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memorandum

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to John DiNunzio, San Luis Obispo Council of Governments

from ESA

subject Morro Bay Estuary Coastal Flood Hazard and Vulnerability Assessment Memorandum

1 Background and Purpose

This memo documents the coastal flood hazard modeling and planning-level vulnerability assessment analyses performed by ESA. It reports the transportation, recreational, and natural assets most vulnerable to coastal flooding and sea level rise (SLR) as part of The Morro Bay Estuary Climate Resiliency Transportation Plan ("The Plan") developed under contract with the San Luis Obispo Council of Governments (SLOCOG).

The Plan aims to enhance mobility between Morro Bay and Los Osos while considering the natural environment, the estuary, and Morro Bay State Park. It focuses on a 2.5-mile stretch of South Bay Boulevard, which is the only route connecting both jurisdictions and is prone to flooding, especially with rising sea levels. Flooding disrupts connectivity and poses risks during emergencies, highlighting the need for a detailed model to address these challenges. The study area includes critical wetland habitats vulnerable to SLR, necessitating a holistic approach that integrates community input and nature-based solutions.

The plan involves developing a conceptual design to adapt to fluvial and coastal flood hazards and to improve non-motorized mobility along South Bay Boulevard. The project uses GIS mapping, community engagement, and technical analyses, including flood modeling, to create adaptive solutions and predict flood risk throughout the bay, beyond the reach of current data. Funded by the California Department of Transportation (Caltrans) Sustainable Transportation Planning Grant Program, this study lays the groundwork for future adaptation projects, ensuring the community's vision and values are prioritized in addressing flood risks and improving infrastructure resilience.

ESA reviewed available coastal flood hazard data from the United States Geographic Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA), and the Federal Emergency Management Agency (FEMA). ESA developed a 2D Delft3D model of the site, building from an existing USGS model (Taherkhani et al. 2023). The model was run for storm and non-storm conditions for SLR scenarios of 0', 1.8', and 6.3'. Output from this model was overlayed on an asset inventory for the area to determine areas and assets that are at risk to tidal inundation and fluvial flooding. At-risk infrastructure, recreational, and natural assets were assessed based on their exposure to hazards, sensitivity to exposure, and adaptive capacity to assign overall vulnerability ratings

to the assets. This memo describes the site characteristics, SLR scenarios, hydrodynamic model setup and results, and methodology and results of the vulnerability assessment.

1.1 Literature Review

The City of Morro Bay has conducted several prior studies on the potential effects of climate change and SLR to the area's infrastructure, natural resources, recreational spaces, and water quality. Notable relevant reports, and their key findings are detailed in Table 1 below.

TABLE 1
RELEVANT REPORTS – KEY FINDINGS

Report	Key Findings
City of Morro Bay Community Baseline Assessment (CBA) ¹	The Morro Bay CBA was part of the City of Morro Bay's Plan Morro Bay, a strategy for conservation and development of the city through 2040. The CBA describes historic and existing conditions to provide the information required to update the City's General Plan and plan for future changes to these conditions. As part of the report, a quantitative vulnerability assessment of beaches, public access ways, state parks, coastal development, utilities, and transportation for SLR horizons of 2016, 2030, 2050, and 2100 is provided. The most vulnerable assets were determined to be transportation (road, bike, pedestrian), state parks, and beaches due to their higher exposure and sensitivity and lower adaptive capacity than other asset classes. This analysis was based on SLR guidance from the National Research Council (NRC) in 2012.
City of Morro Bay Community Vulnerability and Resilience Assessment (CRVA) ²	The Morro Bay CRVA provides a comprehensive analysis of the city's vulnerability to demographic, economic, and climate change-related hazards through 2040. The report found that: residential land uses in Morro Bay are poorly prepared for future changes; more frequent electricity shortages are likely; vulnerability of Morro Bay's roadway network could degrade infrastructure quality and increase maintenance costs; and drought, flood, and SLR pose risks of habitat degradation and special-status species loss in Morro Bay's wetland areas.
Sea Level Rise Adaptation Strategy Report ³	In 2018, the Sea Level Rise Adaptation Strategy Report prepared for the City of Morro Bay to analyze coastal adaptation strategies for Highway 1, the Morro Rock parking lot, and the Embarcadero Waterfront. The report recommended that the city develop a long-term monitoring plan, identify funding mechanisms, make proposed land use zoning consistent with adaptation approaches, and define triggers for adaptive actions.
City of Morro Bay Environmental Sensitive Habitat Area (ESHA) Analysis: 2050 Sea Level Rise Scenario ⁴	The City of Morro Bay Environmental Sensitive Habitat Area (ESHA) analysis analyzes the potential future effects of climate change and SLR to environmentally sensitive habitats. The report concludes that "increases in tidal inundation, coastal flooding, and dune and bluff erosion are anticipated to result in a net loss of ESHAs in the Morro Bay coastal zone, with pronounced effects on foredune and backdune communities, estuarine coastal salt marshes, stream mouths, and areas of riparian and freshwater wetland immediately adjacent to the coast. Landward retreat may occur to some extent but existing topographic features, roads, and structures limit the area available for retreat, and the expected outcome is a narrowing of the bands of coastal habitat" (Rincon Consultants Inc., 2018).
Plan Morro Bay Coastal Resources & Resiliency H++ Update⁵	In 2019, The City of Morro Bay updated their coastal hazard and vulnerability assessment to incorporate the most up-to-date SLR projections published by the Ocean Protection Council (OPC) in 2018, especially the Extreme Risk Aversion Scenario (H++). With the updated model, nearly all ocean fronting roadways were found vulnerable to flooding and inundation, wetlands and intertidal habitats were impacted by inundation by 2030, coastal dunes were impacted by 2030, there was significant loss of beach area by in 2050, as well as moderate vulnerability to coastal developments in 2050 and to the existing wastewater treatment plant by 2100. Note that in the most recent OPC SLR guidance in 2024, the H++ scenario was removed as the rates and amounts of SLR are no longer supported by the best available science.

SOURCE:

- 1. Michael Baker International, 2016
- Michael Baker International, 2017
- 3. Moffat & Nichol, 2018
- 4. Rincon Consultants, Inc., 2018
- 5 Moffat & Nichol, 2019

This analysis differs from previous studies in that it focuses on transportation resiliency, specifically along South Bay Boulevard between State Route 1 and Los Osos Creek with spurs along South Park Road (i.e., Main Street), Quintana Avenue, and Turri Road. It also includes the Morro Estuary Natural Reserve and Morro Bay State Marine Reserve. The report uses 2024 OPC SLR guidance that has been updated based on best-available science since the guidance from the OPC in 2018 and NRC in 2012 used in previous studies. It develops a hydrodynamic model for the area for three SLR scenarios to determine hazard exposure rankings for individual transportation, natural resource, and recreational assets. Uniquely, this vulnerability assessment provides cumulative vulnerability scores for individual at-risk assets.

2 Site Characteristics

The project site focuses on a 2.5-mile stretch of South Bay Boulevard between State Route 1 and Los Osos Creek, including spurs along South Park Road (Main Street), Quintana Avenue, and Turri Road (Figure 1). The study area also encompasses the Morro Bay State Marine Reserve. Flood events frequently close roads, severing connectivity between Morro Bay and Los Osos and blocking one of the primary evacuation routes in the event of a radiation accident at Diablo Canyon Nuclear Power Plant. High estuary tide levels combined with high creek flows exacerbate flooding, particularly in the lower reaches of Chorro Creek and Los Osos Creek. With SLR, the frequency and severity of road closures are expected to increase dramatically.

The study area includes critical wetland habitats adjacent to South Bay Boulevard and its spurs. These habitats, part of the Morro Bay State Marine Reserve, are vital for various animals and plants, including some endemic species found only locally. These habitats are also vulnerable to SLR.

These existing vulnerabilities, along with potential future vulnerabilities, will be addressed in further detail later in the report.

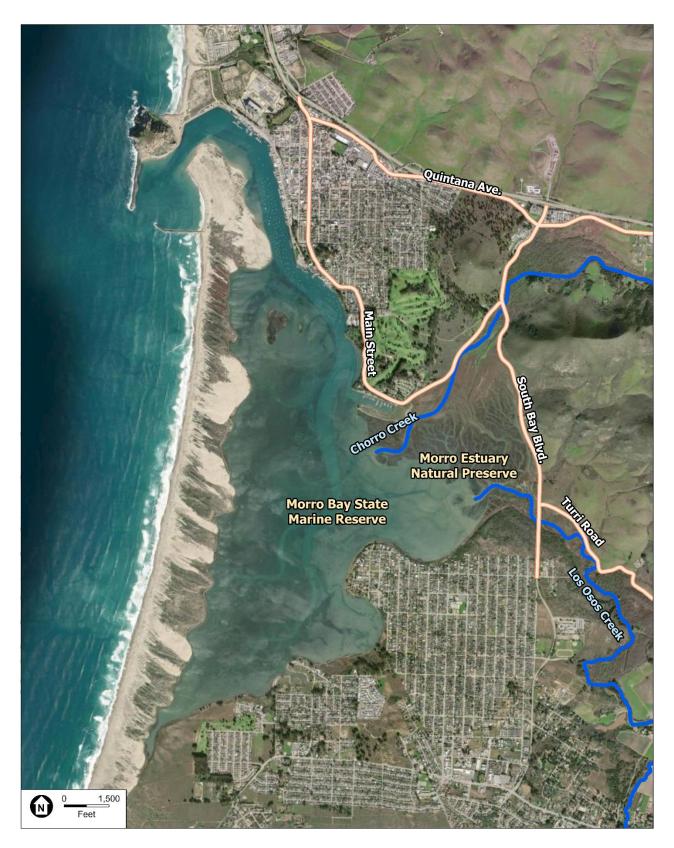


Figure 1 Project Area

2.1 Site Hydrology

The tides at the project site are semi-diurnal with a tidal range approximately from 0 to 5.4 feet (ft) above the North American Vertical Datum of 1988 (NAVD 88). Local tidal datums are given in Table 2. Tidal water levels were characterized at the site using the following:

- Existing records from National Oceanic Atmospheric Administration (NOAA) gauge at Port San Luis (Station # 9412110);
- Existing records from Cal Poly State University Station MBXC1 at the Coast Guard T-Pier;
- Previous reporting by Phil Williams Associates (PWA) at the site location.

TABLE 2
TIDAL DATUMS AND OTHER KEY WATER LEVELS

Datum/Water Level	NOAA Port San Luis Gauge (ft NAVD88) ¹	Coast Guard Pier (ft NAVD) ²	PWA Report (ft NAVD) ³	
Highest Observed Water Level	7.6 (1/18/1973)	6.9 (7/14/2022)	12.3	
Highest Astronomical Tide (HAT)	7.0			
Mean Higher-High Water (MHHW)	5.3	5.4	7.7	
Mean High Water (MHW)	4.5	4.6	5.5	
Mean Tide Level (MTL)	2.8	2.9	3.1	
Mean Sea Level (MSL)	2.7	2.9		
Mean Diurnal Tide Level (DTL)	2.6	2.7		
Mean Low Water (MLW)	1.0	1.2	1.2	
NAVD88 Datum	0.0	0.0	0.0	
Mean Lower-Low Water (MLLW)	-0.1	-0.0	0.2	
Lowest Astronomical Tide (LAT)	-2.1			
Lowest Observed Water Level	-2.5 (1/07/1951)	-2.0 (1/22/2023)	-2.3	

SOURCE:

2.2 Modeled Sea Level Rise Scenarios

ESA provided a series of recommended SLR scenarios for evaluation after reviewing the Ocean Protection Council's (OPC) State of California SLR Guidance (OPC 2024) and local SLR projections at the site. The specific time horizons and amount of SLR scenarios selected are presented in Table 3 and represent existing conditions, mid-century high SLR, and end-of-century high SLR. The SLR scenarios are produced from water level and conditions data gathered by the Port San Luis NOAA tide gauge and incorporate the local estimate of vertical land motion.

In addition, we utilized results from the USGS Coastal Storm Modeling System (CoSMoS), which is a dynamic modeling approach developed by USGS that provides detailed meter-scale predictions of coastal flooding across large geographic areas, integrating both future SLR and storm scenarios. CoSMoS simulates coastal flooding for

^{1.} NOAA Tides & Currents, 2024

^{2.} Cal Poly State University San Luis Obispo, 2024

^{3.} Philip Williams & Associates, 2007

the 100-year return period storm scenario under multiple incremental SLR scenarios ranging from 0 to 3 meters (0 to 9.8 ft), plus an extreme 5-meter (16.4 ft) scenario.

TABLE 3
SLR SCENARIOS CONSIDERED

Time Horizon	SLR (ft)	Scenario				
2024	0.0	Existing Conditions				
2060	1.8	High SLR				
2100	6.3	High SLR				
SOURCE: OPC SLR Guidance 2024						

2.3 Sources of Vulnerability

Sources of vulnerability in the project study area include fluvial flooding from Chorro Creek and Los Osos Creek, sheet flows over South Bay Boulevard during heavy precipitation events, wave run-up and tidal flooding during high tide events, as well as potential for tidal inundation over time.

2.4 Data Sources

Table 4 summarizes the data sources for the coastal hazards assessment. This assessment relied on publicly available coastal datasets, and data collected previously by ESA and others.

TABLE 4
DATA SOURCES

Data Type	Time Range	Source	Notes
Hydrodynamics			
Ocean Tides	1983-2001 8/10/2021 – 9/6/2024	NOAA #9412110 Cal Poly State University San Luis Obispo	Long-term ocean tides 15 miles south of the site at Port San Luis Coast Guard Pier
	8/5/1987 – 8/7/1987	PWA 1988	State Park Marina
Bathymetry/Topography			
Bay Bathymetry	2014	USGS CoNED	CoNED data with a corrected LiDAR segment stitched into the original bathymetry provided by USGS direct correspondence
Wind			
Wind Speed and Direction	1/1/2023 - 3/1/2024	NOAA #9412110	Meteorological observations
Long-term Wind Speed and Direction for SWAN Model	2006-present	NOAA NCEI SLO Airport	Meteorological observations
Fluvial			
Streamflow		USGS	Estimated a 10-year event using the USGS StreamStats for Chorro Creek and Los Osos Creek

3 Hydrodynamic Model Setup

This section describes the model and selected modeling scenarios that ESA used to conduct hydrodynamic analysis at Morro Bay.

3.1 Model Domain

ESA developed a 2D Delft3D model of the site by building upon an existing USGS model (Taherkhani et al. 2023). This model includes all areas inside Morro Bay that are submerged by "king tides" (exceptionally high tides) and extends three kilometers offshore of the bay mouth to allow forcing from ocean tides. The curvilinear grid was developed from the original USGS grid and modified with grid refinement inside the bay. The model uses a structured mesh, enabling local mesh refinement in specific areas to accurately capture the key physical dimensions of the study area.

The model that ESA developed for the project site includes a grid extension of the USGS model prepared by Taherkhani et al. (2023) to better represent Chorro Creek and Los Osos Creek's influence on the project study area. ESA's model encompasses the entirety of Morro Bay, including the intertidal zone, covering an area of approximately 10,000 acres in extent. The domain was extended to cover a greater area around the inlets of Chorro Creek and Los Osos Creek, which are critical to the hydrodynamic processes being modeled.

Tidal conditions were generated in the model by downloading tidal data from the NOAA Port San Luis Station and applying them at the north, south, and west ocean boundaries of the model. Initial conditions were set based on downloaded water level data to represent realistic starting points for water level in Morro Bay Estuary. Streamflow was simulated in the model with inputs from Chorro Creek and Los Osos Creek. Wind conditions were similarly generated in the model by downloading wind data at the NOAA Port San Luis Station. Uniform wind was added as a physical parameter to the model with linear interpolation.

The model was run to focus on the events from January 27, 1983, January 9, 2023, February 4, 2024, and August 1, 2023. The first three events were modeled as storm events with extreme water levels in the region, and the August 1, 2023, event was modeled as non-storm spring tide conditions. The model created full 2D outputs of the site at 30-minute intervals to evaluate the spatial characteristics and water level of the bay.

3.2 Model Grid and Bathymetry

The initial model uses a curvilinear grid consisting of approximately 77,000 grid cells. The grid is coarsest inside the bay at the north and south boundary, where the resolution is roughly 260x220m (850x720 ft), and the resolution gradually increases in some locations along the central, intertidal portions of the bay, where the resolution is roughly 12x15m (39x49 ft). The Chezy roughness coefficient for the bed was set to 65 everywhere and some dry points were incorporated in the grid. The existing model was calibrated with four monitoring stations: at the mouth (BM), near the center (BC), towards the back center near oyster farms (BO), and at the far south end of the bay near the head (BS).

The model grid was extended landward after several initial runs to cover the extent of CoSMoS scenario of 5m (16.4 ft) SLR combined with the 100-year return period coastal flood inside the bay (Figure 2). The new grid extent was informed by this scenario because it results in the floodplain. The new grid includes approximately

86,000 elements with main differences being the area covered around Chorro Creek, Los Osos Creek, Main St. along the southern end of the Morro Bay Golf Course, and into the neighborhoods on the southeast side of the bay.

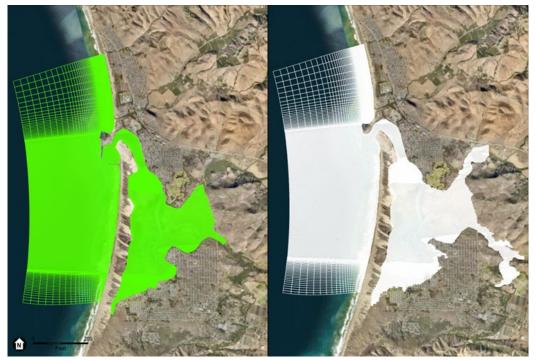


Figure 2
Original USGS Model grid(left) and Extended ESA Grid including Chorro and Los Osos Creeks, and the Extension of the CoSMoS 5m SLR Scenario (right)

The bathymetry for the model (Figure 3) used USGS Coastal National Elevation Database CoNED (2014) data with a marsh Light Detection and Ranging (LiDAR) correction factor based on 2014 real-time kinetic positioning (RTK) data of the marsh stitched into the model. The corrected marsh digital elevation model (DEM) shows about 1ft lower marsh at the creek outlet and allows for greater definition of the channel on the west side of the marsh along State Park Road.

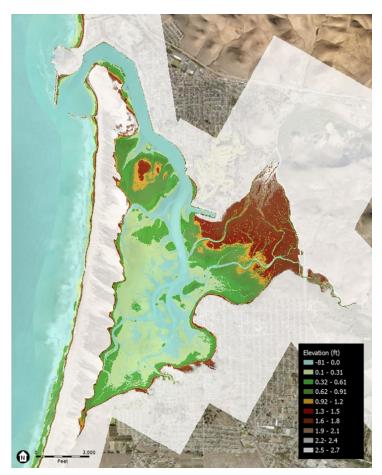


Figure 3Model Bathymetry

3.3 Boundary Conditions

NOAA Station Port San Luis is the closest observation station to the project study area. Time series data was downloaded for storm and non-storm periods from NOAA's public access Tides & Currents water level website. These water levels were then used as boundary conditions for inputs to the Deflt3D model at the north, south, and west boundaries.

ESA selected storm events from January 9th, 2023, and February 4th, 2024, to represent water levels under storm conditions. Further investigation revealed that these events had water levels only slightly higher than those observed during the non-storm conditions that ESA analyzed. Thus, ESA added a storm run from the extreme water levels recorded on January 27th, 1983 to utilize conservatively high water levels for the region. These additional water levels were subsequently used as the boundary conditions for storm scenario model runs (Figure 4).

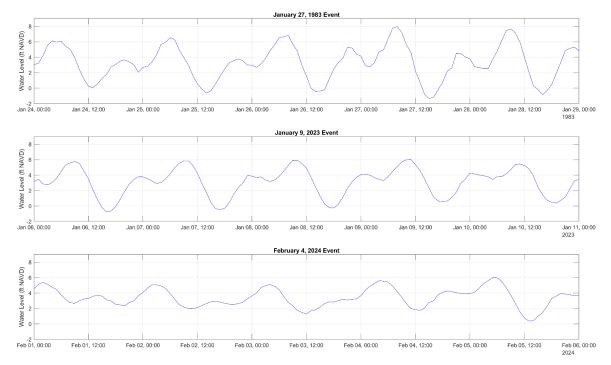


Figure 4
Water Level Time Series NOAA Station Port San Luis

The flood pattern in areas influenced by both coastal and fluvial sources is more complex. To better represent the physics in these compound flood areas more accurate river bathymetry and streamflow input was needed. For the purpose of this project, ESA chose to add constant streamflow estimated as 100-year return period event using the USGS StreamStats online tool to conservatively represent the two creek inputs.

