STINSON BEACH ADAPTATION RESPONSE COLLABORATION

DRAFT Sea Level Rise Vulnerability Assessment

Prepared for
Marin County Community Development Agency

April 24, 2023

Photo by Virtual Planet Technologies

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1. INTRODUCTION

This document was prepared by ESA for Marin County Community Development Agency (CDA) for the Stinson Beach Adaptation and Resilience Collaboration (ARC) project and provides an update to Marin County's 2016 Marin Ocean Coast Sea Level Rise Vulnerability Assessment. Notable updates and background on Stinson Beach are summarized below. The following sections describe the sea level rise and storm scenarios considered for the study (Section 2), data sources for asset and hazard information used for the analysis (Section 3), updated hazards analyses methods to update estimates of coastal erosion, wave runup, and Easkoot Creek flooding (Section 4), vulnerability assessment findings (Section 5), and conclusions and next steps for the study (Section 6).

1.1 Background

Future sea-level rise is expected to create a permanent rise in ocean water levels that would shift the water's edge landward. If no action is taken, higher water levels would increase erosion of the beach and upland migration of marsh habitats. Additionally, the combination of higher ocean water levels and squeeze of beaches and marshes around Stinson Beach would result in greater flooding and damage during coastal storms.

The purpose of this vulnerability assessment is to assess the projected impacts of sea level rise by mid-century (2050-2060) and late century (2080-2100) in Stinson Beach and identify potential risks to development and natural habitats. The results of this vulnerability assessment will inform public and private stakeholders and decision-makers of these potential impacts and inform the development of sea-level rise adaptation strategies to avoid or minimize these impacts.

The findings of this report will be discussed with the public and local stakeholders to initiate a sea level rise adaptation planning process for Stinson Beach. In the following tasks of the Stinson Beach ARC, the project team will identify adaptation measures that reduce or eliminate the identified sea level rise vulnerabilities as well as evaluate their performance, costs and benefits over time of potential adaptation pathways. Ultimately, the project team will work towards developing an Adaptation Roadmap for Stinson Beach that outlines a sea level rise monitoring approach, defines exposure thresholds and trigger points for action, evaluates potential adaptation measures, prioritizes measures for implementation, and identifies next steps for sea level rise adaptation.

Key Terms

This study examines the vulnerability of Stinson Beach to sea level rise and related hazards. The following key terms are summarized here as background information on the hazards considered in this study in the general order that they appear in this report:

- **Asset** – a built or natural resource that benefits humans or wildlife
- **Sea level rise** – the increase in ocean water levels due to climate change
- **Coastal hazards** – the following chronic and temporary hazards were evaluated:
  - **Tidal inundation** – regular wetting of areas adjacent to the ocean or lagoon and other waterbodies connected to the ocean. This study examines areas inundated by astronomical "spring" tides that occur during a full or new moon and result in the highest tides of the month.
  - **Coastal Flooding and Wave Run-up** – extreme temporary coastal storm events that result in elevated water levels due to a combination of storm surge, wind setup and large waves. Temporary coastal flooding with wave run-up can impact beach and bluff shorelines, while coastal flooding can impact low areas around bays and lagoons etc. This study examines the flooding potential for a 100-year coastal storm event that has a one percent chance likelihood of occurring any given year.
  - **Coastal Erosion** – the landward shift of the shoreline, dune face, and/or coastal bluff in response to wave action and other terrestrial forces
  - **Groundwater** – water under the surface fluctuates seasonally with peak levels during the wet season. This study examines the level of groundwater with sea level rise and its effects on onsite wastewater treatment (i.e. septics) and other utilities.
  - **Fluvial flooding** – temporary flooding along a river/creek as a result of extreme rainfall and runoff
- **Beach width** – beach width is defined from the mean high water shoreline to the back of beach (whether a dune, bluff, coastal armoring structure, residence or other development). Beach width varies seasonally from its widest in summer/fall and narrowest in winter/spring.
- **Vulnerability** – the vulnerability of any given asset is based on the following contributing factors:
  - **Exposure** – The hazard exposure of an asset is based on the type of hazard an asset is subjected to under existing or future conditions and the timing at which the hazard occurs
  - **Sensitivity** – An asset's sensitivity to a given hazard is defined as the asset's level of impairment if impacted (e.g. flooded temporarily, inundated permanently, or if impacted by erosion or waves).
  - **Adaptive Capacity** – The adaptive capacity of an asset is the ability of that asset to change over time and respond to a hazard.
- **Adaptation Pathways** – A planning approach to address the uncertainties of climate change and/or sea level rise decision making. In an adaptation pathways approach, multiple adaptation measures are identified to address the range of potential future conditions. Steps along an adaptation pathway are taken incrementally in response to increasing hazard exposure, risk tolerance or other triggers.

1.2 Stinson Beach Setting

The Stinson Beach community is mostly situated on a dynamic sand spit with limited low relief foredunes that fronts Bolinas Lagoon with approximately one-quarter of the total parcels on the adjacent uplands. The Stinson Beach area was recently characterized by ESA (2021) in terms of historic conditions, ecological conditions and shoreline dynamics along the beach side of the community. The beach can be divided into four distinct reaches based on morphology and development: the Seadrift reach is armored by a rock revetment at the front of the dune formation there, the Patios reach is fronted by unarmored dunes, the Calles reach has little to no dunes with homes built at or behind the beach itself with individual armoring structures at some homes, and the NPS reach has just a few unarmored structures interspersed with taller dunes. Behind the beach, the homes, park and related access roads in these reaches are adjacent to Bolinas Lagoon (Seadrift and Patios) that transitions upland to the southeast into the floodplain of Easkoot Creek (Calles and NPS).

Stinson Beach is within the tsunami hazard zone as mapped by California Geologic Survey[1] (State of California 2022) and American Society of Civil Engineers[2] (ASCE 2022). The CA tsunami hazard zone covers all of the low-lying areas in Stinson Beach and Bolinas Lagoon, including and beyond Shoreline Highway to the adjacent uplands. Also, the low areas in Stinson Beach may be subject to mass deformation (translation and subsidence, spreading) due to liquefaction during an earthquake (Hall and Niemi. 2008, Lawson 1908, PWA 2006). This study does not include these tsunami and seismic hazards. These additional hazards are detailed in the Public Safety Element of the Marin Countywide[3].

Stinson Beach vicinity pre- and post-development as shown in US Geological Survey T-Sheets for Tamalpais (1897 right and 1993 left)

1.2.1 Recent Hazard Impacts at Stinson Beach

Stinson Beach is vulnerable to coastal and fluvial hazards today. The impacts of these hazards have included beach erosion and flooding during past El Niños, road flooding during storm surge in Bolinas Lagoon, as well as road, home and park flooding from Easkoot Creek and elevated groundwater levels especially during the wet season.

[1] CGS tsunami web map for Marin County is accessible at https://www.conservation.ca.gov/cgs/tsunami/maps/marin
[2] ASCE Tsunami Hazard Tool is accessible at https://asce7tsunami.online/
[3] Public Safety Element accessible at https://www.marincounty.org/depts/cd/divisions/planning/housing-and-safety-elements

Recent impacts at Stinson Beach occurred during and after the atmospheric river event around January 5, 2023, in which a series of storms resulting directed large waves, high ocean levels and heavy rainfall at Stinson Beach (see photos below). During January 5, offshore swell height ranged from 20-30 feet[4], which coincided with a peak recorded tide level at Point Reyes of 7.64 feet[5] (approximately the 2-year recurrence water level at this tide gauge). Wave runup propagated into inland developed areas along Stinson Beach, especially down the Calles, and the beach and dunes were eroded[6]. Rains associated with this event also caused flooding of Easkoot Creek and damages to the NPS parking lots and adjacent areas in addition to very high and emergent groundwater throughout the community.

January 5, 2023 coastal storm impacts at Stinson Beach: (left) beach and dune erosion at NPS Lifeguard Station (Source: Twitter @WestMarinFeed) and (right) wave overtopping on Calle del Resaca Twitter @Sammy_Herdman).

In a post-storm assessment, Marin County staff noted damage to some 20 houses in the Calles, ranging from minor water damage to structural damage, and an additional 10 houses or so in Seadrift identified minor flood damage. Along the southern beach, NPS dunes were eroded along their entire extent, undercutting several restroom facilities and damaging an ADA accessible boardwalk to the beach. Combined with flood damage to the NPS north parking lot, these impacts forced the closure of Stinson Beach to vehicle access for 3 weeks and resulted in reduced visitor facilities.

Stinson Beach County Water District (SBCWD) staff performed a visual assessment of the on-site wastewater treatment systems (OWTS) after the storm events and observed minor damage at five (5) properties and major damage on one (1) property. Minor damages typically included broken or missing segments of sewer lateral pipe, displaced septic tank risers, sand intrusion in the septic tank and/or sewer pipe, disconnected electrical conduits to septic control panel(s) and/or alarm(s). Major damages were sustained by a leach field that was exposed and/or carried away from erosive wave action. Hidden impairments to the OWTS included high groundwater conditions that affected the proper operation to hundreds of OWTS. MARIN COUNTY STAFF

[4] Scripps CDIP Point Reyes buoy station data home page accessible at https://cdip.ucsd.edu/themes/cdip?d2=p70&pb=1&u2=s:029:st:1:v:waves_1week:max_frq:0.33:dt:202301

[5] NOAA Point Reyes Tide Gauge accessible at https://tidesandcurrents.noaa.gov/waterlevels.html?id=9415020

[6] NOAA aerial imagery accessible at https://storms.ngs.noaa.gov/storms/2023_california/index.html#16/37.9015/-122.6533

Following the early January storm events, groundwater surfaced in various streets and lowland areas and was, in general, close to existing grade. As a result, the older gravity fed leach fields were saturated and functionally impaired. In some cases, wastewater flowed back into the septic tank. In other cases, homeowners turn a shutoff valve to prevent back-flow of sewage into the septic tank. The modern OWTS in Stinson Beach typically have raised leach field beds and pumps that prevent wastewater back flow into the septic tank. Ultimately, wastewater treatment and disposal were significantly affected for weeks from the high groundwater elevations that were reached following the early January 2023 rains.

1.3 Notable Updates in this Vulnerability Assessment

Marin County first examined sea level rise vulnerabilities for its Pacific coast including Stinson Beach with the County-wide study entitled Collaboration: Sea-level Marin Adaptation Response Team (C-SMART). Specifically, the Stinson Beach ARC study supersedes the previous C-SMART work to include or expand upon the following hazards and asset considerations:

- Coastal flooding from both typical high tides (monthly spring tide) as well as extreme storm (100-year recurrence) at each sea level rise scenario considered (C-SMART looked at various combinations of storm severity and sea level rise amount). See Section 2 below for further details.
- Coastal storm wave run-up hazard areas subjected to high-velocity water in addition to the coastal storm flooding hazard areas analyzed in C-SMART. This hazard zone indicates areas that may be damaged more severely during storms due to wave momentum, and are mapped as the VE zone in flood insurance rate maps for FEMA.
- Updated estimates of coastal erosion and future beach/dune widths with sea level rise with details on beach width for typical summer and winter conditions considering existing development and armoring. This study applies recent work (ESA 2021) that characterized the shoreline morphology, coastal dynamics and future evolution at Stinson Beach to estimate shoreline, dune and bluff erosion. Notably, both dune and shoreline erosion are projected with future sea level rise to estimate beach and dune persistence for distinct reaches of shoreline. Beach widths were estimated with sea level rise for average conditions (no storms) considering minimum winter beach widths as well as recovered summer beach widths. Estimates also consider the long-term influence of development on beach persistence in front of and in between coastal armoring structures.
- Groundwater levels and emergence hazard areas modeled by the United States Geological Survey (USGS). Stinson Beach depends on onsite wastewater treatment systems (OWTS) that are one of the first major vulnerabilities of the community. The assessment of groundwater allows a high-level assessment of potential vulnerabilities that exist for OWTS and other buried or at grade utilities.
- Discussion on potential vulnerabilities of other utilities including electrical, water supply, natural gas, and utilities trenches as well as stormwater drainage culverts.
- Easkoot Creek flooding with sea level rise – flooding maps were recently prepared by OEI (2022) for the National Park Conservancy’s Stinson Beach Integrated Flood Study. The study anticipates that channel bypassing through the NPS parking lot to the ocean will continue. The study modeled these conditions for the same future sea level rise scenarios as those considered for this study.

1.4 Summary of Stinson Beach Vulnerabilities

The C-SMART Sea Level Rise Vulnerability Assessment found that Stinson Beach includes some of the most flood-vulnerable built assets in West Marin, as well as critically vulnerable recreational and natural resources (Marin County 2016). This update refines the assessment of exposed assets to permanent and temporary hazards as summarized below in terms of the sea level rise scenarios evaluated (existing conditions and future sea level rise of 1.6 feet, 3.3 feet and 6.6 feet). The following paragraphs summarize the vulnerability of Stinson Beach assets to coastal hazards with sea level rise, according to the hazard mapping data gathered and created for the study and presuming no adaptation measures to mitigate the vulnerabilities. Timeframes are provided for each sea level rise amount summarized below in terms of the extreme (2040, 2060, 2080) and medium-high (2050, 2070, 2100) risk aversion projections per OPC 2018 guidance (see Section 2 for more details). See the following sections for further details on data sources (Section 3), hazard types and relevant analyses (Section 4) and vulnerabilities by asset category (Section 5).

Under existing conditions (no sea level rise), Stinson Beach is already exposed to coastal hazards:

- Homes, roads and other facilities are exposed to coastal storm flooding and wave run-up along the beach side of the community.
- Calles homes, portions of Calle del Arroyo and NPS facilities (parking, picnic areas, etc.) are exposed to flooding from Easkoot Creek, while Shoreline Highway is exposed to flooding from Easkoot Creek as well as coastal storm flooding in several locations.
- Nearly half of parcels are exposed to groundwater that is emergent or very shallow (<3.3 feet), especially during the wet season, including Seadrift, Patios, Calles and around the historic district. Elevated groundwater saturation of on-site septic systems significantly limits household water use (as system treatment capacity is reduced, less water can be used in a home), increases pumping costs, and affects wastewater treatment. Elevated groundwater infiltrates utility main trenches causing corrosion of ferrous pipes and degradation of the trench section, including the roadway surface overlaying the trench.
- Winter beach widths along most of the shoreline have the potential to completely erode during El Niño winters and extreme coastal storms. The effects of such El Niño winters include 50 to 60 feet of dune erosion and 100 to 160 feet of winter shoreline erosion (see Section 5 discussion on vulnerability of beaches).
- Marsh habitats in Bolinas Lagoon consist of narrow bands along Seadrift and Shoreline Highway, with high marsh and transitional habitat extending up Easkoot Creek (landward of Patios and Calles).

With 1.6 feet sea level rise scenario (projected to occur at 2040 to 2050):

- There is a notable increase in asset exposures to extreme storm flooding from the ocean and lagoon side of the community. Coastal storm wave runup becomes more extensive along the beachfront. Many of the homes along Bolinas Lagoon, around Seadrift Lagoon and in the Patios and Calles become exposed to coastal storm flooding, whether due to wave run-up and overtopping from the ocean or storm surge in Bolinas Lagoon.

- Coastal erosion exposes properties and homes along much of the ocean coast.
- Sections of Shoreline Highway are increasingly exposed to coastal storm flooding along Bolinas Lagoon and a few short segments become exposed to tidal inundation, while the Highway is vulnerable to coastal bluff erosion where it descends from the bluffs above and adjacent to NPS. Coastal erosion exposes the most seaward homes along Calles.
- Groundwater levels in the lower areas of Stinson will rise and increase exposure of utilities in Seadrift, Patios, Calles and NPS as well as around the historic district.
- Winter beaches will become narrower under average conditions with the potential to erode completely during intense winters and individual storms.
- Existing marsh habitats near Stinson will become squeezed along Shoreline Highway and Seadrift, while the transition from Easkoot Creek to Bolinas Lagoon converts from predominantly high marsh to mid and low marsh.

With 3.3 feet sea level rise scenario (projected to occur at 2060 to 2070):

- Nearly all homes, roads and facilities in Seadrift, Patios, Calles and NPS are exposed to extreme coastal storm flooding and/or wave run-up.
- Coastal erosion exposes additional homes along the beach while tidal inundation begins to expose Calle del Arroyo and many homes in the Patios and Calles.
- Greater extents of Shoreline Highway along Bolinas Lagoon are vulnerable to coastal storm flooding and several segments are exposed to regular tidal inundation.
- Winter beaches may disappear completely in front of armoring and development along Seadrift and Calles, leaving coves of beach along the Patios and NPS.
- Marsh habitats near Stinson will become further squeezed along Shoreline Highway and Seadrift, while the transition from Easkoot Creek to Bolinas Lagoon converts to more low marsh.

