Eureka-Arcata Route 101 Corridor CAIP

Comprehensive Adaptation & Implementation Plan (CAIP)

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District 1

CALIFORNIA DEPARTMENT OF TRANSPORTATION

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Eureka-Arcata Route 101 Corridor

Comprehensive Adaptation & Implementation Plan (CAIP)

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Executive Summary

United States 101 (US 101) is the primary highway in Caltrans District 1, serving regional and interregional travel and connecting communities along the Northern California coast. In Humboldt County, the highway serves as a principal arterial route serving commercial, residential, regional through traffic, and access for emergency services including fire, ambulance and law enforcement. The highway also provides access to many recreational areas, including state and national parks, rivers, and beaches along the North Coast.

The six-mile portion of US 101 between Eureka and Arcata—Humboldt County's two largest population centers—is known as the Eureka-Arcata Corridor (hereafter Corridor). This four-lane divided highway, located in a largely semiurban setting along the northeastern shoreline of Humboldt Bay, carries a high volume of daily traffic (it is the highest volume route in the District). The surrounding land uses include commercial, agricultural, residential, aviation, and preserved wildlife habitat areas. The outside shoulders along the Corridor accommodate bicyclists with a designated bike lane, though much of the bicycle traffic has shifted to the recently built Humboldt Bay Trail (Bay Trail) that runs parallel to the Corridor.

The Corridor is situated along Humboldt Bay, which is experiencing the fastest rate of sea level rise (SLR) on the California Coast. Consequently, much of the Corridor is vulnerable to SLR and other coastal hazards. Since portions of the Corridor are likely to experience increased flood exposure and frequency of flooding under future SLR scenarios, the impacts of development on coastal resources have the potential to change with future conditions. To be consistent with the Coastal Act, proposed development must be sited, designed, and conditioned to consider the impact of development on coastal resources over its full design life. The Comprehensive Adaptation and Implementation Plan (CAIP) presented here uses the best available science to identify a suite of strategies necessary to adapt the Corridor to a changing climate and rising seas.

To satisfy Special Condition 2 of the 2019 Coastal Development Permit (CDP 1-18-1078; California Coastal Commission, 2019), California Department of Transportation (Caltrans) must develop a long-term plan for the Corridor from the Eureka Slough Bridges to 11th Street in Arcata. This plan considers and aims to minimize impacts to wetlands, coastal waters, or estuaries and construction that also aims to minimize impacts or alterations natural shoreline processes. This plan addresses the increasing risk posed by climate change and associated coastal hazards. Without proactive planning, the Corridor and associated infrastructure will remain vulnerable to coastal hazard impacts that could impact public safety, mobility, connectivity, the economy, and the long-term viability of the transportation system.

The CAIP identifies conceptual adaptation strategies—protect, accommodate, retreat, and hybrid approaches—to address SLR and other coastal hazards along the Corridor. The primary focus of this adaptation plan is along the current US 101 alignment and construction along Old Arcata Road is not presently feasible. To align with funding and project delivery constraints, the Corridor was divided into 13 segments. Segments with elevations below 16 ft NAVD88 (North American Vertical Datum of 1988), were identified for adaptation. This elevation threshold is based on analyses indicating 15.9 ft NAVD88 provides resilience to 2100 under the intermediate-high SLR scenario with 100-year flood events. Projects with planning horizons beyond 2100 should revisit design elevations at the time of planning. Of the segments evaluated, ten require adaptations, while three already exceed the target elevation and do not.

Adaptation options were developed for each of the 10 vulnerable segments and generally include raised embankments or, where appropriate, viaducts. Nature-based features, such as living shorelines or improvements to drainage infrastructure, are also incorporated. A multicriteria analysis found that raised embankments with nature-based elements provided the highest overall performance for most segments. Viaducts performed better in two segments but at a substantially greater cost.

The CAIP uses a phased adaptation approach tied to environmental triggers and evolving SLR projections. The Eureka/Arcata 101 SLR Resilience Project (0M270), which will raise the roadway to 12 ft NAVD88, is expected to provide resilience to severe flood conditions (more than 4” of water on the roadway is anticipated to occur less than once every 100 years, on average) until at least 2050, potentially extending to 2060 and beyond. Interim measures—such as living shorelines or incremental raising of the Bay Trail—could enhance short- to mid-term resilience if sea levels rise faster than projected. Long-term structural adaptations would be implemented as thresholds are reached.

Designed as a living document, the CAIP will be refined over time based on monitoring data, updated SLR projections, environmental conditions, and funding availability. It is a foundational planning level document that provides a framework for future projects along the Corridor to address SLR and other coastal hazards. The CAIP builds upon previous adaptation planning in the region, incorporates new findings from updated research and technical studies, and considers plans for the Corridor in the context of regional and local plans, policies, and guidance. Thoughtful adaptation planning will improve the Corridor’s resilience to climate change and extreme storm events and is crucial for maintaining connectivity and access to coastal resources in coastal Northern California. The plan will also inform future planned projects within and adjacent to the Corridor.

Document Preparation

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List of Acronyms

$M	millions of dollars
ADT	average daily traffic
C	coastal
C&N	California and Northern
C2	2-year coastal storm event
CAIP	comprehensive adaptation and implementation plan
CCC	California Coastal Commission
CDFW	California Department of Fish and Wildlife
CDP	coastal development permit
CEQA	California Environmental Quality Act
cfs	cubic feet per second
CIP PS	cast in place/prestressed
CoNED	Coastal National Elevation Database
CoSMoS-GW	Coastal Storm Modelin System-Groundwater
CSE	column supported embankment
CSZ	Cascadia Subduction Zone
E & KRR	Eureka and Klamath River Railroad
ED	environmental document
EFDC	Environmental Fluid Dynamics Code
ELC	Eureka littoral cell
ESAL	equivalent single axle load
ESHA	environmentally sensitive habitat area
FHWA	Federal Highway Administration
GH	generalized hydrograph
GHG	greenhouse gas
GPD	Generalized Pareto Distribution
HBAP	Humboldt Bay Area Plan
HDM	Highway Design Manual
HDPE	high density polyethylene
HEC-RAS	Hydrologic Engineering Center-River Analysis System
LCE	Local Coastal Element
M	magnitude
MHHW	mean higher high water
MHW	mean high water
MMMW	mean monthly maximum water
NAVD88	North American Vertical Datum of 1988
NB	northbound
NOAA	National Oceanic and Atmospheric Administration

OPC	Ocean Protection Council
PA&ED	project approval and environmental document
PG&E	Pacific Gas and Electric Company
PID	Project Initiation Document
PM	postmile
PR	project report
PS&E	plans, specifications, and estimates
PVC	polyvinyl chloride
Q	riverine
Q10	10-year riverine storm event
Q100	100-year riverine storm event
Q2	two-year riverine storm event
RCP	reinforced concrete pipe
RWL	reference water level
SAF	San Andreas Fault
SAMSIP	South Arcata Multimodal Safety Improvement Program
SANDAG	San Diego Association of Governments
SB	southbound
SHOPP	State Highway Operation and Protection Program
SLR	sea level rise
SR	State Route
SWAN	Simulating Waves Nearshore
TAC	technical advisory committee
TBDEM	topobathymetric digital elevation model
TI	traffic index
US DOT	United States Department of Transportation
USGS	United States Geological Survey
VA	vulnerability assessment
VLM	vertical land motion
WSE	water surface elevation

1 Introduction

In California, US 101 is an interregional highway running from Los Angeles to the Oregon border. It is a vital transportation artery connecting communities throughout the state and between states. This route is of particular importance along the northern California coast as it is often the only highway route available. Specifically, US 101 serves as a principal transportation route through Humboldt County—a 137-mile stretch with no other South to North highways. US 101 serves commercial, residential, and through traffic, while providing access to emergency services and many recreational areas, including state and national parks, rivers, and beaches. The six-mile portion of US 101 between the cities of Eureka and Arcata, referred to as the Eureka-Arcata Corridor (hereafter Corridor), is a four-lane divided highway set in a largely semiurban setting (Figure 1). As the primary connection between the cities of Eureka and Arcata, the Corridor carries a high volume of daily traffic (approximately 40,000 trips/day) and is surrounded by a mix of commercial, agricultural, residential, and preserved wildlife habitat (Caltrans, 2025c). In addition to serving motorists, cyclists have also used the Corridor to commute. However, since completion of the Humboldt Bay Trail, a substantial portion of the bicycle traffic has shifted to the trail.

Flood-related closures and the resulting loss of highway functionality along the Corridor would have substantial effects on the communities in the region, the economy, and the environment. Within the California Department of Transportation (Caltrans) District 1, which encompasses Del Norte, Humboldt, Mendocino, and Lake Counties, there are no significant rail services. Consequently, the district economy, especially the agricultural industry, is heavily dependent on the state highway system. Closure of the Corridor would result in an estimated loss of $2.7 million dollars per day, with an additional loss of $200 thousand dollars in gross regional product (Caltrans, 2024; Appendix B). There are no interstate highways in District 1, so the major state roads, such as US 101, are the designated principal arterials. The Corridor connects the community to critical infrastructure, such as hospitals, schools and services.

Since portions of the Corridor are likely to experience increased flood exposure and frequency of flooding with future SLR projections, the impacts of development on coastal resources have the potential to change with future conditions. To be consistent with the Coastal Act, proposed development must be sited, designed, and conditioned to consider the impact of development on coastal resources over its full design life. The Comprehensive Adaptation & Implementation Plan (CAIP) presented here uses the best available science to identify a suite of strategies necessary to adapt the Corridor to a changing climate and rising seas.

Figure 1. Map of the Eureka-Arcata Corridor. Red portion shows the limits of the CAIP (postmile 79.9 to 86.3). Inset map shows the location of the Corridor within Humboldt County (light green) and in relation to other state highways (white lines). White box around northern Humboldt Bay indicates area shown in larger image.

Purpose, Need, and Objectives

To satisfy Special Condition 2 of the 2019 Coastal Development Permit (CDP 1-18-1078; CCC, 2019), Caltrans must develop a long-term plan for the Corridor. The plan must consider the portion of the Corridor covered by CDP 1-18-1078, which extends from the Eureka Slough Bridges to 11th Street in Arcata (postmile (PM) 79.9 to 86.3) (Figure 1; Caltrans Postmile Services). This plan must address the increasing risk of SLR and associated coastal hazards, such as tsunamis and flooding, posed by climate change. Without proactive planning, the Corridor and associated infrastructure will remain vulnerable to coastal hazard impacts that could threaten public safety, mobility, access to emergency services, and the long-term viability of the transportation system.

The purpose of the CAIP is to develop long-term strategies that address the anticipated impacts of climate change and coastal hazards along the Corridor.

Objectives of the CAIP include:

- Identifying a suite of strategies to protect, relocate, or otherwise adapt the development authorized under CDP 1-18-1078.
- Providing an updated analysis of current and projected coastal hazards along the Corridor from 2025 through at least 2100.
- Conducting a high-level adaptation alternatives analysis to allow the California Coastal Commission (CCC) to consider the feasibility and Coastal Act consistency of potential alternatives prior to a planned project and CDP application. The goal is to help ensure a permittable project is ultimately proposed.
- The CAIP is a living document and aims to establish a timeline of vulnerability for the Corridor based on the best available science. The construction of the adaptation strategies will be determined based on future need, including feasibility and funding availability.

The plans outlined in the CAIP build upon steps previously taken by Caltrans and other agencies to address SLR along the Corridor and enhance the resilience of coastal resources to SLR. Infrastructure improvements relevant to CDP-1-18-1078 include components of the Eureka-Arcata US 101 Corridor Improvement Project, such as the Tide Gate Replacement Project (Caltrans Project 0J740), Indianola Undercrossing Project (Caltrans 36600), and Jacoby Creek Bridge Replacement (0E000). Separate planning and projects relevant to the Corridor include the Eureka Slough Bridges Replacement Project (Caltrans Project 0M760), Eureka/Arcata 101 SLR Resilience Project (Caltrans Project 0M270), planning for the State Route (SR) 255/101 Interchange, and construction of the Bay Trail.

1.1 Background

Safety Corridor

Historically, several intersections along US 101 that link the Corridor to areas of industrial, residential, and commercial development have had high rates of severe collisions. To improve safety along the Corridor, Caltrans initiated the Eureka-Arcata US Highway 101 Corridor Improvement Project, which included five distinct projects. On September 12, 2019, the CCC issued CDP 1-18-1078 to Caltrans. The permit authorized development of the five safety improvement projects along the Corridor from Eureka Slough Bridges to 11th Street in Arcata (PM 79.9 to 86.3).

CDP 1-18-1078 Special Conditions

As part of CDP 1-18-1078, the CCC adopted Special Conditions to indicate to Caltrans the modifications or assurances needed for consistency with the Coastal Act for future projects within the Corridor. Special Conditions 1 and 2 require that Caltrans undertake SLR adaptation planning to inform decisions about what changes to the approved highway improvements should be made in the future to minimize the risks of flood hazards in the longer term.

Special Condition 1 requires that Caltrans complete SLR monitoring and reporting for the Corridor. Beginning in 2020, Caltrans has submitted Annual Reports to the CCC. These reports include (1) a comparison of the preceding year's water levels to baseline (2020) levels, (2) documentation of any temporary or ongoing flooding events, erosion, or other coastal hazards impacts during the reporting period as well as conditions causing the impacts, (3) descriptions of actions taken to address temporary hazards impacts, and (4) documentation of the progress Caltrans has made towards developing the CAIP.

Special Condition 2 requires that Caltrans develop and submit a full Comprehensive Adaptation and Implementation Plan (CAIP) for the Corridor that identifies a suite of strategies necessary for protecting, relocating, or otherwise adapting the highway to maintain safety from flooding and other coastal hazards. Previous vulnerability assessments for infrastructure along the Corridor indicate a clear need to address climate change and SLR through various adaptation strategies (Caltrans and ICF, 2019). The California Ocean Protection Council (OPC) SLR guidance has been updated since the Caltrans and ICF study, *Caltrans Eureka-Arcata Corridor: Sea Level Rise Vulnerabilities and Adaptation Solutions*, was published. To support the CAIP and development of effective and efficient adaptation solutions, additional technical studies were conducted using the most recent OPC guidance for SLR (California OPC, 2024). The findings of these technical studies are presented in Section 6 Technical Studies.

The proposed strategies aim to minimize risk and enhance highway stability and structural integrity through at least 2100. The CAIP must include an updated analysis of current and future coastal hazards in the Corridor, from 2025 through at least 2100. The CAIP SLR analysis will consider medium-high and extreme risk aversion scenarios following the best available science at the time of plan preparation, and current guidance from the OPC. The CAIP must also include an adaptation alternatives analysis that will enable the Coastal Commission to provide initial feedback on Coastal Act consistency; however, project-specific details will be evaluated at a later phase of Caltrans project delivery.

The adaptation alternatives to be evaluated include accommodation strategies (e.g., viaducts), protection measures (e.g., levees, living shorelines, or other natural or engineered features), and relocation. The CAIP aims to establish a timeline of vulnerability for the Corridor based on the best available science. The construction of the adaptation strategies will be determined based on future need, including feasibility and funding availability.

1.2 Eureka-Arcata U.S. 101 Corridor

US 101 is the region's primary freight, transit, and non-motorized route and is essential for the transport of natural resources and finished products in and out of the region. The section of highway that makes up the Corridor is classified as a Principal Arterial route by the Federal Highway Administration (FHWA) (Caltrans District 1, 2017). The Corridor currently consists of approximately six miles of expressway (areas with at-grade intersections in addition to on- and off-ramps) and one mile of freeway (fully controlled access with on- and off-ramps only). Although the Corridor is surrounded by agriculture and wetlands, it is in a largely semiurban setting with a high volume of traffic.

The first road connecting Eureka and Arcata was built in the 1860s and generally followed the route of present-day Old Arcata Road, which is located about a half mile to the east of and generally runs parallel to the present-day alignment of the Corridor (Figure 1). By the 1900s, Eureka and Arcata were also connected by The California & Northern Railway. From Eureka, the railway followed a path along the shore of eastern Humboldt Bay and headed directly north at Bracut, skipping the inland towns along what is now Old Arcata Road. In 1918, the State Division of Highways began construction of a direct road between Eureka and Arcata. This new highway followed the railway tracks along Humboldt Bay and north of Bracut it ran through tidal flats of Humboldt Bay. In 1954, the Division of Highways expanded the highway from a two-lane facility to four lanes. While the original highway followed the bay north of Gannon Slough into Arcata, the new highway went directly north on its present course.

Today, the combined population of the cities of Arcata and Eureka is approximately 45,000. However, the larger population that uses the Corridor is around 90,000 and includes residents of the surrounding unincorporated areas, such as McKinleyville (CCC, 2019). Currently, most of Humboldt County's growth is occurring in and around cities and communities along US 101 between Fortuna (20 miles south of Eureka) and McKinleyville (15 miles to the north), thus Caltrans anticipates increasing use along the Corridor.

As the principal connection between Eureka and Arcata, the Corridor also provides bicycle access between the two cities and the surrounding area. The Bay Trail, a separated bicycle and pedestrian trail that is now part of the larger California Coastal Trail, was completed in 2025. The Bay Trail generally runs parallel to the Corridor and provides direct multimodal trail access between Eureka and Arcata. A planned connection at Indianola Cutoff will link bicyclists and pedestrians to the Bay Trail.

Despite the region's growth, the land on either side of the Corrido has remained primarily agricultural land, wildlife refuge or restored land, or undeveloped tidelands. The Fay Slough Wildlife Area is adjacent to the Corridor near the Jacobs Avenue/Airport Road intersection and agricultural lands along Gannon Slough, Jacoby Creek, Eureka Slough, Washington

Slough, and Brainard Slough also adjoin the Corridor. Several small areas of industrial, residential, and commercial development have emerged over time, including development at Bracut, Indianola Cutoff, Brainard, Jacobs Avenue, and Murray Field Airport. Many of these developments were built on historically tidal marsh habitat and are still surrounded by environmentally sensitive wetland habitat.

1.3 Environmental Setting

The Corridor is located on a low-lying stretch of land adjacent to Humboldt Bay. Humboldt Bay is the largest estuary between San Francisco Bay and Coos Bay, Oregon. The bay is dominated by marine influences but freshwater input, though relatively small in contribution, has important localized effects on sedimentation, nutrients, and productivity. The bay and surrounding wetlands provide habitat for over 400 species of birds, mammals, fish, and marine invertebrates, many of which have ecological, economical, or cultural significance (CCC, 2019).

The land to the east of the Corridor can be divided into two distinct hydrographic areas: the Eureka Slough complex to the south and the wetland area comprised of Brainard Slough, Jacoby Creek, and Gannon Slough to the north. Historically, these areas were tidelands and characterized by a complex system of tidal and freshwater sloughs (Figure 2). The 1870 US Coast Survey of Humboldt Bay shows several locations where Eureka or Fay Slough formed a direct connection with Arcata Bay (City of Arcata GIS, 2023; Figure 3). Beginning in the late 1800s, the margins of Humboldt Bay were diked and drained for agricultural use or blocked from tidal inundation with the construction of the railroad. Sloughs that once drained directly into Humboldt Bay were redirected through culverts, tide gates, or narrow openings now spanned by bridges.

Figure 2. Mean monthly maximum water inundation coverage (green) for the year 2012 and the 1870 historical shoreline (black line) coverage (from Laird, 2007).

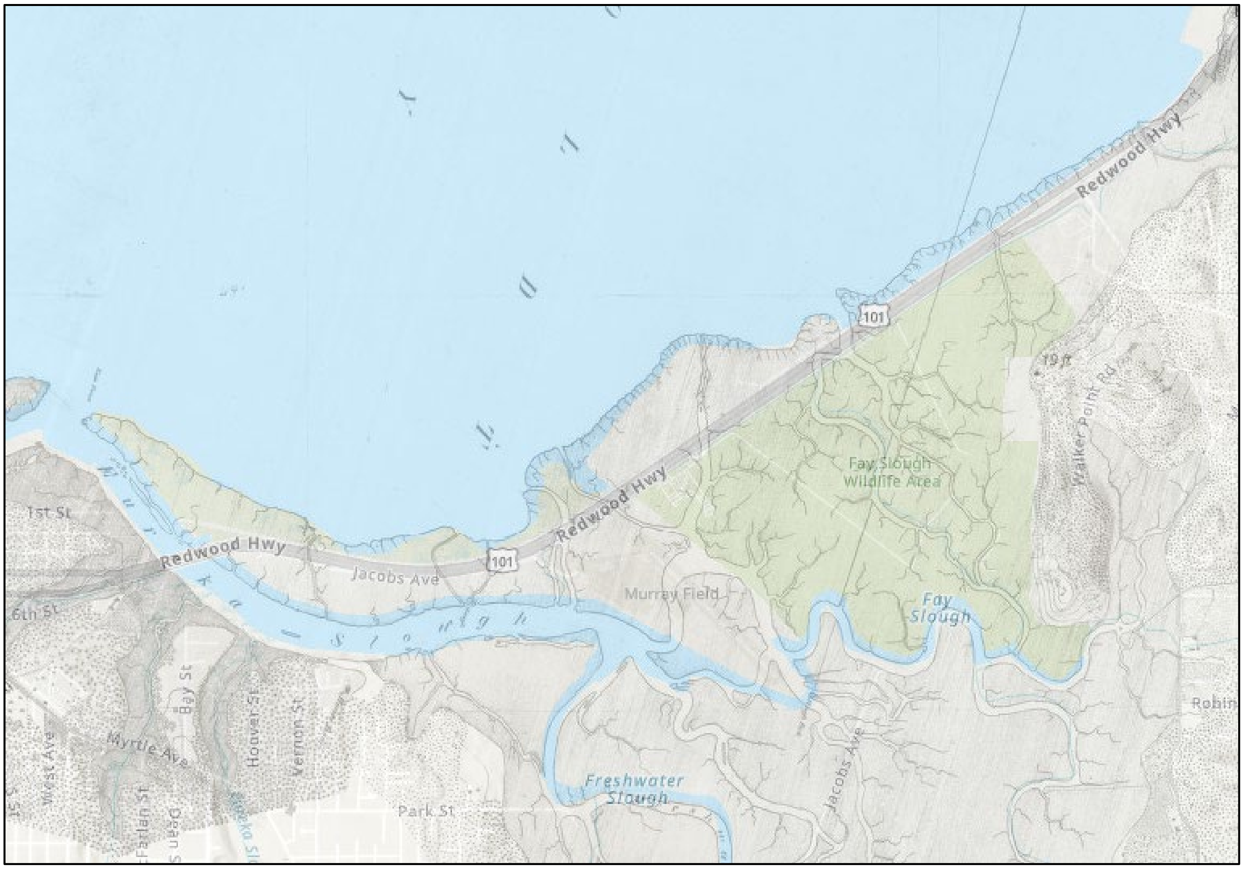


Figure 3. 1870 US Coast Survey Map of Humboldt Bay overlaid on 2023 imagery. Note the direct connections of Eureka and Fay Slough with Arcata Bay (City of Arcata GIS, 2023).

1.4 Key Terms

This section includes a list of key terms used in the CAIP. Some key terms are frequently encountered in discussions surrounding climate change. However, definitions can vary depending on the application. The definitions provided below fit into the context of climate change adaptation for transportation infrastructure.

Adaptive Capacity: Represents the ability of an asset to adjust to climate change or SLR through engineering modifications, operational changes, or policy interventions.

Climate Change Adaptation: Actions/strategies taken to reduce or avoid the impacts of extreme weather events or of longer-term climatic change (e.g., SLR) on an asset or facility. Extreme weather events are those that are larger in scale and intensity than have generally occurred historically.

Coastal Flooding: Refers to flooding of dry and low-lying land submerged by seawater. This can be caused by high tides, storm surge, wind setup, or wave overtopping.

Compound Flooding: Refers to the simultaneous or successive occurrence of multiple flood drivers, such as fluvial, rainfall, coastal, groundwater, and tsunamis.

Dike: A human-made structure that protects land that would otherwise be permanently submerged.

Exposure: The presence of people or assets in an area that is subject to harm. For the vulnerability assessment included in the CAIP, exposure is determined by the Corridor's proximity to Humboldt Bay and tributary rivers.

Flood Depth: Depth of water above a surface (e.g., water depth above the highway).

Flooding: Refers to a temporary, episodic, event-based condition, where water submerges normally dry land.

Flood Hazard: A potential source of harm due to flooding (e.g., coastal flooding).

Flood Risk: The likelihood and severity of harm from a flood hazard.

Fluvial (Riverine) Flooding: Refers to flooding resulting from rivers or streams overflowing their banks and submerging adjacent (normally dry) land.

Inundation: Refers to a chronic condition, such as areas that are flooded by high tides. Also used to describe flood conditions (e.g., inundation extent on maps).

Levee: A human-made barrier with the primary purpose of reducing the frequency of flooding to the floodplain.

Maladaptation: When an action or adaptation, intended to provide a solution, degrades the situation or increases vulnerability.

Nature-Based Adaptation Strategies: A coastal adaptation or erosion control method that is comprised of natural or mostly natural elements, [or] which contributes to the persistence and enhancement of coastal processes and ecological benefits while also protecting inshore areas (CCC, 2026).

Probability: The likelihood or chance that an event will occur, ranging from impossible to certain. In terms of SLR, it is not possible to directly assign probabilities to each sea level scenario. However, additional assumptions about the future (e.g., level of warming) can be used to estimate the probability of exceeding a particular sea level scenario under future conditions. For example, given 3°C warming in 2100, there is a 5% probability of exceeding the intermediate sea level scenario (OPC, 2024).

Resilience: Refers to the ability of roads, highways, and bridges to withstand or recover from extreme flooding events or impacts from other coastal hazards. Resilience is Caltrans' ability to prevent a hazard from turning into a long-term transportation disaster (Caltrans, 2022a).

Risk: A combination of the probability of a hazard occurring multiplied by the consequences of that hazard (typically expressed in dollars), often used to prioritize assets for improvements. Risk is a way to capture the vulnerability of the system in terms of dollars or system impacts. For example, if the highway is closed from a hazard, the economy would be impacted by a certain number of US dollars.

Sensitivity: The degree to which an asset is affected by SLR, typically defined through operational and structural impact thresholds. For transportation infrastructure, sensitivity can be quantified by specific water depth thresholds that trigger monitoring requirements, operational changes, or facility closure.

Vulnerability: The degree to which an asset is susceptible to harm from exposure to hazards, often used to prioritize assets for improvements. Vulnerability is closely related to risk but often expressed in a more qualitative manner. Vulnerability is generally defined as the combination of sensitivity and exposure, mitigated by adaptive capacity or resiliency.

The Federal Highway Administration Vulnerability Assessment training identifies three main approaches to highway vulnerability assessments: stakeholder input approach, indicators approach (setting thresholds), and quantitative risk (related to cost) approach. The CAIP incorporates all three approaches.

Water Level/Water Surface Elevation: Water elevation in reference to a datum such as NAVD88.

1.5 Climate Change Adaptation and the California Coastal Act

Development in the Coastal Zone is governed by the California Coastal Act (Coastal Act), which seeks to address land use, public access and recreation, and protection of coastal and ocean resources. The Coastal Act also provides a framework for managing coastal development in the context of coastal hazards such as storms, flooding, erosion, and SLR. To meet the requirements put forth by the Coastal Act, Caltrans will likely need to identify adaptation strategies for transportation infrastructure that are or expected to become vulnerable to coastal hazards, including SLR. Furthermore, Coastal Commission guidance recommends using the "best available science on SLR scenarios to inform planning decisions and project design" (CCC, 2024). State SLR Guidance is updated by the OPC approximately every five years and represents a synthesis of the best available science on SLR.

1.5.1 Adaptation Approach

Current OPC Guidance (OPC, 2024) provides five SLR scenarios which are defined and labeled according to a target value of global mean SLR (GMSLR) in 2100: low (1.0 ft

GMSLR), intermediate-low (1.6 ft), intermediate (3.3 ft), intermediate-high (4.9 ft), and high (6.6 ft). All SLR scenarios are plausible, but the likelihood of a scenario occurring varies and is embedded in the scenario itself (e.g., the Intermediate Scenario is more likely than the High Scenario). There is greater certainty for near-term projections (before 2050) compared to longer-term projections. Beyond 2050, the range of possible SLR projections expands due to greater uncertainty in future warming and physical processes (e.g., rate of ice sheet loss).

For less adaptive, long-lifespan (i.e., 50+ years) projects, OPC guidance recommends planning for resilience to the Intermediate-High SLR Scenario using the nearest tide gauge (North Spit, Humboldt Bay Tide Gauge for the Corridor area). For even longer-term planning of critical infrastructure, such as highways, OPC guidance recommends planning for resilience to the High SLR Scenario. Meeting these targets can either be accomplished through project design, or the “adaptation pathways” or “phased adaptation” approach (Figure 4). This approach allows decision makers to build resilience by implementing phases of short- and long-term strategies over time. The sequencing of adaptation actions throughout the lifespan of a project can facilitate cost-effective short-term solutions while planning for future adaptations that will be triggered by thresholds or tipping points. The phased approach also provides a way to address the uncertainty in longer-term SLR projections and enables flexibility and adjustments over the course of a project’s lifespan.

The adaptation pathways/phased approach is particularly well-suited for projects that cannot incorporate adaptations to higher or more extreme rates of SLR in the near-term or all at once. In the context of Caltrans planning, the phased approach allows for systematic implementation of several smaller programmable projects that comprise a larger Corridor adaptation plan.

The CAIP incorporates guidance provided by OPC, including the stepwise process to apply SLR scenarios in planning and projects. The CAIP also follows the recommended precautionary and “adaptation pathways” approach, whereby actions can be implemented over time (Figure 4).

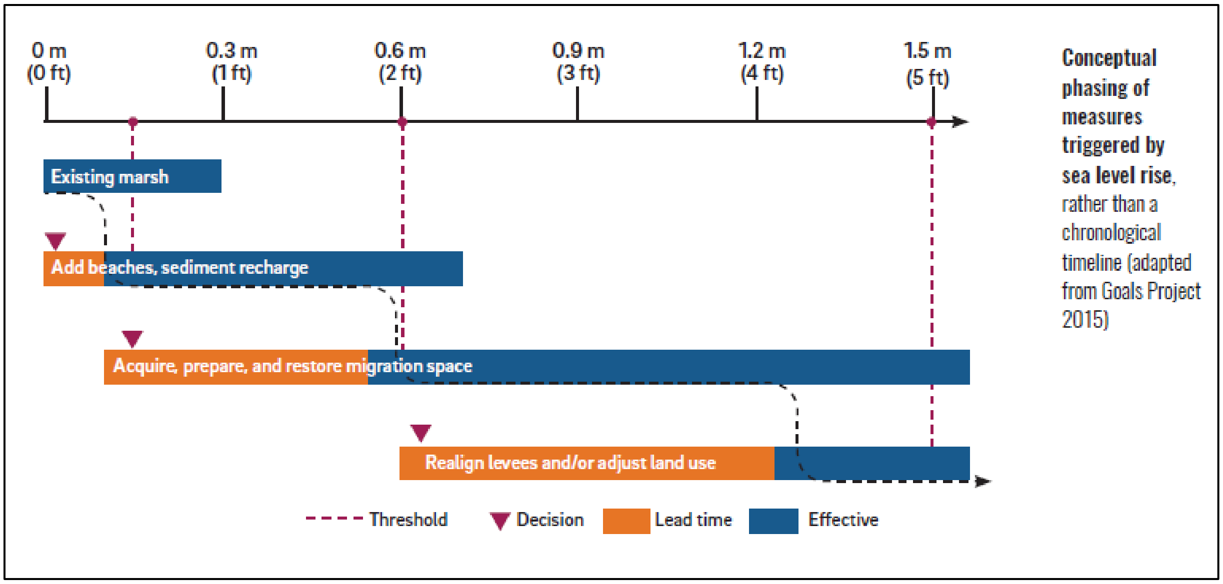


Figure 4. Hypothetical adaptation pathway showing conceptual phasing of measures triggered by SLR. Figure source: San Francisco Bay Shoreline Adaptation Atlas in OPC (2024).

1.5.2 Strategies and Timelines

The CAIP consists of short, medium, and long-term adaptation strategies. For example, SLR monitoring or minor grade raises that provide resilience to SLR for approximately 25 years are considered short-term adaptations, construction of a living shoreline that protects assets for 25 to 75 years might be considered a medium-term adaptation, and larger adaptation projects, such as elevated viaducts, that enhance resilience for 75+ years are considered long-term adaptation solutions. In the absence of a designated project lifespan, the asset's service life can be used to determine which SLR projection to use. Culverts typically have a service life of 50 years and bridge design life per the American Association of State Highway and Transportation Officials specifications is 75 years (Highway Design Manual (HDM) Ch. 880, Caltrans, 2025a). OPC SLR projections are updated approximately every five years. To ensure the best available science is informing plans and project details (e.g., structure elevation), all future planning efforts will need to reassess SLR projections and impacts at the time of project nomination.

The CAIP considers protect, accommodate, retreat, and hybrid strategies for climate change adaptations (Table 1 and Figure 5). Protect strategies prevent flooding and erosion impacts through physical barriers and protective measures. Examples include engineered shoreline protections, such as seawalls and rock revetments, or soft shoreline protections. Soft shoreline protections, also known as "green" or "nature-based" solutions, rely on natural components and processes to provide protection. Accommodate strategies adapt existing infrastructure to be more resilient to impacts from coastal hazards – allowing impacts to pass through the system without harming it. Examples include viaducts, or improved drainage systems and flood-proofing measures. Retreat strategies move assets out of harm's way. Examples include relocating roadways inland to avoid SLR and coastal erosion impacts. Hybrid strategies combine protect, accommodate, and/or retreat strategies for an asset or collection of assets.

Table 1. Adaptation approaches and options (modified from District 1 Climate Change Vulnerability Assessment and FHWA Climate Resilience Pilot, Crow et al., 2014).

<table>
<tr><th>Strategy</th><th>Adaptation Option</th><th>Example</th></tr>
<tr><td rowspan="2">Protect</td><td>Provide major structural protection</td><td rowspan="2">Engineered: Bulkheads or revetments

Nature-based: Living shorelines</td></tr>
<tr><td>Provide protection at existing elevations/locations</td></tr>
<tr><td rowspan="2">Accommodate</td><td>Elevate the infrastructure above the impact zone</td><td rowspan="2">Viaducts, upsized culverts</td></tr>
<tr><td>Enhance drainage to minimize closure time and/or deterioration levels</td></tr>
<tr><td rowspan="3">Retreat</td><td>Abandon infrastructure</td><td rowspan="3">Relocate roadway out of harm's way</td></tr>
<tr><td>Relocate infrastructure</td></tr>
<tr><td>Temporarily restrict use of infrastructure</td></tr>
</table>

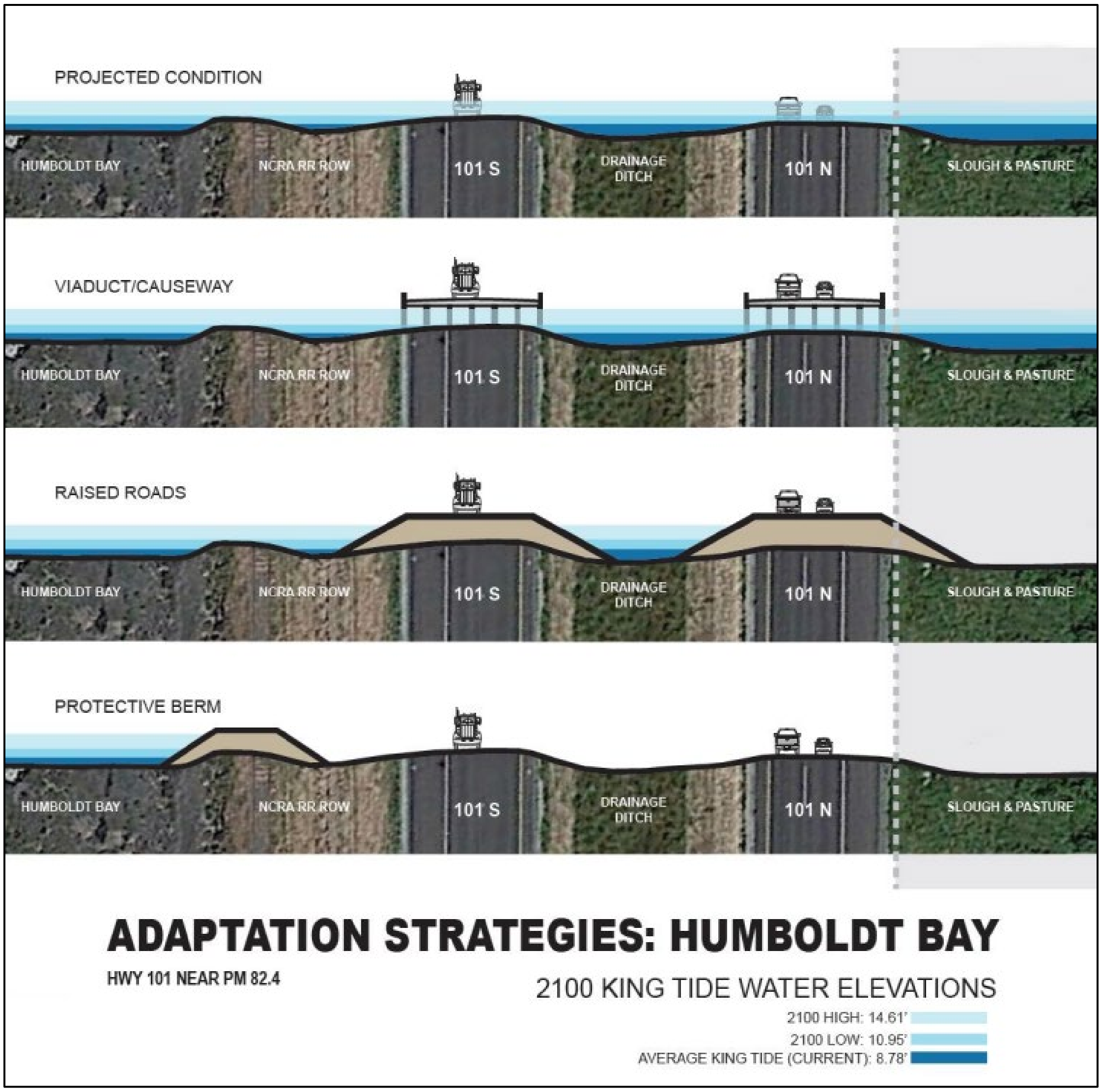


Figure 5. Visual examples of adaptation strategies for the Corridor. Strategies shown include accommodate (viaduct/causeway and raised road) and protect (protective berm). Note that projected 2100 High and Low water levels are based on the International Panel on Climate Change Fourth Assessment Report (2007) – data, science, and models have since been updated. Figure from GHD, Trinity Associates, and ESA PWA, (2014).

2 Policy and Guidance Documents

Numerous documents contributed to the development of this CAIP. A comprehensive list of policy and guidance documents can be found in Appendix C. Primary documents relied upon for the CAIP are listed and summarized below.

2.1 California State Policies

California Coastal Act (California, 1976): Nearly all of the Corridor is in the Coastal Zone. As such, development must be consistent with the Coastal Act. The Coastal Act governs decisions regarding adaptation strategies designed to address current or future vulnerabilities related to coastal hazards and mandates protection/enhancement and restoration of coastal resources including public access, recreation, marine environments, water quality, agricultural land, and environmentally sensitive habitat.

> **Coastal Act: Public Resources Code Division 20 Section 30421:** States that state and regional agencies shall identify, assess, and, to the extent feasible and consistent with their statutory authorities, avoid, minimize, and mitigate the impacts of SLR.

Various policies implemented at the state level have directly addressed not only greenhouse gas (GHG) mitigation, but climate adaptation planning as well. These policies require State agencies to consider the effects of climate change in their investment and design decisions, among other considerations. State adaptation policies that are relevant to Caltrans include:

Director's Policy 004: Environmental Policy (Caltrans,1992): Requires Caltrans to evaluate the environmental benefits and consequences of its activities and implement practices that minimize environmental impacts. Requires Caltrans to integrate environmental considerations into all Departmental decisions and activities. Includes examining ways to ensure timely coordination and review of transportation programs and projects and resolution of environmental issues during the planning stages with all federal, state, and regional agencies, other public agencies, public interest groups, and the private sector to not adversely affect project delivery. Through cooperation and partnerships with these interest groups, develop innovative and effective mitigation strategies and techniques.

Executive Order S-13-08 (California, 2008): Requires all planning and construction projects by state agencies in areas vulnerable to future SLR to consider a range of SLR scenarios for the years 2050 and 2100 to assess project vulnerability and reduce risks and increase resilience to SLR.

Director's Policy 30: Climate Change (Caltrans, 2012): Outlines roles and responsibilities for coordinated efforts to incorporate climate change and GHG reduction efforts into Departmental decisions and activities. Climate change adaptation efforts shall include development of methods to protect people, places, and resources from impacts of climate change, including consideration of SLR and planning and implementing appropriate design changes to bridges and other transportation infrastructure.

Executive Order B-30-15 (California, 2015): Requires the consideration of climate change in all state investment decisions through full life cycle cost accounting, the prioritization of adaptation actions that also mitigate GHGs, the consideration of the state's most vulnerable populations, the prioritization of natural infrastructure solutions, and the use of flexible approaches where possible.

Assembly Bill 1482: Climate Adaptation (California, 2015): Requires all state agencies and departments to prepare for climate change impacts by continued collection of climate data, considering climate in state investments, and promotion of reliable transportation strategies.

Assembly Bill 2800: Climate Change and Infrastructure Planning (California, 2016): Requires that state agencies account for climate impacts during planning, design, building, operations, maintenance, and investments in infrastructure. It also requires the formation of a Climate-Safe Infrastructure Working Group represented by engineers with relevant experience from multiple state agencies, including Caltrans.

Executive Order N-82-20 (California, 2020): Climate and biodiversity policy aimed at conserving natural resources and using them as tools to combat the effects of climate change. Calls for expanding the use of nature-based strategies to enhance climate resilience.

Senate Bill 1: Coastal Resources: sea level rise (California, 2021): Requires transportation funding be used, where feasible, to preserve and protect environmental resources and reduce environmental impacts using project features that promote adaptation to withstand the negative impacts of climate change. Requires state agencies to identify, assess, and, to the extent feasible and consistent with their statutory authorities, avoid, minimize, and mitigate the impacts of SLR; grants the CCC policy authority over identification, assessment, and, to the extent feasible, avoidance and mitigation of the adverse effects of SLR.

2.2 California State Guidance

State of California SLR Guidance (OPC, 2024): The OPC guidance provides state and local decision-makers with guidance to incorporate the best available science on SLR into planning, design, permitting, investments, and other decisions. The OPC report includes SLR scenarios, which are based on global projections in the latest Intergovernmental Panel on Climate Change report, and policy recommendations. OPC guidance is updated approximately every five years.

SLR Policy Guidance (CCC, 2024): The CCC guidance provides information on how to apply the Coastal Act to the challenges presented by SLR through CDP decisions. The guiding principles include using the best science; a precautionary approach by considering high or extreme SLR projections, particularly for critical infrastructure; considering local conditions, goals, and priorities when developing adaptation strategies; accounting for the social and economic needs of the public; maximizing protection of public access, recreation, and sensitive coastal resources; maximizing natural shoreline values and processes; coordinating and planning regulatory decision making with appropriate local, state, and federal partners; and maximizing public participation in planning and regulatory process.

2.3 Caltrans Climate and Design Guidance

Caltrans Highway Design Manual, 7th Edition (Caltrans, 2025a): Establishes uniform policies and procedures to carry out the state highway design functions of Caltrans. Per the Highway Design Manual, Caltrans is required to assess SLR according to OPC's State of California SLR Guidance.

Caltrans Adaptation Priorities Report – District 1 (Caltrans, 2021): Identifies Humboldt Bay as one the most vulnerable areas in District 1 due to high risk from SLR.

Caltrans Design Manual for Hybrid Coastal Protection Strategies (Caltrans, 2022a): Incorporates effects of SLR into previously developed highway design procedures to mitigate the impact of SLR hazards. Design guidance is focused on nature-based adaptation strategies.

Climate Change Emphasis Area Guidance for Corridor Planning (Caltrans, 2022b): Guidance for incorporating climate change adaptation and mitigation into the Corridor planning process.

2.4 Regional and Local Plans, Policies, and Guidance

Humboldt Bay Area Plan Draft Document (Draft): Establishes policies that govern the use of land in the unincorporated area around Humboldt Bay and over 20 miles of Pacific coastline. Note this is a draft document and has not undergone review by the Humboldt County Planning Commission, Board of Supervisors, or vetted by the CCC.

Draft Local Coastal Element (City of Arcata, 2026): The Local Coastal Element (LCE) is a component of the Land Use Plan and identifies policies to enact the Coastal Act locally and contains implementation measures where necessary to enact the provisions and policies of the Coastal Act. The LCE is a legal mandate that governs private and public actions.

3 Caltrans Planning Framework

3.1 List of Partners and Agencies

Caltrans District 1 is the lead agency for developing the CAIP for the Corridor. Cal Poly Humboldt and Northern Hydrology & Engineering conducted technical studies that examined the impacts of coastal hazards to the Corridor. State agencies, including the CCC and California Department of Fish and Wildlife (CDFW), provided regulatory guidance throughout the development of the CAIP. A Technical Advisory Committee (TAC) was established to provide guidance and feedback throughout development of the CAIP. The TAC was comprised of representatives from the CCC, CDFW, City of Eureka, City of Arcata, Humboldt County, Cal Poly Humboldt, Northern Hydrology and Engineering, Caltrans, GHD, the Wiyot Tribe, Humboldt County Association of Governments, and California State Water Resources Control Board.

The TAC provided feedback during four in-person workshops including the modeling parameters, adaptation options, location of important adjacent infrastructure, access concerns regarding future land use, and weighting of criteria in the multicriteria evaluation tool. The TAC was also provided a draft of the CAIP for early feedback prior to the public comment period.

3.2 The CAIP

The CAIP is a foundational, planning-level document that provides the framework for subsequent phases within the Caltrans Project Delivery Process (Figure 6). The CAIP also contributes to the Caltrans Climate Adaptation Assessment Process, a headquarters/statewide effort, by providing relatively high-resolution information on coastal hazards and the vulnerability of and potential impacts to the Corridor (Caltrans, 2020). Potential adaptations to enhance resilience are also identified in the CAIP. It is recommended that Caltrans projects in the Coastal Zone, where a CDP is required, consider SLR in all phases of project planning. This is particularly important during project nomination and scoping (pre-K and K Phases), and in preparation of environmental documents (0 Phase). CAIP development involved early coordination with the CCC and local agency staff to appropriately address SLR along the Corridor. Coordination throughout the project delivery process (described in more detail below) will help ensure

SLR is adequately addressed in projects along the Corridor, improve project outcomes, and minimize delays in processing CDP applications.