3.4 Model Verification

ESA verified the Delft3D model results by comparing water level outputs with observational data collected by Cal Poly and the Central & Northern California Ocean Observing System (CeNCOOS). Both sources of observational data were collected at the T-Pier near the mouth of Morro Bay along the Embarcadero. Cal Poly provided observational data from 8/10/2021 – 9/6/2024 and CeNCOOS observational data covered 1/1/2023-1/5/2023 and 1/11/2023- 2/1/2023. The CeNCOOS data does not include the validation period of 1/6/2023-1/1/2023 modeled by the January 9th run, so the model was only verified against the Cal Poly data on this date. The alignment of the observational data with the model data at the T-Pier shows that the model accurately captured the tidal patterns and magnitudes during the validation period (Figure 5).

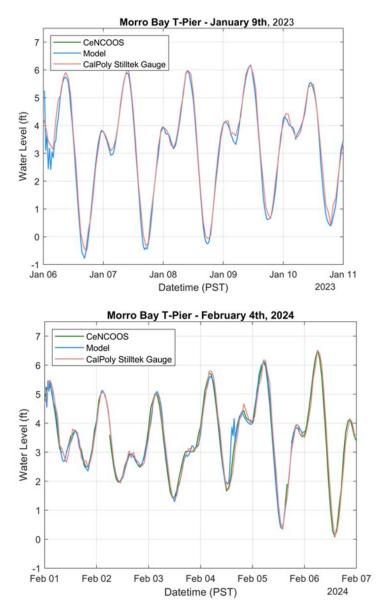


Figure 5Validation of model results with Cal Poly water level data for January 9th, 2023 (top) and with CeNCOOS and Cal Poly water level data for February 4th, 2024 (bottom)

Although streamflow and river bathymetry were not fully simulated, ESA plotted model results from the mouth of Chorro Creek to compare with Cal Poly's Hobo 1 observation data. The plot shows that the model output is consistently higher than the observed data, as expected because ESA conservatively chose to use a constant extreme streamflow as the creek discharge boundary condition.

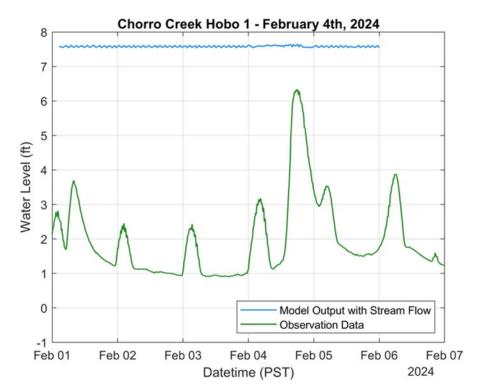


Figure 6
Comparison of modeled and observed Chorro Creek water level for February 4th, 2024.

4 Hydrodynamic Model Scenarios

ESA selected several scenarios to model in developing an understanding of current and potential future site conditions. Table 5 presents the selected scenarios. The selected storm event produced the highest historical water levels in the area, providing a conservative estimate of water levels in Morro Bay under storm conditions. We chose the non-storm event as a representation of water level conditions seen in Morro Bay without storms enhancing water levels in the area. ESA modeled two verification runs to test the fit of the model output results with verified observational data. Model verification results are further discussed above in Section 3.4. We modeled each selected event for three scenarios of SLR. Further discussion of the selected SLR scenarios is presented above in Section 2.2.

TABLE 5
MODELING SCENARIOS

Scenario	Event	SLR
Storm	January 27, 1983	0.0, 1.8, 6.3 ft
Non-Storm	August 1, 2023	0.0, 1.8, 6.3 ft
Verification Event 1	January 9, 2023	0.0, 1.8, 6.3 ft
Verification Event 2	February 4, 2024	0.0, 1.8, 6.3 ft

5 Hydrodynamic Results

Figure 7 shows the modeling results from the Non-Storm and Storm scenarios for the three selected SLR amounts. Higher water levels are predicted for each increasing amount of SLR, and storm conditions are expected to see higher water levels than non-storm conditions. For each scenario, water levels throughout the main segment of the Bay remain relatively even, especially in non-storm conditions where the reaches of Chorro and Los Osos Creeks experience water levels at or below those of the Bay. For Storm scenarios, extreme water levels are seen at the eastern edges of the creek inlets. Note that modeling results can be viewed in Appendix B at a legible scale.

ESA selected two points in the study area to quantify water level modeling results. We placed Point A along Main Street behind the pocket beach. We placed Point B at the eastern edge of the study area along S. Bay Blvd. These areas are presently known to flood during storm conditions, limiting road access. The quantified water level results at these points are presented in Table 6 below. Water levels at the two points are similar for each modeling scenario.

TABLE 6
MORRO BAY FLOOD MODELING RESULTS

indy Cove Point B – S. Bay Blvd.
8.2
3 10.8
1 16.3
_

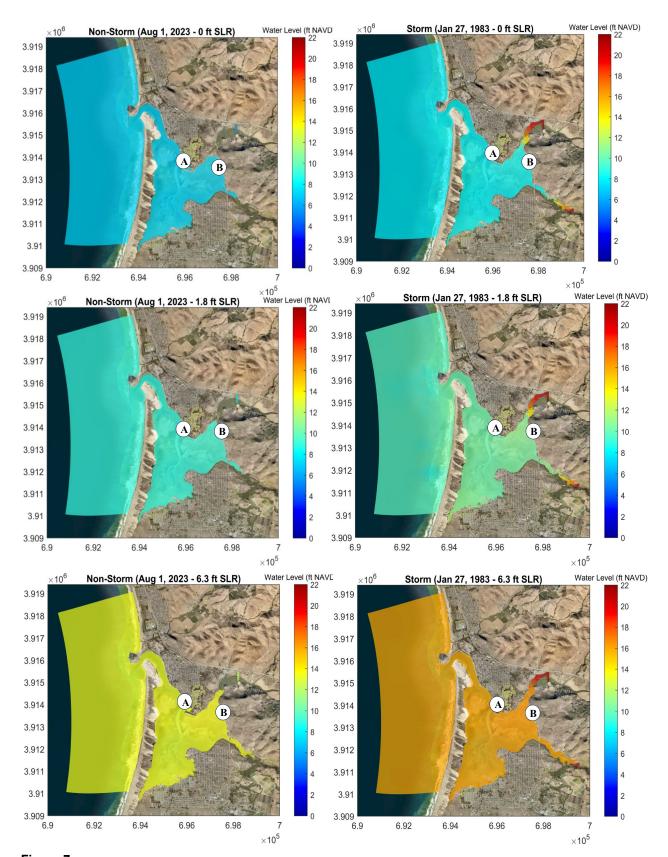


Figure 7Water levels inside Morro Bay under selected modeling scenarios

6 Wave Modeling

Wind waves were simulated using the Simulating Waves Nearshore (SWAN) model. SWAN is a third-generation phase-averaged wave action model developed at Delft University of Technology (Delft University of Technology 2019). Delft3D software (Version 4.04.01, Deltares 2011) was used to prepare inputs and execute the SWAN model. The same grid used in the Hydrodynamic modeling was used in SWAN for wind wave simulation.

6.1 Wind Analysis

Observed wind data from the nearby San Luis Obispo County Regional Airport (SLO) was downloaded from NOAA National Center for Environmental Information (NCEI)'s website. The data was processed with the QA/QC flag so data flagged as bad quality was removed for any further analysis and converted to 10-m over water. Two blocks of data are available, one from 1973-1997 and the other from 2006 to present. After initial examination, the data used for the windy analysis covers the period from 2006 to the present (2025), as the earlier dataset from the 1900s contained unrealistically high measurements and was therefore excluded from further analysis..

The wind environment at the project site can be inferred by examining the wind rose at SLO (Figure 8). It can be observed that the dominant wind direction is from the northwest, with strong winds over 25 mph. The secondary wind direction is from the southeast.

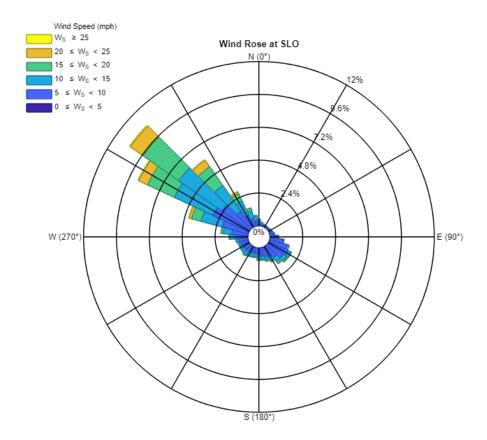


Figure 8
Wind Rose at San Luis Obispo County Regional Airport (SLO)

An extreme value analysis (EVA) was conducted on the wind data at SLO, plotted in Figure 9 and documented in Table 7. The analysis shows the 1-, 10-, and 100-year return period values for wind speed are approximately 25, 32, and 40 mph respectively, according to different variations of extreme value distributions including Gumbell, Weibull, and Generalized Extreme Value (GEV). Based on this analysis and the orientation of the shorelines at the project site, we chose to simulate wind speeds of 30 and 40 mph from 180 to 360 at a 10-degree increment. For wind waves and water levels, we simulated the following scenarios: existing conditions, 1.8 ft of SLR, and 6.3 ft of SLR, selected based on OPC 2024.

TABLE 7
WIND EVA

	Wind Speed (mph)					
Return Period (Year)	Gumbell (ML)	Gumbell (LS)	Weibull (ML)	Weibull (LS)	GEV (PWM)	GEV (MPS)
1	25.1	25.1	25.1	25.1	25.1	25.1
2	28.6	28.6	29.2	29.3	28.3	28.5
5	30.6	31.5	31.7	31.7	30.4	31.1
10	32.0	33.4	32.8	32.7	32.2	33.0
20	33.3	35.2	33.7	33.5	34.2	34.9
50	35.0	37.6	34.5	34.4	37.3	37.6
100	36.3	39.4	35.1	34.9	40.1	39.8
500	39.3	43.5	36.1	35.9	48.6	45.5

ML = Maximum Likelihood (estimation method)

LS = Least Squares (fitting method)

PWM = Probability-Weighted Moments

MPS= Maximum Product of Spacings

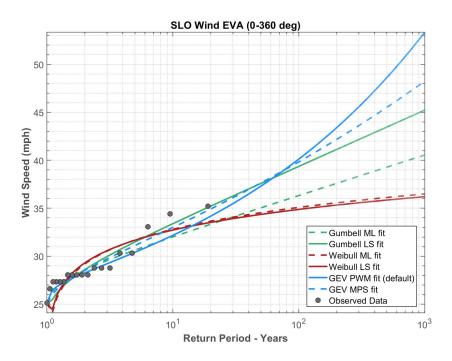


Figure 9Extreme Value Analysis of Wind Data at SLO

Figure 10 shows an example result for one of the scenarios (40-mph Wind from 270 Degrees for existing conditions 1.8' SLR, and 6.3' SLR), zoomed in on the eastern side of Morro Bay. The simulated significant wave heights, peak wave period, and peak wave direction for all scenarios are extracted at a point at the edge of the marsh and documented in Table 8 to Table 10. For existing water levels, we see a maximum wave height of about

1 foot; with higher sea levels, waves increase to 2 ft, likely associated with the loss of dissipation from the marsh with higher sea levels. The 1.8 ft of SLR scenario potentially represents wave height during extreme storms for existing conditions. Therefore, it can be inferred that wave heights are about 1 to 1.5 ft for existing conditions, 1.5 to 2 ft with 2 ft of SLR and more than 2 ft for 6 ft of SLR.

TABLE 8
SIMULATED SIGNIFICANT WAVE HEIGHT (FT) AT MARSH EDGE

Significant Wave Height (ft)	WSE = 7' NAVD		WSE = 8.8' NAV	WSE = 8.8' NAVD)
Wind Direction	Wind Speed = 30 mph	Wind Speed = 40 mph	Wind Speed = 30 mph	Wind Speed = 40 mph	Wind Speed = 30 mph	Wind Speed = 40 mph
180	0.8	1.0	1.0	1.3	1.2	1.6
190	0.9	1.1	1.1	1.4	1.3	1.7
200	0.9	1.1	1.1	1.4	1.3	1.7
210	0.9	1.1	1.1	1.4	1.3	1.7
220	0.9	1.1	1.1	1.4	1.4	1.8
230	0.9	1.1	1.1	1.4	1.4	1.8
240	0.9	1.1	1.1	1.4	1.4	1.8
250	0.9	1.0	1.2	1.4	1.4	1.9
260	0.9	1.0	1.2	1.5	1.4	1.9
270	0.9	1.0	1.2	1.5	1.4	1.9
280	0.8	1.0	1.1	1.4	1.4	1.9
290	0.8	0.9	1.1	1.3	1.3	1.7
300	0.8	0.9	1.0	1.3	1.2	1.7
310	0.7	0.9	1.0	1.3	1.2	1.6
320	0.7	0.8	1.0	1.2	1.2	1.6
330	0.7	0.8	0.9	1.2	1.2	1.6
340	0.6	0.8	0.9	1.2	1.2	1.5
350	0.6	0.8	0.9	1.1	1.1	1.5
360	0.6	0.8	0.8	1.1	1.1	1.5

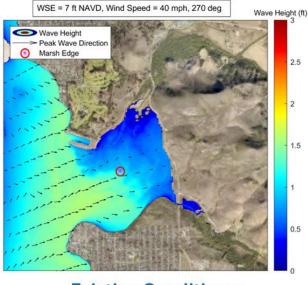
TABLE 9
SIMULATED PEAK PERIOD (S) AT MARSH EDGE

Peak Period (s)	WSE = 7' NAVD		WSE = 8.8' NAVD		WSE = 13.3' NAVD	
Wind Direction	Wind Speed = 30 mph	Wind Speed = 40 mph	Wind Speed = 30 mph	Wind Speed = 40 mph	Wind Speed = 30 mph	Wind Speed = 40 mph
180	1.6	1.7	1.6	1.8	1.8	2.0
190	1.6	1.7	1.7	1.8	1.8	2.0
200	1.6	1.8	1.7	1.8	1.9	2.1
210	1.6	1.8	1.7	1.9	1.9	2.1
220	1.6	1.8	1.7	1.9	1.9	2.1

Peak Period (s)	WSE = 7' NAVD	WSE = 7' NAVD		WSE = 8.8' NAVD		WSE = 13.3' NAVD	
Wind Direction	Wind Speed = 30 mph	Wind Speed = 40 mph	Wind Speed = 30 mph	Wind Speed = 40 mph	Wind Speed = 30 mph	Wind Speed = 40 mph	
230	1.6	1.8	1.7	1.9	1.9	2.2	
240	1.6	1.8	1.7	1.9	1.9	2.2	
250	1.6	1.8	1.8	1.9	1.9	2.2	
260	1.6	1.8	1.7	1.9	1.9	2.3	
270	1.6	1.7	1.7	1.9	1.9	2.3	
280	1.5	1.7	1.7	1.9	1.9	2.2	
290	1.5	1.6	1.7	1.8	1.8	2.1	
300	1.4	1.6	1.6	1.8	1.8	2.1	
310	1.4	1.5	1.6	1.8	1.8	2.0	
320	1.4	1.5	1.6	1.7	1.8	2.0	
330	1.4	1.5	1.6	1.7	1.8	1.9	
340	1.4	1.5	1.6	1.7	1.8	1.9	
350	1.4	1.5	1.6	1.7	1.7	1.9	
360	1.4	1.5	1.6	1.6	1.7	1.8	

Table 10
Simulated Peak Direction at Marsh Edge

Peak Direction	WSE = 7' NAVD	WSE = 7' NAVD		WSE = 8.8' NAVD		WSE = 13.3' NAVD	
Wind Direction	Wind Speed = 30 mph	Wind Speed = 40 mph	Wind Speed = 30 mph	Wind Speed = 40 mph	Wind Speed = 30 mph	Wind Speed = 40 mph	
180	225	215	225	225	225	225	
190	225	225	225	225	225	225	
200	225	225	225	225	235	225	
210	225	225	225	225	235	225	
220	225	225	225	225	235	235	
230	225	225	225	225	235	235	
240	225	225	225	225	235	235	
250	225	225	235	225	235	235	
260	225	225	235	235	235	235	
270	235	235	235	235	255	245	
280	235	235	245	245	275	285	
290	245	235	275	275	285	285	
300	245	245	275	275	295	295	
310	255	245	275	275	295	295	
320	285	255	285	275	295	295	
330	285	335	285	285	295	295	
340	345	335	285	285	295	295	
350	5	5	15	5	295	295	
360	5	15	15	15	25	25	





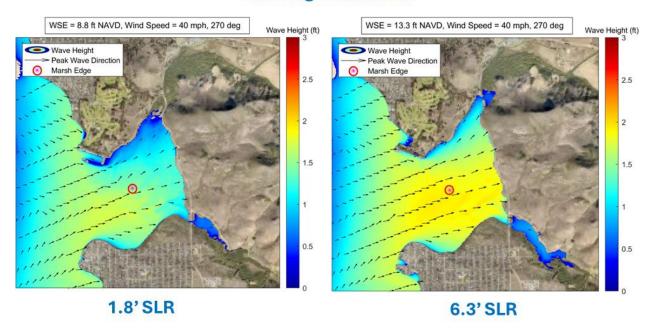


Figure 10Simulated Wave Height and Direction for a 40-mph Wind from 270 Degrees zoomed in on the eastern side of Morro Bay.

6.2 Wave Runup Analysis

Wave runups further increase the total water levels and pose additional threat to South Bay Boulevard. ESA conducted a simple wave runup analysis using the Technische Adviescommissie voor de Waterkeringen (TAW) method on representative nearshore slopes at the site. The TAW method is a specific empirical formula used to calculate wave runup, primarily developed by the Dutch Technical Advisory Committee for Flood Defenses, which is considered a widely accepted standard for estimating wave runup on structures like dikes and seawalls.

After examining the topography, it was determined that a representative slope of 0.2 can be used for South Bay Boulevard and 0.08 can be used for the Windy Cove and Main St area. Table 11 documents the calculated wave runup and total water level.

TABLE 11
WAVE RUNUP AND TOTAL WATER LEVEL ANALYSIS

	Significant Wave Height (ft)	Wave Period (s)	Wave Runup (ft)	SWL (ft NAVD88)	TWL (ft NAVD88)
Windy Cove / Main St					
Existing Conditions	1.0	1.80	0.58	8	8.6
1.8' SLR	1.5	1.90	0.75	11	11.7
6.3' SLR	2.0	2.30	1.04	16	17.0
South Bay Blvd					
Existing Conditions	1.0	1.80	1.44	8	9.4
1.8' SLR	1.5	1.90	1.86	11	12.9
6.3' SLR	2.0	2.30	2.61	16	18.6

ESA conducted a wave runup analysis at the Windy Cove/Main St area and on South Bay Blvd. Table 11 presents the results, showing the wave runup and total water level (TWL) under various SLR scenarios. The TWL is the sum of the still water level (SWL) and the wave runup at each location. As both wave runup and SWL increase with increasing SLR, due to the associated increase in significant wave height and wave period, we expect TWL to increase at both locations. The analysis shows the TWL at Windy Cove/Main St. is 8.6ft, 11.7ft, and 17.0ft for existing conditions, 1.8 ft of SLR, and 6.3 ft of SLR respectively. The TWL at South Bay Blvd is 9.4ft, 12.9ft, and 18.61ft for existing conditions, 1.8 ft of SLR, and 6.3 ft of SLR respectively. Analysis under these SLR conditions were selected based on OPC 2024.

7 Tidal Flooding

State Park Road has sections located next to Morro Bay at Windy Cove and sections running along the Morro Bay Estuary from the Morro Bay State Park Marina to S Bay Boulevard. Additionally, S Bay Blvd runs adjacent to Morro Bay Estuary from Chorro Creek Bridge to Los Osos Bridge. These sections of road are potentially at risk of becoming exposed to regular tidal flooding with SLR due to their proximity to tidally influenced systems. ESA conducted a still water analysis to evaluate the impacts of tidal flooding on these roadways with SLR.