With 6.6 feet of sea level rise scenario (projected to occur at 2080 to 2100):

- Nearly the entire community is exposed to regular tidal inundation or coastal erosion.
- The majority of Shoreline Highway along Bolinas Lagoon is exposed to regular tidal inundation. The few areas along Shoreline Highway and in the NPS area that are not permanently affected are exposed to extreme coastal storm flooding and wave run-up.
- Winter beaches will disappear entirely except along the NPS shore which has the space to migrate inland. Summer beach widths may recover minimally along beach segments with armoring and development as currently distributed, with more potential for seasonal beach recovery in the Patios and NPS segments of shoreline.
- Marsh habitats in Bolinas Lagoon will convert to mostly open water and mudflat, with small isolated areas of low mid and high marsh along the lagoon side of Seadrift, Patios and Calles.

2. SEA LEVEL RISE AND STORM SCENARIOS

This section summarizes California State guidance on sea level rise and documents the scenarios evaluated for this project. The sea level rise scenarios considered in this study are consistent with prior C-SMART studies, with some additional scenarios, described below. To better understand near term vulnerabilities of the Stinson community, this study examines the impacts of extreme events (i.e. 100-year storm) in conjunction with every sea level rise scenario considered. This is an expansion from the C-SMART vulnerability assessment which only examined modest (i.e. 1-year to 20-year) storm events in conjunction with lower amounts of sea level rise.

2.1 California State Sea level Rise Policy Guidance

In 2018, the California Ocean Protection Council (OPC) updated the *State of California Sea Level Rise Guidance* (CA OPC 2018), which includes projections for sea level rise at various locations along the coast of California through 2150. The guidance is based on the science update prepared by the OPC and the California Natural Resources Agency, in collaboration with the Governor's Office of Planning and Research, the California Energy Commission, and the California Ocean Science Trust (Griggs et al. 2017).

The 2018 CA OPC Guidance provides a range of probabilistic projections of sea level rise based on the latest science (Griggs et al. 2017) and is intended to help inform decision-makers. However, these projections may underestimate the likelihood of extreme sea level rise, particularly under high-emissions scenarios, so an extreme scenario, called the H++ scenario, was also included in the guidance. The H++ scenario assumes rapid ice sheet loss on Antarctica, which could drive rates of sea level rise 30-40 times faster than the sea level rise experienced over the last century. The updated guidance presents sea level rise projections that correspond to different levels of risk tolerance. These risk tolerance levels are represented as low, medium-high, and extreme risk aversion as described below:

- The low risk aversion projection is appropriate for adaptive, lower consequence projects (e.g., unpaved coastal trails).
- The medium-high risk aversion projection is appropriate as a precautionary projection that can be used for less adaptive, more vulnerable projects or populations that will experience medium to high consequences as a result of underestimating sea level rise (e.g., coastal community such as Stinson Beach).
- The extreme risk aversion (H++) projection is appropriate for high consequence projects with little to no adaptive capacity and which could have considerable public health, public safety, or environmental impacts (e.g., coastal power plant, wastewater treatment plant, etc.).

The above risk aversion categories can be considered typical, however a specific asset/location may require evaluation of a range of risk aversion scenarios on a case-by-case basis. While the CA OPC Guidance provides projections through 2150, it is important to note that sea level rise is expected to continue for centuries, because the earth's climate, cryosphere[7], and ocean systems will require time to respond to the emissions that have already been released to the atmosphere. Although sea level rise is typically presented as a range in the amount of sea level rise that will occur by a certain date (e.g., 1-2 feet of sea level rise by 2050), it can also be presented as a range of time during which a certain amount of sea level rise is projected to occur (e.g., 1.5 feet of sea level rise between 2040 and 2070). Even if emissions are reduced to levels consistent with the low-emissions-based projections, sea level will continue to rise to higher levels, just later. The State of California expects to publish updated sea level rise projections and guidance later in 2023.

The California Coastal Commission (CCC) maintains its own guidance on sea level rise for new and updated Local Coastal Programs and Coastal Development Permits (CCC 2018). The CCC guidance identifies the 2018 OPC guidance as the best available science on sea level rise.

2.2 Sea Level Rise Scenarios for Stinson Beach ARC

Sea level rise scenarios were selected for this study to be consistent with the latest State guidance and to utilize available coastal hazard maps for the Stinson Beach area. A total of four sea level rise scenarios were selected for the Stinson Beach ARC project, including existing conditions (existing sea level) as well as future sea level rise of 1.6 feet, 3.3 feet and 6.6 feet. State Guidance (OPC 2018) assumes existing conditions are defined with respect to a baseline of the year 2000, or more specifically the average relative sea level over 1991 – 2009.

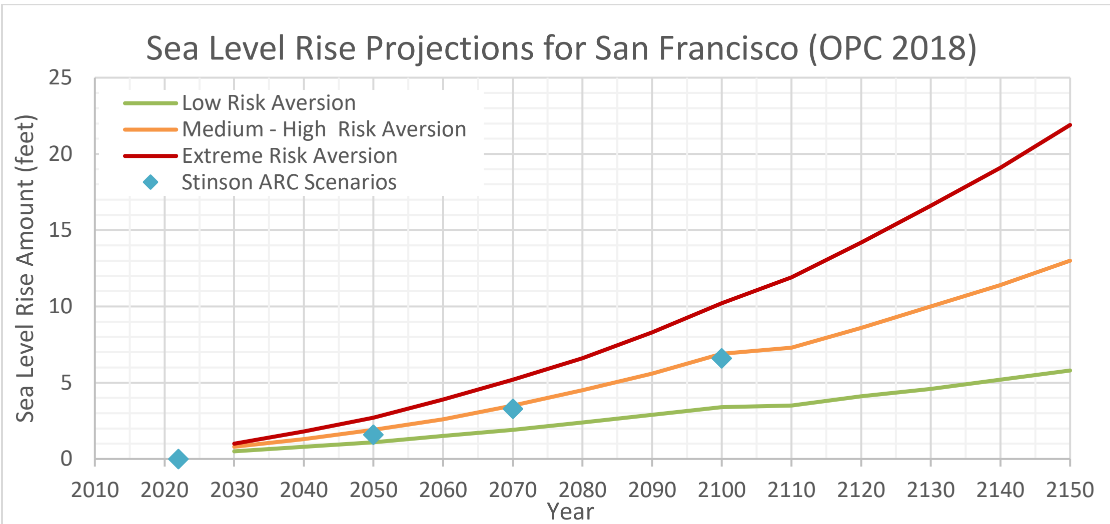
The selected sea level rise scenarios for the Stinson Beach ARC are consistent with previous C-SMART studies except they do not include the lowest sea level rise scenario (0.8 feet) evaluated in C-SMART. The C-SMART sea level rise scenarios represent a ranging combination of sea level rise and storm condition: lower intensity storms (none, annual, 20-year recurrence) were evaluated in the near term (zero to 1.6 feet SLR) while extreme (100-year recurrence) storms were only evaluated over the longer term (3.3 feet to 6.6 feet SLR).

This Stinson Beach ARC vulnerability assessment provides an important update by evaluating the potential impacts of average conditions (i.e. regular high tides) as well as extreme storm conditions (i.e. 100-year recurrence) at every sea level rise scenario from existing conditions (no sea level rise) to 6.6 feet of sea level rise. **Table 1** below presents the selected sea level rise scenarios with approximate year of occurrence rounded to the nearest decade, based on CA OPC (2018) for the Extreme and Medium-High and Low risk aversion projections. Stinson Beach vulnerabilities for multiple coastal hazards were evaluated at each of the Stinson Beach ARC sea level rise scenarios (see Section 3).

[7] The cryosphere is the portions of the Earth's surface where water is in solid form, like glaciers and ice caps.

TABLE 1. SEA LEVEL RISE SCENARIOS FOR STINSON BEACH ARC

	Approximate timing based on OPC (2018) projections for San Francisco tide gauge		
Sea level Rise Scenario	**Extreme Risk Aversion**	**Medium-High Risk Aversion**	**Low Risk Aversion Scenario**
0 feet, Existing Conditions	n/a	n/a	n/a
1.6 feet (0.5 m)	2040	2050	2060
3.3 feet (1 m)	2060	2070	2100
6.6 feet (2 m)	2080	2100	>2150



Stinson Beach ARC sea level rise scenarios are plotted along the medium-high risk aversion projection typically used in community-based planning.

3. DATA SOURCES

Several sources were utilized to compile a database of assets and hazard exposure in Stinson Beach. Most of these data are from existing data sources that are described in this section. New and updated hazard mapping data produced by ESA are described in Section 4.

3.1 Asset Data

Stinson Beach assets are mapped in **Figure 1.** Asset data were provided to ESA by Marin County CDA in shapefile and geodatabase formats (points, lines and polygon features). The data are primarily compiled from the C-SMART study. The most current shapefiles Parcels and Building Footprint were downloaded from MarinMap by CDA and provided for this study to ensure the latest property information is included. There were no updates to the other data used in the C-SMART process so the source data were used as is with minimal processing/compilation for analysis and mapping. In addition to the asset data provided by CDA, ESA also applied marsh habitat mapping that was previously developed for the C-SMART process (ESA 2015).

Asset data obtained for the study are classified into the following categories, asset managers are shown in parentheses:

- **Emergency Services**: Fire stations (Stinson Beach Fire Protection District), lifeguard station (National Park Service, Pacific Telephone & Telegraph station **Development (buildings and parcels)**: single and multi-unit residential (private), commercial, school (Bolinas-Stinson Union School District)
- **Transportation**: Shoreline Highway (CalTrans), local roads (Marin County and private)
- **Utilities**: no GIS information was available for utilities, see discussion below on utilities information and vulnerability. The Stinson Beach County Water District office and Pacific Telegraph building are included in this category. Utilities that are present in Stinson Beach include electricity, water supply, onsite septic systems and gas storage, communications.
- **Recreation**: NPS picnic areas, restrooms/showers (NPS), restaurant (private), parking lots (NPS), Seadrift boat launch (private), coastal access points, CA Coastal Trail (NPS)
- **Historic and Archaeological resources:** historic downtown district of Stinson Beach and archaeological resources
- **Natural Resources**: beaches (National Park Service, Marin County Parks, Greater Farallones National Marine Sanctuary), marshes in Bolinas Lagoon Natural Preserve (Greater Farallones National Marine Sanctuary, Marin County Parks), Easkoot Creek; sensitive species (none present in data for Stinson Beach, however Western Snowy Plovers have been observed along Stinson and Seadrift (ESA 2020)).

The compiled asset data will be provided in a file geodatabase as a deliverable for the project once the Vulnerability Assessment Update is complete.

SOURCE: ESRI, ESA, County of Marin, NWI

Stinson Beach ARC . 202101080

Figure 1
Stinson Beach Assets

ESA

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3.2 Hazard Mapping Data

Hazard data were obtained in GIS format to conduct an exposure analysis of assets for the study. ESA gathered available data on coastal hazards and sea level rise for Stinson Beach. The following hazard sources were utilized:

- **Tidal inundation, coastal storm flooding, groundwater levels**: inundation from monthly spring tides and flooding from the 100-year recurrence coastal storm event with existing conditions and future sea level rise are outputs from the U.S. Geological Survey's (USGS) Coastal Storm Modeling System (CoSMoS) 2.0 (USGS 2013). Projected existing and future groundwater levels are outputs from the USGS CoSMoS-GW model (Belfus et al. 2020). More information on these CoSMoS hazard data can be found at https://ourcoastourfuture.org/science-and-modeling/ .
- **Flood prone low-lying areas**: areas below the projected water surface elevation modeled by CoSMoS (USGS 2013) for tidal inundation or coastal storm flooding (listed above) but which have no direct surface hydrologic connection to the ocean. These areas are vulnerable to flooding if there is a subsurface connection like a storm drain or if surrounding protections (e.g, a berm or levee) fail, or if groundwater rises high enough to inhibit drainage of local precipitation.
- **Coastal storm wave run-up**: new wave run-up hazard maps based on the latest FEMA VE zone maps were developed by ESA to assess wave damage hazards along Stinson Beach associated with the 100-year recurrence coastal storm event. This hazard zone indicates areas of potential high momentum forces from waves running up and over the beach and landward property. See Section 4 below for more information on the methodology used to map existing and future wave runup hazard areas.
- **Coastal erosion**: updated beach erosion maps were prepared by ESA to assess potential erosion vulnerabilities beyond the back of beach and dunes. See Section 4 for further details. Cliff erosion was previously mapped by ESA (2016) for the C-SMART study, which is relevant to the Shoreline Highway descent into Stinson.
- **Fluvial flooding**: ESA obtained the most recent available FEMA Flood Insurance Study and Flood Insurance Rate Maps (FEMA 2017 for Easkoot Creek) as well as recent modeling by O'Connor Environmental, Inc. (OEI 2014 and 2022) to define fluvial flood hazards for the 100-year event under existing conditions and with future sea level rise. This study considers both OEI sources, the latest from 2022includes flood maps with future sea level rise, but they do not include future precipitation changes due to climate change nor do they include channel sedimentation with sea level rise. An important note, the 2022 maps were developed primarily for analysis at NPS with a channel bypass included, so model results are not recommended for evaluation downstream of Calle del Arroyo. The coastal storm surge governs flood risk in the lower Easkoot Creek floodplain so CoSMoS hazards adequately capture the exposure downstream of Calle del Arroyo.

ESA compiled the above hazard data in GIS for mapping and analysis of asset exposures (see Section 5).

4. UPDATED HAZARD ANALYSES AND MAPPING

To assess hazard exposures with sea level rise at Stinson Beach, ESA used the existing hazard mapping data described in Section 3 above and conducted additional analyses to produce new and updated hazard mapping for shoreline and dune erosion and coastal storm wave run-up.

4.1 Coastal Erosion

Updated beach and dune erosion estimates and corresponding erosion hazard maps were prepared for this vulnerability assessment update. Shoreline erosion was mapped previously for C-SMART starting from a 2010 shoreline (ESA 2015). To update estimates of shoreline and dune erosion for this study, ESA re-applied its shoreline evolution models developed for the Stinson Beach Nature-Based Adaptation Feasibility Study (ESA 2021) to estimate potential beach and dune erosion with sea level rise with a more recent baseline condition of beach and dune width. The shoreline evolution modeling applied for the Stinson Beach ARC assumes winter beach conditions for each shoreline reach specified in the 2021 study, and tracks the position of the shoreline, dune face, and beach width over time with sea level rise based on long term erosion rates, beach geometry and typical seasonal fluctuations of beach width. The erosion analysis models two armoring scenarios to identify vulnerabilities to development (no armoring assumed) as well as beaches (armoring assumed at all development), see below for further details.

ESA modeled potential erosion extents of the shoreline/dunes/beach without armoring to determine potential exposure of existing **development**. This provides the worst-case scenario for development to highlight potential vulnerabilities in the case that existing armoring fails at some point and assumes other armoring is not constructed. This erosion analysis resulted in greater estimated erosion extents than projected previously for C-SMART and provides further detail on beach and dune persistence. Generally speaking, dune erosion hazard zones for 1.6 feet sea level rise prepared for the Stinson Beach ARC extend about 100 feet to 200 feet landward of the shoreline erosion hazard zones prepared for C-SMART for much of the shore. The difference in erosion extents is slightly less for 3.3 feet sea level rise and the two erosion hazard zones are relatively comparable with 6.6 feet sea level rise. Overall, erosion projections at the west end of Seadrift are reduced compared to C-SMART, owing to the steeper shore profile used for the 2021 and current studies. The modeled erosion extents without armoring were then mapped to analyze potential impacts to existing development including potential erosion beyond existing armoring structures if they were to fail. This approach conservatively estimates the potential vulnerability of built infrastructure and development to coastal erosion.

To update the vulnerability assessment of **beach areas** for this study, ESA reapplied the shoreline evolution models with the assumption that development is protected with sea level rise. This provides the worst case scenario for beaches assuming they are squeezed into existing development (if development were removed, for example, the beach could transgress with sea level rise and be more resilient). The model results were used to quantify the potential impacts to recreation and ecology in terms of the remaining beach and dune widths with future sea level rise. See Section 5 for details on beach vulnerability with sea level rise.