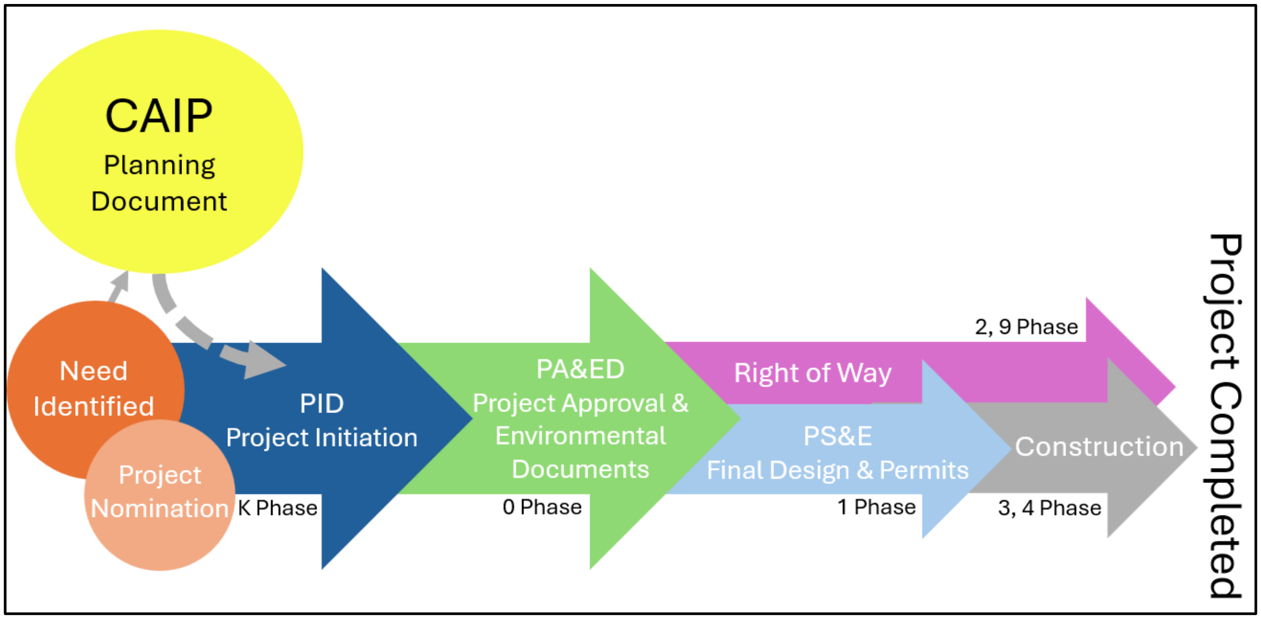


Figure 6. The Comprehensive Adaptation and Implementation Plan (CAIP) in the context of the Caltrans Project Development Process. The CAIP is a pre-K Phase foundational planning document that provides the framework for subsequent planning phases (labeled and indicated by colored arrows) and documents. See 'Caltrans Project Development Process' below for a description of each phase. (Figure modified from Caltrans, District 4, 2022).

3.3 The Project Development Process

This section was adapted from *How Caltrans Builds Projects* (Caltrans, 2011) and California Transportation Asset Management Plan.

Transportation planning is a long-range (20+ year), area-wide, multiagency collaborative process to identify and plan for future transportation needs. Transportation planning aims to prepare and provide mobility for all travelers in a fiscally and environmentally responsible manner.

Each district identifies State Highway Operation and Protection Program (SHOPP) projects based upon performance goals set by the State Highway System Management Plan. SHOPP projects are identified through asset management prioritized inventories of need. Where applicable, Comprehensive Multimodal Corridor Studies, Feasibility Studies and locally developed plans and studies are also used to inform the scope of SHOPP Project Initiation Documents (PID, Figure 6). Non-SHOPP PIDs are typically identified by Regional Transportation Planning Agencies within the district and are based upon a local plan. The PID, developed during the K-phase, connects transportation planning and asset management to project delivery and serves as the first formal step toward creating a solution for transportation problems. The primary purpose of a PID is to provide stakeholders, decision makers, and the Project Development Team with a broad understanding of the project's purpose and need, as well as engineering details that describe the scope, schedule, and cost of the project. The PID scopes a project, often within an established budget, and Caltrans can then use the PID as a candidate for programming.

After the California Transportation Commission approves and programs a project, the project enters the Project Approval and Environmental Document (PA&ED) Phase (0Phase, Figure 6), and the project team can begin detailed studies. The PA&ED phase aims to provide sufficient information to obtain environmental compliance and project approval. For projects that are vulnerable to SLR, Caltrans guidance directs the team to complete a technical SLR study no later than the PA&ED phase, and potentially earlier depending on the project. During PA&ED, the project team refines the information in the PID and develops the Project Report (PR), which supplies the details needed to decide the project's final scope, schedule, and cost. The project team must consider all reasonable and feasible alternatives to comply with federal and state law. The team conducts environmental studies to analyze the effects and impacts of these alternatives. All projects must comply with the California Environmental Quality Act (CEQA), and any project using federal funds or requiring federal action must comply with the National Environmental Policy Act as well. The team presents environmental findings in the Environmental Document (ED). After the PR and ED receive approval, the project moves to the next steps, where the team first completes detailed design and then acquires any necessary right of way and permits.

The Plans, Specifications, and Estimates (PS&E) phase (1 Phase, Figure 6) begins once the PR and ED are approved. The team determines the final right of way requirements (2, 9 Phase, Figure 6) and initiates procurement. The PS&E phase generates a complete set of project plans that allow a contractor to bid and build the project.

Other agencies protect resources under their regulatory jurisdictions through the permitting process, often by requiring mitigation to offset project impacts. The project team consults with agencies throughout engineering and environmental studies, project approval, and design stages. Some agencies finalize agreements concurrently with Caltrans' completion of the PA&ED phase, while others do so once the team completes the detailed design during PS&E. The permits and approvals required for a project depend on the affected resources (see Table 2 for list of anticipated permits, certifications, and agreements for potential CAIP projects).

Table 2. Anticipated permits, certifications, and agreements for construction and implementation of CAIP adaptation options on the Corridor (Adapted from Caltrans, 2011).

Resource	Agency	Permit, Certification, or Agreement
Eligible Historic Sites or Publicly Owned Parks, Recreational Areas, or Wildlife or Waterfowl Refuges	Caltrans (delegated from FHWA)	Section 4(f) of the US Department of Transportation Act (49 US Code § 303)
Coastal Resources	Coastal Commission City of Arcata, City of Eureka, County of Humboldt	Coastal Development Permit Local Coastal Development Permit (potential to consolidate with State)
Fish and Wildlife Habitat	CA Department of Fish and Wildlife U.S. Fish and Wildlife Service National Marine Fisheries Service	Incidental Take Permit or Consistency Determination Consultation Consultation
Water	CA Department of Fish and Wildlife Regional Water Quality Control Board U.S. Army Corps of Engineers CA State Lands Commission CA Coastal Commission	Section 1600 Lake and Streambed Alteration Agreement Section 401 Water Quality Certification Section 404 Individual Permit State Lands Agreement Coastal Development Permit (potential to consolidate local CDP)
Cultural	State Historic Preservation Office	Concurrence with National Historic Preservation Act

Once project design is complete, all properties and permits for the project have been obtained, and funding for the construction phase is in place, a bid package is assembled for advertising. The construction phase (3, 4 Phase) involves all activities from approval of the construction contract through project close-out. It is during the construction phase that transportation plans become a reality – improvements are built as specified in the plans.

The project development process is complex, involving coordination across numerous teams and stakeholders. On average, the timeline from the start of the PID to construction spans five to ten years, with larger projects spanning upwards of 20 years. The structured, multi-phase process is designed to ensure projects are developed and constructed in the best interest of the State while optimizing the use of finite resources.

3.4 Engagement

During the development of the CAIP, Caltrans consulted with technical experts, held four in-person workshop meetings with the TAC (refer to Section 3.1 List of Partners and Agencies), and engaged with the public during the public review period and the 101 Open House. Descriptions of engagement activities and methods, and a list of stakeholders, can be found in Appendix D. Future engagement activities for CAIP updates will follow the recommendations of the PEP. However, as projects are programmed for construction each project will develop its own PEP.

4 Constraints and Opportunities

4.1 Funding

Transportation infrastructure funding is limited at the local, state, and federal level with needs far outweighing available funding. Therefore, important considerations are applied to all projects to ensure the best use of limited funds and resources.

State Highway Operations and Protection Program (SHOPP) and the Minor Program

The SHOPP is a four-year program to fund projects that collectively improve the condition, operation, and sustainability of the State Highway System and associated transportation infrastructure in California. The SHOPP funds emergency repairs, safety and condition improvements, and some highway operational and modal improvements. SHOPP funds are fiscally constrained by the State Transportation Improvement Program Fund estimate for the corresponding year, which typically cannot fund all existing and anticipated needs. Only the highest priority projects are allocated funding.

The Minor Program is a component of the SHOPP that allocates funding for smaller, lower-cost capital projects that meet SHOPP eligibility criteria. These funds allow Caltrans to address modest project needs that are beyond the scope of the Caltrans Maintenance Program. This program funds small scale projects, in Fiscal Year 2024-25 the Minor B Program covered up to $461,000 and the Minor A Program covered $461,001 to $1.2 million (Caltrans, 2025b).

The SHOPP and Minor Program are potential funding sources for projects that would involve replacement or repair of damaged assets or assets near the end of their design lives. Climate specific performance targets can be used to fund SLR adaptation projects. Additional performance targets for assets such as culverts, pavement, or bridges, could be used to supplement climate adaptation or resilience projects, as appropriate and feasible. More often, projects that address core assets are supplemented by climate funds.

Special Legislative Funds

Special legislative funds could be used to support adaptation projects along the Corridor. This type of funding would likely need to be strongly supported/requested by partner agencies (e.g., the Coastal Commission).

Climate Adaptation Grants

Currently, climate related grant funding is limited at both the state and federal level. Caltrans is not typically eligible for state grant programs, with much of the existing funding available to local agencies and the like. Caltrans does administer a number of grant programs, typically available to local agencies, with one program providing a nexus for climate planning. Caltrans is eligible for federal grants should future opportunities come available. In the recent past, the United States Department of Transportation (US DOT) Promoting Resilient Operations for Transformative, Efficient, and Cost-saving Transportation program provided grant funding opportunities for large scale resilience type projects, although this program has been suspended by the US DOT and it is unknown if it will return.

Sustainable Transportation Planning Grants provided through Caltrans fund local and regional adaptation planning for California's transportation infrastructure, such as roads, railways, bikeways, trails, bridges, ports, and airports. This type of funding could be used, for example, by Humboldt County to enhance resilience of the Bay Trail to SLR and coastal hazards.

Senate Bill 1 (California, 2021) directs the state to provide funding to local and regional governments to develop SLR adaptation plans and implementation projects. The Senate Bill 1 Grant Program contains funding tracks for pre-planning and planning phases and for the project phase. This type of funding could be used by, for example, Cal Poly Humboldt to investigate potential adaptation plans for parcels adjacent to the Corridor, such as the Fay Slough Wildlife Area, or the City of Arcata to plan or implement restoration projects on parcels along the northern portion of the Corridor. The SB1 Grant Program has funding allocated through 2026. Future funding opportunities through the program are uncertain.

Emergency Work Funding

Emergency work is intended to restore and repair damages facilities to the condition that existed prior to the triggering event, or to prevent imminent failure of a facility. Emergency work is therefore limited in scope and funding. While minor alterations may be made to comply with current safety standards (i.e., use of the most current guardrail system etc.) large scale changes, such as replacing a road with a viaduct or relocating a road are not eligible to be funded under an emergency, nor is this type of work covered by emergency environmental permits. If the emergency repair is completed and found to be inadequate, Caltrans can prioritize the location and seek other funding opportunities for traditional programming.

4.2 Land Use and Existing Development

There are 83 parcels adjacent to the Corridor right of way, most of which are east of the Corridor, and even more hydraulically connected parcels. This creates opportunities for coordinated planning to mitigate flood risk and manage land use. About half of the immediately adjacent parcels are state or publicly owned, while the other half are privately owned.

The Jacobs Avenue area (approximate PM 80.01 to 80.84) at the north end of Eureka was developed on diked former tidelands and is vulnerable to compound flooding. This area includes commercial, light industrial, warehouse, and residential (mobile home park) uses. The Jacobs Avenue area is protected from coastal flooding by a system of dikes along the southern shoreline that borders Eureka Slough. Humboldt County developed the "Sea Level Rise Adaptation Plan for Transportation Infrastructure and Other Critical Resources in the Eureka Slough Hydrographic Area, Humboldt Bay." Humboldt County was the lead agency for this plan and the grantee for the Adaptation Planning Grant administered by Caltrans. The plan was developed in collaboration with the City of Eureka and Humboldt County Association of Governments who served as co-sponsors. This plan, primarily authored by ESA and GHD, identified raising the surrounding dikes as a possible adaptation strategy to protect Jacobs Avenue from SLR flooding, though implementation of this plan is contingent on funding (GHD et al., 2021).

The Murray Field County Airport (PM 81.0) is located just north of the Jacobs Avenue industrial area. The airport currently serves cargo, business, corporate, and personal aircraft. The airport is situated on leveled fill in an area that was historically tidal marsh and is still surrounded by environmentally sensitive wetland habitat. In November 2025, Cal Poly Humboldt, in partnership with Humboldt County and Caltrans District 1, was awarded funds by the Coastal Conservancy to complete the Murray Field Airport Sea Level Rise Planning and Economic Feasibility Study. The study will utilize existing and forecasted hydrological data to understand challenges posed by SLR to the airport facilities and explore feasibility of options such as adaptation, protection, or relocating.

The CDFW Fay Slough Wildlife Area (approximate PM 81.16 to 82.50) is located to the east of the Corridor between Eureka Slough/Murray Field Airport and Indianola Cutoff. The 484-

acre wildlife area is previously grazed land that has been restored to coastal and seasonal wetlands and is used for wildlife viewing, birdwatching, and hunting. Portions of the wildlife area are managed as freshwater wetlands.

The Brainard Industrial Park (approximate PM 81.12 – 81.93) is a peninsula of land on the bay side of the Corridor across from Harper Motors. The site was created on filled and paved former tidelands and is protected by a perimeter dike, along which the Bay Trail is routed. Historically, the California Redwood Company operated a lumber mill and air-dry yard. The northern portion of the site is currently vacant or underutilized industrial and administrative structures. In 2019, the site was annexed into Eureka City limits with the intention of providing an industrial site for new industrial or manufacturing jobs. The 76-acre property is currently zoned General Industrial.

The City of Arcata Baylands (Jacoby Creek/Gannon Slough Wildlife Area) is a 586-acre wildlife area located east of the Corridor between Bayside Cutoff and the SR 255/101 Interchange (approximate PM 83.92 to 85.67). Portions of the Baylands are currently leased for cattle grazing, however, the City of Arcata's LCE states, "Coastal wetland habitats will be allowed to migrate [o]nto the City-owned Jacoby-Creek/Gannon Slough Wildlife Area as part of the overall management of the wildlife area…" This is referred to as Zone 2 Restoration Areas in the Draft LCE (City of Arcata, 2026). Tidal reintroduction to land east of the highway was also identified as a potential approach to enhance habitat quality and reduce compound flood impacts in the lower Jacoby Creek valley (Michael Love & Associates et al., 2024; Jacoby Creek Water Sustainability and Anadromous Fish Habitat Enhancement Feasibility Study).

According to the City of Arcata's LCE, the SLR adaptation strategy for land to the west of the highway, specifically the "urban peninsula" on G Street, will be a combination of protect in place and measured retreat. To the extent practicable, the peninsula will be defended while floodwater and tidal inundation can be accommodated in lower lying areas preserved for that purpose. "Existing development endangered by flooding, such as the wastewater treatment plant, South G Street, commercial and industrial uses, working agricultural lands, and infrastructure shall be permitted to be protected by the least environmentally damaging means practicable." The City's strategy does not include adding protective barriers to any developed or undeveloped areas that are not currently protected by the existing dike system around the Bay. Retreat will be initiated as a second phase in the SLR Adaption Zone 1, which includes South G Street.

As the existing parcels and transportation infrastructure are interconnected, collaborative planning is essential to an equitable (or agreeable outcome) that supports the unique and individual needs. There are community-wide opportunities to collaborate with parcel owners to help with adaptation strategies for SLR.

Humboldt Bay Trail (Bay Trail)

The Bay Trail is a paved, multi-use path that connects the communities surrounding Humboldt Bay. The City of Eureka, City of Arcata, and County of Humboldt each developed portions of the Bay Trail over the last 15 years. It supports both recreational use and active transportation and is part of the regional Great Redwood Trail and the statewide California Coastal Trail. The trail follows the edge of Humboldt Bay, running primarily between the railroad and the Corridor, except for a one mile stretch that detours along the dike around the Brainard Mill Site. In addition to providing multimodal coastal access, the trail offers some protection to the Corridor – for example, the section between Brainard and Bracut has armoring and certain segments of the trail are higher in elevation than the existing highway. This portion of the Bay Trail was specifically designed to mitigate immediate flood risks along the shoreline, which benefits the Corridor. Technical information for Humboldt Bay Trail South is available in the Project Description Report (Humboldt County, 2020) which describes the basis of design for the elevations of the trail corridor.

Adjoining Roads

There are several county and city roads that adjoin the Corridor. These include Jacobs Avenue, Indianola, Bayside, two access roads into the Fay Slough Wildlife Area, Brainard, north- and southbound driveways, and Cole Avenue.

4.3 Environmental Considerations

Environmental

The Corridor is adjacent or close to environmentally sensitive habitat areas (ESHAs). CDP findings indicate the riparian area adjacent to the 101 Slough north of Harper Motors and an area of riparian forest adjacent to the Brainard Slough north of Bracut qualify as ESHAs. Additional areas along the Corridor would likely qualify as ESHAs, including three-parameter and coastal wetlands.

Since critical habitat has been identified adjacent to the Corridor, permits and mitigation for projects in this area will be required, and seasonal work windows are anticipated (Caltrans, 2025c).

Wildlife Connectivity

The *Wildlife Connectivity: Transportation Projects Act* (Assembly Bill No. 2344; California, 2022) requires Caltrans to identify and remediate potential wildlife connectivity barriers for projects implemented in designated connectivity areas along the state highway system. Future adaptation projects, particularly those involving hydraulic structures, offer opportunities to enhance wildlife connectivity by incorporating water-conveying underpasses or modified culverts that facilitate passage for both fish (in accordance with

Senate Bill 857 (California, 2005) and wildlife (e.g., otters). Design of crossing structures would be informed by connectivity needs and characteristics of the specific location (e.g., topography). This legislation might also encourage the construction of infrastructure, such as a viaduct, that inherently supports fish and wildlife movement.

4.4 Engineering and Design

Design specifications discussed below are from the Caltrans Highway Design Manual (Caltrans, 2025a) and Standard Plans (Caltrans, 2024).

Design Life of Structures and Assets

The design life of bridges, tide gates, culverts, and pavement has the potential to constrain adaptation timelines (Table 3). For example, adaptation of a bridge is not likely to occur until either the design life has been met, or the structure has failed. Arrival at the end of a structure's design life could provide an opportunity to incorporate adaptation measures, such as a higher bridge or upsized culvert.

Table 3. Various structures or assets and their corresponding design life.

Structure/Asset	Design Life in Years
Pavement	No less than 40
Culvert	Variable, approximately 20 - 50
Tide gate	Highly variable, 5 - 30
Bridge	75

Design Considerations

Guidance from the HDM Ch. 880, *Shore Protection*, states that design high water level should be determined as a first step to designing shore protection (Caltrans, 2025a). A starting point of reference for the determination of the design high water level is that the protection withstands high water levels caused by meteorological conditions having a recurrence interval of one-half the service life of the protected facility. The HDM also indicates the initial analysis, which is based on meteorological conditions, may have to be adjusted to conform with a subsequent analysis which considers the level of related risks, local historic high-water marks, SLR and climate change. The elevation of the design high tide may be taken as mean sea level plus one-half the maximum tidal range (Rm).

The width of the Corridor will depend, in part, on whether the northbound (NB) and southbound (SB) lanes are constructed as separate or combined structures. If built as separate facilities (embankment or viaduct), each direction would be approximately 39 to

53 feet wide consisting of two 12-foot lanes, a 5-foot inside shoulder, and a 10-foot outside shoulder (HDM Ch. 300, Caltrans 2025a). The larger width of 53' includes a 14' wide bike/pedestrian trail on the northbound facility, which would be redundant to the separated Humboldt Bay Trail. If the lanes are consolidated onto a single facility, the total width of the Corridor would range from approximately 80 to 94 feet (Table 4). The 14' width of a bike/pedestrian lane and 2' width of a median are based on the Planning and Environmental Linkages report for SR 37 (Caltrans, 2022). Note the total facility width of an embankment would be wider due to roadway prism slopes. The widths in Table 4 do not include this additional width.

Table 4. Width breakdown of separate and single facilities along the Corridor. Asterisk (*) indicates the total width is only applicable to a viaduct, not an embankment. We did not include a width for a bike/pedestrian trail adjacent to an embankment because it would not be fundamentally different from the existing Humboldt Bay Trail.

Viaduct or Embankment	Separate Facilities			Single Facility	
	NB	SB	Total	NB & SB	Total
Outside Shoulder	1 x 10'	1 x 10'	20'	2 x 10'	20'
Travel Lanes	2 x 12'	2 x 12'	48'	4 x 12'	48'
Inside Shoulder	1 x 5'	1 x 5'	10'	2 x 5'	10'
Median	--	--	--	1 x 2'	2'
Total	**39'**	**39'**	**78'**	**--**	**80'**
Bike/Pedestrian	--	1 x 14'	14'	1 x 14'	14'
***Total**	**39'**	**53'**	**92'**	**--**	**94'**

The Corridor design must accommodate large trucks, considering factors such as tangential alignment, curvature, and lane width. A cross-slope of approximately 0.5% should be incorporated to ensure adequate drainage and reduce the risk of skidding.

With a minimum embankment slope of 4:1, grade raises along the Corridor would expand the highway footprint onto adjacent land, possibly affecting right of way needs and triggering environmental impacts that require mitigation. Solutions that allow for steeper slopes should be considered as appropriate and when right of way or environmental constraints are substantial.

The highway system frequently crosses or interacts with floodplains, but the FHWA has emphasized that highways are not designed or intended to function as flood control structures (i.e., as a levee) (USDOT, FHWA, 2008). Consequently, FHWA does not set flood control standards for highway embankments. For example, highway embankments do not include design features, such as an internal impervious core and freeboard, required for a levee or other flood control structure. The fill material typically used in highway embankments does not provide a sufficient barrier against water; therefore, a highway embankment is vulnerable to piping, seepage, and infiltration. Most interstate embankments were constructed to avoid overtopping by a flood with a 2 percent chance of being exceeded in any given year (50-year flood). FHWA notes this requirement does not imply an embankment serves as a flood control, but rather the intent is to prevent loss of the embankment. FHWA guidance clearly states that designating highways as levees is not an acceptable practice and should be opposed. This guidance is based on several factors, including the inadequacy of highway design for flood control purposes, the potential for unsustainable costs, liability, and damages, the need for specialized engineering evaluations by professionals with expertise in flood control systems, and that FHWA lacks the authority to undertake flood control responsibilities.

Vertical clearance requirements as defined by the HDM will constrain roadway elevations under existing structures, for example, the Indianola Undercrossing and the Route 255/101 Separation Bridge (HDM Ch. 300, Caltrans, 2025a).

It has been noted that existing research suggests compacted roadway embankments may enhance resilience to tsunami-driven roadway scour (Francis, 2006). Because of the design uncertainties and substantial environmental costs, this type of measure was not considered throughout this planning level document. However, future projects within the tsunami zone should review potential measures to enhance resilience to tsunamis.

Right of Way

Right of way constraints impose horizontal limitations on the construction of raised embankments or viaducts and must be addressed early in the project development process. Traditional embankments, with a typical 4:1 slope requirement, demand considerably more lateral space than alternatives such as column-supported or geotechnically reinforced embankments. As a result, right of way boundaries can strongly influence the choice of construction method. For instance, geotechnically reinforced embankments may allow for the construction of a raised roadway within tight right of way limits where traditional embankments would be unfeasible. Right of way will also need to be considered for traffic management and construction staging.

Highway Construction

Highway construction costs can be extremely variable depending on the construction scenario. Factors include traffic control, staging, mobilization costs including sourcing material, duration of construction, contractor and equipment availability, and environmental impacts and mitigation. The way in which traffic is maintained and how construction is staged and implemented could affect costs greatly, from adding to time and mobilization costs, producing more materials, and impacting the environment.

4.5 Structures

Levees/Dikes

Levees/dikes are man-made structures built to reduce flood risk by containing, directing, or blocking the flow of water. Around Humboldt Bay, a network of public and privately owned levees or dikes – some of which are registered with the US Army Corps of Engineers (Figure 7) – provides flood protection for areas adjacent to the Corridor. Levees along Eureka, Ryan, and Freshwater Slough are identified as Humboldt County Levees and locally operated and maintained. The dike around Brainard is identified under the California Redwood Company and privately operated and maintained. There is also a dike around Bracut. The one-mile-long Jacobs Avenue dike is situated along Humboldt Bay between the Eureka Slough Bridges and Airport Road. This dike provides flood protection for 31 parcels in Eureka City limits. The Jacobs Avenue dike has multiple property owners who own the portion of the dike adjacent to their respective properties. SLR adaptation concepts for the City of Eureka include elevating the Jacobs Avenue dike to provide protection from SLR flooding. Climate related shifts in streamflow patterns, water elevation, erosion, and the enhanced potential for levee or dike breaches could reintroduce tidal dynamics in certain areas (e.g., east of the Corridor) and alter hydrologic dynamics.

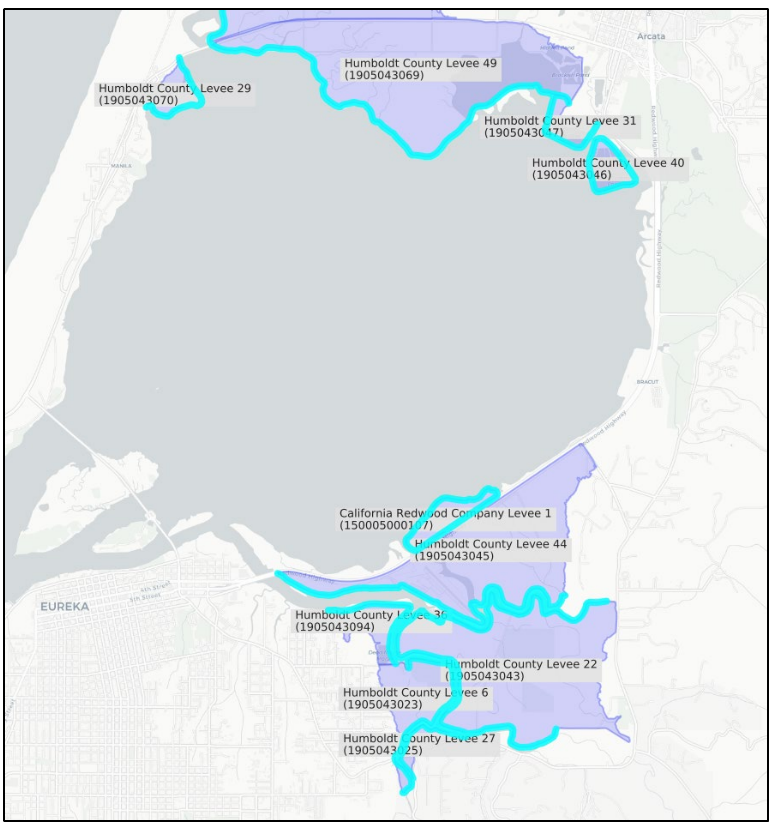


Figure 7. Map of levees in North Humboldt Bay registered under the US Army Corps of Engineers (https://levees.sec.usace.army.mil/map-viewer/index.html). Note not all levees pictured are certified by the US Army Corps of Engineers.

Bridges

The approximate 75-year design life of bridges typically fixes the road alignment in place for an extended period (due in part to substantial investment associated with bridge construction), limiting flexibility for future changes. However, bridges can be designed to facilitate raising the superstructure in the future to adapt to rising water levels, though horizonal alignment would remain fixed. A diagram of a bridge is provided in Figure 8. Superstructure refers to the upper portion of the bridge while substructure refers to the portion below the superstructure that supports the bridge loads. The bridge deck is the upward facing traveled surface of the bridge. The soffit, or lower chord, is the underside or bottom surface of the bridge deck. Freeboard refers to the vertical distance between the design flood water level and the underside (soffit) of the bridge superstructure. Abutments are the substructure at the ends of a bridge span that support its superstructure. Piers are vertical structural elements that support the bridge deck.

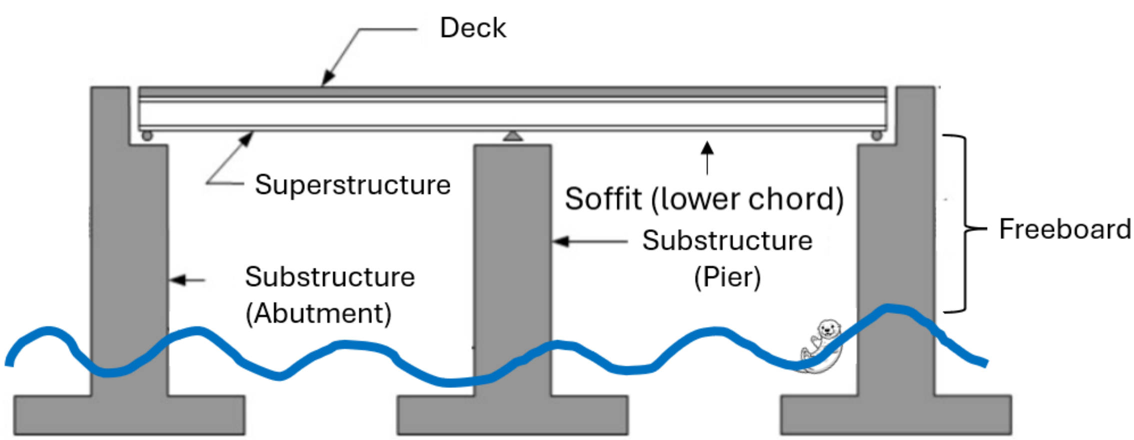


Figure 8. Bridge diagram showing various components discussed in the CAIP.

The bridge abutments of the Indianola Cutoff Undercrossing were designed to allow for a future grade raise. The elevation of Indianola Road below the center of the bridge is 12.08 ft NAVD88. The current clearance height of the bridge is 15.2 ft. If Indianola Road is to be raised in the future, the undercrossing bridge may also need to be raised to maintain a standard clearance of 15 ft (HDM Ch. 300, Caltrans, 2025a).

There are eight bridges along the Corridor with various dates of construction (Table 5). Newer bridges (e.g., southbound Jacoby Creek, Indianola Undercrossing, and Eureka Slough Bridges) are being designed to be adjustable for future elevation increases. Older bridges are not adjustable and will likely need to be replaced by 2100. Future planning efforts along the Corridor will need to consider the design life of bridges as projects develop.

The Route 255/101 Separation Bridge currently has a vertical clearance of 16.40 ft, allowing for a 0.4 ft pavement overlay project to raise the Corridor elevation beneath the existing bridge, in accordance with design standards (HDM Ch. 300, Caltrans, 2025a; Table 6). Caltrans will need to coordinate with the City of Arcata and project engineers to design the on- and off-ramps, ensuring that a future grade increase of the SR 255/101 Separation Bridge elevation can be accommodated when it is due for replacement, likely between 2045 and 2065.

Table 5. Bridge locations, design lives, and elevations. The soffit is the underside or bottom surface of the bridge deck. The deck is the upward facing traveled surface of the bridge.

Name	Bridge #	Year Constructed	75-Year Design Life	Elevation (NAVD88)
Jacoby Creek	04-0023R (northbound)	1955	2030	Soffit: 10.84 ft Deck: 12.64 ft
Jacoby Creek	04-0313L (southbound)	2022	2097 * *designed to be vertically adjustable*	Soffit: 9.71 ft Deck: 13.04 ft
Gannon Slough	04-0024R (northbound)	1955	2030	Soffit: 9.71 ft Deck: 11.29 ft
Gannon Slough	04-0024L (southbound)	1996	2071	Soffit: 9.78 ft Deck: 11.58 ft
SR 255/101 Separation	04-0049	1965	2040	Soffit: ~28 ft above US 101 Deck: ~33 ft above US 101 Clearance height: 16.40 ft Elevation of US 101 underneath: 12.3 ft
Indianola Cutoff Undercrossing	04-0314	2025 (current construction date)	2100 * *designed to be vertically adjustable*	Soffit: 27.25 ft Deck: 29.75 ft Clearance height: 15.2 ft Elevation of county road underneath: 12.08 ft
Eureka Slough	04-0022R (northbound)	1956 (anticipated replacement	2110 after replacement in 2035 * *designed to*	TBD, Current Soffit: 16 ft on south end, 11.7 ft on north end

Name	Bridge #	Year Constructed	75-Year Design Life	Elevation (NAVD88)
		project to start 2029)	*be vertically adjustable*	Current Deck: 20.5 ft on south end, 16.2 ft on north end
Eureka Slough	04-0022L (southbound)	1943 (anticipated replacement project to start 2029)	2110 after replacement in 2035 * *designed to be vertically adjustable*	TBD, Current Soffit: 19.7 ft on south end, 13 ft on north end Current Deck: 24.7 ft on south end, 18 ft on north end

Table 6. Minimum vertical clearances from the HDM (Caltrans, 2025a).

	Traveled Way	Shoulder
Freeways and Expressways, New Construction, Lane Additions, Reconstruction and Modification	16½ ft	16½ ft
Freeways and Expressways, Overlay Projects	16 ft	16 ft
All Projects on Conventional Highways and Local Facilities	15 ft	14½ ft
Sign Structures	18 ft	18 ft
Pedestrian, Bicycle Overcrossings, and Minor Structures	Standard + 2 ft See 309.2(2)	
Structures on the Rural and Single Interstate Routing System	See 309.2(3)	

Geotechnical Considerations

Existing sub surface conditions in the corridor are poor due to former tideland locations and are anticipated to degrade further with SLR. To address this concern, column supported embankments (CSEs) are likely needed to support additional fill. CSEs enable construction of embankments over unstable soils by transferring the embankment load to firm underlying stratum. CSEs have a variety of applications, including construction of roads that traverse soft ground. Along the Corridor, substantial embankment raises (e.g., greater than five feet) would likely require CSE construction.

Culverts

Culverts located in the coastal zone and exposed to variable water flows and saltwater present a unique set of opportunities and challenges. Culverts along the Corridor are subject to fluctuating hydraulic conditions, including tides, storm surges, SLR, and flow from extreme rainfall events. These dynamic conditions can exceed a culvert’s capacity if not properly designed, resulting in flooding, erosion, or structure failure. Without appropriate control features, such as tide gates, culverts may allow saltwater to move inland, potentially harming freshwater ecosystems, agricultural lands, and infrastructure not designed for saline conditions. Additionally, if not designed with ecological considerations, culverts can fragment habitats and impede the movement of fish and wildlife.

Despite these challenges, culverts also present numerous opportunities for innovation and improved resilience. Modifications that enhance ecosystem connectivity, such as incorporation of natural stream beds or fish and wildlife passage features, can support restoration of tidal flow, improve habitat quality, and reduce vehicle-wildlife collisions. Integrating culverts with nature-based solutions, such as living shorelines or wetland restoration, can further enhance coastal resilience by promoting natural water management and ecological benefits.

Within the CAIP boundaries of the Corridor there are 71 culverts (Table 7 and Figure 9). The culvert systems along the Corridor are part of a drainage network (see also 5.1 ‘Hydraulic Setting’) that conveys freshwater out to the bay and, sometimes with the control of tide gates, accommodates tidal flows into wetlands on the east side of the highway. Most culverts along the Corridor are made of reinforced concrete pipe (RCP), though some are high density polyethylene (HDPE) or polyvinyl chloride (PVC). Since wildfire is not likely to occur along the Corridor but corrosion of metal from saltwater is, new culverts should be made of HDPE or concrete.

The Eureka/Arcata 101 SLR Resilience project (0M270; see Section 4.6 Relevant Transportation Projects) has proposed that the culverts planned to be replaced will be upsized to a minimum 2-foot diameter to increase capacity. This project also proposes the existing 8-ft W x 6-ft H box culvert at Rocky Gulch (PM 83.61) and the existing 5-ft W x 4-ft H box culvert at Old Jacoby Slough (PM 84.30) will be replaced with larger 12-ft W x 8-ft H box culverts to allow for an expanded connection to the bay. These larger connections will serve as an accommodate measure to address SLR and compound flooding on the east side of the highway.

None of the culverts along the Corridor currently incorporate wildlife crossing features, such as otter benches. Numerous otter-vehicle collisions have occurred along the Corridor and collision locations are frequently at the site of or near hydraulic connections to the bay. To reduce otter-vehicle collisions and improve highway safety, future culvert projects along the Corridor should incorporate otter benches into their hydraulic designs where appropriate and feasible. Future viaduct or bridge projects should span the full width of the bed, bank, and channel to accommodate wildlife passage on dry banks.

The span of Caltrans culverts is typically not wider than 12 ft for a precast single culvert, or 14 ft for cast in place or double box culvert, which cost more than a precast single culvert.

For box culverts with spans greater than these values a special design is required which would increase design support costs. Caltrans considers culverts 20 ft or larger to be a bridge, so bottomless culverts larger than 20 ft would result in greater maintenance costs such as bridge maintenance inspections.

Table 7. Location, type, and dimensions of culverts along the Corridor. Shaded cells indicate limits of 0M270 work (PM 79.9 to 85.0). Culvert data was accessed October 2025.

Culvert Type	PM	Diameter (ft)	Width (ft)	Height (ft)	Length (ft)	Notes
RCP	80.09	1.5	--	--	88	Median drain along Jacobs Ave.
RCP	80.17	1.5	--	--	84	Median drain along Jacobs Ave.
RCP	80.33	1.5	--	--	73	Median drain along Jacobs Ave.
RCP	80.57	1.5	--	--	78	Median drain along Jacobs Ave.
RCP	80.83	1.5	--	--	84	Median drain along Jacobs Ave.
RCP	80.83	1.5	--	--	123	Median drain along Jacobs Ave.
RCP	80.83	1.5	--	--	124	Median drain along Jacobs Ave.
RCP	80.83	1.5	--	--	112	Median drain along Jacobs Ave.
RCP	80.83	1.5	--	--	142	Median drain along Jacobs Ave.
RCP	80.83	1.5	--	--	51	Median drain along Jacobs Ave.
RCP	80.87	3	--	--	177	Airport Rd.
Box	81.14	--	3	4	93	End connected to 95-ft culvert
Box	81.14	--	3	4	95	Tide gate
Box	81.3	--	6	4	64	Access to Harper Motors/FSWA
RCP	81.48	1.5	--	--	94	Median drain along Brainard
RCP	81.72	1.5	--	--	94	Median drain along Brainard
Box	81.84	--	6	4	66	CDFW access rd.
RCP	81.99	1.5	--	--	99	Median drain
RCP	82.27	1.5	--	--	104	Median drain
RCP	82.56	1.5	--	--	90	Median drain
RCP	82.67	1.5	--	--	34	Northbound offramp Indianola
Box	82.67	--	3	4	73	East of HWY - Indianola Cutoff
RCP	82.74	1.5	--	--	40	Northbound onramp Indianola
RCP	82.84	1.5	--	--	104	Median drain
PVC	83.01	0.8	--	--	15	Caltrans Maintenance Station
HDPE	83.01	2	--	--	20	Caltrans Maintenance Station
HDPE	83.01	2	--	--	85	Caltrans Maintenance Station
HDPE	83.01	2	--	--	28	Caltrans Maintenance Station

Culvert Type	PM	Diameter (ft)	Width (ft)	Height (ft)	Length (ft)	Notes
PVC	83.01	1	--	--	10	Caltrans Maintenance Station
HDPE	83.01	2	--	--	110	Caltrans Maintenance Station
HDPE	83.01	2	--	--	37	Caltrans Maintenance Station
HDPE	83.01	2	--	--	18	Caltrans Maintenance Station
PVC	83.01	0.8	--	--	12	Caltrans Maintenance Station
HDPE	83.01	2	--	--	50	Caltrans Maintenance Station
RCP	83.08	1.5	--	--	89	Median drain
Box	83.61	--	8	6	168	Open culvert, connected to bay
RCP	83.69	1.5	--	--	102	Median drain
Box	84.30	--	5	4	185	Tide gate, connected to bay
RCP	84.65	1.5	--	--	1.08	Median drain w/closed tide gate
RCP	84.93	1.5	--	--	85	Median drain
RCP	85.05	1.5	--	--	47	South G St. Ramp
RCP	85.06	1.5	--	--	98	South G St. Ramp
Box	85.10	--	6	4	286	Connects S G St. ditch to E. HWY
RCP	85.20	1.5	--	--	80	Median drain
RCP	85.54	1.5	--	--	84	Median drain
Box	85.57	--	6	4	187	W. HWY to Gannon Slough
RCP	85.60	1.5	--	--	45	NB Off Ramp
Box	85.7	--	6	3.5	130	NB Off Ramp
Box	85.73	--	6	3	100	SB On Ramp
Box	85.75	--	6	3.5	34	NB On Ramp
RCP	85.77	1.3	--	--	62	NB Off Ramp
Box	85.77	--	6	3	80	SB Off Ramp
RCP	85.80	1.3	--	--	50	NB Off/On Ramp
RCP	85.80	1.5	--	--	60	SB On/Off Ramp
RCP	85.8	1.5	--	--	50	SB On/Off Ramp
Box	85.85	--	6	3	80	NB Off Ramp
Box	85.90	--	6	3	150	NB On Ramp
Box	85.90	--	6	3	80	SB On Ramp
RCP	85.92	1.50	--	--	110	NB On Ramp
RCP	85.92	1.50	--	--	46	SB Off Ramp East
Box	85.93	--	6	3	130	SB Off Ramp West
RCP	86.09	1.5	--	--	120	7th St. E. of HWY

Culvert Type	PM	Diameter (ft)	Width (ft)	Height (ft)	Length (ft)	Notes
Box	86.10	--	5.5	5	100	7th St. W. of HWY
RCP	86.10	4.5	--	--	89	14th St to 7th St drainage
Box	86.10	--	3	3	110	14th St to 7th St drainage
RCP	86.10	2	--	--	107	14th St to 7th St drainage
RCP	86.10	1.5	--	--	215	14th St to 7th St drainage
RCP	86.10	4.5	--	--	322	14th St to 7th St drainage
RCP	86.10	1.5	--	--	55	14th St to 7th St drainage
RCP	86.10	4.5	--	--	269	14th St to 7th St drainage
RCP	86.10	4.5	--	--	580	14th St to 7th St drainage

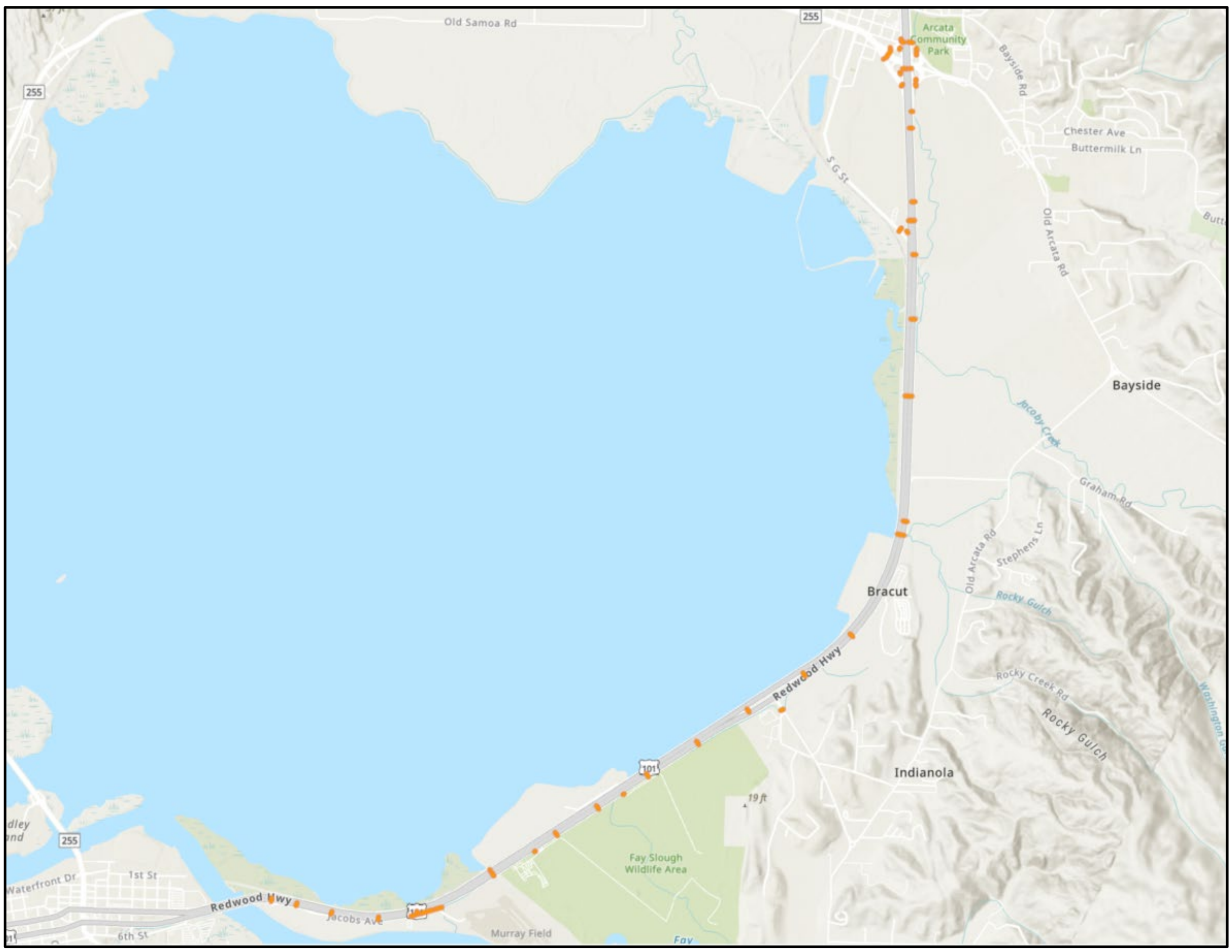


Figure 9. Map of Caltrans culverts (orange symbols) along the Corridor. For a map showing additional culverts and tide gates used in the hydraulic modeling, including county-owned culverts, refer to Section 6.1.1 Hydrologic Hazards.