Tidal water levels with and without SLR were compared to roadway elevations to assess how the frequency of roadway flooding and closure would change with SLR. Different than previous sections, the analysis conducted in this section examined incremental SLR scenarios ranging from 0 to 5 ft to specifically identify which segments of roadway would be vulnerable to inundation during regular tidal flooding events, without considering the addition of water level due to storm surge or wave action.

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The selected scenarios cover the following period range for the High SLR scenario, based on the OPC 2024 SLR State Guidance:

- 1 ft of SLR: Projected to occur by approximately 2048 (between 2040-2050)
- 2 ft of SLR: Projected to occur by approximately 2063 (between 2060-2070)
- 3 ft of SLR: Projected to occur by approximately 2074 (between 2070-2080)
- 4 ft of SLR: Projected to occur by approximately 2082 (between 2080-2090)
- 5 ft of SLR: Projected to occur by approximately 2090 (between 2080-2090)

Tidal data were compared to the roadway elevations of State Park Road and S Bay Boulevard obtained from USGS CoNED LiDAR data, described in Section 3.2. Table 12 presents the critical elevations of the most vulnerable sections of State Park Road and S Bay Boulevard, along with the corresponding tidal water levels that would trigger flooding and necessitate road closures. A road closure threshold has been established at 0.5 ft of water above the roadway elevation, as this water depth is assumed to impede safe vehicle passage and warrant closure for public safety. Therefore, tidal water levels exceeding roadway elevations by, for example, 0.25 ft are assumed to not trigger a roadway closure event in this analysis. Note that the purpose of this analysis is to inform the vulnerability assessment and is not intended to inform flood thresholds for managing actual road closures.

TABLE 12
MORRO BAY ESTUARY TIDAL FLOODING THRESHOLDS

Roadway	Roadway Area Minimum Elevation (ft NAVD)	Tidal Water Level to Cause Road Closure (ft NAVD)	
State Park Road - Windy Cove	7.25	7.75	
State Park Road – Morro Bay State Park Marina to S Bay Blvd	7.5	8.0	
S Bay Blvd – Chorro Creek Bridge to Los Osos Creek Bridge	10.0	10.5	

The tide record from the Port San Luis Tide Gage (Station #9412110, NOAA 2025) was obtained from 1948 to 2025. This 77-year record is assumed to be representative of the local tidal patterns and is used as a proxy for future tidal records. Figure 11 presents the tidal record at Port San Luis for existing conditions (top pane), and potential future conditions with SLR (lower four panes) with dashed lines indicating the thresholds for flooding causing road closure of State Park Road at Windy Cove (yellow), State Park Road between Morro State Park Marina and S Bay Blvd (orange), and S Bay Blvd between Chorro Creek Bridge and Los Osos Creek Bridge (red). The water levels shown represent tidal water levels as measured at Port San Luis and, therefore, may differ from the actual water level that occurs in the project area. Also, these water levels represent tidal still water levels and do not include an added wind or wave setup component that may increase the likelihood of roadway flooding.

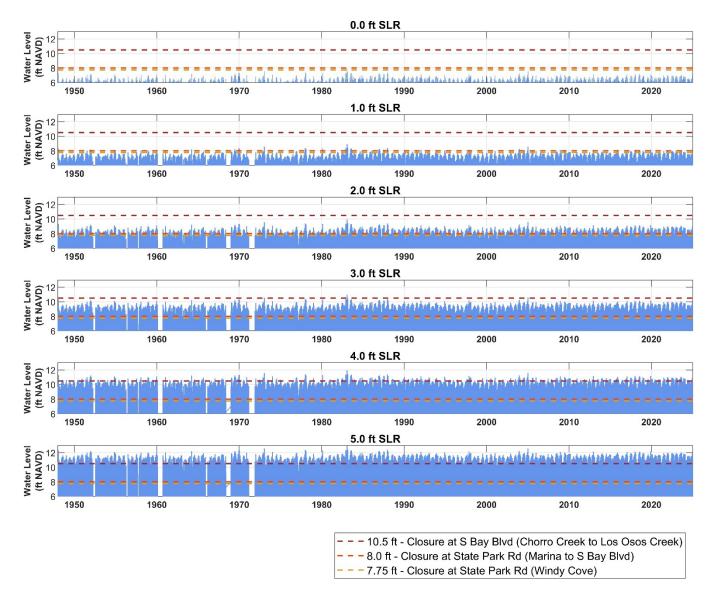


Figure 11
Tidal Water Level at Port San Luis with SLR, with the Thresholds for Flooding Causing Road Closure

Figure 12 shows histograms of the inundation event durations where the tidal water surface elevation exceeds flood condition elevations. The three rows represent closure of State Park Road at Windy Cove (top), State Park Road from the marina to S Bay Blvd (middle), and S Bay Blvd (bottom). Each column represents a SLR scenario from 0 to 5 ft. In addition, unlike the ESA Hydrodynamic Model, the results from the histograms (Figure 12) were derived solely from the Morro Bay tide gauge dataset, which does not include storm-driven processes like wave runup, resulting in lower water levels than those produced by the hydrodynamic modeling.

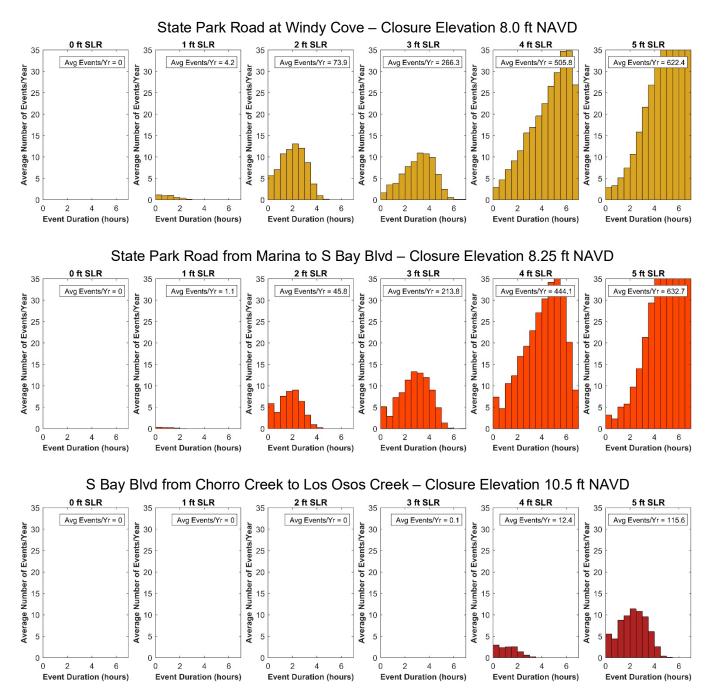


Figure 12Histograms of Tidal Flooding Causing Road Closure Event Durations With SLR at State Park Road and South Bay Boulevard

State Park Road at Windy Cove is the first area to be exposed to tidal flooding with SLR. Under existing conditions, it is not expected to close due to tidal flooding, but with 1 ft of SLR tidal flooding causing closure is expected to occur approximately four times per year. With 2 ft of SLR, there are projected to be 74 closure events per year, rising to 266 closure events per year after 3 ft of SLR. With 4 ft of SLR and beyond, the Windy Cove roadway is expected to close daily.

The next roadway affected by tidal flooding is the section of State Park Road from the Morro Bay State Park Marina to S Bay Boulevard. It is unaffected by tidal flooding until 1 ft of SLR, at which point closure is expected on average once per year. Closure events are projected to increase to 46 events per year after 2 ft of SLR and 214 events per year with 3 ft of SLR. With 4 ft of SLR and beyond, this section of State Park Road is expected to close daily.

Finally, S Bay Boulevard between Chorro Creek and Los Osos Creek is not expected to be affected by tidal flooding before 3 ft of SLR, at which point the roadway is projected to flood on average once every ten years. With 4 ft of SLR, the frequency of flooding causing closure rises to 12 times per year on average, rising to 116 times per year after 5 ft of SLR.

Note that this tidal flooding assessment does not consider the effects of wind waves, which will exacerbate flooding.

8 Vulnerability Assessment

This section presents the methods and findings of the flood and SLR vulnerability assessment. This assessment and quantification of the vulnerability of transportation, recreational, and natural assets surrounding the Morro Bay Estuary integrated multiple approaches: field observations, stakeholder and community engagement, and technical analyses.

The technical component included hydrodynamic modeling of estuary water levels under SLR scenarios to identify flood hazards and quantify impacts to essential transportation assets. The results of the vulnerability assessments were developed using the ESA Hydrodynamic Model under both storm and non-storm conditions, representing the most conservative scenarios by incorporating dynamic coastal processes such as storm surge, wave setup, and runup, along with SLR scenarios. In addition, the study focused on the vulnerability of wetland areas, which may be affected by SLR and the worsening of coastal hazards due to climate change. It is important to note that the scope of this assessment does not include utilities or other assets, as these were deemed outside the study's parameters.

8.1 Introduction

To develop effective adaptation alternatives to address flood and SLR vulnerability, the risk of not acting must be understood first. For this reason, the vulnerability assessment analyzes impacts from a hypothetical "no action" scenario, where no measures are taken to adapt to SLR. By considering the "no action" scenario, SLOCOG and other decision makers can understand the full potential impacts of flooding and SLR, identify areas and/or individual assets with the greatest vulnerabilities, and then plan adaptation to reduce identified vulnerabilities.

ESA assessed transportation, recreational, and natural assets throughout Morro Bay Estuary that are potentially at risk from SLR, including their elevation, exposure to wave hazards, sensitivity to flooding and tidal inundation, criticality, and relative level of adaptive capacity. Using these criteria, ESA assigned a vulnerability rating to rank the assets by when they will become vulnerable to the hazard considering storm and non-storm (e.g. regular tidal inundation) hazard conditions as well as the consequences of their exposure to these hazards.

To estimate vulnerability under various flooding scenarios, ESA utilizes GIS to create flood layers for short-, medium- and long-term flooding with and without modeled storm conditions (modeled storm conditions defined

in Section 3.3). Short-term vulnerabilities affect areas/assets under storm conditions, which are characterized by the boundary conditions applied in the model (Section 3), with 0 ft of SLR, medium-term vulnerabilities are affected under storm conditions with 1.8 ft of SLR, and long-term vulnerabilities are affected under storm conditions with 6.3 ft of SLR. Overlaying these flood layers with transportation, recreational, and habitat maps reveal which assets are vulnerable at each time horizon. In addition to the flood layers created with the Delft-3d model, the ESA team reviewed existing and available coastal flood hazard data sets, including CoSMoS, NOAA SLR Viewer, and FEMA Flood Insurance Rate Maps (FIRMs). See section 8.3 for further clarification.

8.2 Assets

Assets throughout Morro Bay Estuary were divided into three primary categories: Transportation – roads and mobility assets, recreational assets, and natural assets. The specific assets within each category are listed in Table 13 below. Chorro Creek Bridge is also referred to as Twin Bridges. These assets are shown on maps of Morro Bay Estuary in Appendix A.

Table 13
Morro Bay Estuary Assets

Asset Category	Assets	
Transportation	State Park Road – Windy Cove Main Street South Bay Boulevard – Chorro Creek Bridge to Bay Pines Chorro Creek Bridge to Los Osos Creek Bridge Quintana Road Turri Road Chorro Creek Bridge Los Osos Creek Bridge	
Recreational	Windy Cove Beach Morro Bay State Park Marina Parking Lot Windy Cove Parking Lot Cerro Cabrillo Trailhead Parking Lot Park Ridge Trailhead Parking Lot Chumash Trailhead Parking Lot Morro Bay State Park Marina Bicycle Parking Morro Bay Golf Course	
Natural	Morro Bay State Marine Reserve El Moro Elfin Forest Natural Preserve	

The vulnerability assessment is divided into four primary study areas. These study areas were visited during the Morro Bay Estuary Climate Resiliency Stakeholder Field Tour on October 21, 2024. Their locations are as follows:

- Area 1 State Park Rd near water access
- Area 2 State Park Rd from Marina to S Bay Blvd

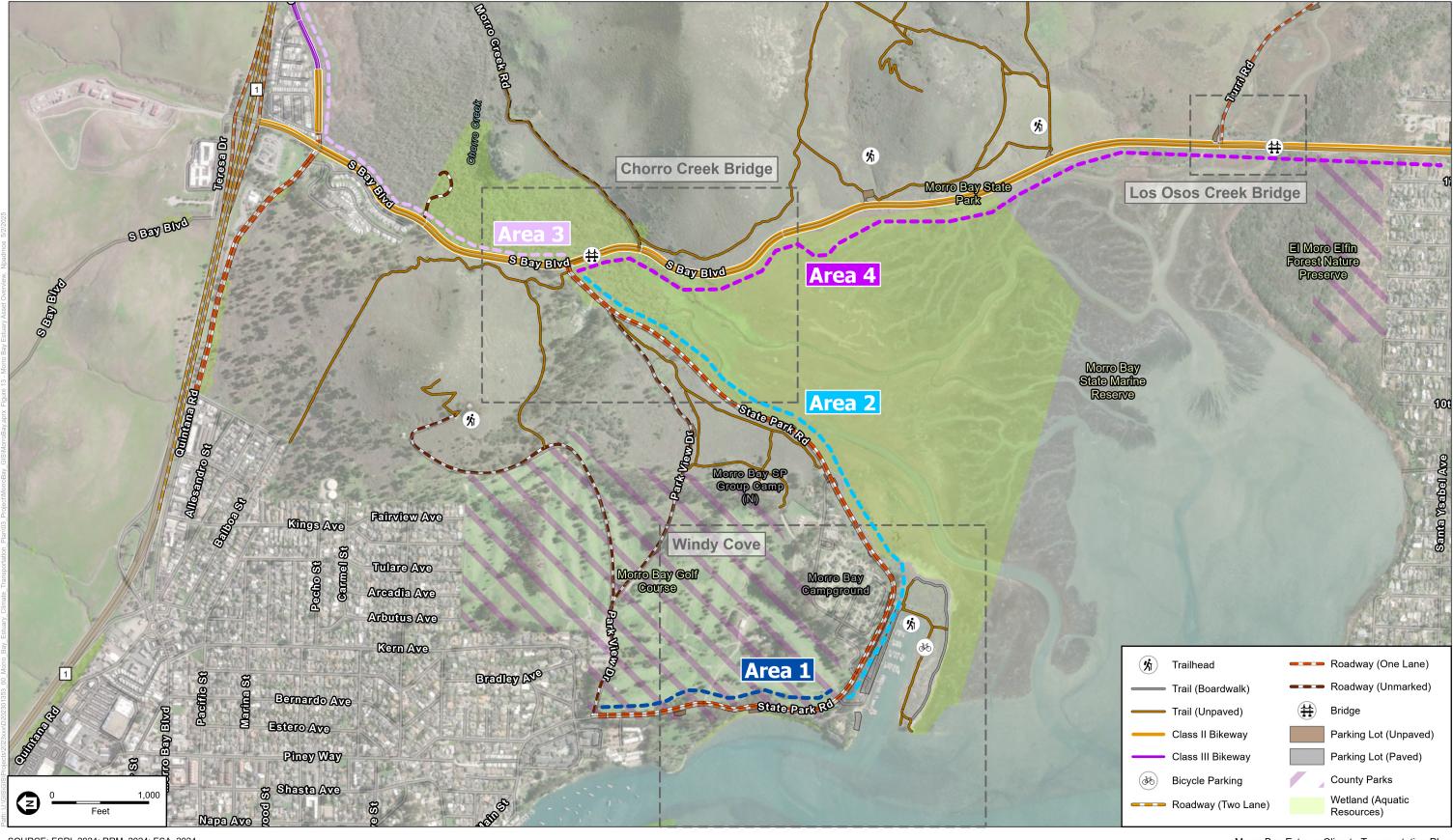
- Area 3 S Bay Blvd from Chorro Creek Bridge to Bay Pines Travel Trailer Park
- Area 4 S Bay Blvd from Los Osos to Chorro Creek Bridge

The study areas are represented as linear dashed lines shown in light blue, dark blue, lavender, and purple, respectively, in an overview asset map of the area of the field tour map in Figure 13. In addition, Figure 14 provides a zoomed view of specific points of interest, which include Los Osos Creek Bridge, Chorro Creek, and Wind Cove. A summary of each study area's primary transportation function, transportation assets, recreational assets, natural assets, types of hazards, proximity to hazards, potential modes of failure, and consequences of failure is provided in Table 14 below.

TABLE 14
SUMMARY OF STUDY AREAS

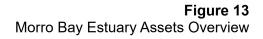
Area 1 – State Park Rd near water access			
Assets: State Park Rd – V	Vindy Cove, Windy Cove, Windy Cove Parking Lot		
Location	Connecting South Morro Bay to the Marina and beyond Passes by Morro Bay Golf Course and Morro Bay water access		
Function	A main route to South Bay Blvd Provides beach access, marina access, and other coastal amenities		
Mobility assets	Unpaved pedestrian trail No bicycle facility		
Types of hazards	 Temporary flooding caused by storm events Tidal inundation from SLR Increased erosion resulting from waves rushing up on the adjacent coast 		
Exposure to hazards ¹	 Parts of the road are within a 100-year flood hazard zone. With 0.8 ft of SLR, a 20-year storm is expected to encroach on the road Tidal encroachment of the road is expected to occur with 1.6 to 2.5 ft of SLR 		
Modes of failure	 Large storm causes coastal flooding of the roadway SLR leads to water levels slowly encroaching on the roadway Increased erosion due to SLR and wave activity encroach on the roadway 		
Consequence of failure	Access to marina, beach, and other coastal amenities lost Costs associated with roadway repair		
Area 2 – State Park Rd fro	om Marina to S Bay Blvd		
Assets: State Park Rd – N	fain St, Morro Bay State Park Marina Bicycle Parking, Morro Bay Golf Course, Morro Bay State Marine Reserve		
Location	 From the marina to S Bay Blvd Passing by the Morro Bay Estuary to the south and Morro Bay campground and county park to the north 		
Function	Connects south Morro Bay, the marina, beach access, and county park to S Bay Blvd		
Mobility assets	No pedestrian facilities No bicycle facilities Trailhead and hiking access		
Types of hazards	Temporary flooding caused by storm events Tidal inundation from SLR Increased erosion resulting from waves rushing up on the adjacent coast		
Exposure to hazards ¹	 Currently not expected to be impacted by an extreme storm event. With 2.5 ft of SLR or less, a 20-year storm is expected to flood parts of the roadway Tidal encroachment of the road is expected to occur with 2.5 to 3.3 ft of SLR 		
Modes of failure	Large storm causes coastal flooding of the roadway SLR leads to water levels slowly encroaching on the roadway Increased erosion due to SLR encroach on the roadway		
Consequence of failure	Limits accessibility to and from south Morro Bay, as well as coastal resources and recreational amenities		

