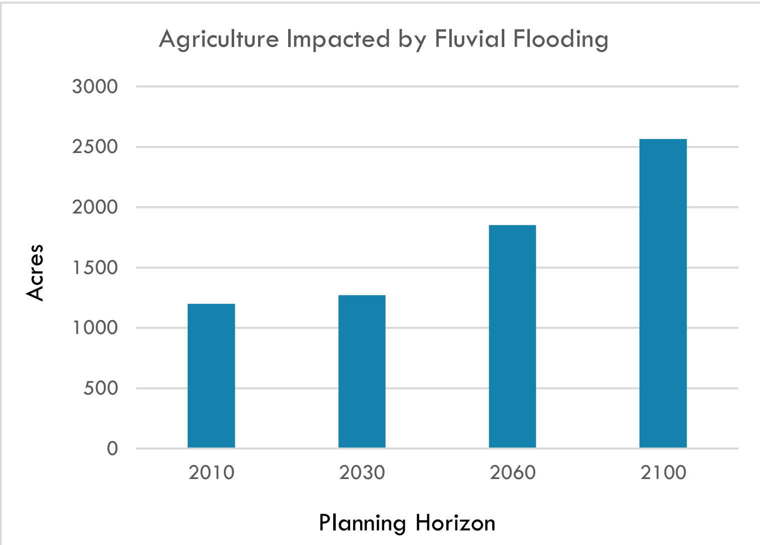


Figure 15. Agriculture Impacted by Fluvial Flooding

As many as 1,852 acres of agriculture land behind the two tide gates will be routinely flooded by 2060 unless tide gates are replaced with new structures that can accommodate higher flows (>700cfs) and higher tides (2.4 ft.) (Table 11). Salinas Valley agricultural fields are vulnerable to increased frequency and elevation of flooding as well as the potential for salt water inundation that may reduce the productivity of these fields. Periodic flooding of agriculture fields also risks significant food safety liabilities for the industry.

Storm intensity is predicted to increase within Monterey County by 2100. These more infrequent but intense rainfall events are predicted to cause rivers and creeks to rise rapidly leading to downstream flooding within the vast low-lying Salinas Valley. The projected fluvial flood hazard zones for the 2030, 2060 and 2100 time horizons are depicted in Figure 16. Buildings within the Moss Landing Community Plan area that are projected to be impacted by flooding from the Reclamation Ditch are shown in Figure 17.

Areas adjacent to the Tembladero and Castroville slough channels, directly outside of our study area, are vulnerable to storm and climate induced flooding. In the community of Castroville, the 2030 hazards projected are similar to the FEMA Flood Zone maps. Additional flooding impacts are projected for the northern portion of Castroville due to the added effects of coastal storm induced flooding. The projected coastal flood hazard zone is similar to the flooding extent experienced during the 1995 flood. By 2060, a slightly greater portion of the community of Castroville (areas adjacent to the Tembladero and Castroville slough channels) is vulnerable to storm and climate induced flooding. A significantly greater area of agriculture land will be flooded as discharges within the OSR and Tembladero/Gabilan drainages are impeded by higher water elevations within the harbor due to sea level rise. Increased ocean elevations during winter storms will further increase flooding during winter storm events.

Table 11. Assets Vulnerable to Fluvial Flooding

ASSET	UNIT	TOTAL	2030 (WITH PROTECTION)	2060 (NO PROTECTION)	2100 (NO PROTECTION)
Land Use and Buildings					
Total Buildings	Count	6,642	36	46	84
Residential	Count	5,815	1	2	8
Commercial	Count	71	24	24	29
Public	Count	52	1	2	6
Visitor Serving	Count	3	3	3	3
Other	Count	701	7	15	38
Educational Facilities	Count	5	0	1	1
Post Offices	Count	1	1	1	1
Emergency Services	Count	1	0	0	0
Farmland	Acres	15,393	1,272	1,852	2,565
Transportation					
Roads	Feet	687,784	3,113	11,118	17,712
Rail	Feet	45,730	0	0	0
Highway 1	Feet	62,949	562	3,964	6,551
Parks, Recreation, and Public Access					
Parks	Acres	6,513	433	444	450
Beaches	Acres	161	0	0	0
Coastal Access Points	Count	17	1	2	6
Parking Lots	Acres	9	0	2	3
Water and Utility Infrastructure					
Storm Drains	Feet	29,201	0	0	7
Culverts and Tide Gates	Count	29	5	6	6
Natural Resources					
Dunes	Acres	1,227	323	422	489
Critical Habitat	Acres	2,306	0	1	2
National Wetlands	Acres	5,889	910	985	1,072

Figure 16. Reclamation Ditch Fluvial Flood Hazard Zones within the Study Area.

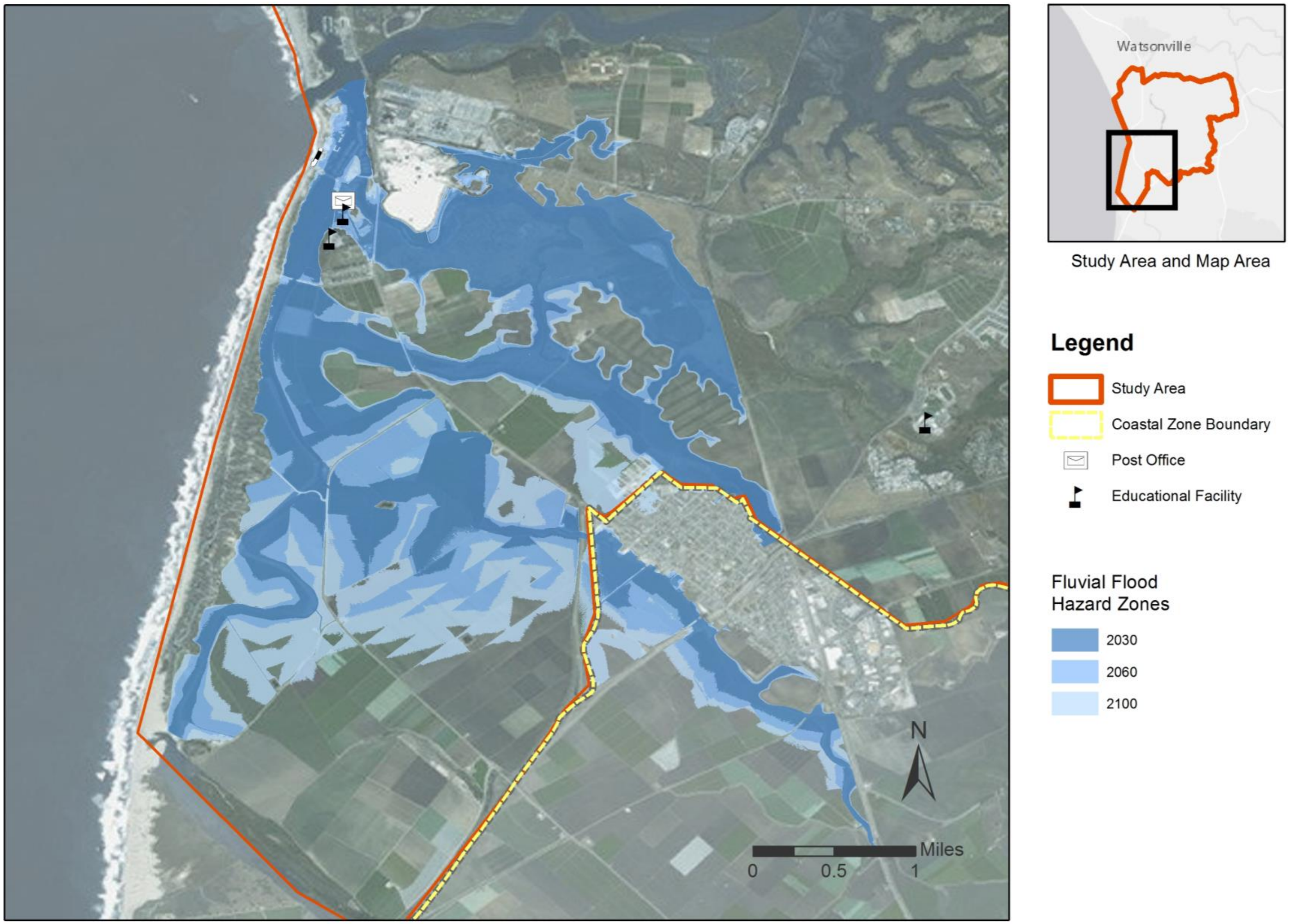
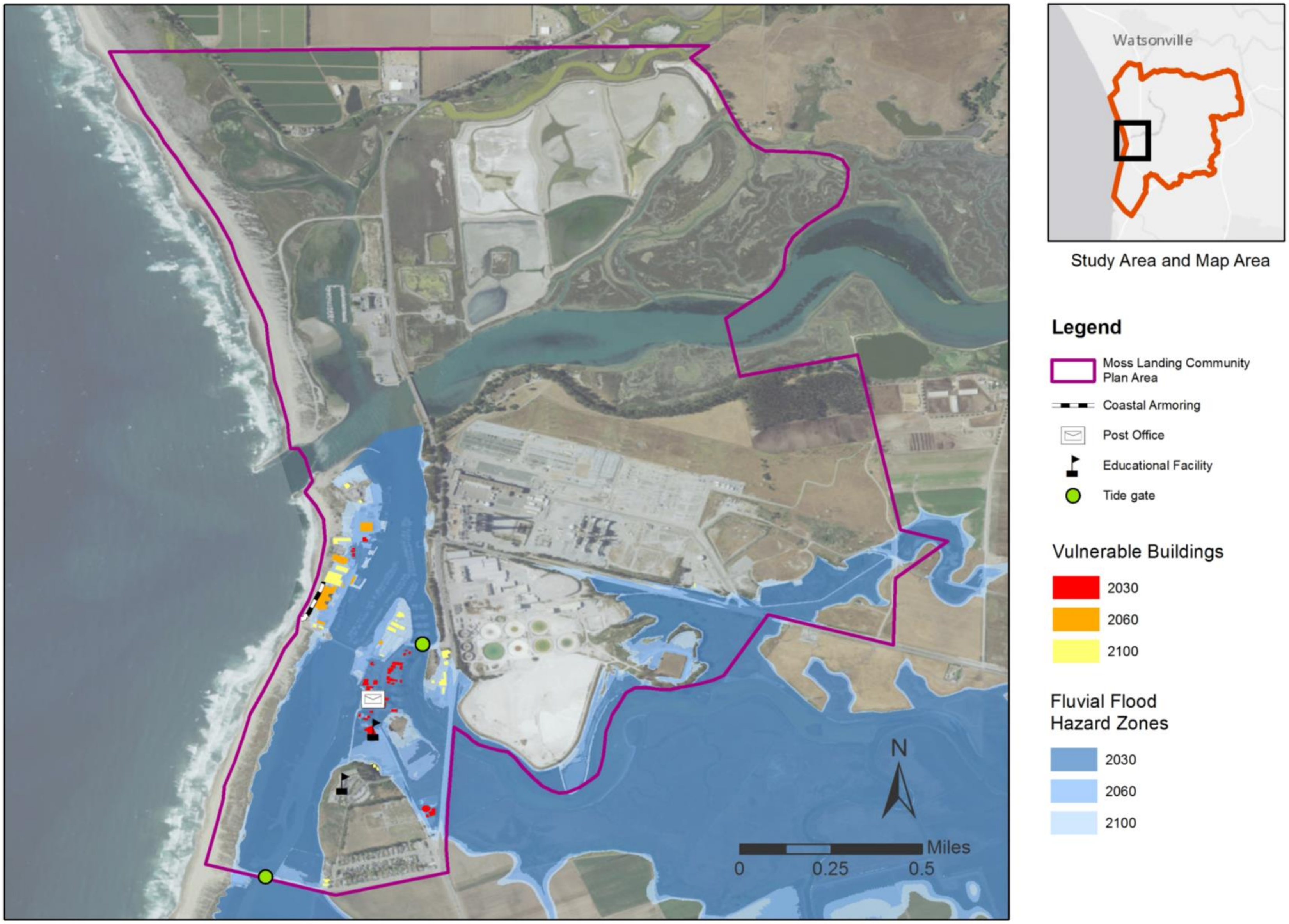


