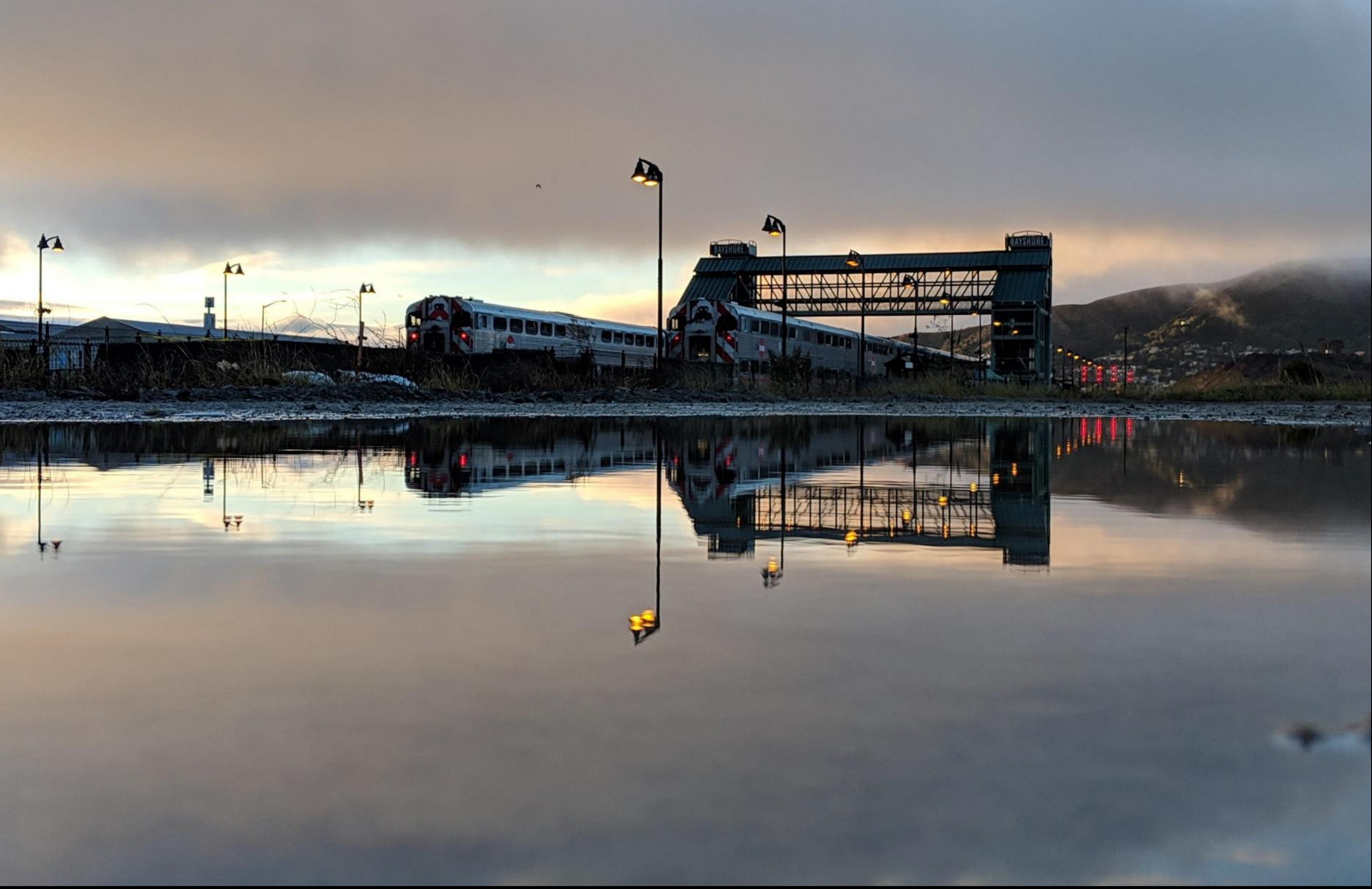

Peninsula Corridor Electrification Project (PCEP)
Sea Level Rise Adaptation Plan FY24