The existing sea level beach widths were determined for winter conditions from a recent winter shoreline (January 2019) and for summer conditions using an average seasonal beach width fluctuation of 80 feet, both of which were previously calculated (ESA 2020). Future shoreline positions were estimated for each reach using profile transgression principles that consider dune height behind beaches as a source of sediment (Patios and NPS reaches currently have erodible dunes). Future beach widths were then determined assuming that shoreline armor is maintained at Seadrift and that development is protected/armored for the Patios and Calles reaches when the dunes/beach are eroded, respectively. Thus, shoreline erosion proceeds until the shoreline meets the armoring, leading to zero beach width in winter. The shoreline, beach and dunes in NPS reach are assumed to migrate inland with sea level rise while preserving some beach width in winter, despite the presence of a few buildings. Once the dunes are eroded in the Patios reach (estimated to occur by 3.3 feet sea level rise), the winter beach approaches zero as the shoreline meets the armoring. A nominal summer beach recovery width of 10 feet is used in front of armoring structures, assuming there is sufficient sediment in the system to refill the intertidal beach profile at least up to 6.6 feet of sea level rise. In the Patios and NPS reaches, summer beach recovery at higher sea levels also considers the effect of adjacent armored reaches that extend further seaward and create beach coves between armoring segments as the shore and dunes retreat with sea level rise. The persistence of summer beach width in reaches with dunes (Patios, NPS) is assumed to aid the summer beach recovery in adjacent armored backshores (Seadrift, Calles).

4.2 Wave Run-up

Wave run-up during coastal storms is a significant hazard in Stinson Beach, as indicated by the construction of several coastal armoring structures and modification/removal of homes after major storm impacts over the last few decades. CoSMoS wave run-up information for the area does not distinguish the high-momentum hazard zone within which wave action can damage property and harm people. ESA estimated the high-momentum wave run-up hazard zone corresponding to a 100-year coastal storm event for existing and future scenarios using FEMA VE zone wave runup zone parameters along Stinson Beach shoreline. Existing conditions (no sea level rise) wave run-up hazard zones were derived from the latest FEMA VE zone mapping, while future conditions VE zones were calculated using the methods outlined in Relating Future Coastal Conditions to Existing FEMA Flood Hazard Maps: Technical Methods Manual (Battalio et al. 2016) and mapped in GIS. In summary, future wave run-up zones migrate inland with sea level rise as the shoreline and beach erode. In areas with erodible dunes (Patios and NPS), the wave run-up elevation increases by the same amount as sea level rise because the shore can adjust to higher sea levels by eroding landward. In areas with coastal armoring, wave run-up elevation can be increased by up to 2 to 4 times the amount of future sea level rise because the beach (which acts as a buffer to wave run-up) erodes in front of armoring structures resulting in waves breaking closer to shore in deeper water, resulting in greater runup elevations at the armoring structure and increased overtopping compared to existing conditions.

5. VULNERABILITY ASSESSMENT

The vulnerability assessment update is based on a GIS analysis that overlays the coastal hazard zones described above with the compiled asset data described above to identify hazard exposures under existing conditions and with future sea level rise.

In order to develop an effective adaptation plan to address sea level rise vulnerability, it is helpful to assess the risk of not taking action as a baseline for comparison with other alternatives to be developed in subsequent study tasks. For this reason, this Vulnerability Assessment analyzes hazard impacts from a “no action” or “business as usual” scenario in which sea level adaptation or resilience actions are not taken. By considering this scenario, the public, County, and other decision makers can better understand the potential impacts of sea level rise and identify areas and/or individual assets with the greatest vulnerabilities. For development, this means assuming the absence or failure of coastal armoring devices to understand potential vulnerabilities posed by the full extent of coastal erosion and flooding over time. For habitats, this means assuming that development is maintained in place to understand vulnerabilities of beaches and marshes to encroaching coastal erosion and tidal inundation over time.

The following sections present vulnerabilities for assets exposed to each hazard type considered in this study. Asset vulnerability for a given hazard is a function of the quantity of exposed assets, the consequences of exposure, and the adaptive capacity of the asset (i.e. asset’s ability to be modified to mitigate or avoid exposure). Asset exposures were determined by intersecting each asset layer with each hazard zone in ArcGIS. In general, point assets (like access points) in each hazard zone are counted, linear assets (like roads) are measured in feet, while area assets (like parcels) are measured in acres. The resulting asset exposure for each hazard type is summarized in the following sections. Hazard Exposure maps that overlay assets and hazards are provided as **Figure 2** through **Figure 11**. Beach and Marsh habitat evolution with sea level rise is shown in **Figure 13** and **Figure 14**. **Figure 15** presents existing and future tidal inundation coastal flooding exposure of Shoreline Highway along Bolinas Lagoon. Tabular summaries of asset exposures for each hazard and time horizon are provided in the following sections.

Note that the method of assigning vulnerability based on intersection with a mapped hazard area is very helpful in planning. More detailed analyses may be beneficial and appropriate for individual locations/assets where the precise failure mechanism(s) and associated exposures can be assessed with greater precision (e.g. design and maintenance plan for dune restoration along the beach or a floodwall along portions of Bolinas Lagoon).

5.1 Hazard Exposure

Hazard exposure was determined by overlaying the asset data layers with hazard zones in GIS. **Table 2** summarizes the quantities of assets that are exposed to each hazard type under the sea level rise scenarios. Hazards analyzed include the following categories of permanent (chronic long-term) and temporary (extreme event-based) impacts.

- Areas in the potential **tidal inundation** hazard zone would be impacted regularly by inundation (permanent impacts, greatest consequences). These areas are also impacted by temporary coastal storm flooding and/or wave run-up. Adjacent **low-lying areas** that correspond to the tidal inundation areas are included as potentially impacted.
- Areas subject to the potential **coastal erosion** (shoreline/beach, dune and bluff) hazard zones may be lost/damaged entirely (permanent impacts, greatest consequences). Beach erosion consists of landward shoreline movement and scour of assets built on the beach or dunes. Bluff erosion includes sloughing and erosion of the bluff top and face due to coastal erosion from wave action on the toe of bluff as well as terrestrial erosion processes.
- Areas in the potential **coastal storm wave run-up** hazard zone (100-year recurrence event) may be heavily damaged or disrupted from flowing water, but assets/property may be recoverable, and could return to service after the storm and any needed repairs (temporary impacts, low to high consequences).
- Areas in the potential **coastal storm flooding** hazard zone (100-year recurrence event) would be inundated by extreme high ocean and lagoon water levels caused by storm surge (temporary impacts, significant consequences). USGS CoSMoS storm scenarios assume that the storm coincides with a "high spring tide" (tide levels that occur approximately twice every month). Adjacent low areas shown as **potential storm flooding** are also included as they may become flooded during the 100-year coastal storm event.
- Assets in the **groundwater** hazard zones would be impacted regularly depending on relative depth of buried asset or location of at-ground assets where groundwater is emergent (permanent impacts, greatest consequences). USGS CoSMoS mapping for depth to groundwater is classified as marine/tidal, emergent (0 ft), very shallow (0 to 3.3 feet), shallow (3.3 to 6.6 feet), moderate (6.6 to 16.4 feet) and deep (>16.4 feet). Depth to groundwater was examined specifically for the purpose of evaluating the vulnerability of onsite wastewater treatment systems. Asset exposures to emergent groundwater are also summarized.
- Assets in the **Easkoot Creek flooding** hazard zone would be inundated by elevated creek water levels caused by extreme precipitation events (temporary impacts, significant consequences).

Tidal inundation, coastal erosion, coastal storm wave run-up and flooding mapped by USGS CoSMoS are shown in **Figure 2** through **Figure 5**. Easkoot Creek flooding maps are shown in **Figure 6** and **Figure 7**. Groundwater levels are mapped in **Figure 8** through **Figure 11**. Beach and marsh habitats with sea level rise are shown in **Figure 13** and **Figure 14** respectively. A focused map of tidal inundation and coastal storm flooding along Shoreline Highway is shown in **Figure 15**.

Areas and assets are tagged as exposed to a coastal hazard only once based on a hierarchy of permanent and temporary coastal hazards: classified as subject to either tidal inundation, coastal erosion, coastal storm water run-up or coastal storm flooding, based on the most extreme hazard present. Hazards from greatest to least exposure are: tidal inundation (permanent) > coastal erosion (permanent) > coastal wave runup (temporary) > coastal flooding (temporary). For example, an area exposed to tidal inundation (permanent), coastal wave runup (temporary), and coastal flooding (temporary) would be designated as exposed to tidal inundation.

Hazard exposures are color-coded in **Table 2**; groundwater emergence (purple) and Easkoot Creek flooding (green) exposures are summarized separately from the four coastal hazards (blue:

tidal inundation, erosion, coastal flooding and wave run-up). The quantities of exposed assets listed for a particular hazard type may decrease with sea level rise in **Table 2** because assets may become exposed to another hazard and be recategorized at increased sea levels. Some examples include:

- Some emergent groundwater areas ultimately become tidal at higher sea levels.
- Some buildings and roads that are only exposed to coastal storm flooding at lower sea levels become exposed to tidal inundation or erosion with higher sea levels.

The following section further describes the vulnerabilities of each asset category.

TABLE 2. ASSET EXPOSURE SUMMARY

Asset			Existing sea level					1.6 feet sea level rise					3.3 feet sea level rise					6.6 feet sea level rise				
Category	Class	Unit	Emergent Ground-water	Tidal Inund-ation	Coastal Storm Wave Runup	Coastal Storm Flooding	Creek Flooding	Emergent Ground-water	Tidal Inund-ation	Coastal Erosion	Coastal Storm Wave Runup	Coastal Storm Flooding	Emergent Ground-water	Tidal Inund-ation	Coastal Erosion	Coastal Storm Wave Runup	Coastal Storm Flooding	Emergent Ground-water	Tidal Inund-ation	Coastal Erosion	Coastal Storm Wave Runup	Coastal Storm Flooding
Emergency Facilities	**Fire Station & Annex**	**count**	1	0	0	0	0	1	0	0	0	1	1	0	0	0	1	1	1	0	0	0
Emergency Facilities	**Lifeguard HQ**	**count**	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0
Development	**Buildings**	**count**	266	39	228	17	122	293	153	49	363	343	279	329	162	427	154	102	560	234	67	7
Development	**Parcels - Residential Single**	**count**	277	332	210	121	85	283	405	170	333	324	270	486	194	361	149	54	542	224	131	28
Development	**Parcels - Residential Multi**	**count**	12	1	6	2	11	12	2	4	9	10	11	8	7	10	3	10	15	8	3	2
Development	**Parcels - Commercial**	**count**	24	4	2	3	8	23	4	1	2	6	23	6	1	2	4	22	6	2	3	4
Development	**Parcels - Other**	**count**	49	29	10	22	26	39	40	12	12	41	34	49	13	15	35	27	59	15	7	20
Development	**Parking Lots**	**count**	1	0	0	0	2	2	0	0	0	1	2	0	0	2	0	2	0	0	3	0
Development	**School**	**count**	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	1
Ecology	**Beaches**	**n/a**	See Table 13 for vulnerability summary																			
Ecology	**Marshes**	**n/a**	See Table 14 for vulnerability summary																			
Recreation	**Parks**	**count**	7	5	3	4	5	6	5	3	1	5	6	5	3	2	5	6	7	3	1	5
Recreation	**Access Points**	**count**	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0
Recreation	**Picnic Areas**	**count**	1	0	0	0	1	1	0	0	0	0	1	0	0	0	0	1	0	0	1	0
Recreation	**Coastal Trail**	**count**	1	0	0	0	0	1	0	0	0	1	1	0	0	0	1	1	0	0	1	0
Recreation	**Boat Launch**	**count**	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0
Recreation	**Easkoot Bridge**	**count**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Recreation	**Restroom/Shower**	**count**	0	0	3	0	0	0	0	1	2	0	0	0	2	1	0	0	0	3	0	0
Transportation	**Local Roads**	**feet**	5819	8	837	395	3707	5534	2864	28	8988	7799	3761	8343	321	7760	5024	2747	23206	201	31	514
Transportation	**Shoreline Highway**	**feet**	2889	0	0	436	1288	2577	1063	2295	0	7618	2937	7590	2795	0	4041	1578	14648	2967	0	3012
Utilities	**Water District Office**	**count**	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0
Utilities	**Electrical, Communications, Gas**	**n/a**	See separate section for vulnerability discussion																			
Utilities	**Septic Systems**	**n/a**	See separate section for vulnerability discussion																			

Notes: Coastal hazard exposure for a given location is tagged only once based on a hierarchy of permanent and temporary coastal hazards, see report text for details.
Creek flooding hazards only mapped for existing sea level, see separate discussion about increasing frequency with sea level rise.
Tidal inundation and coastal storm flooding include both the direct and "low-lying" areas mapped by USGS CoSMoS.
Some assets (e.g. Buildings) are exposed to more than one hazard at each sea level rise scenario.
For each sea level rise amount, counts are cumulative in each hazard group: coastal hazards (blue), groundwater (purple) and creek flooding (green).

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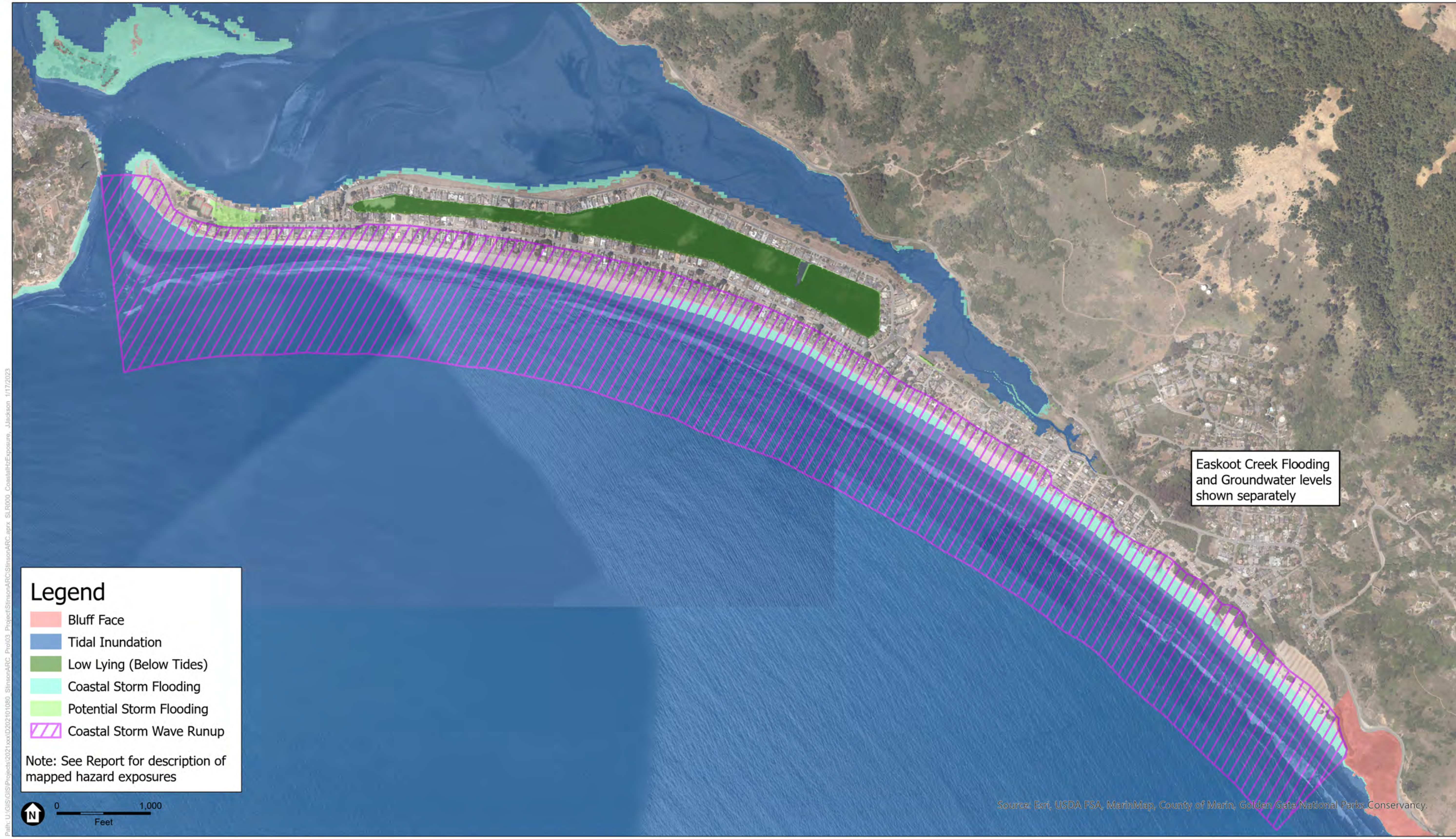