Tide gates

Numerous tide gates are located along the Corridor to regulate water flow – preventing inland tidal flooding during high tides while allowing stormwater to drain into the bay during low tides (Table 8). These structures provide important flood control and protection and support surrounding agricultural and commercial land uses. However, they can also disrupt natural tidal exchange and sediment transport, potentially impacting coastal ecosystems. With rising sea levels, tide gates may become less effective as elevated water levels impair their function, increasing the potential for fluvial flooding and requiring redesign or adaptation. SLR planning along the Corridor will need to re-evaluate the use of tide gates to achieve a balance between protecting infrastructure and preserving ecological integrity.

The Eureka/Arcata 101 SLR Resilience project (0M270; see Section 4.6) has proposed that the culvert at Rocky Gulch will be upsized and remain without a tide gate. This hydraulic connection will serve as an accommodate measure to address SLR and, in coordination with adjacent landowners, will likely support future restoration or mitigation efforts.

In addition to Caltrans' tide gates, there are numerous city, county, and privately-owned tide gates in areas adjacent to the Corridor (not shown in Table 6).

Table 8. Caltrans tide gates along the Corridor. Locations, postmile (PM), year constructed, design life, and invert elevation (ft).

Location	PM	Year Installed	25-Year Design Life	Size (quantity)	Invert Elevations (NAVD88)
HWY 101 Slough Auxiliary Slide Gates	80.84 NB	2019	2044	5' x 5' (2) 14" x 18"	-1.84 ft (bottom of 5'x5' gates)
Fay Slough	81.14 NB	2020	2045	36" x 48"	-1.41 ft
Brainard Slough/Rocky Gulch	83.61 NB	2020	2045	24"	1.44 ft
Old Jacoby Slough	84.26 SB	2020	2045	60" x 60"	2.35 ft
Gannon Slough South	84.93 NB	2020	2045	72" x 60" (3)	2.2 ft

Utilities

The Corridor is located near several key utility systems. A Pacific Gas and Electric Company (PG&E) underground gas line runs along the Corridor, from Murray Field Airport in Eureka to South G Street in Arcata, as shown in Figure 10 and Figure 11. In addition, PG&E electric transmission infrastructure is situated to the east of the Corridor, alongside fiber optic lines and water pipes. These utilities represent important considerations for future planning and adaptation measures along the Corridor.

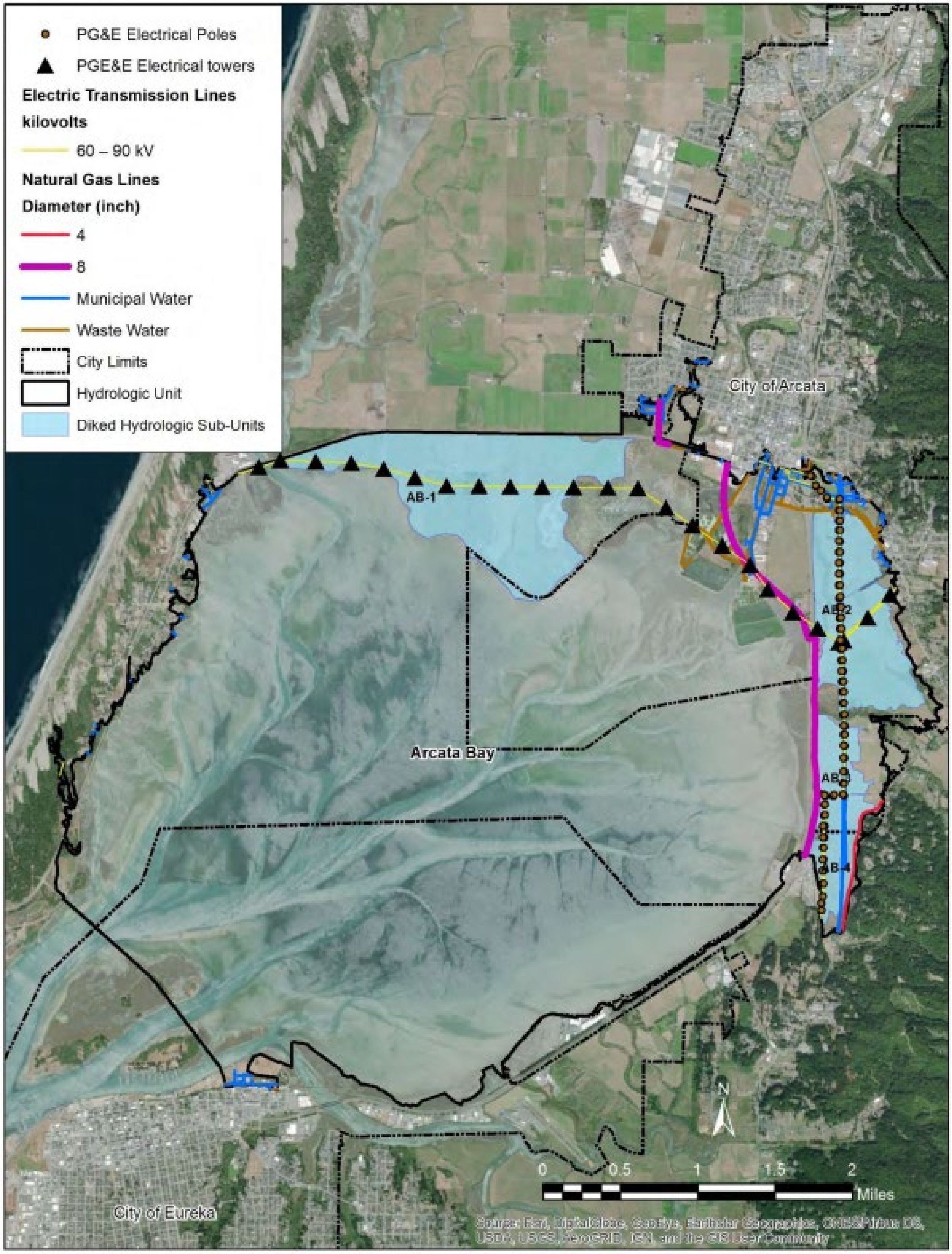


Figure 10. Map of utilities along the northern portion of the Corridor (from Laird, 2020).

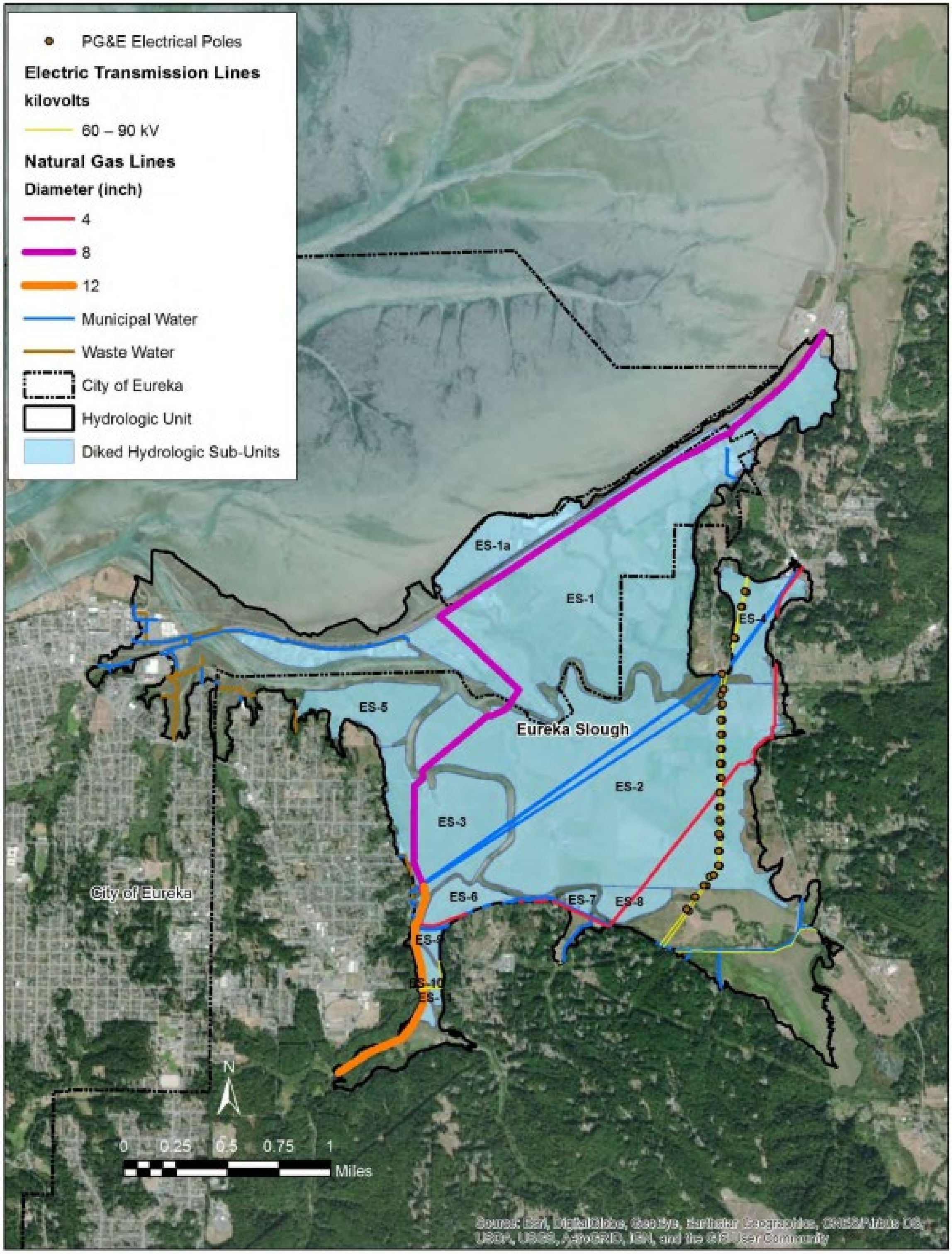


Figure 11. Map of utilities along the southern portion of the Corridor (from Laird, 2020).

4.6 Relevant Transportation Projects

Caltrans Projects

The Eureka/Arcata 101 SLR Resilience Project (0M270) is a proactive project located along the Eureka-Arcata Corridor. The purpose of the project is to maintain service along segments of the Corridor that are subject to the imminent threat of SLR. The project was developed to provide an interim adaptation solution while longer-term solutions are developed in the CAIP. To mitigate potential damage from rising sea levels and storm surges, the project proposes to raise the roadway and implement several nature-based infrastructure improvements which the CAIP will be able to build upon in future adaptation projects. The project limits of 0M270 are currently scoped as PM 79.9 to 85.0 (Eureka Slough Bridges to South G Street Onramp in Arcata). The project's design elements are based on results from Cal Poly Humboldt's Technical Studies (see Section 6) which indicate a grade raise to 12 ft NAVD88, the majority of which would need to be implemented only on the southbound lane, would provide adequate resilience until approximately 2070. The lower elevation target of 12 ft would reduce the project footprint and environmental impact and allow for greater incorporation of nature-based improvements. It should be noted the postmile limits of project 0M270 do not extend the entire length of CAIP. Therefore, certain sections of the Corridor (Segment 11 and 12, see Section 7.5) are not addressed by 0M270 and will need adaptation consideration prior to other segments. Detailed design elements will be refined once the project is in the design phase. It is anticipated that 0M270 will go to construction in the mid-2030s.

The Eureka Slough Bridges Project (0M760) will replace the north- and southbound Eureka Slough Bridges located on US 101 at the northern end of the City of Eureka. The project would address seismic deficiencies and improve the function and geometrics of both bridges, and the final design will account for SLR. The preferred alternative would replace the two existing bridges with two new, mirrored structures. Each bridge would have two traffic lanes, standard inside and outside shoulders, and a separate bicycle and pedestrian path on the outside edge. Construction is estimated to begin in 2030. Details and updates can be found on the Caltrans District 1 Projects page: Eureka Slough Bridges Project | Caltrans.

Other projects within the Eureka-Arcata US 101 Corridor Improvement Project that are already completed or under construction include the Indianola Undercrossing (36600), acceleration and deceleration lane improvements, guardrails, replaced tide gates, a traffic signal at Airport Road, and the Jacoby Creek bridge replacement (0E000). More information can be found on the Caltrans D1 Projects page: Eureka-Arcata Route 101 Corridor Improvement | Caltrans.

Other Agency Projects

The Route 255 South Arcata Multimodal Safety Improvement Program (SAMSIP) is led by the City of Arcata and, while not part of the CAIP, the project is immediately adjacent and has the potential to affect drainage around US 101. The SAMSIP aims to improve multimodal facilities, connectivity, and safety in south Arcata and at the SR 255/101 Interchange by converting the existing clover interchange into a more condensed design that supports multimodal transportation (as illustrated in the alternative presented in Figure 12 below). The planning level design phase of this project has been completed. The recommended alternative identified in the plan, shown in Figure 12, proposes roundabouts at both ramp termini, with ramps moved to the southern side of SR 255 only. This alternative proposes that one lane be removed in each direction on Samoa Boulevard and proposes a bikeway and sidewalk on the north side of Samoa Blvd. The proposed facility would consist of a shared-use path with flexible post separation. The PID approval process may be completed as soon as June 2026.

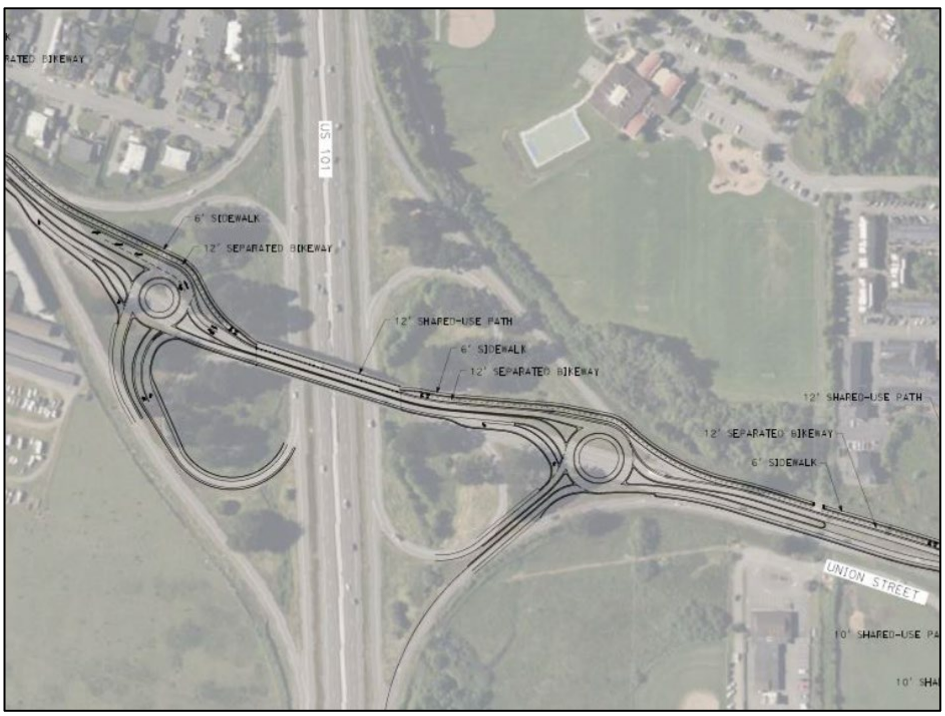


Figure 12. The South Arcata Multimodal Safety Improvement Program recommended alternative.

5 Location Specific Considerations

5.1 Hydrologic and Hydraulic Overview

The drainage systems surrounding the Corridor are comprised of a network of levees and dikes, channels, sloughs, culverts, and tide gates. During high tide, tide gates close, causing runoff to be temporarily stored on the floodplain to the east. When the tide recedes, runoff from the east side of the Corridor is conveyed to the Bay (Figure 13). High water levels along the Corridor are influenced by the duration and amount of precipitation, tidal elevation, and the outflow capacity of the drainage system.

During high tide events on Jacoby Creek and Washington Gulch, elevated bay water levels increase tailwater elevations, which in turn raise water levels within the creeks. When tidal elevations combine with high creek flows, the banks can be overtopped, resulting in flooding of adjacent pasturelands. These floodwaters typically remain within the floodplain until they either infiltrate the ground or drain through Old Jacoby Creek or Gannon Slough.

Figure 13. Simplified drainage pattern of water flowing out to the bay. Note that there is a box culvert and tide gate on the southern end of Brainard connecting drainage on the western side of the highway to the eastern side with an outlet to Eureka Slough.

5.2 History of Flooding

Historically, extreme weather events have caused coastal and fluvial flooding in the low-lying areas surrounding the Corridor. Heavy precipitation – such as nearly 12 inches in one week recorded during the winter of 1996/97 (National Centers for Environmental Information, 1996) – can inundate adjacent pastures and flatlands east of the Corridor. The

1997 storm event flooded approximately 70% of these eastern areas (Figure 14). During a storm in December 2002, Jacoby Creek breached its banks and flooded the surrounding lands, flooding Bayside Road to within 150 ft of the Corridor. One storm event in recent history resulted in the closure of the Corridor. On December 31, 2005, a combination of high tides and strong winds led to extremely elevated water levels – measuring 9.55 ft NAVD88 at the North Spit Tide Gauge (National Oceanic and Atmospheric Administration (NOAA), 2026). Wind setup elevated water surface elevations, likely by at least a foot, resulting in approximately 10.55 ft NAVD88 for water surface elevation. Water from Humboldt Bay spilled over the railroad corridor and flooded a section of the Corridor between Brainard and Bracut because the water surface elevation was higher than the railroad prism, which was 9.6 ft NAVD88 prior to being raised to 11.5 ft in 2025. This event flooded a section of the Corridor between Brainard and Bracut (Figure 15), resulting in a temporary road closure and erosion damage to the adjacent rail prism.

Figure 14. Flooding of low-lying land adjacent to the Corridor during January 1997. Top left: Flooding near Murray Field Airport; Top right: Flooding near Indianola Cutoff; Bottom: Flooding of low-lying land in the Eureka Slough Area.

Figure 15. Flooding on the Corridor between Brainard and Bracut during the storm event on December 31, 2005. This event resulted in temporary closure of the Corridor and erosion damage to the adjacent rail prism. Figure from GHD et al. (2022).

To comply with Special Condition 1 of CDP-1-18-1078, Caltrans has conducted annual king tide monitoring along the Corridor since 2019. Each year, water level data from the North Spit Tide Gauge (NOAA, 2026) are analyzed, and conditions at selected locations along the Corridor are photographed during king tide events. As previously noted, no roadway flooding has occurred since the monitoring began. However, the North Spit Tide Gauge recorded monthly maximum water levels above nine feet (NAVD88) in January 2022 (9.38 ft) and December 2024 (9.33 ft; F*igure 16*). These levels are slightly below the peak water level recorded during the 2005 flood event (9.55 ft). Although roadway flooding has not been observed since 2005, Caltrans has documented full drainage ditches and water encroaching near the roadway (Figure 17).

Figure 16. Maximum water elevation and summary statistics for the North Spit Tide Gauge for all annual reporting periods (April 1 through March 31), 2019 to 2026. a) Maximum water elevation (y-axis; ft NAVD88) by month (see individual plot titles) and year, b) From left to right: maximum, mean monthly maximum, and mean sea level (y-axis; ft NAVD88) summarized by year. Water elevation data from NOAA, 2026.

Figure 17. Photo documentation of water adjacent to the Corridor during the December 2024 king tide event.

6 Technical Studies

Numerous studies have evaluated how climate change and SLR threaten the region's coastal assets and the feasibility of various adaptation solutions. Key studies include:

- *Humboldt Bay Shoreline Inventory, Mapping and SLR Vulnerability Assessment* (Laird et al., 2013): Comprehensive inventory and mapping of existing shoreline features and conditions along Humboldt Bay, with an assessment of regional vulnerability.
- *Humboldt Bay: SLR Hydrodynamic Modeling, and Inundation Vulnerability Mapping Final Report* (Anderson, 2015): Developed SLR hydrodynamic modeling to generate maps of inundation vulnerability around Humboldt Bay.
- *Humboldt Bay Area Plan (HBAP) SLR Policy Background Study* (Humboldt County, 2018): Summary of SLR projections, description of vulnerable assets, and presentation of local adaptation policies and strategies for the HBAP update.
- *City of Arcata SLR Vulnerability Assessment* (Laird, 2018a) – Assessment of SLR vulnerability for assets within the City of Arcata.
- *Humboldt County Humboldt Bay Area Plan SLR Vulnerability Assessment* (Laird, 2018b): Assessment of vulnerability and risk to coastal resources in the Humboldt Bay area based on OPC guidance.
- *Caltrans Eureka-Arcata Corridor: SLR Vulnerabilities and Adaptation Solutions* (Caltrans and ICF, 2019): Analysis of the vulnerability of proposed Caltrans Corridor projects to SLR and other coastal hazards.

- *SLR Adaptation Plan for Transportation Infrastructure and Other Critical Resources in the Eureka Slough Hydrographic Area, Humboldt Bay* (GHD et al., 2021): Analysis of conditions in the Eureka Slough Hydrographic Area and presentation of a framework for SLR adaptation strategies.
- *Natural Shoreline Infrastructure in Humboldt Bay for Intertidal Coastal Marsh Restoration and Transportation Corridor Protection*: 50% *Design Report* (GHD et al., 2022): Study of the feasibility of a natural shoreline project to protect the Corridor from flood hazards.
- *Humboldt Bay SLR Regional Planning Feasibility Study* (Humboldt County Long Range Planning Division, 2023): Development of options for SLR adaptation planning in the Humboldt Bay region, along with a summary of public engagement efforts involving over 50 stakeholder groups.
- *SLR Vulnerability and Capital Improvement Project Adaptation Plan* (GHD, 2023): Support for the City of Eureka's need to develop a phased adaptation plan, summarizing infrastructure vulnerabilities with a focus on SLR projections for 2050.

CAIP Technical Studies

Caltrans partnered with Cal Poly Humboldt and Northern Hydrology and Engineering to conduct Corridor-specific technical studies that support the CAIP and the development of effective and efficient adaptation solutions. These studies use the latest OPC guidance for SLR (OPC, 2024) (referencing the statewide average and applying a localized vertical land motion rate) to provide an updated assessment of vulnerability along the Corridor.

The comprehensive hazard analysis conducted by Cal Poly Humboldt and Northern Hydrology and Engineering examined hydrologic, coastal, groundwater, and geologic hazards for the region surrounding Humboldt Bay. Summaries and highlights of technical memos are presented below. Complete technical memos can be found online at https://www.northcoastclimateaction.org/eureka-arcata-county.

* *Please note that CAIP Technical Studies were authored by Cal Poly Humboldt and Northern Hydrology and Engineering. Wigi, the traditional Wiyot name for Humboldt Bay, is used in this section, consistent with original Technical Memos.*

6.1.1 Hydrologic Hazards

The hydrologic analysis combined coastal and riverine (fluvial) processes to conduct model simulations of existing conditions and characterize in-channel and floodplain hydraulics within the project reach (Buchanan and Archibald, 2025). The findings were used to assess vulnerability along the Corridor, including under future climate change scenarios.

Methods

A two-dimensional CAIP Model was developed in the Hydrologic Engineering Center-River Analysis System (HEC-RAS 6.5; U.S. Army Corps of Engineers, 2021) to simulate existing conditions along the Corridor. Key steps of the modeling exercise included creating high-resolution terrain surfaces of the existing channel and drainage network and floodplains from a combination of LiDAR and field survey, two-dimensional modeling of existing terrain and hydraulic structures, and analysis of key existing ground hydraulic results over a suite of scenarios to quantify existing conditions along the Corridor. Tidal boundary conditions were defined using either the mean monthly maximum water level (MMMW) or 2-year coastal storm event (C2). The fluvial boundary conditions were set to the 2-, 10- and 100-year storm conditions (Q2, Q10, Q100, respectively). SLR scenarios included 0 (current), 0.82 (2050 Intermediate), and 3.12 (2100 Intermediate) feet of SLR (Table 9). The Intermediate SLR scenario was selected because it most represents the SLR that is most likely to occur between now and 2050. Beyond 2050, the Intermediate SLR scenario provides a reasonable upper bound for the most likely range of SLR by 2100.

Table 9. Summary of event conditions and scenarios used in the CAIP model. Compound frequency estimated based on product of fluvial and tidal probabilities.

Event Condition	Scenario	Tidal Boundary Condition	Fluvial Boundary Condition	Sea Level Rise (ft)	Probability (% Chance per Year) 2023
I	1	MMMW[1]	2-yr	0	50%
	2	MMMW	2-yr	0.82	
	3	MMMW	2-yr	3.12	
	4	MMMW	10-yr	0	10%
	5	MMMW	10-yr	0.82	
	6	MMMW	10-yr	3.12	
	7	MMMW	100-yr	0	1%
	8	MMMW	100-yr	0.82	
	9	MMMW	100-yr	3.12	
II	10	2-yr[2]	2-yr	0	25%
	11	2-yr	2-yr	0.82	
	12	2-yr	2-yr	3.12	
	13	2-yr	10-yr	0	5%
	14	2-yr	10-yr	0.82	
	15	2-yr	10-yr	3.12	
	16	2-yr	100-yr	0	0.50%
	17	2-yr	100-yr	0.82	
	18	2-yr	100-yr	3.12	

[1] Peak of MMMW tide = 8.36 ft

[2] Peak of coastal 2-yr storm = 9.26 ft

The CAIP model was also used to evaluate how the Corridor and areas east are impacted during coastal flood events with no fluvial flooding. The same SLR scenarios described above were used in the coastal analysis. Boundary conditions consisted of coastal flood levels from the coastal modeling analysis.

The model domain, the area covered by the model, extended just north of the 14th Street Bridge in Arcata to West Grant Road in Eureka, west to the crest of the Samoa Dunes, and east to Myrtle Avenue/Old Arcata Road (Figure 18).

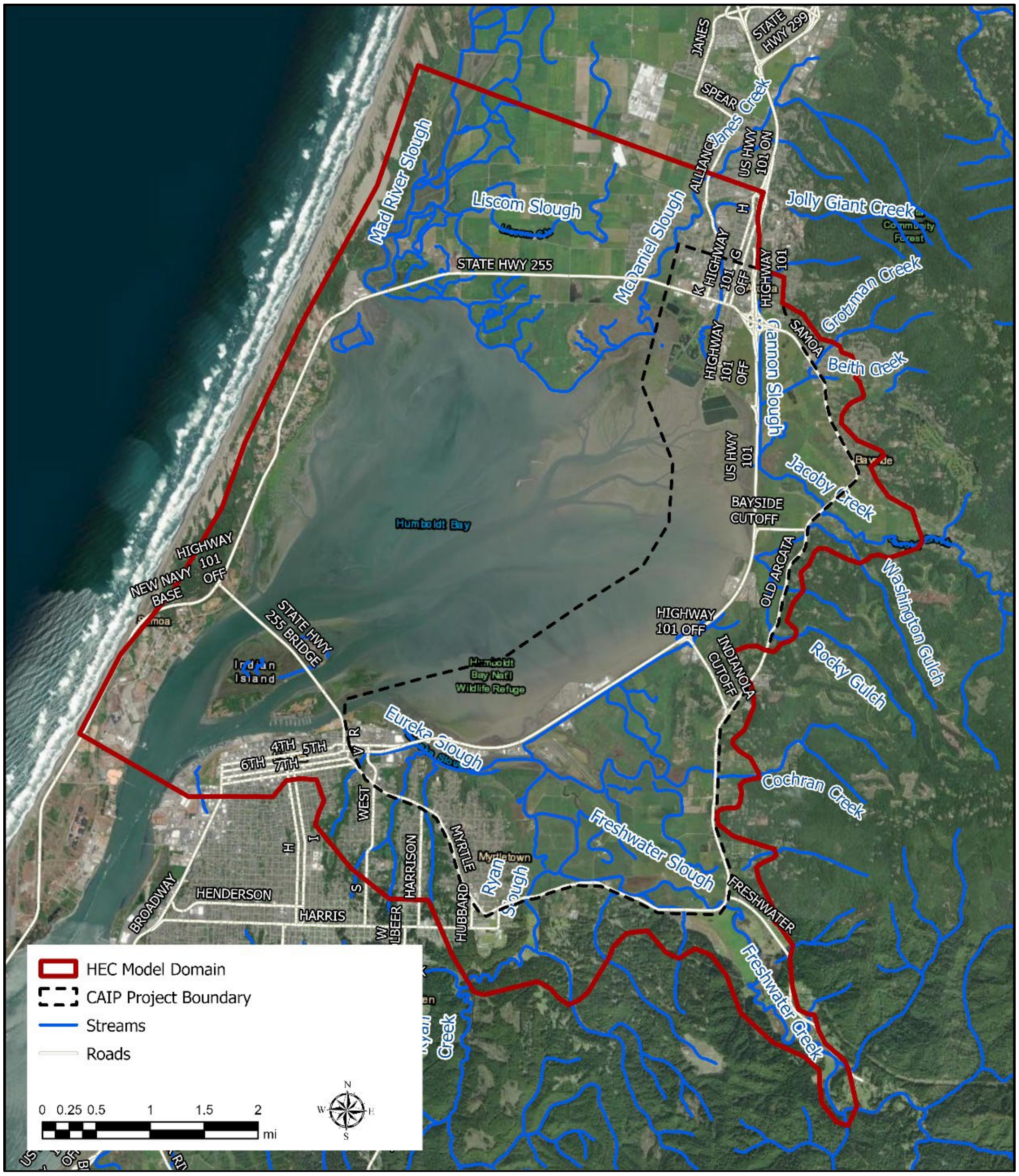


Figure 18. CAIP model area showing boundary condition locations and major streams and road infrastructure in the project area.

The model included 166 hydraulic structures: 9 bridges, 49 tide gates, and 108 culverts (Figure 19, only priority structures labeled). Detailed performance analysis was conducted for 19 structures along the Corridor (16 culverts and 3 pairs of bridges).

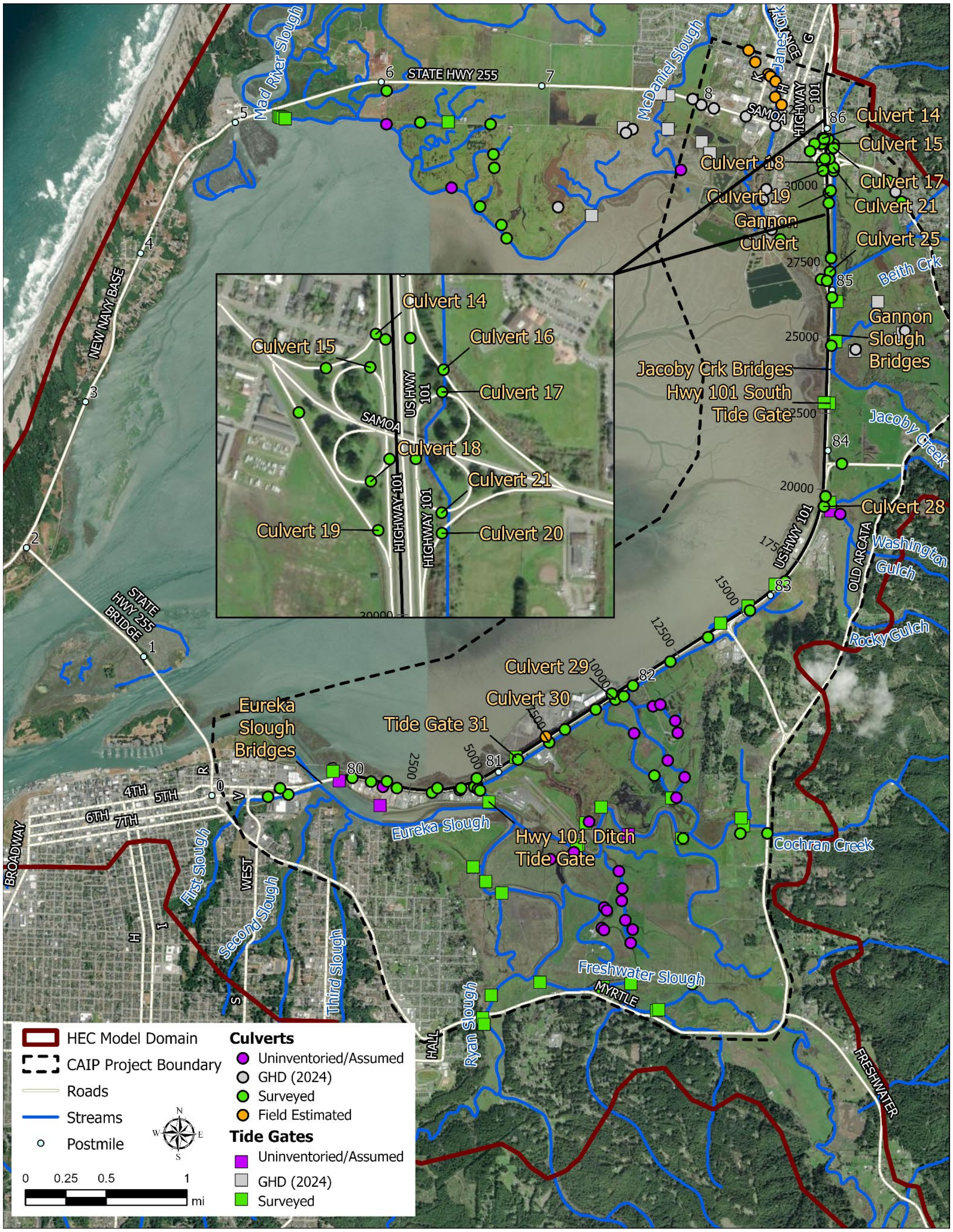


Figure 19. Locations of tide gates, culverts, and bridges included in the two-dimensional CAIP model. Orange text (e.g., "Eureka Slough Bridges") indicates priority structures included in the detailed hydraulic analysis.

Highway drainage ditches run parallel to the roadway and collect runoff from the pavement surface. These ditches are connected to Humboldt Bay through culverts and other drainage structures. During high tides or storm surge events, bay water can flow back through these connections, reducing drainage capacity or causing water to accumulate in the ditches. Drainage ditch geometry was characterized using available LiDAR data and field survey information.

Each simulation represented a 2-3 day storm event, capturing the temporal evolution of flood depths, water surface elevations, flow velocities, and flood duration. The two-dimensional HEC-RAS model provides detailed output at locations along the Corridor and areas to the east, complementing the coastal model's coverage (Environmental Fluid Dynamics Code (EFDC; Anderson, 2015) and Simulating WAves Nearshore (SWAN) models, see Section 6.1.2 for details).

Model outputs include:

- Water surface elevation at highway and drainage infrastructure locations
- Maximum flood depth across the model area
- Flow velocity for bridge scour assessment
- Flood duration above critical thresholds

The hydrologic model's strength is its detailed representation of flow pathways and infrastructure interactions in areas where the coastal model lacks resolution, making it essential for characterizing flooding on the Corridor and on the east side of the highway.

Results

The model was qualitatively evaluated by comparing a subset of photos taken during king tide events at various locations to model results for the MMMW and 2-year fluvial scenario. The MMMW peak of 8.36 ft is roughly equivalent to a king tide event in Humboldt Bay. Results from the validation exercise indicate the model accurately captured water surface elevations, inundation extent, and overtopping.

Results indicated coastal conditions primarily drive flood dynamics within the Corridor. This is evident in the significant increases in flood depths and extents along both the north- and southbound lanes as coastal storm magnitudes intensify. For example, comparing the MMMW & Q100 + 3.12 feet SLR scenario to the C2 & Q100 + 3.12 feet SLR scenario, flood duration and mean flood depths along the northbound centerline increase by approximately 4 and 7 times, respectively, highlighting the overriding influence of coastal conditions. Southbound lanes, which are closer to Humboldt Bay, generally experience more flooding under SLR scenarios than northbound lanes, though northbound lanes are also impacted by changes in sea level. The most frequently flooded sections of the Corridor were the SR 255/US101 Interchange and the stretch between Murray Field and Bracut Industrial Park. The influence of fluvial flooding is evident, especially in the northbound lanes, which are affected as floodwaters from the east reach the roadway. In contrast, the southbound lanes are minimally affected by fluvial conditions, showing little variation in mean or maximum flood depths or extents as fluvial flows increase.

Current Conditions (No SLR)

In the absence of SLR, neither US 101 nor any bridges analyzed are overtopped for any modeled conditions. However, during the 100-year fluvial flood, the SR 255/101 Interchange is overtopped for all modeled coastal boundary conditions, though flooding is confined to the northbound roadway.

Bridges: The Gannon Slough and Jacoby Creek Bridges experience headwater and/or tailwater elevations within one foot of the soffit during combined coastal and fluvial flood events. Water levels at this height leave the bridges vulnerable to debris accumulation and wind waves, exacerbating flood impacts, and potentially leading to structural damage. This occurs in all C2 events for the southbound Jacoby Creek Bridge and both Gannon Slough Bridges, as well as during the MMMW Q100 event for the northbound Gannon Slough Bridge. Notably, even without SLR, the soffit of the northbound Gannon Slough Bridge is impacted by floodwaters during a combined 2-year coastal and 100-year fluvial storm.

Drainage: Water level elevations are generally below maximum levels for priority infrastructure during most flood events. Four culverts (17, 21, 29 and Gannon; Figure 19) experience headwater or tailwater elevations that exceed the recommended height of 1 foot below the edge of travel lanes during the 100-year fluvial flood scenario.

Future Scenarios (SLR)

Corridor infrastructure experiences minimal impacts under 0.82 ft of SLR. However, severe and widespread SLR-driven flooding occurs with 3.12 ft of SLR (regardless of a storm event). At this higher water level, the road centerline is regularly inundated. The northbound Gannon Slough Bridge is most impacted by rising sea levels, while the existing Eureka Slough Bridges remain unaffected in all modeled flood events and 3.12 ft of SLR.

Intermediate SLR Scenario for 2050 (0.82 ft)

Road Impacts: The southbound and northbound lanes of the Corridor do not experience significant overtopping in terms of extent, depth or duration. For example, less than 150 ft of highway centerline is inundated at 0.82 ft of SLR even during the most extreme modeled event (i.e. C2 & Q100). Maximum flood depths remain shallow, with neither the northbound or southbound centerlines exceeding 0.16 ft (1.92 in) in any scenario. The duration of flooding last from 0 to 5 hours.

Bridges: With 0.82 ft of SLR, the northbound Gannon Slough Bridge soffit is moderately submerged (e.g., flood depth is less than 1 foot) in most flood scenarios, increasing the potential for debris blockage, structural fatigue, and reduced hydraulic performance. The

Jacoby Creek Bridges generally maintain more freeboard across modeled events. However, the lower chord (soffit) of the southbound Jacoby Creek Bridge is submerged in all C2 scenarios, suggesting limited capacity to accommodate future SLR. While the northbound Jacoby Creek Bridge has slightly more freeboard than the southbound, the maximum allowable headwater/tailwater elevations are exceeded during numerous coastal storm events, further highlighting the limited resilience to future SLR at this location. The lower chords and decks of the southbound and northbound Eureka Slough Bridges are unaffected by any modeled flood events. There is significant freeboard across all modeled scenarios, indicating that the Eureka Slough Bridges are unlikely to be impacted except under the most extreme combinations of SLR and coastal or fluvial storm conditions.

Drainage: Most culverts continue to experience modeled water levels at least one foot below the road elevation in all flood scenarios with 0.82 ft SLR. Approximately half of the priority culverts experience maximum tailwater or headwater elevations being surpassed with a 0.82 ft SLR under various storm conditions.

Intermediate SLR Scenario for 2100 (3.12 ft)

Road Impacts: With existing road elevations, flood depths frequently exceed one foot on the northbound and southbound centerline of the Corridor, and overtopping durations often surpassed 48 hours. During two-year coastal storms with 3.12 ft of SLR, over 55% of the Corridor becomes inundated, with average overtopping depths exceeding 1.1 ft and durations reaching approximately 65 hours. These conditions indicate a high likelihood of frequent road closures and an increased risk of structural damage.

Areas of the highway that are particularly susceptible to flooding include the SR 255/101 Interchange, both the northbound and southbound lanes between approximately Murray Field and Bracut Industrial Park (postmiles 81.1–83.1) and near Bayside Cutoff (approximately postmile 83.9). While the northbound lanes are generally at lower elevations, the southbound lanes, being closer to Humboldt Bay, experience deeper and more widespread flooding under MMMW conditions with 3.12 ft of SLR.

Although the total inundated roadway length is typically greater in the southbound lanes across most modeled events, extreme conditions—such as the 2-year coastal storm with 3.12 feet of SLR—result in more severe flooding in the northbound lanes, with higher mean and maximum flood depths. For example, under 3.12 ft of SLR, maximum flood depths reach 2.39 ft in the southbound lanes and 3.16 ft in the northbound lanes.

Bridge Impacts: With 3.12 ft of SLR, the soffit of northbound Gannon Slough Bridge is fully submerged across all event conditions. Importantly, the bridge deck itself is overtopped in all 3.12 ft SLR scenarios, with flood depths ranging from 0.18 to 1.12 ft and durations lasting 0.75 to 9.5 hours. Significant soffit engagement and submergence suggest the bridge will likely experience reduced flow conveyance, including effects to upstream water surface elevations, and elevated hydraulic pressures with increasing SLR. In contrast, the decks of the Jacoby Creek Bridges (northbound and southbound) are not overtopped in any of the modeled scenarios, even with 3.12 ft SLR. During the C2 & Q100 event, headwater elevations come within roughly two inches of the Jacoby Creek Bridge northbound deck's lowest point and the soffits of both bridges are submerged in all scenarios involving 3.12 ft of SLR.

Drainage Impacts: Most priority structures are overtopped during the larger flood events modeled under 3.12 ft of SLR.

A comprehensive interpretation of modeling results, along with implications for highway infrastructure, are addressed in the ‘Vulnerability Assessment’ portion of this section.

6.1.2 Coastal Hazards

The Coastal Hazards Technical Memo assesses the shoreline geomorphology and coastal flooding vulnerability of the region surrounding Wigi (Humboldt Bay). Photos and georeferenced historical maps were used to analyze shoreline conditions and evolution. A hydrodynamic model, wave model, and empirical formulations were used to evaluate coastal flooding vulnerability (Ludka et al., 2025).

Background

Wigi (Humboldt Bay) is the second largest natural bay in California (Costa and Glatzel, 2002). Wigi is situated within the 42-mile-long Eureka littoral cell (ELC) which is bounded by Trinidad Head in the north and False Cape in the south. The ELC has an approximate 4,520 mi^2 contributing watershed. Wigi’s watershed is comparatively small, at 223 mi^2. Wigi consists of three basins, Arcata Bay (or North Bay), Entrance Bay and South Bay (Figure 20). The four largest streams entering Wigi are Jacoby Creek and Freshwater Creek, which discharge into North Bay, Elk River which discharges into the northern end of Entrance Bay, and Salmon Creek that discharges into South Bay. Due to the small watershed size and low freshwater flows, Wigi is tidally dominated and consists of well-mixed marine water. Seasonal estuarine conditions occur in the sub-estuary regions of the bay tributaries (Costa and Glatzel, 2002).

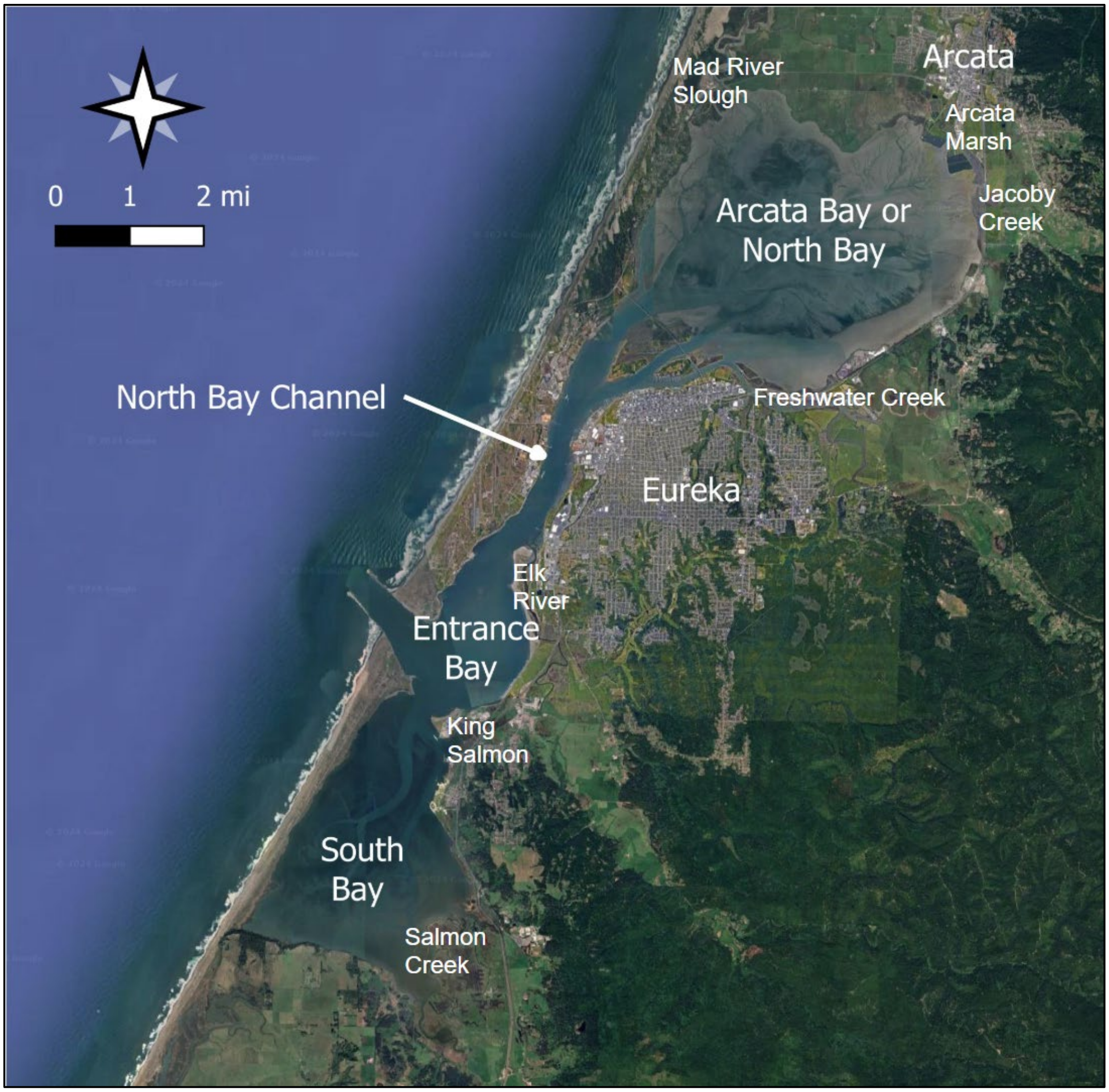


Figure 20. Wigi (Humboldt Bay) with its basins and major surrounding cities and tributaries.