March 2024

ICF

Contents

1 Introduction

Caltrain is undergoing electrification of its mainline along the San Francisco Peninsula from San Francisco to San Jose. Caltrain is operated by the Peninsula Corridor Joint Powers Board (PCJPB). The primary purpose of electrification is to improve system performance and curtail long-term environmental impacts including lowering greenhouse gas (GHG) emissions to mitigate climate change. Electrification improvements include overhead pantograph wires along the entire route and parallel stations, traction power substations, a switching station, and other associated facilities. The PCJPB adopted the Peninsula Corridor Electrification Project (PCEP) Environmental Impact Report (EIR) and Mitigation Monitoring and Reporting Plan (MMRP) in January 2015.

In certain locations along the Caltrain corridor, the railbed and associated facilities are near the San Francisco Bay, and the inundation risk due to storm surge, and high tides are exacerbated by sea level rise associated with climate change. This *Sea Level Rise Adaptation Plan* is part of PCJPB's commitment outlined in Mitigation Measure HYD-7 of the MMPR for the PCEP to understand the PCEP infrastructure's vulnerability to inundation from these drivers and develop adaptations to improve resilience to climate change in the future.

2 Caltrain Inundation Vulnerability Profile

This report considers Caltrain's vulnerabilities to inundation across its rail corridor running down the San Francisco Peninsula to San Jose. Along this main line, there are sections of this track running directly adjacent, or near, the San Francisco Bay and are at risk of inundation. This report analyzes the track right of way (ROW), stations, and key assets identified by Caltrain. To assess Caltrain's vulnerabilities to inundation from sea level rise, storm surge, and tides, ICF utilized the Adapting to Rising Tides (ART) Program inundation scenarios developed from the Bay Area Conservation and Development Commission (BCDC) guidance and takes a "One Map, Many Futures" approach which reflects that inundation can consist of several components: sea level rise, storm surge, and tides. BCDC is a state agency that has permitting authority within San Francisco Bay and adjacent shorelines and works to increase the resilience of San Francisco Bay Area communities to sea level rise and storms with information about vulnerability and programs to promote adaptation. The ART Program, run by BCDC, works with local, state, regional and federal agencies to gather, develop and analyze the data needed to understand the impacts of climate change on Bay Area communities including physical infrastructure, land surface, and inundation scenarios. As part of the ART Project, ICF used the Bay Area Shoreline Flood Explorer, a web-based map, as a planning guide to understand current and future risk of flooding.

2.1 Vulnerability Assessment Methodology

ICF applied the ART Bay Area Shoreline Flood Explorer[1] throughout this analysis to analyze Caltrain stations, assets, and track right of way (ROW) under three levels of inundation, 24'', 66'', and 108'' to understand future inundation vulnerability. More information on the methodology and projections are included in this chapter.

The ART Bay Area Shoreline Flood Explorer accounts for three types of flooding to determine a Total Water Level (TWL) above mean higher high water (MHHW): sea level rise, storm surge, and tidal

[1] BCDC. Adapting to Rising Tides: Bay Shoreline Flood Explorer. https://explorer.adaptingtorisingtides.org/learn.

influence. The dataset reflects that inundation can occur through a variety of different drivers. The same level of inundation could be a result of strong storm surge and high tides now *or* daily tides due to sea level rise alone on a blue-sky day in the future. Combinations of sea level rise, storm surge, and tidal influences can cause many different scenarios of inundation which may occur across time into the future. This approach allows the focus to be on incremental action, despite uncertainties in predicting storms and the rate of sea level rise. The three types of flooding can happen individually to cause flooding, or cumulatively, adding to the severity of flooding. Flood Explorer allows a single TWL to be assessed and reflects a variety of flooding combinations from sea level rise, storm surge, and high tides, as shown in Figure 1.