SOURCE: USGS CoSMoS (2020), ESA Wave Runup (Current Study), ESRI Imagery, County of Marin

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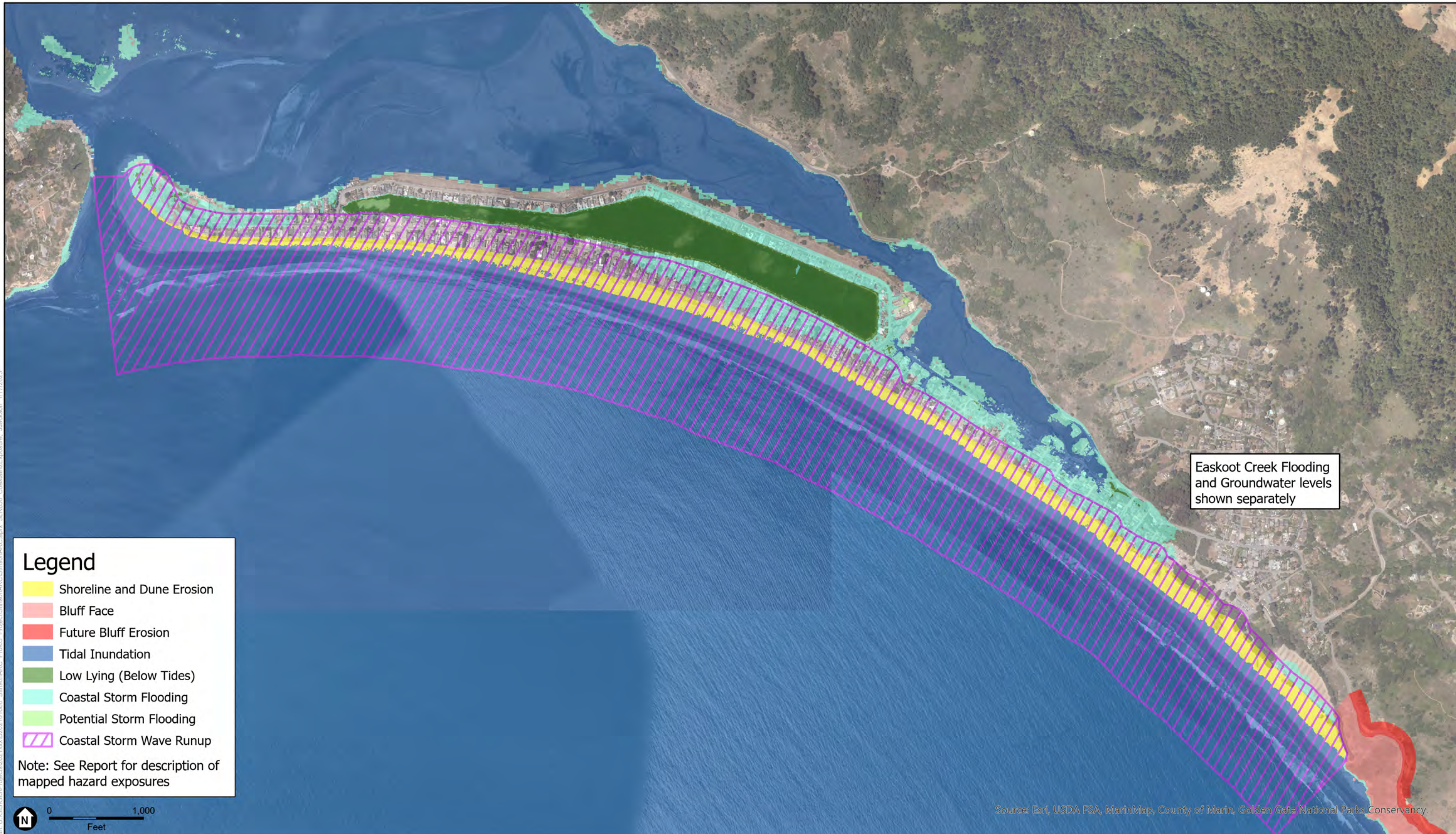
Figure 2
Coastal Hazards with Existing Sea Level

ESA



SOURCE: USGS CoSMoS (2020), ESA Wave Runup (Current Study), ESRI Imagery, County of Marin

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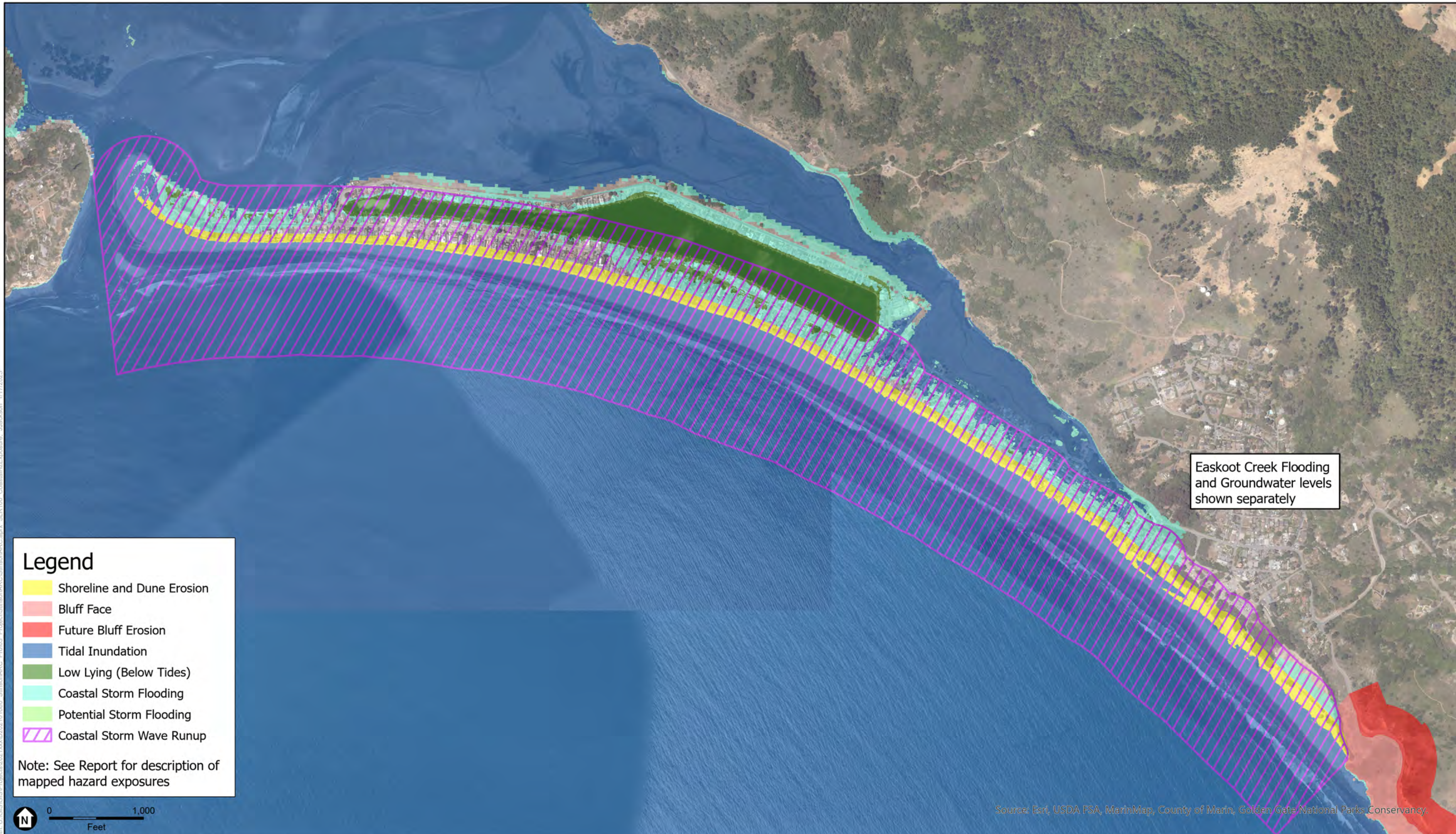
Figure 3
Coastal Hazards with 1.6 feet Sea Level Rise

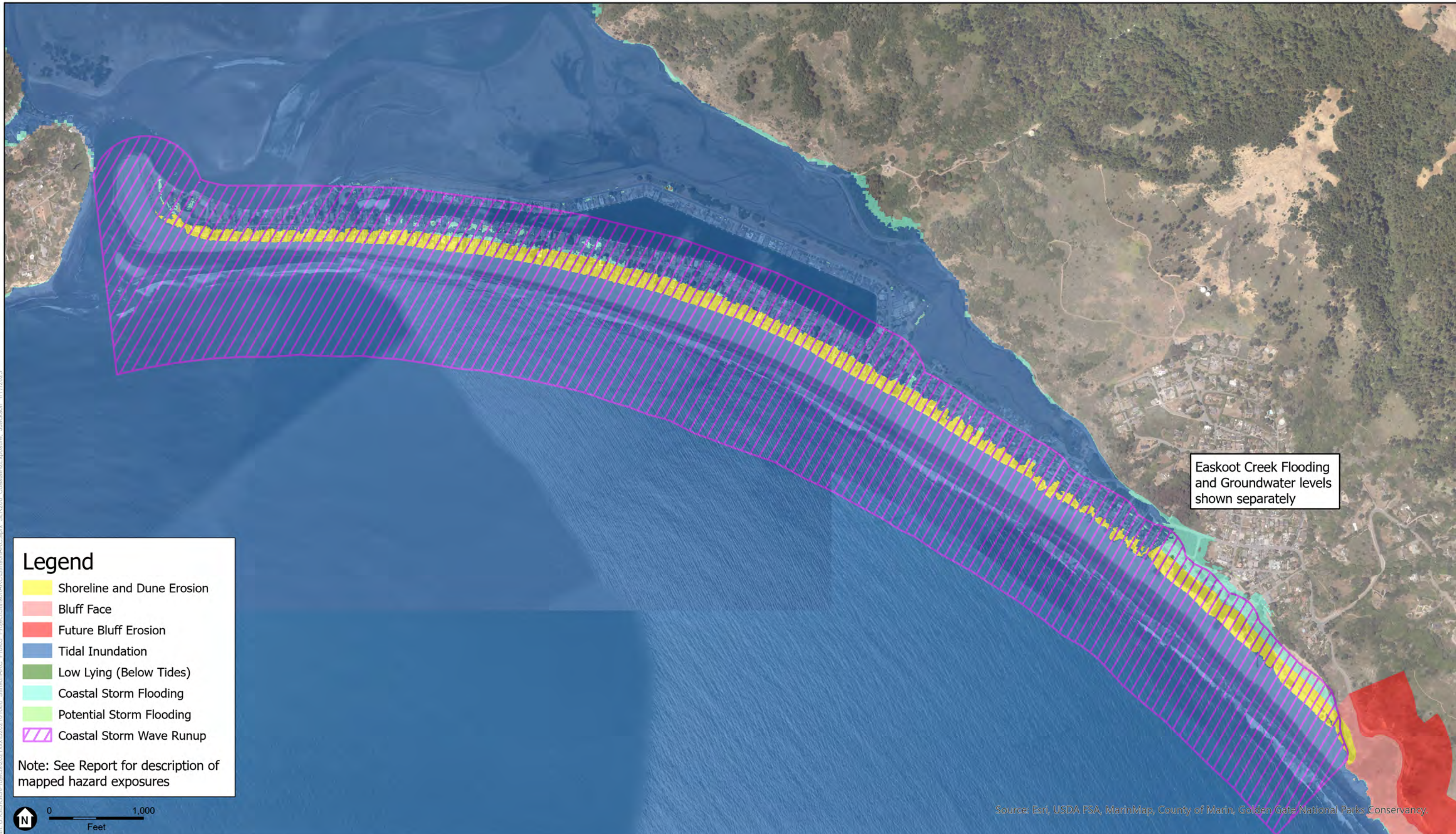
ESA



SOURCE: USGS CoSMoS (2020), ESA Wave Runup (Current Study), ESRI Imagery, County of Marin

Stinson Beach ARC . 202101080

Figure 4
Coastal Hazards with 3.3 feet Sea Level Rise



SOURCE: USGS CoSMoS (2020), ESA Wave Runup (Current Study), ESRI Imagery, County of Marin

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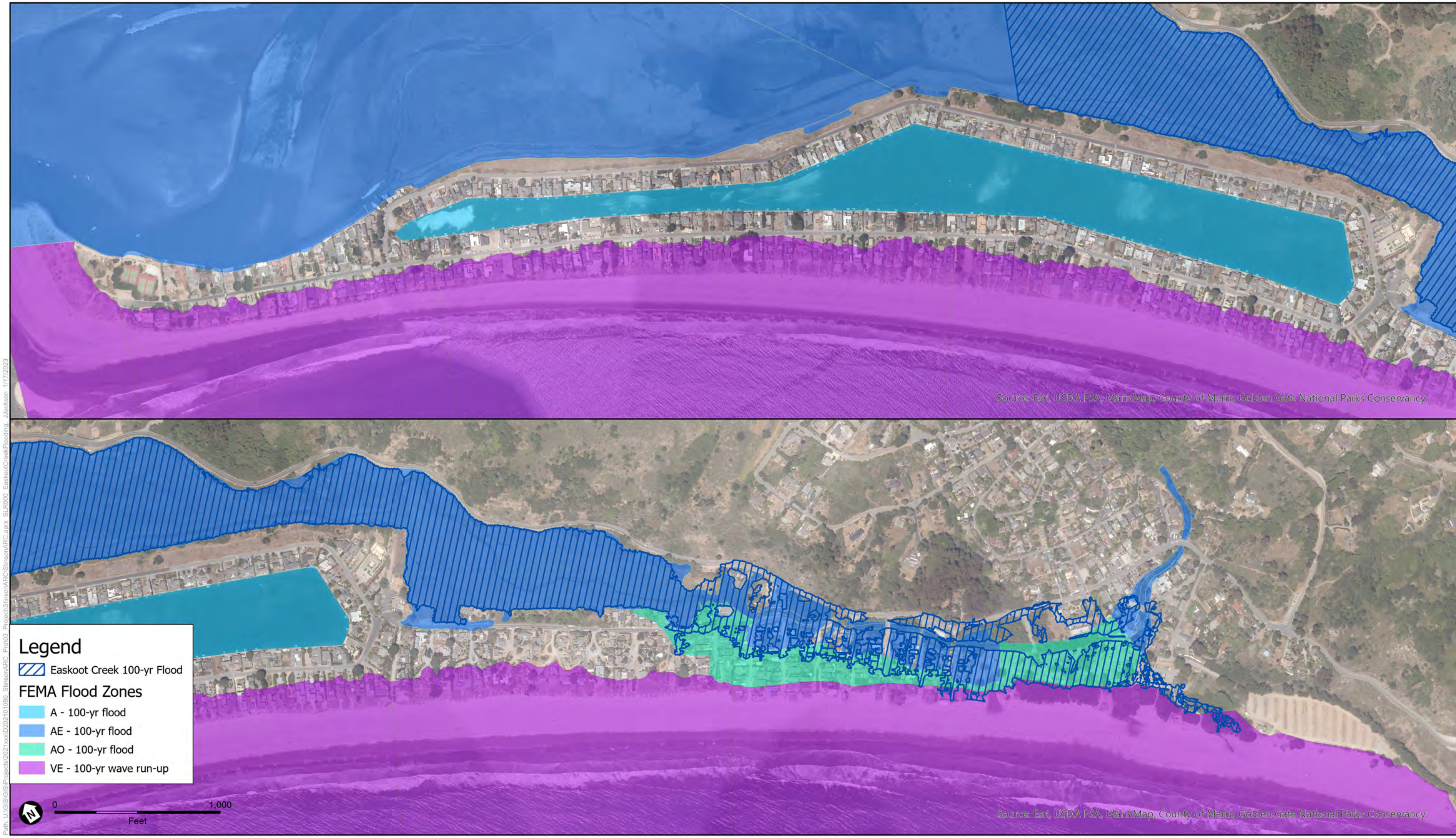
Figure 5
Coastal Hazards with 6.6 feet Sea Level Rise