Aven 2 C.Dev. Dlval from	Costs associated with roadway repair Chara Crack Bridge to Box Bines Track Trailer Bork
	Chorro Creek Bridge to Bay Pines Travel Trailer Park
Assets: S Bay Blvd – Cho	rro Creek Bridge to Bay Pines, Quintana Rd
Location	From Cabrillo Hwy to the State Park Rd intersection
	Has Black Hill to the east, Chorro Creek to the west, and Morro Bay Estuary to the south
Function	Provides access to Bay Pines Travel Trailer Park Output On the World Park Park Park Park Park Park Park Park
	Connects Cabrillo Hwy to Baywood Park, Los Osos, and Morro Bay (via State Park Rd) Crosses Chorro Creek
Mobility assets	No pedestrian facilities
WODING ASSES	Class II bicycle lanes
	Bus stop
Types of hazards	Temporary flooding caused by storm events raising water levels in Chorro Creek
Exposure to hazards ¹	Expected to be impacted by extreme storm events. Flooding is likely to become more frequent with climate
	change.
Manda	Not expected to be tidally inundated by SLR
Modes of failure	Large storm leads to significantly increased flows through Chorro Creek that flood S Bay Blvd near the Chorro Creek Bridge.
Consequence of failure	Limits accessibility between Baywood Park and Los Osos and Morro Bay and Bay Pines Travel Trailer Park
	and adds 30 minute detour, as well as limits emergency evacuation options
	Costs associated with roadway repair
Alea 4 - O Bay Biva ii oi	m Los Osos to Chorro Creek Bridge
	rk Ridge Trailhead Parking Lot, Chumash Trailhead Parking Lot, Morro Bay State Marine Reserve, El Moro Elfin
Forest Natural Preserve Location	From Los Osos to Chorro Creek crossing
Forest Natural Preserve	
Forest Natural Preserve	From Los Osos to Chorro Creek crossing Bordered to the west by Morro Bay Estuary and to the east by various hiking trails Provides access to Bay Pines Travel Trailer Park
Forest Natural Preserve Location	From Los Osos to Chorro Creek crossing Bordered to the west by Morro Bay Estuary and to the east by various hiking trails Provides access to Bay Pines Travel Trailer Park Connects Baywood Park and Los Osos to Morro Bay
Forest Natural Preserve Location Function	From Los Osos to Chorro Creek crossing Bordered to the west by Morro Bay Estuary and to the east by various hiking trails Provides access to Bay Pines Travel Trailer Park Connects Baywood Park and Los Osos to Morro Bay Crosses Los Osos Creek
Forest Natural Preserve Location Function	From Los Osos to Chorro Creek crossing Bordered to the west by Morro Bay Estuary and to the east by various hiking trails Provides access to Bay Pines Travel Trailer Park Connects Baywood Park and Los Osos to Morro Bay Crosses Los Osos Creek No pedestrian facilities
Forest Natural Preserve Location Function	From Los Osos to Chorro Creek crossing Bordered to the west by Morro Bay Estuary and to the east by various hiking trails Provides access to Bay Pines Travel Trailer Park Connects Baywood Park and Los Osos to Morro Bay Crosses Los Osos Creek No pedestrian facilities Class II bicycle lanes
Function Mobility assets	From Los Osos to Chorro Creek crossing Bordered to the west by Morro Bay Estuary and to the east by various hiking trails Provides access to Bay Pines Travel Trailer Park Connects Baywood Park and Los Osos to Morro Bay Crosses Los Osos Creek No pedestrian facilities Class II bicycle lanes Trailhead and hiking and mountain biking access
Forest Natural Preserve Location Function Mobility assets	From Los Osos to Chorro Creek crossing Bordered to the west by Morro Bay Estuary and to the east by various hiking trails Provides access to Bay Pines Travel Trailer Park Connects Baywood Park and Los Osos to Morro Bay Crosses Los Osos Creek No pedestrian facilities Class II bicycle lanes
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Forest Natural Preserve Location Function	From Los Osos to Chorro Creek crossing Bordered to the west by Morro Bay Estuary and to the east by various hiking trails Provides access to Bay Pines Travel Trailer Park Connects Baywood Park and Los Osos to Morro Bay Crosses Los Osos Creek No pedestrian facilities Class II bicycle lanes Trailhead and hiking and mountain biking access Temporary flooding caused by storm events raising water levels in Los Osos Creek and coastal storm events Tidal inundation from SLR
Forest Natural Preserve Location Function Mobility assets Types of hazards	 From Los Osos to Chorro Creek crossing Bordered to the west by Morro Bay Estuary and to the east by various hiking trails Provides access to Bay Pines Travel Trailer Park Connects Baywood Park and Los Osos to Morro Bay Crosses Los Osos Creek No pedestrian facilities Class II bicycle lanes Trailhead and hiking and mountain biking access Temporary flooding caused by storm events raising water levels in Los Osos Creek and coastal storm events Tidal inundation from SLR Increased erosion resulting from higher water levels in the estuary Expected that the roadway will be encroached during a extreme storm events under current conditions. With
Forest Natural Preserve Location Function Mobility assets Types of hazards	 From Los Osos to Chorro Creek crossing Bordered to the west by Morro Bay Estuary and to the east by various hiking trails Provides access to Bay Pines Travel Trailer Park Connects Baywood Park and Los Osos to Morro Bay Crosses Los Osos Creek No pedestrian facilities Class II bicycle lanes Trailhead and hiking and mountain biking access Temporary flooding caused by storm events raising water levels in Los Osos Creek and coastal storm events Tidal inundation from SLR Increased erosion resulting from higher water levels in the estuary Expected that the roadway will be encroached during a extreme storm events under current conditions. With 2.5 to 3.3 ft of SLR, an extreme storm is anticipated to inundate the roadway
Forest Natural Preserve Location Function Mobility assets Types of hazards Exposure to hazards ¹	 From Los Osos to Chorro Creek crossing Bordered to the west by Morro Bay Estuary and to the east by various hiking trails Provides access to Bay Pines Travel Trailer Park Connects Baywood Park and Los Osos to Morro Bay Crosses Los Osos Creek No pedestrian facilities Class II bicycle lanes Trailhead and hiking and mountain biking access Temporary flooding caused by storm events raising water levels in Los Osos Creek and coastal storm events Tidal inundation from SLR Increased erosion resulting from higher water levels in the estuary Expected that the roadway will be encroached during a extreme storm events under current conditions. With 2.5 to 3.3 ft of SLR, an extreme storm is anticipated to inundate the roadway Tidal inundation of the roadway is expected to begin between 4.9 and 5.7 ft of SLR or less Large storm leads to significantly increased flows through Los Osos Creek that flood S Bay Blvd near the
Forest Natural Preserve Location Function Mobility assets Types of hazards Exposure to hazards ¹	 From Los Osos to Chorro Creek crossing Bordered to the west by Morro Bay Estuary and to the east by various hiking trails Provides access to Bay Pines Travel Trailer Park Connects Baywood Park and Los Osos to Morro Bay Crosses Los Osos Creek No pedestrian facilities Class II bicycle lanes Trailhead and hiking and mountain biking access Temporary flooding caused by storm events raising water levels in Los Osos Creek and coastal storm events Tidal inundation from SLR Increased erosion resulting from higher water levels in the estuary Expected that the roadway will be encroached during a extreme storm events under current conditions. With 2.5 to 3.3 ft of SLR, an extreme storm is anticipated to inundate the roadway Tidal inundation of the roadway is expected to begin between 4.9 and 5.7 ft of SLR or less Large storm leads to significantly increased flows through Los Osos Creek that flood S Bay Blvd near the Los Osos Creek bridge Coastal storm leads to increased sea levels that temporarily flood the roadway from the estuary SLR leads to water levels slowly encroaching on the roadway
Forest Natural Preserve Location Function Mobility assets Types of hazards Exposure to hazards ¹	 From Los Osos to Chorro Creek crossing Bordered to the west by Morro Bay Estuary and to the east by various hiking trails Provides access to Bay Pines Travel Trailer Park Connects Baywood Park and Los Osos to Morro Bay Crosses Los Osos Creek No pedestrian facilities Class II bicycle lanes Trailhead and hiking and mountain biking access Temporary flooding caused by storm events raising water levels in Los Osos Creek and coastal storm events Tidal inundation from SLR Increased erosion resulting from higher water levels in the estuary Expected that the roadway will be encroached during a extreme storm events under current conditions. With 2.5 to 3.3 ft of SLR, an extreme storm is anticipated to inundate the roadway Tidal inundation of the roadway is expected to begin between 4.9 and 5.7 ft of SLR or less Large storm leads to significantly increased flows through Los Osos Creek that flood S Bay Blvd near the Los Osos Creek bridge Coastal storm leads to increased sea levels that temporarily flood the roadway from the estuary SLR leads to water levels slowly encroaching on the roadway Increased erosion due to SLR encroach on the roadway
Forest Natural Preserve Location Function Mobility assets Types of hazards Exposure to hazards	From Los Osos to Chorro Creek crossing Bordered to the west by Morro Bay Estuary and to the east by various hiking trails Provides access to Bay Pines Travel Trailer Park Connects Baywood Park and Los Osos to Morro Bay Crosses Los Osos Creek No pedestrian facilities Class II bicycle lanes Trailhead and hiking and mountain biking access Temporary flooding caused by storm events raising water levels in Los Osos Creek and coastal storm events Tidal inundation from SLR Increased erosion resulting from higher water levels in the estuary Expected that the roadway will be encroached during a extreme storm events under current conditions. With 2.5 to 3.3 ft of SLR, an extreme storm is anticipated to inundate the roadway Tidal inundation of the roadway is expected to begin between 4.9 and 5.7 ft of SLR or less Large storm leads to significantly increased flows through Los Osos Creek that flood S Bay Blvd near the Los Osos Creek bridge Coastal storm leads to increased sea levels that temporarily flood the roadway from the estuary SLR leads to water levels slowly encroaching on the roadway Increased erosion due to SLR encroach on the roadway Severs connectivity between Morro Bay and Los Osos and blocks one of the primary evacuation routes in
Forest Natural Preserve Location Function Mobility assets Types of hazards Exposure to hazards ¹ Modes of failure	From Los Osos to Chorro Creek crossing Bordered to the west by Morro Bay Estuary and to the east by various hiking trails Provides access to Bay Pines Travel Trailer Park Connects Baywood Park and Los Osos to Morro Bay Crosses Los Osos Creek No pedestrian facilities Class II bicycle lanes Trailhead and hiking and mountain biking access Trailhead and hiking and mountain biking access Temporary flooding caused by storm events raising water levels in Los Osos Creek and coastal storm events Tidal inundation from SLR Increased erosion resulting from higher water levels in the estuary Expected that the roadway will be encroached during a extreme storm events under current conditions. With 2.5 to 3.3 ft of SLR, an extreme storm is anticipated to inundate the roadway Tidal inundation of the roadway is expected to begin between 4.9 and 5.7 ft of SLR or less Large storm leads to significantly increased flows through Los Osos Creek that flood S Bay Blvd near the Los Osos Creek bridge Coastal storm leads to increased sea levels that temporarily flood the roadway from the estuary SLR leads to water levels slowly encroaching on the roadway Increased erosion due to SLR encroach on the roadway Severs connectivity between Morro Bay and Los Osos and blocks one of the primary evacuation routes in the event of a radiation accident at Diablo Canyon Nuclear Power Plant.
Forest Natural Preserve Location Function Mobility assets Types of hazards Exposure to hazards ¹ Modes of failure	From Los Osos to Chorro Creek crossing Bordered to the west by Morro Bay Estuary and to the east by various hiking trails Provides access to Bay Pines Travel Trailer Park Connects Baywood Park and Los Osos to Morro Bay Crosses Los Osos Creek No pedestrian facilities Class II bicycle lanes Trailhead and hiking and mountain biking access Temporary flooding caused by storm events raising water levels in Los Osos Creek and coastal storm events Tidal inundation from SLR Increased erosion resulting from higher water levels in the estuary Expected that the roadway will be encroached during a extreme storm events under current conditions. With 2.5 to 3.3 ft of SLR, an extreme storm is anticipated to inundate the roadway Tidal inundation of the roadway is expected to begin between 4.9 and 5.7 ft of SLR or less Large storm leads to significantly increased flows through Los Osos Creek that flood S Bay Blvd near the Los Osos Creek bridge Coastal storm leads to increased sea levels that temporarily flood the roadway from the estuary SLR leads to water levels slowly encroaching on the roadway Increased erosion due to SLR encroach on the roadway Severs connectivity between Morro Bay and Los Osos and blocks one of the primary evacuation routes in

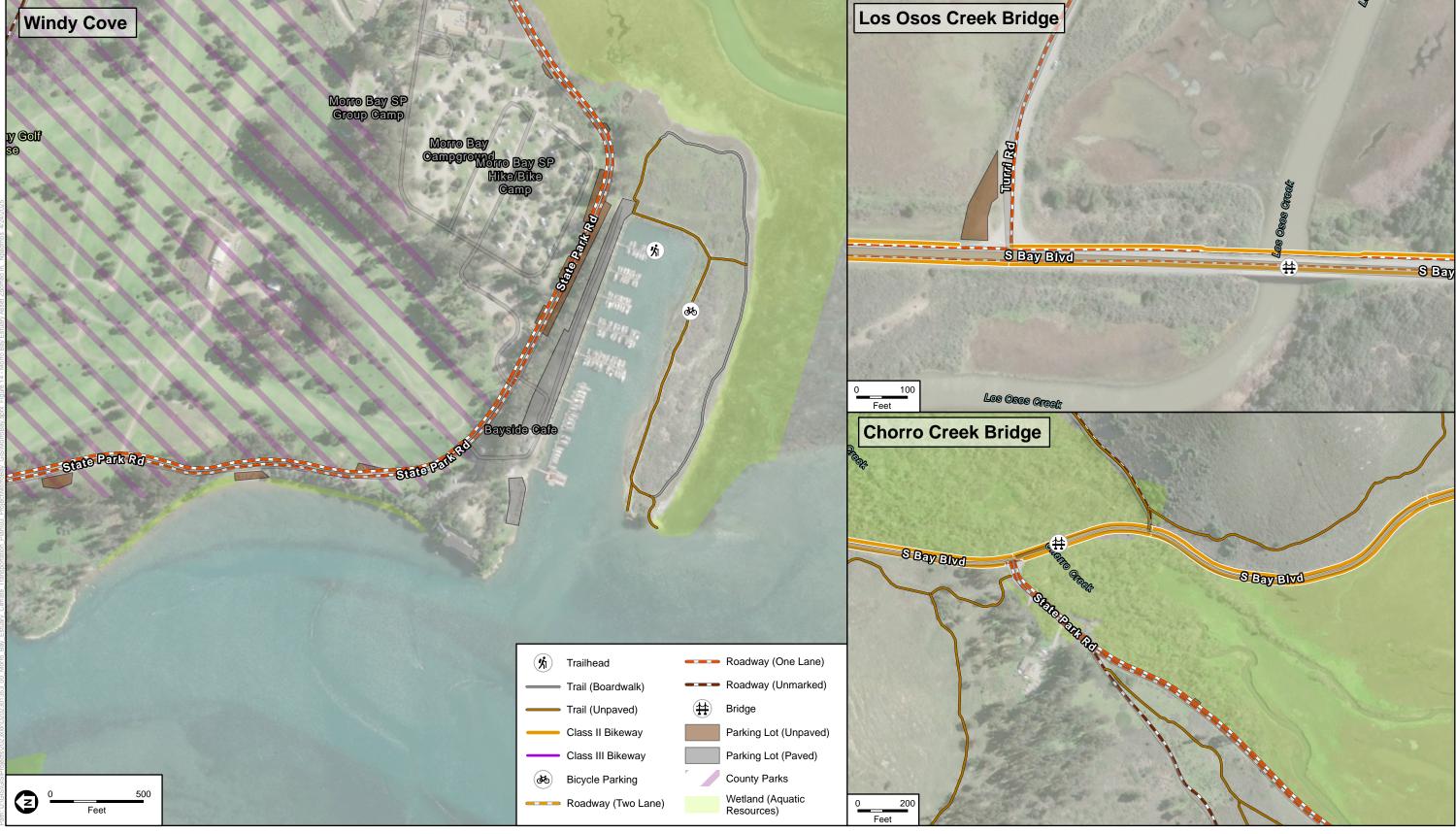


SOURCE: ESRI, 2024; RRM, 2024; ESA, 2024

Morro Bay Estuary Climate Transportation Plan

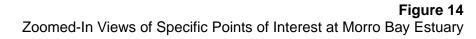






SOURCE: ESRI, 2024; RRM, 2024; ESA, 2024

Morro Bay Estuary Climate Transportation Plan





Prior to the Delft3D modeling, the tables were developed to gain a preliminary understanding of the assets and hazards for a stakeholder visit to the project area. Modes of failure and proximity to hazards were developed using existing and available data, results from CoSMoS, NOAA SLR viewer, and FEMA Flood Insurance. CoSMoS provides publicly accessible projections of tidal inundation, coastal flooding, and beach and bluff erosion for existing conditions, with SLR scenarios and 1-year, 20-year, and 100-year storm return periods, across the central coast of California (Barnard et al. 2018).

Note that CoSMoS storm scenarios assume that the storm coincides with a "high spring tide" (tide levels that occur approximately twice every month), representing a near-worst-case scenario. CoSMoS data provides regional projections with relatively coarse resolution while the Delft3D model created for this study is tailored to the Morro Bay Estuary with specific site topography and bathymetry and run for specified SLR and storm scenarios.

8.3 Methods and Definitions

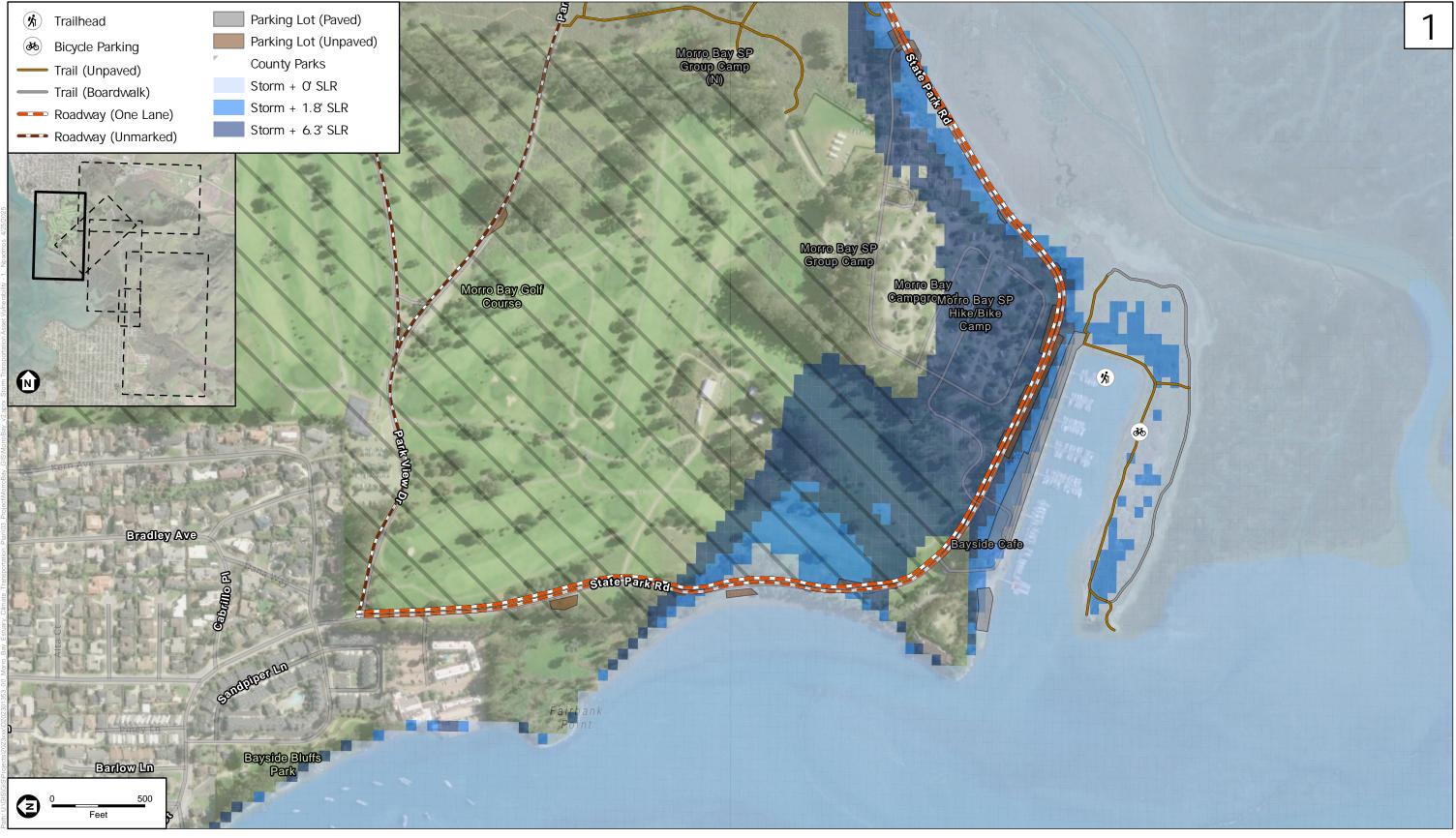
This section presents a summary of asset vulnerabilities to flooding with SLR and climate change. The vulnerability of each asset category was assessed based on three factors: hazard exposure, sensitivity, and adaptive capacity. The factors contributing to an asset rating in each category are explained in Table 15. Each asset was assessed in each category from high to low as described and an overall aggregated vulnerability score was assigned. Storm conditions are characterized by the boundary conditions applied in the model (Section 3), which consist of extreme coastal and fluvial water levels.