Figure 17. Buildings within the Moss Landing Community Plan Area vulnerable to Fluvial Flooding from the Reclamation Ditch



5.4 Coastal Dune Erosion

Currently several properties are threatened by wave impacts and are protected by a variety of armoring and dune enhancement projects. By 2030, erosion within the dune face of Moss Landing Island is projected to affect two permanent buildings, several portable facilities and 150 acres of park land (Table 12).

Coastal dune erosion and wave overtopping threaten the Salinas River and Moss Landing State Beaches, jeopardize the functionality of visitor serving amenities and reduce the buffering capacity of the dunes to protect inland natural, urban and agricultural resources.

Significant portions of these beach dunes are projected to be vulnerable to coastal erosion by 2060, causing the loss of 278 acres of dune habitat and risking bisection of the linear dune system in at least three locations (Figure 18). This hazard threatens dune habitat and reduces the protective buffer the dunes play for inland resources.

Figure 18. Dunes along the Moss Landing Coast vulnerable to Coastal Erosion

Sand dunes south of Sandholdt Road are projected to be breached by coastal erosion before 2060 leading to the creation of an alternate discharge/inlet to the ocean that will compromise current harbor functions further. By 2060, large portions of the dunes between the Salinas River and Sandholdt Road are projected to be bisected by wave induced erosion, leading to wave overtopping and flooding of the Old Salinas River and Salinas Valley. Buildings vulnerable to projected erosion hazards both within the Moss Landing Community Plan Area and the Monterey Dunes Colony are shown in Figure 19. Portions of the Monterey Dunes Colony are vulnerable to impacts from dune erosion by 2060 and most properties (88%) are vulnerable by 2100.

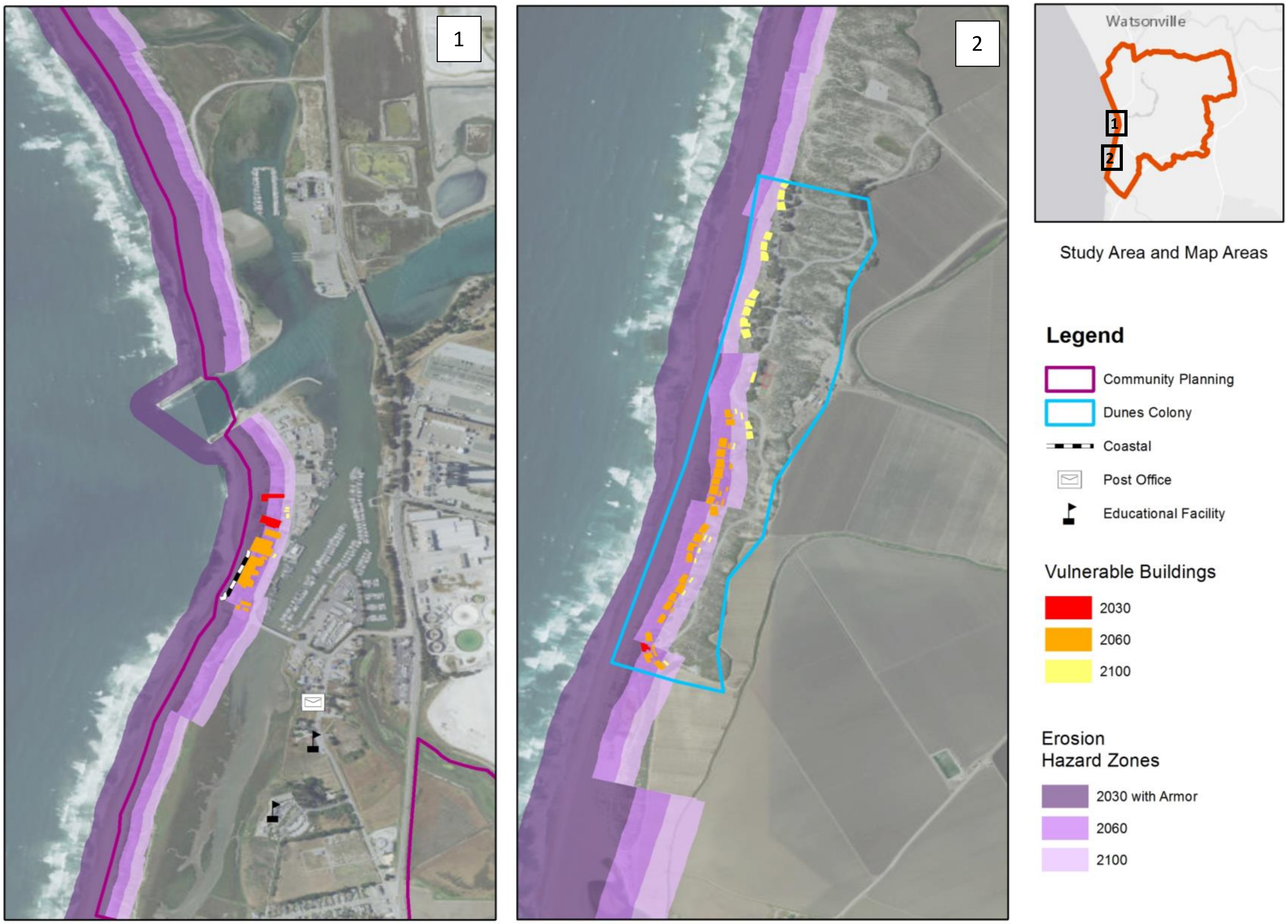
Some coastal access points (along Jetty and Sandholdt roads) may be compromised by coastal dune erosion and wave overtopping. Several older coastal protection structures (rip-rap and concrete rubble) are present along the Moss Landing Island but were not included in the CCC GIS layer. Additional information on these hip walls, rip-rap and dune stabilization efforts is needed to improve the dune erosion projections along Moss Landing Island.

Unless current coastal armoring is upgraded, new structures are constructed along the island, or natural adaptation strategies are put in place, erosion is projected to progress inland to the edge of Sandholdt road by 2060, threatening 8 structures (Figure 19). By 2100, ESA erosion models project ocean waves will bisect the dunes of Moss Landing Island in numerous locations. This erosion threatens 11 structures along Sandholdt Road between the parking lot south of Sandholdt Bridge and Phil's Fish Market. Harbor side infrastructure north of the Moss Landing Marine Labs Small Boats Operations are inland of the modeled erosion zone but within the projected winter flood area.