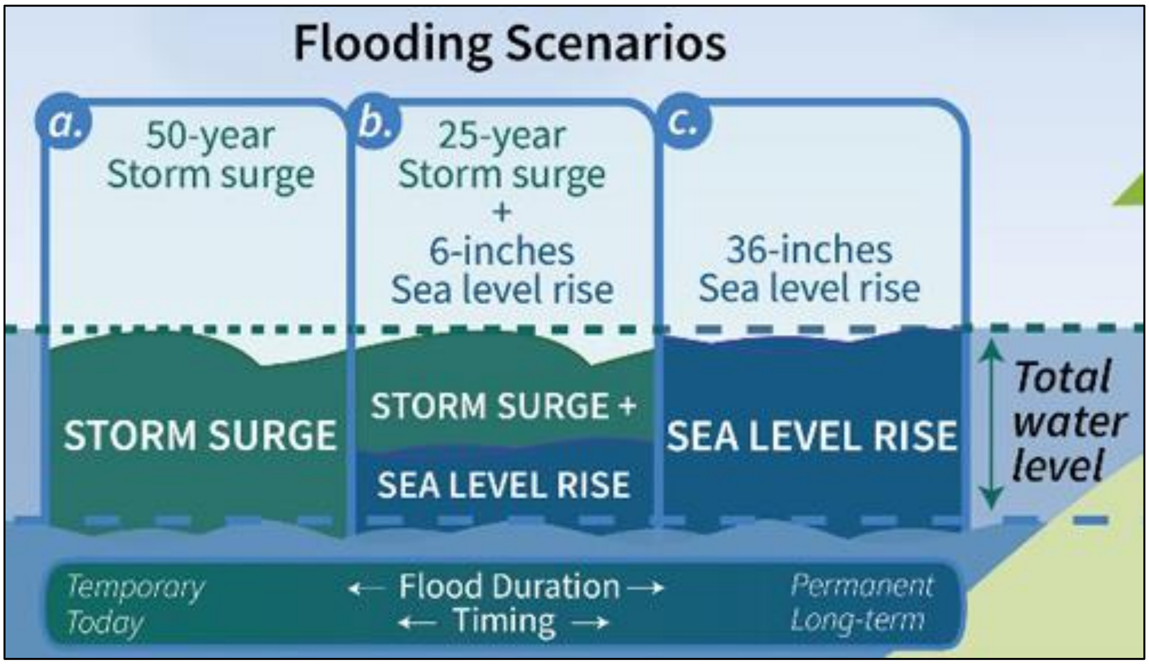

Figure 1. Different flooding scenarios resulting in the same total water level (TWL). Daily tidal cycles can exacerbate inundation scenarios during high tide periods.

In the Bay area region, sea level rise, storm surge, and high tides have the following characteristics:

Sea Level Rise

Sea level rise refers to the average increase in ocean water levels and causes permanent inundation. The latest studies from BCDC indicate that the Bay should be prepared for 6-10 inches by 2030 and 13-23 of sea level rise by 2050, though it's more difficult to predict amount of sea level rise closer to the end of the century (i.e., 2100). BCDC's ART map reflects a variety of possible sea level rise depths from 0 to 108 inches.

BCDC recommends considering the Flood Explorer maps in the context of the latest sea level rise projections for the San Francisco Bay Area from the California Ocean Protection Council's Sea Level Rise Guidance (OPC Guidance).[2,3] The OPC Guidance provides probabilistic projections for the

[2] California Ocean Protection Council. 2018. State of California Sea-Level Rise Guidance: 2018 Update. https://www.opc.ca.gov/webmaster/ftp/pdf/agenda_items/20180314/Item3_Exhibit-A_OPC_SLR_Guidance-rd3.pdf.

[3] BCDC. 2018. California State Sea Level Rise Guidance and the ART Maps. https://www.adaptingtorisingtides.org/wp-content/uploads/2014/12/ARTMapsAndOPCGuidance06.04.18.pdf.

height of sea level rise over various timescales for several GHG emissions scenarios. Sea level rise probabilistic projects are with respect to a baseline of the year 2000 (average relative sea level from 1991 to 2009).