Table 15
Vulnerability Assessment Outline

Factor	Rating	Explanation			
Hazard Exposure – Does the asset have short-, medium-, or long-term vulnerability?					
Hazard Exposure	Very Low	Not exposed under storm conditions after 6.3 ft of SLR			
	Low	Exposed under storm conditions only after 6.3 ft of SLR			
	Medium	Exposed under storm conditions after 1.8 ft of SLR			
	High	Exposed under storm conditions with 0 ft of SLR			
Sensitivity – What	Sensitivity – What is the sensitivity of the asset to hazard exposure and what is the consequence of exposure?				
Low		Flooding would have no or low impact on the asset function. The asset would quickly rebound			
Sensitivity	Medium	Flooding would cause minor damage or temporary operational interruption			
	High	Flooding would cause significant damage or longer-term operational interruption			
Adaptive Capacity – What is the asset's ability to change in response to hazard exposure with rising sea levels?					
Adaptive Capacity	Low	Requires significant effort to modify and adapt			
	Medium	Requires moderate effort to modify and reduce flooding impacts			
	High	Could be easily modified to reduce/avoid flooding impacts			

Hazard Exposure: Each asset was assigned a flooding exposure level of very low, low, medium, or high, depending on the storm and SLR conditions under which the asset is exposed. Example maps showing asset exposure in one of six project area sections are shown in Figure 15, where light blue, blue, and dark blue flood layers indicate short-, medium-, and long-term exposure, respectively. Hazard maps for all project area sections, including all SLR scenarios with both non-storm and storm conditions, are available for transportation and recreational assets in Appendix B. Hazard Exposure ratings for each asset are defined in Section 8.4.

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SOURCE: ESRI, 2024; SLO County, 2024; RRM, 2024; ESA, 2024

NOTE: Storm conditions are characterized by the boundary conditions applied in the model (Section 3) which consist of extreme coastal and fluvial water levels

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Sensitivity: Each asset was assigned a level of sensitivity relating to its susceptibility to harm from SLR and/or the consequences of its exposure. For example, a key through-road that disrupts the area's transportation system when inoperable has high sensitivity, whereas an unpaved parking lot with a relatively small effect when closed has a low sensitivity. Sensitivity ratings for each asset are defined in Section 8.4.

Adaptive Capacity: Each asset was assigned an adaptive capacity based on its ability to change and adapt in response to increasing exposure to hazards associated with rising sea levels. For instance, an unpaved trail that could be easily rerouted or raised has a high adaptive capacity, while a large road that is difficult to reroute or raise has a low adaptive capacity. Adaptive Capacity ratings for each asset are defined in Section 8.4.

8.4 Vulnerability Results

The vulnerability of assets to flooding and SLR is a combination of the likelihood of being flooded (hazard exposure), consequence of being flooded (sensitivity), and ability to be modified (adaptive capacity). Table 16 summarizes asset exposure, sensitivity, and adaptive capacity rankings and the composite vulnerability ranking based on the ranking system described in Section 8.3. A more detailed explanation of each asset's hazard exposure, sensitivity, and adaptive capacity is provided in the sub-sections below.

Table 16
Summary of Vulnerability Assessment Results

Asset	Hazard Exposure	Sensitivity	Adaptive Capacity	Vulnerability Rating	
Transportation Assets					
State Park Road					
Windy Cove	High	High	Low	High	
Main St	High	High	Low	High	
S Bay Blvd					
Chorro Creek Bridge to Bay Pines	Low	High	Low	Medium	
Chorro Creek Bridge to Los Osos Creek Bridge	High	High	Low	High	
Quintana Rd	High	High	Low	High	
Turri Rd	Medium	High	Low	High	
Chorro Creek Bridge	High	High	Low	High	
Los Osos Bridge	Low	High	Low	Medium	
Recreational Assets					
Windy Cove – Beach	High	Medium	Low	High	
Morro Bay State Park Marina Parking Lot	High	Medium	Low	High	
Windy Cove Parking Lot	High	Medium	Medium	Medium	
Cerro Cabrillo Trailhead Parking Lot	Low	Low	High	Low	
Park Ridge Trailhead Parking Lot	Very Low	Low	High	Low	
Chumash Trailhead Parking Lot	Low	Low	High	Low	
Morro Bay State Park Marina Bicycle Parking	High	Medium	Low	High	
Morro Bay Golf Course	High	Medium	High	Medium	

Asset	Hazard Exposure	Sensitivity	Adaptive Capacity	Vulnerability Rating	
Natural Assets					
Morro Bay State Marine Reserve	High	Medium	Low	High	
El Moro Elfin Forest Natural Preserve	Very Low	Medium	Low	Low	

8.4.1 Thresholds

The thresholds approach was used to examine the approximate timeframe of asset impact. The threshold method, introduced in the ESA Summary of Additional Guidance Memo, involves identifying specific amounts of SLR, or thresholds, at which assets become vulnerable, using model results from both this study and CoSMoS. Specific assets were assigned approximate time frames as to when they may become vulnerable. The approximate date of exposure to temporary (storm) and permanent (tidal inundation) hazards for each asset were determined based on the OPC 2024 High SLR scenario.

The results from this analysis are shown in Table 16. Note that modeling for this study by ESA accounts for ocean water levels, Bay hydrodynamics and wind waves, and creek flooding, whereas CoSMoS results only account for ocean water levels and exclude Bay hydrodynamics and wind waves and creek flooding. For this study, ESA modeled 1.8 ft of SLR (2060) and 6.3 ft of SLR (2100). Therefore, in most cases, ESA's model results show higher water levels that indicate impacts occur sooner compared to CoSMoS results. In certain cases, CoSMoS results show impacts occurring sooner due to the fact that CoSMoS modeled additional SLR scenarios between 1.8 ft and 6.3 ft or other modeling differences. The bold timeframes in Table 17 highlight impacts that are expected to occur sooner. ESA recommends these timeframes for planning purposes.

Based on these results, the assets currently exposed to coastal hazards are State Park Road, Quintana Road, Chorro Creek Bridge, Windy Cove Beach and parking lot, Morro Bay State Park Marina bicycle parking, Morro Bay Golf Course, and Morro Estuary State Marine Reserve. The assets likely to become exposed to coastal hazards in the near future (before 2060) are S Bay Blvd (between Chorro Creek Bridge and Los Osos Creek Bridge), and Turri Road.

TABLE 17 **ASSET VULNERABILITY TIME FRAMES**

Asset	Approximate time frame temporarily impacted (s		Approximate time frame of when the asset is permanently impacted (non-storm)	
	Bay/creek water level with wind setup (ESA Hydrodynamic Model) ¹	Ocean water level excluding Bay & creek dynamics & wind waves (CoSMoS 100-yr) ²	Bay water level with wind setup (ESA Hydrodynamic Model) ¹	Ocean water level excluding Bay & creek dynamics & wind setup (CoSMoS 100-yr) ²
Transportation – Roads and M	lobility Assets			
State Park Road				
Windy Cove	Now	Now	Now to 2060	2057 to 2068
Main St	Now	Now to 2044	Now to 2060	2068 to 2075
S Bay Blvd				
Chorro Creek Bridge to Bay Pines	2060 to 2100	2116 to 2133	2100+	2150+
Chorro Creek Bridge to Los Osos Creek Bridge	Now to 2060	2068 to 2075	Now to 2060	2089 to 2103
Quintana Rd	Now	2116 to 2133	Now to 2060	2150+
Turri Rd	Now to 2060	Now	2060 to 2100	2057 to 2068
Chorro Creek Bridge	Now	2044 to 2057	2100+	2089 to 2103
Los Osos Bridge	2100+	2103 to 2116	2100+	2116 to 2133
Recreational Assets				
Windy Cove – Beach	Now	Now	Now to 2060	Now to 2044
Morro Bay State Park Marina Parking Lot	Now	Now to 2044	Now to 2060	2068 to 2075
Windy Cove Parking Lot	Now	Now	Now to 2060	2044 to 2057
Cerro Cabrillo Trailhead Parking Lot	2060 to 2100	2089 to 2103	2060 to 2100	2103 to 2116
Park Ridge Trailhead Parking Lot	2100+	2150+	2100+	2150+
Chumash Trailhead Parking Lot	2060 to 2100	2075 to 2089	2060 to 2100	2075 to 2089
Morro Bay State Park Marina Bicycle Parking	Now	Now to 2044	Now to 2060	2068 to 2075
Morro Bay Golf Course	Now	Now to 2044	Now to 2060	2068 to 2075
Natural Assets				
Morro Bay State Marine Rreserve	Now	Now	Now to 2060	Now to 2044
El Moro Elfin Forest Natural Preserve	2100+	2150+	2100+	2150+

NOTES:

- 1. 1.8 ft of SLR is projected in 2060 and 6.3 ft of SLR is projected in 2100 under a high SLR scenario for Port San Luis (OPC 2024)
 2. SLR time frames are calculated using CoSMoS SLR converted to years based on a high SLR scenario (OPC 2024)

8.4.2 Transportation Assets

Generally, the transportation assets surrounding Morro Bay, from Windy Cove to Los Osos Bridge have a low adaptive capacity, high sensitivity, and high hazard exposure. Thus, roads and bridges are highly vulnerable to coastal hazards, which is further exacerbated by SLR. Table 18 below describes the extent of each roadway that is exposed to storm flooding with SLR in the near-term (now with 0 ft of SLR), mid-term (1.8 ft of SLR in 2060), and long-term (6.3 ft of SLR in 2100).

TABLE 18
LENGTH OF ROAD VULNERABILITY BY SCENARIO

	Length of Road Vulnerability (mi)					
Location	Non Storm Now	Storm Now	Non Storm 1.8 ft SLR (2060)	Storm 1.8 ft SLR (2060)	Non Storm 6.3 ft SLR (2100)	Storm 6.3 ft SLR (2100)
1 State Park Road – Windy Cove	<0.1	0.1	0.2	0.2	0.2	0.2
2 State Park Road – Marina to S Bay Blvd	0.4	1.0	0.8	1.1	1.1	1.4
3 South Bay Blvd – Chorro Creek Bridge to HW1	0.0	0.6	0.0	0.6	<0.1	0.6
4 Quintana Road	0.0	0.3	0.0	0.3	0.0	0.3
5 South Bay Blvd – Chorro Creek Bridge to Los Osos	0.5	1.0	0.8	1.1	1.2	1.2
6 Turri Road	<0.1	0.7	0.2	0.9	0.8	1.3

As described below, the four study areas will become more impacted by flooding during storm events and during non-storm conditions. The methodology for determining closure events per year in non-storm conditions is described in Section 7. Storm conditions are based on the hydrodynamic modeling described in Sections 3 to 5.

Area 1 – State Park Rd near water access

Due to low elevation and exposure, State Park Road in Windy Cove is currently highly vulnerable. State Park Rd. at this specific location is currently impacted by storm event flooding. The flooding is expected to worsen with SLR. The road is flooded and impassable during large storm events, which occurs for approximately 3 days per year. By about 2060, with 2 ft of SLR or less, State Park Road could be flooded during high tides approximately 74 times per year. By about 2090, with 5 ft of SLR or less, State Park Road could be impassable due to daily flooding.

Area 2 - State Park Rd from Marina to S Bay Blvd

This section of State Park Rd is on the edge of the Morro Bay Estuary, confined by the bay and the Morro Bay State Park. In this section, State Park Rd is highly sensitive due to its location, and it is susceptible to flooding and erosion from the Chorro Creek outlet channel. Currently, approximately 0.4 miles of State Park Road are impacted by tidal inundation during exceptionally high tides (king tides). By about 2060, with 2 ft of SLR or less, 0.8 miles of State Park Road are estimated to have regular flooding approximately 46 days per year. By about 2090, with 5 ft of SLR or less, the road could be flooded daily.

Results from hydrodynamic modeling show that portions of State Park Road from the marina to Chorro Creek Bridge are susceptible to flooding during storm events (as defined in Section 8.3). SLR will increase the length of road flooded from approximately 1 mile to 1.4 miles in the long-term. In the near-term with 1 ft of SLR or less (2050 or sooner), the road is expected to be impassable for approximately 1 day per year during storm events. The mid-term and long-term could see the road flooded nearly daily, so a storm event will only exacerbate the existing flooding.

Area 3 - S Bay Blvd from Chorro Creek Bridge to Bay Pines Travel Trailer Park

South Bay Blvd north of Chorro Creek Bridge and Quintana Road are generally higher in elevation and out of the coastal hazard zone in non-storm conditions. Modeling results show that the roads are above the 2100 SLR tide elevations.

Flood hazard results from ESA's hydrodynamic model as well as CoSMoS show that Area 3 is not likely to be flooded by tides. However, during periods of exceptionally high tides and high creek flows, the high tides and potentially the constriction of flows through the Chorro Creek bridge contribute to floodwaters backing up in Chorro Creek. This causes flooding to Chorro Creek Bridge, Quintana Road, and the Bay Pines Travel Trailer Park. Historically, Chorro Creek bridge has been flooded for approximately 2 days during extreme storm events. Quintana Road has historically remained flooded for approximately 2 days as well. With SLR, creek flood levels may be higher and back up further into Chorro Creek and onto the floodplain, increasing flood elevations and durations during storm events. In addition, by 2100, with 6.3 ft of SLR, Chorro Creek bridge may be flooded daily.

Area 4 - S Bay Blvd from Los Osos to Chorro Creek Bridge

South Bay Blvd is a primary evacuation route from Los Osos and provides connectivity from the City of Morro Bay to Los Osos. Similar to State Park Road on the northwest side of Morro Bay, South Bay Blvd between Chorro Creek Bridge and Los Osos is on the edge of Morro Bay Estuary, confined by the bay and the state park. The road here is susceptible to temporary flooding caused by storm events, tidal inundation with SLR, and erosion. Tidal inundation is not predicted to occur in the near-term. By 2060 with 1.8 ft of SLR (the mid-term), exceptionally high tides may encroach onto South Bay Blvd from just south of Chorro Creek Bridge to just south of the Cerro Cabrillo Trailhead. In the long term, following 4 ft of SLR this flooding would extend to Chorro Creek Bridge and is expected to occur 12 times per year, rising to 116 events per year with 5 ft of SLR or less (around 2090 or sooner). South of the Cerro Cabrillo Trailhead, South Bay Blvd gains elevation and is above tidal elevations in the long-term. Los Osos Bridge is also above tidal elevations in the long-term.

Flood hazard results show this section of South Bay Blvd is susceptible to flooding during storm events in the near-term, from Chorro Creek Bridge to the Cerro Cabrillo Trailhead. Flooding in this section of the road could close the road for approximately one day per year on average now/in the near-term without SLR. With SLR, in the mid- (2060) and long-term (2100), flooding along this section of South Bay Blvd is predicted to worsen and may increase in duration. The flooding does not extend further south towards Los Osos in storm events with SLR. Los Osos Bridge shows flooding in the hazard maps (Figure B-12), but the Delft3D model results do not include the bridge structure. The Los Osos Bridge is not expected to flood with SLR.

Area 4 includes Turri Road, the turnoff just directly north of Los Osos Bridge. The flood hazard maps show the model predicts no tidal inundation of Turri Road in the near- or mid- term. In the long-term, by 2100, Turri Road is susceptible to tidal inundation. The storm scenario predicts there are segments of Turri Road that could flood

during storm events in the near-term (now, without SLR), near the Chumash Trailhead and further east (see Figure B-11). By 2060, flood inundation extends to segments of the road east of the Chumash Trailhead, and by 2100, most of the portion of Turri Road that is along the Los Osos creek is vulnerable to storm flooding.

8.4.3 Recreational Assets

This section describes the vulnerability of recreational assets around the Morro Bay Estuary to storm flooding and SLR.

Area 1 – State Park Rd near water access

Windy Cove in Area 1 is inaccessible currently during high tides. Based on an approximate flooding limit of 6.5 ft NAVD, there are approximately 10 to 20 days of the year that the beach is currently inaccessible at high tide and is expected to become inaccessible daily during high tide by the mid-term (2060). Combined with the high sensitivity and difficulty providing adaptation measures to the cove, Windy Cove has a high vulnerability to SLR. The Windy Cove parking lot likewise is currently inundated during large storm events and could become tidally inundated by the mid-term (2060).

Area 2 - State Park Rd from Marina to S Bay Blvd

The paved Morro Bay State Park Marina Parking Lot is currently exposed to storm flooding and is anticipated to become exposed to tidal inundation by the mid-term (2060). Flooding of the parking lot may cause closure but is unlikely to have broader impacts on the transportation network. Overall, the Morro Bay State Park Marina Parking Lot has a high vulnerability. The bicycle parking has the same exposure conditions.

The western portion of the Morro Bay Golf Course is currently exposed to storm flooding. The flood risk area is expected to increase in the mid and late century with SLR, with tidal inundation of the area between now and 2060. Currently, 1.8 acres are within the storm flooding area, which rises to 8 acres with 1.8 ft of SLR and 27 acres after 6.3 ft of SLR. The golf course has moderate sensitivity to storm flooding and tidal inundation as it is. Although these events are unlikely to affect the broader transportation network they could render the course inoperable.

Area 3 – S Bay Blvd from Chorro Creek Bridge to Bay Pines Travel Trailer Park

No recreational assets in Area 3 were included in the vulnerability assessment.

Area 4 – S Bay Blvd from Los Osos to Chorro Creek Bridge

The Cerro Cabrillo, Park Ridge, and Chumash trailhead parking lots have low to very low hazard exposures. The Cerro Cabrillo and Chumash trailhead parking lots become exposed to flooding under storm conditions in the long-term (2100), while the Park Ridge trailhead parking lot is not exposed under any modeled scenarios. Each of the trailhead parking lots is unpaved, providing a high adaptive capacity, and has low sensitivity to storm flooding and tidal inundation. Each of the trailhead parking lots has a low overall vulnerability.

8.4.4 Natural Assets

This section discusses the hazard exposure, sensitivity, and adaptive capacity of natural assets surrounding the Morro Bay Estuary.

Natural assets, including wetlands, intertidal, and subtidal habitats are subject to different impacts from SLR and increased storm flooding compared to transportation and recreational assets. As shown in Appendix B, the Morro Bay State Marine Reserve is inundated under existing conditions during king tides, though this does not necessarily make it typically exposed to a hazard, as this is part of the natural functioning of the habitat. However, prolonged changes to inundation frequency may convert marsh habitat to a different habitat type. At the Morro Bay Estuary, where development and steeper topography surrounding the estuary limit the ability of habitats to migrate to higher elevations (lower adaptive capacity due to coastal squeeze), SLR threatens the loss of habitat area and species diversity. Overall, the Morro Bay State Marine Reserve has a high vulnerability to SLR because of the limited ability of the habitats to adapt to changing environmental conditions, such as SLR and the increased frequency of flooding.

Despite a low adaptive capacity, El Moro Elfin Forest Natural Preserve has a low vulnerability to SLR. Its higher elevation indicates that it is not exposed to tidal inundation or coastal flooding, even in the long-term.

9 Conclusions and Next Steps

This section summarizes the key findings and conclusions of hydrodynamic modeling and the vulnerability assessment. Additionally, the next steps in the Morro Bay Estuary Climate Resiliency Transportation Plan are discussed below.

The area surrounding the Morro Bay Estuary is flood-prone, and many of its transportation, recreational, and natural assets are vulnerable to storm flooding and tidal inundation that will worsen in the future with SLR. ESA developed a Delft3D hydrodynamic model by building upon an existing USGS model (Taherkhani et al. 2023). This model includes all areas inside Morro Bay that are submerged by king tides, and it extends three kilometers offshore of the Bay mouth to allow forcing from ocean tides. ESA verified the model by comparing outputs to observational data collected by Cal Poly and CeNCOOS. ESA ran this model for three SLR scenarios from OPC 2024: 0 ft representing existing conditions, 1.8 ft representing a mid-century (2060) high SLR projection, and 6.3 ft representing a late-century (2100) SLR projection. All scenarios were run for storm and non-storm conditions. Additionally, ESA conducted a simple wave runup analysis using the TAW method to estimate the extent of wave runup at Windy Cove/Main Street and South Bay Blvd.

In addition to technical analyses of modeling the estuary water level with SLR, this study also included conducting observations and working with stakeholders and community members to assess and quantify the vulnerability of transportation, recreational, and natural assets surrounding the Morro Bay Estuary. The results of the technical analyses were overlayed with transportation, recreational, and natural resource assets in and around the Morro Bay Estuary to determine when and under what conditions the assets are exposed to tidal inundation and storm flooding with SLR. The hazard exposure timeframe was combined with a sensitivity rating (consequence of being flooded) and an adaptive capacity rating (ability to be modified) to assign overall vulnerability ratings to the area's assets.