Table 12. Assets Vulnerable to Coastal Erosion

ASSET	UNITS	TOTAL	2030 (WITH PROTECTION)	2060 (NO PROTECTION)	2100 (NO PROTECTION)
Land Use and Buildings					
Total Buildings	Count	6,642	3	41	71
Residential	Count	5,815	1	32	56
Commercial	Count	71	0	0	0
Public	Count	52	0	0	0
Visitor Serving	Count	3	0	0	0
Other	Count	701	2	9	15
Educational Facilities	Count	5	0	0	0
Libraries	Count	0	0	0	0
Post Offices	Count	1	0	0	0
Cultural Resources	Count	0	0	0	0
Farmland	Acres	15,392	0	3	19
Transportation					
Roads	Feet	687,784	0	1,744	5,992
Rail	Feet	45,730	0	0	0
Highway 1	Feet	62,949	0	0	0
Parks, Recreation, and Public Access					
Parks	Acres	6,513	150	277	347
Beaches	Acres	161	118	153	160
Coastal Access Points	Count	17	1	7	7
Parking Lots	Acres	9	0	1	0
Water and Utility Infrastructure					
Storm Drains	Feet	29,201	0	0	0
Culverts and Tide Gates	Count	29	0	0	0
Natural Resources					
Dunes	Acres	1,227	131	278	425
Critical Habitat	Acres	2,306	0	235	305

Figure 19. Buildings projected to be vulnerable to erosion within the Moss Landing Community Plan Area and Monterey Dunes Colony



5.5 Future Risks of Specific Infrastructure

This hazard analysis highlights the need for long-range coastal management planning that sets policies regarding how best to balance local interest to protect public and private properties with costs associated with construction and impacts to the beach and coastline that result from these protective structures. A list of specific assets vulnerable to coastal climate change is outlined in Table 14.

Land Use and Buildings

Moss Landing Village

Flood waters in the commercial area (Moss Landing Road) are projected to be higher due to increased storm surge and higher tides pushing more water into the harbor and possibly over the Sandholdt Road sand spit. Buildings within the commercial area at elevations that do not flood today will be affected by wave induced flooding and frequent flooding due to rising tides by 2060. Much of this area will also be at risk to fluvial flooding by 2030. Some of the buildings impacted in this area include the post office, North Monterey County Unified School District Office, and the wastewater pump building, as well as many commercial buildings.

Heights Residential Area

Ten buildings on the southwest corner of the Potrero Road Residential Area are at risk to flooding primarily from coastal storm flooding beginning in 2030.

Moss Landing Island

Risks from increased wave run-up energy and overtopping of the Moss Landing Island leave the harbor vulnerable to catastrophic winter storms. Buildings on the coastal side of Moss Landing Island are at risk from erosion and coastal storm flooding beginning in 2030. MBARI and the MLML Shore Lab have coastal armoring in place that will protect them from erosion through 2030, but by 2060 these structures are predicted to not function as designed and the buildings will be at risk. Flooding from the harbor side due to rising tides and increased river discharge will impact many of these buildings on the Island. Many of the buildings on the Island are also projected to be vulnerable to river flooding by 2060, as fluvial inputs from the Reclamation Ditch drain into the harbor. A few of the buildings on the harbor side of the Island will be further impacted by 2060 from rising tides. By 2100 most of the Island will be at risk from frequent tidal flooding.

Monterey Dunes Colony

Structures within the Monterey Dunes Colony are vulnerable to coastal storm flooding and coastal erosion in 2060. By 2100, 88% of the structures are projected to be vulnerable to erosion.

Harbor

Harbors, by design, locate terrestrial infrastructure and amenities directly adjacent to the aquatic environment. As sea levels rise, these amenities will become less useful as flooding reduces harbor functions during specific climatic conditions (storms, high tides). Some harbor infrastructure may risk the release of hazardous materials when flooded, posing secondary risks to the local environment.

Moss Landing Power Plant

The Moss Landing electric generation facility (owned by Dynegy Moss Landing LLC) is one of the largest natural gas generators on the West Coast. The foot print of the facility is above all projected flooding and erosion hazards, except for the cooling water intake system located on the east bank of the harbor. These intakes will most likely be compromised if wave overtopping of Moss Landing Island (causing sedimentation of the harbor) is allowed to occur.

The number of buildings projected to be impacted by the different coastal hazards at each planning horizon is shown in Figure 20.

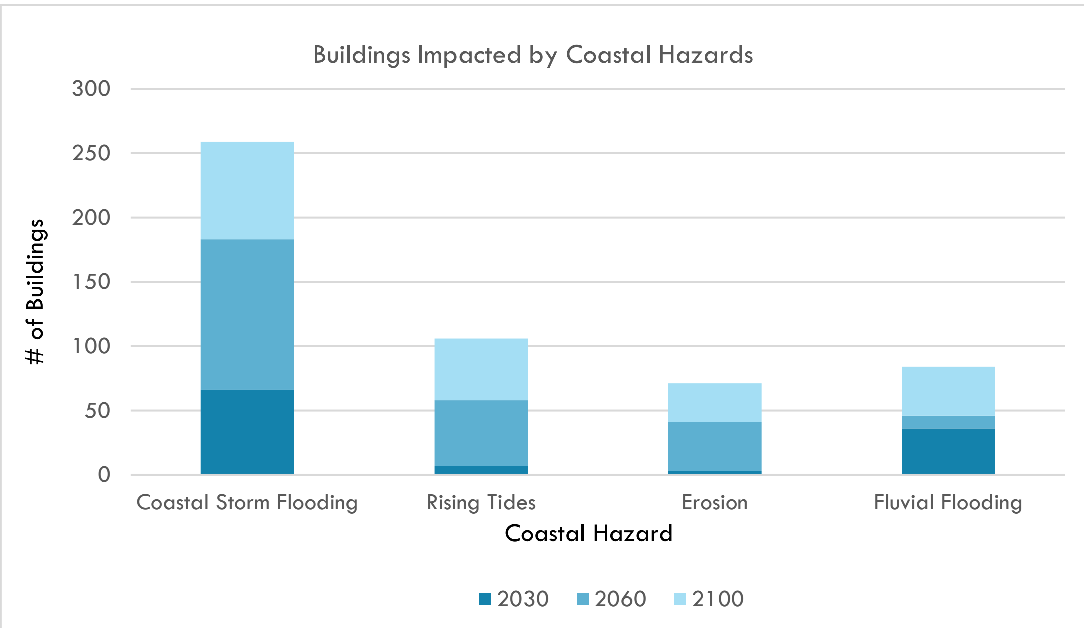


Figure 20. Buildings vulnerable to by different coastal hazards at each planning horizon.

Agriculture within the lower Salinas Valley

As many as 15,293 acres of agricultural land within the lower Salinas Valley (i.e. Moss Landing study area) 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 (Image 2). By 2030 1,272 acres of agriculture land are at risk of periodical flooding during winter rain events. This risk increases to 1,852 acres by 2060 and to 2,565 acres by 2100. By 2030, 92 acres of these agriculture fields will be routinely flooded as higher tides reduce discharge capacity of the tide gates leading to an increase in base water elevation in these drainages. By 2060, coastal structures that protect the Salinas Valley from winter wave induced flooding are predicted to fail and dune erosion along several portions of the Salinas River State Beach will lead to wave overtopping, flooding the Salinas Valley. The risk of flooding due to rising tides for farmland increases to 1,572 acres by 2060 assuming that tide gates no longer function as intended. By 2100, much of the agricultural operations west of Highway One will be flooded during monthly high tides (Figure 21).

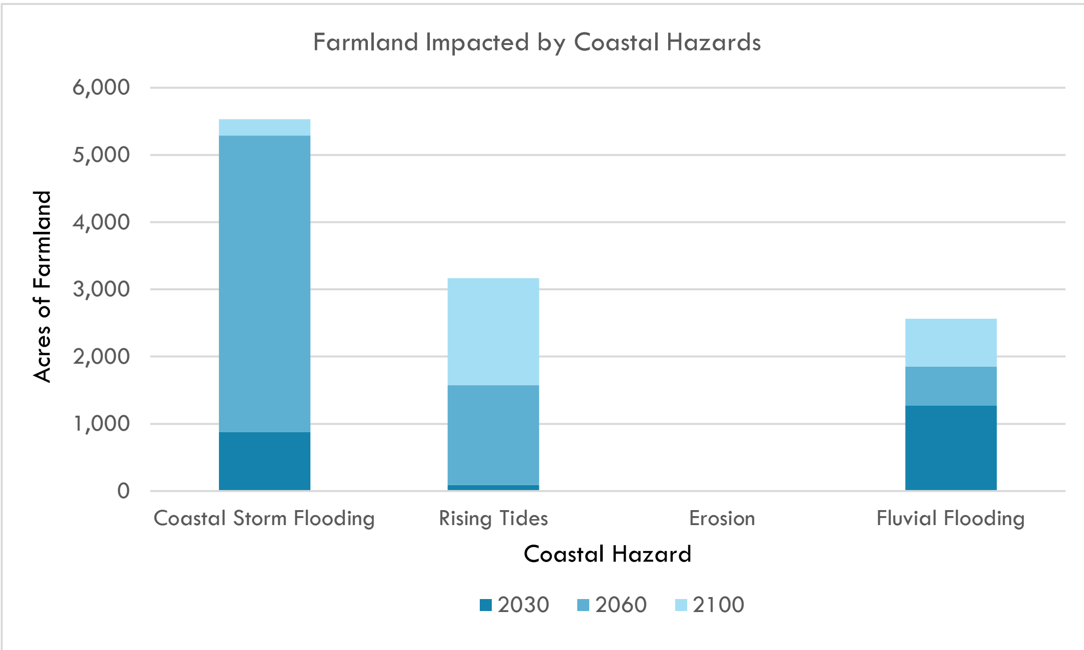


Figure 21. Farmland vulnerable to different coastal hazards at each planning horizon.