ESA

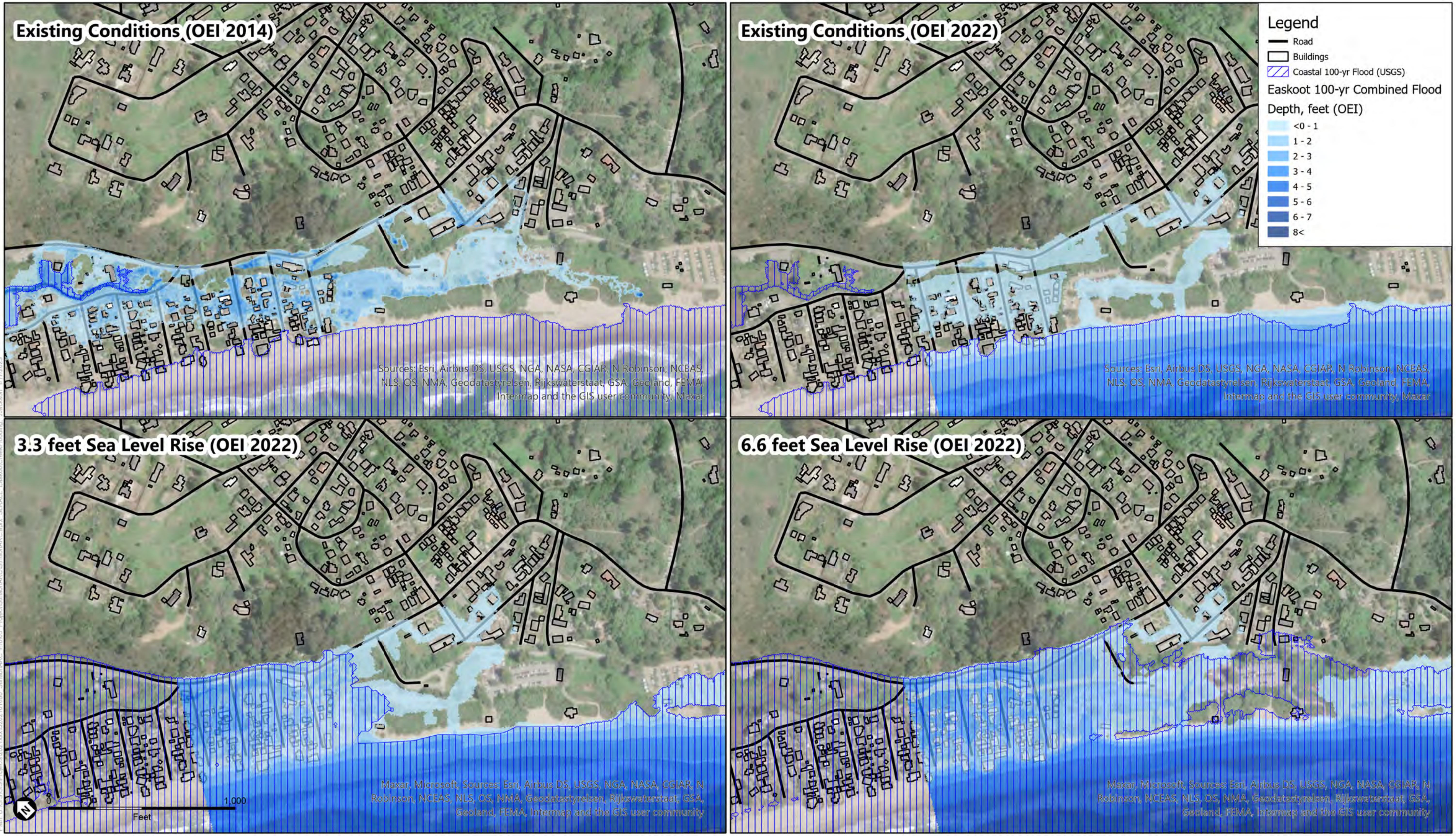


SOURCE: OEI 2014, FEMA 2022, ESRI

Stinson Beach ARC . 202101080

Figure 6
Easkoot Creek Flood Extents and FEMA Flood Zones with Existing Sea Level
100-year Flood Event

ESA

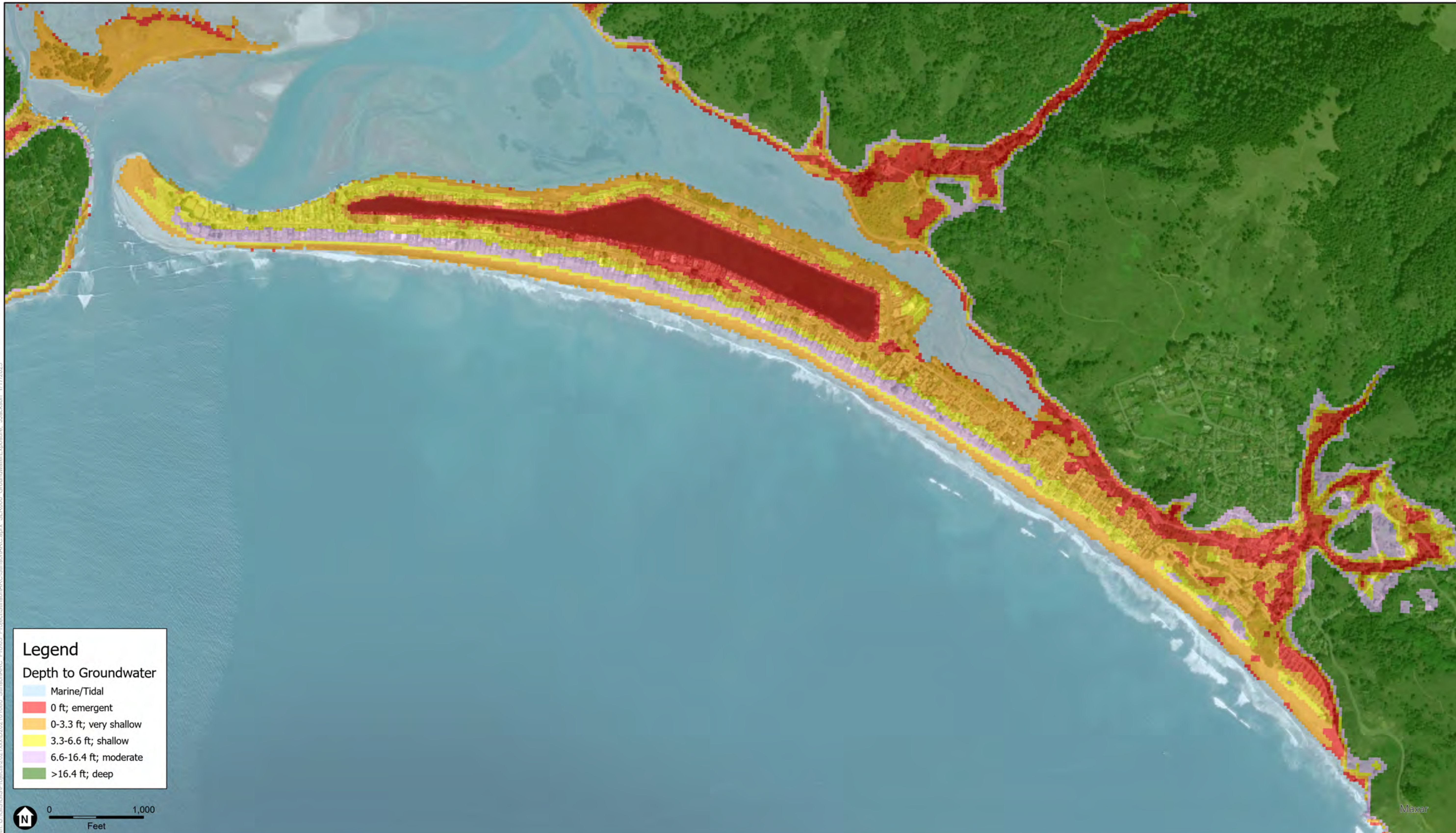


SOURCE: OEI, USGS, Marin County, ESRI

Stinson Beach ARC . 202101080

Figure 7
Combined Easkoot Creek and Coastal Flooding for Existing Conditions and Future Sea Level Rise
100-year Flood Event

ESA



SOURCE: USGS CoSMoS (2022), ESRI Imagery

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Figure 8
Depth to Groundwater with Existing Sea Level