Wigi's tides are mixed semidiurnal, with tidal amplification and phase that lags with distance from the entrance (Costa and Glatzel, 2002; Anderson, 2015). Arcata Bay has a mean tide range of approximately 4.8 feet, diurnal range of 6.7 feet, and a maximum range of about 11 feet during spring tides.

Daily low tides expose extensive mudflats, and high diurnal tides inundate salt marshes. Salt marsh ecosystems in Wigi establish at elevations approximately from mean high water (MHW) to over mean higher high water (MHHW) and are periodically inundated by extreme high tides. Along the Corridor, salt marsh primarily exists in the southern and northern segments. Approximately 70% of the bay is exposed tidal mudflat at low tide, where most of the mudflats are located in the shallower North and South Bays (Costa and Glatzel, 2002). The upper sub-tidal mudflats support an abundance of eelgrass and are incised by subtidal channels.

Rhode (2020) documented many of the land use changes in Wigi that occurred after settlers arrived. In 1881 the Eureka-Arcata navigation channel was dredged. A levee between Butcher Slough (now within Arcata Marsh) and the mouth of Jacoby Creek was constructed in 1892. Between 1895-1898 the former salt marsh edge was leveed from what is now Brainard and Bracut, as well as Freshwater/Eureka Slough, creating approximately 1,000 acres of diked former tideland. Two rail prisms (Eureka and Klamath River Railroad (E & KRR) and California & Northern Railway (C&N)) were constructed in 1900 (C & N's Northwestern Pacific tracks were laid in 1900, while the E & KRR tracks were never laid). The construction of the Eureka/Arcata Corridor in the 1920s created an additional tidal barrier and reduced the marsh area around Freshwater Slough. In the 1950s, the Bracut peninsula was expanded, and an additional two lanes were added to the highway.

By constructing levees and drainage structures, the tidelands were converted to agricultural land (Rohde, 2020). Tidewaters were also blocked by the construction of elevated railroad and road prisms. This infrastructure reduced salt marsh habitat, altered the shoreline, and often fixed the shoreline in place (Figure 21; Laird et al., 2013, Richmond et al., 2023).

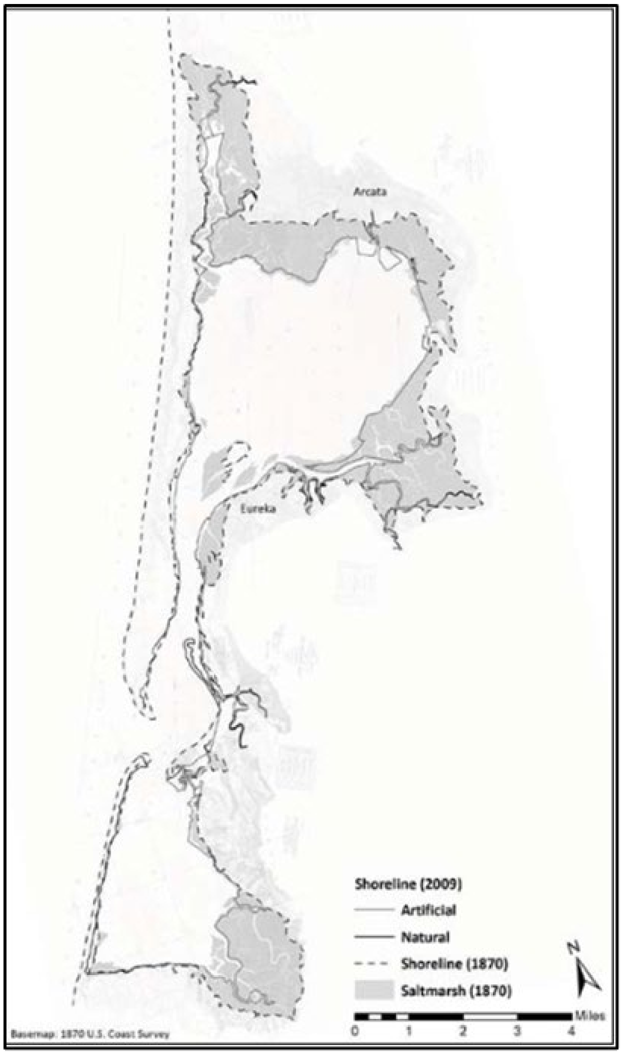


Figure 21. Wigi's 1870 Shoreline compared to the 2009 Shoreline. Figure by Jay Patton from Richmond et al. (2023), based on Laird et al. (2013).

Sediments in Wigi include silt, clays, and coarse material (e.g., sand, shell fragments) and their spatial patterns are associated with bay morphology, hydrodynamics and wave exposure (Thompson, 1971). The bottom of tidal channels are covered by gravelly and shelly sand that becomes finer and muddier with increasing distance from the inlet. Clayey silt dominates the tidal flats, and organic silty clay or clayey peat is found in salt marshes (GHD et al., 2022).

The outer coast wave climate is dominated by large frequent swells (Wheatcroft and Borgeld, 2000; Costa and Glatzel, 2002; George and Hill, 2008) which enter Wigi via the jettied channel into Entrance Bay. The Corridor is located along the shoreline of eastern Arcata Bay, which is sheltered from the large swell waves that frequent Entrance Bay. However, local strong wind events can generate short-period wind-waves with significant wave heights that are a couple feet tall along the Corridor shoreline (Federal Emergency Management Agency, 2014 and Environmental Science Associates, 2018).

Wigi has and will continue to evolve with SLR. Wigi was previously a river valley when sea level was 100-200 meters lower and then drowned as seas rose with the end of the last ice age (~15,000 to 20,000 years ago; Barnhart et al., 1992). Thompson (1971) suggested that the presence of extensive tidal flats and salt marsh imply former high rates of accretion and bay infill. Accretion rates measured in Jacoby Creek marsh appear lower than relative SLR (Curtis et al., 2019; Curtis et al., 2022) while historical accretion rates are estimated to have kept pace or slightly outpaced relative SLR (Thompson, 1971; Brown, 2019). While a sediment budget has not been completed for Wigi, climate change models predict an increase in suspended sediment delivery to the Eureka Littoral Cell and the Bay, which could partially offset impacts from SLR and subsidence (Curtis, 2021).

Methods

The existing shoreline was documented using photographs taken along the Corridor, where the photos are arranged along three shoreline segments (Figure 22).

Project area topography and bathymetry was defined by the 2020 United States Geological Survey (USGS) Coastal National Elevation Database (CoNED) 1-meter topobathymetric digital elevation model (TBDEM) for the Northern California Coast (2020 USGS CoNED TBDEM; Tyler et al., 2020). Figure 23 shows the topography and bathymetry along the Corridor.

Figure 22. Shoreline segments used in the CAIP's Coastal Technical Memo.

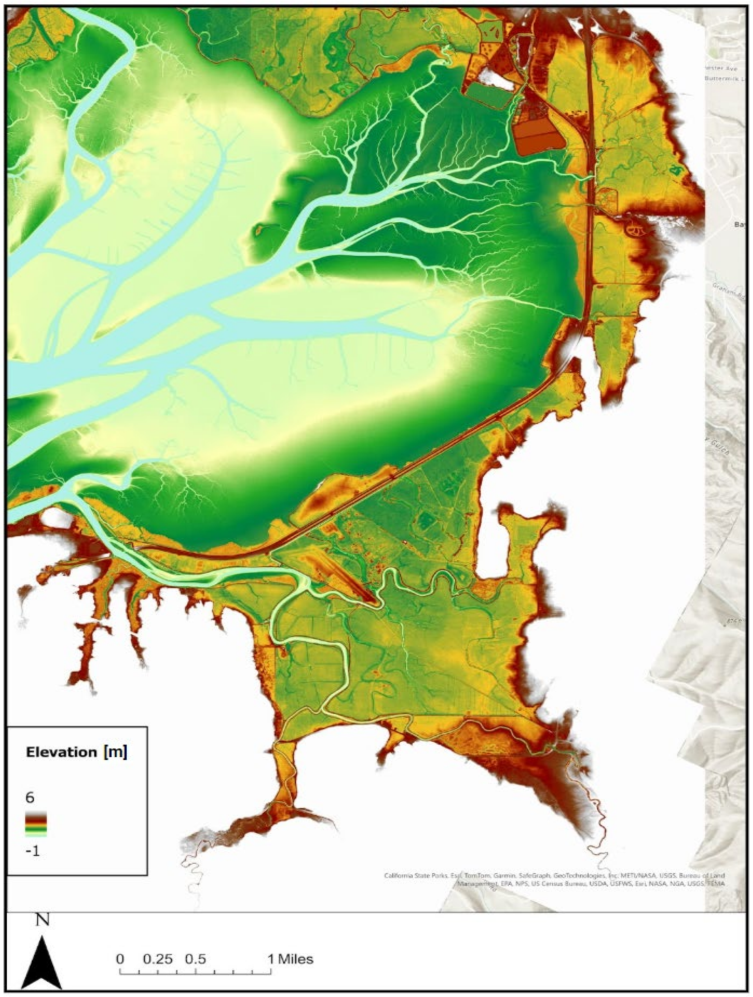


Figure 23. 2020 USGS Coastal National Elevation Database (CoNED) 1-meter topobathymetric digital elevation model (TBDEM). Elevations are in meters relative to NAVD88.

Throughout this technical memo, “extraction points” reference locations along the Corridor that were used to assess shoreline characteristics (Figure 24). Points 1 and 2 are in Section A, Points 3 and 4 are in Section B, and Point 5 is in Section C (Figure 22). The extraction points are located seaward of the toe of the structure to avoid any model edge effects. The protective structure landward of the extraction point was characterized at each location (Table 12).

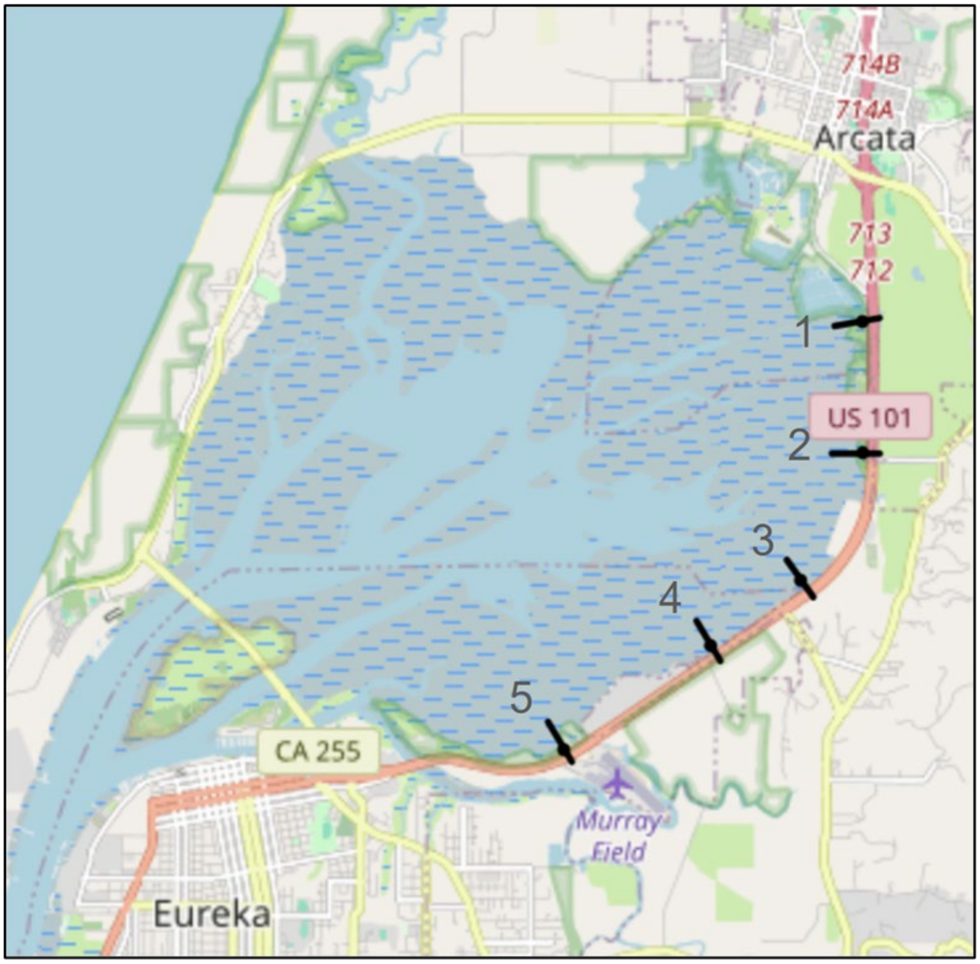


Figure 24. Extraction Points (black circles). Black lines show the orientation of the shoreline protective structure at each location and represent the profile transects shown in Figure 22.

Table 10. Location, elevation, and substrate type for extraction points.

Point	Latitude (°)	Longitude (°)	Elevation [ft, NAVD88]	Substrate Type
1	40.84853830	-124.0831946	6.6	Salt Marsh
2	40.83571592	-124.0831467	6.8	Salt Marsh
3	40.82324657	-124.0911922	3.3	Mud Flat
4	40.81686477	-124.1028397	3.6	Mud Flat
5	40.80667658	-124.1218314	6.3	Salt Marsh

This coastal hazards assessment considered seven sea level futures associated with these sea level scenarios: the current condition; 2050 Intermediate; 2100 Intermediate, Intermediate-High, and High scenarios; and 2150 Intermediate-High and High scenarios (Figure 25 and Table 11). The 2150 Intermediate scenario is not included because the 2100 Intermediate-High and High scenarios bracket this scenario. Statewide average SLR values from the 2024 California SLR Guidance (OPC, 2024) were used in this analysis because a more local vertical land motion (VLM) rate from the Mad River Slough tide gauge (-0.54 mm/yr) was incorporated (Patton et al., 2023). The 2150 Intermediate scenario is not included because the 2100 Intermediate-High and High scenarios bracket this scenario. Furthermore, the coastal memo includes more SLR scenarios than the hydrological memo because the coastal condition coastal conditions—particularly SLR—are the primary drivers of flooding dynamics within the Corridor. As SLR scenarios become more severe, both the extent and depth of flooding increase significantly, highlighting the need for robust coastal flood mitigation strategies. However, larger fluvial flood events also contribute to notable increases in road overtopping depths and inundation extent, particularly in the northbound lanes, which are the first to encounter fluvial floodwaters from the east. For instance, under MMMW + 3.12 feet SLR conditions, increasing fluvial flows from Q2 to Q100 lead to approximately a 1-inch rise in mean flood depth, a 3.6-inch increase in maximum depth, and an additional 2,162 feet of inundated roadway in the northbound lanes.

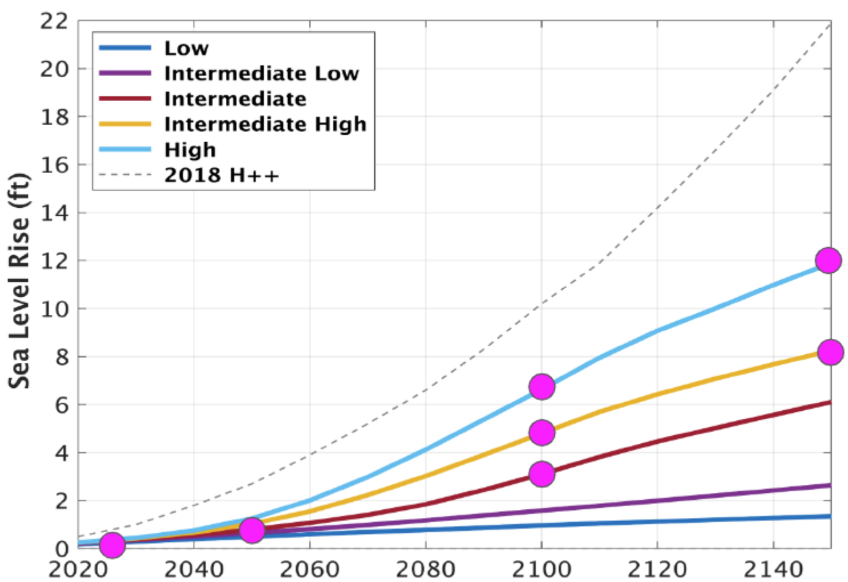


Figure 25. Adapted from California SLR Guidance (OPC, 2024). Regional SLR scenarios for California from 2020-2150 in feet, referenced to 2000. (These projections include the statewide average VLM rate of 0.10 mm of uplift/year.) Magenta circles indicate the SLR futures considered in this report. The outdated H++ scenario (Griggs et al., 2017) is included for comparison.

Table 11. SLR scenarios considered for this report, corresponding to magenta dots in Figure 25. SLR values are relative to the year 2000.

Scenario	2023	2050	2100	2150
Current Condition	X			
Intermediate		0.8 ft (0.24 m)	3.1 ft (0.94 m)	
Intermediate - High			4.9 ft (1.5 m)	8.3 ft (2.5 m)
High			6.6 ft (2.0 m)	11.9 ft (3.6 m)

Figure 26 depicts a visual glossary of water level terminology. Mean sea level changes with relative SLR. The astronomical tide describes water level fluctuations that result from the gravitational effects of astronomical objects, especially the sun and moon. Earth's shape and rotation also affect the timing and spatial pattern of the tides. The non-tidal residual is the variability that a tide gauge measures that is NOT the astronomical tide, nor SLR, nor vertical land motion. The non-tidal residual includes climate oscillations (e.g. El Niño Southern Oscillation), seasonal effects (e.g. seasonal temperature and wind patterns), and storm surge (e.g. inverse barometer effect and regional wind setup). Here, local wind setup is wind setup due to wind blowing water around in the bay. Wave setup is the time-average increase in water levels due to the presence of breaking waves. (Right before waves break there is a small amount of wave setdown which is not shown in the schematic.) Swash is the uprush and downrush of water on the beach due to the presence of waves. Runup is the sum of wave setup and swash uprush combined. Typically, wave runup is characterized using $R_{2\%}$, which is the elevation above a hypothetical wave-free reference water level (RWL) that is exceeded by two percent of the individual wave runup events. Still water level is the water level due to mean sea level, plus the tide and the non-tide residual. Here the term "reference" water level refers to the water level due to still water level plus local wind setup. The total water level is the RWL plus $R_{2\%}$.

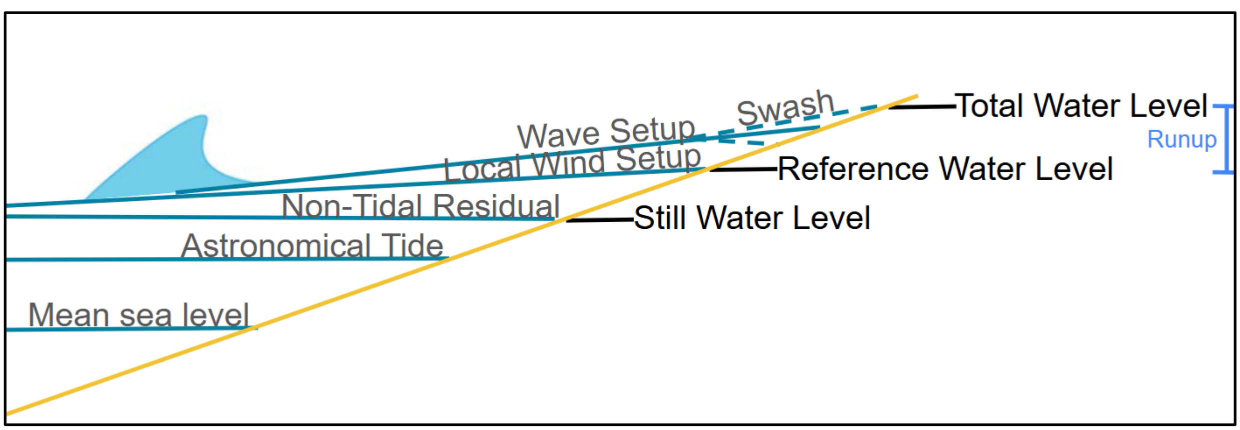


Figure 26. Visual glossary of water level terms.

A hydrodynamic model, wave model, and empirical formulations were used to evaluate coastal flooding vulnerability. Building on the EFDC hydrodynamic model developed by Anderson (2015), RWLs were estimated (tide, non-tidal residual, and local wind setup) based on 74 years of tide gauge and wind observations. Reference water level extreme recurrence intervals were estimated using the Generalized Pareto Distribution-Peaks Over Threshold method.

The two-dimensional SWAN model was used to simulate the generation, propagation and dissipation of waves across the bay.

Look-up tables of bulk wave parameters are generated numerically for the five extraction points to produce a range of realistic forcing conditions. Time series of wave conditions are generated by querying the look-up table for the simulated RWLs and observed wind conditions.

Wave runup, overtopping, and overflow discharge are estimated empirically following EurOTop (2018), using the modeled bulk wave parameters and the shoreline structure's geometric characteristics (e.g. slope, height, crest width). The model framework is applied for a range of sea level futures that account for local vertical land motion.

Results

Documentation of the existing shoreline indicates Segments A and C have larger areas of salt marsh along the shoreline than segment B. By analyzing historical maps, GHD et al. (2022) found that shoreline segment B has experienced greater salt marsh erosion than shoreline segments A and C. They found that marsh edge positions in segment A and C are fairly static, suggesting an ongoing process of erosive scarping, followed by accretion and revegetation. The Bracut and Brainard peninsula shorelines are primarily riprap. Extensive mudflats and some pocket beaches of sand and cobble (formed by erosion of the historical railroad prism) are exposed at lower water levels (not shown). See Ludka et al. (2025) for shoreline photos pertaining to this technical memo, additional photos can be found in Laird et al. (2013), GHD (2018), GHD et al. (2022) and others.

Extraction points at the five locations (Figure 24) were used to compare shoreline features such as elevation from the shoreline to the highway and saltmarsh versus mudflat presence. The differences in the salt marsh extent fronting the shoreline structure at each extraction point can be seen in Figure 27, while the differences in the heights and shapes of the protective shoreline structure are shown in Figure 28 and Table 12. Since completion of the Bay Trail, extraction points 3 and 4 have the tallest protective shoreline structure. However, note that the highway elevation is lowest at Points 3 and 4, so these locations could still be the most vulnerable if water gets in elsewhere (Figure 29).

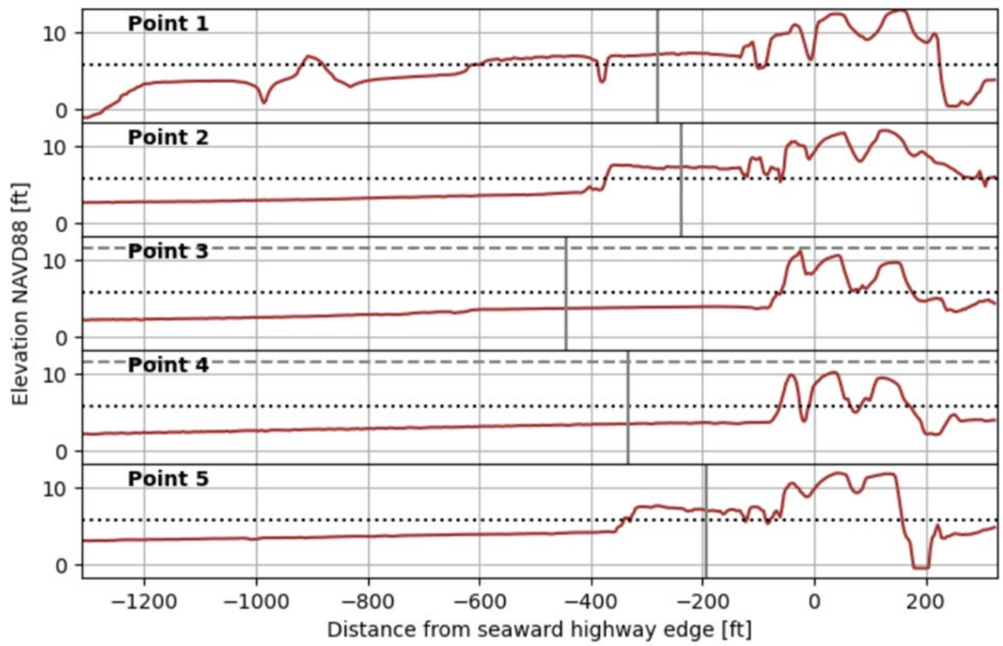


Figure 27. Elevation profiles (using the 2020 USGS CoNED TBDEM) along transects shown in Figure 24. The approximate delineation of mud flat and salt marsh is shown as a dotted black horizontal line. The vertical gray line shows the extraction point location. The dashed horizontal gray line shows the planned elevation of the shoreline protective structure at Points 3 and 4 from the Bay Trail.

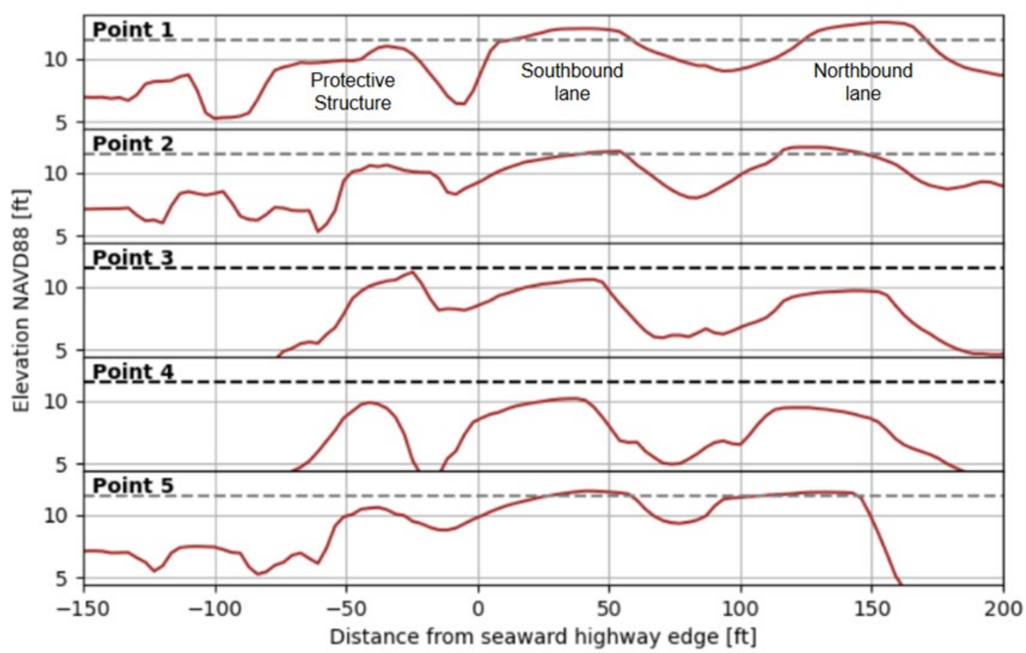


Figure 28. Elevation profiles zoomed in on the shoreline protective structure and highway lanes. The dashed horizontal lines mark 11.5 ft NAVD88, which is the planned max structure height at Points 3 and 4 for the Bay Trail.

Table 12. Estimated protective shoreline structure characteristics (post Bay Trail completion).

Point	1	2	3	4	5
Type*	ORP	ORP	RSP	RSP	ORP
Slope**	0.2	0.5	0.6	0.6	0.3
Crest Elevation [ft]**	11.0	10.6	11.5	11.5	10.6
Orientation [°]***	6	0	303	300	298
Crest Width [ft]*****	NA	NA	6.6	6.6	NA

* ORP = Old Rail Prism: grassy mud and cobble. RSP = Rocky Shore Protection: riprap

** Slope and crest elevation at points 1,2, & 5 were estimated from the 2019 CoNED TBDEM. Slope and crest elevation at points 3 & 4 were estimated from the project plans for the Bay Trail (County of Humboldt Department of Public Works, 2022).

*** Orientation is the cartesian angle (0° is pointing east, 90° is pointing north, etc.) of the vector pointing normal to the structure, from the seaside of the structure toward land. Estimated using Google Earth.

**** The structure crest width is provided for RSP structures for determining overtopping discharge. It is not needed for the ORP structures. The RSP crest width was estimated as larger than specified in the project plans for the Bay Trail because the given 2-ft value does not seem physically possible due to the boulder sizes.

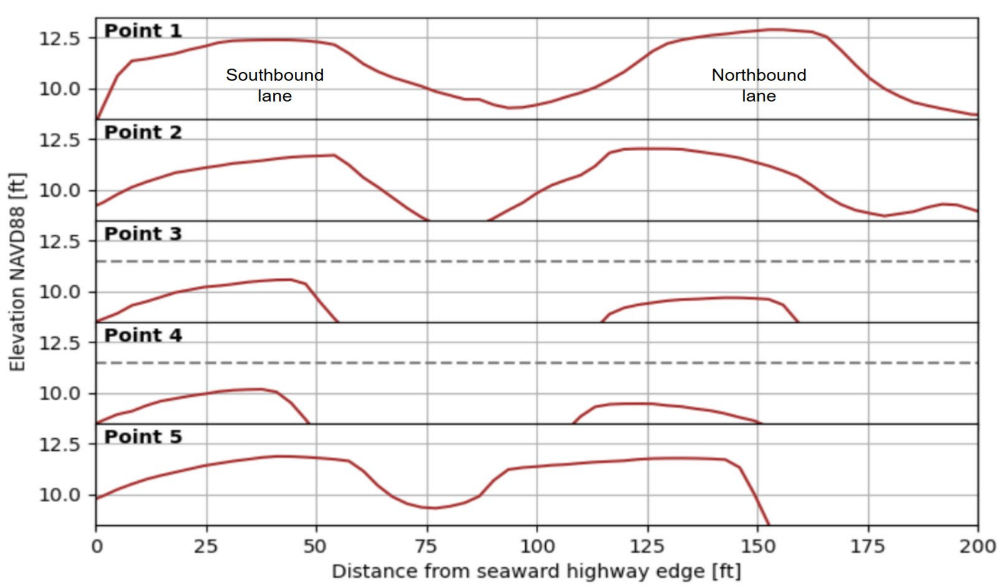


Figure 29. Profiles zoomed in on the highway lanes to emphasize the differences in elevation. The dashed horizontal lines mark 11.5 ft NAVD88, which is the planned maximum structure height at Points 3 and 4 once the Bay Trail is completed.

Results from the 2D model simulations demonstrate how tidal hydrodynamics and general circulation patterns affect water levels in Humboldt Bay. Simulated maximum daily water levels show tidal amplification in the bay, which has a phase that lags with distance from the harbor entrance (Figure 30). Modeled maximum tidal amplification occurs in North Bay and along portions of the Corridor, where the peak still water levels are about a half a foot larger than the entrance boundary condition.

Wind stress on the water surface from higher speed winds can generate relatively large wind setup conditions that can affect water levels in Humboldt Bay. Winds from the northwest create a strong water surface gradient across North Bay as water is pulled from the western shoreline and pushed towards the eastern shoreline. Winds from the south-southwest direction push water out of South Bay into North Bay, and somewhat surprisingly can create larger wind setup values along the Corridor shoreline than wind blowing perpendicular to the shoreline (from the northwest). In addition to the tidal amplification, model results show that wind setup can elevate water levels along the Corridor by another couple feet, where differences in RWLs between extraction points are typically on the order of centimeters (see Figure 4.2.3 in Ludka et al., 2025).

An extreme value analysis was conducted on the daily maximum RWLs at the five extraction point locations using the peaks-over-threshold approach and Generalized Pareto Distribution (GPD) for each SLR scenario. Results from this analysis show that by the 2100 Intermediate SLR future, modeled RWLs are regularly above the structure crest height elevations at all locations, suggesting the existing highway will be regularly flooded at this SLR future (Figure 31).

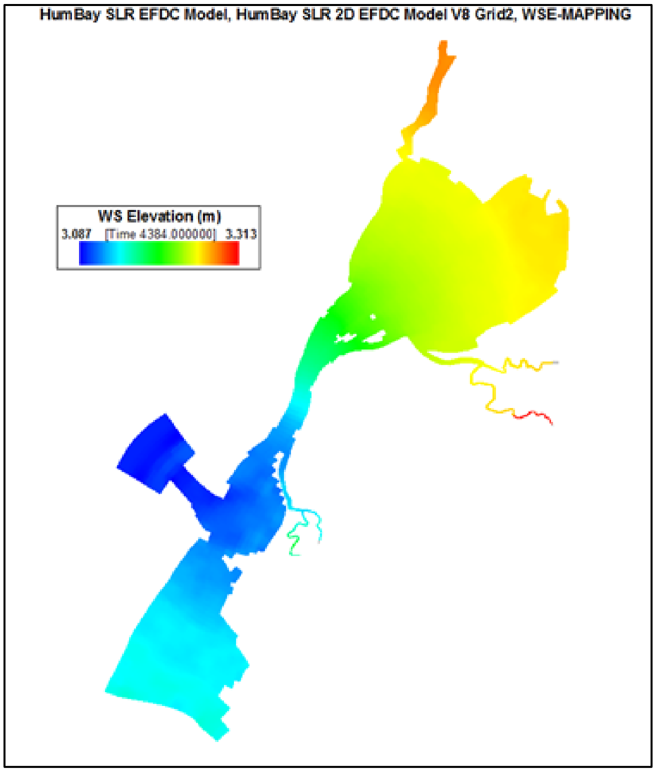


Figure 30. Simulated maximum daily still water levels (low wind conditions).

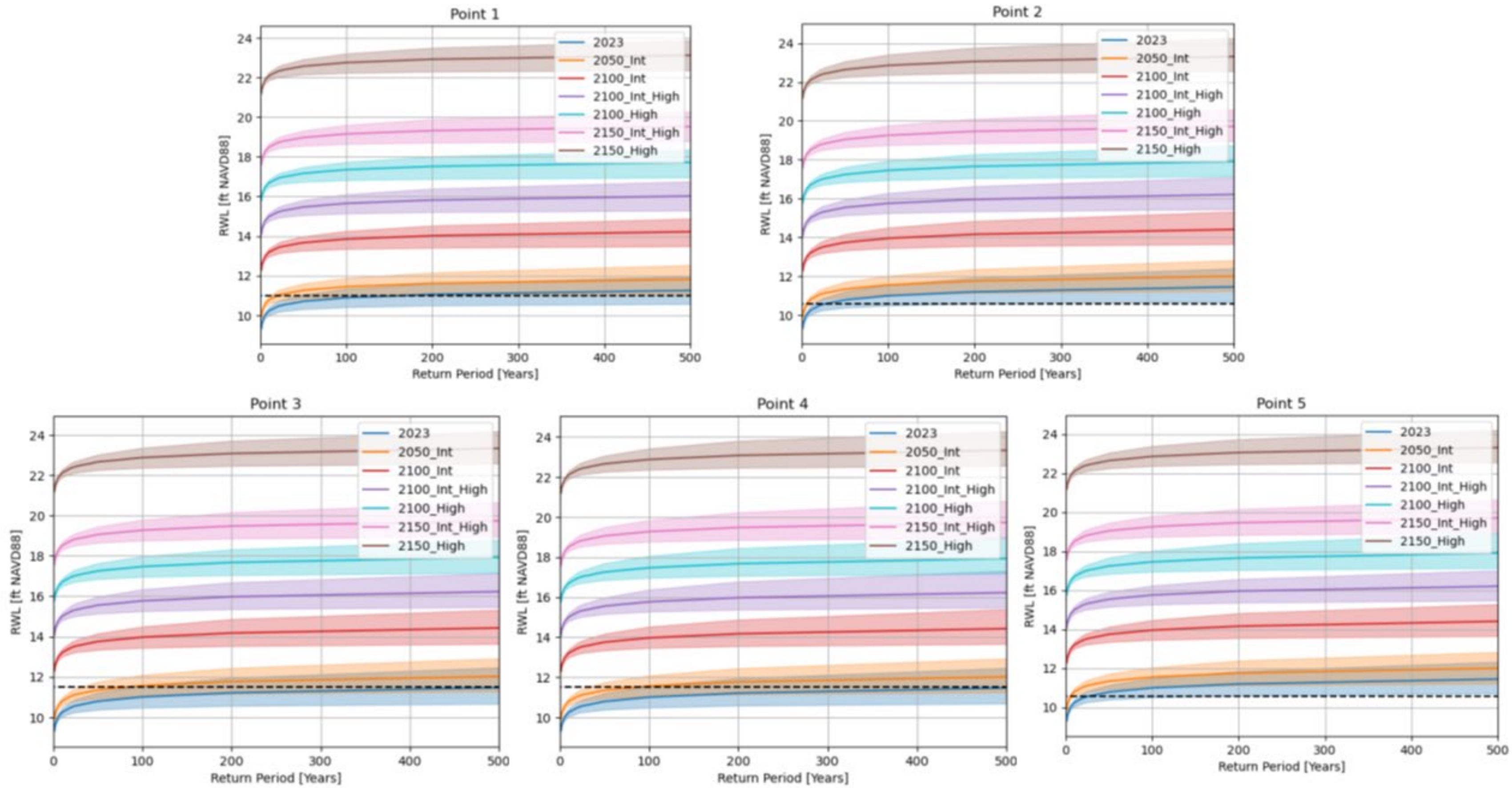


Figure 31. Estimated RWL return values vs. return period at Points 1-5 for various sea level futures (see legends). Shading represents the 95% confidence interval. The crest height of the structure at this location is shown as a black dashed horizontal line.

Figure 32 shows examples of local wind wave (SWAN) model output highlighting wave dissipation over the salt marsh, where depth limited wave breaking dominates.

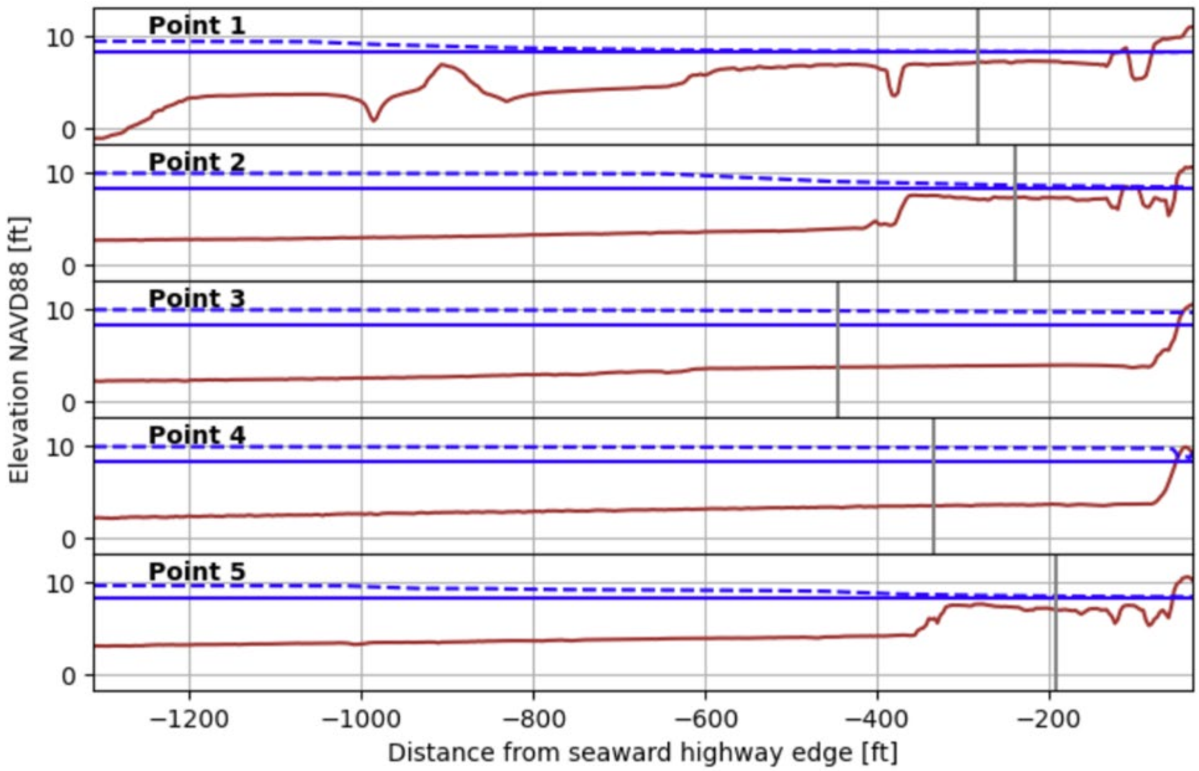


Figure 32. Significant wave height profiles (dashed blue lines) at the extraction points for a 26.8 mile per hour (12 meters per second) westerly wind (blowing toward the east) with a water level of 8.2 ft (solid blue lines). The locations of the extraction points are marked with a vertical gray line. Note the reduction in wave height due to depth-limited wave breaking over the salt marsh at Points 1, 2, and 5.

The wave runup analysis indicates Points 3 and 4 generally experience the largest modeled runup (max of around 4 ft by the 2050 Intermediate SLR future), which is primarily due to the absence of salt marsh fronting these sites (Figure 33). In contrast, max modeled runup at points 1, 2, and 5 is approximately 2 feet or less by the 2050 Intermediate future. While points 3 and 4 experience the greatest wave runup along the shoreline, the elevated railroad prism protecting the Bay Trail serves to mitigate these coastal impacts.

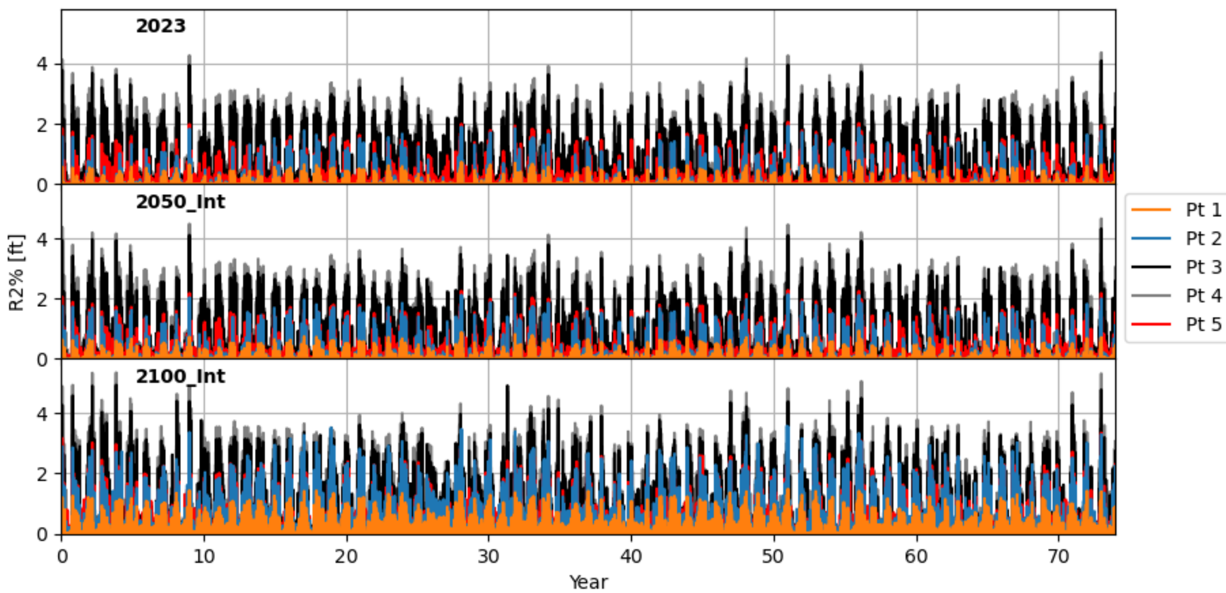


Figure 33. $R_{2\%}$ time series estimated using EurOTop (2018), the modeled wave conditions (see Figures 5.2.1-2 in [Ludka et al., 2025](#)), and shoreline structure characteristics (Table 12). [Top] 2023. [Middle] 2050 Intermediate SLR future. [Bottom] 2100 Intermediate SLR future.

Modeled coastal discharge from wave runup overtopping is only shown for the 2023 and 2050 Intermediate future scenarios because overflow discharges become large at all locations further into the future due to RWLs exceeding structure crest heights (Figure 34). During these SLR scenarios, overtopping and overflow occur most frequently at Points 2 and 5 because these locations have the lowest structure crest height.

The vulnerability of the Corridor is influenced by coastal and fluvial processes. More information on the vulnerability of the Corridor can be found in Section 6.1.5 Vulnerability Assessment.

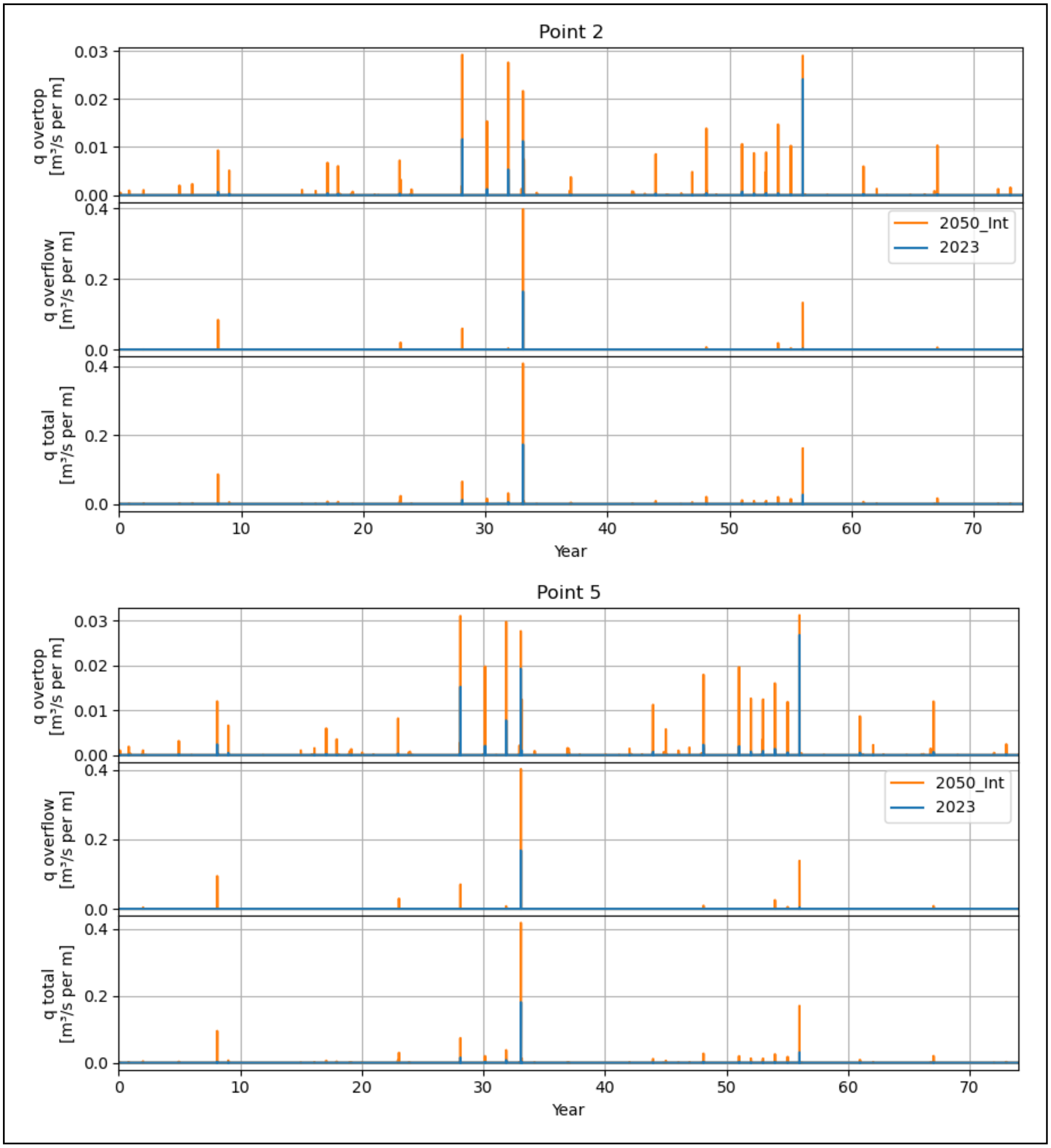


Figure 34. Time series of discharge quantities at Point 2 (top) and Point 5 (bottom) for 2023 and 2050 Intermediate SLR Scenarios using the historical storm record. See Ludka et al., 2025 for complete set of plots for all five extraction points.