Image 2. Flooded agriculture fields in north Monterey County on Saturday, Feb. 18, 2017 after a winter storm. (Photo: Vern Fisher - Monterey Herald)

Transportation

Roads

Figure 22 documents the areas where roads are vulnerable to the combined impacts of coastal climate change and Table 13 lists roads that are vulnerable to the specific hazards and their impact threshold. By 2030, approximately 20,000 feet of roads in the Moss Landing area are vulnerable to periodic flooding during coastal storm events. These include highways, access roads, and residential roads; all prone to increased flood damages as floods become more frequent and severe. Much of Highway 1 between Bennett Slough (north and south of the Elkhorn Slough Bridge) and the Moro Cojo Slough is vulnerable to coastal flooding, as is Moss Landing Road, and portions of Dolan Road, Sandholdt Road and Jetty Road. Parts of Highway 183 south of Castroville are vulnerable to flooding, as is Highway 156 between the Tembladero Slough and Merritt St. Feet of road projected to be impacted by the different coastal hazards at each planning horizon is shown in Figure 22.

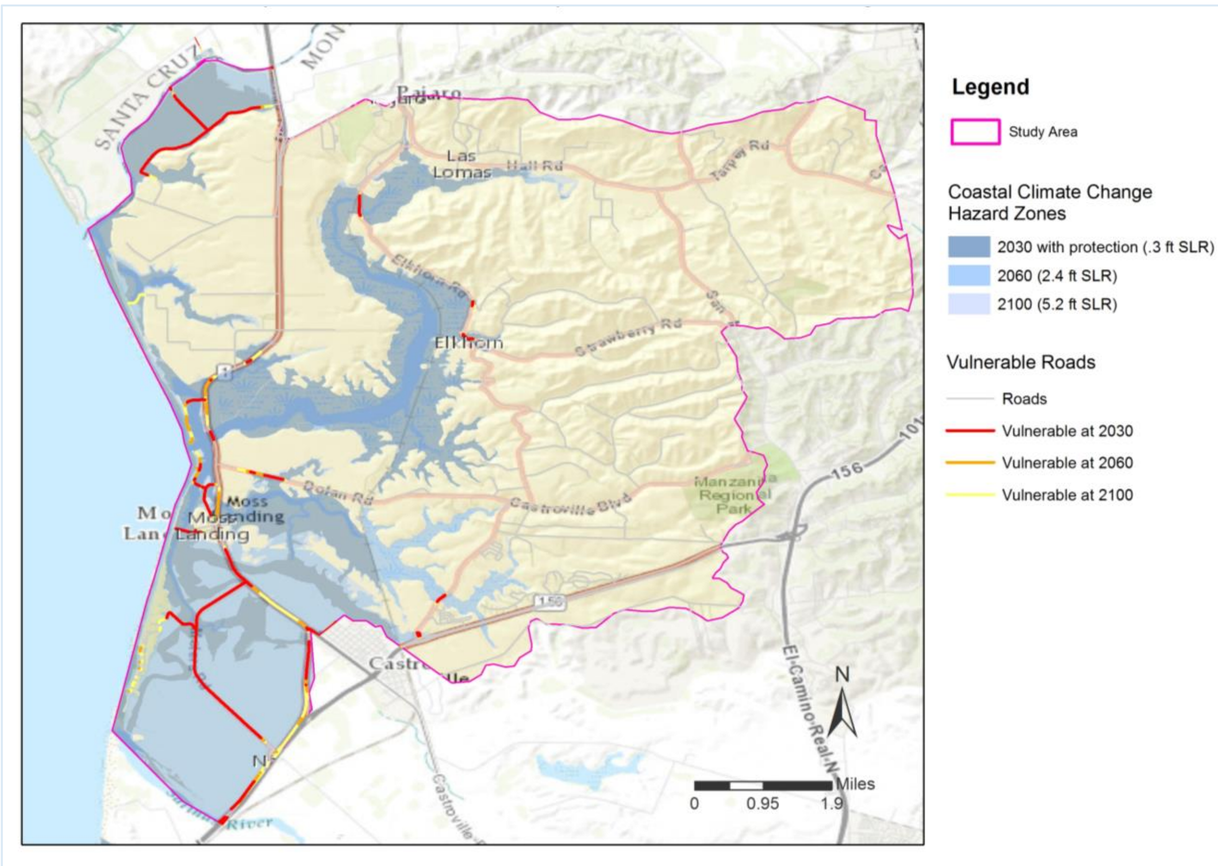


Figure 22. Locations of roadway vulnerable to coastal climate change hazards

Table 13. List of streets vulnerable to each of the hazards at earliest projected time horizon

STREET AND LOCATION	COASTAL STORM FLOODING	EROSION	FLUVIAL	RISING TIDES
Castroville Blvd. over Moro Cojo Slough				2030
Dolan Rd. by Moro Cojo Slough	2060		2030	2030
Elkhorn Rd. over Elkhorn Slough	2060			
Giberson Rd. by McClusky Slough/Zmudowski beach parking	2060			2100
Hwy 1 between Struve Rd. and Jetty Rd.				2060
Hwy 1 along Moss Landing	2060		2060	2100
Hwy 1 and Artichoke Rd over Salinas River	2060			2030
Hwy 1 between Jetty Rd and Elkhorn Slough				2100
Hwy 1 over Bennet Slough between Jetty Rd and Struve Rd	2060			
Hwy 1 over Bennet Slough between Struve Rd	2060			
Hwy 1 over Elkhorn Slough	2060			2030
Hwy 1 over Moro Cojo Slough			2060	
Hwy 1 over Tembladero Slough			2030	2030
Hwy 1 Between Moss Landing and Castroville	2060			2060
Jetty Rd. along sand spit		2060		2060
Jetty Rd. from Hwy 1 to Beach	2060			
Jetty Rd. over Bennet Slough				2060
Laguna Pl.	2060			
Mc Gowan Rd.	2060			
Molera Rd. (all)	2060			
Molera Rd. over Tembladero			2030	2030
Monterey Dunes Way	2060			2100
Monterey Dunes Way over Old Salinas River Channel			2060	
Moss Landing Rd. along Moss Landing Village			2030	2030
Moss Landing Rd. from Whole Enchilada/Hwy 1 intersection	2060			
Moss Landing Rd. over Old Salinas River			2030	
Potrero Rd. (all)	2060			
Potrero Rd. next to Salinas River State Beach parking lot				2100
Potrero Rd. over Old Salinas River Channel			2030	2030
Sandholdt Rd. along Moss Landing Island	2060	2100	2030	2060
Sandholdt Rd. over Old Salinas River Channel	2060			2030
Trafton Rd.	2060			
Whale Way next to Phil's Fish Market	2060	2060		2100

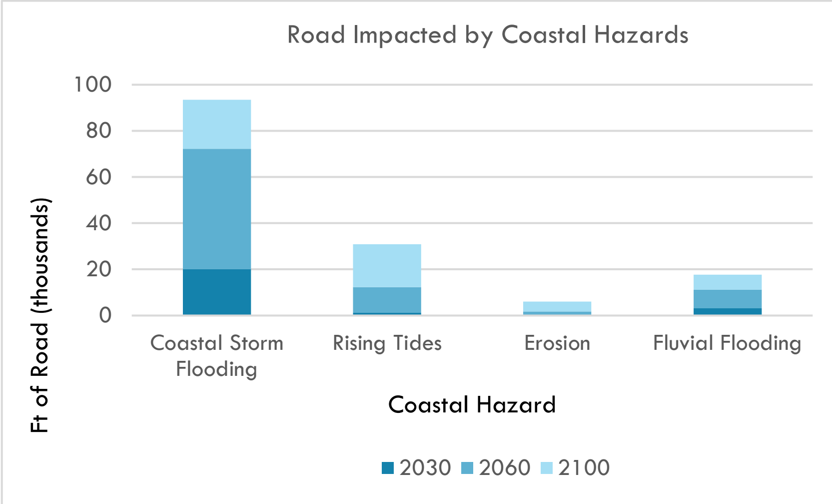


Figure 23. Feet of road vulnerable to different coastal hazards at each planning horizon.

Rail

Large portions of the rail line are already vulnerable to rising tides (Image 3). A total of 12,636 feet rail line is vulnerable by 2060 and 21,072 feet of tracks is vulnerable by 2100 if the rail line is not raised within Parsons Slough, Moro Cojo Slough and south of Castroville.

Image 3. Jan 1, 2014 King Tide pours over the railroad tracks between Kirby Park and the Elkhorn Research Reserve
(Photo: Fred Hochstaedter)

Recreation and Public Access

The Salinas River and Moss Landing State Beaches provide unique and invaluable recreation and coastal access opportunities within the central Monterey Bay. These beaches are vulnerable to increased wave intensity during winter storms. There are 17 designated coastal access locations within the Moss Landing area. By 2060, as many as 10 coastal access locations along the Moss Landing coast line will be severely impacted by Coastal Climate Change (Figure 24). Erosion will specifically impact beach access along Jetty Road and Sandholdt Road. More than five acres of coastal access parking are projected to flood from storm surge by 2060. Access to the harbor will be compromised during winter storms. High tides will regularly flood parks and open space around the Elkhorn Slough. Coastal access will be restricted due to flooded roads.