The transportation assets surrounding Morro Bay are highly vulnerable to SLR. Results from the analyses show that the most vulnerable assets include State Park Road at Windy Cove and along the Estuary towards Chorro Creek Bridge, and South Bay Blvd from the Chorro Creek Bridge to the Cerro Cabrillo Trailhead Parking Lot. By 2060, these assets could experience daily tidal inundation. The cumulative vulnerability ratings for each asset are shown in Table 19 below. All high vulnerability assets except Turri Rd are exposed to storm flooding under

existing conditions or with 1.8 ft of SLR, projected to occur by 2060 under a high SLR scenario. Tidal inundation also threatens the high vulnerable assets between now and 2060.

Table 19
Morro Bay Estuary Asset Vulnerability

Vulnerability	Assets	
High	State Park Rd – Windy Cove State Park Rd – Main St S Bay Blvd – Chorro Creek Bridge to Los Osos Creek Bridge Quintana Rd Turri Rd Chorro Creek Bridge Windy Cove Beach Morro Bay State Park Marina Parking Lot Morro Bay State Park Marina Bicycle Parking Morro Bay State Marine Reserve	
Medium	S Bay Blvd – Chorro Creek Bridge to Bay Pines Los Osos Bridge Windy Cove Parking Lot Morro Bay Golf Course	
Low	Cerro Cabrillo Trailhead Parking Lot Park Ridge Trailhead Parking Lot Chumash Trailhead Parking Lot El Moro Elfin Forest Natural Preserve	

The next step in The Plan is to develop an opportunities, constraints, and alternatives analysis. The ESA team will use the coastal hazard maps created during this vulnerability assessment to identify the opportunities and constraints for enhancing transportation and mobility in the Morro Bay Estuary area. This phase will include identifying potential enhancements that increase the resilience of the transportation system, preserve or restore habitats, maintain or improve recreation, and enhance non-motorized mobility. It will also identify constraints that may limit the feasibility of these solutions. Alternatives will be developed and a framework will be developed for adaptation measures in the near-term (now), mid-term (2060), and long-term (2100). This analysis will be conveyed in a Summary of Alternatives and Adaptation Pathways Framework memorandum.

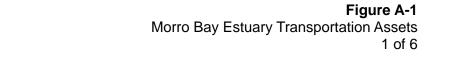
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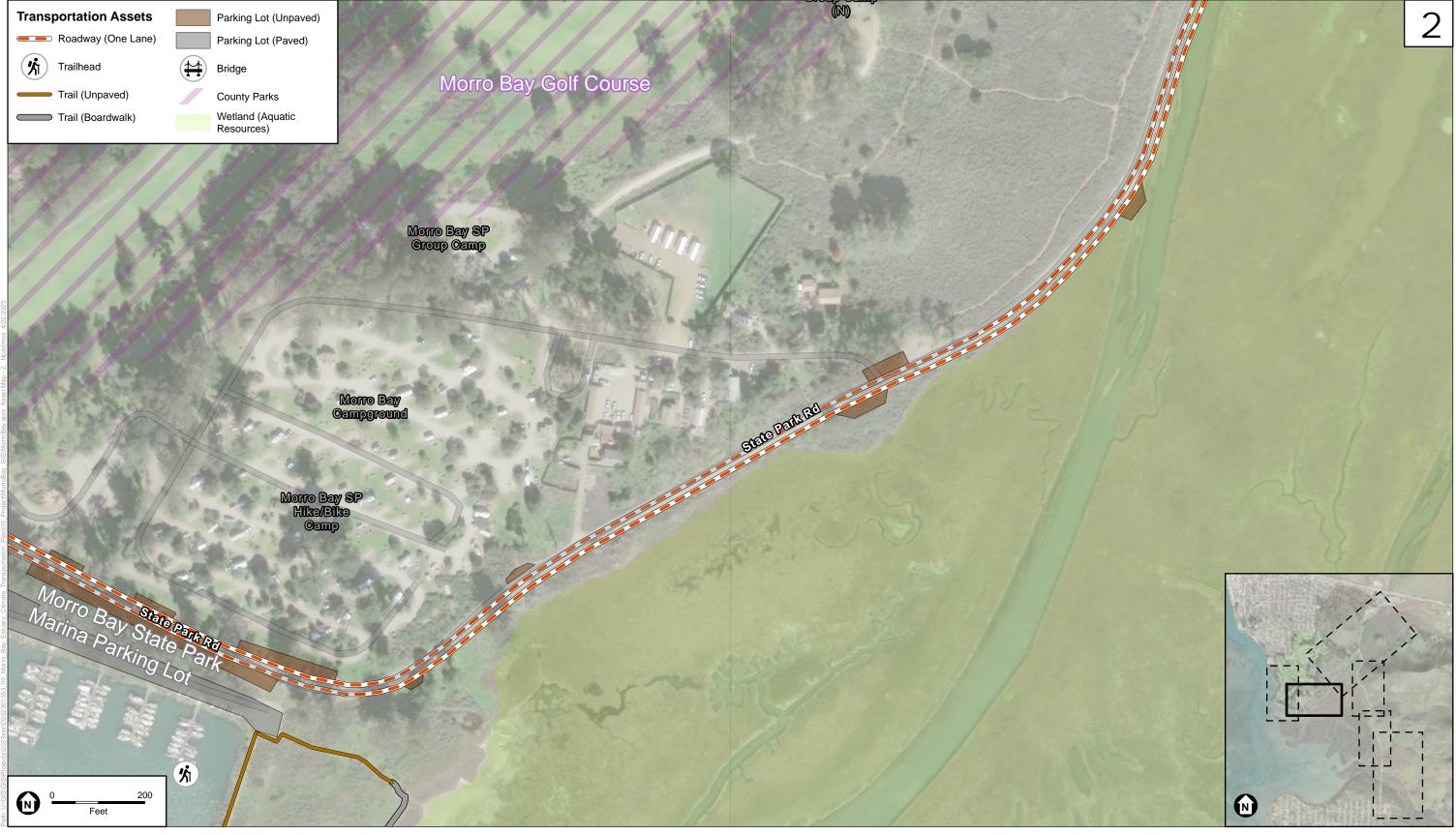
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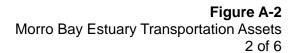
Appendix A Morro Bay Estuary Asset Maps



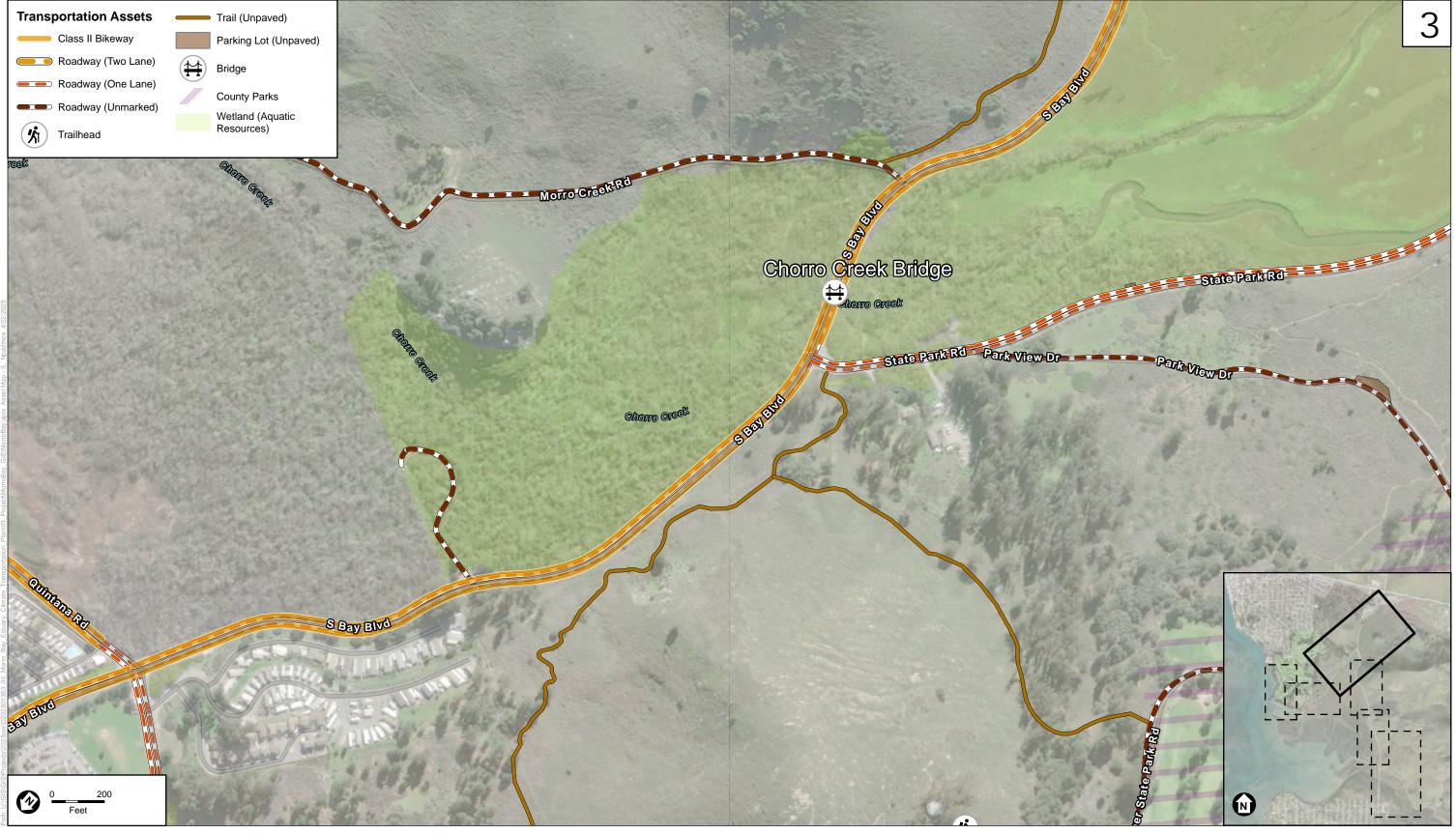


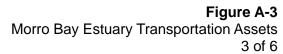




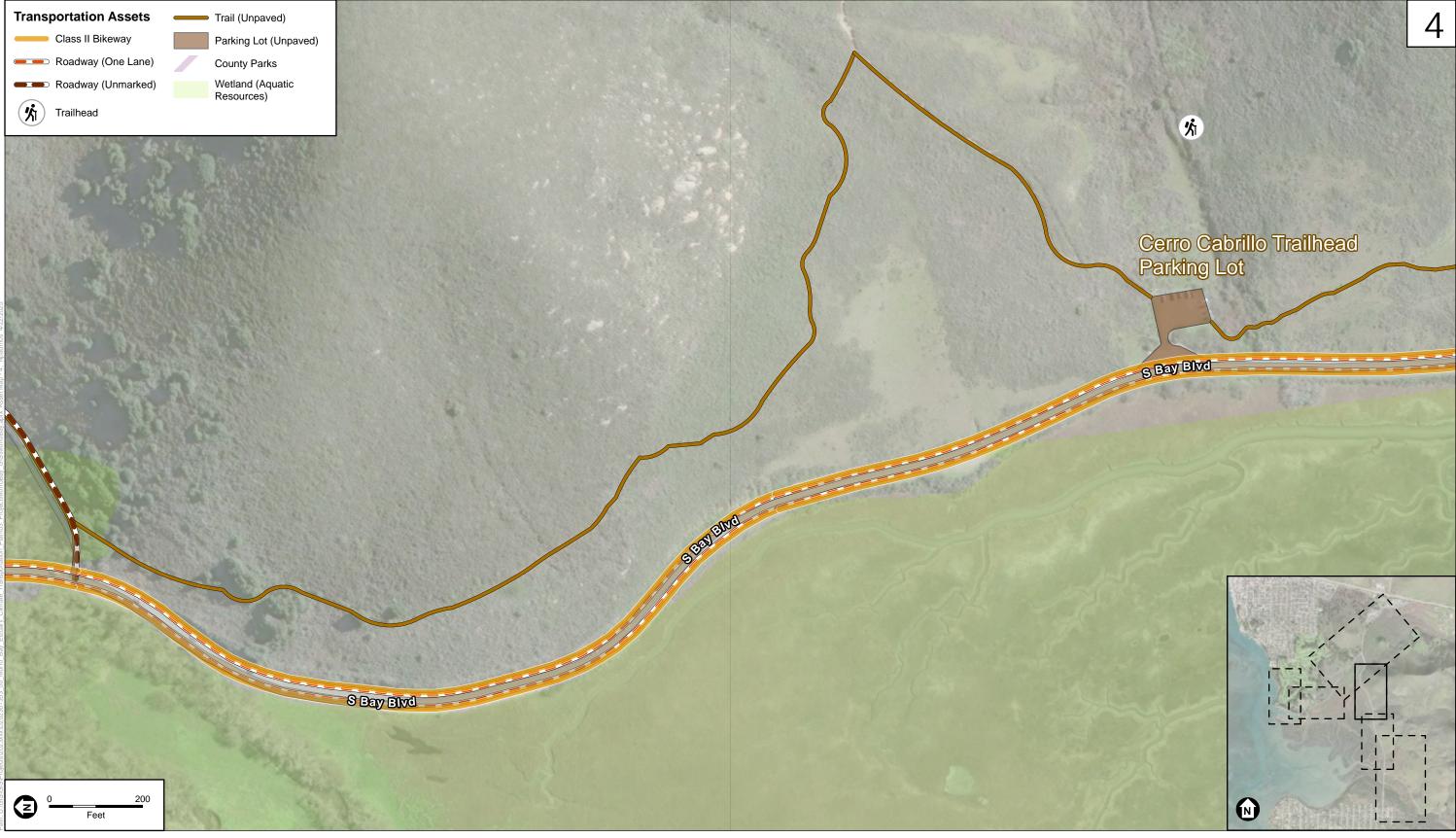


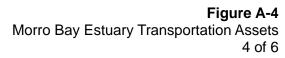




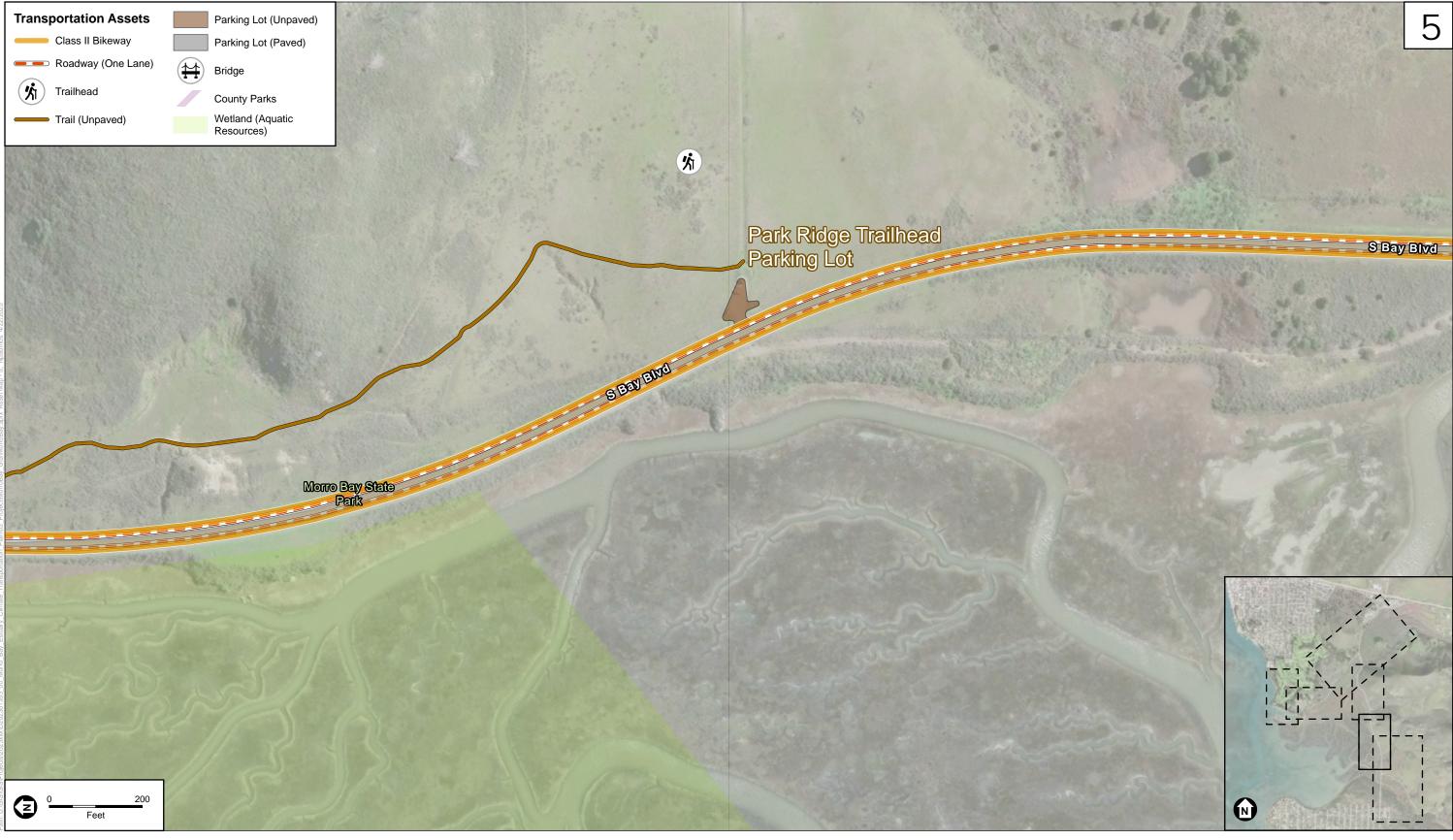


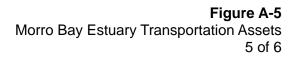






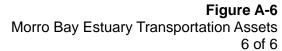








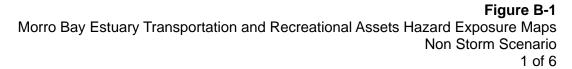




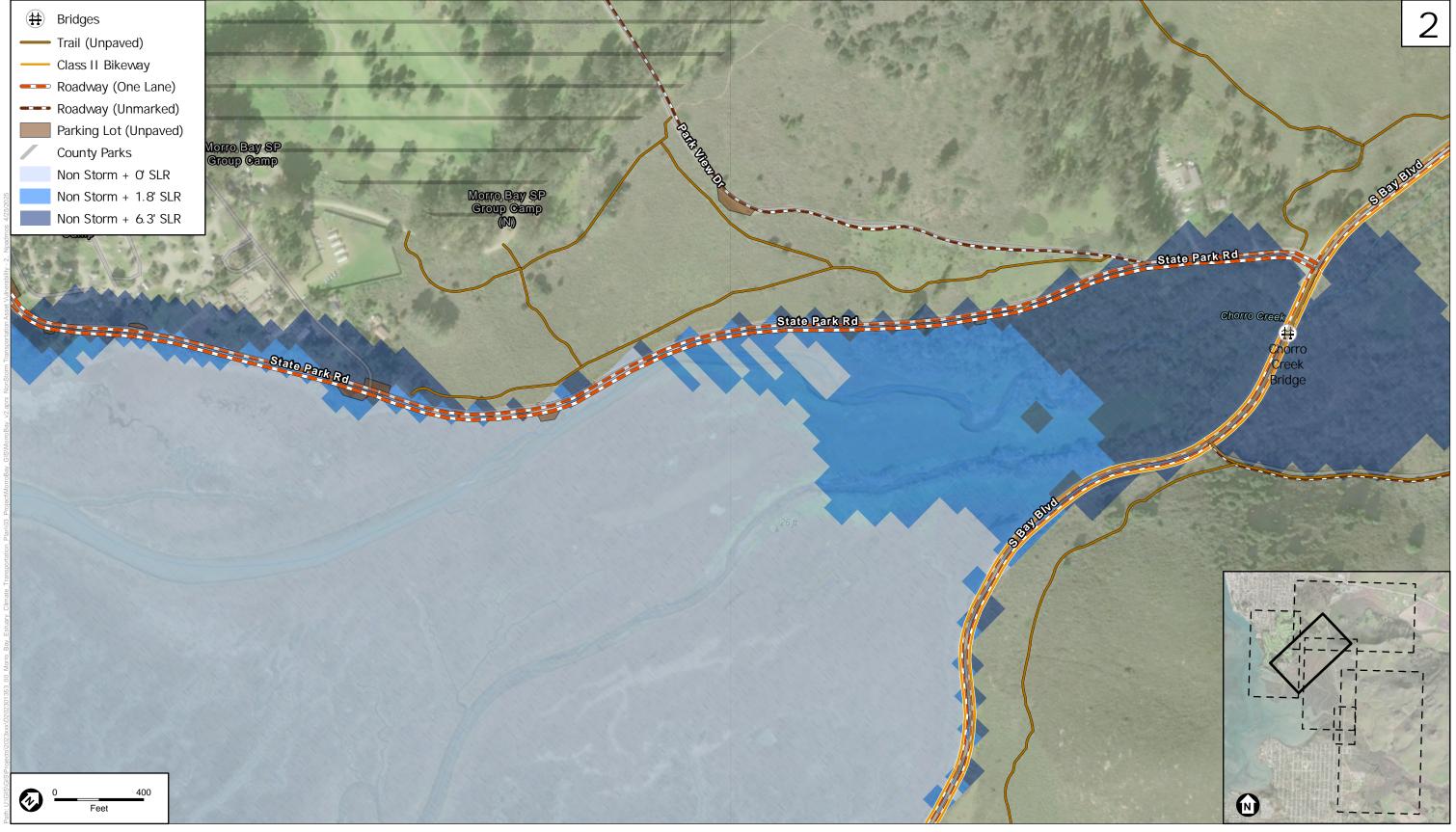


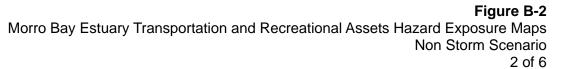
Appendix B Morro Bay Estuary Transportation and Recreational Assets Hazard Exposure Maps