Storm Surge

Storm surge is the buildup of water during a storm, generated by high winds and low atmospheric pressure. Storm surge events cause temporary increases in water levels but have the potential to cause major flooding during winter storms and become more severe as sea level increases. Calculations for these events are based on return period probabilities. For example, a 5-year storm surge has a 1 in 5 chance (20% annual chance) of occurring any given year. Larger storm surges, like a 50-year storm that has a 1 in 50 chance (2% annual chance of occurring), are less frequent but will produce greater and more severe flooding. The ART map reflects a variety of storm surge events.

High Tides

The Bay experiences two high tides and two low tides every day. The height of the highest daily tides, average over time, is called Mean Higher High Water (MHHW), also referred to as high tide. King Tides, which are exceptionally high tides, typically occur several times per year during a new or full moon and when the earth is closest to the moon. King Tides cause water levels to increase as much as 12-inches above normal high tide.

2.1.1 Inundation Levels of Interest

ICF used four scenarios to analyze total water levels (TWL), also referred to as inundation depths. The project team discussed these scenarios with Caltrain and agreed to project flood inundation approximately 50 years into the future. Components include sea level rise and storm surge to capture permanent and temporary inundation and over different emissions scenarios. Inundation scenarios are based on mean-higher-high-water mark (MHHW+) which accounts for maximum inundation resulting from tidal influence. By including these different components, the scenarios account for uncertainty in future GHG emissions.

1. **Scenario 1 - 24":** 2070 OPC Guidance (high GHG emissions) low risk aversion (likely range, i.e. high end of the 67% probability range). The calculated water level in this scenario is 22.8", and for mapping purposes, BCDC uses 24".
2. **Scenario 2 - 66":** 2070 OPC Guidance (high GHG emissions) extreme risk aversion scenario. The calculated water level in this scenario is 62.4", and for mapping purposes, BCDC uses 66".
3. **Scenario 3 - 66":** 2070 OPC Guidance + 100 year Flood low risk aversion. The calculated water level in this scenario is MHHW+66".
4. **Scenario 4 - 108":** 2070 OPC Guidance + 100 year Flood extreme risk aversion scenario. The calculated water level in this scenario is MHHW+108".

Scenario 2 and Scenario 3 are modeled with the same inundation depth, although the drivers that contribute to these inundation levels are different. Scenario 2 describes tide levels with sea level rise only on a blue-sky day and represents the extreme high end of sea level rise considering unabated and growing greenhouse gas emissions at 66". Scenario 3 evaluates a lower sea level rise scenario resulting from more moderate greenhouse gas emissions; however, this scenario also includes the storm surge resulting from a 100-year flood event on top of the sea level rise to produce 66" of inundation. Scenario 2 describes permanent inundation. Sea level rise will cause areas not currently exposed to the tide to be inundated, resulting in the need to protect or move people and infrastructure. In Scenario 3, the inundation is not considered permanent as higher water levels are only experienced during storm surge events, however, there are still potential consequences of inundation to built infrastructure in both scenarios.

Table 1 demonstrates the three inundation depths (24", 66", and 108") and the different scenarios that could result in each level of inundation. For example, a total water level of 24" could result from 0" of sea level rise plus a 5-year storm surge event. Similarly, 24" of water could also result from 6" of sea level rise plus a 2-year storm surge event. Table 2 includes the annual chance of the different storm surge events. For example, a 1-in-100-year storm surge event has a 1% annual chance of occurrence.