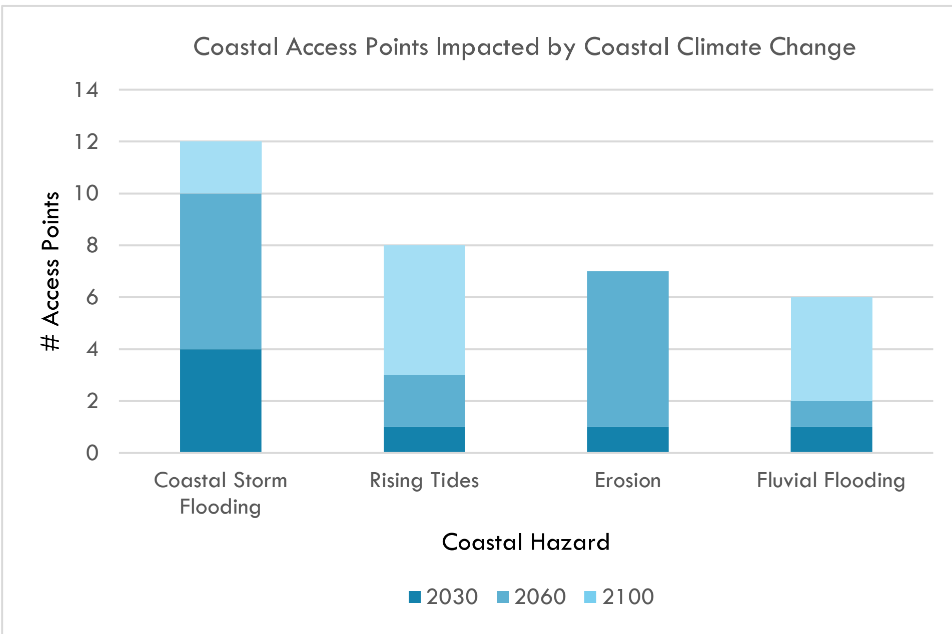


Figure 24. Number of coastal access points vulnerable to different coastal hazards at each planning horizon (N=17).

Water and Utilities

By 2060, both the Potrero and Moss Landing tide gates service capacity will be reduced during winter storms, likely leading to inland flooding. Monterey County Water Resources Agency has studied replacing both tide gate systems to restore proper function. The design will likely not be sufficient to manage all predicted flooding. Monterey County Water Resources Agency is considering pumps and other mechanisms to help protect property and infrastructure.

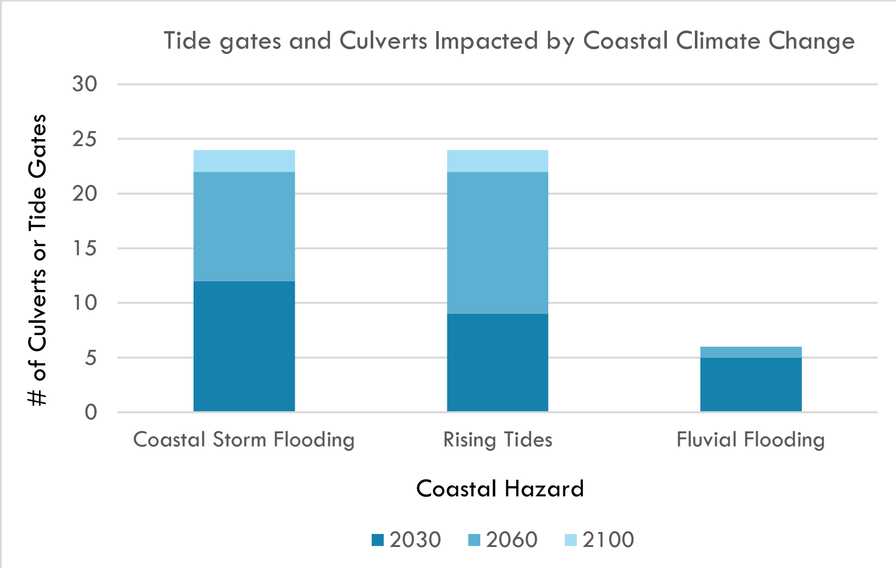


Figure 25. Tide gates and culverts vulnerable to different coastal hazards at each planning horizon.

Four culverts and control structures in Bennett Slough, 11 control structures in Elkhorn Slough, 3 control structures in Moro Cojo Slough and 4 structures in the Old Salinas River /Tembladero are vulnerable to projected increases in storm intensity leading to periodic flooding (Figure 25). Electrical and phone utility data were not available for this analysis.

Natural Resources

Wetlands

The Moss Landing and Elkhorn Slough areas support significant high-quality wetland and upland ecosystems. These natural areas are vulnerable to an increase in the frequency and elevation of flooding. Higher tides will also increase salt water inundation to brackish and fresh water wetlands. The North Monterey County LCP identifies and maps these wetlands and creeks as Environmentally Sensitive Habitat Area (ESHA). Much of the designated ESHA is vulnerable to 2060 impacts of Coastal Climate Change.

Nearly all of the wetlands in Moss Landing are within the coastal storm flood zone for 2030 (80%), and by 2100, 86% are vulnerable to rising tides. Some of these wetland areas, particularly in Elkhorn Slough, are designated critical habitat. All of the Moro Cojo and OSR wetlands are within the boundaries of the 2030 ESA hazard maps. Current tide gate infrastructure will likely not be able to fully mitigate the combined impacts of higher tides, storm surge and increased rain fall and river discharge. Some historical wetland areas that have been reclaimed for farming will become vulnerable to greater flooding in the future and may providing restoration opportunities for agencies in partnership with land owners.

Sand Dunes

The 2030 erosion hazard map extends inland past the eastern edge of the dunes. Breaks in the dunes between Jetty and Potrero roads will reduce the protection this dune provides the harbor from winter storms. Projected breaks within the dunes south of the Potrero tide gates will leave much of the Salinas Valley vulnerable to Coastal Flooding (Figure 18).

The dunes directly north of the Salinas River mouth are especially narrow, and thus, already prone to winter storm erosion and wave overtopping. The dunes have also been eroded by the Salinas River as it flows northward to the ocean. These dunes are vulnerable to erosion and are at risk of breaching during winter storms before 2060. Some rip-rap currently restricts erosion along this portion of the coast but is likely insufficient to resist the projected wave energy and height of 2060 storms. Nearly all of the beaches are projected to erode by 2060, if the beaches and dunes are not allowed to migrate inland. Figure 26 shows the cumulative number of acres of dune that are projected to be eroded by each time horizon.

Jetty Road Sand Spit

By 2030, dune erosion is projected to extend inland, reaching jetty road in one location. By 2060, much of Jetty Road is vulnerable to erosion and unless the dunes are encouraged to migrate inland, north harbor will be vulnerable to the secondary consequences of wave impacts due to the loss of the protective dunes. By 2100, coastal erosion will lead to the loss of much of Jetty Road sand spit, dune habitat and threaten north harbor (Figure 18).

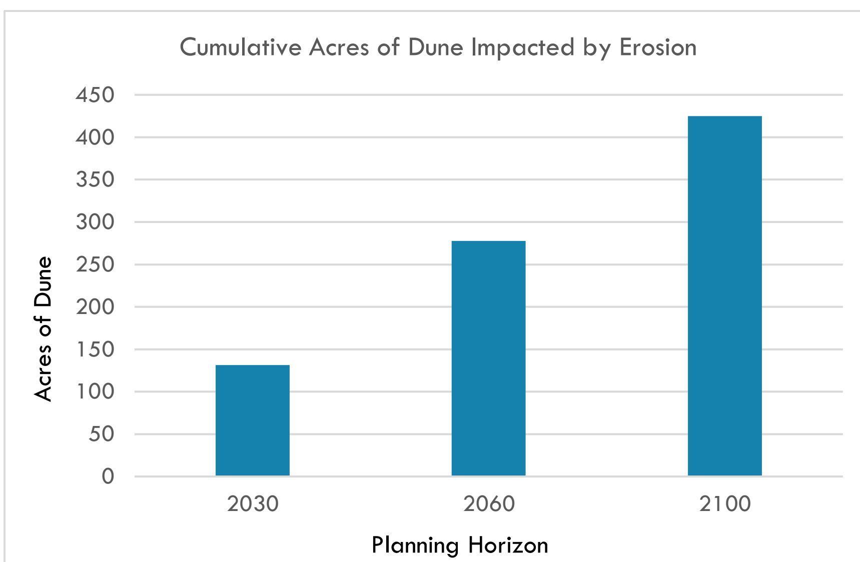


Figure 26. Cumulative acres of dunes within the Study Area vulnerable to coastal erosion

Table 14. Specific assets vulnerable to coastal climate change hazards in the Moss Landing area.

ASSET	COASTAL HAZARD	EARLIEST IMPACT
Potrero Rd Residential Neighborhood	Coastal Storm Flooding	2030
Moss Landing Island/Sandholdt Road Buildings	Erosion Coastal Storm Flooding Rising Tides Fluvial Flooding	2030[23] 2030 2100 2060
Whole Enchilada Complex	Rising Tides Fluvial Flooding	2060 2030
Moss Landing Village	Coastal Storm Flooding Rising Tides Fluvial Flooding	2060 2060 2030
Monterey Dunes Colony	Erosion Coastal Storm Flooding	2060 2100
Moss Landing State Beach	Erosion Coastal Storm Flooding	2030 2060
Salinas River State Beach	Erosion Coastal Storm Flooding	2030 2060
Farmland	Coastal Storm Flooding Rising Tides Fluvial Flooding	2030 2060 2060
Highway 1	Coastal Storm Flooding Rising Tides Fluvial Flooding	2030 2030 2030
Coastal Access Ways	Erosion Coastal Storm Flooding Rising Tides	2100 2060 2060
Potrero Rd and Moss Landing Rd tide gates	Coastal Flooding Rising Tides Fluvial Flooding	2060 2060 2030
Moss Landing Harbor	Coastal Flooding Fluvial Flooding Erosion Rising Tides	2030 2060 2060 2100

[23] MBARI and MLML are projected to be protected through 2030 by the existing coastal armoring.