Main Points and Recommendations

- Levees, drainage structures, railroad prisms and the Eureka/Arcata Highway prism have blocked tidewaters, reduced salt marsh, and modified the shoreline. **The new Bay Trail will further alter the shoreline, where Points 3 and 4 will have the tallest protective shoreline structure crest height. However, the highway elevation is**

lowest at Points 3 and 4, so these locations could still be the most vulnerable if water gets in elsewhere.

  - Recommendation: Collect lidar survey data post Bay Trail construction to accurately map new shoreline configuration.

- Points 1, 2, and 5 are fronted by salt marsh, while Points 3 and 4 are mostly fronted by mudflats due to salt marsh erosion.
  - Recommendation: Collect lidar survey data seasonally, for multiple years, to understand the evolution of sediment levels and vegetation coverage fronting the project shoreline at each location.

- The amount of future SLR depends on emissions and the climate's physical response. The Low scenario represents the lower edge of plausibility and aggressive emissions reductions. The Intermediate-Low scenario is the lower bound of the most likely SLR, while the Intermediate is the upper bound of the most likely SLR. The Intermediate-High scenario is associated with high emissions and low confidence ice processes, while the High scenario requires very high emissions and lots of low confidence ice processes. Additionally, VLM contributes to *relative* SLR. From available data, it is unclear whether locations along the corridor are uplifting or subsiding. As a conservative approach, we use the Mad River Slough tide gauge's subsiding VLM rate (-0.54 mm) for all sites along the corridor.
  - Recommendation: Install a tide gauge along the Corridor shoreline to continuously monitor SLR and VLM.

- Modeled max RWLs are elevated above the entrance bay still water levels due to tidal amplification (~0.5 ft) and wind setup (~2 ft). **Results show that by the 2100 Intermediate SLR future, modeled RWLs are regularly above the crest height elevations at all locations, suggesting the existing highway will be regularly flooded at this SLR future.**
  - Recommendation: Install an anemometer on one of the small sand islands in the middle of North Bay and monitor winds for a couple of years to better understand local winds directly over the bay and their contribution to wind setup.

- As seas rise, wave heights increase due to reduced depth-limited wave breaking. By the 2050 Intermediate SLR future ~2 ft max modeled wave heights occur at Points 3 and 4, while max modeled waves are only ~0.5 ft at Points 1, 2, and 5 due to the protection provided by the salt marsh.
  - Recommendation: Install an array of wave resolving pressure sensors (and/or an acoustic doppler current profiler with wave measuring capabilities) for a couple of years (ideally with the same deployment time period as the anemometer and spanning the seasonal lidar surveys) in eastern Arcata Bay to measure waves and calibrate the wave model.

- Water levels at the shoreline are further elevated by wave runup. By the 2050 Intermediate SLR future, the largest modeled runup is about ~4 ft at Points 3 and 4, due to the absence of salt marsh fronting these sites. In contrast, max modeled runup at points 1, 2, and 5 is approximately 2 ft or less by the 2050 Intermediate future.

  - Recommendation: Install a pressure sensor inside the shoreline protection structure at each location for a couple of years (ideally with the same deployment time period as the anemometer and wave sensors and spanning the seasonal lidar surveys) to calibrate the runup estimations.

- Modeled coastal discharge is only shown for the 2023 and 2050 Intermediate futures because overflow discharges become large at all locations farther into the future due to RWLs exceeding structure crest heights. **During the 2023 and 2050 Intermediate SLR futures, overtopping and overflow occurs most frequently at Points 2 and 5 because these locations have the lowest structure crest height.** ***Discharge only constitutes flooding if it overwhelms drainage capabilities.***

- Modeled total water level results do not identify the only known coastal flooding event as extreme. A comparison of the wind forcing data in our model to local wind gust measurements (converted to an hourly over-water wind speed) suggest that we are underestimating the intensity (and perhaps misjudging the direction) of the wind during this event.

6.1.3 Groundwater Hazards

The Groundwater Hazards technical memo describes the current understanding of potential impacts of SLR on the groundwater in and adjacent to the Corridor and evaluates the groundwater conditions and hazards (Lang, 2025).

Ocean and bay water elevations define the groundwater level boundary for coastal aquifers and influence the adjacent groundwater elevations. Rising sea levels are expected to increase coastal groundwater elevations. The resulting rise in the water table can lead to numerous impacts, including increased surface runoff due to reduced infiltration, loss of usable land, habitat changes, increased contaminant transport, compromised sewer and septic systems, road infrastructure damage, and potential foundation damage to buildings. Additionally, higher sea levels can promote saltwater intrusion, pushing brackish or saltwater further inland.

Methods

The groundwater analysis combined findings from the groundwater component of the USGS Coastal Storm Modeling System (CoSMoS-GW) and more detailed, local groundwater models developed specifically for the CAIP to provide more localized predictions.

The two models developed for the CAIP focused on the Jacoby Creek/Bayside Bottoms and Fay Slough areas on the north and south end of the project area, respectively (Figure 35).

The project area is already known to have groundwater at or near the ground surface during most of the wet season and this would be expected to become worse with SLR. Thus, this modeling analysis evaluated potential SLR impacts on groundwater elevations during dry weather conditions with little to no precipitation and maximum evapotranspiration. The simulations also included the network of stream and slough channels present within the project area as these can both infiltrate and drain surface water into or out of the groundwater. As SLRs, the water level in these channels could potentially become deeper, promoting more infiltration into the groundwater during the dry season and maintaining higher year-round groundwater elevations.

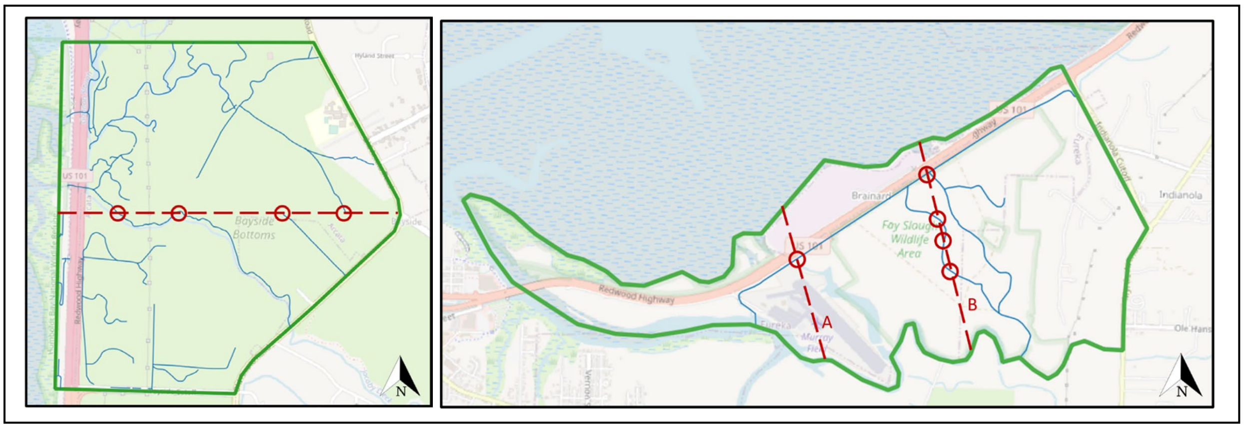


Figure 35. Model areas for the two local models developed for the CAIP hazard analysis. Left: Jacoby Creek/Bayside Bottoms model areas showing the cross section used to extract groundwater elevations for model comparisons. The red circles indicate locations where the cross section intersects blue line channels present in the City of Arcata stream channel GIS layer (City of Arcata 2024). Right: Fay Slough model area showing the cross section used to extract groundwater elevations for model comparisons. The red circles indicate locations where the cross section intersects blue line channels present in the USGS National Hydrography Dataset (USGS 2024). In both images the channel layer has been clipped to the model area.

Results

The results from the USGS CoSMoS-GW modeling provide an estimate of groundwater elevation response to various SLR scenarios. The predictions are conservative, steady-state annual average values that do not account for the possible wet-dry extremes experienced in California's climate. The USGS CoSMoS-GW simulations also do not account for the presence of sloughs or coastal stream channels that can promote drainage or infiltration to and from adjacent land. Projections from the CoSMoS-GW indicate that low elevation coastal regions will generally become submerged by rising sea levels, rather than by rising groundwater. With 0.8 ft of SLR (2050 Intermediate projection), an expansion of area with emergent groundwater (groundwater at or above the land surface) is predicted to occur in the northern part of the project area around Gannon Slough. With an increase of

3.1 ft (2100 Intermediate projection) the remaining low-lying areas around the Corridor are predicted to be submerged by rising sea level.

CoSMoS-GW projections also indicate limited saltwater intrusion, mainly due to a strong east-to-west groundwater flow from hillslopes, which maintains high groundwater pressure, and the absence of large-capacity extraction wells that could draw saltwater inland. Local domestic and irrigation wells are likely protected from saltwater impacts as they tap into deep, confined aquifers (below 80 ft) that are often artesian, meaning they are under sufficient pressure to maintain freshwater conditions.

Results for the two local models indicate that most of the region modeled in this analysis is predicted, without the implementation of significant infrastructure or physical modification, to convert to marine/tidal conditions and be inundated with SLR of 3.1 ft or higher (Figure 36).

Despite differences in model inputs such as accuracy of drainage ditch channel morphology, the USGS CoSMoS-GW modeling matched well with the local model's average annual conditions.

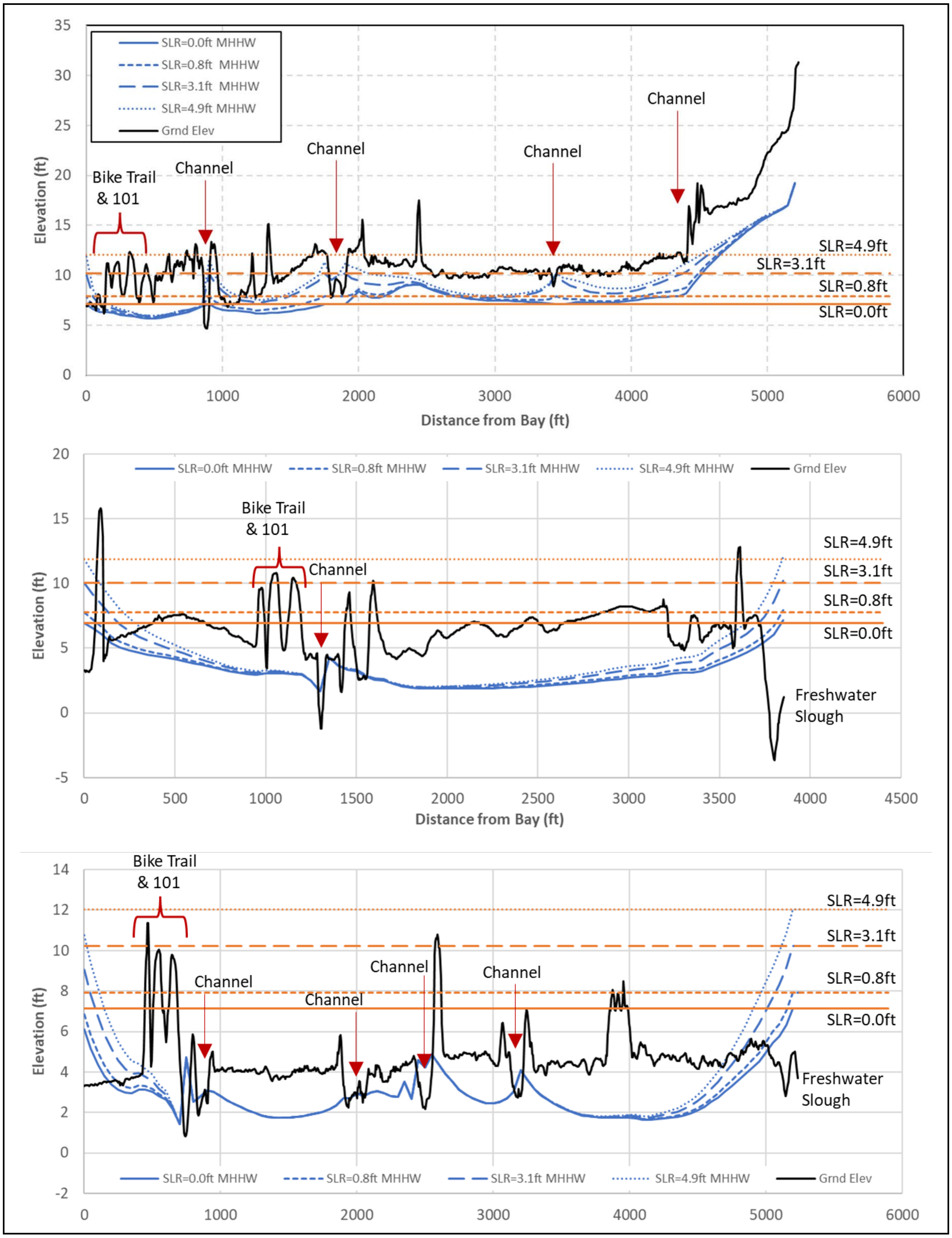


Figure 36. Comparison of local, steady-state model results that predict groundwater elevation (blue lines) for current conditions (SLR=0.0 ft) and three higher sea level scenarios for the Jacoby Creek/Bayside Bottoms(top), cross section A in the Fay Slough area (middle), and cross section B in the Fay Slough area (bottom)(see legend). The orange lines show the static water elevations for each of the scenarios.

6.1.4 Geologic Hazards

The Geologic Hazard assessment consists of five technical memos that cover Strong Ground Motion, Surface Rupture, Coseismic and Interseismic Land-Level Changes, Liquefaction, and Tsunamis. Technical memos were prepared by Mark A. Hemphill-Haley (2025a – 2025e). Additional information from Caltrans resources have been incorporated into sections below.

Strong Ground Motion

The North Coast of California is a highly seismically active area because of its proximity to the intersection of three tectonic plates: the Pacific plate to the south, the Gorda plate to the north, and the continental North America plate to the east (Oppenheimer et al., 1993; Velasco et al., 1994; Schwartz and Hubert, 1997; Furlong and Schwartz, 2004). Most of the seismicity is associated with low-magnitude (M) earthquakes, but the area has experienced 20 earthquakes greater than M6 in the last 50 years (USGS, 2020).

There are five seismic sources with the potential to generate intense and possibly long-duration shaking in onshore and offshore areas of the North Coast of California. These sources are: (1) the southern end of the Cascadia subduction zone (CSZ); (2) the northern end of the San Andreas transform fault zone (SAF); (3) the Mendocino fault; (4) the Gorda plate; and (5) the fold and thrust belt of the accretionary wedge of the overriding North America plate, which underlies the coastal, nearshore, and inland areas of Humboldt County. The seismic shaking generated by these sources may drive or trigger other geological hazards, such as liquefaction, surface rupture, tsunamis, and vertical land motion.

The Cascadia Subduction Zone (CSZ) consists of the megathrust (regional thrust fault) and associated deformation zone formed at the tectonic boundary between the subducting Juan de Fuca and Gorda plates and the overriding North America plate (Pacific Northwest Seismic Network, 2020). The CSZ extends for approximately 1,300 km (800 miles) from Northern California to Vancouver Island, B.C. (Zimmerman et al., 2005). Subduction zones are the only sources capable of generating earthquakes greater than M8.5 (Pacific Northwest Seismic Network, 2020). Earthquakes of this magnitude generate strong shaking lasting for several minutes, a feature of earthquake behavior commensurate with the area (length and width) of the fault rupture (Wells and Coppersmith, 1994). Destructive tsunamis are commonly generated during subduction zone earthquakes as large volumes of seawater are displaced from sudden upheaval of the seafloor during fault rupture (Voit, 1987; Satake and Atwater, 2007; Sugawara et al., 2008), or from massive submarine landslides set in motion by the shaking (Watts, 2000; McAdoo and Watts, 2004; Didenkulova et al., 2010; Løvholt et al., 2015; Earthweb, 2020). Like other subduction zones, the CSZ has ruptured along segments of different lengths as well as full-margin ruptures (Nelson et al., 1995, 2006; Satake et al., 2003; Leonard et al., 2010; Goldfinger et al., 2012, 2013). Field evidence indicates the CSZ has ruptured in greater than M8 earthquakes in the past and is currently locked by friction at depths shallower than about 30 km, building seismic stresses for a future rupture (Savage et al., 1991; Hyndman and Wang, 1995; Wang et al., 2003; Wang and Tréhu, 2016).

In Northern California, investigations into the record of past CSZ earthquakes have focused on Humboldt Bay and the lower Eel River Valley (Li, 1992; Carver et al., 1998; Patton, 2004; Pritchard, 2004; Engelhart et al., 2016; Hemphill-Haley, 2017; Padgett et al., 2021) and sites between the Klamath River and northern Crescent City (Abramson, 1998; Carver et al., 1998; Garrison-Laney, 1998; Peterson et al., 2011; Hemphill-Haley et al., 2019). In southern Humboldt Bay Patton (2004) reported evidence for four past CSZ earthquakes, two of which may have been accompanied by tsunamis. The last ~M9 full-rupture earthquake on the CSZ occurred in 1700 C.E. Recurrence of great subduction zone earthquakes for the southern CSZ range from an estimated 245-720 years from the on-land record at Humboldt Bay and Crescent City to approximately 240 years from the offshore turbidite record (Goldfinger et al., 2012, 2013). The next great (>M8) CSZ event has the potential to cause immediate coastal subsidence up to two meters (Dura et al., 2025). Evidence from past events indicates this sudden downward vertical motion would likely submerge low-lying intertidal wetlands and floodplains and have severe consequences for infrastructure. Historical records of the intensity and duration of strong shaking from modern events of the past 50-60 years may be used as reliable analogs for effects on infrastructure from potential future events on the southern CSZ.

The SAF is part of a 100 km wide transform boundary that forms the interface between the Pacific and North America tectonic plates (Wallace, 1990; Schulz and Wallace, 1997). The entire SAF extends for about 1200 km (750 mi) from near the Salton Sea in southern California to the Mendocino triple junction offshore from Cape Mendocino in the north and is divided into three sections (northern, central, and southern) based on different characteristics including slip rates and historical rupture history (Beeson et al., 2017; Berkeley Seismological Lab, 2020; Schulz and Wallace, 1997). Potential strong shaking from earthquakes along the northern SAF is significant for the North Coast because of proximity and history of past events. The northern SAF has been the source of possibly 8-12 large earthquakes over the past few millennia (Kelson et al., 2006; Niemi, 2010; Weldon et al., 2013; Zhang et al., 2006). Within the last 200 years, there have been three significant ruptures along the northern SAF: the 1838 Peninsula San Andreas earthquake (~M7); the 1906 San Francisco earthquake (M7.9); and the 1989 Loma Prieta earthquake (M6.9) (Bakun and Prescott, 1993; Ellsworth et al., 2013; Holzer, 1992; Schwartz et al., 2014; Streig et al., 2014; Toppozada and Borchardt, 1998). The 1906 earthquake caused extensive damage in Humboldt County, and based on the severity of damage and scale of liquefaction, is described as the County's strongest historic event.

The Mendocino fault is a transform fault that marks the boundary between the Pacific Plate and the Gorda Plate. It runs east-west and is part of the Mendocino Triple Junction -- a high seismicity region and a frequent source of felt seismic shocks for the North Coast (Bryant, 2001). Although most earthquakes generated in this area are small, more than 400 earthquakes greater than M4.5 have occurred along the Mendocino fault since 1960 (USGS, 2020).

The Gorda Plate is a small oceanic tectonic plate located off the coast of Northern California and Southern Oregon that is being subducted beneath the North America Plate at the CSZ. The Gorda Plate is an area of frequent fault rupture and seismicity (Tobin and Sykes, 1968; Kilbourne and Saucedo, 1981; Wilson, 1989; Fox and Dziak, 1999; Gulick et al., 2001; Dziak et al., 2001; Chaytor et al., 2004; Rollins and Stein, 2010) and the primary source of felt earthquakes for the North Coast of California (USGS, 2020). Historically, the plate has generated small to moderate earthquakes (M4 to M6) that occur more frequently and large earthquakes (greater than M7), which are much less common.

Faults within the fold and thrust belt of the CSZ accretionary prism also have the potential to generate strong shaking. These include the Little Salmon Fault and the Mad River Fault Zone.

Surface Rupture

Surface ruptures occur when movement on a fault deep within the earth breaks through to the surface. Surface fault rupture does not occur with all earthquakes, but it has the potential to cause large deformations to infrastructure.

Most of the area around the Corridor is not susceptible to surface rupture (Table 13). However, the Fickle Hill fault, an Alquist-Priolo fault that traverses the Corridor near the 11th Street overcrossing in Arcata, poses a surface rupture hazard to the northernmost portion of the Corridor (Figure 37). Additional faults near the Corridor, including the Bayside, Bracut, and Freshwater faults, have a low probability of activity that would affect the area.

Table 13. Geologic hazard information at various sites along the Corridor.

Site	Surface Fault Rupture Potential	Liquefaction Depth (ft)	Potential for Lateral Spreading	Source
Eureka Slough	No	70	Yes	Structure Preliminary Geotechnical Report (Caltrans, Geotech, 2023)
Indianola Intersection	No	10 to 14 34 to 40	Yes	Foundation Report (Caltrans, Geotech, 2022)
Jacoby Creek	No	40	Low	Foundation Report (Caltrans, Geotech, 2019)

Site	Surface Fault Rupture Potential	Liquefaction Depth (ft)	Potential for Lateral Spreading	Source
Gannon Slough	No	50	Not determined	Structure Preliminary Geotechnical Report (Caltrans, Geotech 2017)

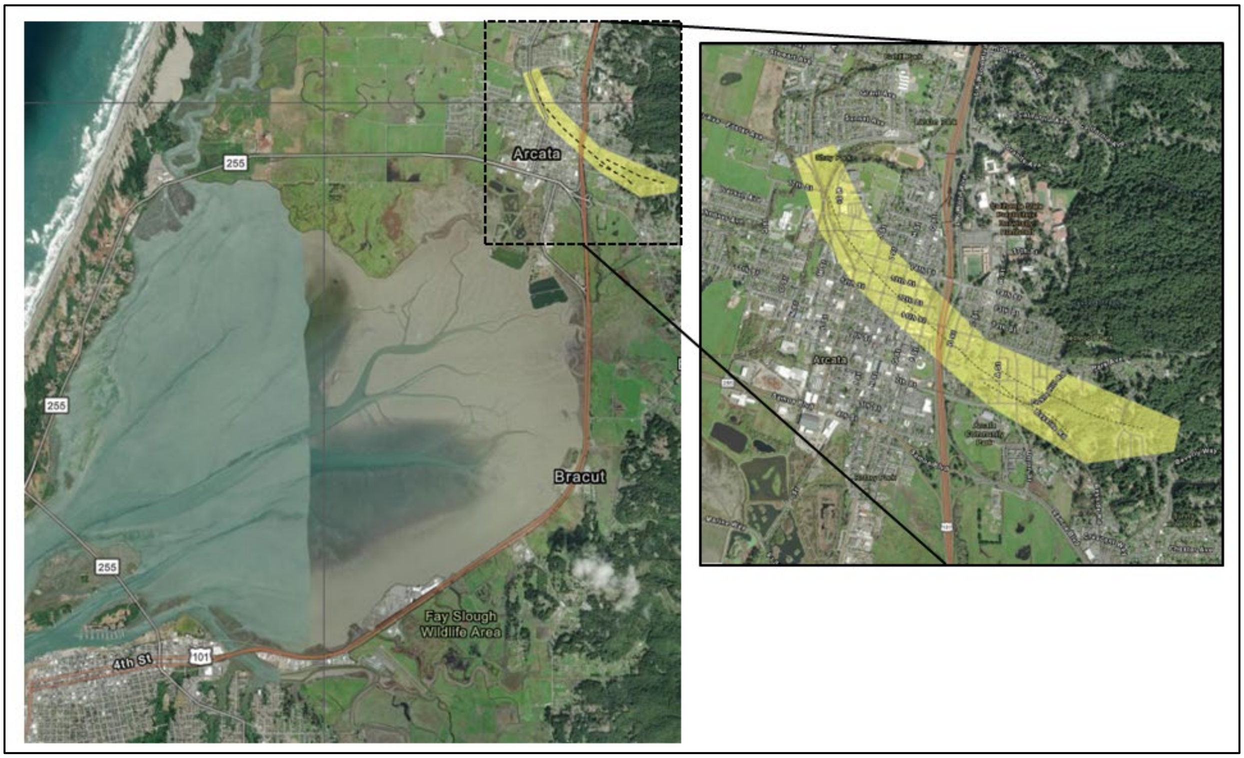


Figure 37. Alquist-Priolo fault traces (dashed lines) and zones (yellow) in the vicinity of the Corridor (https://maps.conservation.ca.gov/cgs/informationwarehouse/eqzapp/).

Coseismic and Interseismic Land-Level Changes

Vertical land motion (VLM) encompasses both uplift (positive) and subsidence (negative) of a datum on land. VLM modifies rates of relative SLR -- subsidence exaggerates SLR at a particular location while uplift slows relative SLR. VLM can occur cosesimically or during intervals between seismic events (interseismic). Coseismic changes are episodic, occurring over periods of seconds to minutes and can result in significant amounts of uplift or subsidence. Substantial coseismic VLM has occurred during past subduction events and is possible during the next great Cascadia Subduction Zone event (Dura et al., 2025). Paleoseismic studies in the Humboldt Bay region indicate historic coseismic subsidence of 1.6 to 3.3 ft (Padgett et al., 2019, 2021, 2022). The vertical motion is the result of land movement from fault rupture, and in the case of subduction zone earthquakes, areas with sudden vertical change may be found in coastal areas along the length of the subduction zone (Atwater et al., 2003; Imakiire and Koarai, 2012).

Interseismic land-level changes occur between coseismic events, occur slowly (decades to centuries) and have relatively small rates of change (mm or cm per year). Unlike temporary flooding from extreme weather events such as coastal storms or floods, coseismically subsided areas abruptly and permanently drop in elevation – often to elevations always inundated by tides. As a result, infrastructure located near sea level in regions adjacent to subduction zones could become submerged and inoperable due to earthquake-induced subsidence. Due to relatively high rates of interseismic subsidence, Humboldt Bay is experiencing the highest rate of relative SLR on the California Coast (Anderson, 2018). Subsidence rates vary throughout the region but are generally faster in South Humboldt Bay (-3.56 mm/yr) than Arcata Bay (-1.11 mm/yr) (Patton et al., 2017).

Liquefaction

Liquefaction occurs when saturated sediment temporarily loses strength, cohesiveness, and volume and behaves as a liquid, typically triggered by intense shaking or excessive loading. The most prevalent cause of liquefaction is strong shaking from earthquakes, but in the coastal environment liquefaction can also be triggered by excessive loading from large or sustained storm waves as well as tsunamis (Seed and Idriss, 1982; Committee on Earthquake Engineering, 1985; Idriss and Boulanger, 2008; Chaney and Fang, 1991; Dalrymple, 1979; Lee et al., 1993; Sassa and Sekiguchi, 1999; Kastens and Cita, 1981; Young et al., 2009). Liquefaction can have serious consequences for above-ground infrastructure and underground pipelines, cables, and footings. Roadways may crack, buckle, or collapse as the ground shifts, causing the roadways to become impassable. Retaining walls may also collapse. Bridges are particularly vulnerable, as liquefaction can undermine their foundations and cause them to tilt or collapse from loss of bearing capacity, excessive settlement, lateral spreading, etc..

Liquefaction is a hazard for areas of Humboldt County underlain by geologically young, saturated sedimentary deposits (Humboldt County, 2017; van Dohlen, 2015). The area around the Corridor, and all low-lying areas around Humboldt Bay, are potential liquefaction hazard zones (Figure 38).

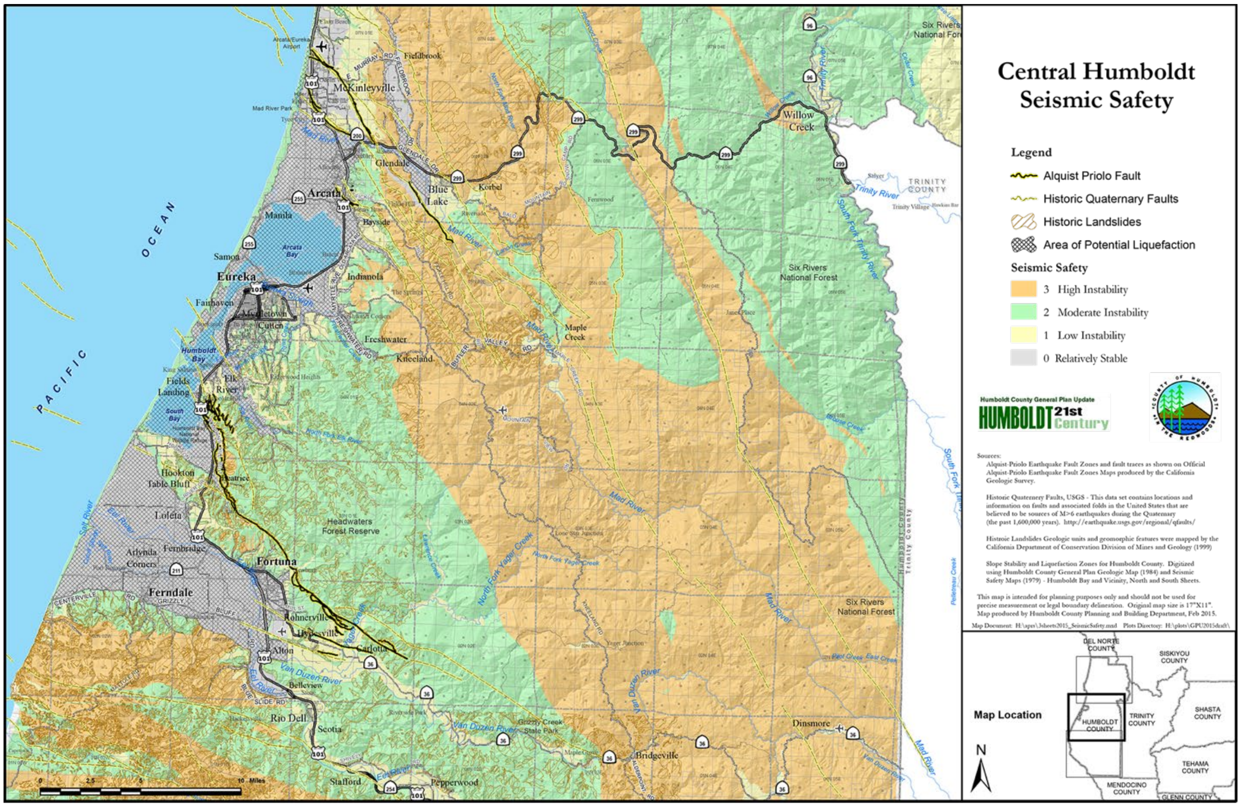


Figure 38. Map showing varying levels of seismic instability, including potential liquefaction hazard zones (gray hatch pattern), for a portion of Humboldt County (from van Dohlen, 2015, https://earthworks.stanford.edu/catalog/stanford-nk595pg0743.)

In coastal Humboldt County, evidence of liquefaction was observed following earthquakes in 1954, 1980, 1992, and 2010 (Chaney, 1991; Lajoie and Keefer, 1981; O’Brien, 1992; Reagor and Brewer, 1992; Storesund et al., 2010). There were also reports of liquefaction triggered by the 1906 San Andreas Fault earthquake. The effects of liquefaction from the1908, 1992, and 2010 events were insignificant in terms of the built environment. Most liquefaction evidence was observed on non-industrial areas of sand spits, river floodplains, or beaches, and confined to areas underlain by sandy or saturated deposits that were highly susceptible to failure from liquefaction and close to the epicenter of the earthquake and areas of strongest shaking. The 1954 earthquake, the epicenter of which is estimated to have been directly beneath the Eureka-Arcata area, caused damage in areas of unstable ground. Damage to structures and underground pipelines occurred and US 101 between Eureka and Arcata was cracked and bulged in various locations (Stover and Coffman, 1993; Youd and Hoose, 1978). Surface deformation from the 1906 San Andreas earthquake was also significant (Lawson, 1908; Youd and Hoose, 1978; Dengler, 2008). The combination of high intensity and long duration shaking resulted in widespread deformation from liquefaction, particularly in the Eel River Valley.

Numerous studies have assessed liquefaction potential along the Corridor (Table 13; Caltrans Division of Engineering Services, 2001, 2006; Caltrans Geotechnical Services, 2017, 2019, 2022, 2023). These studies indicate most of the highway between Eureka and Arcata is located near current mean sea level with high groundwater levels. Subsurface geology along the Corridor consists largely of Holocene bay marsh and bay margin sediments and Holocene alluvial deposits consisting of alluvial clay, silt, sand, gravel, and boulders overlain largely by artificial fill (Kelley, 1984; McLaughlin et al., 2000; Caltrans Geotechnical Services, 2022).

Detailed liquefaction investigations have been conducted at various locations along the Corridor. Findings from investigations at Eureka Slough indicate liquefiable sediments exist in the upper 70 feet (Caltrans Geotechnical Services, 2023). Additionally, this site could experience bearing capacity failure and lateral spreading. The Indianola Road-US 101 intersection area has a strong potential for liquefaction (Caltrans Geotechnical Services, 2022). These studies described young bay muds at elevations ranging from -20 to -47 feet in the vicinity of Indianola Road and US 101 as low-strength, low-plasticity clays. These are underlain by slightly less compressible and higher strength silty sand, sandy silt, and silt with interbedded clays. Further underlying materials tend to be of higher strength clays which overlay older deposits that are of greater strength and low compressibility (Caltrans Geotechnical Services, 2022). Liquefaction in this area could cause roadbed embankments to settle by up to four inches and move up to nine feet by lateral spread displacement. At Jacoby Creek, investigations indicate materials above 40 feet have a high potential for liquefaction while materials below 40 feet are unlikely to liquify. The potential for lateral spreading is minimal. Unlike the rest of the Corridor, more compact sediments near or underlying Bracut likely reduce this location's susceptibility to liquefaction.

Tsunamis

The North Coast of California, including areas along the Corridor, is vulnerable to tsunamis (Figure 39). Tsunamis in this region, as well as other areas adjacent to subduction zones, can be classified into two types: (1) local or nearfield tsunamis, which are caused by seafloor displacement due to rupture along the subduction zone megathrust or by landslides triggered by seismic shaking; and (2) distance-source or far-field tsunamis, which originate from seismic disturbances in distant locations. Historically, tsunami events in the region have been triggered by M8 and M9 earthquakes along the CSZ.

A tsunami in the region could expose the Corridor to coastal flooding, wave energy, erosion, and strong currents during tsunami-driven inundation. Following tsunami-driven inundation, debris-filled waters also pose a significant hazard to people and infrastructure. Statewide analyses using a 2475-year recurrence model indicate inundation along the Corridor would be less than one meter (Thio, 2019; Figure 40). These modeling results also indicate there is no substantial difference in the inundation pattern between near- or far-field tsunamis. Tsunami currents from the 2010 Chile earthquake persisted in Humboldt Bay for around 30 hours and had a peak velocity of approximately 0.35 m/s and amplitude of 0.23 m. The signal from the 2011 Japan earthquake persisted in the Bay for more than 40 hours and had a peak velocity of 0.84 m/s and amplitude of 0.81 m (Admire et al., 2014).

SLR will amplify the effects of future tsunamis. Under future SLR scenarios, wave heights of tsunamis generated by more frequent, smaller earthquakes have the potential to equal or exceed historical wave heights of tsunamis triggered by larger earthquakes (Dura et al., 2021).

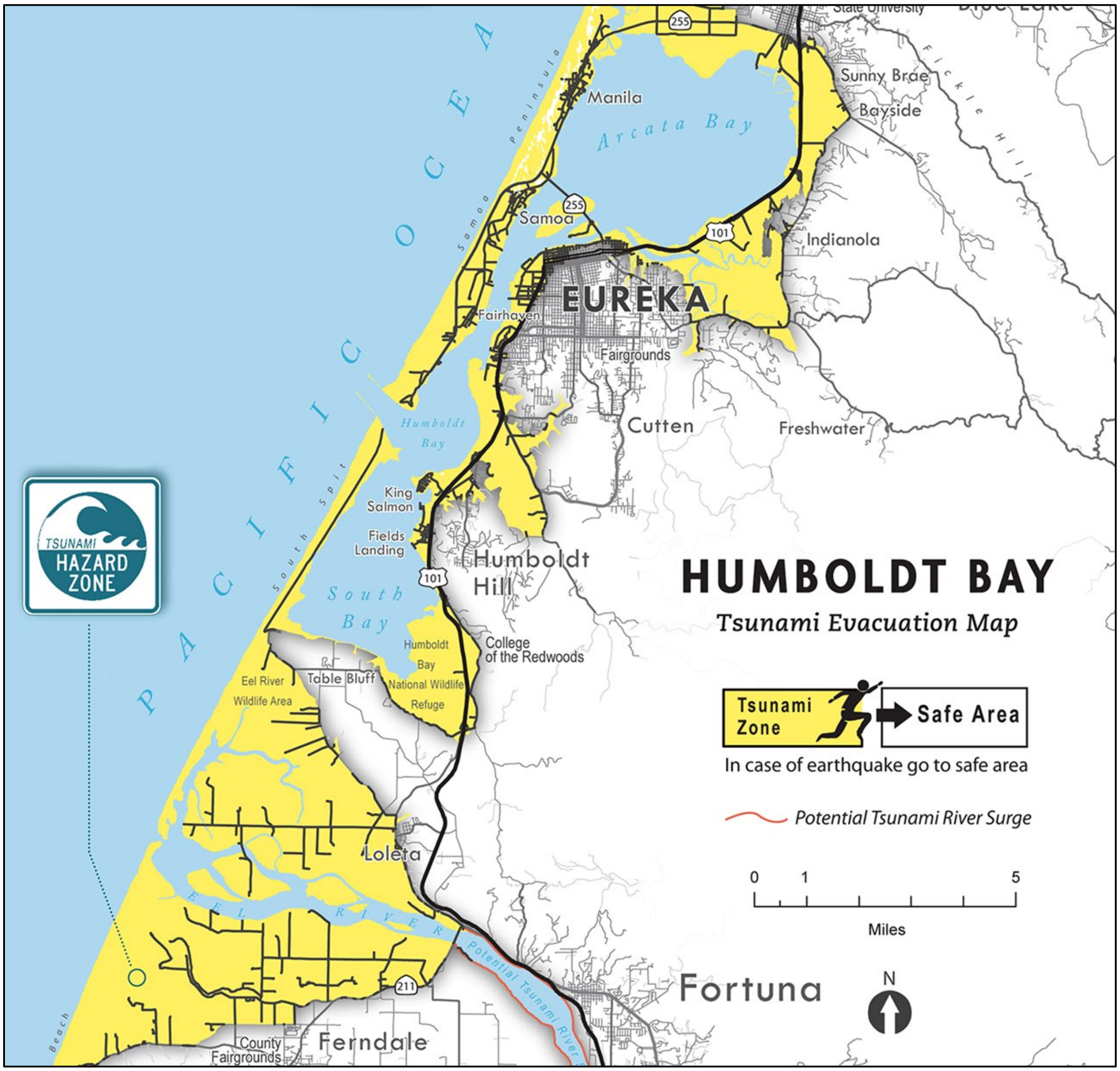


Figure 39. Map of tsunami inundation zone for Humboldt Bay (Modified from Redwood Coast Tsunami Work Group, 2020).

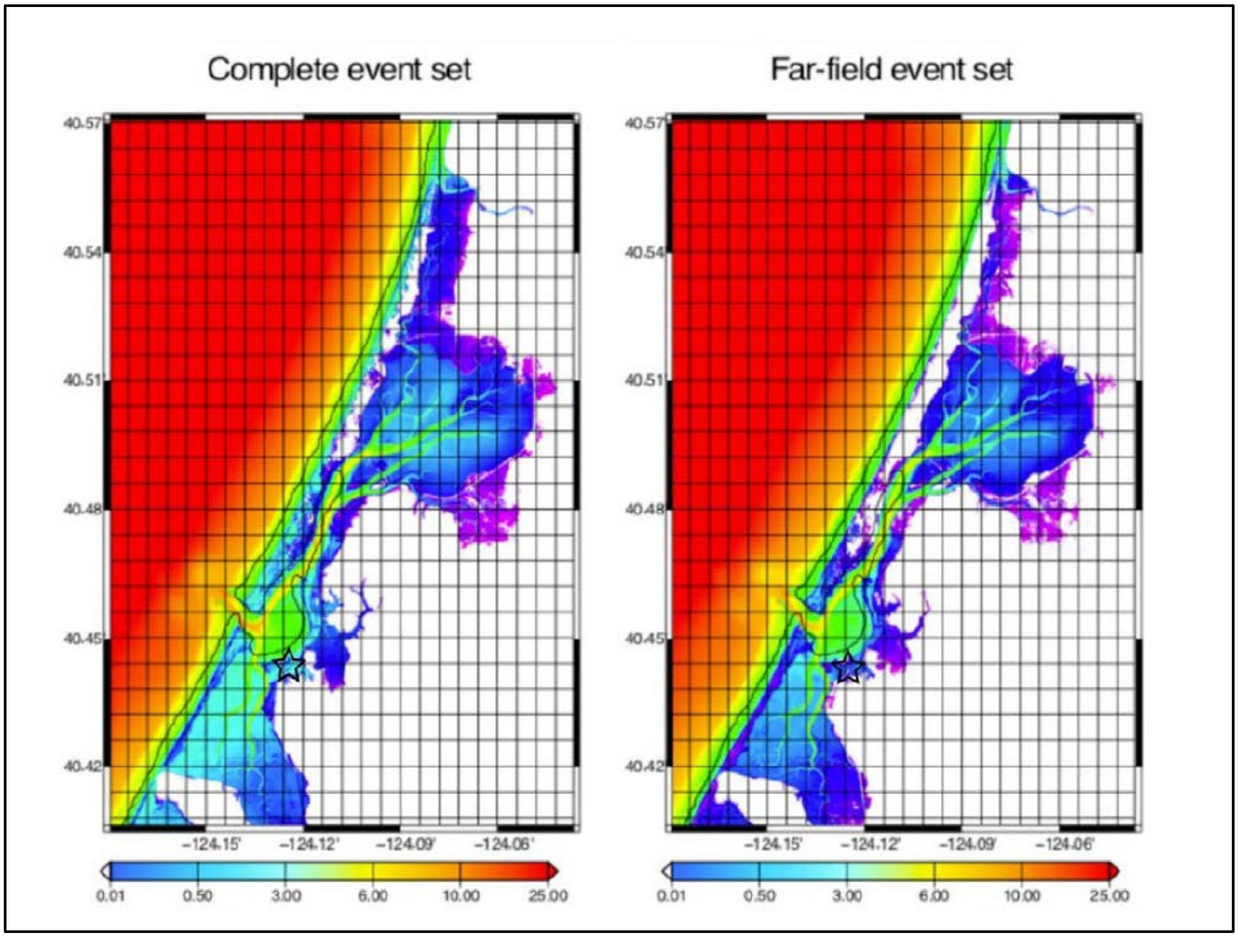


Figure 40. Probabilistic tsunami flow depths for Humboldt Bay considering a 2,475-year model (from Thio, 2019). Left map includes local and far-field sources (caused by seafloor displacement due to rupture along the subduction zone megathrust or by landslides triggered by seismic shaking) while the map on the right considers only far-field sources (which originate from seismic disturbances in distant locations). There is not substantial difference in the inundation pattern between the two source models. Elevation units are in meters. Purple represents depths less than 0.01 meters.

Seismic Performance of Roadbed Support Systems

The seismic performance of various roadbed support systems was evaluated and is summarized in Table 14. The evaluation indicates pile-supported structures outperform traditional earth embankments and require minimal repairs. Pile-supported roadbed and bridge designs also tend to be most suitable for liquefaction mitigation. Furthermore, non-engineered embankment design is prone to failure during seismic shaking.

Table 14. Seismic performance comparison of structure support systems including deep foundations, ground modification, and no ground modification.

Seismic Condition	Deep Foundations	Ground Modification		No Ground Modification
	Viaducts and Bridges	Stone-Column Supported Roadbed	Column-Supported Embankment	Traditional Earthen Embankment
Liquefaction & pore-pressure	Piles should bypass liquefiable layers.	Stone columns densify surrounding soil and provide drainage paths for water; Reduce pore pressure buildup and delay liquefaction triggering.	If composite ground (densification + reinforcement) treatment is conducted it may lower cyclic shear stress and excess pore pressure	Entire foundation layer beneath the embankment may liquefy.
Liquefaction-induced vertical settlement	Typically, minor settlement.	Typically, minor settlement	Typically, minor settlement	Large settlements can exceed usable limits even at moderate shaking.
Liquefaction-induced lateral spreading/horizontal deformation	Deep piles restrain ground movement.	Moderate improvement; Stone columns increase shear resistance but may still permit some lateral movement.	Improved ground shear strength and reduced spreading.	Highly susceptible to lateral spreading
Strong-motion considerations	Deep foundations can be designed to handle strong ground motions.	Improved base stability.	Moderate deformation possible.	Earth fill can amplify surface accelerations; Earthen embankments on soft soils are susceptible to differential movement.