Table 1. Flooding Scenarios for 24", 66", and 108" of Inundation

Scenario 1: 24" of Inundation		Scenario 2,3: 66" of Inundation		Scenario 4: 108" of Inundation	
Sea Level Rise	Storm Surge	Sea Level Rise	Storm Surge	Sea Level Rise	Storm Surge
0"	5-year	24"	100-year	66"	100-year
6"	2-year	30"	50-year	72"	50-year
12"	King Tide	36"	25-year	77"	25-year
24"	No Storm Surge	42"	5-year	84"	5-year
		48"	2-year	90"	2-year
		52"	King Tide	96"	King Tide
		66"	No Storm Surge	108"	No Storm Surge

Table 2. Storm Surge Event Annual Probabilities

Storm Surge Event	Annual Chance
1-in-100-year	1%
1-in-50-year	2%
1-in-25-year	4%
1-in-5-year	20%
1-in-2-year	50%

2.1.2 Spatial Mapping Methodology

The 24", 66", and 108" scenarios were used to determine exposure to Caltrain's assets, stations, and track ROW. Geospatial data for each of the scenarios for San Francisco and San Mateo counties were downloaded directly from the Adaption to Rising Tides website on January 5th, 2024.[4,5] Santa Clara County was not analyzed since Caltrain's ROW is not at risk from inundation to sea level rise in this area. Using ArcGIS, shapefiles of Caltrain's assets of concern, stations, and ROW were iteratively intersected with the sea level rise inundation layers and overtopping layers for 24" above MHHW, 66" above MHHW, and 108" above MHHW to show the resultant overlap between infrastructure and exposure. Summarizes of Caltrain's vulnerabilities (includes Caltrain's stations, assets, and ROW) to inundation are mapped in Figure 2 and further detailed in Section 2.2.

2.2 Caltrain Vulnerabilities

Based on the methodology discussed above, ICF assessed vulnerabilities to 11 key assets, shown in Table 4, 14 stations along the track ROW (listed in Table 5), and the full track ROW (mile posts are listed in Table 6) under 24", 66", and 108" of inundation. Assets and locations that are projected to be inundated during 24" are also projected to be inundated a higher scenario. Similarly, areas which are projected to be inundated at 66" are also projected to be inundated at 108". Caltrain's vulnerabilities are summarized in Table 3 and mapped below in Figure 2, with more detailed results in Sections , Section 2.2.2, and Section 2.2.3.

Table 3. Summary of Caltrain's Vulnerabilities to Inundation

Inundation at 24" Scenario	Inundation at 66" Scenario	Inundation at 108" Scenario
Track ROW: 0.1 miles	**Key Asset:** Traction Power Substation 1 and Interconnect	**Key Asset:** Traction Power Substation 1 and Interconnect
	Key Asset: Parallel Station 3	**Station:** Millbrae
	Station: San Francisco (4th and King Street)	**Station:** Broadway
	Track ROW: 5.7 miles	**Station:** Hayward Park
		Station: Redwood City
		Track ROW: 12.4 miles

At certain locations along the right of way, Brisbane Lagoon, Oyster Point, and Islais Creek pose significant vulnerability to Caltrain. These three locations are highlighted below in Figure 2 in purple.

- Islais Creek is a small creek located in San Francisco. The Caltrain track runs immediately to the west from approximately mile post 2.1 to 2.8 and is projected to be inundated at 66" and 108".
- Brisbane Lagoon is located in Brisbane CA, and the Caltrain track runs immediately to the west of the lagoon. From mile post 6.2 to 7.5 the track is projected to be inundated at 108".

[4] BCDC. 2017. Adapting To Rising Tides Bay Area Sea Level Rise & Mapping Project. https://explorer.adaptingtorisingtides.org/download.
[5] BCDC. 2017. Adapting To Rising Tides Bay Area Sea Level Rise & Mapping Project. https://explorer.adaptingtorisingtides.org/download.