6. Economic Impacts of Future Climate Risks

Costs of emergency response

The Monterey County Hazard Mitigation Plan reports that more than 800 flood claims have been paid by FEMA within the unincorporated county for more than $21 million dollars. The County plan estimates 4800 residential and 600 commercial properties are vulnerable to flooding within the entire county. Our study identified additional properties that are vulnerable to flooding associated with coastal climate change that may expand those potential losses.

Property valuation

A simple property loss calculation was completed to provide rough estimates of the cumulative costs of the projected risks for each time horizon. Costs for residential and commercial properties were estimated using average values reported within the County Hazard Mitigation Plan[24]. These estimates were used to quantify the cumulative property loss valuation and the economic impact of replacing at risk buildings, infrastructure and services (Table 15).

Municipal Replacement Costs of critical infrastructure

For municipal buildings and infrastructure, the Monterey County Hazard Mitigation Plan identifies costs to replace or move general categories of infrastructure found to be at risk of various natural hazards (not including property costs to relocate). These average values were used for this analysis.

Approximately $85 million in public, private and commercial properties are at risk by 2030 from the combined hazards of coastal climate change. Most of these properties are at risk of winter flooding. An additional $100 million in agriculture properties are at risk of flooding as well, even accounting for tide gate protections. In total, $184 million in properties and infrastructure are within the combined hazard areas projected for 2030. These estimates use the total property value (assuming total property loss) rather than the projected damage to structures and crops. Estimated damage would be far greater if the two tide gate structures did not reduce ocean derived storm flooding.

By 2060 the value of property and infrastructure within the hazard area increases to almost one half billion dollars. The significant increase is due mostly to the increase in the vulnerability of the Salinas Valley are no longer protected by the tide gates. During each time horizon, half the total property

[24] Monterey County Multi-Jurisdictional Hazard Mitigation Plan, 2014, Table 5-1

vulnerable to climate change is for agriculture lands (not accounting for agriculture inland of the coastal zone boundary).

Table 15. Total Value (2016 dollars) of Major Infrastructure at Risk

ASSET	UNITS	2030 (WITH PROTECTION)	2060 (NO PROTECTION)	2100 (NO PROTECTION)
Buildings				
Residential	property value	$8,925,000	$30,975,000	$59,325,000
Commercial	property value	$17,057,808	$19,104,745	$21,833,994
Public	replacement cost	$27,500,000	$56,500,000	$64,500,000
Agriculture	property value	$99,550,000	$264,500,000	$276,600,000
Property losses		*$153,032,808*	*$371,079,745*	*$422,258,994*
Transportation				
Roads	replacement cost	$31,397,838	$113,468,215	$147,527,568
Rail	replacement cost	$2,199,400	$4,452,280	$6,923,840
Highway 1	replacement cost	$868,362	$5,079,940	$6,475,920
Transportation losses		*$34,465,600*	*$123,000,435*	*$160,927,328*
Water and Utility Infrastructure				
Storm Drain Structures	relocate and replacement cost	$0	$107,955	$185,682
Combined losses		***$187,498,407***	***$494,188,134***	***$583,372,004***

Costs = $5.7mill per mile for storm and sewer; $280 per linear foot for roads, $525,000 replacement cost for residential and $680,000 for commercial properties, farmland valued at $50,000 per acre.

Similar property valuations were estimated within the 2016 report by The Nature Conservancy. The TNC report estimated that $160 million in properties and infrastructure would be vulnerable within this area by 2030 (excluding agriculture, our estimate of at risk properties is $90 million) and TNC estimates $260 vulnerable by 2100 and this study estimates approximately $300 excluding agriculture. The TNC report also provides an estimate cost of coastal armoring and of the valuation of coastal beach and wetland habitat (attributed to tourism economy).

In this report, we have focused on understanding if and how existing protective structures can provide the anticipated protection against coastal erosion and fluvial flooding. This analysis finds that the hazards projected for 2100 within the Moss Landing community and the lower Salinas Valley are so severe and necessary adaptation measures will be so significant, that economic valuations of natural habitat and real property, as well as cost comparisons among various adaptation options will likely not reflect future values or future economic realities.

7. Adaptation

7.1 Adaptation Strategy Selection

The risks associated with each of the modeled coastal processes (wave run-up and overtopping, coastal erosion, rising tides and fluvial flooding) threaten various coastal infrastructure differently. Selection of adaptation options must be driven by the possible damage of each risk and the frequency of reoccurring impact. Wave and river flooding can damage buildings and agricultural crops, temporarily restrict use of public amenities, make storm drains ineffective and limit the use of roads, parking lots and walkways. Storm flood risks represent periodic impacts and responses to these threats may be lower in cost and can often be temporary.

Dune and beach erosion and flooding during high tides, are permanent or reoccurring impacts that can lead to a complete loss of infrastructure and use of those properties. Such losses will require extensive rebuilding or reinforcement, a change in use of the property, or abandonment of the property.

Future investments in the protection of coastal structures will need to be weighed by County staff and private property owners against factors including the structure's replacement costs, limitations provided by regulatory agencies, and expected longevity and effectiveness of the adaptation strategy selected. Secondary 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 analysis highlights the need for long-range coastal management planning that sets policies that best balance property value with costs of adaptation and the resulting changes to the public coastline and wetland resources that will occur.

7.2 Recommended Actions within Local Plans

Moss Landing Community Plan

The current version of the Moss Landing Community Plan briefly discusses sea level rise, but does not discuss what adaptation measures Moss Landing can or should take. An objective of this SLR vulnerability report is to provide additional information on future risks and possible adaptation strategies to address the future hazards this community is projected to face.

Hazard Mitigation Plan (2014)

The Multi-Jurisdiction Hazard Mitigation Plan identifies "the primary goal of all local governments is to promote the public health, safety, and welfare of its citizens." The plan identifies six goal statements for local hazard mitigation planning in Monterey County (Table 16).

Table 16. Goals for local hazard mitigation from the Monterey County Hazard Mitigation Plan

GOAL	DESCRIPTION
Goal #1	Promote disaster-resistance and ***climate adaptation*** strategies in ***future development***.
Goal #2	Retrofit, reinforce, or otherwise protect ***existing community assets***, especially ***critical infrastructure***, for hazard resilience.
Goal #3	Encourage ***natural systems protection*** through plans and policies; vegetation, debris and sediment control measures; maintenance and restoration programs; ecosystem services; and other activities for areas such as the Salinas and Carmel rivers and the Monterey County coast.
Goal #4	Provide ***regulatory tools*** for applicable hazards and integrate hazard mitigation principles into appropriate ***local plans*** such as the General Plan during the next General Plan update.
Goal #5	Increase ***public education and awareness*** on hazard risks and available mitigation techniques for reducing hazard risk; build and support ***personal preparedness*** to enable the public to better prepare for, respond to, and recover from disasters.
Goal #6	Improve ***local government capacity*** for disaster resiliency; facilitate ***coordination*** between participating jurisdictions and state and federal agencies, local utility companies, local businesses, non-profit organizations, and other stakeholders to promote hazard risk reduction.

7.3 Strategies Discussed in Related Studies

Economic Impacts of Climate Adaptation Strategies for Southern Monterey Bay

In a 2016 study[25], The Nature Conservancy (TNC) compared the costs and benefits of allowing coastal erosion to occur within Moss Landing. This strategy allows the beaches and coastal ecosystems to retreat naturally, in contrast to increased shoreline armoring along much of the Salinas State Beach. The report concludes that because of the high cost of the armoring, the economic benefits of allowing erosion are greater than armoring the shoreline, despite property losses. The study reported that by 2100, the difference in net present value of local infrastructure is $1.1 billion when comparing adaptation strategies with and without armoring. TNC also analyzed the costs and benefits of allowing erosion to occur through use of conservation easements and found that the conservation easements have a significantly higher net present value than allowing the landowners to bear the costs of adaptation. Successful implementation of a coastal adaptation easement program will rely on an NGO or government agency to purchase the land from private landowners.

[25] Leo et al. 2016. *Economic Impacts of Climate Adaptation Strategies for Southern Monterey Bay.* pg. 62-63

Natural Infrastructure

Partners at the Center for Ocean Solutions (COS) at Stanford University have completed two studies to evaluate the natural capacity of Moss Landing wetlands and dune ecosystems to mitigate risks of climate change on inland resources (Figure 27)[26]. The 2016 report by COS suggests: "If these habitats are lost, degraded or unable to adapt by migrating inland, then local communities also lose beneficial services they provide which include: sequestering carbon, improving water quality, buffering ocean chemistry, providing nursery or nesting grounds, and protecting from erosion and inundation." Two key findings of the COS report for Moss Landing are:

- Built structures—including some coastal dependent structures—limit adaptation options for parts of Moss Landing. Critical infrastructure such as the Moss Landing power plant, harbor, and Highway 1 all present challenges to implementing many otherwise viable strategies.
- Nature-based climate adaptation options in the Moss Landing case study area include restoration or preservation of dune and wetland habitats. In addition, nourishing beachfront locations with additional sediment is an option if appropriate environmental concerns are addressed.