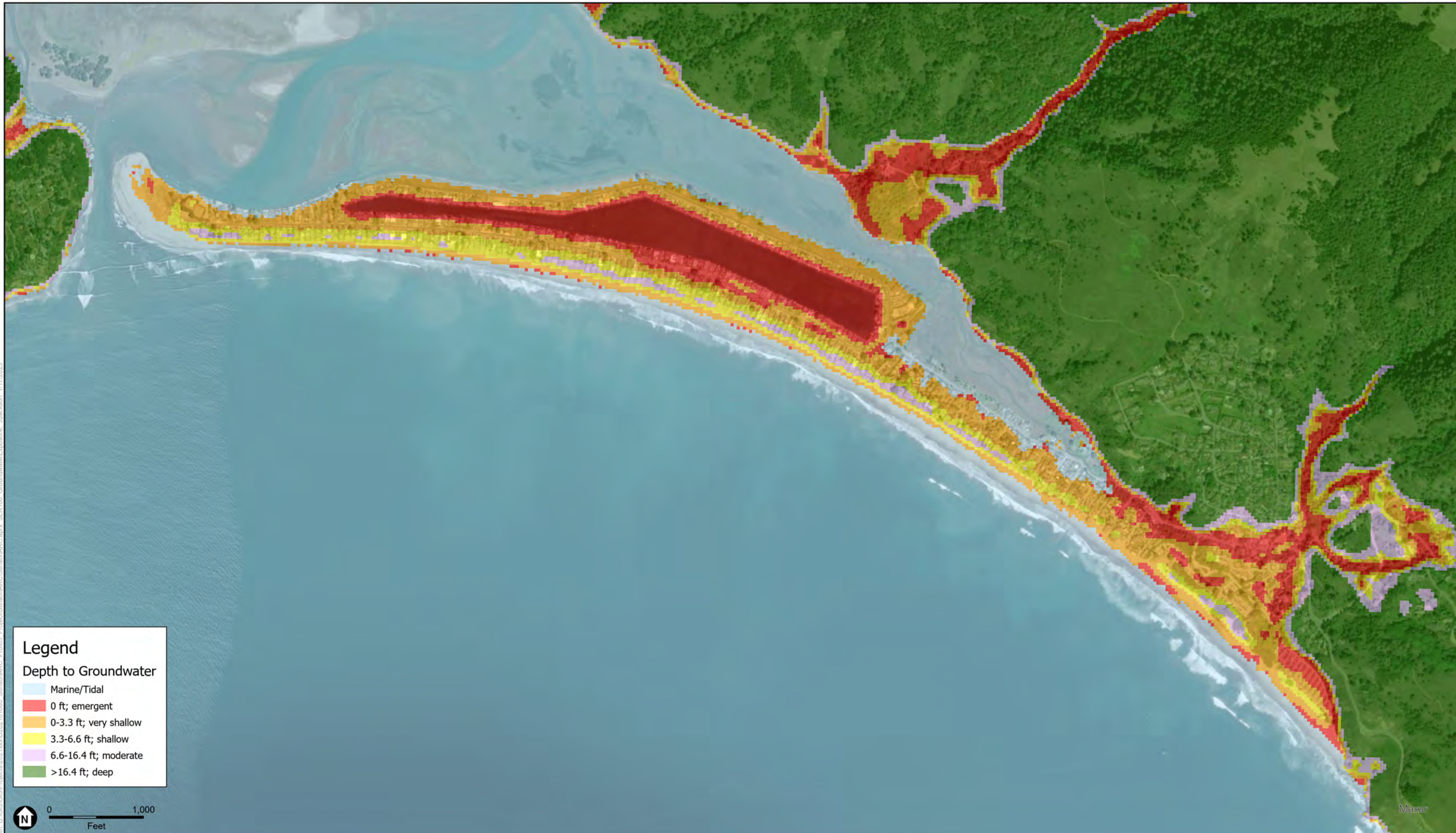
ESA

SOURCE: USGS CoSMoS (2022), ESRI Imagery

Stinson Beach ARC . 202101080

Figure 9
Depth to Groundwater with 1.6 feet Sea Level Rise

ESA



SOURCE: USGS CoSMoS (2022), ESRI Imagery

Stinson Beach ARC . 202101080

Figure 10
Depth to Groundwater with 3.3 feet Sea Level Rise

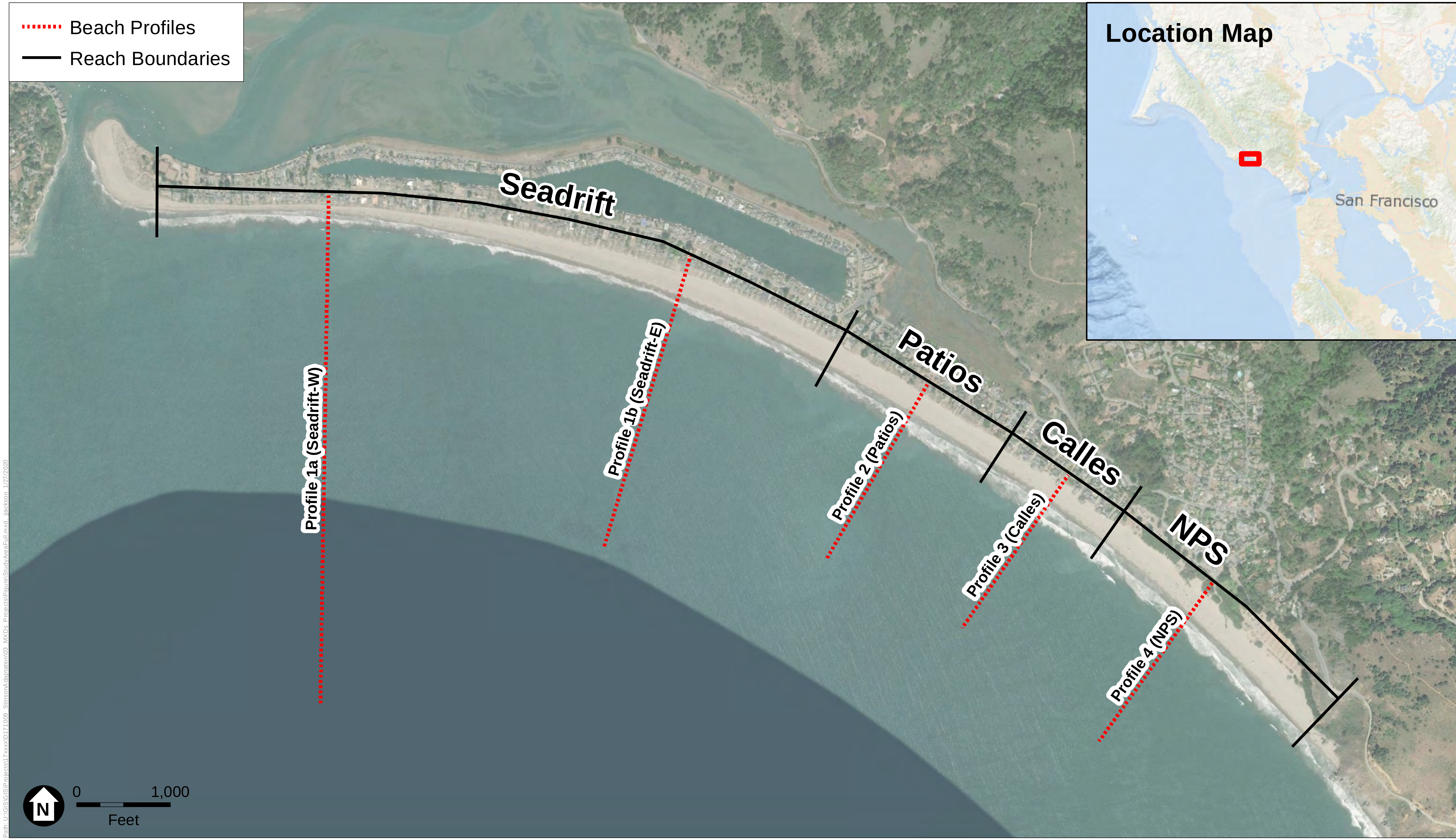
ESA

SOURCE: USGS CoSMoS (2022), ESRI Imagery

Stinson Beach ARC . 202101080

Figure 11
Depth to Groundwater with 6.6 feet Sea Level Rise

ESA

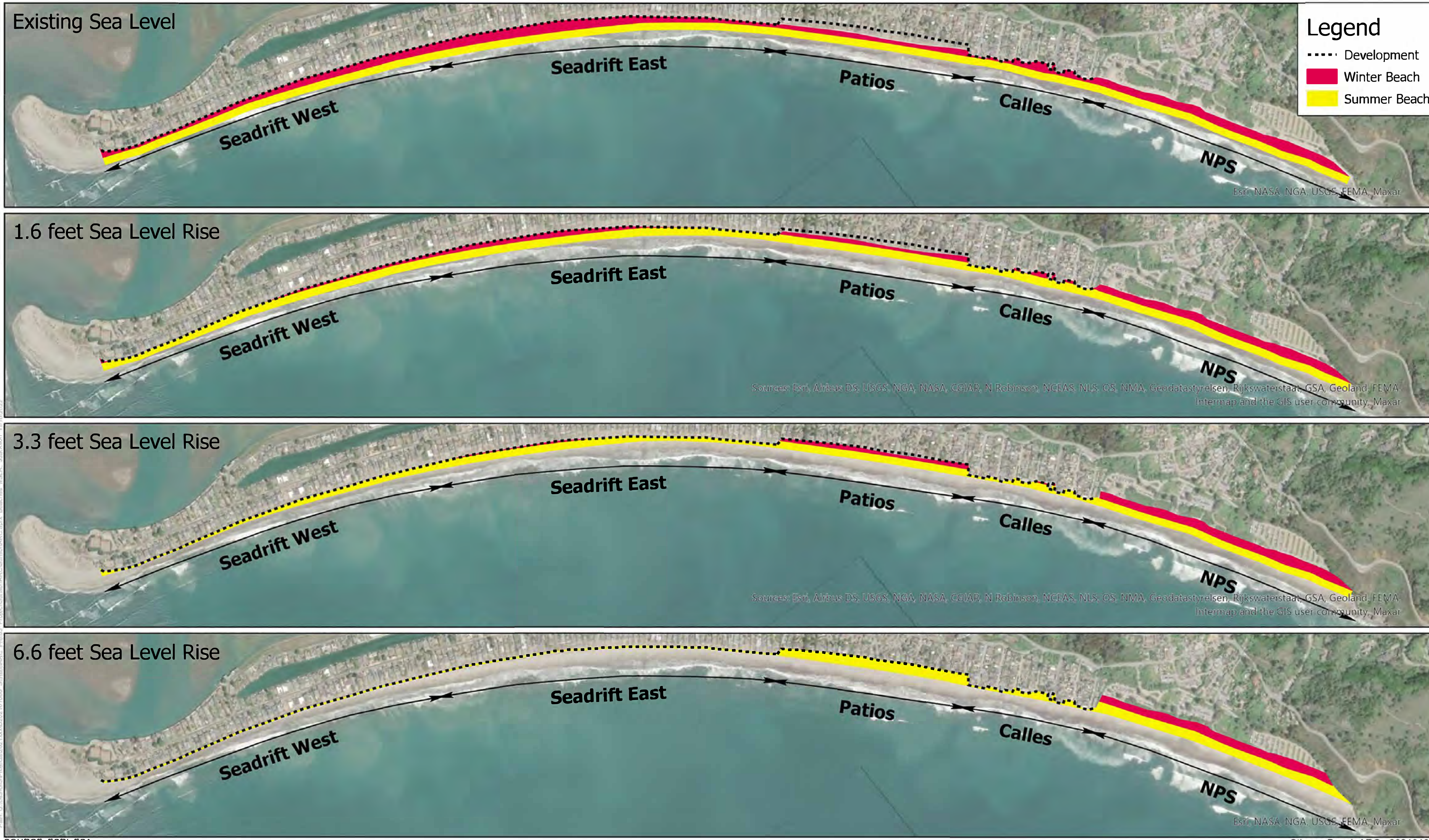


SOURCE: ESA (2019), Marin County (2018)

Stinson Beach ARC . 202101080

Figure 12
Stinson Beach Study Reaches

ESA



SOURCE: ESRI, ESA

Stinson Beach ARC . 202101080

Figure 13
Summer and Winter Beaches
with Increasing Sea Level Rise

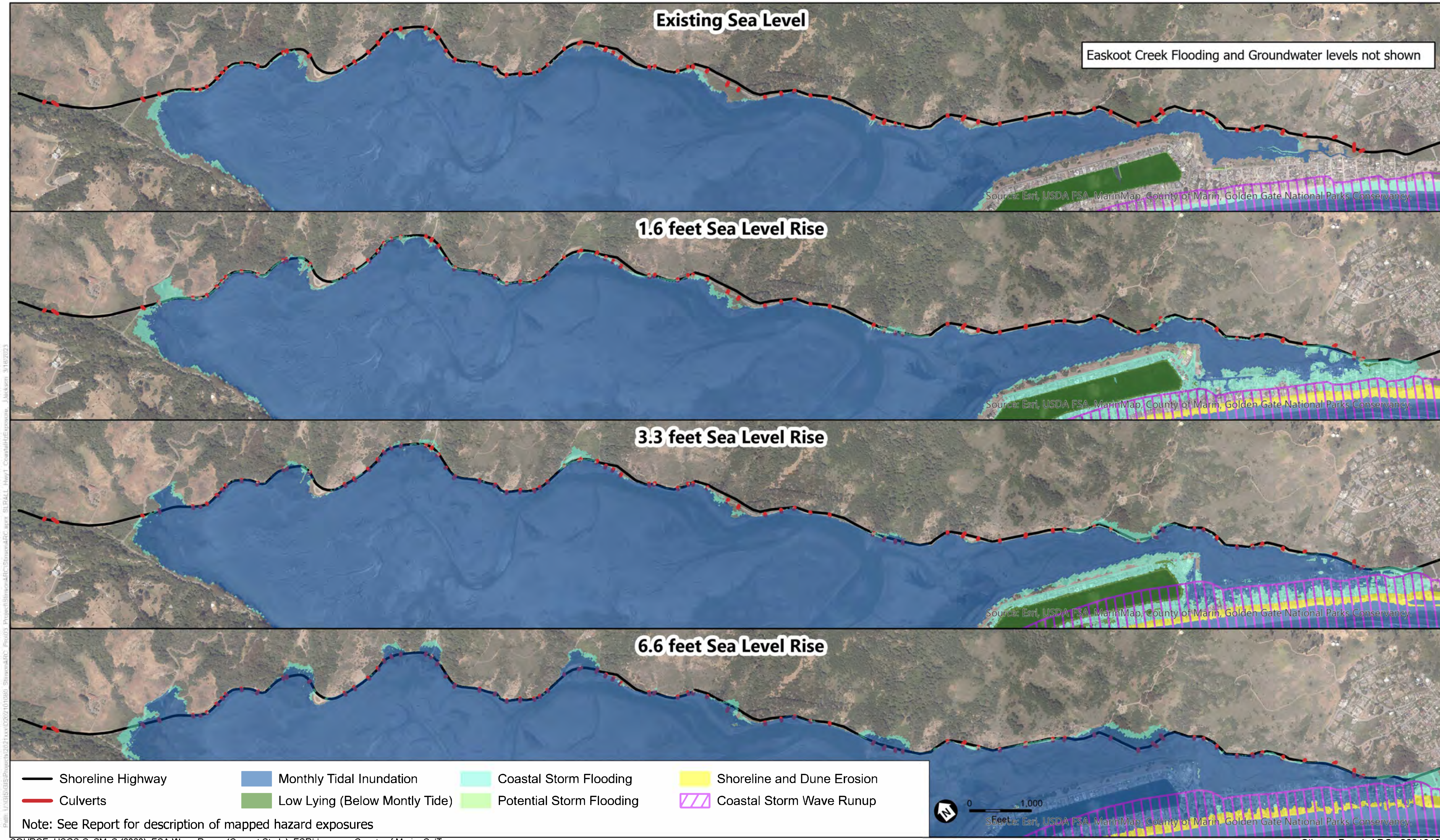
ESA

SOURCE: ESRI, ESA 2015. Geomorphic Response of Beaches and Marshes. Technical Memorandum dated 8/31/2015. Authored by J. Jackson, B. Battalio, and J. Lowe. Submitted to the Marin County Community Development Agency.

Stinson Beach ARC . 202101080

Figure 14
Marsh Habitats in Bolinas Lagoon
with Increasing Sea Level Rise

ESA



SOURCE: USGS CoSMoS (2020), ESA Wave Runup (Current Study), ESRI Imagery, County of Marin, CalTrans

Stinson Beach ARC . 202101080

Figure 15
Shoreline Highway Coastal Storm Flooding and Monthly Tidal Inundation
With Sea Level Rise

ESA

5.2 Asset Vulnerabilities

This section summarizes asset vulnerability by hazard type with discussion of the consequences of each exposure category (permanent or temporary) and the adaptive capacity of exposed assets. For reference, asset exposure maps are provided in **Figure 2** through **Figure 15**. As described above, asset exposure is characterized as permanent or temporary.

- **Permanent exposure** includes tidal inundation and coastal erosion (beach/dune or bluff). Emergent groundwater and/or elevated groundwater levels can also be considered as permanent but are discussed separately from tidal inundation and coastal erosion.
- **Temporary exposure** includes coastal storm wave run-up, coastal storm flooding, and Easkoot Creek flooding.

If an asset is exposed to both permanent and temporary exposure, it is counted only in the permanent total. Thus, permanent and temporary exposures together summarize the total number of assets exposed to coastal hazards. Groundwater is discussed separately and is not included in the characterization of permanent or temporary exposure.

Tables for each asset category are presented in the following sections to summarize hazard exposure with sea level rise. Totaling the number of permanent and temporary exposures in each sea level rise scenario equals the total number of assets exposed at that sea level. For example, a total of 689 buildings are exposed at 3.3 feet sea level rise (486 are exposed to tides or coastal erosion, while an additional 203 buildings are exposed to extreme flooding). Assets that are exposed to permanent hazards at a given sea level are likely also exposed temporary hazards at the same sea level.

5.2.1 Emergency Facilities

Emergency facilities in Stinson Beach for which data was obtained include a fire station, fire station annex, and NPS lifeguard station. Several major access routes support emergency services. Shoreline Highway, Calle del Arroyo, Dipsea Road and Seadrift Road are emergency access and evacuation routes and are discussed in the Transportation section below.

Emergency facilities are considered highly sensitive to impacts from coastal hazards due to the critical nature of these facilities. Impacts may reduce emergency response capabilities and response times. Exposed emergency facilities are considered highly vulnerable. Exposure of emergency facilities is summarized in **Table 3** below.

TABLE 3. SUMMARY OF EMERGENCY FACILITIES HAZARD EXPOSURE (PERMANENT AND TEMPORARY)

Facility	Existing sea level		1.6 feet sea level rise		3.3 feet sea level rise		6.6 feet sea level rise	
	Permanent	Temporary	Permanent	Temporary	Permanent	Temporary	Permanent	Temporary
Fire Station & Annex				1		1	1	
Lifeguard HQ		1	1		1		1	

Permanent exposure: tidal inundation and coastal erosion.

Temporary exposure: storm flooding (100-year event) from Easkoot Creek, extreme coastal storm surge or wave run-up.

Fire Department: The Stinson Beach Fire Station Annex is shown to be exposed to emergent groundwater under existing conditions. The Annex becomes exposed to coastal storm flooding with 1.6 feet sea level rise and later becomes exposed to regular tidal inundation with 6.6 feet sea level rise. The Main Station is not exposed to coastal hazards with up to 6.6 feet sea level rise but is adjacent to Easkoot Creek and could be subject to flooding based on existing FEMA flood maps and creek bank erosion (not evaluated in this study). The fire station satellite is located behind the Annex on Easkoot Creek and has similar hazard exposures as reported for the Annex. Consequences of impact to the Annex are medium to low since it is primarily used for storage. Damages to the satellite may impact communications for the area, which is already isolated and without great service. The Annex on Calle del Arroyo has a low adaptive capacity on its own..

Lifeguard Department: The National Park Service lifeguard station is exposed to coastal storm wave runup under existing conditions and is exposed to coastal erosion with 1.6 feet sea level rise. Consequences from impacts to the Lifeguard Station include structure and content damages, as well as disruption of lifesaving capabilities.

Pacific Telephone & Telegraph station: Located at 28 Arenal Avenue in Stinson, this building is located adjacent to Easkoot Creek and is exposed to extreme (100-year) creek flooding as well as emergent groundwater for existing and future conditions. There are potentially significant consequences from flooding of the building: communications may become impaired for the community that is already isolated and without great service.

5.2.2 Buildings and Parcels

Stinson Beach buildings include homes, commercial businesses, public and critical resources. Much of these buildings seaward of Shoreline Highway are relatively vulnerable to sea level rise compared to other communities in West Marin (Marin County 2016). Most buildings are sensitive to impacts from coastal erosion, flooding and wave run-up, which can lead to damage of contents and surrounding property, and even structural damages in the case of erosion and wave run-up. Buildings are considered to have medium to low adaptive capacity depending on structure and foundation construction method and whether they are single family homes or larger buildings. Thus, if a building is exposed to hazards it is considered highly vulnerable.

A large number of homes are exposed to coastal storm wave run-up under existing conditions, while others are exposed to flooding from Easkoot Creek. With as little as 1.6 feet sea level rise, a large number of homes in Calles and Patios reaches become exposed to coastal storm flooding, while wave run-up hazard zones extend further inland from the beach. With 6.6 feet of sea level rise, all structures west of Shoreline Highway are exposed to regular tidal inundation or coastal erosion with the exception of the historic district. **Table 4** and **Table 5** below respectively summarize the total number of buildings and parcels that are exposed to permanent and temporary hazards at each sea level rise scenario. Tax exempt parcels and buildings include the water district, fire, school, and other City/County/federal lands, common areas are within Seadrift.

TABLE 4. SUMMARY OF BUILDING HAZARD EXPOSURE (PERMANENT AND TEMPORARY)

Category	Existing sea level		1.6 feet sea level rise		3.3 feet sea level rise		6.6 feet sea level rise	
	Permanent	Temporary	Permanent	Temporary	Permanent	Temporary	Permanent	Temporary
Commercial	0	9	0	13	9	5	12	2
Multi Residential	0	32	11	26	17	20	35	2
Single Residential	39	303	185	410	449	170	618	4
Other	0	9	6	13	11	8	13	8
Grand Total	**39**	**353**	**202**	**462**	**486**	**203**	**678**	**16**

Permanent exposure: tidal inundation and coastal erosion.

Temporary exposure: storm flooding (100-year event) from Easkoot Creek, extreme coastal storm surge or wave run-up.

TABLE 5. SUMMARY OF PARCEL HAZARD EXPOSURE (PERMANENT AND TEMPORARY)

Category	Existing sea level		1.6 feet sea level rise		3.3 feet sea level rise		6.6 feet sea level rise	
	Permanent	Temporary	Permanent	Temporary	Permanent	Temporary	Permanent	Temporary
Commercial	4	6	4	7	6	5	6	5
Multi Residential	1	15	6	11	14	3	15	3
Single Residential	332	154	440	110	514	36	546	8
Other	29	20	43	17	52	13	62	4
Grand Total	**366**	**195**	**493**	**145**	**586**	**57**	**629**	**20**

Permanent exposure: tidal inundation and coastal erosion.

Temporary exposure: storm flooding (100-year event) from Easkoot Creek, extreme coastal storm surge or wave run-up.

Many oceanfront parcels in Seadrift extend onto the beach, some extend into Bolinas Lagoon and others front Seadrift Lagoon; therefore a high number of parcels are shown to be permanently impacted at existing sea level. This is an example where a more detailed analysis may indicate less risk to specific parcel areas. Similarly, many buildings around Seadrift Lagoon and along Easkoot creek are shown to be exposed to emergent groundwater under existing conditions (see **Table 2**), meaning these areas could be subjected to ponded surface water during heavy precipitation events and/or extreme tides. Building GIS information does not distinguish between buildings elevated on piles and those built on grade, which could indicate lesser risk to elevated structures.

Notable community buildings in Stinson include Bolinas-Stinson School, Stinson Community Center. The School playground and field are exposed to tidal inundation and coastal storm flooding with 6.6 feet of sea level rise. Stinson Community Center is not exposed to coastal hazards with 6.6 feet of sea level rise, though it is adjacent to Easkoot Creek and may be subject to creek bank erosion and flooding with future climate change.

Table 6 below summarizes the maximum water depths of regular tidal inundation, extreme (100-year) coastal storm flooding and Easkoot Creek flooding within building footprints as determined in GIS. **Table 6** includes all exposed buildings whether a small portion or the entire building is exposed to any of these flood hazards. Depths are based on the ground elevations and water surface elevations from the hazard modeling data and do not account for finished floor elevations of each individual home. Building flood depths could be refined in future efforts with complete information on finished floor elevations for all homes in Stinson Beach.