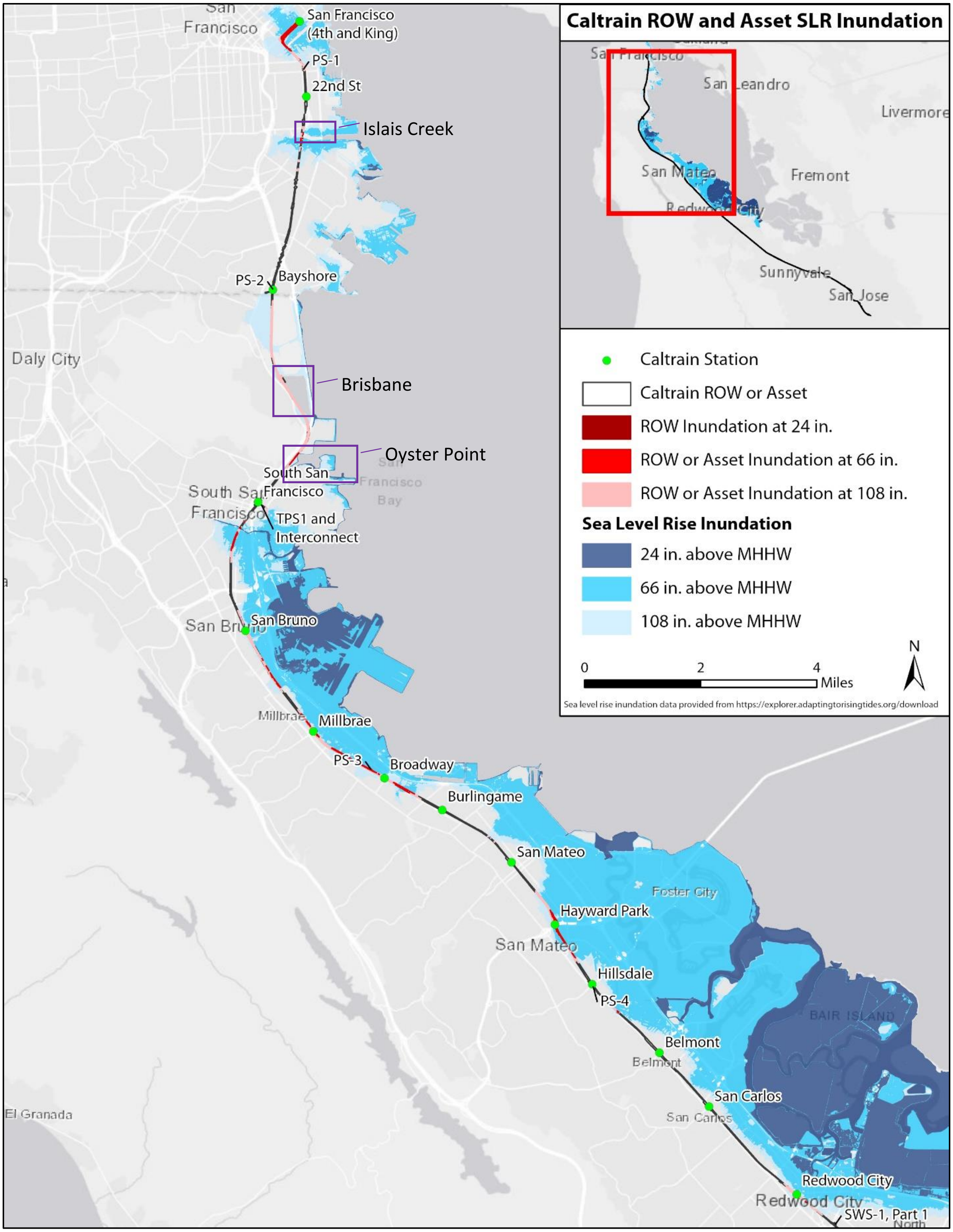

Figure 2. Caltrain's key locations and assets, stations, and ROW vulnerabilities to 24", 66", and 108" of inundation.

- Oyster Point is located in South San Francisco. The Caltrain track runs immediately to the north and west of Oyster Point and is projected to be inundated at 66" from mile post 7.9 to 8.3 and at 108" from mile post 7.5 to 8.5.

2.2.1 Key Asset Inundation Vulnerability

In 2018 under previous work, ICF identified the following assets listed in Table 4 to be reviewed for inundation. Table 4 indicates projected inundation for the selected Caltrain assets under four scenarios and three different inundation depths.