Seismic Condition	Deep Foundations	Ground Modification		No Ground Modification
	Viaducts and Bridges	Stone-Column Supported Roadbed	Column-Supported Embankment	Traditional Earthen Embankment
Overall performance in strong motion conditions	**Highest** Tend to remain functional after major earthquakes; Highest cost and construction time.	**Moderate-to- high** Improved performance over untreated soils; Cost-effective in moderate-risk zones.	**Moderate-to-high** Improved performance compared to untreated embankments; Less expensive than full piers; Performance related to column design.	**Lowest** Frequent major damage in liquefaction zones without additional ground improvement.

Key Terms:

Pier: typically a large, wall-like vertical support, often with a rectangular cross-section, used for heavy loads like bridges.

Column: typically smaller than piers and are often cylindrical support structures.

Column-supported embankment (CSE): a ground improvement technique that uses columns of strong material to support an embankment built on soft, compressible soil.

Traditional earth embankment: a raised earthen structure built from compacted soil and rock.

Pore pressure: the pressure exerted by fluids, such as water or oil, trapped within the pore spaces of a material, such as soil or rock.

6.1.5 Vulnerability Assessment

Overview and Scope

Cal Poly Humboldt and Northern Hydrology & Engineering conducted a vulnerability assessment evaluating coastal and riverine flood hazards affecting the Corridor. The assessment focuses on transportation infrastructure vulnerabilities including roadway flooding, shoreline erosion, drainage ditch capacity for highway runoff, and bridge freeboard.

The vulnerability assessment integrates outputs from hydrodynamic and hydrologic modeling (see Sections 6.1.1 Hydrologic Hazards and 6.1.2 Coastal Hazards) and statistical probability analysis to quantify vulnerability across multiple SLR and riverine flooding scenarios. A spreadsheet-based tool was developed to facilitate communication of hazards and develop composite analysis of the hazards represented in the scenario testing. The vulnerability assessment spreadsheet provides an interactive tool to combine simultaneous hazard impacts and inform adaptive management planning for the Corridor.

Conceptual Framework

The vulnerability assessment follows the framework established by the United Nations Economic and Social Commission for Western Asia (2014) and adapted for transportation infrastructure by FHWA (2017). This framework defines vulnerability as a function of exposure, sensitivity, adaptive capacity, and risk (see Section 1.4 Key Terms for definitions; Figure 41). The vulnerability assessment evaluates adaptive capacity by testing

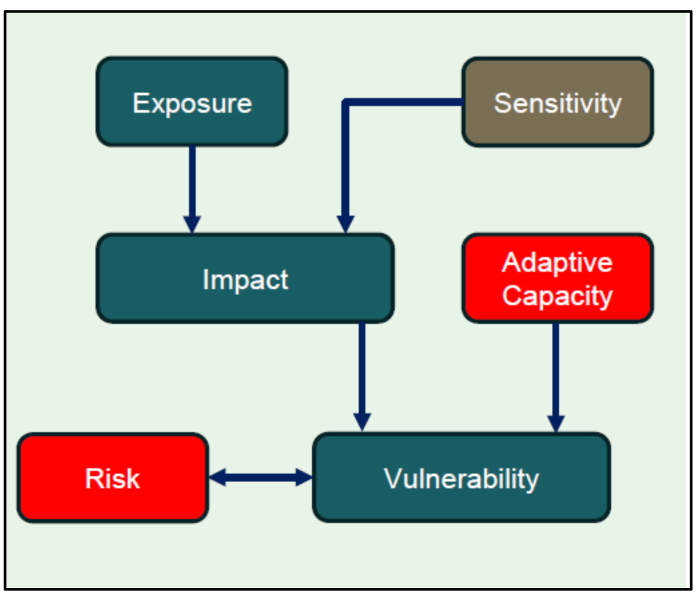


Figure 41. Conceptual diagram showing relationship between Exposure, Sensitivity, Adaptive Capacity, Vulnerability, and Risk.

infrastructure modifications such as grade raises and quantifies risk through exceedance probability analysis across multiple flood and SLR scenarios.

SLR Scenarios

The vulnerability assessment evaluates seven SLR scenarios based on the OPC's most recent SLR Guidance (OPC, 2024). These scenarios represent a range of possible sea-level futures from low to high warming trajectories, with projections extending to 2150 (Figure 25).

To develop locally relevant scenarios the statewide OPC guidance was adjusted for local vertical land motion. The statewide assumption of 0.1 mm/yr upward VLM was removed, and the local Mad River Slough subsidence rate of 0.54 mm/yr downward VLM was incorporated (Patton et al., 2023). This results in a net relative SLR rate that is 0.64 mm/yr higher than the statewide projections. Using the Mad River Slough subsidence rate as the local VLM, rather than the rate calculated for North Spit Humboldt Bay and used to develop the OPC's Humboldt Bay SLR guidance, provides a more localized estimate of relative SLR for the Corridor.

The analysis focuses on four primary planning horizons: 2023 (current conditions), 2050, 2100, and 2150. Scenarios are grouped into four categories: Current Condition, Intermediate, Intermediate-High, and High. Each scenario was developed using a specific relative SLR value that is added to current water level probability distributions developed from hydrodynamic modeling to define future asset flood hazard projections.

Impact Thresholds

The impact thresholds for important hazards (Table 15) were defined in consultation with Caltrans District 1. Hazards related to water elevations resulting from either high bay water levels, wave action, riverine flooding or a combination of these processes include flooding of highway shoulder or lanes, shoreline erosion along the highway, impacts on drainage ditch effectiveness, and submergence of bridge structural elements. The additional impact identified in Table 15, groundwater shoaling, was addressed in a separate document (Lang, 2025) and is not included in or needed for the vulnerability assessment tool developed to evaluate the combined impacts of the coastal-riverine flooding scenarios—once the low-lying areas are submerged by rising sea level, the change in groundwater elevations with additional SLR is minimal.

Three impact categories were established to evaluate the extent to which assets are affected by physical processes such as fluvial flooding, coastal storm surge, and SLR. The three impact categories span minor to severe conditions and are classified as: 1) Dry to wet conditions (green column in Table 15), 2) Conditions requiring monitoring and potential operational or maintenance changes (orange), and 3) Severe conditions that may cause damage, disruption of services, and require repairs (red).

The vulnerability assessment calculates the number of days per year each threshold is exceeded under each SLR scenario, providing a quantitative basis to evaluate when operational changes or infrastructure modifications become necessary.

Highway Travel Lanes Thresholds

Three impact thresholds were established for highway travel lanes based on operational experience and engineering judgment:

- **Dry to Wet Condition (≤0.5 inches water depth)** This threshold represents the initiation of impacts requiring monitoring. Water depths of 0.5 inches or less may not significantly impede traffic flow but indicate that flooding is beginning and conditions should be monitored. Typical duration is 1-3 hours for tidal events.
- **Monitor Condition (0.5 to 4 inches water depth)** Water depths in this range indicate increasing change in operations and maintenance needs. Vehicle operations may be affected, particularly for smaller vehicles or at higher speeds. Maintenance crews may need to deploy signage or provide traffic control. Extended duration flooding in this range may cause pavement damage.
- **Severe Condition (>4 inches water depth)** Water depths exceeding 4 inches represent significant disruption of service likely requiring road closure. At this depth, most vehicles experience loss of traction and control, creating safety hazards. Research indicates 4 inches is the depth at which passage of small vehicles is no longer considered safe (Maghsoodifar et al., 2025). Additionally, prolonged flooding at this depth can cause structural damage to pavement and underlying materials, requiring repairs. Note this threshold should be re-evaluated before conducting future modeling. Caltrans' management reserves the right to determine the appropriate flood response and resulting road operations or closure on a case-by-case basis.

Shoreline Erosion Thresholds

Shoreline erosion potential is categorized based on wave overtopping rates (Table 15).

Highway Drainage Ditch Thresholds

The drainage ditch thresholds only apply to the western edge of the Corridor (southbound lanes). Drainage ditch volume (capacity) is only affected by coastal flood levels (establishes initial ditch volume) and wave overtopping volume, but not highway runoff volume. For this vulnerability assessment, it is assumed that drainage ditch freeboard accommodates highway runoff. Drainage capacity is evaluated based on the freeboard between the ditch water level and the lowest highway elevation:

- **Adequate Drainage (> 6 inches freeboard)** When ditch water levels remain more than 6 inches below the highway surface, adequate drainage capacity is maintained and normal operations continue.
- **Monitoring Condition (3-6 inches freeboard)** Reduced freeboard in this range indicates diminished drainage capacity. Localized ponding may occur, particularly during concurrent high tides and rainfall events.
- **Critical Condition (< 3 inches freeboard)** When freeboard is less than 3 inches, the drainage system is near capacity and there is high potential for highway flooding from landward side runoff. This condition may occur before water levels in the bay reach the highway elevation, making drainage capacity a critical vulnerability factor.

Bridge Freeboard Encroachment Thresholds

Bridge vulnerability is assessed using three categories:

- **Adequate Clearance (> 1 ft below soffit)** A minimum of 1 foot of clearance between the wave crest or water surface and the bridge soffit (underside of the lowest bridge member) is required to maintain safe operations and avoid debris impacts.
- **Reduced Clearance (soffit to deck elevation)** When wave crests or water levels rise above the soffit elevation but remain below the deck elevation, monitoring is required due to increased potential for debris impact on structural members.
- **Bridge Deck Inundation** Wave crests or water levels above the bridge deck require bridge closure and may indicate structural concerns. Zero tolerance is applied to this threshold.

*Table 15. Eureka-Arcata 101 Corridor Hazard Impact Thresholds table. * See the Coastal Hazards Technical Memo for additional information on shoreline vulnerability and the Hydrologic Hazards Technical Memo for additional information on bridge freeboard encroachment. cfs = cubic feet per second.*

Asset Assessed	Impact	Asset Impacts			Physical Processes Considered
		Dry to Wet Condition: Initiation of Impacts and Monitoring	**Monitor Condition: Increasing Change in Operations and Maintenance**	**Most Severe Condition: Significant Disruption of Service, Damage and Repairs**	
Highway Travel Lanes and Shoulder	Flood Depth (Typical Duration from ~1 to 3 hours)	Up to 0.5" of water in shoulder and/or travel lane or lanes at lowest elevation of highway	Between 0.5'' to 4" of water in travel lane or lanes at lowest elevation of highway	Greater than 4" of water in travel lane or lanes at lowest elevation of highway	• Coastal flooding from tides, storm surge, wind setup, wave overtopping volume • Fluvial flooding • Sea-level change
Highway Roadway Prism and Surfacing	Groundwater Shoaling	Groundwater inundating drainage infrastructure and roadside ditches	Land adjacent to Corridor submerged year-round	Groundwater weakens pavement structure and bearing capacity in the sub-base	• Groundwater elevations • Sea-level change
Shoreline*	Wave Overtopping and Erosion	No damage or erosion with wave overtopping rate less than 0.001 cfs/ft	Minor damage and erosion with wave overtopping rate between 0.001 to 0.054 cfs/ft	Major damage and erosion with wave overtopping rate greater than 0.054 cfs/ft	• Wind-wave overtopping discharge rate • Sea-level change
Highway Drainage Ditch Capacity to Accommodate Highway Runoff	Freeboard: Distance between Drainage Ditch Water Level and Lowest Elevation of Highway Travel Lane	Greater than 6 inches of freeboard	Between 3 to 6 inches of freeboard	Less than 3 inches of freeboard	• Coastal flooding from tides, storm surge, wind setup, wave overtopping volume • Fluvial flooding • Sea-level change
Bridge Freeboard Encroachment*	Flood and Wave Crest Elevation	Water elevation greater than 1 ft below lower chord elevation of bridge	Water elevation greater than bridge soffit elevation and lower than bridge deck elevation	Lowest elevation of bridge deck inundated	• Coastal flooding from tides, storm surge, wind setup, wave height • Sea-level change

Vulnerability Zones

To enable detailed analysis of vulnerability at a sub-Corridor scale, the Corridor was divided into six zones (Figure 42). Three zones (W_12, W_34, W_56) represent the western project area (southbound) lanes, and three zones (E_12, E_34, E_56) represent the eastern project area (northbound) lanes. Zone boundaries were established based on topographic features, drainage patterns, and areas of initial flooding identified in the HEC-RAS model. The west side zones are exposed to Humboldt Bay and are influenced by coastal processes including tides, storm surge, wave overtopping, and shoreline characteristics. The east side zones are more heavily influenced by riverine flooding, though coastal water levels affect these areas through tidal backwater effects in drainage systems and tributary streams.

The impact categories were used to determine when severe impacts would be observed at a particular frequency. Because transportation infrastructure often uses a 100-year return period as the design storm, the vulnerability assessment was also set up to evaluate when the probability of severe impacts exceeded 0.01 day (d)/yr (approximately 0.01 events per year or 100-year storm frequency). This standard is common practice in transportation engineering and provides a consistent basis for evaluating vulnerability across different infrastructure types and locations. In addition to revealing when in time a particular zone will become vulnerable to specified levels of flooding, the vulnerability assessment enables comparison of vulnerabilities across zones – this is crucial for prioritization of adaptation projects, as a single project that treats the entire Corridor at once is likely not feasible.

For each zone, a representative monitoring cross section was selected at the lowest highway elevation within the zone. Water levels at this cross section were extracted from the HEC-RAS simulations. The methodology assumes that flooding at the monitored low cross section indicates that the entire zone experiences flooding or operational impacts requiring closure. This conservative assumption supports transportation planning and emergency management decision-making. An interactive vulnerability spreadsheet was created for each zone. The spreadsheet can be used to investigate the effects of, or level of impact expected from, specific scenarios on various assets. The spreadsheet also helps determine when a specific zone is vulnerable to a certain level of flooding and it can be modified to explore, for example, how reasonable changes in roadway elevation influence asset sensitivity and risk (Table 15 and Table 16).

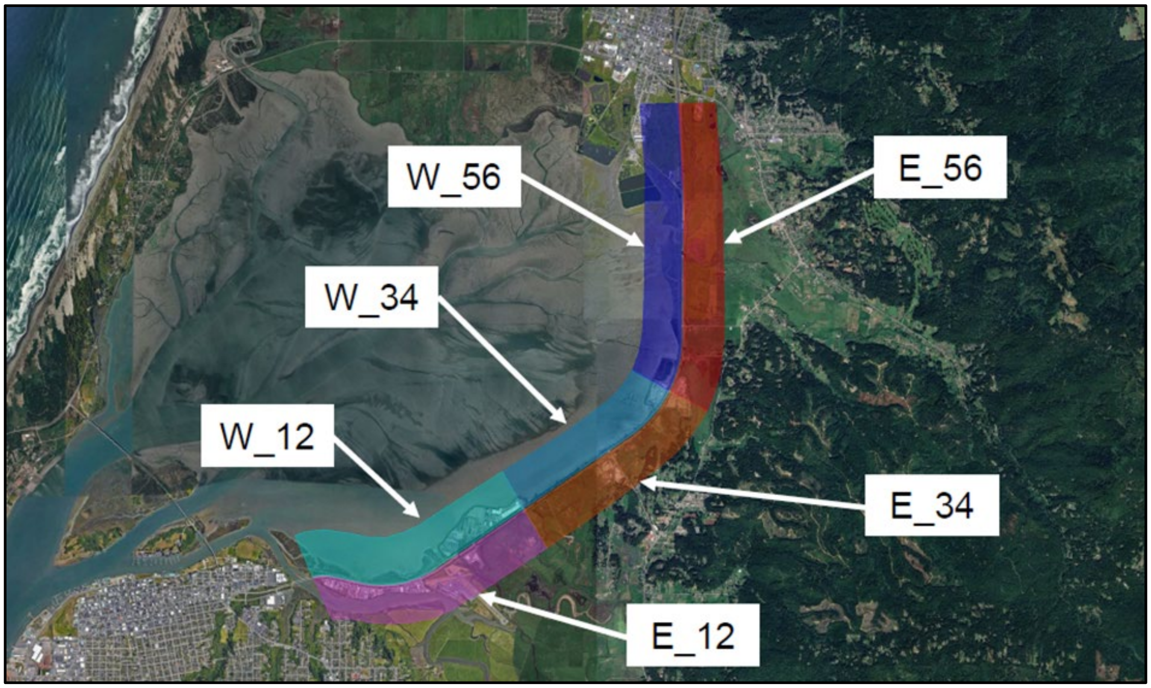


Figure 42. The six zones included in the vulnerability assessment.

Exceedance Probability Methodology – Extreme Value Mixture Model Approach

A novel statistical approach was developed to characterize tidal flooding frequency in terms more directly applicable to transportation operations than traditional flood frequency analysis. Rather than using annual maximum water levels to derive return period estimates (e.g., 0.01 events per year or 100-year flood), this methodology analyzes all daily maximum higher high tides to develop exceedance probability curves expressed as the number of days per year a given water level is exceeded. The distributions were developed using the 74-year time series of daily maximum higher high tides simulated from the coastal model.

For large events, the gamma-GPD mixture model (used here) converges with traditional extreme value analysis. For example, an exceedance probability of 0.01 days per year approximately corresponds to a 100-year return period event. However, for more frequent events, the mixture model provides substantially different—and operationally more relevant—estimates. A traditional 10-year event (0.1 events per year) has an expectation of approximately 0.17 days per year using the mixture model distribution approach. This slightly elevated exceedance probability reflects the reality that 10-year coastal flood conditions may occur multiple times during extended storm sequences or more than once per year.

To develop future exceedance probability curves, each SLR scenario value is added to the base 2023 water level distribution. This shifts the entire probability curve upward, increasing the frequency with which any given elevation is exceeded. The approach assumes that the statistical characteristics of tides and storm surge remain consistent with the historical record, with SLR acting as a uniform vertical offset.

This method produces exceedance probability curves for each SLR scenario at each planning horizon (Figure 43). For any given threshold elevation (such as the lowest highway elevation in a zone), the curves indicate how many days per year that elevation will be exceeded under each scenario. This information directly supports operational planning by quantifying how frequently monitoring, maintenance, or closure actions may be required within each of the six assessment zones.

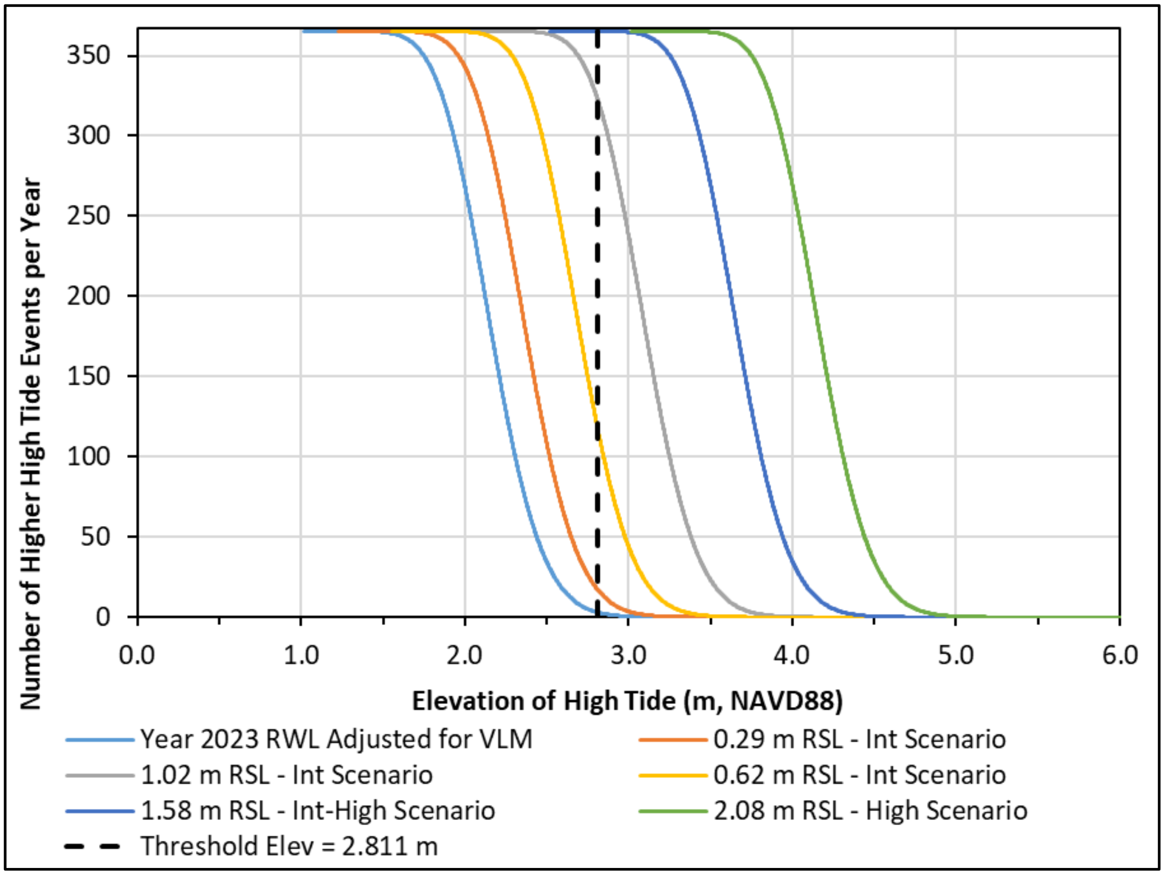


Figure 43. Exceedance probability curves for current conditions and multiple SLR scenarios (see legend).

Integration of Coastal and Riverine Models

A critical methodological challenge was integrating the coastal model outputs (which provide detailed bay water levels but limited coverage east of the highway) with the hydrologic model outputs (which provide detailed coverage at the highway but represent discrete scenario simulations over the course of a storm event rather than long-term, continuous time series). This integration was accomplished through the development of empirical relationships (R^2 values typically exceeded 0.99) between bay reference water levels and simulated water levels at asset locations for each zonal monitoring cross-section from the coastal or riverine-dominated flood levels. This enables the conversion of the 74-year coastal model time series into a continuous highway water level time series, which includes potential coastal and riverine flooding impacts and effects of infrastructure.

Wave Crest Elevation and Wave Overtopping Analysis

Wave crest elevations are the crest level of locally generated wind waves above reference water level (RWL) and contribute to bridge freeboard. The FEMA methodology was adopted for the vulnerability assessment that determines wave crest elevation as RWL plus 0.7 times the wind wave height.

Wave overtopping occurs when wind waves run up and overtop the shoreline features (railroad grade, riprap, earthen berms) that separate Humboldt Bay from US 101. Overtopping contributes to both shoreline erosion and flooding of highway drainage ditches. Overtopping discharge rates and duration were estimated using EuroTop (2018) empirical equations and the bulk wave parameters (e.g. wave height, wave period) determined from the coastal modeling and shoreline features (Ludka et al., 2024).

The coastal modeling effort generated 74-year time series of hourly RWL and bulk wave parameters at all grid cells in the bay. A joint probability distribution of log-transformed wave height and RWL at the five Corridor extraction points demonstrated no significant relationship except that the highest wave heights tended to occur with the highest RWL. It was assumed that a similar joint probability distribution existed for overtopping rates and RWL as overtopping is a function of wave height. Since a full joint probability analysis was beyond the scope of this project, nonlinear relationships were determined to define the mean and maximum wave height, overtopping rate, and overtopping duration as a function of RWL.

These relationships were used to define mean and maximum wave crest elevation and overtopping rates and duration associated with each RWL of the exceedance probability curves (Figure 43). For example, the mean overtopping rate represents the typical (average) overtopping intensity and the maximum represents peak overtopping conditions at a specific RWL when wave overtopping occurs. Both metrics, including none, are available as user-selectable options in the vulnerability assessment tool.

Vulnerability Assessment Tool

An Excel-based vulnerability assessment tool was developed to integrate all data sources, perform calculations, and generate outputs for decision support related to assessment and mitigation for highway and bridge inundation, drainage impacts, and shoreline erosion. A separate spreadsheet workbook was created for each of the six vulnerability zones (W_12, W_34, W_56, E_12, E_34, E_56). Each zone spreadsheet contains workbooks assessing the individual hazards and summary analysis compositing the total impact expected to the zone for a specific scenario. The tool allows a user to control input related to the scenario and highway condition to determine how a zone's vulnerability varies with possible and reasonable mitigation actions.

The tool uses the closest extraction point data to each zone's monitoring cross section, and performs calculations in a logical sequence:

1. **Bay Reference Water Levels**: The 74-year coastal model RWL hourly time series serve as the starting point at each extraction point.
2. **Daily Maximum Tide Levels**: The 74-year hourly RWL values are filtered to identify the daily maximum tide level (or daily higher-high tide level).
3. **Probability Distribution**: The exceedance probability curve is determined by fitting the gamma-GPD mixture model to the daily maximum tide levels. The probability curve is defined at 1 mm (0.001 m) increments of RWL for various interpolation and lookup functions.
4. **Sea-Level Rise Application**: Each SLR scenario is added to the base probability distribution to create a set of future exceedance curves.
5. **Highway Water Surface Elevations**: Functional relationships convert bay RWL (in each probability distribution) to highway water levels; creating a probability distribution of highway water surface elevations.
6. **Drainage Ditch Water Levels**: Separate functional relationships convert bay RWL (in each probability distribution) to ditch water level, and then a ditch elevation-volume relationship converts level to volume. Depending on the chosen wave option (none, mean, maximum) wave overtopping volume is determined for each bay RWL by multiplying the overtopping rate and duration nonlinear relationships, adding to the ditch volume, and the resulting volume is back converted to ditch level using the elevation-volume relationship. This creates a probability distribution of drainage ditch water levels.
7. **Wave Overtopping Discharge Rate**: Based on the chosen wave condition (none, mean, maximum) a probability distribution of wave overtopping rates is created by applying the overtopping rate nonlinear relationship to each bay RWL (in each probability distribution).
8. **Wave Crest Elevations**: Based on the chosen wave condition (none, mean, maximum) a probability distribution of wave crest elevations is created by determining the wave height for each bay RWL (in each probability distribution), and then adding 0.7 times the wave height to each bay RWL.

9. **Maximum Highway Water Surface Elevations**: The maximum highway water surface elevation probability distribution is determined by finding the maximum highway water surface elevation or drainage ditch elevation at each bay RWL (in each probability distribution).
10. **Threshold Exceedance**: For each vulnerability threshold (e.g. highway flooding, shoreline erosion), the number of days per year exceeding that threshold is calculated from the appropriate probability distribution for current conditions and each SLR scenario.

User Input for Scenario Analysis

The tool includes several user-controlled options that enable scenario testing and sensitivity analysis (Table 16). Users can modify the lowest highway elevation within a zone to simulate grade raising. The tool automatically recalculates all vulnerability metrics for the modified geometry. This feature supports evaluation of adaptation strategies and determination of required grade raise amounts to meet specific protection targets. Impact thresholds can be modified to test sensitivity to different operational criteria or to reflect updated Caltrans standards. Users can select varying levels (none, mean, maximum) of the contribution of wave overtopping to total vulnerability. Users can also choose which SLR scenarios to display in output visualizations, allowing focused analysis of specific planning horizons or warming trajectories.

The final utility of the tool is for sensitivity analyses. The magnitude of hazard impact contribution for many of the impacts can be modified to evaluate their effect on the composite impact. Users can include, modify, or exclude the wave overtopping contribution, modify impact criteria threshold values, change the maximum elevation of shoreline protection such as the Bay Trail, vary the drainage ditch capacity threshold, and modify the deck and soffit elevations of bridges within the Corridor. Sensitivity analysis helps identify which factors have the greatest influence on vulnerability and where additional data collection or refined analysis would be most valuable.

Table 16. Input table in vulnerability spreadsheet tool. Example shown is for the portion of southbound lanes between Bracut and the SR 255/US 101 Separation Bridge (Zone W_56).

Input Information and Variables for Assets in each Vulnerability Zone

Input info into green cells only

Asset	Information	Input Data: Name/Value	Input Data: Unit (US)	Converted Variable: Value	Converted Variable: Metric	Notes/Comments
Basic	Vulnerability Zone	W_56				
	Coastal Extraction Point	2				selected coastal extraction point closest to low highway elevation
	HEC-RAS Extraction Locatio	VZ-1_SB				HEC-RAS transect extraction location
Highway	Asset Name	Highway 101 South Bound West Lane				the initial flood inundation location from HEC-RAS model for this vulnerability zone
	Lowest Elevation	10.12	ft (NAVD88)	3.085	m (NAVD88)	lowest point at approximate west fog line
	Minimum Highway Inundatior	0.5	in	0.013	m	minimum tolerable flood depth on highway
	Maximum Highway Inundatio	4	in	0.102	m	flood depth when highway is closed; less than this highway is monitored
Drainage Ditch	Asset Name	Highway 101 South Bound West Drainage Ditch				drainage ditch information based on 2019 LiDAR data; not as-built from Bay Trail Project
	Ditch Flowline Elevation	8.6	ft (NAVD88)	2.621	m (NAVD88)	flowline elevation at the low highway elevation
	Maximum ditch freeboard	6	in	0.152	m	assumed maximum tolerance from highway to drainage ditch water level
	minimum ditch freeboard	3	in	0.076	m	assumed minimum tolerance from highway to drainage ditch water level
Shoreline	Asset Name	Bay Trail Shoreline Segment				this is the new crest elevation of the elevated railroad grade as part of the Bay Trail Project
	Crest Elevation	10.6	ft (NAVD88)	3.231	m (NAVD88)	approximate shoreline elevation at coastal point
Bridge #1	Asset Name	Gannon Slough Bridge - South Bound				assumed
	Soffit Elevation	9.78	ft (NAVD88)	2.981	m (NAVD88)	HECRAS input from Caltrans data
	Soffit Freeboard	12	in	0.305	m	freeboard from WSE to soffit
	Deck Elevation	11.58	ft (NAVD88)	3.530	m (NAVD88)	HECRAS input from Caltrans data
	Deck Inundation Tolerance	0	in	0.000	m (NAVD88)	assumed
Bridge #2	Asset Name	Jacoby Creek Bridge - South Bound				assumed
	Soffit Elevation	9.71	ft (NAVD88)	2.960	m (NAVD88)	HECRAS input from Caltrans data
	Soffit Freeboard	12	in	0.305	m	freeboard from WSE to soffit
	Deck Elevation	13.03	ft (NAVD88)	3.972	m (NAVD88)	HECRAS input from Caltrans data
	Deck Inundation Tolerance	0	in	0.000	m	assumed

Spreadsheet Tool Output

Timeline tables show the year and frequency of flood conditions (dry through severe) for various SLR scenarios. This output enables the viewer to identify the approximate decade when target resilience (i.e., fewer than 0.01 days/year of severe flood conditions) is reached under each SLR scenario. Timeline tables for Zone W_34, the southbound portion of the Corridor between Brainard and Bracut, are shown in Table 17. This output supports identification of "trigger years" for adaptive management action. A complete set of tables for all six vulnerability zones can be found in Appendix E. Anticipated vulnerabilities are also shown in Figure 44.

Table 17 (a-e). Timeline tables generated using the vulnerability spreadsheet tool. Tables show flood depth over highway travel lanes and the shoulders for Zone W_34, the southbound portion of the Corridor between Brainard and Bracut. The green row represents the number of days per year in which the water depth is less than or equal to 0.5 inches on the roadway. The orange row represents the number of days per year when the water depths are between 0.5 and 4 (inclusive) inches on the roadway. The red row represents the number of days per year when the water depth is greater than 4 inches on the roadway.

17a) The lowest road elevation in W_34 is set to 9.28 ft NAVD88 (current roadway conditions). Note that in the 2100 high SLR scenario, water depth is greater than 4 inches on the roadway 365.21 days in a year.

Relative sea-level change for OPC (2024) scenarios relative to Year 2000

Vulnerability Threshold	Year 2023 0.207 ft SLC	2050 - Int 0.8 ft SLC	2080 - Int 1.8 ft SLC	2100 - Int 3.1 ft SLC	2100 - Int-High 4.9 ft SLC	2100 - High 6.6 ft SLC	2150 - Int-High 8.3 ft SLC	2150 - High 11.9 ft SLC
# d/yr <= 0.5 in	365.23	365.05	360.36	284.43	22.62	< 0.01	< 0.01	< 0.01
0.5 in < # d/yr <= 4 in	< 0.01	0.10	1.99	21.85	14.36	0.04	< 0.01	< 0.01
# d/yr > 4 in	< 0.01	0.10	2.90	58.97	328.27	365.21	365.25	365.25

17b) The lowest road elevation in W_34 is set to 12 ft NAVD88. This is the planned roadway elevation for the Eureka/Arcata 101 SLR Resilience Project (0M270). Moderate and severe flood conditions are projected to occur less than 0.01 days/year through the 2080 Intermediate SLR Scenario.

Relative sea-level change for OPC (2024) scenarios relative to Year 2000

Vulnerability Threshold	Year 2023 0.207 ft SLC	2050 - Int 0.8 ft SLC	2080 - Int 1.8 ft SLC	2100 - Int 3.1 ft SLC	2100 - Int-High 4.9 ft SLC	2100 - High 6.6 ft SLC	2150 - Int-High 8.3 ft SLC	2150 - High 11.9 ft SLC
# d/yr <= 0.5 in	365.25	365.25	365.24	364.13	286.06	38.43	< 0.01	< 0.01
0.5 in < # d/yr <= 4 in	< 0.01	< 0.01	< 0.01	0.51	22.51	21.19	0.07	< 0.01
# d/yr > 4 in	< 0.01	< 0.01	< 0.01	0.61	56.68	305.63	365.18	365.25

17c) The lowest road elevation in W_34 is set to 16 ft NAVD88. This elevation would provide targeted resilience to 2100 Intermediate-High SLR Scenario; both moderate and severe flood conditions occur less than 0.01 days/year.

Relative sea-level change for OPC (2024) scenarios relative to Year 2000

Vulnerability Threshold	Year 2023 0.207 ft SLC	2050 - Int 0.8 ft SLC	2080 - Int 1.8 ft SLC	2100 - Int 3.1 ft SLC	2100 - Int-High 4.9 ft SLC	2100 - High 6.6 ft SLC	2150 - Int-High 8.3 ft SLC	2150 - High 11.9 ft SLC
# d/yr <= 0.5 in	365.25	365.25	365.25	365.25	365.25	363.77	285.65	< 0.01
0.5 in < # d/yr <= 4 in	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.86	31.15	0.04
# d/yr > 4 in	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.61	48.45	365.21

17d) The lowest road elevation in W_34 is set to 17 ft NAVD88. This elevation would provide greater resilience than 16 ft roadway elevation, but moderate and severe flood conditions are still projected to occur more frequently than 0.01 days/year in the 2100 High SLR Scenario.

Relative sea-level change for OPC (2024) scenarios relative to Year 2000

Vulnerability Threshold	Year 2023 0.207 ft SLC	2050 - Int 0.8 ft SLC	2080 - Int 1.8 ft SLC	2100 - Int 3.1 ft SLC	2100 - Int-High 4.9 ft SLC	2100 - High 6.6 ft SLC	2150 - Int-High 8.3 ft SLC	2150 - High 11.9 ft SLC
# d/yr <= 0.5 in	365.25	365.25	365.25	365.25	365.25	365.19	354.35	1.51
0.5 in < # d/yr <= 4 in	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.04	5.79	3.56
# d/yr > 4 in	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.02	5.10	360.18

17e) The lowest road elevation in W_34 is set to 18 ft NAVD88. This elevation would provide targeted resilience to the 2100 High SLR scenario; both moderate and severe flood conditions are projected to occur less than 0.01 days/year.

Relative sea-level change for OPC (2024) scenarios relative to Year 2000

Vulnerability Threshold	Year 2023 0.207 ft SLC	2050 - Int 0.8 ft SLC	2080 - Int 1.8 ft SLC	2100 - Int 3.1 ft SLC	2100 - Int-High 4.9 ft SLC	2100 - High 6.6 ft SLC	2150 - Int-High 8.3 ft SLC	2150 - High 11.9 ft SLC
# d/yr <= 0.5 in	365.25	365.25	365.25	365.25	365.25	365.25	364.56	41.14
0.5 in < # d/yr <= 4 in	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.42	33.90
# d/yr > 4 in	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.27	290.21

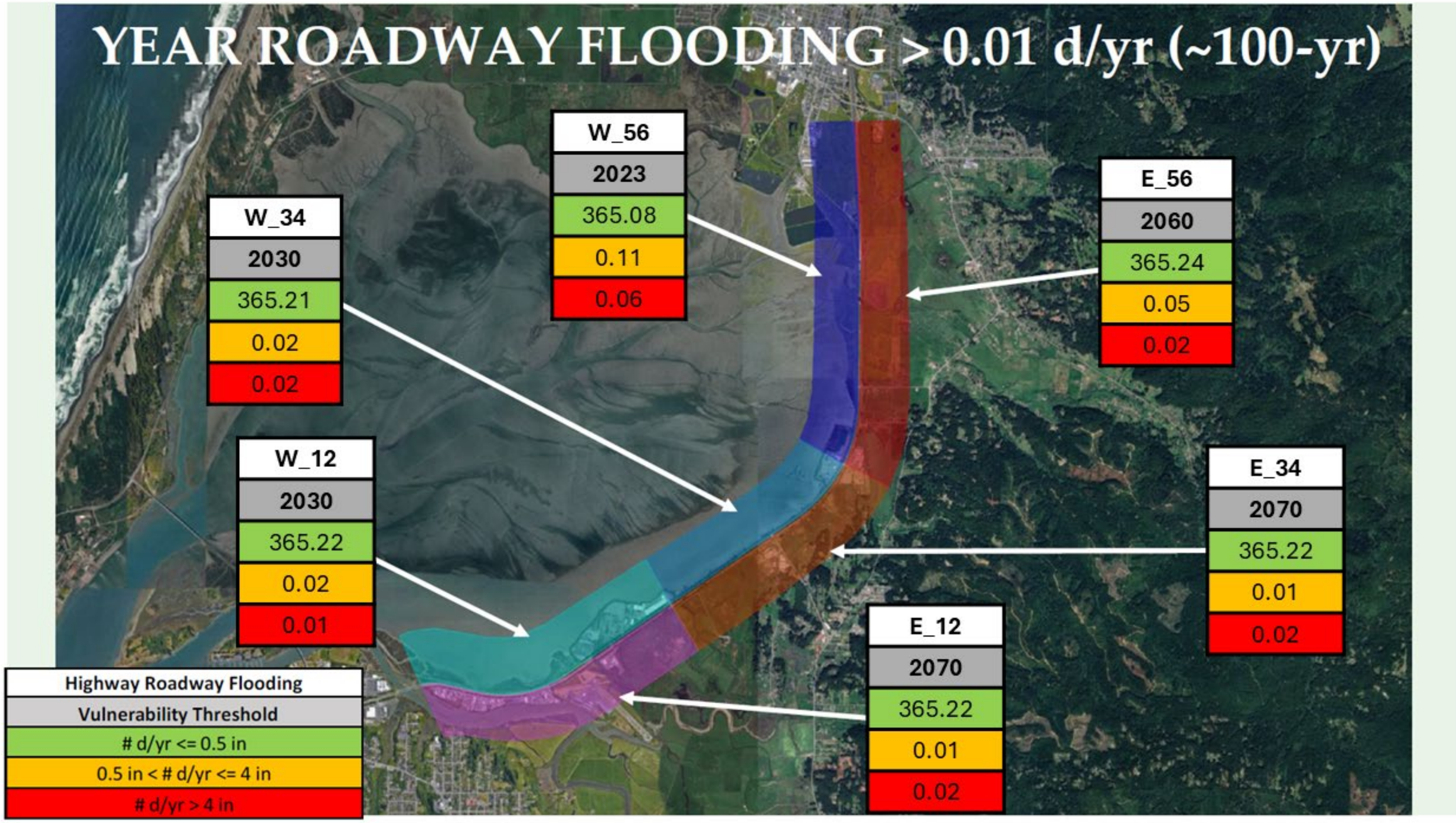


Figure 44. Results of the vulnerability assessment for the Corridor. For each of the six zones, vulnerability across all three thresholds is shown (see legend) for the decade at which frequency of severe flooding (> 4" of water) exceeds 0.01 days/year is shown. Note that for zone W_56, severe flooding is expected to occur more than 0.01 days/year in 2023.

6.2 Recommended Studies

Traffic Volume

The most recent traffic volume study was completed in 2024 (Table 18). An updated study should be conducted prior to implementation of long-term adaptation projects along the Corridor. Since traffic volume forecasts are based on population projections, the population change and traffic or travel forecast should be monitored to plan for the appropriate facility.

Table 18. Traffic volume data provided by District 1 System Planning on February 12, 2024. ESAL = Equivalent Single Axle Load, TI = traffic index, ADT = Average Daily Traffic.

2-4 Lane Facility TI (100% ESAL) 1-2 Lanes in One Direction		
HUM-101-PM 79.9/85.0		
Annual ADT (Base Year)	2020	37,800
	2032	43,600
	2042	48,500
	2052	53,500
Peak Hour Volume (Base Year)	2020	4,160
	2032	4,800
	2042	5,340
	2052	5,890
Directional %		58.4
DH Truck %		11.0
10-year TI (2042)		11.0
20-year TI (2052)		12.0
40-year TI (2072)		13.0

Groundwater & Coastal Hazards

As noted in the Groundwater Technical Memo, there are insufficient data to fully calibrate the local models that were developed to assess groundwater hazards for the Corridor. To better understand the groundwater dynamics and how SLR may impact conditions, Cal Poly Humboldt recommends the installation of piezometers, within and adjacent to stream or slough channels, to collect observations and confirm the seasonal dynamics of groundwater elevation. Observations near the highway would also provide insight into the wetting and drying near the road base and along the drainage ditches. As noted in the Coastal Hazard memo, it would also be beneficial to monitor vertical land motion and water levels along the shoreline of the Corridor.

Wildlife Crossing

It is recommended to place remote sensor cameras at culverts and other areas (e.g. bridges) where wildlife crossing data are needed to get a baseline of wildlife activity in this area. Utilizing remote sensor cameras and other data from field observations (e.g. wildlife trails, tracks, scat, rubs, etc.) are important to understand potential impacts to connectivity and identify opportunities for new or enhanced crossing infrastructure. Currently, wildlife monitoring efforts are underway at several locations along the Corridor.

7 CAIP Adaptation Strategies

Conceptual adaptation strategies, to be used for scoping and planning, were identified based on the specific vulnerabilities of the Corridor. The strategies described in sections 7.1 through 7.4 and listed in Table 19 are intended to provide a general overview of potential adaptation options. A more detailed evaluation of adaptation options for the CAIP can be found in Sections 7.6 and 7.7.

It is important to remember the CAIP is a living document, as technology advances, additional adaptation options may become available. Adaptation measures that are currently in exploration phases, such as floating concrete rafts or underwater tunnels, may become more feasible in the future. The following sections consider existing technology and feasible adaptation options but recognize that future planning efforts will likely consider novel technologies and adaptation options. This is especially pertinent if such measures alleviate location-specific challenges (e.g., building in soft, deep bay mud) while providing enhanced resilience to SLR and other coastal hazards. As noted in a previous adaptation planning document, "…the evaluation, selection, and implementation of the most appropriate solution should be based on information that is most relevant and up to date." (Crow et al., 2014).

Table 19. Conceptual adaptation strategies for the Corridor.

Strategy	Description	Potential Location	Benefits	Drawbacks
Protect	Hard armoring along adjacent bay shoreline	South of Brainard	Availability of materials, supports raised embankment adaptation	Potential for maladaptation or high maintenance costs
	Soft armoring/living shoreline	Various	Ecological benefits; improved stability; enhanced aesthetics and wildlife viewing; potential to protect other coastal resources	Potentially complex logistics (e.g., permitting, sediment availability and delivery to site)
	Elevate Corridor on earthen embankment	Jacobs Ave.	Cost-effective strategy for maintaining access to existing development. Prevents flood impacts from coastal side of Corridor to adjacent parcels.	Some coastal hazards still have potential to impact road (e.g., rutting and fatigue failure); greater susceptibility to seismic hazards
Accommodate	Improved drainage (e.g., upsized culverts)	Two culverts south of Jacoby Creek/City of Arcata parcel	In-kind mitigation credit; creation of saltwater/brackish habitat with connection to bay (Fay Slough option); improved drainage	Maintenance time and cost.
		Bottomless culvert between Fay Slough and Humboldt Bay		
	Breach levees/dikes	Old Brainard Mill area	Creation of saltwater/brackish habitat and mitigation credit for tidewater goby habitat	Potentially complex coordination among agencies, businesses, and stakeholders affected by adaptation
		Levee at Fay Slough Wildlife Area	Accommodation of ocean and fluvial water; connection to bay	
	Raise adjustable bridges	Jacoby Creek SB	Maintain connection to bay; in-kind mitigation credit	Cost and environmental impact
	Elevate Corridor on earthen embankment, includes hydraulic connectivity	Various	Flexibility for adaptive embankment design; cost-effective strategy for maintaining access to existing development	Some coastal hazards still have potential to impact roadway (e.g., rutting and fatigue failure); greater susceptibility to seismic hazards

Strategy	Description	Potential Location	Benefits	Drawbacks
Accommodate *(continued)*	Elevate Corridor with a viaduct	Various	Mitigation value for restoring saltwater marsh habitat; not prone to settlement or stability issues that would be present with an embankment; structure width can be narrower than embankment (smaller footprint); lower susceptibility to damage from seismic hazards	More expensive to build (compared to embankment); affects land use inland of Corridor; cannot be easily raised in future
Retreat	Minor retreat inland	Various	Maintains traffic flow during construction	Right of way acquisition; remaining need to address elevation and vulnerability to SLR; wetland impacts
	Major retreat to Old Arcata Road	Entire Corridor	In-kind mitigation, more cost-effective grade raise due to assumed shallower bedrock and coarser sediment	High cost; Right of way acquisition needed to maintain four-lane highway; substantial effect on adjacent properties; increased vehicle miles travelled (VMT); existing vulnerability to riverine flooding; design life of Eureka Slough Bridges Replacement Project limits feasibility of retreat to Old Arcata Rd.
Hybrid	Protect with living shoreline and accommodate (e.g., viaduct or large culvert)	Various	Increased resilience, adaptation is tailored to specific location	Complex coordination and implementation

7.1 Protect

Protect strategies are adaptation options that defend assets from coastal hazards. These strategies aim to reduce exposure to hazards by constructing physical barriers, such as seawalls, or reinforcing natural systems, such as living shorelines. The spectrum of protection strategies ranges from hard (“gray”) structures to soft (nature-based or “green”) infrastructure.