In addition to the buildings listed in **Table 6** as flooded due to tidal inundation, coastal storm surge or Easkoot Creek flooding, many buildings are also exposed to wave run-up during extreme coastal storms (see **Table 2**). While depths of flooding in wave runup hazard zones were not determined for this study, buildings subjected to temporary wave runup impacts are included in **Table 4** and **Table 5**. The consequences to buildings from wave impacts are more severe in that high velocity water has the potential to knock out windows, doors, and cause structural damage in addition to water damages.

TABLE 6. NUMBER OF BUILDINGS FLOODED AT RANGE OF DEPTHS WITH SEA LEVEL RISE

Flood Depth (feet)	Existing sea level	1.6 feet sea level rise	3.3 feet sea level rise	6.6 feet sea level rise
Spring Tide Inundation				
>0 to 1.5	1	28	59	63
1.5 to 3		6	40	75
3 to 4.5			6	131
4.5 to 6				97
6 to 7.5				31
7.5 to 9				9
Coastal Storm Flooding (100-yr)				
>0 to 1.5	3	58	25	10
1.5 to 3	6	95	67	26
3 to 4.5	5	89	70	39
4.5 to 6		58	69	28
6 to 7.5		41	71	80
7.5 to 9		13	66	72
9 to 10.5		1	40	103
10.5 to 12			13	92
12 to 13.5			5	23
13.5 to 15			1	9
Easkoot Creek Flooding (100-yr)				
>0 to 1.5	37			
1.5 to 3	29			
3 to 4.5	2			
4.5 to 6	0			

5.2.3 Transportation

Access to and from Stinson Beach is provided by several key roads: Shoreline Highway (CalTrans), Calle del Arroyo (Marin County) and Dipsea Road/Seadrift Road within Seadrift (private). These roads and others in Stinson are vulnerable to Easkoot Creek flooding and coastal storm flooding and wave run-up under existing conditions. Roads in Stinson Beach are sensitive primarily to the permanent effects of coastal erosion, tidal inundation and emergent groundwater. While roads are not necessarily permanently damaged from Easkoot Creek flooding, coastal storm flooding and wave runup, the temporary road closures and reduced capacity from these hazards can result in impaired resident evacuation and delayed emergency response. For example, direct travel from Stinson to Olema is about 13.5 miles (22 minutes) along Shoreline Highway; if

Shoreline Highway is flooded the alternative routes are 35-40 miles (~1.5 hours) through Muir Beach and inland through Fairfax .

For small amounts of sea level rise, roads could be raised and/or realigned to higher elevations (medium adaptive capacity).However for greater amounts of sea level rise, needed road adaptation may become more complex as the roads are constrained to their current location either by topography or land use. Roads may be elevated in place, but this may have implications to property access during construction and may require modifications to property access connections, especially for greater amounts of sea level rise. Maintaining property access connections/private road connections to an elevated Calle del Arroyo would require major modifications and could result in issues around how elevation impacts any infrastructure (lines, pipes) contained in roadway as well as lateral connections to parcels. Road elevation may also impact emergency vehicle access to properties in Stinson Beach. The Shoreline Highway segment through Stinson and along Bolinas Lagoon is a critical transportation corridor that may require more significant efforts to elevate or realign. Existing and future monthly tidal inundation and 100-year coastal storm flooding impacts along Shoreline Highway are presented in **Figure 15**. Shoreline Highway is also shown to be exposed by bluff erosion between Steep Ravine and its descent above NPS with as little as 1.6 feet sea level rise (shown in C-SMART erosion mapping used in this study as well as new USGS CoSMoS 3.2 cliff erosion mapping).

Maximum flooding depths along critical access roads for each sea level rise scenario are summarized in **Table 7** below. Column 2 in **Table 7** lists the maximum flooding depth along these roads (in feet) for the 100-year flood on Easkoot Creek for existing conditions. Easkoot Creek flood depths are from the O'Connor Environmental, Inc. (OEI) 2014 study, flood depths are comparable in the 2022 OEI study that also includes the coastal storm flood source (i.e. CoSMoS) in flood mapping results. Easkoot Creek flooding from increased flowrates with climate change (more intense precipitation) was not considered. Columns 3 through 10 list the maximum tidal inundation and 100-year coastal storm flooding depths for existing and future sea level rise. The maximum flooding depths were computed along the centerline for each roadway in GIS to indicate potential flooding; the depths may be higher on the shoulder of the roadways than indicated in the table. The extent of Shoreline Highway evaluated extends from the southeast descent into Stinson all the way along Bolinas Lagoon to the Wye, since access to the north depends on this entire segment of the Highway.

TABLE 7. PROJECTED MAXIMUM WATER DEPTHS (FEET) ON IMPORTANT ACCESS ROADS IN STINSON BEACH

Road	Existing	Existing sea level		1.6 feet SLR		3.3 feet SLR		6.6 feet SLR	
	Easkoot Creek Flooding	Spring Tide Inundation	Coastal Storm Flooding	Spring Tide Inundation	Coastal Storm Flooding	Spring Tide Inundation	Coastal Storm Flooding	Spring Tide Inundation	Coastal Storm Flooding
Shoreline Hwy (CalTrans**)**	2.0	0.0	1.9	1.7	6.7	2.9	10.0	6.2	11.9
Calle del Arroyo (County)	2.2	0.0	0.0	1.6	7.4	3.2	10.8	6.3	12.5
Dipsea Rd (Private)	0.0	0.0	0.0	0.0	5.9	0.9	9.4	4.2	10.7
Seadrift Rd (Private)	0.0	0.0	0.0	0.0	7.1	1.6	11.4	5.2	11.7

Note: Max flood water depth was calculated along road centerlines. Road managers are listed in parentheses.

Table 8 below lists Stinson roads exposed under each sea level rise scenario and whether impacts are permanent (tidal inundation, coastal erosion) or temporary (Easkoot Creek flooding, coastal storm wave run-up and/or flooding). Note that Calle de Onda permanent exposure shown for existing sea level corresponds to the Easkoot Creek bridge crossing.

TABLE 8. LENGTHS OF STINSON BEACH ROADS (FEET) EXPOSED TO COASTAL HAZARDS

Road (manager)	Existing sea level		1.6 feet sea level rise		3.3 feet sea level rise		6.6 feet sea level rise	
	Permanent	Temporary	Permanent	Temporary	Permanent	Temporary	Permanent	Temporary
Alameda Patio (P)		121	100	249	189	159	294	54
Arenal Ave (MC)		303		303		303		303
Calle del Arroyo (MC)		974	1882	1933	2838	976	2841	974
Calle del Embarcadero (P)		228	105	469	281	293	379	195
Calle del Mar (MC)		198		198		198		198
Calle del Occidente (P)		118	4	361	168	196	349	15
Calle del Onda (P)	8	319	40	691	337	394	459	271
Calle del Pinos (P)		391	2	747	45	704	412	336
Calle del Pradero (P)		392		820	25	795	435	385
Calle del Resaca (P)		227	71	504	219	356	400	175
Calle del Ribera (P)		221	131	475	262	344	385	221
Calle del Sierra (MC)		294		713	228	503	411	319
Dipsea Rd (P)				3444	484	4558	6962	
Francisco Patio (P)				168	95	74	168	
Joaquin Patio (P)			23	121	144		144	
Jose Patio (P)				170	141	29	170	
Marine Way (MC)		201		201		201		201
McKennas Gulch Fire Rd (?)						102	150	52
Rafael Patio (P)			40	171	124	87	211	
Sacramento Patio (P)			206	30	236		236	
Seadrift Rd (P)		763	89	7780	1943	5927	7870	
Shoreline Hwy (CT)		1723	3359	8905	10384	5329	17615	4299
Sonoma Patio (P)			97	135	230	2	232	
Stinson Beach Fed. Park (N)		86		86		86		469
Walla Vista (P)		102	102	726	675	204	897	
Willow Camp Way (N)								83

Road managers are shown in parenthesis: P=private, MC=Marin County, SP=CA State Parks, CT=CalTrans, N=NPS

Permanent exposure: tidal inundation and coastal erosion.

Temporary exposure: storm flooding (100-year event) from Easkoot Creek, extreme coastal storm surge or wave run-up.

5.2.4 Utilities

Buildings in Stinson Beach have several types of utilities associated with them including electricity, natural gas (from individual on-site storage tanks), water distribution, telephone/internet, metered water connections, and onsite wastewater treatment systems (OWTS) in the form of septic tanks and leach/dispersal fields. No GIS data are available for these utilities. The vulnerability of Stinson Beach utilities presented below is based on Stinson Beach County Water District (SBCWD) records and hazard exposure analysis by ESA. ESA obtained detailed, though not parcel-specific, information on OWTS from Stinson Beach County Water District (SBCWD), which provides water service to 718 metered water connections, monitors 721 privately owned on-site wastewater treatment systems (OWTSs), and provides garbage disposal services for the community.

Coastal hazards present the following consequences to underground utilities and adjacent areas:

- **Elevated groundwater levels and emergent groundwater/surface water:** Underground utility features (e.g. underground power/telephone/cable conduits) vulnerable to high groundwater levels may act as conduits that redirect groundwater to lowland areas depending on whether porous trenching/backfill materials were used, causing groundwater to rise to the surface. This emergent groundwater may result in temporary flooding, surface erosion, or degradation of the overlaying roadway. Ferrous utility mains saturated from high groundwater are also subject to accelerated corrosion.
- **Groundwater level fluctuation with tidal and rain events:** Storm events have the most pronounced effect on groundwater elevations. Seasonally high groundwater levels during the wet weather months (between January and April) significantly impact OWTS treatment and dispersal within the lowland areas as indicated in the CoSMoS maps. To limit impacts to water quality, homeowners within these lowland areas must disconnect the older gravity fed leach/dispersal field(s) from the septic tank by switching a diversion valve which causes the septic tank to act as a holding tank until groundwater levels recede. The septic/holding tank then requires routine pumping every 2-3 weeks, depending on use. Older OWTS that pump septic tank wastewater effluent into a deep leach/dispersal field saturated in groundwater become disposal systems without wastewater treatment. Treatment of wastewater is crucially impaired when the leach/dispersal field becomes an anaerobic environment due to high groundwater levels.
- **Coastal storm flooding and wave run-up:** Homes exposed to coastal storm flooding and wave run-up may experience impacts to utilities lower to the ground and around the structure as well as buried utilities with open connections (e.g., open end of trench or utility conduit). Consequences include corrosion and other flooding related disruption of utility services.
- **Coastal erosion and tidal inundation:** These permanent impacts will have significant implications for the structures as well as supporting utilities. Tidal inundation may corrode utilities at grade.

Additional information on utility vulnerabilities due to sea level rise is provided below.

On-site Wastewater Treatment Systems (OWTS)

There are several classifications of OWTS in Stinson Beach. As shown in **Table 9**, system types include: Standard, Alternative, or Other systems (seepage pit, gray water or holding tank). The majority (78%) of the OWTS are Standard systems. Standard systems traditionally include a septic tank and leach/dispersal field. More modern Standard systems may include an intermittent sand filter pretreatment device to mitigate fast percolating sandy soils and high groundwater conditions. Alternative systems represent approximately 16% of the OWTS and include innovative pretreatment, dispersal, and/or disinfection components. Alternative systems have smaller footprints that are more compatible with the smaller parcels and existing residences. There are 41 systems (6%) classified as a seepage pit, holding tank, and gray water systems. These systems are used for commercial or residential facilities where poor soils conditions or site setback requirements prohibit either a Standard or Alternative system. In general, standard systems extend deeper into the ground and are therefore more vulnerable to elevated groundwater than the alternative and other systems. The bottom dispersal area of an alternative system may vary from 12” above grade to 12” below existing grade, whereas a standard systems vary from 27” to 60” below grade.

TABLE 9. ONSITE WASTEWATER TREATMENT SYSTEMS (OWTS) AT STINSON BEACH BY TYPE

System Type	Dispersal Field	Pretreatment Device	Number of Systems
Standard	Gravity	n/a	388
	Pressure Distribution	n/a	19
	Pressure Distribution	Sand Filter	160
		Subtotal =	567
System Type	**Dispersal Field**	**Pretreatment Device**	**Number of Systems**
Alternative	Gravity	ATU - Aerobic Treatment Unit	4
		ATU - Aerobic Treatment Unit	5
		Recirculating Textile Filter	44
		Recirculating Gravel Filter	3
		Peat Fiber Biofilter	2
	Subsurface Drip	ATU - Aerobic Treatment Unit	17
		Sand Filter	1
		Recirculating Textile Filter	20
		Recirculating Gravel Filter	2
	Septic Mound	n/a	1
	Bottomless Sand Filter	n/a	14
		Subtotal =	113
System Type	**Dispersal Field**	**Pretreatment Device**	**Number of Systems**
Other	Holding Tank	n/a	23
	Seasonal Holding Tank	n/a	7
	Seepage Pit	n/a	10
	Gray Water	n/a	1
		Subtotal =	41

Source: Stinson Beach County Water District

Anticipated higher tides and groundwater elevations associated with climate change will significantly affect the proper operation of individual OWTS in the lowland areas. If OWTS do not adequately treat wastewater due to high groundwater or other impacts, local water quality will suffer with consequences to human and ecosystem health at the surrounding beach and wetland environments. OWTS regulations for wastewater treatment are based on a minimum of 2 or 3 feet of unsaturated native soils, where biological and chemical nutrient breakdown occurs. Higher groundwater or flooding changes the aerobic environment to anaerobic for naturally occurring bacteria, thereby reducing treatment and allowing pollutants to travel further from the OWTS source. OWTS within the lowlands areas have a higher risk of failure from increases of groundwater elevations.

As indicated in **Table 10**, there are approximately 478 residential OWTS in the Calles, Patios, and Seadrift Subdivisions currently at high risk of seasonal high tidal or groundwater events. Additionally, there are 45 commercial and residential OWTS within the Downtown area with moderate to high risk. This represents approximately 72% of the Stinson Beach community’s

OWTS. Maximum daily discharge permitted use for these moderate to high risk OWTS is 168,000 gallons-per-day (gpd). For context, a typical single-family residence uses approximately 100 gpd on average. OWTS located north of Shoreline Highway, on the hillside, have low to moderate risk levels, depending on the subsurface soils, from groundwater inundation.

TABLE 10. EXISTING RISK LEVELS FOR SEASONAL HIGH GROUNDWATER/TIDES AT STINSON BEACH PARCELS

Location	Property Count	Risk Level
Calles/Patios/Seadrift	478	High
Downtown Area	45	Moderate to High
North of Shoreline Hwy	198	Low to Moderate

Source: Stinson Beach County Water District

OWTS were evaluated for future hazards with respect to higher groundwater levels. Currently, no spatial data are available on septic system locations and depths so a simplified methodology was used to assess potential septic system vulnerabilities. Approximate depth from the ground surface to groundwater at each parcel was determined at the centroid point for each Stinson parcel. For the Seadrift parcels that extend onto the beach, the parcels were first trimmed back to the revetment so that the effective centroid is located landward of the revetment (these parcels presumably do not have septic systems within the beach itself). The resulting parcel centroids were then intersected with the mapped groundwater levels to determine the number of parcels in each groundwater exposure category. **Table 11** below provides the number of parcels - including residential (single and multi-unit) and other (commercial, exempt, etc.) - in various depth to groundwater categories.

The graphic shown below illustrates a standard residential building with septic system at varying depths of groundwater from: shallow groundwater (left), moderately elevated above groundwater (middle) and deeper than the limit of measure reported by CoSMoS (right, uphill).