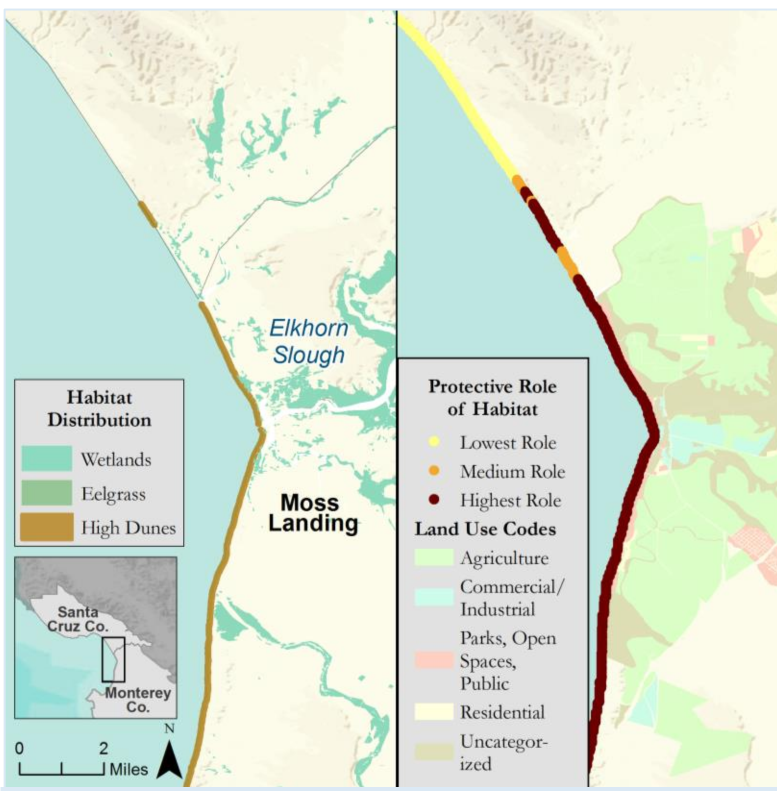


Figure 27. Protective role of habitat in Moss Landing
(Figure source: COS, 2016)

[26] Center for Ocean Solutions. 2016. *Coastal Adaptation Policy Assessment: Monterey Bay*

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 tailored to the specific needs of each community 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.

Coastal Commission support of Cities that update their Local Coastal Plans to include the adaptation measures prioritized by the community can aid successful implementation of a community's adaptation strategy

Example of adaptive dune restoration activities to increase the resiliency of foredunes to wave impacts. (Photo: R. Clark)

7.4 Current Strategies Used within Moss Landing

The Moss Landing community currently uses several adaptation and protection strategies to minimize risks of flooding and coastal erosion. Most of the properties on the Moss Landing Island have enhanced the dune plant community in front of their buildings to increase dune height and stability. To reduce flooding of properties from water within the Old Salinas River, a berm has been constructed on the west side of Moss Landing Road. Monterey County also manages a complex system of tide gates and lift stations to lower water levels within the lower Salinas Valley. Monterey Water Resources Agency actively maintains this infrastructure during storm events to ensure they work properly. Monterey County also manages the Salinas River lagoon by releasing water to the Old Salinas River and by breaching the mouth when water elevations pose flood hazards (greater than 5 ft.).

7.5 Moss Landing Climate Adaptation Strategy Options

Numerous reports have compiled lists of adaptation options and describe their use in addressing different climate risks (
Table 17). Examples of climate adaptation strategies being applied to address local hazards are only just becoming available (see Marin Ocean Coast SLR Vulnerability Assessment[27]). Information on the costs of these strategies is limited but examples of most strategies exist and can provide a range of costs[28]. Local public works departments are best able to estimate the true costs of various construction projects and municipal planners, NGOs and consultants continue to evaluate the feasibility and efficacy of planning and regulatory options. Numerous planning documents exist that provide narrative description of each adaptation option[29].

2017-2030 Adaptation Options

Conditional Rebuilding Restrictions

Impose restrictions on reconstructing buildings that may be damaged by projected hazards. These restrictions can include adhering to stricter codes or more resilient designs, or rebuilding only under the agreement to not armor in the future. Options for Moss Landing hazards include:

- **Adopt policies to limit municipal capital improvements that would be at risk**

  Prudent adaptive management to climate change begins with not placing new municipal infrastructure at risk to future hazards. County policies that establish review processes for proposed Capital Improvement Projects located within future hazard zones have been adopted by the City of San Francisco (http://onesanfrancisco.org/wp-content/uploads/Guidance-for-Incorporating-Sea-Level-Rise-into-Capital-Planning1.pdf). These guidelines help staff to review proposed infrastructure projects to ensure that those projects will not become vulnerable to projected climate risks within the expected lifespan of the project.

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

[28] ESA PWA. 2012. *Evaluation of Erosion Mitigation Alternatives for Southern Monterey Bay.*

[29] Grannis, J. 2011. Adaptation Tool Kit: Sea Level Rise and Coastal Land Use

Table 17. List of Adaptation Strategies (short= 0-5 years, med= 5-30 years, long= 30+ years)

TYPE	DURATION OF PROTECTION	RIVER FLOODING	COASTAL STORM FLOODING	EROSION	WAVE IMPACTS	RISING TIDES
Hard						
Levee	medium	●	●			●
Seawall or Revetment	medium		●	●	●	
Tidal Gate	medium		●			●
Flood wall	medium	●	●			●
Groin	medium		●	●	●	
Soft						
Wetland shoreline	medium		●		●	
Dune restoration	medium		●	●	●	●
Beach Nourishment	short		●		●	
Offshore structure	medium		●		●	
Accommodate						
Elevate	medium	●	●			
Managed Retreat						
Retreat	long	●	●	●	●	●
Rolling easement	long	●	●	●	●	●
Strict land use re-zone	long	●	●	●	●	●
Regulatory Tools						
Stricter Zoning	long	●	●	●	●	●
Floodplain Regulations	long	●	●		●	●
Building Codes and Resilient Designs	long	●	●		●	●
Setbacks/Buffers	long	●	●	●	●	●
Rebuilding Restrictions	long	●	●	●	●	●
Planning Tools						
Comprehensive Plan	long	●	●	●	●	●

- **Zoning**

  The Moss Landing Community Plan is being drafted and can be a useful document to establish future adaptation options. Rezoning areas that are at risk of future flooding for uses that can accommodate these temporal impacts can minimize repair costs while retaining the economic use of these properties. Rezoning commercial and residential properties within the 2030 hazard areas to more resilient uses can help to reduce future property loss and protect coastal access and recreation from coastal squeeze while helping high risk properties retain property value. Rezoning areas for commercial use further inland (i.e. transferable development credits) may enable the community to migrate inland with the coast.

- **Elevate**

  Raising buildings above 2030 flood may be a cost-effective midterm adaptation strategy. As tidal flooding becomes common, however, use of these buildings may once again be compromised.

- **Setbacks and Buffers**

  Adopting setbacks and buffers helps ensure that no building occurs too close to projected hazard areas and will allow for the shoreline to retreat naturally.[30] Establishing setbacks for future development on the Moss Landing Island will reduce future loss of beach, limit building obstructions to lateral access and increase the useful life of these buildings. Placing required parking near future hazards (shoreward) may help establish buffers that can be incrementally abandon as coastal erosion encroaches on these properties.

Prioritize coastal protection structures for upgrade or removal

There are a number of developments on the Moss Landing Island sand spit that are vulnerable to coastal erosion by 2030. To increase near term resiliency of the island, the County may consider adopting a combination of strategies including allowing existing hard armoring to be maintained to protect current buildings, the adoption of new building guidelines for future development to be placed outside the 2030 hazard zone and designed to be resilient to future hazards and support of efforts to maintain beach elevation and width to provide for a more resilient demarcation between beach and buildings.

- **Investigate beach nourishment and Groins to maintain Moss Landing island beach width**

  A groin is a structure perpendicular, rather than parallel, to the coastline, extending from the beach to the sea. On long beaches, many groins can help distribute sand more evenly and reduce erosion. These structures however can also contribute to new erosion patterns and new wave patterns. Construction of a groin in concert with harbor derived beach nourishment may increase beach width along the Island, especially where current buildings are encroaching on public beach. The offshore submarine canyons may compromise the effectiveness of this strategy and additional sediment transport studies are warranted.

[30] Grannis, J. 2011. Adaptation Tool Kit: Sea Level Rise and Coastal Land Use

Beaches are a key natural buffer as well as a popular human asset. Beach nourishment involves bringing sand from elsewhere and depositing it on the beach in order to restore the eroded beach. Beach nourishment can maintain the use-value of a beach and can help protect infrastructure beyond the beach from erosion and flooding. However, it is a temporary and costly solution that changes the profile of the natural beach and shoreline, and the new sand (usually a different grain size) often erodes quicker than the natural sand. And, like any human process that disturbs nature's processes, beach nourishment can damage local ecosystems and species.

- **Dune Restoration**

  Dunes are critical in acting as a buffer between the ocean and the areas behind the dunes, just like seawalls, except because dunes are natural, they also preserve existing ecosystems and have the ability to move inland with the beach and the sea level in order to preserve the whole beach-dune system. Dune restoration involves removing non-native plants in favor of native species, which allow the dune to migrate and provide a home for other native species.