Hard “Grey” Armoring

Historically, hard armoring has been used extensively to protect California’s coastal assets from wave damage, erosion, and coastal flooding. However, the use of hard armoring structures such as seawalls, revetments, and bulkheads can exacerbate problems rather than provide a solution (Melius and Caldwell, 2015). Such maladaptation can have unintended consequences and negatively impact shorelines by contributing to habitat destruction, beach loss, and increased erosion in adjacent areas. However, earth retaining systems (i.e., retaining walls) may be necessary in places where construction of a stable slope to maintain elevation cannot be achieved due to insufficient space or environmental concerns or in places where facilities cannot be moved or elevated. In the context of the CAIP, hard armoring (in the form of retaining walls) along the shoreline adjacent the Corridor is considered as a measure to support raised embankments when other “soft armoring” strategies cannot provide sufficient support.

Soft “Green” Armoring/Living Shoreline

The benefits of incorporating living shorelines into Corridor adaptation plans are numerous. These nature-based solutions have the potential to sequester carbon, improve water quality, restore and enhance intertidal marsh habitat adjacent to the Corridor, and protect transportation infrastructure. Creating living shorelines along the Corridor would increase salt marsh habitat for native plant communities and rare plant species, such as Humboldt Bay Owl’s Clover, Point Reyes Bird’s Beak, and Western Sand Spurrey. The living shoreline would support vertical accretion of sediment, thereby increasing resilience to SLR, and accommodate upward migration of tidal wetlands with SLR. The ability of the living shoreline to absorb and buffer wind and wave energy would improve shoreline stability, reduce erosion, and reduce wave runup and overtopping onto the Bay Trail and Corridor (Figure 45). The living shoreline also has the potential to enhance recreation through, for example, improved scenic vistas and wildlife viewing.

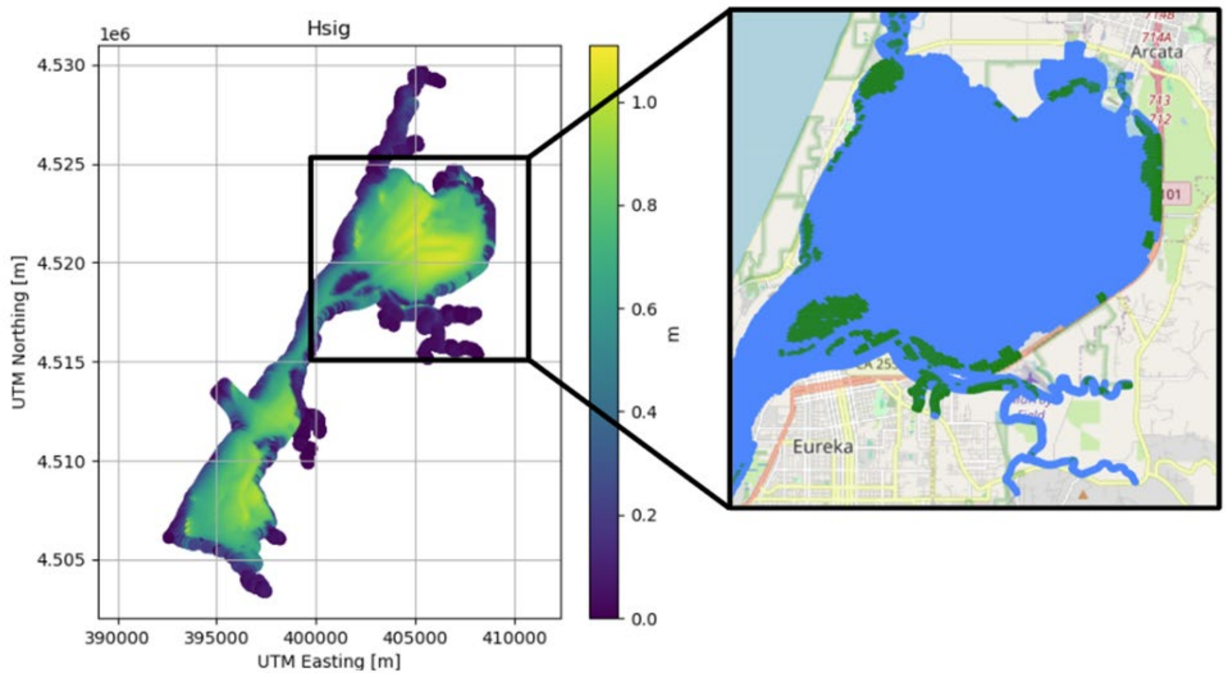


Figure 45. [Left]: Example of significant wave height from SWAN model run for the LUT node representing a 9.8 ft water level NAVD88 with a 45 mph (21 mps) westerly wind (blowing toward the east). [Right]: Modeled salt marsh locations mapped in green. Note the reduction in wave height due to depth limited wave breaking over the salt marsh. Figure from Ludka et al., 2025.

A recent study by GHD (2022) evaluated the feasibility of creating a living shoreline along a portion of the Corridor between Brainard and Bracut (Figure 46). The design report laid the groundwork for future implementation of a nature-based approach to restore and perpetuate intertidal coastal marsh and enhance resilience to coastal hazards, including SLR. Construction of a living shoreline along this portion of the Corridor has substantial benefits for the shoreline, railroad grade, Bay Trail, and highway infrastructure. The old railroad grade and Bay Trail currently provide shoreline protection to the highway. From Brainard to Bracut the Bay Trail is higher in elevation than the highway and throughout the Corridor the Trail reduces direct wave impacts to the roadway. The longer this protective infrastructure is maintained and improved, the longer the highway can maintain its current alignment and grade. Plans for living shorelines along the Corridor could take on different configurations and provide various services to the Corridor, including wave attenuation, enhanced resilience to still water (water level due to mean sea level, plus the tide and the non-tide residual) levels, increased storage capacity, etc.

The drawbacks of incorporating soft protection measures along the Corridor are mainly logistical; numerous permits and approvals would be required and the timeline for construction and maintenance would depend on the availability and delivery of useable sediment.

Figure 46. Living shoreline feasibility study. Top: Project area; Bottom: Existing conditions and visual simulation of living shoreline along the Corridor (from GHD, 2022).

Raised Earthen Embankment

A raised earthen embankment (without hydraulic connections to the bay) would make the highway less vulnerable to coastal storms and SLR and minimize flood impacts to adjacent parcels. In the CAIP, this adaptation strategy is only considered as an option for Jacobs Avenue — where maintaining access to existing development and minimizing flood vulnerability is important. Specific elevations of embankments will be based on up-to-date science and OPC guidance and therefore determined at the time of project design. Based on SLR projections at the time of this report, the findings from CAIP technical studies indicate a road raise to approximately 16 to 18 ft NAVD88 would provide adequate protection from coastal hazards through 2100 (see 6.1.5 ‘Vulnerability Assessment’). The elevation along the Corridor ranges from just under 9 ft to approximately 30 ft at the Indianola Bridge. Since much of the Corridor lies over land that is characterized by shallow groundwater and soft, deep bay mud, a raise of five or more feet would amount to a substantial load. Since much of the Corridor would require more than a five-foot raise to reach the target 16 to 18 ft NAVD88, construction of an earthen embankment would likely require CSEs, and/or lightweight fill, and/or geosynthetic reinforced embankments or walls

(Figure 47). There are several benefits to using CSEs, including the possibility of adaptive embankment design – that is, raising the road in the future as sea level rises or as science and projections advance, change, or become more certain. While it is possible to design the CSEs with a robust foundation that can support further elevation raises in the future, the final target elevation needs to be identified for appropriate design. CSEs also provide a cost-effective strategy for maintaining access to existing development such as Jacobs Avenue and the Old Mill site at Brainard. Additionally, a CSE can have a 2:1 slope or possibly a 1.5:1 slope if geosynthetic reinforced walls are incorporated into the design, whereas traditional embankments typically need a 4:1 slope to avoid requiring design exemption from safety standards. The difference in slope requirements allows for a higher grade raise within spatially confined areas (e.g., due to right of way limits or adjacent developments such as Jacobs Avenue). However, weight restrictions constrain the vertical height of fill. Preliminary discussion suggests the shallower bedrock under the segment of the Corridor adjacent to Bracut would likely support traditional embankment construction, though geotechnical investigations would need to be completed prior to design.

Raised earthen embankments would not reduce vulnerability to certain coastal hazards. For example, where the embankment and structural section is saturated for extended periods under longer-term SLR conditions, roadway rutting and fatigue failure due to wetting and drying of the road base would persist. The potential for earthquake damage, including liquefaction, and tsunami damage, would also be present.

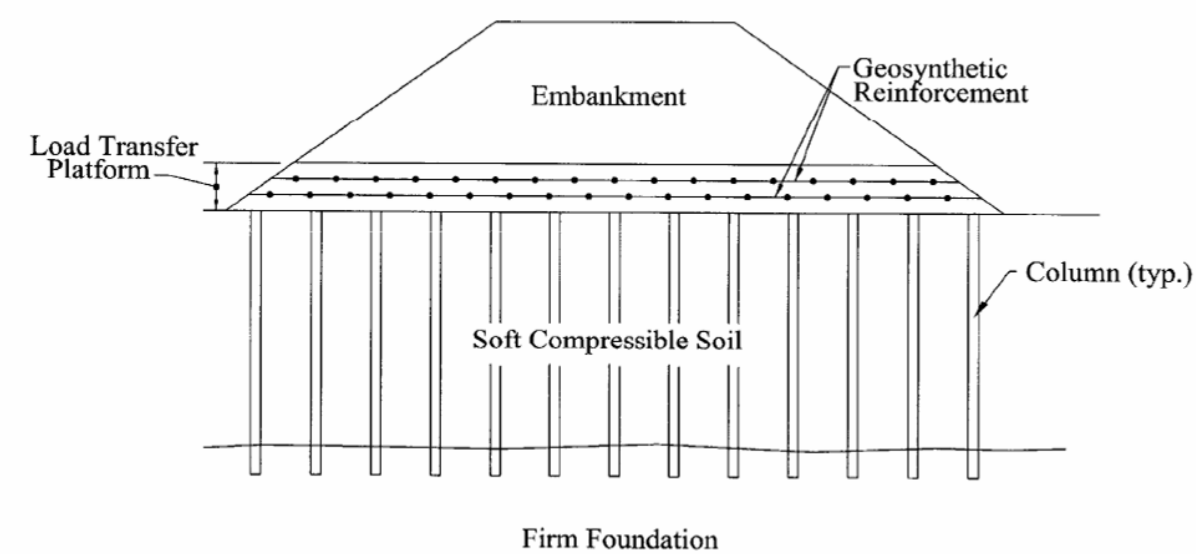


Figure 47. Diagram of column supported embankment (Geo-institute, 2025).

7.2 Retreat

Retreat options involve moving the roadway to locations that are less vulnerable to SLR and coastal hazards. Retreat options can allow natural coastal processes to occur but may be infeasible due to high costs.

Minor Retreat

A minor retreat is when the highway is moved slightly inland from its current alignment. A minor inland retreat could involve shifting both south and north bound lands east, or just the southbound lane to the northbound alignment and building a new northbound road further inland. This approach maintains traffic flow better during construction than elevating the existing road. However, the feasibility, environmental impact, and cost to acquire right of way throughout the new alignment(s) likely reduces the feasibility of this option.

Major Retreat

Relocating the highway from its existing alignment to Old Arcata Road represents a more drastic retreat option. Although this option offers certain advantages, it is generally viewed as unfavorable due to its high cost and extreme impact on the surrounding communities, including Freshwater Corners, Indianola, Bayside, and Sunny Brae, as well as the taking of agricultural land. While shallower bedrock conditions along Old Arcata Road could make a grade raise here more cost effective than raising the grade along the existing US 101 alignment, constructing a four-lane highway would require substantial horizontal space. More than 500 parcels lie along this stretch of Old Arcata Road, most of them are residential or house community-serving uses such as schools and churches. Moving the highway to this location would therefore result in widespread property impacts and substantial right-of-way acquisition efforts and costs. Acquisition assumes willing sellers and broad community support. Caltrans makes every effort to avoid the eminent domain process—it is considered a last resort as it often has a profound and disruptive impact on the community. It can also result in inequitable hardships for residents. The eminent domain process is costly to the taxpayer, requires approval of the CA Transportation Commission, must proceed through the court system, and can prolong project timelines. Additionally, a major retreat of the highway from its current alignment would reduce or eliminate access to established commercial and residential developments, including areas such as Jacobs Avenue. Old Arcata Road also currently experiences frequent fluvial flooding (Figure 48). Developing the highway along this alignment would require significant grade increases at multiple locations to elevate the roadway above existing and projected future flood levels. To obtain a wholistic evaluation of the major retreat strategy, the Multicriteria Evaluation Tool was applied (see Section 7.6). The low score (below 2) indicates the option is less than favorable.

Figure 48. Flooding along Old Arcata Road and the Jacoby Creek Valley on March 18, 1975 (Humboldt County Department of Public Works).

7.3 Accommodate

Accommodate strategies adapt existing infrastructure to be more resilient to impacts from coastal hazards, allowing impacts to “pass through” the system without harming it. Accommodation measures include improved drainage, such as upsized or additional culverts or tide/flap gates, breaching existing levees/dikes, lengthening or raising existing bridges, and elevating the highway with a viaduct or an earthen embankment that provides substantial hydraulic connectivity between tidal wetlands and Humboldt Bay. Accommodation measures could be implemented for various components or portions of the Corridor.

Improved Drainage

Improving drainage along the Corridor could enhance resilience to coastal and fluvial flooding. For example, the addition of culverts south of Jacoby Creek would help convey water toward the bay and away from the roadway. Similarly, installing a large bottomless culvert or bridge at the historic tidal connection between Fay Slough and Humboldt Bay would increase flood storage and conveyance capacity. In addition to establishing hydraulic connectivity across the Corridor and improving drainage, a connection at Fay

Slough would create brackish and saltwater habitat for estuarine species such as tidewater goby.

Rising water levels could also be accommodated by raising or lengthening existing bridges. Specifically, future bridge replacements at Gannon Slough and NB Jacoby Creek Bridges could be designed with a vertically adjustable superstructure (as with the recently updated SB Jacoby Creek Bridge and plans for Eureka Slough Bridges).

Breaching Levees/Dikes

Allowing levees/dikes to breach, through unintentional events or intentional adaptation measures, can help accommodate rising sea levels. For example, breaching the levee on the inland side at the Fay Slough Wildlife Area would accommodate ocean and fluvial water and enhance hydraulic connectivity with the bay.

Raised Earthen Embankment with Drainage

Portions of the Corridor could be elevated with an earthen embankment with hydraulic structures that enable drainage and the restoration of tidal flow. This measure is included in the *Accommodate* section rather than *Protect* because the enhanced drainage components would be designed to support the exchange of fluvial and tidal waters beneath the Corridor, thereby accommodating natural patterns of water movement. However, this strategy may be viewed as a hybrid *Protect-Accommodate* approach by the CCC at the time of permitting. Design specifications, including elevation, slope, and geotechnical considerations, are addressed above under “Raised Earthen Embankment” in the *Protect* strategy section.

Viaduct

Elevating portions of the Corridor on a viaduct would enhance resilience to coastal hazards. As with a raised earthen embankment, specific elevations would be based on up-to-date science and OPC guidance which would be determined at the time of project planning. At the time of this report, SLR projections and findings from Cal Poly Humboldt technical studies indicate an elevation of approximately 18-20 ft NAVD88 would provide adequate protection from coastal hazards through 2100 (see 6.1.5 ‘Vulnerability Assessment’). Note that the range of the viaduct elevation (based on current SLR projections) is two feet higher than the earthen embankment. Since viaducts cannot be easily raised to accommodate rising waters, it is recommended that conservative elevations be selected. Viaduct design will also need to consider the vertical transition to embankment sections.

Portions of the Corridor that are potentially compatible with a viaduct include the segment between Airport Road and the northern branch of Fay Slough, the north end of Brainard to the southern end of Indianola Undercrossing, the northern end of Indianola Undercrossing to the southern end of Bracut, and Bayside Cutoff to the SR 255/101Interchange (Figure 52).

Viaducts could be built as a single structure with lanes for north and southbound traffic or two separate structures, one for each direction of traffic. A single viaduct may have lower initial construction costs and would likely have a smaller footprint than two separate structures. However, the single viaduct option would also have reduced redundancy. For example, a structural failure or maintenance on one part of the viaduct could disrupt traffic in both directions. Additionally, unless north and southbound traffic is physically separated, c may more easily spill over into opposing lanes. Two separate viaducts for north and southbound traffic would provide greater redundancy compared to the single structure option. For example, an incident on one viaduct would not necessarily affect the other. Similarly, maintenance could be performed on one structure while the other remained open. The redundancy of two structures can also be advantageous in seismic zones such as the Corridor and more easily facilitate seismic retrofit projects. Two structures would also provide greater flexibility for staging construction—one side could be built at a time. Unlike the single structure viaduct, the two-structure option could be built approximately on the existing alignment where feasible.

The approximate cost per square foot of viaduct ranges from $200 to $600 with an additional 40% for contingencies to account for low-level of design, economic and environmental uncertainties, year of construction, inflation, etc. (see Section 7.7 Cost Comparison of Viaducts vs Embankments). The project would also need to account for construction staging, design, and support costs.

There are numerous benefits associated with viaduct construction along the Corridor. Environmental benefits include restoration of hydraulic connectivity between historical tidal flats inland of the Corridor and Humboldt Bay and avoidance or minimization of coastal squeeze, and habitat creation. The width of a viaduct structure could be narrower than an earthen embankment, as there is no need for embankment slopes. This results in a smaller footprint (i.e., reduced wetland impact) and alleviates the need for additional right of way. Viaducts along the Corridor could also support multimodal transportation with a retreat option for the Bay Trail by providing a 10-ft-wide shoulder on the viaduct. Viaducts are less prone to rutting and fatigue failure compared to earthen embankments, as they are not affected by water infiltration into the road prism of an earthen berm (De Oliveira et al., 2025). Additionally, maintenance of drainage channels would be markedly reduced or non-existent.

Some drawbacks of viaducts include an extremely high cost to build, potential for more complex coordination with surrounding land use, significant increase in temporary environmental impacts and land acquisition costs if building off alignment, and reduced flexibility for future raises.

Full-span viaduct (Eureka Slough Bridges to Arcata)

Rerouting the Corridor westward into the bay as a full-span viaduct (white and blue dashed line in Figure 49) was mentioned as an option in early planning, but would require about 22,800 ft of viaduct estimated at around $1.43 to $1.65 billion, depending on whether a bike/pedestrian lane is included. Note this estimate does not include costs for mitigation, which are substantial and highly dependent on the construction scenario and thus difficult to estimate. Connections to existing ancillary infrastructure would be lost or unmaintained. It would also have substantial environmental impacts from construction across the bay and geotechnical/logistical challenges. Rerouting west of the current alignment was considered because this would shorten the overall vehicle miles travelled and would not have the same level of wetland, agricultural, residential, and environmental justice concerns as a reroute to the east of the Corridor would.

Figure 49. Example of full span viaducts across Arcata Bay (white and blue dashed line) and along current highway alignment (solid white line).

7.4 Hybrid

Combining adaptation strategies may prove more effective than a single strategy approach. For example, accommodating waters through larger bridge openings or upsized culverts could address fluvial flooding on the inland side of the Corridor. Additionally, protecting infrastructure with a living shoreline could mitigate wave overtopping from the bay-ward side of the Corridor.

7.5 Adaptation Options by Corridor Segments

Since the implementation of adaptation measures depends on feasibility and funding, it is unlikely the entire six miles of the Corridor would be adapted for long-term resilience in a single project. To better align with funding opportunities and availability, and with the project development process, the Corridor was divided into smaller segments. Segment delineation was based on logical termini – or rational end points for a transportation project, such as intersecting roadways or natural features, a change in surrounding land use, or a change in roadway vulnerability. The adaptation need of a segment was determined by elevation—segments with any portion below 16 ft NAVD88 were flagged for evaluation of adaptation strategies. This elevation is based on results from the CAIP technical analyses (Section 6) that indicate an elevation of 15.9 ft NAVD88 meets resilience targets (fewer than 0.01 days/year with roadway flood depth > 4”) to the year 2100 in the intermediate-high SLR scenario (see 6.1.5 ‘Vulnerability Assessment’).

The Corridor was divided into 13 segments ranging in length from 0.20 to 0.95 miles (Table 20 and Figure 52). Three of the 13 segments have roadway elevations greater than 16 ft and will not require adaptation. The remaining 10 segments include portions of roadway that lie below 16 ft NAVD88 – with some areas as low as 8.9 ft – and will require adaptation projects to improve resilience to coastal hazards to 2100 (Figure 50 and Figure 51).

Table 20. Description of Corridor segments including segment number, location, and length. Gray italicized text indicates segments do not require adaptation because the existing elevation is greater than 16 ft NAVD88.

Number	Segment Description	Postmile Limits	Length (miles)
1	Eureka Slough Bridges to Airport Rd.	79.900 to 80.850	0.95
2	Airport Rd. to N. Fay Slough	80.850 to 81.300	0.45
3	N. Fay Slough to N. Brainard	81.300 to 81.901	0.60
4	N. Brainard to S. Indianola	81.901 to 82.448	0.55
5	*S. Indianola to N. Indianola*	*82.448 to 82.840*	*0.39*
6	N. Indianola to S. Bracut	82.840 to 83.239	0.40
7	*S. Bracut to N. Bracut*	*83.239 to 83.500*	*0.26*
8	N. Bracut to Bayside Cutoff	83.500 to 83.956	0.46
9	Bayside Cutoff to Jacoby Creek	83.956 to 84.434	0.48
10	Jacoby Creek to South G St.	84.434 to 84.930	0.50
11	South G St. to SR 255/101 Separation Bridge	84.930 to 85.810	0.88
12	SR 255/101 Separation Bridge to 7th St.	85.810 to 86.010	0.20

Number	Segment Description	Postmile Limits	Length (miles)
13	*7th St to 11th St.*	*86.010 to 86.330*	*0.32*

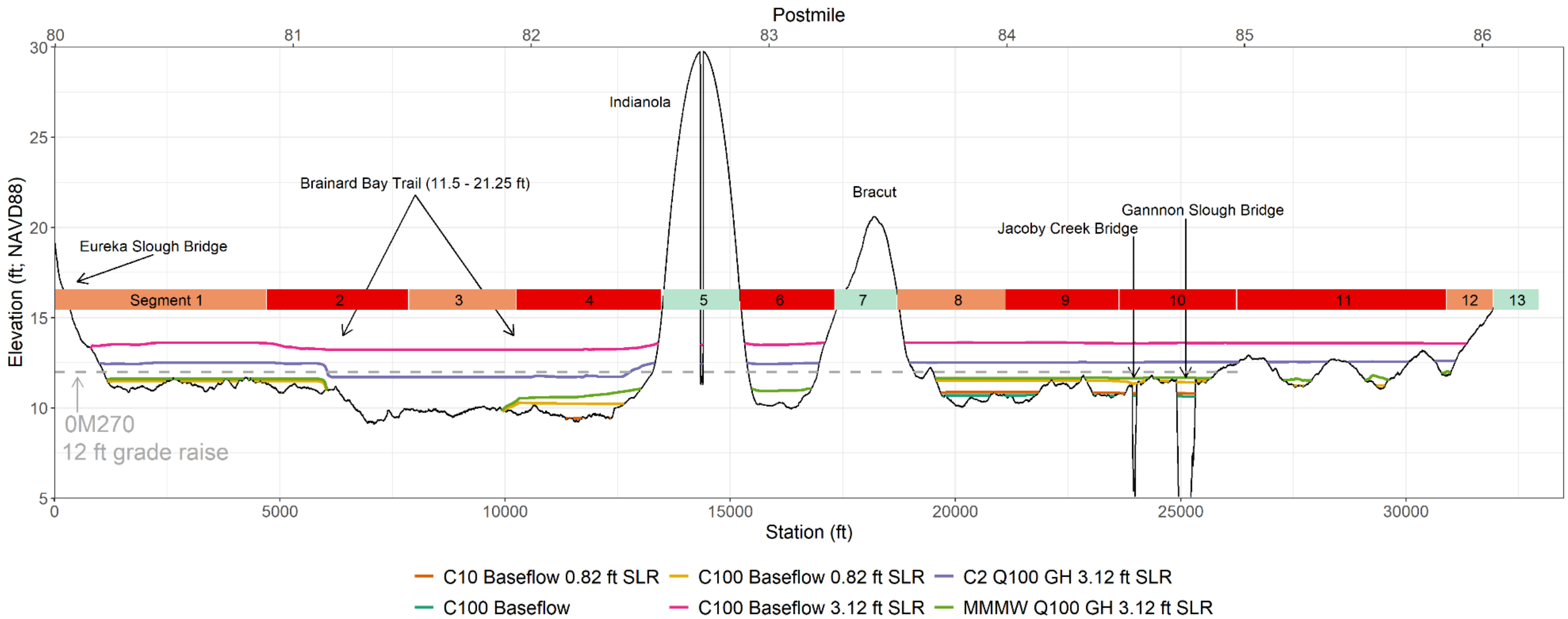


Figure 50. Profile plot of the southbound west edge of the Corridor (black line). Corridor segments are placed at 16 ft NAVD88 to show the minimum target elevation of raised embankments or viaducts. The color of each segment indicates the potential adaptation option (see legend in Figure 52). Maximum water surface elevation (WSE) is shown for storm event (C = Coastal, Q = riverine; 2 = 2-year storm, 10 = 10-year storm, 100 = 100-year storm) and SLR scenarios (0.82 ft and 3.12 ft represent intermediate scenarios for 2050 and 2100, respectively) that result in flooding of the highway (see legend). GH = Generalized Hydrograph. Gray dashed line at 12 ft indicates the future elevation of the roadway upon completion of the planned 0M270 Eureka/Arcata 101 SLR Resilience Project (PM 79.9 to 85.0).

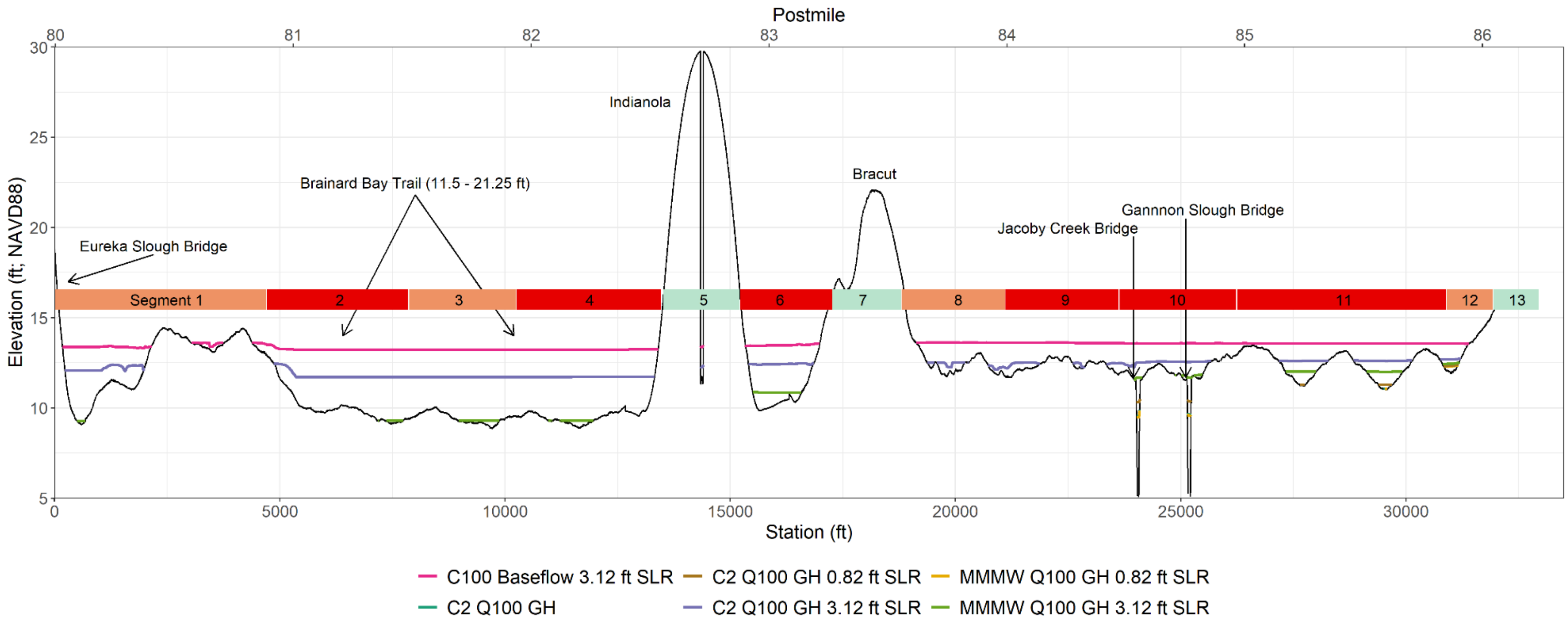


Figure 51. Profile plot of the northbound east edge of the Corridor (black line). Corridor segments are placed at 16 ft NAVD88 to show the minimum target elevation of raised embankments or viaducts. The color of each segment indicates the potential adaptation option (see legend in Figure 52). Maximum water surface elevation (WSE) is shown for storm event (C = Coastal, Q = riverine; 2 = 2-year storm, 10 = 10-year storm, 100 = 100-year storm) and SLR scenarios (0.82 ft and 3.12 ft represent intermediate scenarios for 2050 and 2100, respectively) that result in flooding of the highway (see legend). GH = Generalized Hydrograph. Gray dashed line at 12 ft indicates the future elevation of the roadway upon completion of the planned 0M270 Eureka/Arcata 101 SLR Resilience Project (PM 79.9 to 85.0).

A list of adaptation options was created for each of the 10 Corridor segments needing treatment. These strategies address vulnerabilities identified in technical studies and reflect segment-specific considerations such as surrounding land use and existing or historic hydraulic connections. Maps of Corridor segments and descriptions of possible treatments are provided below.

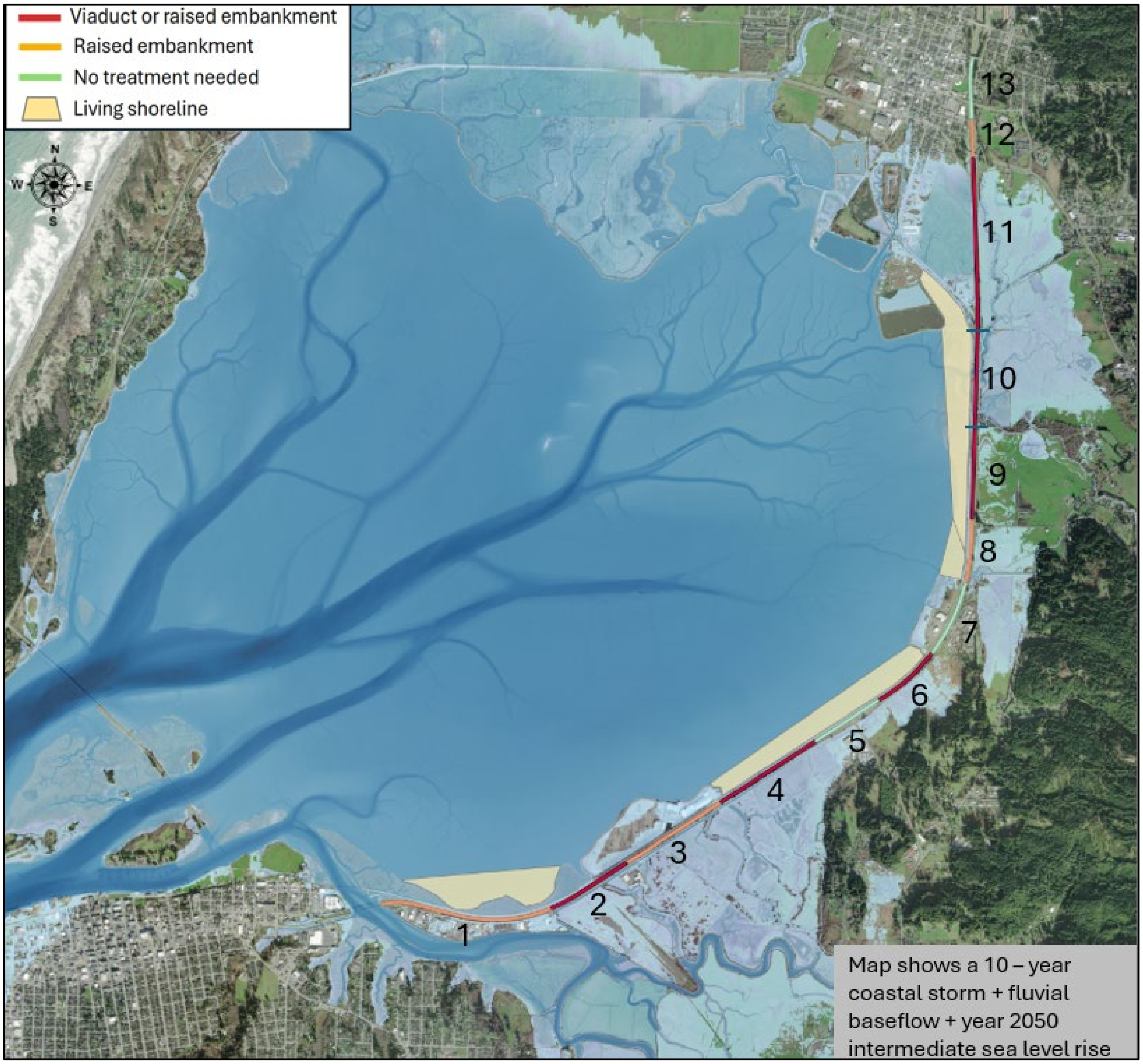


Figure 52. Overview of road segments with treatment options (see legend) along the Eureka-Arcata 101 Corridor. SLR projection of 0.82 ft corresponds approximately with the Intermediate SLR Scenario for the year 2050.

Segment 1 (Eureka Slough Bridges to Airport Road)

Segment length: 4,628 ft (0.95 miles)
Raised embankment potential cost*: $30M - $31M

**Note that cost estimates reflect construction capital plus a 40% contingency rate and include north and southbound travel lanes. The cost estimate range reflects separate and single facilities. See Section 7.7 Cost Comparison of Viaducts vs Embankments for more detail.*

The proposed adaptation option for Segment 1 is a raised embankment, with the potential inclusion of a living shoreline (Figure 53). Due to the number of parcels along Jacobs Avenue, this portion of the Corridor is not suitable for viaduct construction. While these parcels are currently more vulnerable to flooding from the inland side due to levee/dike overtopping, introducing a viaduct in this area could increase their exposure to coastal flooding. Additionally, a viaduct in this location would offer limited opportunity for environmental mitigation compared to other segments.

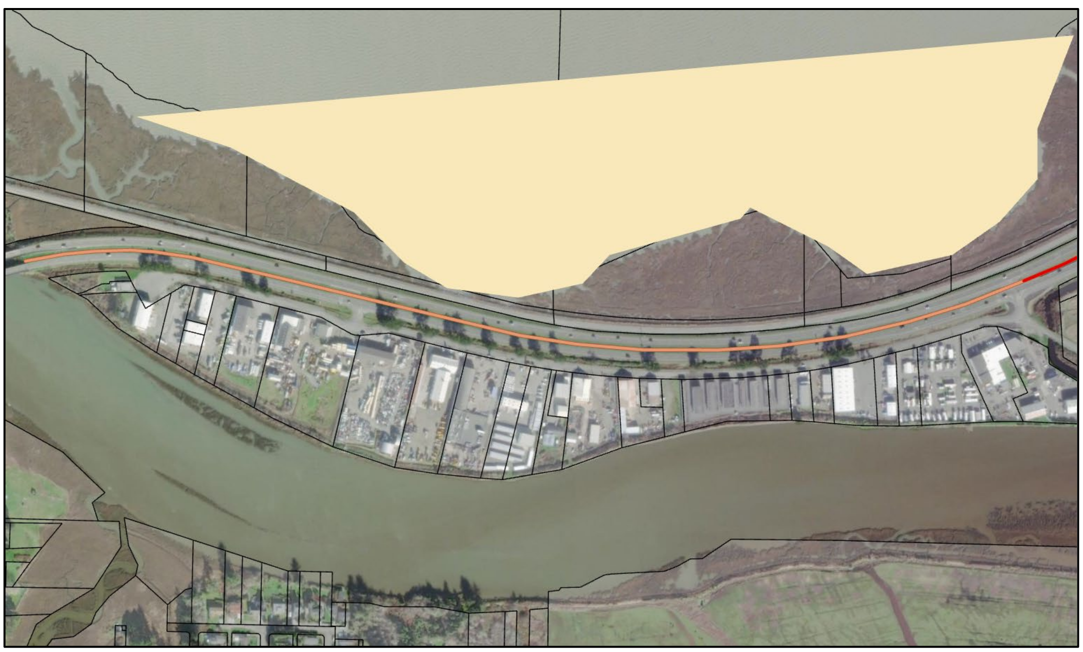


Figure 53. Map showing Segment 1 (orange line) which spans Eureka Slough Bridges to Airport Road. The tan polygon indicates potential living shoreline location. Black lines outline individual parcels.

Segment 2 (Airport Road to North Fay Slough)

Segment length: 2,330 ft (0.45 miles)
Raised embankment potential cost: $15M-16M
Viaduct potential cost: $140M - $169M

The proposed adaptation options for Segment 2 include a raised embankment or viaduct with additional options for hydraulic connections to the bay or the Brainard Mill Site and living shorelines. The adaptation options for this segment must consider access to nearby parcels, including the California Department of Fish and Wildlife Fay Slough Wildlife Area parking lot and the Harper Motors/Mid City Motorworld properties (Figure 54). Note there are two potential alignment endpoints (cost estimates are shown for the longer option):

1. A connection at the southern edge of the Fay Slough Wildlife Area
2. The southbound side of the off-ramp serving Harper Motors and public access to the Wildlife Area

Additionally, the feasibility of adding a hydraulic connection from the Fay Slough channel through the Brainard property is dependent on future property acquisition. This connection could pass through the Brainard site or directly to the bay, depending on the final design and land availability.

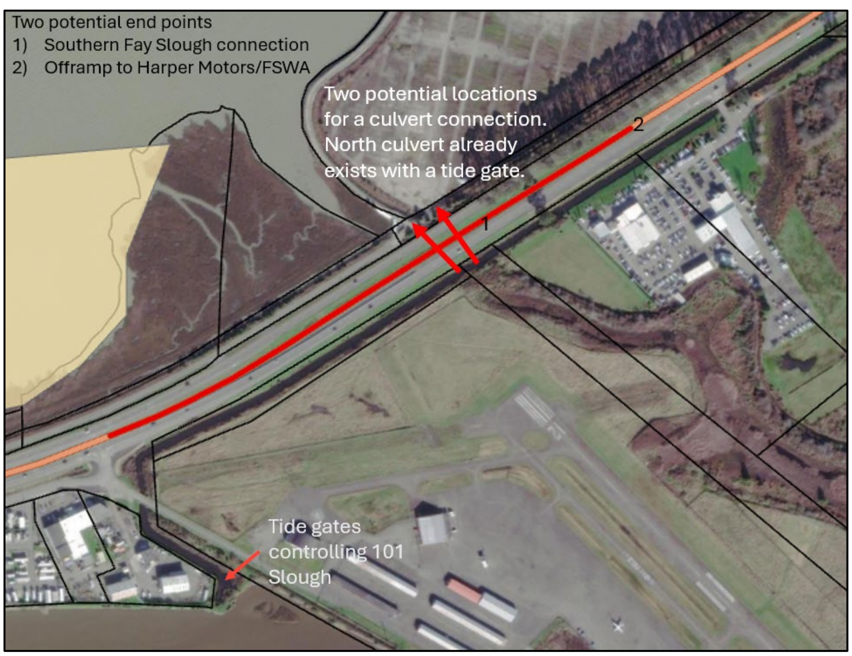


Figure 54. Map showing Segment 2 (red line) which spans Airport Road to North Fay Slough. Adaptation options along this segment include a raised embankment or viaduct with the potential for hydraulic connections and a living shoreline. The tan polygon indicates potential living shoreline location. White band with blue waves that crosses the Corridor near Fay Slough indicates potential location of hydraulic connection directly to bay (lower band) or through Brainard Mill site (upper band). Black lines outline individual parcels.

Segment 3 (North Fay Slough to North Brainard)

Segment length: 3,119 ft (0.60 miles)
Raised embankment potential cost: $20M-$21M

Segment 3 spans North Fay Slough to North Brainard (Figure 55). The adaptation solution proposed for this portion of the Corridor is a raised embankment with a potential hydraulic connection between the historic Fay Slough Channel on the north end of Harper Motors and the old Brainard Mill site. The embankment approach will preserve access to the private road inland of the Corridor at the northern end of this segment. This road provides access to a private residence and a CDFW facility used for regional resource management and maintenance activities.

Figure 55. Map showing Segment 3 (orange line) which spans North Fay Slough to North Brainard. The adaptation options along this segment of the Corridor include a raised embankment with potential hydraulic connection to the old Brainard Mill site. Black lines outline individual parcels.

Segment 4 (North Brainard to South Indianola)

Segment length: 3,037 ft (0.55 miles)
Raised embankment potential cost: $20M (single and separate facility)
Viaduct potential cost: $182M-$220M

Segment 4 spans North Brainard to South Indianola (Figure 56). This portion of the Corridor is particularly vulnerable to overtopping. Adaptation options along this stretch of the Corridor include a viaduct or a raised embankment, with the potential for inclusion of a living shoreline and hydraulic connection to the bay. Implementation of a living shoreline as a near- to mid-term response could enhance the Corridor's resilience to coastal flooding (GHD, 2022). Longer-term adaptation response of a raised embankment or viaduct could follow as necessary. CDFW may also need to raise the access road to their maintenance facility parcel. Models project that flooding will also occur from water overtopping levees on the inland side along Freshwater Slough.

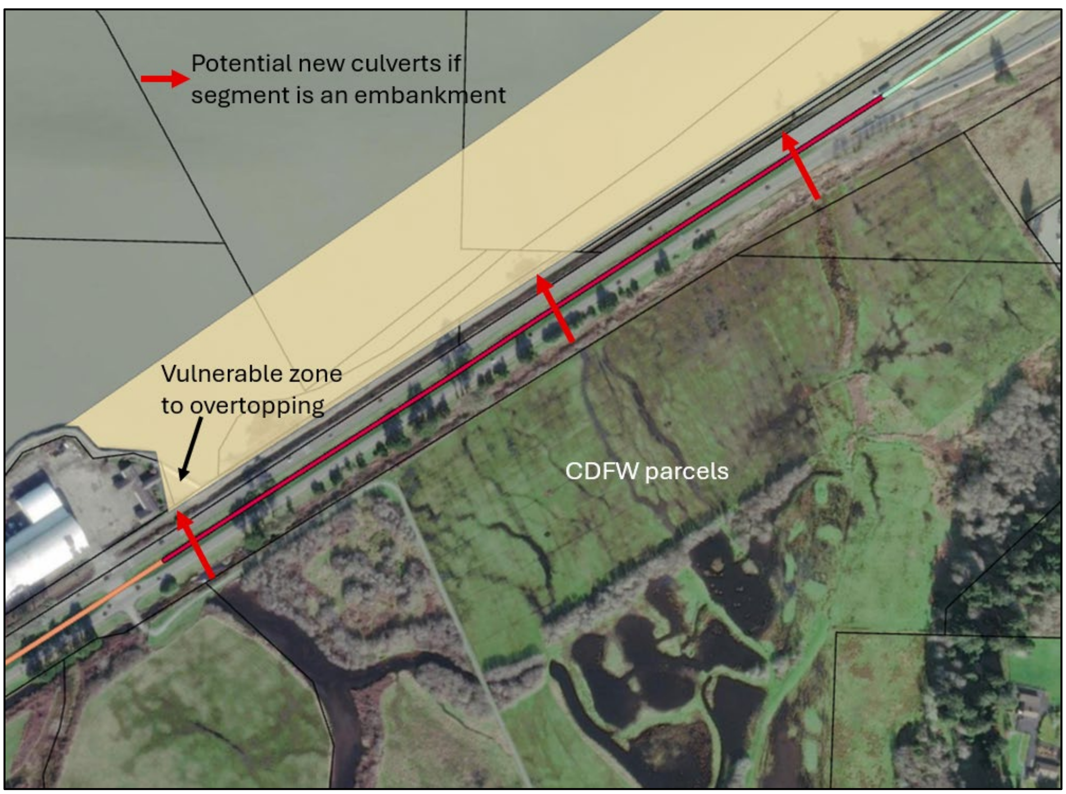


Figure 56. Map showing Segment 4 (red line) which spans North Brainard to South Indianola. Adaptation options along this segment of the Corridor include a raised embankment or viaduct, with options for a living shoreline and hydraulic connections to the bay. The tan polygon indicates potential living shoreline location. Black lines outline individual parcels.

Segment 5 (South Indianola to North Indianola)

Segment length: 2,070 ft (0.39 miles)

Segment 5 would not need additional work as the elevation of the embankment here will be 16 – 30 ft NAVD88 once the Indianola Undercrossing Project is complete (Figure 57). The elevation of Indianola Road beneath the highway is 12.08 ft NAVD88, below the 16 ft treatment threshold for the highway. Since Indianola Road is a county road, adaptation of this road will need to be coordinated with the County. Potential adaptation options include raising the elevation of Indianola Road and reducing the clearance height, which is currently 15.2 ft. Additionally, approaches to the bridge were overbuilt to accommodate a 1-2 ft raise of the bridge in the future. A living shoreline could be implemented here to enhance the resilience of coastal assets such as the Bay Trail, Indianola Road, and the highway (GHD, 2022).