Conceptual diagram of homes with septic systems at varying distances above groundwater table. (Source: ESA)

TABLE 11. NUMBER OF PARCELS CATEGORIZED BY DEPTH TO GROUNDWATER WITH SEA LEVEL RISE

Seadrift (330 parcels)

Groundwater Level	Existing sea level	1.6 ft sea level rise	3.3 ft sea level rise	6.6 ft sea level rise
Marine/Tidal	0	0	8	203
Emergent (at surface)	51	72	103	63
0 to 3.3 ft deep	127	131	98	64
3.3 to 6.6 ft deep	71	71	105	0
6.6 to 16.4 ft deep	81	56	16	0

Patios (196 parcels)

Groundwater Level	Existing sea level	1.6 ft sea level rise	3.3 ft sea level rise	6.6 ft sea level rise
Marine/Tidal	0	11	36	96
Emergent (at surface)	2	1	0	0
0 to 3.3 ft deep	68	64	46	16
3.3 to 6.6 ft deep	20	18	12	3
6.6 to 16.4 ft deep	5	2	2	0

Calles (127 parcels)

Groundwater Level	Existing sea level	1.6 ft sea level rise	3.3 ft sea level rise	6.6 ft sea level rise
Marine/Tidal	0	0	24	90
Emergent (at surface)	13	14	10	1
0 to 3.3 ft deep	77	84	75	36
3.3 to 6.6 ft deep	35	29	18	0
6.6 to 16.4 ft deep	2	0	0	0

NPS (3 parcels)

Groundwater Level	Existing sea level	1.6 ft sea level rise	3.3 ft sea level rise	6.6 ft sea level rise
0 to 3.3 ft deep	1	2	2	2
3.3 to 6.6 ft deep	2	1	1	1

Downtown/Uplands (295 parcels)

Groundwater Level	Existing sea level	1.6 ft sea level rise	3.3 ft sea level rise	6.6 ft sea level rise
Emergent (at surface)	31	31	31	32
0 to 3.3 ft deep	36	36	36	36
3.3 to 6.6 ft deep	14	14	14	13
6.6 to 16.4 ft deep	26	26	26	26
Over 16.4 ft deep	188	188	188	188

Note: Total of 851 parcels analyzed. Depth to groundwater calculated at parcel centroid.

Replacement of older OWTS in areas vulnerable to seasonal high groundwater is triggered by failure of the system or building remodels that increase habitable space. Between 5 to 20 OWTS permits are issued annually for replacement of older systems. New OWTS typically include alternative pretreatment devices, raised dispersal beds, and telemetry control panels with continuous alarm and pump monitoring. Dispersal beds may be raised 12-inches above native soil to meet a minimum 36-inch separation to seasonal high groundwater. Further increasing the raised bed heights above native grade jeopardizes both wastewater treatment and dispersal. As result, the raised dispersal beds that are traditionally used for replacement of older systems will not adequately treat and disperse wastewater for future increases of groundwater elevation. See **Figure 8** through **Figure 11** for maps of emergent groundwater locations under sea level rise scenarios.

There are approximately 234 older OWTS within the lowlands areas subject to high groundwater inundation (SBCWD). During periods of high groundwater elevations, many of these older OWTS have a shutoff valve that allows the homeowner to use the septic tank as a holding tank. Pumping and hauling sewage away to an offsite treatment plant is necessary until the high groundwater levels recede. Pumping the tank is typically performed every 3 to 4 weeks, depending on use. When groundwater levels drop below the leach field, then the homeowner may switch the shutoff valve to activate the leach field. While sewage disposal is achieved, wastewater treatment within the saturated soils is comprised. Depending on the soil type, a minimum of 3 to 20 feet of groundwater separation is necessary for proper wastewater treatment per the SBCWD On-site Wastewater Management Code (Title IV). Fast percolating soils require 20 feet of separation for older OWTS and 3 feet for modern OWTS.

Modern OWTS have pumps and often raised leach field beds that allows wastewater to be discharged during periods of elevated groundwater. Additionally, modern OWTS include pretreatment devices that help reduce the strength of wastewater prior to disposal. Nonetheless, at least 3 feet of groundwater separation is necessary from the bottom of the leach field beds to seasonal high groundwater for additional wastewater treatment. With the seasonally high groundwater elevations resulting from the January 2023 storms events, wastewater treatment was diminished in Stinson Beach.

Other Utilities

Other utilities in Stinson Beach include underground water distribution, electricity, telecommunications, storm water mains and laterals. Additionally, liquid propane tanks and privately owned gas laterals serve individual properties. Underground utility pipelines typically consist of metal, plastic, or asbestos concrete pipes encased in a rock or sand backfill. Higher groundwater and tides are anticipated to increase operational and maintenance costs to both public utility mains and privately owned utility laterals.

Underground water distribution pipelines commence from the water treatment and storage tanks located within the upland areas of Stinson Beach. These pressurized pipelines provide both fire and domestic water throughout Stinson Beach. Higher groundwater may lead to corrosion of metal pipelines. Water main or lateral leaks within the sandy soils in Stinson Beach are difficult to detect and typically result in significant operational costs to both SBCWD and individual homeowners.

Electricity and telecommunication facilities in Stinson Beach consist of underground lines in the Seadrift community and overhead lines in the remaining communities. Individual residential and commercial connections are typically overhead in the older communities. New buildings or remodels, however, typically have underground services from the utility pole. Potential vulnerability issues for these utilities include groundwater infiltration of new underground services and/or infiltration of existing underground trenches. Groundwater infiltration of existing underground telecommunication service is currently an issue along Shoreline Highway fronting the library. Groundwater emerges from telecom trenches causing roadway degradation and unsafe conditions for pedestrians.

Corrugated metal culverts are utilized throughout Stinson Beach to connect roadside drainage swales to the existing creeks and ultimately Bolinas Lagoon. Higher tides and brackish water will intensify corrosion of these facilities.

Individual liquid propane tanks provide gas service to both residential and commercial facilities. Private gas service companies routinely fill tanks. These tanks will be increasingly vulnerable to wave run-up and significant storm events in the lowland areas.

5.2.5 Recreation

This section describes sea level rise vulnerabilities of parks and coastal access in Stinson Beach. Park and preserve areas in and around Stinson Beach include Bolinas Lagoon Open Space Preserve, Audubon Canyon Ranch, Village Green Park, Golden Gate National Recreation Area (GGNRA), Upton Beach, and Mount Tamalpais State Park (offshore area along Upton Beach). Specific recreational amenities in Stinson Beach include coastal access locations (CA Coastal Trail, foot and boat access), NPS park picnic areas, parking, and beach amenities including restrooms/showers.

Bolinas Lagoon Open Space Preserve, GGNRA, Upton Beach and Mount Tamalpais State Park are all inundated regularly by tides (whether within the lagoon or on the beach) and are exposed to extreme coastal and fluvial flooding. These hazards will worsen with sea level rise and will ultimately expose Audubon Canyon Ranch, Bolinas-Stinson School, and other Stinson Beach Community and Facility open spaces. Park service staff report existing issues with buried infrastructure as well as seasonal/perennial groundwater discharge in low points around the GGNRA (OEI 2022). Initial efforts to map groundwater with sea level rise (OEI 2022) as well as CoSMoS groundwater maps indicate that emergent groundwater may spread to most of the GGNRA area (the NPS proposes future study to refine groundwater modeling and projections). Coastal erosion will impact beaches at Upton and GGNRA. Upton Beach will become squeezed by development along the Calles, while the landward location of development and presence of unarmored dunes along the Patios may enable a summer beach to persist with up to 6.6 feet of sea level rise. The lower level of development, capacity for managed retreat of existing structures, and existing dunes along the GGNRA enable the persistence of a beach with up to 6.6 feet of sea level rise (**Figure 13**).

Coastal access points at Walla Vista, Stinson Bridge (main entrance road into GGNRA) and GGNRA are vulnerable to hazards with sea level rise. The Walla Vista / Van Praag beach accessway is exposed to coastal storm wave runup under existing conditions, and with future sea level rise, the accessway will also become exposed to coastal erosion. The GGNRA entrance bridge over Easkoot Creek is vulnerable to flood flows in the creek, and is exposed to coastal flooding at 6.6 feet sea level rise.

GGNRA restrooms and restaurant are vulnerable to wave runup under existing conditions and are vulnerable to coastal erosion with as little as 1.6 feet sea level rise. The Lifeguard station is similarly vulnerable (see critical facilities discussion). Picnic areas and parking lots at GGNRA are currently exposed to Easkoot Creek flooding and will become exposed to coastal wave runup and flooding with 1.6 to 3.3 feet of sea level rise depending on location.

5.2.6 Historic and Archaeological Resources

The historic district of Stinson Beach is currently exposed to Easkoot Creek flooding for the 100-year event. The area is also exposed to elevated and emergent groundwater levels under existing conditions. These hazards will increase with sea level rise and pose risks to the historic structures, underlying utilities and plumbing.

Currently, there are no recorded archaeological resources within the study area that appear vulnerable for the sea level scenarios considered. No sea level rise vulnerabilities were identified for up to 6.6 feet sea level rise at known archaeological resources near Stinson Beach based on the available spatial data provided by Marin County CDA. These data are not maintained by CDA, and the team acknowledges that there may be additional, unrecorded cultural resources associated with the lower elevation landforms around Stinson Beach. These unrecorded archaeological resources may be vulnerable to sea level rise in addition to associated storm events and erosion.

5.2.7 Natural Resources

The vulnerability of beaches and marshes around Stinson Beach is discussed below.

Beaches

Shoreline and beach characteristics at Stinson Beach were previously studied and reported in the Stinson Beach Nature-Based Adaptation Feasibility Study (ESA 2021). **Figure 12** depicts the five shoreline reaches and analysis transects used to summarize historic beach widths and future beach and dune widths estimated for this study.

Over the past century, the average shoreline position along Stinson Beach was relatively stable along the southeastern beach (erosion or accretion of just inches per year) while the Seadrift beach eroded steadily (0.9 feet/year on average). Recent short-term accretion rates suggest the shoreline and beach have undergone steady recovery since the 1990s. However, significant storm erosion events over the past century have impacted development along the entire shore, wasted dunes and led to the construction of the Seadrift rock revetment (after the 1983 El Niño) as well as the removal and modification of homes in the Calles. These storm-driven erosion events present a challenge for adaptation solutions. To quantify the potential impacts of extreme winters at Stinson beach, ESA (2021) extracted the mean high water (MHW) shorelines from available sources: airborne LiDAR collected before and after both El Niño winters of 1998 and 2016 by the USGS for the west coast to produce digital elevation models (DEMs) representing pre- and post-winter conditions. The 2016 El Niño winter resulted in 100 to 160 feet of erosion along the Stinson shoreline while the 1998 El Niño winter resulted in 30 to 100 feet of shoreline erosion (ESA 2021). While the shoreline mostly recovered after these events, these extreme winters provide an indication of the potential impacts to the beach footprint along Stinson. Historic beach widths along Stinson Beach are summarized in **Table 12** below.

TABLE 12. HISTORIC STINSON BEACH WIDTHS, 1929 – 2019

Reach	Fall beach width, average (feet)	Winter beach width, average (feet)	Average seasonal shoreline change envelope (feet)	Extreme winter shoreline erosion (feet)
Seadrift West	148	92	66	85
Seadrift East	217	102	115	140
Patios	215	127	88	151
Calles	210	134	76	158
NPS	198	138	69	136
Average	**198**	**119**	**79**	**134**

Source: ESA 2020

Future dune and beach widths were estimated by applying the shoreline evolution models developed previously by ESA for the nature-based adaptation feasibility study (see Section 4 for discussion of methods). As indicated in **Table 13** below, beaches are vulnerable to sea level rise at Stinson Beach, especially in the Seadrift and Calles reaches where existing development and armoring restrict inland beach migration. The beach is at risk of disappearing in a typical winter with as little as 3 feet of sea level rise at Seadrift and Calles reaches, which may lead to reduced capacity for summer beach recovery and influence beach widths in adjacent Patios and NPS reaches. Note that the projections in **Table 13** represent average conditions; erosion impacts from extreme coastal storms (whether a single storm event or El Niño winter) could further reduce beach widths (see **Table 12**) and erode dunes, negatively affecting beach resilience with future sea level rise. Recent storm impacts to Stinson from the 2015-2016 El Niño winter include 45 to 65 feet of dune erosion in hot spots on the order of a couple hundred feet along shore (ESA 2021). Thus, it is possible that portions of the dunes in Patios and NPS reaches are eroded sooner than indicated in **Table 13**. See **Figure 13** that depicts the winter and summer beach widths represented in **Table 13** below.

TABLE 13. SUMMARY OF STINSON BEACH WIDTHS WITH SEA LEVEL RISE

Reach	Existing sea level			1.6 ft sea level rise			3.3 ft sea level rise			6.6 ft sea level rise		
	Dune Width	Beach Width		Dune Width	Beach Width		Dune Width	Beach Width		Dune Width	Beach Width	
		Winter	Summer		Winter	Summer		Winter	Summer		Winter	Summer
Seadrift West	n/a	60	140	n/a	11	91	n/a	0	35	n/a	0	10
Seadrift East	n/a	80	160	n/a	31	111	n/a	0	60	n/a	0	10
Patios	70	60	140	32	60	140	7	53	133	0	0	100
Calles	n/a	65	145	n/a	16	96	n/a	0	40	n/a	0	10
NPS	180	60	140	145	60	140	110	60	140	38	60	180

Note: Widths are projected average conditions with sea level rise and do not include potential storm erosion.

Marshes

Bolinas Lagoon is internationally recognized (Ramsar) and is a critical stopover for birds as part of the Pacific Flyway, home to critical and endangered species. Marsh habitats in Bolinas Lagoon were previously mapped and evaluated for the C-SMART Vulnerability Assessment (ESA 2015). **Figure 14** shows the potential marsh habitat distribution along Seadrift and Stinson for existing sea level and future sea level rise. Potential existing and future marsh habitat 'bands' were defined in Bolinas Lagoon by relating the topography to tidal elevation ranges for each habitat type with a concept called elevation capital. Future habitat distribution was calculated for each sea level rise scenario assuming a nominal sediment accretion rate in Bolinas Lagoon of 6.8 mm/yr. Additional information on the development of these marsh habitat maps can be found in the memorandum Geomorphic Response of Beaches and Marshes prepared for the County by ESA (2015). The potential habitat zones shown in **Figure 14** are limited by the analysis domain (shown as dashed red line). With future sea level rise, marsh habitats may become squeezed along existing development and Shoreline Highway; building outlines and road centerlines are shown in **Figure 14** to reflect the existing limits to marsh migration space around Stinson Beach.

At existing sea level, marsh habitat near Stinson consists of narrow fringes along the lagoon side of Seadrift and Shoreline Highway and a larger expanse of marsh habitat along the lower Easkoot Creek floodplain behind the Patios. With future sea level rise, the marsh habitats (low, mid and high marsh) along the upland fill of Seadrift will be subjected to coastal squeeze while habitats adjacent to Easkoot Creek have some capacity to migrate upland/upstream along the floodplain. Overall, without action, mid and high marsh will convert to low marsh and mudflat/subtidal habitat with higher amounts of sea level rise. **Table 14** summarizes existing and potential future marsh habitat acreages in the vicinity of Stinson Beach limited at existing development. For context, ESA 2015 mapped nearly 630 acres of low to high marsh habitat in Bolinas Lagoon. The Stinson Beach vicinity summary in **Table 14** illustrates the potential vulnerability of marsh habitats to coastal squeeze along private development as well as Shoreline Highway with sea level rise. If sedimentation in Bolinas Lagoon is lower than the assumed 6.8 mm/yr, marsh habitats in Bolinas Lagoon could be lost more rapidly with sea level rise than indicated in **Figure 14** and **Table 14** .

TABLE 14. BOLINAS LAGOON MARSH HABITATS IN THE VICINITY OF STINSON BEACH (AREA IN ACRES)

Habitat Type	Existing sea level	1.6 feet sea level rise	3.3 feet sea level rise	6.6 feet sea level rise
Transition	14.5	13.6	14.5	11.5
High marsh	14.9	6.1	5.0	6.2
Mid marsh	3.7	4.4	2.0	1.5
Low marsh	58.4	34.5	23.1	7.3
Intertidal	112.5	135.8	114.4	14.2
Subtidal	14.6	28.1	67.4	198.2

Note: Marsh habitat transgression is limited at existing development

6. CONCLUSION AND NEXT STEPS

In conclusion, Stinson Beach is vulnerable to coastal erosion, coastal storm flooding and wave runup as well as Easkoot Creek flooding under existing conditions. With sea level rise, these hazards will worsen and monthly tidal inundation will encroach upon roads and development with as little as 1.6 feet of sea level rise. Large areas of residential development, access roads, septic systems and other utilities, beaches, marshes, and other asset west of Shoreline Highway are increasingly vulnerable to these hazards with additional sea level rise.

The following tasks of the Stinson Beach ARC will identify applicable adaptation measures, evaluate measures for various considerations, identify triggers and thresholds for action, develop and analyze potential adaptation pathways (trajectories) for the Stinson Beach community and outline a sea level rise monitoring approach. The findings will be documented in the project deliverable titled Stinson Beach Sea Level Rise Adaptation Roadmap report

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