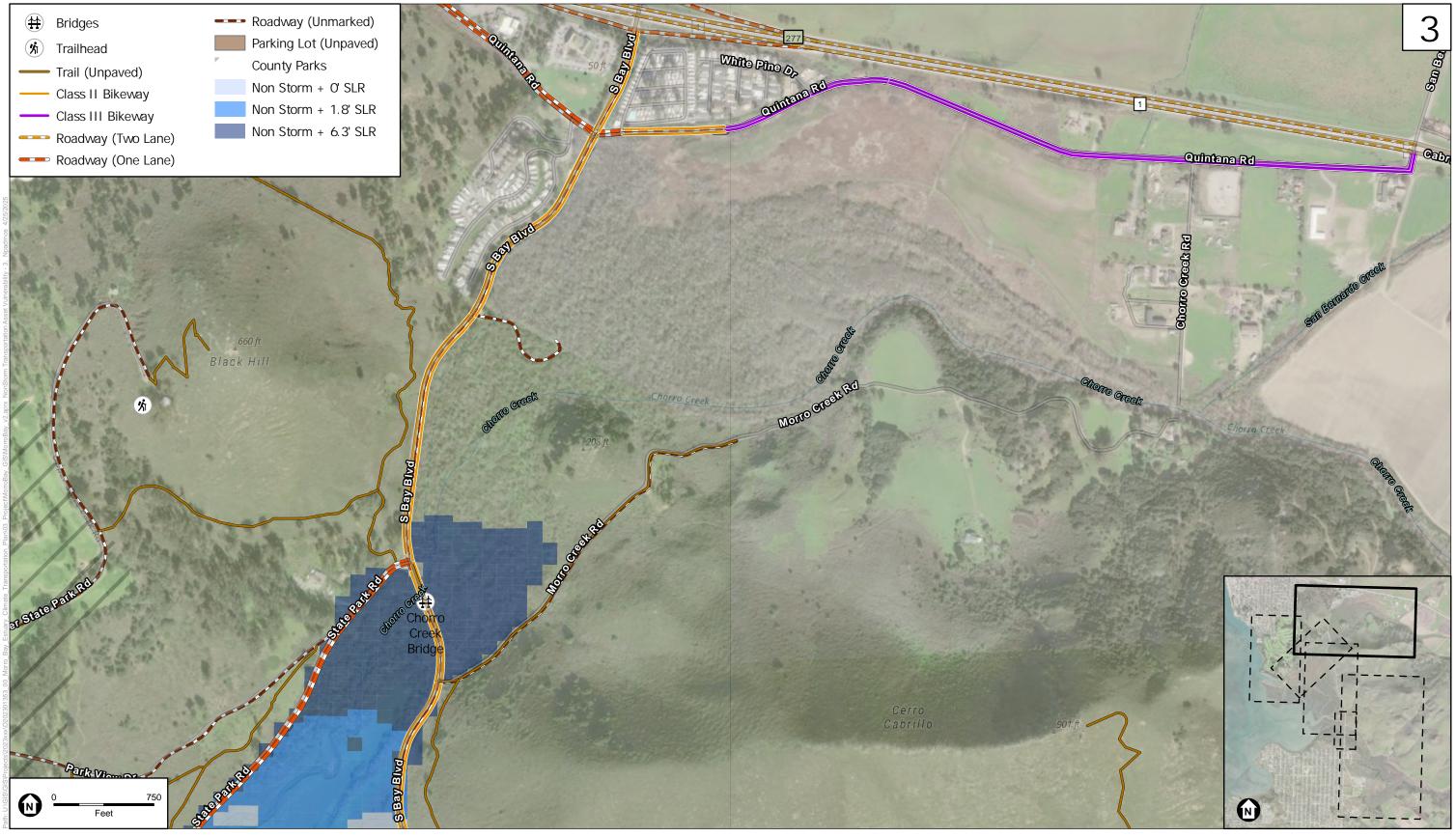




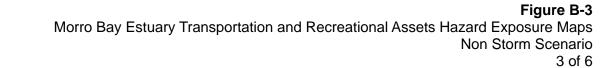




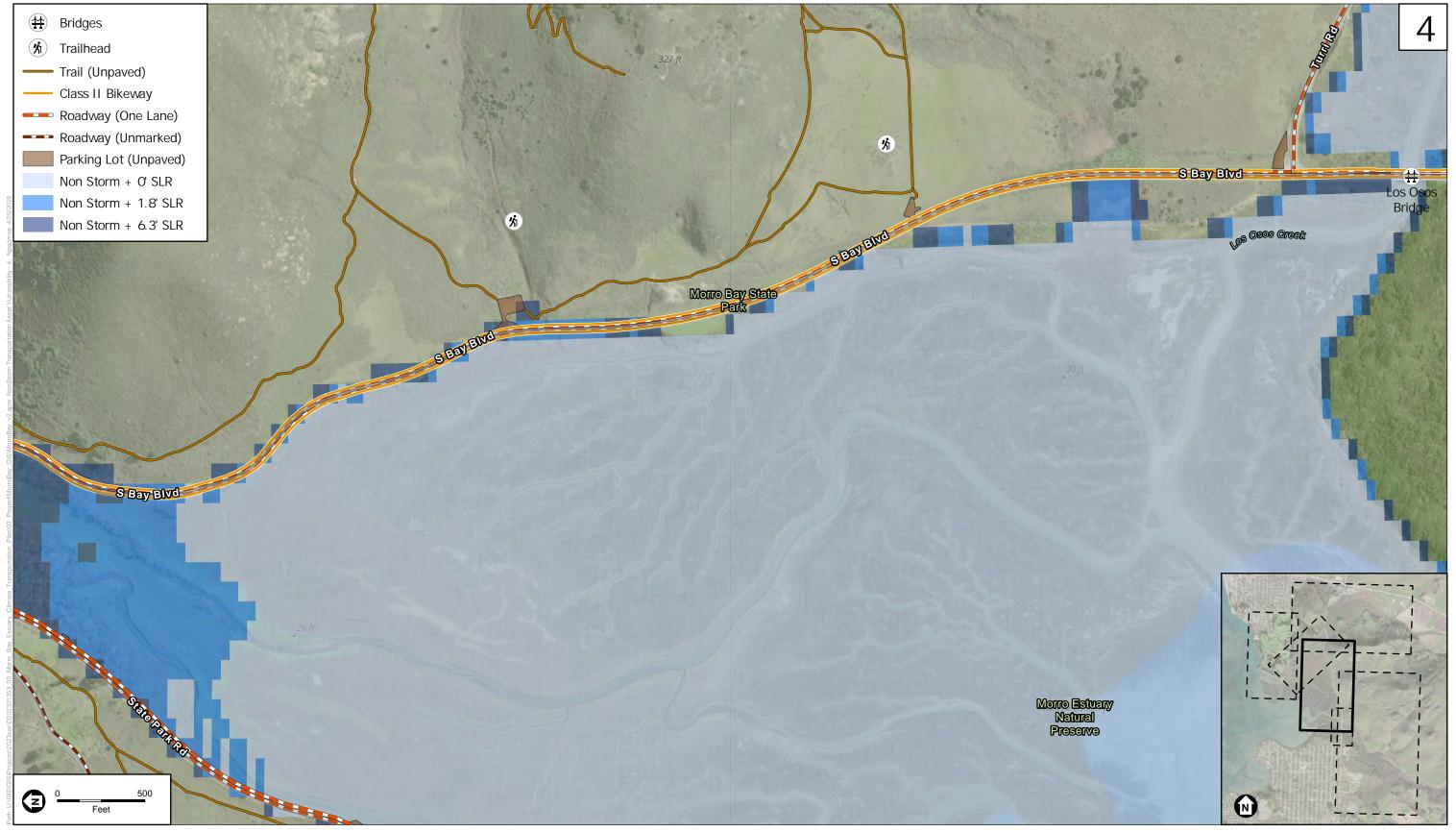


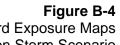


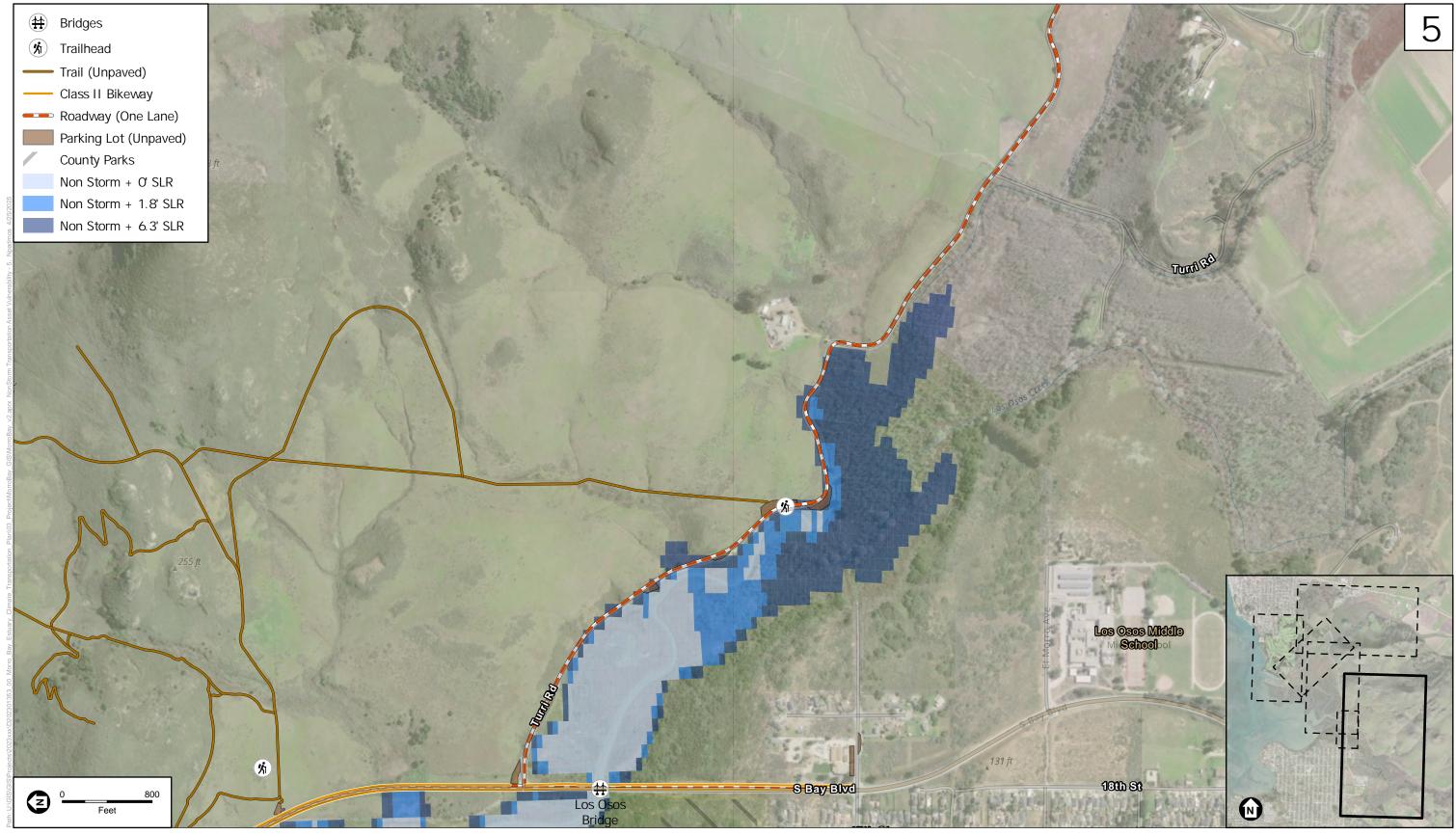
NOTE: The hydrodynamic model for this study did not extend beyond 1000 feet north of Chorro Bridge