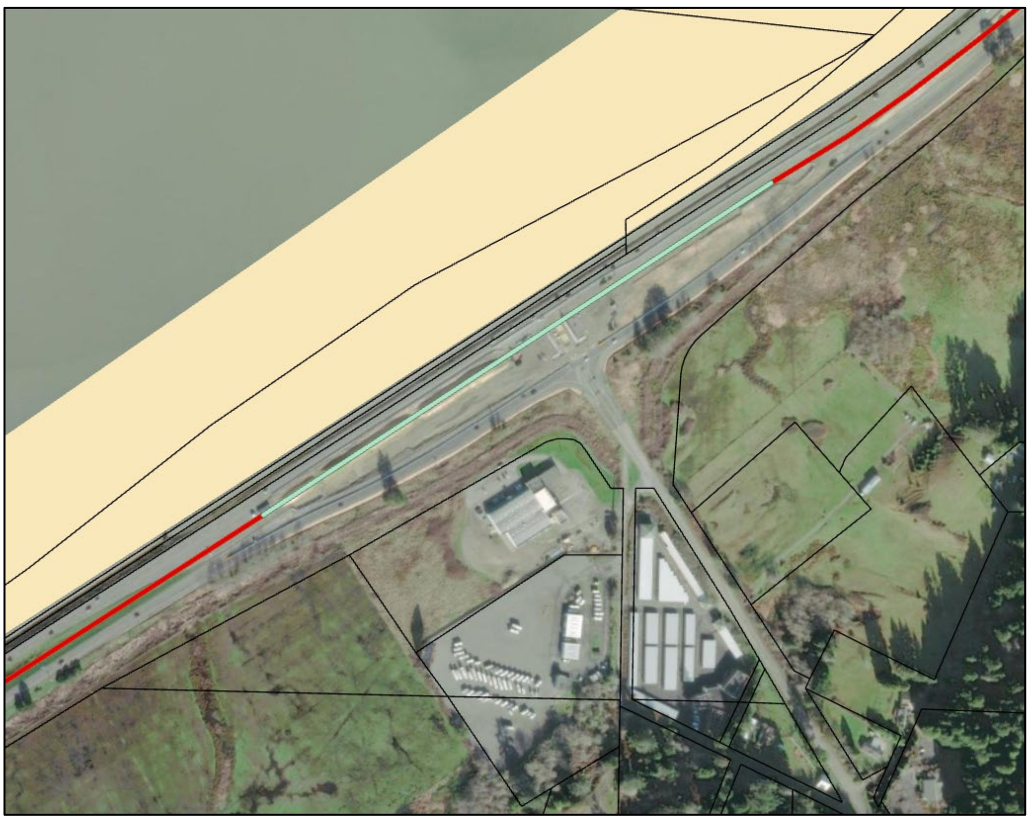


Figure 57. Map showing Segment 5 (green line) which spans South Indianola to North Indianola. No adaptation options are planned for this segment as elevations are greater than 16 ft NAVD88. The tan polygon indicates potential living shoreline location. Black lines outline individual parcels.

Segment 6 (North Indianola to South Bracut)

Segment length: 2,015 ft (0.40 miles)
Raised embankment potential cost: $14M-$15M
Viaduct potential cost: $121M-$146M

Segment 6 spans North Indianola to South Bracut (Figure 58). Adaptation options include a viaduct or raised embankment, with the potential for hydraulic connections and a living shoreline. This portion of the Corridor has a history of compound flooding as it includes the location where overtopping of the highway occurred during a storm event in 2005. The Bay Trail now provides more protection to the highway from overtopping, but adaptation options should consider additional features to reduce vulnerability (e.g., restoration projects on adjacent parcels that would allow for enhanced storage capacity and accommodation of floodwaters).

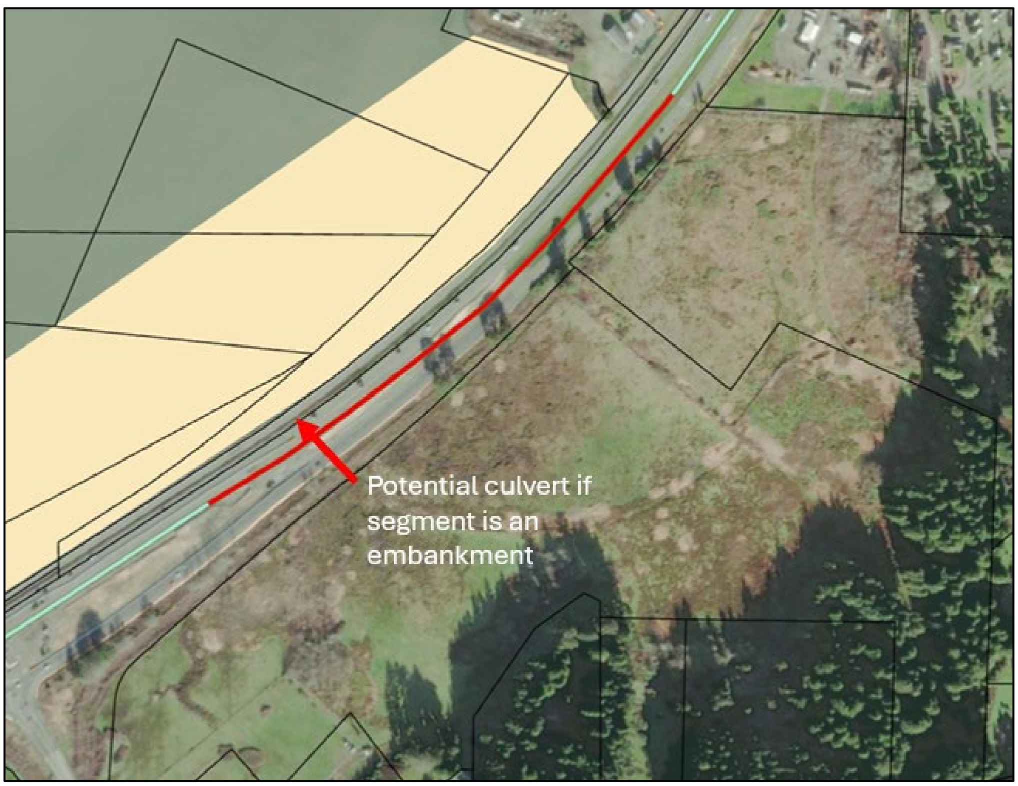


Figure 58. Map showing Segment 6 (red line) which spans North Indianola to South Bracut. The adaptation options along this segment include a raised embankment or viaduct with potential hydraulic connections to the bay and living shoreline. The tan polygon indicates potential living shoreline location. Black lines outline individual parcels.

Segment 7 (South Bracut to North Bracut)

Segment length: 1,378 ft (0.26 miles)

The elevation throughout Segment 7, which spans South Bracut to North Bracut, is above 16 ft NAVD88 (Figure 59). As such, there are no plans for adaptations along this portion of the Corridor. Maintaining the highway infrastructure in its present state will also preserve access to businesses at Bracut Industrial Park and to the east of the highway. Note that culvert upsizing is planned in Segment 8 on the north side of Bracut.

Figure 59. Map showing Segment 7 (green line) which spans South Bracut to North Bracut. No adaptation options are planned for this segment as elevations are greater than 16 ft NAVD88. The tan polygon indicates potential living shoreline location. Black lines outline individual parcels.

Segment 8 (North Bracut to Bayside Cutoff)

Segment length: 2,445 ft (0.46 miles)
Raised embankment potential cost: $16M (single and separate facility)

Adaptation options for Segment 8, which spans North Bracut to Bayside Cutoff, include a raised embankment with the potential addition of a living shoreline and enhanced hydraulic connection to the bay (Figure 60). The choice of a raised embankment only and not a viaduct reflects the current need to maintain access to the Bayside Cutoff offramp. However, if future regional planning supports retreat from Bayside Cutoff (i.e., the road is decommissioned or does not require a connection with the highway), a viaduct may become a more viable alternative for this segment of the Corridor. Additionally, a forthcoming Caltrans project will upgrade the existing box culvert at Rocky Gulch, increasing its size from 8' x 6' to 12' x 8'. This size selection of the culvert may be changed during the Design Phase based on design level hydraulic modeling, funding constraints, and logistics. Lastly, the ground elevation here is higher than other parts of the Corridor, making it an easier area to raise the embankment in the future.

Figure 60. Map showing Segment 8 (orange line) which spans North Bracut to Bayside Cutoff. The adaptation option here includes a raised embankment with potential living shoreline and hydraulic connection to the bay. The tan polygon indicates potential living shoreline location. Black lines outline individual parcels.

Segment 9 (Bayside Cutoff to Jacoby Creek)

Length: 2,470 ft (0.48 miles)
Raised embankment (excluding new culverts) potential cost: $16M-$17M
Viaduct potential cost: $148M-$179M

Segment 9 spans the Bayside Cutoff onramp to south of the Jacoby Creek Bridge where an elevated bank line/levee is formed (Figure 61). The adaptation options for this segment include a raised embankment or viaduct with the potential for addition of a living shoreline and hydraulic connection to the bay. The parcels adjacent to this segment of the Corridor are owned by the City of Arcata and are currently leased for cattle grazing. However, future saltwater inundation of lands inland of the Corridor is consistent with the City of Arcata's Draft Local Coastal Element which indicates a plan, "...to accommodate the higher water levels and increased inundation from flooding in these low lying areas." (City of Arcata, 2026).

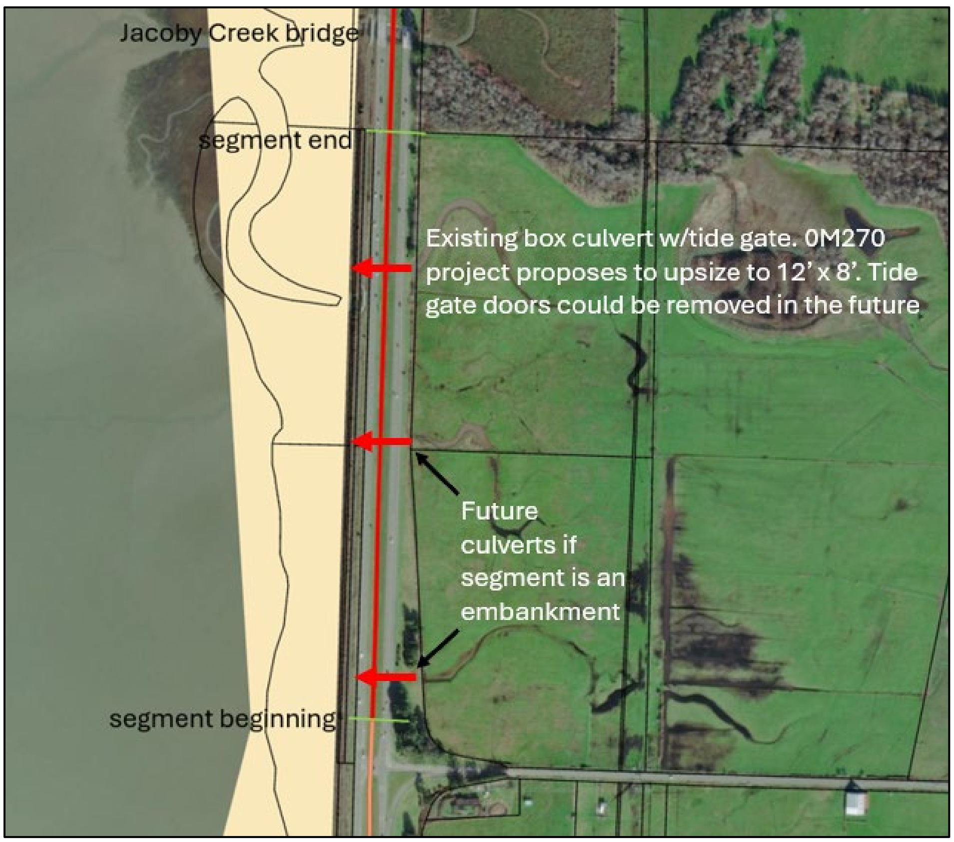


Figure 61. Map showing Segment 9 (red line) which spans Bayside Cutoff to south of Jacoby Creek Bridges. The adaptation options here include a raised embankment or viaduct with potential addition of a living shoreline and hydraulic connections to the bay. The tan polygon indicates potential living shoreline location. Black lines outline individual parcels.

Segment 10 (Jacoby Creek to South G Street)

Length: 2,650 ft (0.50 miles)
Raised embankment potential cost: $17M-$18M
Viaduct potential cost: $159M-$192M

Segment 10 spans Jacoby Creek Bridges to South G Street (Figure 62). The adaptation options here include a viaduct or raised embankment with the potential for a living shoreline. Gannon Slough and Jacoby Creek are already hydraulically connected to the bay through their respective bridges. The parcels adjacent to this segment of the Corridor are owned by the City of Arcata. Increased saltwater inundation on these parcels is consistent with the City of Arcata's Draft Local Coastal Element which indicates a plan, "…to accommodate the higher water levels and increased inundation from flooding in these low lying areas" (City of Arcata, 2026). The northbound bridges have design lives until 2030. The design life of the southbound Gannon Slough bridge is 2071 and the southbound Jacoby Creek Bridge is 2097, though this newer bridge is designed to allow for future raises in response to rising water elevations.

Figure 62. Map showing Segment 10 (red line) which spans Jacoby Creek Bridges to South G Street. The adaptation options here include a raised embankment or viaduct with potential addition of a living shoreline (tan polygon). Black lines outline individual parcels.

Segment 11 (South G Street to SR 255/101 Separation Bridge)

Length: 4,636 ft (0.88 miles)
Raised embankment potential cost: $30M-$31M
Viaduct potential cost: $278M-$336M

Segment 11 spans South G Street to the SR 255/101 Separation Bridge (Figure 63). The adaptation options here include a raised embankment or viaduct with options for improved drainage (upsized culvert) and a living shoreline. These adaptation options are consistent with the plans and policies referenced in the City of Arcata's Draft Local Coastal Element (City of Arcata, 2026). The segment ending depends on the City of Arcata's South Arcata Multimodal Safety Improvement Plan (SAMSIP) design of on/offramps. Currently, the proposed alternative is to have on/offramps rerouted to the southern end of the interchange. To address an existing flood issue at the interchange, Caltrans may conduct a drainage improvement project (i.e., vegetation management). This segment does not fall within the boundaries of the 0M270 project but is vulnerable to freshwater flooding in the near-term. Therefore, adaptation measures should be considered within the time frame of 0M270.

Figure 63. Map showing Segment 11 (red line) which spans South G Street to the SR 255/101 Separation Bridge. The adaptation options here include a raised embankment or viaduct with potential addition of a living shoreline (tan polygon) and upsized culvert. Black lines outline individual parcels.

Segment 12 (SR 255/101 Separation Bridge to 7th Street)

Length: 1,110 ft (0.20 miles)
Raised embankment potential cost: $7M (single and separate facility)

Segment 12 spans the SR 255/101 Separation Bridge to 7th Street in Arcata (Figure 64). This segment is less vulnerable than others but ranges from approximately 12 to 16 ft NAVD88 and is projected to experience intermittent fluvial flooding by 2050. Consistent with the interim approach of 0M270, this segment could receive a pavement overlay (e.g., of 5") to raise its elevation at a more affordable expense. However, long-term planning will need to consider a greater elevation raise, such as a raised embankment. A low point along the highway exists beneath Route 255/101 Separation Bridge at 12.2 ft NAVD88. This bridge was constructed in 1965. The end of the bridge's design life or need for major repairs would present an opportunity to raise US 101 underneath the bridge. This segment does not fall within the boundaries of the 0M270 project but is vulnerable to freshwater flooding in the near-term. Therefore, adaptation measures should be considered within the time frame of 0M270.

Figure 64. Map showing Segment 12 (orange line) which spans the SR 255/101 Separation Bridge to 7th Street in Arcata. The adaptation options here include a raised embankment. Black lines outline individual parcels.

Segment 13 (7th Street to 11th Street)

Length: 3,700 ft (0.32 miles)

The elevation throughout Segment 13, which spans 7th to 11th Street in Arcata, is above 16 ft NAVD88 (Figure 65). As such, there are no plans for adaptations along this portion of the Corridor. This segment is included here because the CDP requires the CAIP to extend from the Eureka Slough bridges to 11th Street in Arcata. The Fickle Hill fault line, which runs beneath the highway, presents a geologic hazard for this portion of the Corridor. However, since no other adaptation treatments are necessary to provide resilience to flooding, the CAIP does not include recommendations for mitigating this hazard.

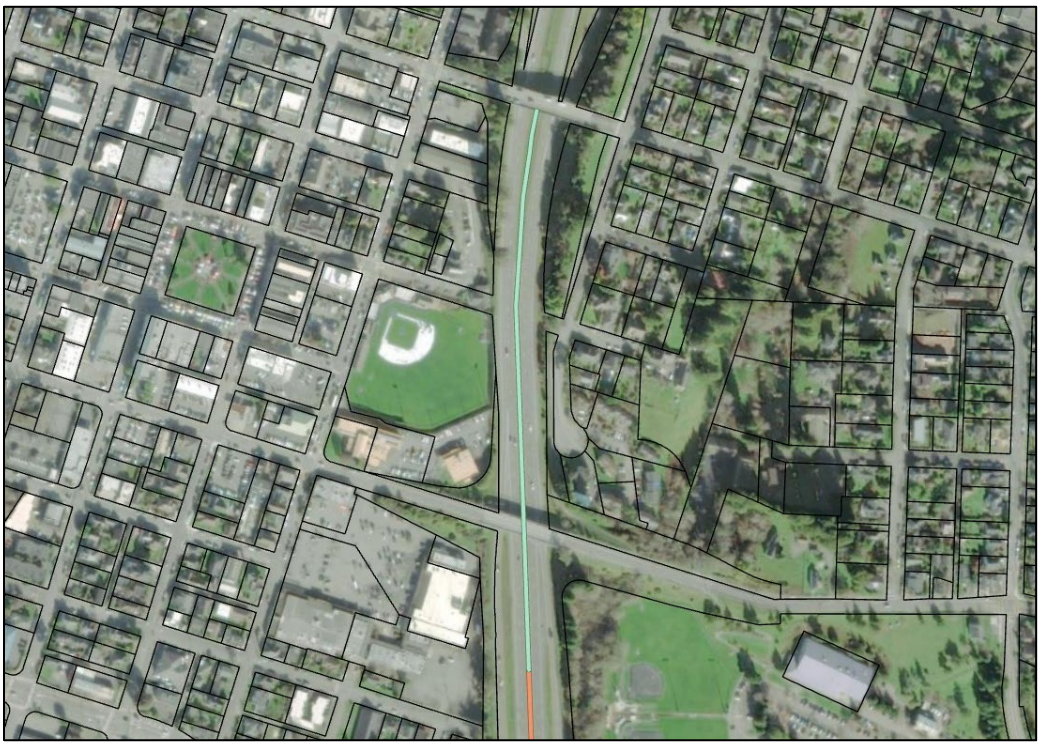


Figure 65. Map showing Segment 13 (green line) which spans 7th to 11th Street in Arcata. There are no adaptation options for this portion of the Corridor as the elevation is greater than 16 ft NAVD88. Black lines outline individual parcels.

7.6 Multicriteria Evaluation Tool

A qualitative analytical approach was used to evaluate potential adaptation strategies for each segment of the Corridor. This approach is based on a tool developed by Dudek (consulting firm) and the San Diego Association of Governments (SANDAG) to support transparent and informed planning and decision making, particularly in the process of refining potential adaptation strategies (Dudek, 2021). The tool Dudek and SANDAG created facilitates stakeholder engagement by providing a methodical way to discuss trade-offs among strategies from various perspectives. In other words, it serves as a way to produce performance indicators in the adaptation selection process.

The Evaluation Tool evaluates strategies using criteria that fall within the following five categories: I. Society and Equity, II. Economy, III. Environment, IV. Feasibility, and V. Robustness. Society and Equity, Economy, and Environment represent the three pillars of sustainability while Feasibility and Robustness directly relate to project implementation. The criteria selected for evaluating potential adaptation strategies in the CAIP reflect local conditions and objectives of the CAIP. Since the importance of some criteria may depend on the values of the affected community, the Evaluation Tool is designed to allow weights to be assigned to each criterion to reflect local priorities. Input from the technical advisory committee and internal review was used to inform weighting of criteria and has been incorporated into the evaluation. Future updates may consider adding criteria to evaluate the cost benefit of strategies. For example, would the strategy result in unintended environmental and economic consequences to adjacent parcels?

The following sections provide information to help evaluate the performance of each adaptation strategy using the selected criteria. A summary of considerations used to evaluate the performance of adaptation options is shown in Table 21.

7.6.1 Evaluation Criteria

I. SOCIETY AND EQUITY

Considering equity in adaptation planning helps ensure the effects of coastal hazards and SLR do not have a disproportionate impact on marginalized communities or individuals. The evaluation criteria described below help incorporate society and equity into adaptation planning for the Corridor.

1. Support or protect multimodal transportation options?

Supporting and protecting multimodal transportation helps ensure equity. It preserves access for vulnerable populations, including those who may not have access to private vehicles. It also advances transportation justice by reducing dependence on private cars and protecting affordable transportation infrastructure. Additionally, multimodal systems promote public health and safety by encouraging active travel and reducing traffic-related risks. **Strategies that facilitate access to all or multiple modes of transportation meet this criterion, while strategies that focus on a sole mode of transportation do not.**

2. Access to housing, services, jobs?

Providing access to housing, services, and jobs is a crucial component for addressing society and equity in transportation planning. Transportation connects people to jobs, education, healthcare, and essential services. Adaptation options that align transportation planning with housing, services, and employment help ensure disadvantaged and marginalized communities are integrated into the economy and more people can access resilient transportation networks. Adaptation options that consider affordable or existing housing help reduce displacement and allow long-term residents to benefit from improved access and resilience. Preserving or establishing connectivity between underserved communities and economic hubs improves upward mobility and reduces inequities. **Strategies that support or provide access to housing, services, and jobs meet this criterion, while strategies that harm or eliminate access do not.**

II. ECONOMIC

Following the SANDAG Prioritization Tool, the economic criteria described below were selected for their simplicity and ability to capture a range of economic considerations without requiring a detailed, quantitative analysis.

3. Maintain essential infrastructure or community assets?

Disruptions to essential infrastructure and key community assets can have major economic consequences, as these systems often require substantial investment to repair or replace. This includes essential services like electrical systems, water and wastewater systems, major roadways, parks, schools, and other essential facilities. **Strategies that protect essential infrastructure or community assets meet this criterion, while strategies that harm essential infrastructure or community assets do not.**

4. Improve the economy?

This criterion considers how an adaptation strategy may impact the economy on both the community and regional scale. For example, implementing a living shoreline that supports saltwater habitats and protects public access can boost tourism, leading to increased employment and higher revenue from sales and hotel taxes, business licenses, and more. Strategies that stimulate technological innovation might further support job creation and economic growth. **Strategies that create new jobs or expand the local tax base meet this criterion, while strategies that eliminate existing jobs or harm the local tax base do not.**

5. Support regional transportation?

This criterion evaluates how well a proposed adaptation option maintains the functionality, connectivity, and efficiency of the regional transportation network in the face of climate change impacts. Regional transportation includes not only major highways but also the integration with arterial roads, public transit routes, freight Corridors, and emergency evacuation routes that serve the community. **Adaptation options that support regional**

transportation by contributing to a resilient, well-connected, and reliable network meet this criterion, while strategies that weaken regional transportation do not.

III. ENVIRONMENT

The criteria described below are designed to evaluate adaptation strategies from an environmental perspective, recognizing that alongside society and the economy, the environment is one of the three core pillars of sustainability. A healthy environment is fundamental to the success of climate resilience efforts, as well as to our health, economy, and security. Adaptation strategies that harm the environment can lead to unintended consequences, including reduced resilience, creation of new risks, or greater long-term costs for recovery, restoration, or mitigation. In contrast, adaptation strategies with strong environmental performance help ensure climate resilience efforts are effective and sustainable.

6. Utilize nature-based approach?

Nature-based solutions use natural ecological systems or processes to reduce vulnerability to climate change and other coastal hazards while providing benefits to coastal resources. Traditional shoreline protective devices (e.g., seawalls, revetments, bulkheads) can interfere with natural processes, such as sediment transport, and negatively affect coastal habitats and access. Since nature-based solutions work with natural systems, they are less likely to have unintended negative consequences. As such, nature-based adaptations are often prioritized because they offer a multifunctional, sustainable, cost-effective approach to managing climate risks. **Adaptation strategies that utilize a nature-based approach and provide ecosystem benefits meet this criterion, while strategies that use primarily hard or gray approaches or do not incorporate a nature-based approach do not.**

7. Self-mitigating?

In the context of Caltrans projects, mitigation is the process by which measures are applied to avoid, minimize, or compensate for the adverse effects and environmental impacts caused by a project. Mitigation is mandated under CEQA guidelines whenever a project may result in a significant impact to the environment. CEQA mitigation is a critical part of the project development and environmental review process. This criterion evaluates whether an adaptation option reduces or eliminates its environmental impacts and therefore reduces or eliminates the need for offsite mitigation. **Strategies that are self-mitigating, where the project's environmental impacts are reduced or eliminated through its design meet this criterion, while strategies that are not self-mitigating do not.**

8. Environmental performance?

This criterion evaluates how well an adaptation option supports or enhances environmental quality, including impacts to air and water quality, ecosystems, biodiversity, and natural resource use. The criterion considers whether an option avoids or minimizes harm to the environment and, ideally, delivers environmental co-benefits such as habitat restoration, improved water management, or reduced pollution. **Strategies with no permanent negative impacts (temporary negative impacts are less than a year) or all final environmental impacts are beneficial meet this criterion, while strategies that result in numerous or extensive environmental impacts do not.**

9. Coastal Squeeze?

Coastal squeeze occurs when coastal habitats, such as salt marshes and tidal flats, are trapped between rising sea levels and fixed structures (e.g., seawalls, roads, buildings), leaving the habitat no room to migrate inland. This can lead to loss of coastal habitat, reduced biodiversity, and a decline in important ecosystem services such as storm protection, water filtration, and carbon storage. This criterion evaluates the extent to which a proposed adaptation option may contribute to or help mitigate coastal squeeze. **Adaptation options that avoid coastal squeeze by allowing ecosystems to shift naturally meet this criterion, while adaptation options that block migration of coastal habitat do not.**

IV. FEASIBILITY

The feasibility of a strategy is often a key concern. Some approaches may be straightforward, while others can present substantial challenges or obstacles. The criteria described below incorporate various aspects to consider in evaluation of a strategy's feasibility.

10. Consistent with existing plans, policies, programs?

The feasibility of certain strategies may be constrained by local plans or state and federal laws. This criterion helps evaluate how adaptation options fit within the limits of local plans and state and federal regulations. **Strategies that are consistent with existing plans, policies, and programs meet this criterion, while strategies that are inconsistent with existing plans, policies, and programs do not.**

11. Cost?

This criterion evaluates the financial resources required to construct an adaptation measure. **Low-cost strategies meet this criterion while strategies with high costs do not.**

V. ROBUSTNESS

12. Provide resilience to multiple hazards?

This criterion evaluates whether an adaptation option can reduce risks from more than one type of hazard, such as SLR, riverine flooding, or wave energy. Adaptation measures that address multiple threats simultaneously are often more cost-effective and robust. This criterion favors solutions that enhance overall system resilience by providing broad protection against a range of current and future climate risks. **Strategies that provide resilience to more than two hazards meet this criterion, whereas strategies that focus on a single hazard do not.**

13. Flexible/adaptable?

This criterion evaluates whether an adaptation option can be modified or relocated in response to changing conditions. Given the uncertainty of climate projections and future impacts, flexible solutions allow for adaptive management, making it easier to respond to new information or risks. This criterion favors options that can evolve with future circumstances. **Strategies that can be easily adapted to changing conditions meet this criterion, while strategies that cannot be easily adapted do not.**

14. Susceptible to seismic hazards?

In regions with seismic activity, it is important to assess whether an adaptation measure is resilient to ground shaking, liquefaction, or surface rupture. This criterion helps ensure that adaptation investments are not only climate-resilient but also have low susceptibility to seismic hazards. **Strategies with low susceptibility to seismic hazards meet this criterion, while strategies with high susceptibility to seismic hazards do not.**

Table 21. Summary of considerations used to evaluate the performance of adaptation options according to criteria. Colors correspond to categories in the Multicriteria Evaluation Tool Spreadsheets (Appendix F).

SOCIETY & EQUITY			
PRIORITIZATION CRITERIA	***Agree (3)***	***Neutral (2)***	***Disagree (1)***
1. Support or protect multimodal transportation options?	Supports or protects multimodal transportation options	Neither supports nor harms multimodal transportation options	Has a negative impact on multimodal transportation options
2. Access to housing, services, jobs?	Supports or protects access to housing, services, and jobs	Neither supports nor harms access to housing, services, and jobs	Has a negative impact on access to housing, services, and jobs

ECONOMIC			
PRIORITIZATION CRITERIA	***Agree (3)***	***Neutral (2)***	***Disagree (1)***
3. Maintain essential infrastructure or community assets?	Protects essential infrastructure or community assets	No impact on essential infrastructure and/or community assets	Harms essential infrastructure or community assets
4. Improve the economy?	Creates new jobs or expands the local tax base	No impact on jobs or local tax base	Eliminates existing jobs or harms local tax base
5. Support regional transportation?	Improves functionality, connectivity, and efficiency of the regional transportation network.	No impact functionality, connectivity, and efficiency of the regional transportation network.	Reduces functionality, connectivity, and efficiency of the regional transportation network.

ENVIRONMENT			
PRIORITIZATION CRITERIA	***Agree (3)***	***Neutral (2)***	***Disagree (1)***
6. Utilize nature-based approach?	Utilizes a nature-based approach and provides ecosystem benefits	Utilizes a mix of nature-based and gray approaches	Utilizes primarily hard or gray approaches or does not incorporate nature-based approach
7. Self-mitigating?	Strategy is self-mitigating -- the measure's environmental impacts are reduced or eliminated through its design, reducing or eliminating the project's need for additional offsite mitigation	Strategy is partially self-mitigating, but significant amount of additional offsite mitigation is required. More than 50% of the mitigation types are not self-mitigating and must be addressed with offsite mitigation and higher than 1:1 ratios	Strategy is not self-mitigating
8. Environmental performance?	No permanent negative environmental impacts or all final environmental impacts are beneficial (e.g., restores wetlands). Negative temporary impacts are less than a year	Minimal negative environmental impacts or considerations	Numerous or extensive environmental impacts or considerations to be offset with a significant offsite mitigation plan
9. Coastal squeeze?	Avoids coastal squeeze (e.g., allows inland migration of tidal marsh or other coastal habitat)	Neutral effect or minimal contribution to coastal squeeze	Contributes substantially to coastal squeeze (e.g., blocks inland migration of tidal marsh or other coastal habitat)

FEASIBILITY			
PRIORITIZATION CRITERIA	***Agree (3)***	***Neutral (2)***	***Disagree (1)***
10. Consistent with existing plans, policies, programs?	Consistent with existing plans, policies, programs	Not addressed by existing plans, policies, programs	Inconsistent with existing plans, policies, programs
11. Efficient use of funds?	Efficient use of funds. Low-cost relative to high or widespread benefits; efficient use of resources with strong return on investment	Moderately efficient use of funds. Reasonable cost-benefit ratio; benefits are noticeable but require moderate investment.	Not cost effective. High-cost relative to benefits; limited return on investment; may strain resources (e.g., maintenance costs)

ROBUSTNESS			
PRIORITIZATION CRITERIA	***Agree (3)***	***Neutral (2)***	***Disagree (1)***
12. Provide resilience to multiple hazards?	Provides resilience to more than two hazards	Provides resilience to two hazards	Provides resilience to one hazard
13. Flexible and/or removable?	Can be easily adapted to changing conditions	Ability to adapt unknown or if adaptation known, process is complex or expensive	Cannot be adapted to changing conditions
14. Susceptible to seismic hazards?	Low susceptibility, tends to remain functional after major earthquakes when designed according to current codes	Moderate susceptibility, little to no seismic-induced damage to structure or susceptibility unknown	High susceptibility, frequent damage in seismic zones

7.6.2 Evaluation of Adaptation Options

The performance of adaptation options for each segment of the Corridor was evaluated by using a rating scale from 1 to 3. A score of 1 indicates the strategy does not meet the criteria, 2 indicates that it has a neutral effect on the criteria, and 3 indicates the strategy does meet the criteria (see the summary of considerations for rating in Table 21 If a criterion was not applicable to a strategy, a neutral score of 2 was assigned, as there was no 0 or N/A score available. Based on feedback from the TAC and internal review, the "Cost" criterion was weighted more heavily (15%) than other criteria (6.54%). This weighting reflects the importance of cost in the Caltrans project delivery process and the emphasis on developing feasible, fundable projects. Once the adaptation strategies were rated across all criteria, a total score was calculated. After evaluating the adaptation strategies across all criteria, a total score was calculated. A summary of adaptation option performance and the corresponding total scores are presented in Table 22, with complete evaluation tables for each segment available in Appendix F.

Adaptation options incorporating nature-based features, such as a living shoreline or hydraulic connection to the bay, achieved the highest scores. In contrast, the simple 'raised embankment' strategy scored poorly across most segments, with a total score below 2 reflecting its poor environmental performance. Adding a living shoreline or hydraulic connection to the bay improved embankment performance across all segments (total score above 2). Raised embankments with hydraulic connections to the bay and living shoreline, as well as viaducts with a living shoreline, received the highest scores when available for a given segment. The higher scores reflect the strong environmental performance of nature-based solutions, enhanced seismic resilience for viaduct options, and the relatively low cost of raised embankments. While viaducts with a living shoreline achieved the highest score in most segments, it is important to note that viaducts are substantially more expensive than raised embankments—a factor that may influence future adaptation projects, particularly in a fiscally constrained setting (see Section 7.7 for a detailed cost comparison).

Table 22. Summary of adaptation option performance (total score) by Corridor segment (1 through 13). The top score for each segment is marked in bold and filled with gold. Gray columns indicate no treatment was needed for that segment. Asterisk indicates the "Upsized Culvert" option only applies to Segment 11.

	Segment												
Adaptation Option	1	2	3	4	5	6	7	8	9	10	11	12	13
Raised Embankment	1.89	1.89	1.89	1.89		1.89		1.89	1.82	1.82	1.82	**2.02**	
Raised Embankment with Living Shoreline (LS)	**2.39**	2.39		2.39		2.39		**2.39**	2.33	2.33	2.33		
Raised Embankment with Connection to Bay or *Upsized Culvert		2.13	**2.13**	2.13		2.13		2.13	2.13	2.13	2.13		
Raised Embankment with LS and Connection to Bay or *Upsized Culvert		2.39		2.39		2.39		**2.39**	2.39	2.39	2.39		
Viaduct		2.24		2.24		2.24			2.24	2.24	2.24		
Viaduct with Living Shoreline		**2.44**		**2.44**		**2.44**			**2.44**	**2.44**	**2.44**		

7.7 Cost Comparison of Viaducts vs Embankments

While the exact cost of constructing viaducts and embankments at a future point in time is uncertain, various resources were used to generate a preliminary cost comparison to support the decision-making process. Some cost considerations such as long-term maintenance, mitigation for hazards and the environment, right of way acquisition, and permitting, were not factored into this estimate but some are considered (qualitatively) in the multicriteria evaluation above.

Profile

s for raised embankments (which include column-supports) were obtained with the Geo-Institute's Conceptual Cost estimating tool for CSEs (Geo-Institute, 2025). The road width used in estimates was 78 ft wide for the separate facility and 80 ft wide for the single facility. Earthwork costs were not factored into the embankment cost estimates. The total estimate includes an additional 40% for contingencies. Cost estimates are lower than bid results from the Indianola Undercrossing Project (approximately $10,000/ft). This discrepancy is explained by the wider footprint of the roadway at Indianola to accommodate the road raise to 30 ft NAVD88, incorporate on/off ramps, and the inclusion of lightweight fill in the cost estimates.

Cost estimates for viaducts are based on the "Comparative Bridge Costs" document from Caltrans Division of Engineering Services – Structure Design (2024). Following recommendations from Caltrans Structures Engineers, cost estimates for the CIP PS (cast in place/prestressed) box girder were used, which is the most common type of bridge used in California. The cost of the CIP PS box girder ranges from $200 – 550/ft^2. Additional factors specific to project location, such as constructability challenges in soft bay mud and additional costs related to pier height/pile length, are likely to result in values at the higher end of the cost range. Therefore, $550/ft^2 was used to generate cost estimates for each segment of the Corridor. An additional 40% contingency was applied (following recommendations from Caltrans Division of Engineering Services).

The single facility viaduct width was approximated to be 80-94 ft, depending on whether a bike/pedestrian lane was included. The separate facility viaduct was approximated to be 39-53 ft wide, depending on whether a bike/pedestrian lane was included. This would amount to 78-92 ft total width. In District 4, Caltrans estimated a cost of $295 to $534 million per mile for a 21-mile-long single facility viaduct along SR 37, with the higher cost reflecting components like environmental mitigation and removal of the existing roadway (Caltrans, 2022). Our estimates for a single facility range from $325 million (no bike/ped lane) to $382 million (with bike/ped lane) per mile. Our estimates for separate facilities are approximately $317 million (no bike/ped lane) to $374 million (with bike/ped lane) per mile (combined northbound and southbound costs). These cost estimates include a 40%

contingency in addition to broad materials cost estimates and do not include mitigation, property acquisition, staging costs, or removal of the existing roadway.

Mitigation cost savings for a viaduct when compared to an embankment are too difficult to equate this early in the planning process and will be completed in future phases of the Caltrans project delivery process.

Cost estimates will be refined and updated in the Project Initiation Document phase of future projects. Overall, the viaduct structures were estimated to be about six times as much as raised embankments, though this estimate excludes mitigation, permitting, maintenance costs, and right of way acquisition (Table 23).

Table 23. Broad cost estimates for raised embankments and viaducts by segment, shown in millions of dollars ($M; based on the year 2024).

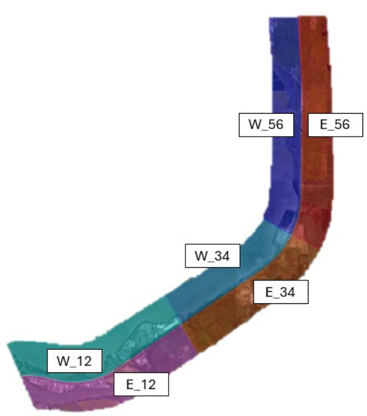
Segment Number	Segment Description	Length (ft)	Embankment		Viaduct			
			Single Facility	Separate Facility	Single Facility *no bike/ped*	Single Facility *with bike/ped*	Separate Facility *no bike/ped*	Separate Facility *with bike/ped*
1	Eureka Slough Bridges to Airport Rd.	4,628	$31M	$30M	---	---	---	---
2	Airport Rd. to N. Fay Slough	2,330	$16M	$15M	$144M	$169M	$140M	$165M
3	N. Fay Slough to N. Brainard	3,119	$21M	$20M	---	---	---	---
4	N. Brainard to S. Indianola	3,037	$20M	$20M	$187M	$220M	$182M	$215M
6	N. Indianola to S. Bracut	2,015	$15M	$14M	$124M	$146M	$121M	$143M
8	N. Bracut to Bayside Cutoff	2,445	$16M	$16M	---	---	---	---
9	Bayside Cutoff to Jacoby Creek	2,470	$17M	$16M	$152M	$179M	$148M	$175M
10	Jacoby Creek to South G St.	2,650	$18M	$17M	$163M	$192M	$159M	$188M
11	South G St. to SR 255/101	4,636	$31M	$30M	$286M	$336M	$278M	$328M
12	SR 255/101 to 7th St	1,100	$7M	$7M	---	---	---	---

8 Conceptual Implementation Plan

In response to CDP 1-18-1078, Special Condition 2(A)(3), the CAIP includes a timeline for adaptation implementation. The CAIP is designed to remain flexible and responsive to evolving SLR scenarios and environmental conditions. It uses a phased adaptation approach in which measures are implemented sequentially or triggered by defined environmental thresholds.

The 0M270 Eureka/Arcata 101 SLR Resilience Project, which plans to raise the roadway to 12 feet NAVD88, is expected to provide protection for most of the Corridor to *at least* 2050, and modeling indicates resilience to severe flood conditions (> 4" flood depth) may extend to approximately 2060 or later, depending on the location (Table 24). Segments 11 & 12, which have vulnerable spots outside the limits of the 0M270 Eureka/Arcata 101 SLR Resilience Project, would likely be raised to 12 ft to provide resilience to 2050. If sea levels rise faster than anticipated, interim measures—such as raising the Bay Trail—could be implemented to enhance short-term resilience for both the trail and the highway.

Table 24. Timing of vulnerability for zones in the CAIP Vulnerability Assessment (VA) and corresponding CAIP segments. Vulnerability Year indicates decade at which severe flood conditions (> 4" of water depth) occur more than 0.01 days/year (1% chance of occurring at least once a year). Note that resilience of east zones/segments may be extended by some protection provided by 0M270 (indicated by plus sign next to vulnerability year).

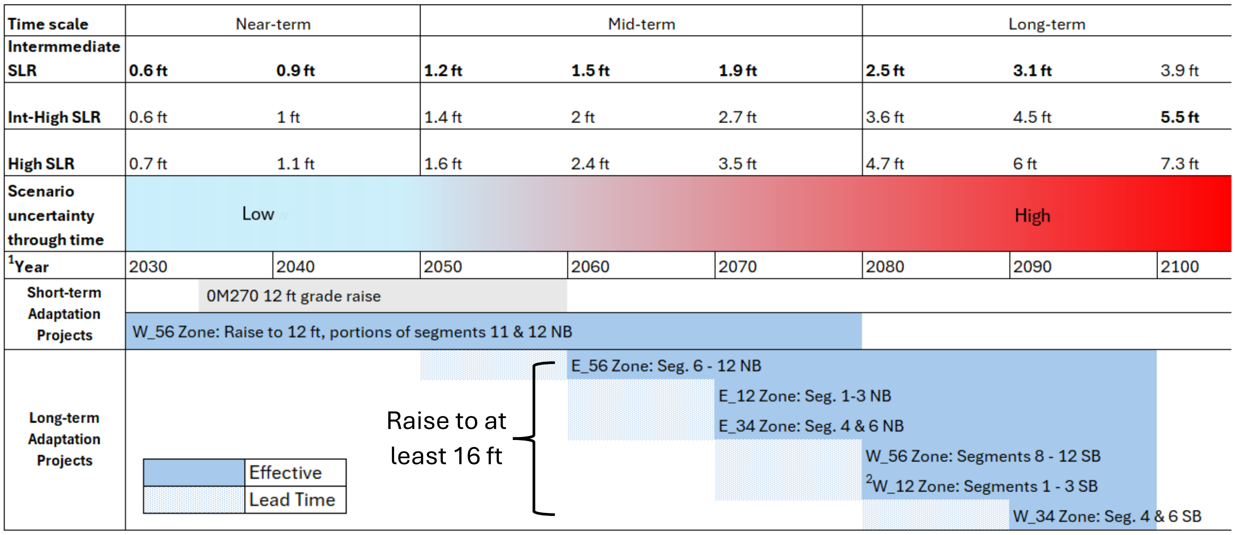
<table>
<tr><th colspan="2">Vulnerability Assessment Zone</th><th>Vulnerability Year</th><th>Vulnerability Year, After 0M270 Project</th><th>CAIP Segments Within VA Zone</th></tr>
<tr><td rowspan="6">
</td><td>W_56</td><td>Present</td><td>Segment 8 – 10: 2080
Segments 11 & 12: Present</td><td>8 - 12</td></tr>
<tr><td>W_34</td><td>2030</td><td>2090</td><td>4 - 6</td></tr>
<tr><td>W_12</td><td>2030</td><td>2080</td><td>1 - 3</td></tr>
<tr><td>E_56</td><td>2060</td><td>2060+</td><td>8 - 12</td></tr>
<tr><td>E_34</td><td>2070</td><td>2070+</td><td>4 - 6</td></tr>
<tr><td>E_12</td><td>2070</td><td>2070+</td><td>1 - 3</td></tr>
</table>

Living shorelines may also serve as short- to mid-term adaptation strategies, potentially funded through mitigation associated with other projects. These features could provide added protection between completion of the 0M270 project and implementation of longer-term solutions, such as viaducts or raised embankments. As sea levels continue to rise and the effectiveness of living shorelines and protection from the Bay Trail diminishes, the strategy would transition to these more permanent structural adaptations.

The conceptual phased implementation plan (Figure 66) is informed by vulnerabilities identified in CAIP technical studies, planned transportation projects along the Corridor, and the 2024 OPC SLR Scenarios. Under the intermediate SLR scenario, the need for additional highway adaptations beyond 0M270 is not anticipated until around 2060 (see Section 6.1.5 Vulnerability Assessment). However, if monitoring indicates accelerated SLR, interim adaptations would be advanced accordingly. For example, incremental raising of the Bay Trail could provide temporary resilience until environmental triggers are reached, at which point construction of longer-term measures could be implemented.

Feedback from the TAC supports interim adaptations such as 0M270 until a longer-term project is initiated. Primary concerns from the TAC included 1) economic concerns and logistics need to be at the forefront of project planning i.e., what can realistically be afforded? 2) environmental performance also needs to be a top priority 3) any future adaptation plan needs to be done in concert with existing and planned future land use on appropriate and economically sound timelines. The TAC supports the flexible approach and the option to modify flood threshold levels in future analyses, including at other highway locations.

The CAIP is intended to function as a living document. It will be updated to reflect the best available science, observed conditions, and funding considerations. Following completion of the 0M270 project, Caltrans will monitor as-built conditions and updated SLR scenarios to confirm the anticipated SLR pathway and refine the timing of future adaptation projects. If additional short- or mid-term measures further enhance Corridor resilience, the implementation timeline for long-term CAIP projects may shift accordingly. Ultimately, the timing of adaptation actions will be guided by ongoing monitoring, updated projections, environmental triggers, and available funding.



[1] Note anticipated start year of CAIP projects depends on best available science, updated SLR projections, and funding.

[2] If the half signal at Jacobs avenue remains at the time of project initiation, it is likely that Segment 1 southbound (SB) and northbound (NB) lanes would need to be adapted simultaneously as not to create substantial elevation difference between joined lanes.

Figure 66. Conceptual adaptation implementation plan for the Corridor following the phased adaptation approach. Adaptation and resilience projects span short- to long-term time scales. Current OPC (2024) SLR projections are shown for the Intermediate, Intermediate-High, and High scenarios for the North Spit tide gauge for 2030 to 2100. A qualitative indicator of projection uncertainty (blue to red gradient) is shown for 2030 through 2100; scenario uncertainty increases (becomes redder) with time, relative to the present. In this conceptual plan, the timeline for implementation of an adaptation project is based on zone and segment vulnerability and the intermediate (up to 2100) and intermediate-high (2100) SLR scenarios (indicated with SLR values). The project implementation year shown is based on current SLR projections and will need to be re-evaluated with future OPC SLR updates. The time frame for the interim Eureka/Arcata 101 SLR Resilience Project (0M270) is also shown. Implementation of certain adaptations (e.g., raising the Bay Trail, not shown) could impact the timeline for highway adaptations. The 16 ft elevation is based on analyses indicating 15.9 ft NAVD88 provides resilience to 2100 under the intermediate-high SLR scenario with 100-year flood events. Projects with planning horizons beyond 2100 should revisit design elevations at the time of planning.