  CCWG staff has worked with the State Coastal Conservancy and California State Parks to begin native plant rehabilitation of key sections of the Salinas River State Beach and will be completing long term monitoring of this project to document the success of these soft/natural adaptation strategies in coming years. Such dune enhancement and restoration efforts may be a valuable short to medium term adaptation strategy. If these dunes are allowed to migrate inland (leading to the loss of agricultural lands), they may continue to provide protection from ocean flooding.

Reduce risks of flooding

The periodic flooding projected within the 2030 hazard maps can be planned for. Actions to protect and accommodate projected flooding can reduce risks to those properties.

- **Upgrade the flood berm along Moss Landing Road**

  A small berm has been constructed between the Old Salinas River and buildings along Moss Landing Road. The berm does not appear to be uniformly designed or constructed but does provide a first line of protection from high waters within the Old Salinas River. Upgrading this berm may be a cost-effective way to help reduce risks of coastal flooding risks projected for the Moss Landing Commercial area through 2030.

- **Evaluate Tide Gate upgrades to improve flood release**

  Through the 2030 planning horizon, the Moss Landing and Potrero tide gates are predicted to continue to serve an important protection from tidal flooding to upstream properties, primarily agriculture and natural habitats. The tide gates however have restricted discharge from these two watersheds during large rain events which have exacerbated flooding up stream. Upgrades to these gates that allow overflow during large events may help to reduce flooding extent and duration of flooding along upstream farmlands.

- **Establish Managed Retreat policies to support future adaptation**

  Managed retreat is an adaptation strategy aimed to facilitate and regulate the gradual move away from areas vulnerable to flooding or erosion. Managed retreat can take many forms, including zoning, setbacks, buffers, restrictions, rolling easements, and land acquisition. These strategies can be used in conjunction with other adaptation measures to facilitate the most fluid and equitable adaptation approach to the varying threats that sea level rise poses. Managed retreat programs can work in tandem with other adaptation strategies to reduce impacts of flooding, maintain local character, improve natural habitat areas and secure coastal access.

- **Improve flood attenuation through Creek and Wetland Restoration**

  Wetlands can act as a critical buffer from waves, tides, and erosion and they will transition inland as the sea level rises if they are given the space to do so. Additionally, wetlands provide natural pollution filtration and shoreline stability, sequester carbon, and can attenuate flood waters, along with providing important habitat that supports local fishing and tourism. Numerous Wetland restoration efforts are underway within the Elkhorn and Moro Cojo sloughs. The County and local community can support these activities and ensure that future designs help improve climate resiliency of the Moss Landing community.

  The Greater Monterey Integrated Regional Water Management Plan outlines strategies to improve the function of local drainages to benefit the goals of numerous stakeholders. Proposed watershed management and drainage enhancement projects within the IRWM plan can help the lower Salinas Valley become more resilient to predicted increases in flooding during rain events. Numerous low-lying areas along these drainages (notably Carr Lake) can be acquired and redeveloped to provide aquatic habitat, open space, recreation and flood attenuation and storage that would greatly reduce the predicted negative interactions associated with more intense rain fall and higher seas.

2030-2060 Adaptation Options

Identify areas for future protection accounting for costs, feasibility and secondary impacts

- **Tide gate upgrades**

  By 2060 the ability of the current tide gates to provide protection from coastal and tidal flooding may be significantly reduced due to the projected 12–29 inch increase in water elevations within the harbor. Further analysis with help from the Monterey County Water Resources Agency is necessary to determine the expected reduction in service and the possible increase in water elevation behind the structures. Replacing tide gates with pump stations may increase the capacity of the system to retain current water levels within the Old Salinas River but it will likely be expensive to size and operate a system large enough to manage predicted increases in winter river discharges of up to 700cfs.

The estimated total costs of installing and operating new pumps on one or both tide gate systems should be evaluated in comparison with the benefit to 1,592 acres of farmland at risk of periodic coastal flooding.

- **Hard Armor Protection**

  Hard armoring can be used in areas with high-density development or with critical infrastructure in order to protect existing coastal infrastructure from flooding or erosion. Hard armoring, such as sea walls, tide gates, revetments, dikes, levees, riprap, etc., can be effective in creating a barrier between the land and the sea, and can sometimes be used as a new, elevated surface for parks, walkways, roads, or other public uses.

  However, there are many drawbacks to hard armoring that make it a relatively unsustainable long-term protection measure. The high costs of building, maintaining, and increasing hard armoring over time must be taken into account. Maintaining or upgrading hard armoring means the area between the armoring and the ocean—the beach, dunes or wetlands— has nowhere to migrate as the sea level rises, and so while the hard armoring will protect coastal development, the ecosystem and all its benefits, including its role as a natural barrier, will disappear. Hard armoring can also increase erosion of unprotected neighboring properties through the reflection of wave energy. Additionally, hard armoring allows development in increasingly vulnerable areas, which can result in a larger impact on the community if the armoring fails (such as in New Orleans due to Hurricane Katrina with the failure of the levees).

  Despite the negatives associated with hard armoring, selective use may be one option for areas of Moss Landing. Structures on Moss Landing Island and within the Monterey Dunes Colony are projected to be at risk of coastal erosion by 2060. Strategies should be developed that identify areas where coastal armoring is feasible and appropriate and areas where building retrofits and retreat are more appropriate. These decisions should take into account projected risks from Coastal Climate Change for the total life of the properties being protected. Future risks to the harbor should also be considered.

Identify areas for managed retreat to retain sufficient beach area for recreational use

Protection of all properties and infrastructure identified at risk during each time horizon is likely infeasible. Therefore, The Moss Landing community 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 to ensure the long-term sustainability for 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.

Providing for the managed retreat of the Salinas River dunes complex onto adjacent farm and residential properties may provide significant longer-term protection from river and storm flooding near the Salinas River mouth.

Identify areas for redevelopment and transfer of development credits

To ensure that Moss Landing remains a viable coastal community, areas should be identified where urban redevelopment can occur, safe from projected hazards. Areas of North Harbor, Moss Landing Heights and Dolan neighborhoods are outside of projected hazard zones.

2060-2100 Adaptation Options

Between 2060 and 2100, increased coastal wave damage, greater flooding depths and periodicity and higher tides will threaten significant portions of Moss Landing Island and commercial area properties. Protection of all properties from these risks will be costly, technically challenging and will degrade the communities charm. Decisions regarding what the urban/beach front area will look like in 2100 will need to be made much earlier if adaptation is to be strategic and cost effective. Adopting coastal adaptation and retreat policies once all efforts to protect infrastructure fail is a costly strategy.

Between 2060 and 2100, risks from Coastal Climate Change increase significantly. Much of the Island and commercial district are projected to be flooded during high tides and impacted by winter storms. Highway One and other roads will need to be upgraded or realigned if they are to continue to function. Adaptive community planning can help Caltrans and other agencies make better decisions regarding how to upgrade roads and utilities to best serve the Moss Landing of 2100.

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.

EXPLORING ADAPTATION POLICY

The Coastal Commission 2015 Guidance 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"*

The Marin Climate Adaptation effort[31] has completed focus area analysis of coastal communities (i.e. Bolinas) similar to this Moss Landing 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 have been identified for removal and no procedures have been identified to support municipalities to *"convert at risk areas to open space."* Such procedures are likely necessary if Moss Landing is to remain a viable community in 2100. The overwhelming hazard projections for this community suggest that long term adaptive planning and managed retreat programs are necessary and should be developed as early as possible (i.e. 2030) for future implementation (i.e.2060-2100).

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

Cost implications from routine impacts of projected hazards will lead many property owners to choose between upgrading their properties to be more resilient or abandon the current uses of those properties. Establishing equitable retreat policies that outline how and when various portions of the community should be relocated will enable the community to adapt and become more resilient.

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.

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. City and utility agencies and companies can integrate future land use changes into current infrastructure repair and replacement decisions to minimize future costs of infrastructure loss and realignment. Basic cost estimate (based on previous reports) to realign roads and infrastructure that will be at risk by 2100 is outlined in Table 15.

8. Conclusion

The adaptive capacity of Moss Landing to respond to the combined vulnerabilities projected within the 2030 ESA hazard maps is high. The increased risks after 2060, however, of higher energy storm surge, greater fluvial discharge and higher ocean water elevations become a significant threat to the long-term viability of Moss Landing Island and commercial area.

This hazard assessment is intended to provide projections of future risks so the community can begin to adapt and redevelop strategically before emergencies happen. State funding is available to help communities adapt to future risks projected by this study. This hazard evaluation is intended to provide a predictive chronology of future risks to support local planning and future discussions with state regulatory and funding agencies.

POSSIBLE NEXT STEPS

- Conduct a more complete inventory and risk assessment for utility infrastructure (data were not available for this analysis).
- Adopt Capital Improvement Project review guidelines for sea level rise hazard areas.
- Integrate 2030 hazard maps into Moss Landing Community Plan.
- Work with Moss Landing Marine Labs and Monterey Bay Aquarium Research Institute to address lateral access restrictions along the Moss Landing sand spit beach.
- Encourage additional dune restoration activities between Salinas River mouth and the harbor entrance.
- Draft the Moro Cojo tide gate management strategy.
- Work with local stakeholder groups to develop flood accommodation strategies for agriculture within the 2030 hazard area.
- Refine flood and erosion hazard maps to provide additional detail and accuracy;
- Identify assets that are “regional” and the regional risks;
- Consider potential risks to various properties independently for each hazard to better define policy and building guideline alternatives.

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