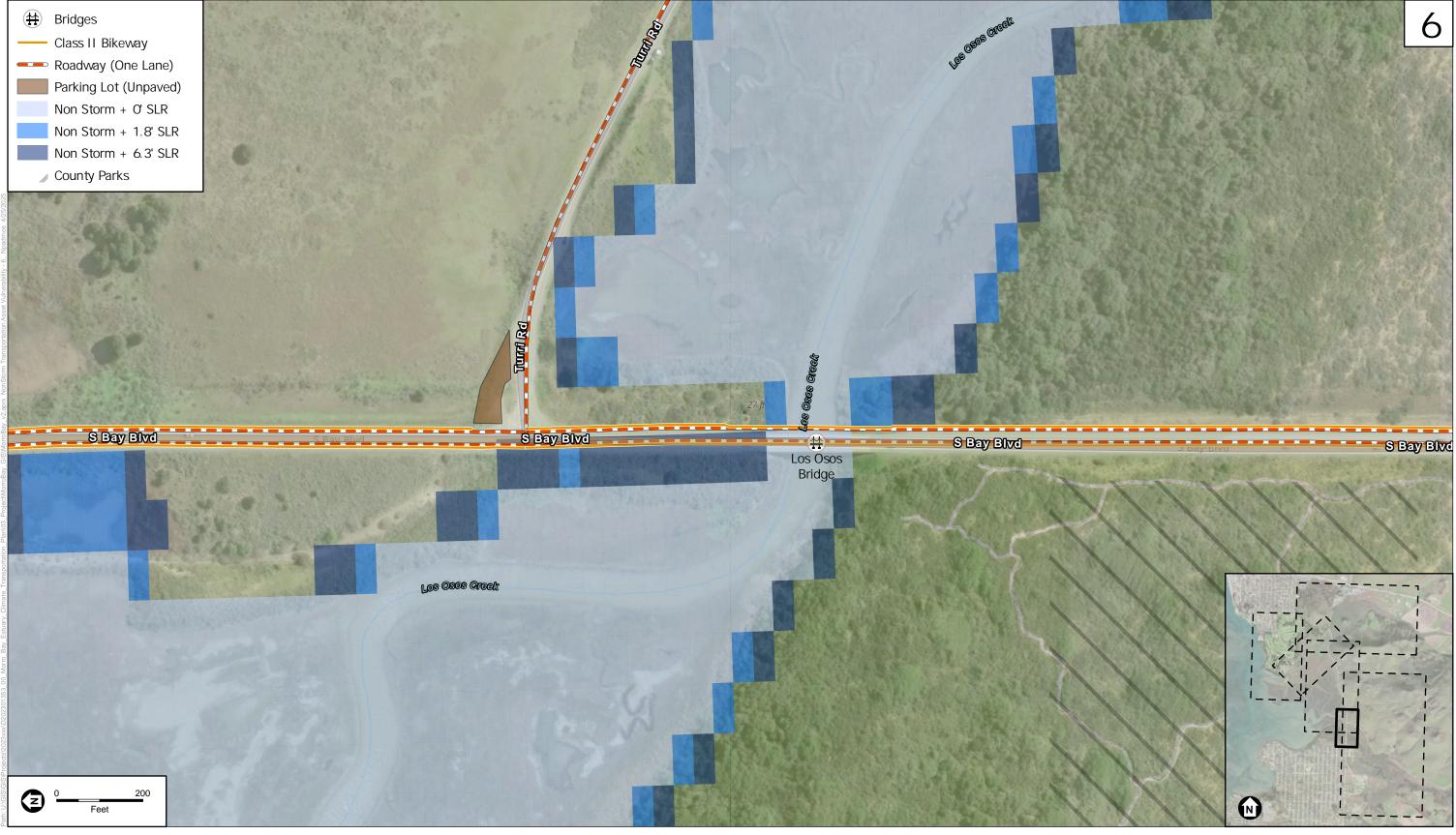






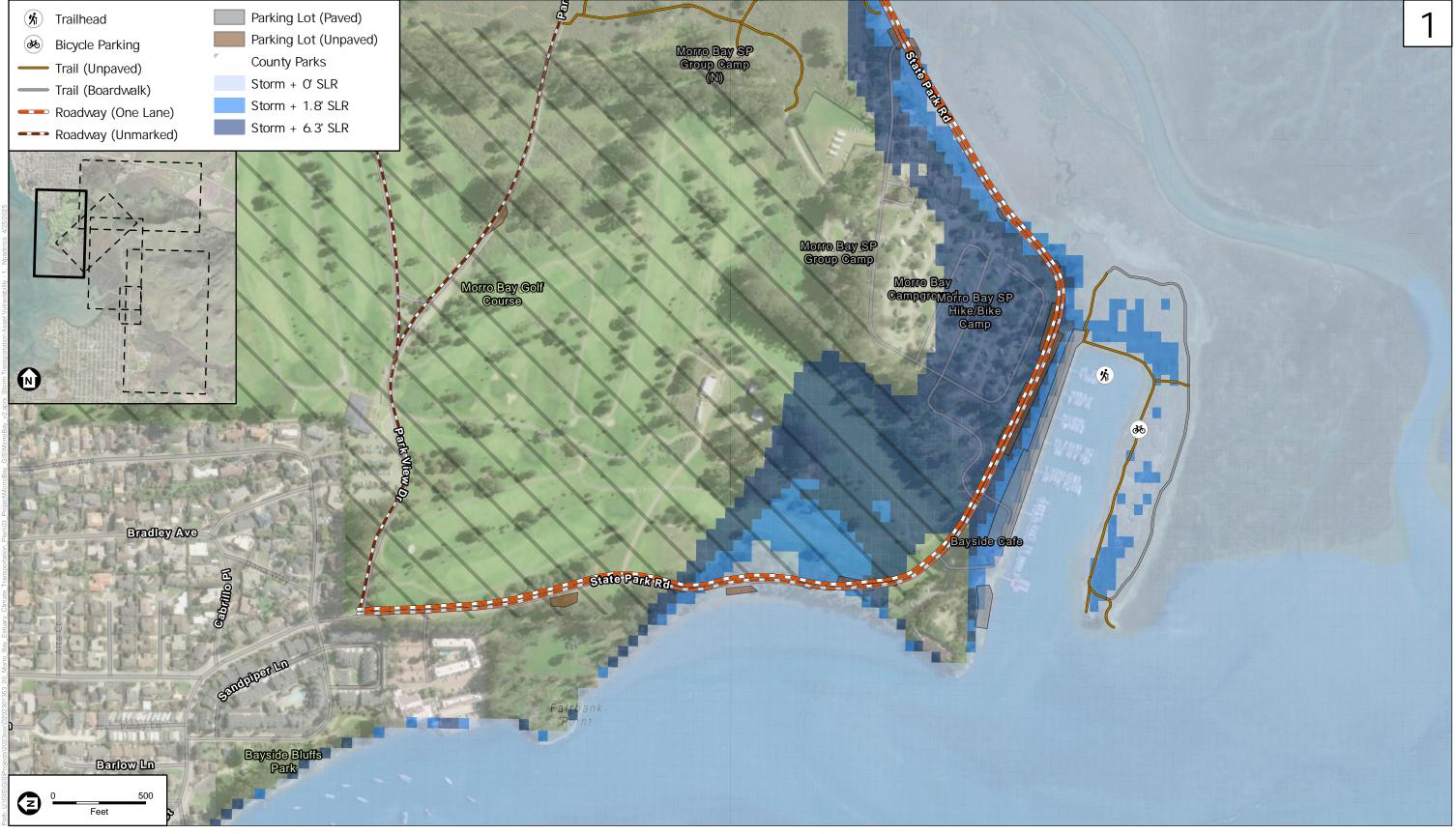






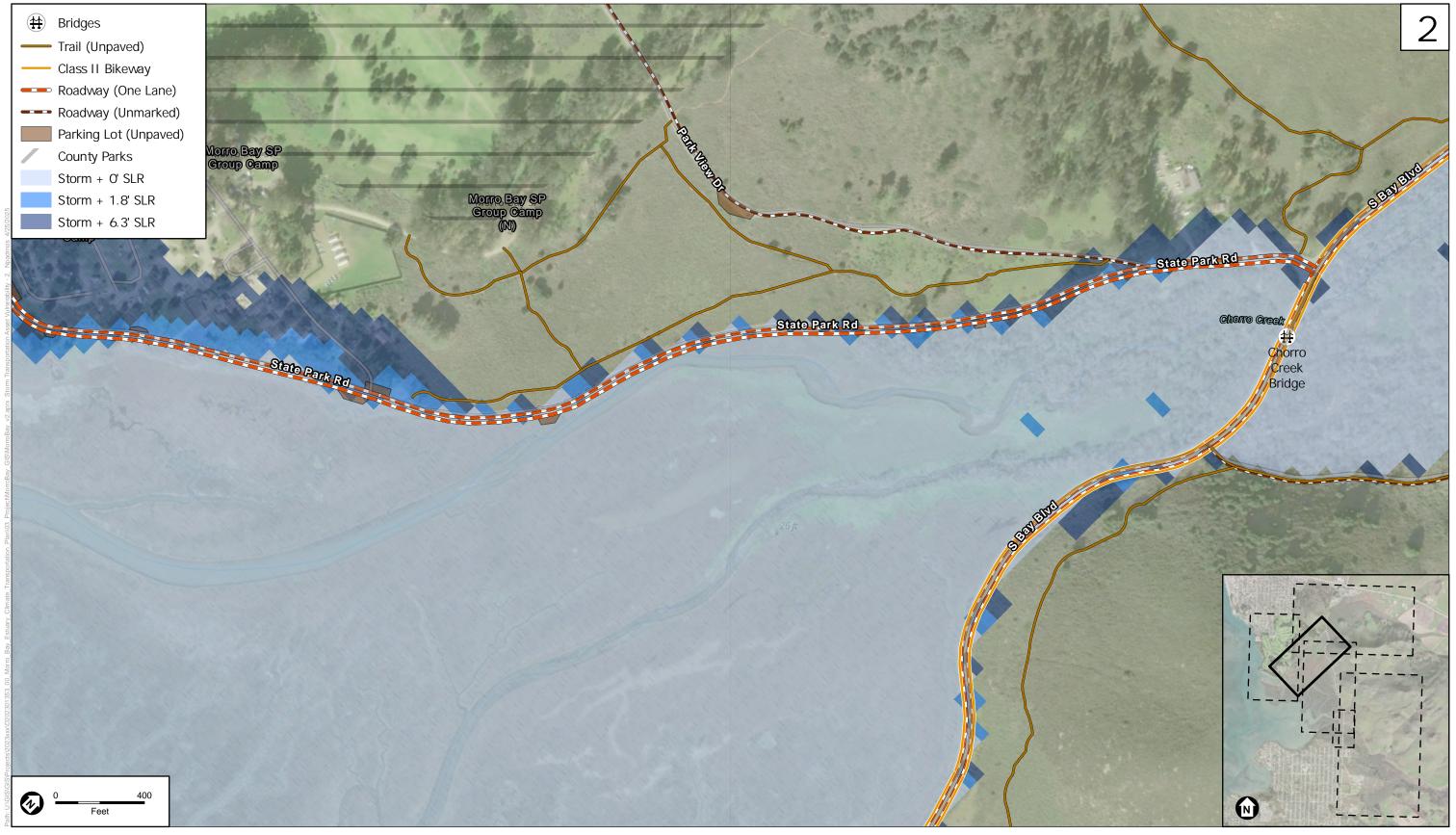






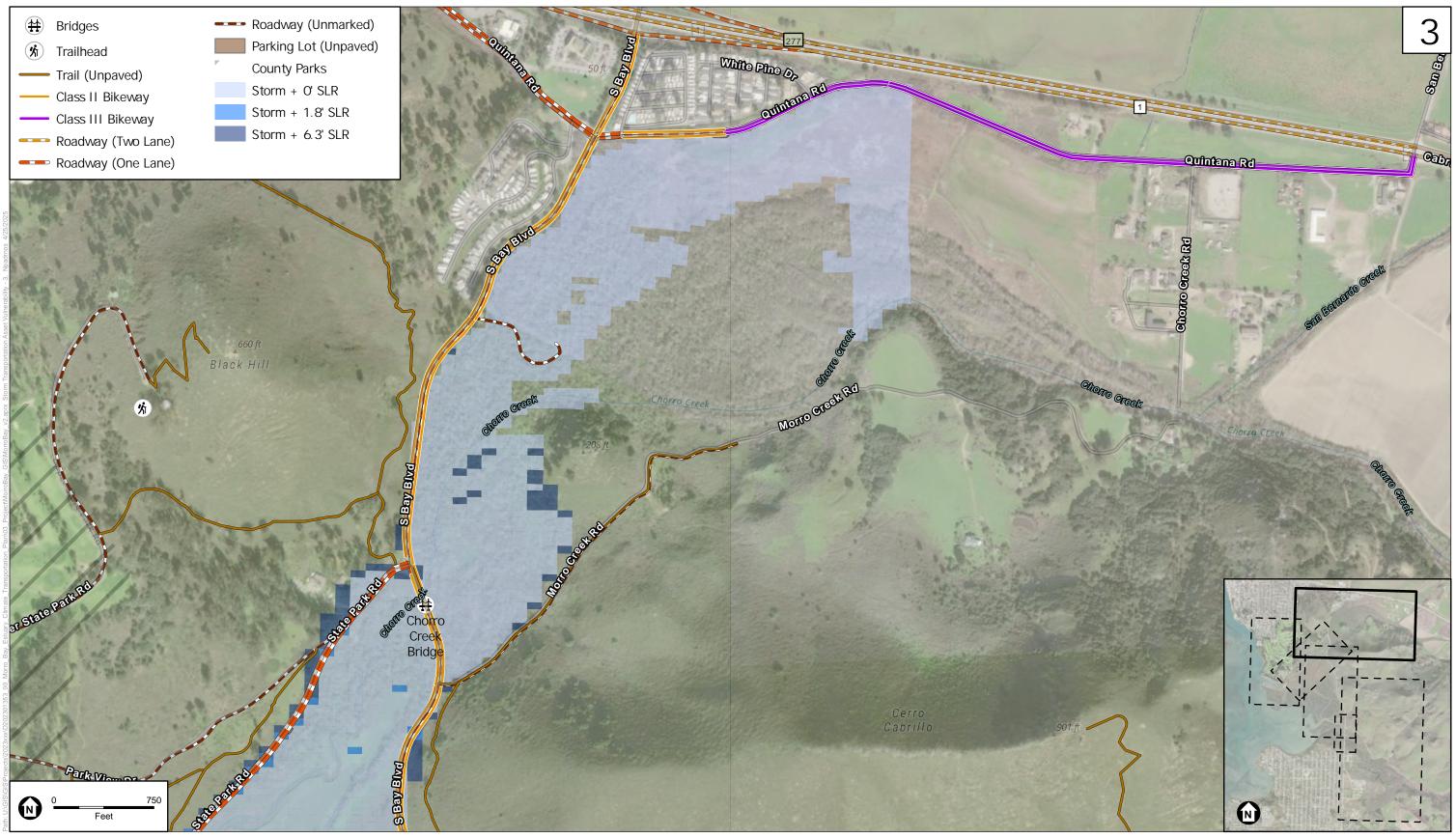
NOTE: Storm conditions are characterized by the boundary conditions applied in the model (Section 3) which consist of extreme coastal and fluvial water levels





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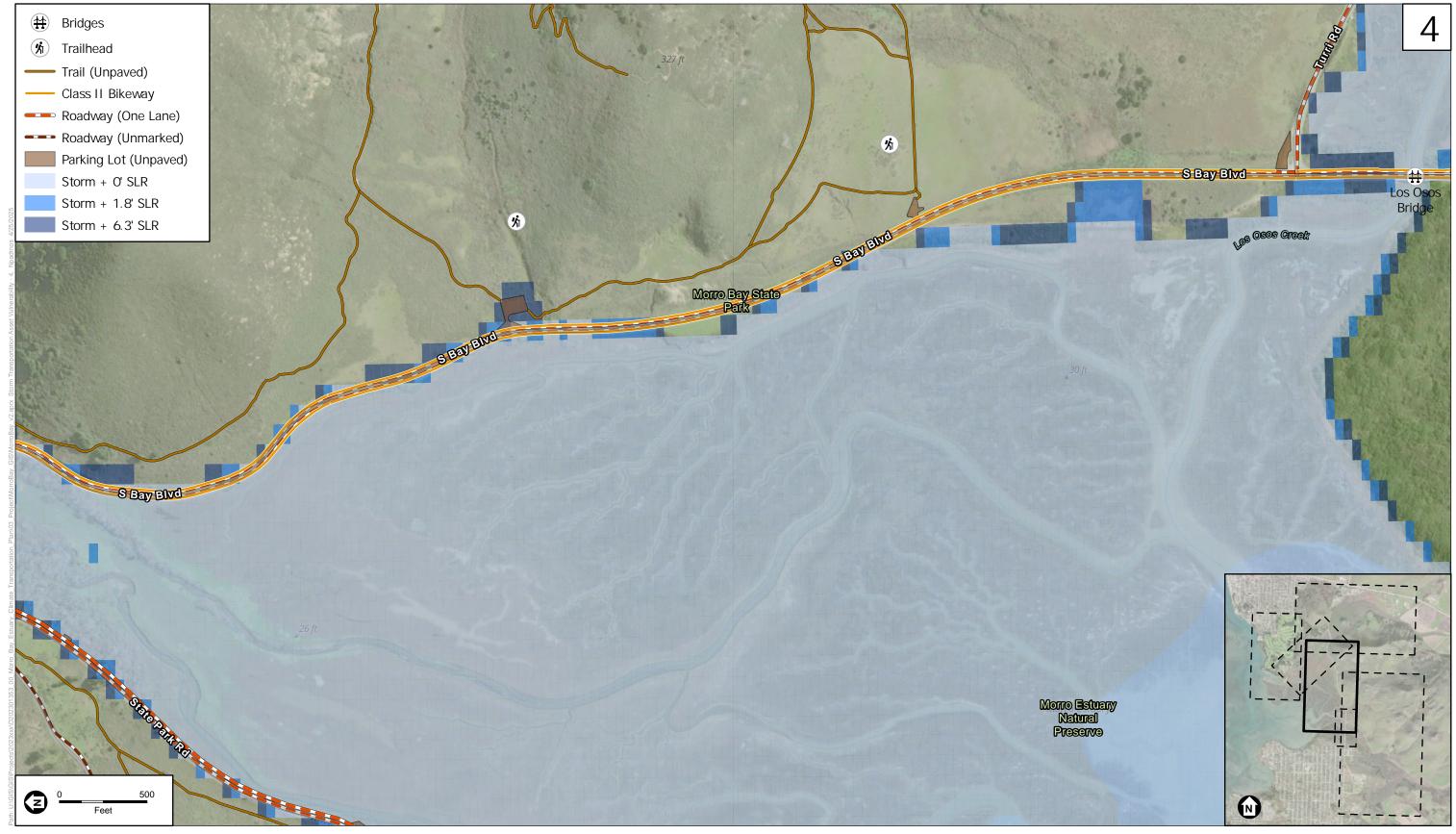




NOTES: The hydrodynamic model for this study did not extend beyond 1000 feet north of Chorro Bridge

Storm conditions are characterized by the boundary conditions applied in the model (Section 3) which consist of extreme coastal and fluvial water levels

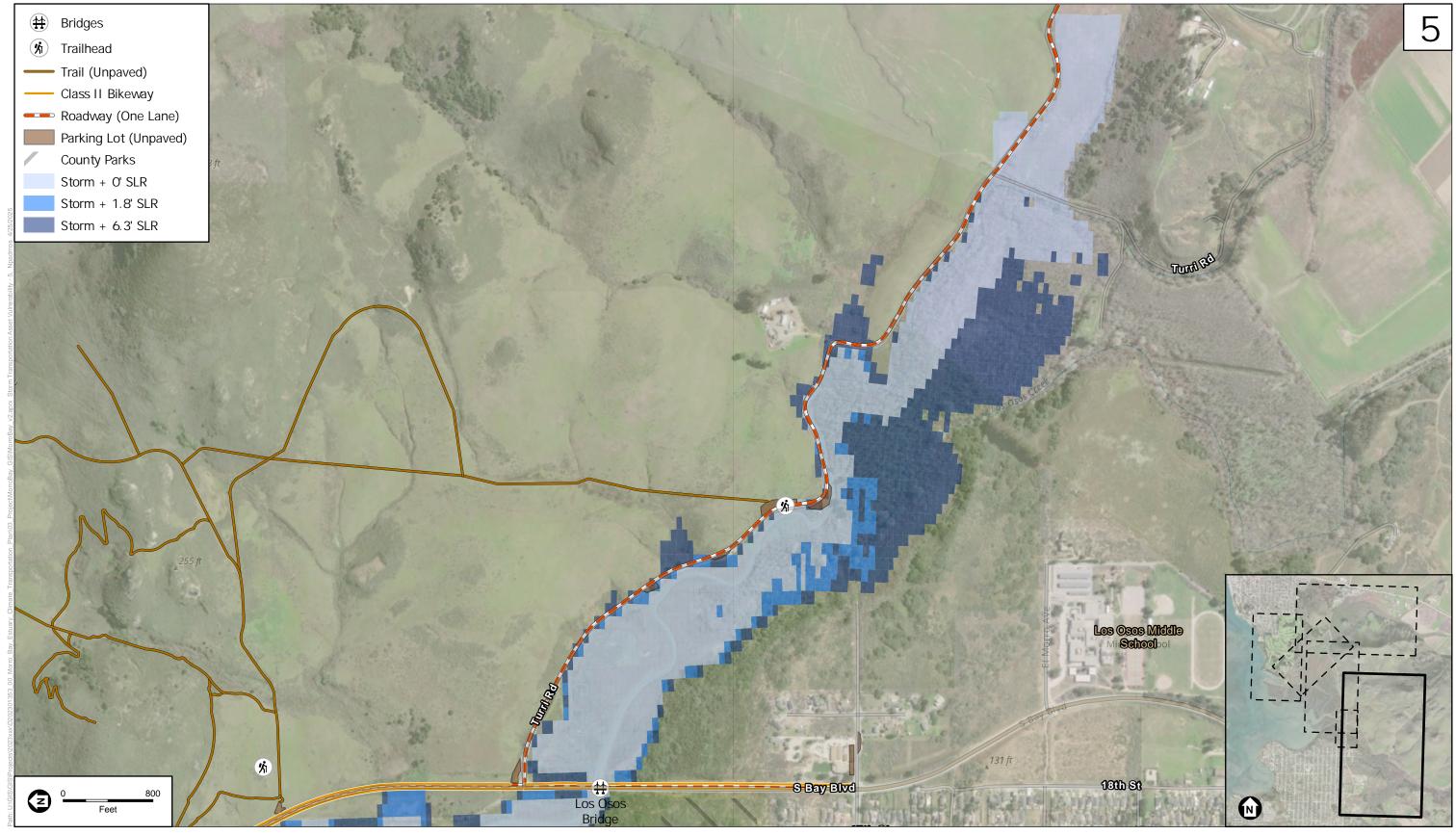




NOTE: Storm conditions are characterized by the boundary conditions applied in the model (Section 3) which consist of extreme coastal and fluvial water levels



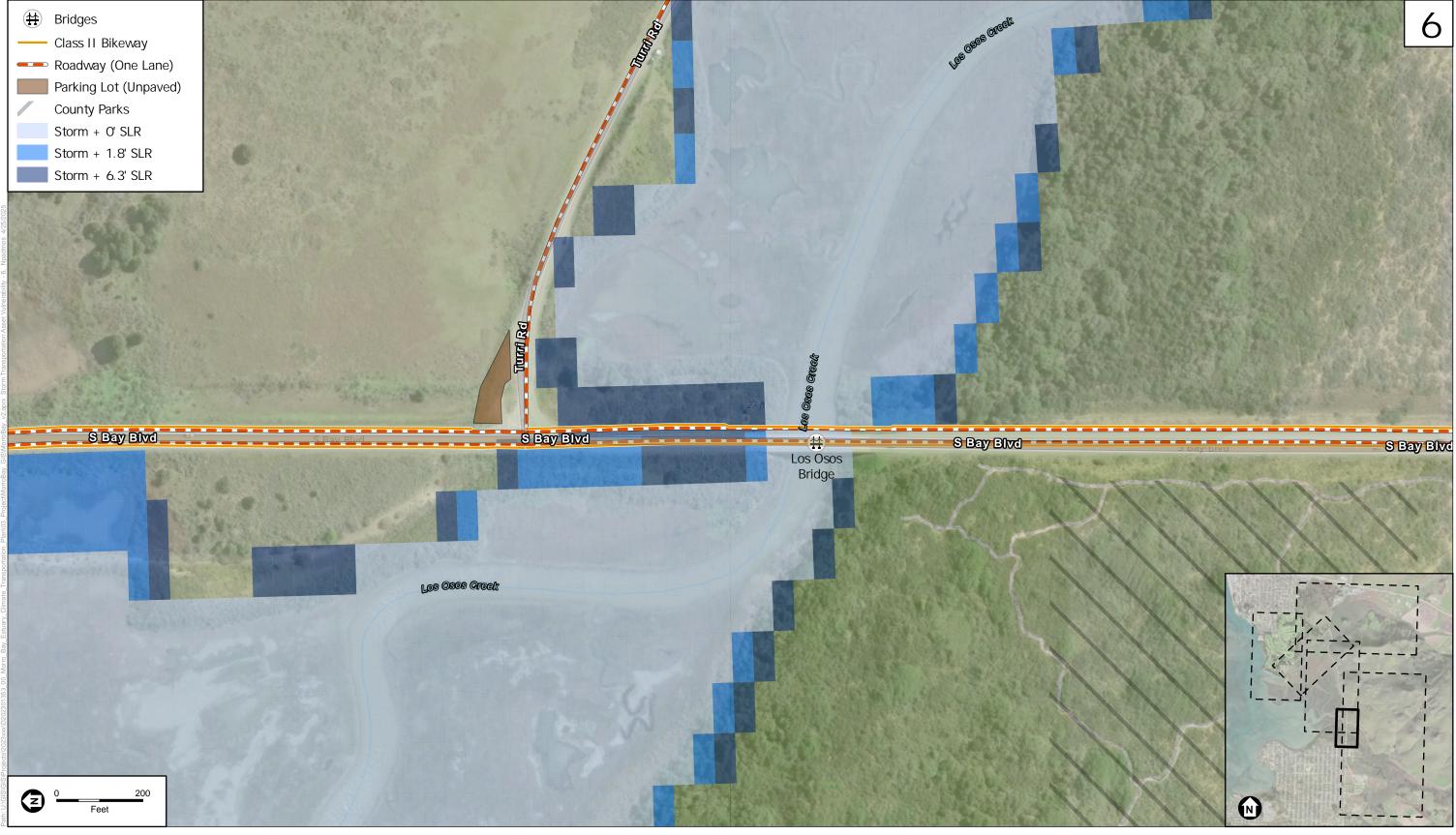




Morro Bay Estuary Climate Transportation Plan



NOTE: Storm conditions are characterized by the boundary conditions applied in the model (Section 3) which consist of extreme coastal and fluvial water levels



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