The two assets projected to be inundated are TPS1 and Interconnected (a traction power substation) at 108" and PS-3 (a parallel station) at 66" and 108". Inundation depths are inches above MHHW+ (mean higher high water mark).[6]

Table 4. Caltrain Assets and Sea Level Rise Scenario Inundations[7]

Asset	Type	Mile Post (miles from San Francisco)	Asset Ground Elevation (inches)[8]	Sea Level Rise Scenario			
				2070 OPC High Emissions		2070+100-yr Flood (ART Map Temporary)	
				24"	66"	66"	108"
PS-1	Parallel Station	1.1	275.6	No	No	No	No
PS-2	Parallel Station	5.0	263.8	No	No	No	No
TPS1 and Interconnect	**Traction Power Substation**	9.1	165.4	No	No	No	**Yes**
PS-3	**Parallel Station**	14.7	98.4	No	**Yes**	**Yes**	**Yes**
PS-4	Parallel Station	20.2	303.1	No	No	No	No
SWS-1, Part 1	Switching Station	26.1	240.2	No	No	No	No
SWS-1, Part 2	Switching Station	26.1	232.3	No	No	No	No

[6] BCDC. Adapting to Rising Tides: Bay Shoreline Flood Explorer. https://explorer.adaptingtorisingtides.org/learn.
[7] Note that Asset Elevation is based on elevation above USGS benchmarks while the Inundation Scenarios are based on elevations above MHHW+, which is above USGS benchmarked elevation in most areas.
[8] Asset elevations were gathered from USGS National Map Viewer elevation point query tool. The overall accuracy of the elevation service currently has a root mean square error (RMSE) of 0.53 meters (20.8 inches). These interpolated point elevations are not official and do not represent precisely measured ground surveyed values. https://www.usgs.gov/faqs/how-accurate-are-elevations-generated-elevation-point-query-service-national-map

Asset	Type	Mile Post (miles from San Francisco)	Asset Ground Elevation (inches)[8]	Sea Level Rise Scenario			
				2070 OPC High Emissions		2070+100-yr Flood (ART Map Temporary)	
				24″	66″	66″	108″
PS-5	Parallel Station	31.8	366.1	No	No	No	No
PS-6	Parallel Station	38.6	1051.2	No	No	No	No
TPS2 and Interconnect	Traction Power Substation	45.2	826.8	No	No	No	No
PS-7	Parallel Station	48.9	1480.3	No	No	No	No

2.2.2 Caltrain Stations Inundation Vulnerability

Caltrain's stations along the ROW were also assessed for inundation at 24″, 66″, and 108″. Table 5 below indicates which stations are projected to experience inundation under each modeled scenario.

The assessment indicates that five stations are projected to be inundated: San Francisco (4th and King Street) at 66″, and Millbrae, Broadway, Hayward Park, and Redwood City at 108″.

Table 5. Caltrain Station Sea Level Rise Inundations

Station Name	Ground Elevation (inches)	Sea Level Rise Scenario			
		2070 OPC Guidance High Emissions		2070+100-yr Flood (ART Map Temporary)	
		24″	66″	66″	108″
San Francisco (4th and King Street)	141.7	No	**Yes**	**Yes**	**Yes**
22nd Street	421.3	No	No	No	No
Bayshore	271.7	No	No	No	No
South San Francisco	189.0	No	No	No	No
San Bruno	224.4	No	No	No	No
Millbrae	169.3	No	No	No	**Yes**
Broadway	181.1	No	No	No	**Yes**
Burlingame	378.0	No	No	No	No
San Mateo	334.6	No	No	No	No
Hayward Park	153.5	No	No	No	**Yes**
Hillsdale	157.5	No	No	No	No

Station Name	Ground Elevation (inches)	Sea Level Rise Scenario			
		2070 OPC Guidance High Emissions		2070+100-yr Flood (ART Map Temporary)	
		24″	66″	66″	108″
Belmont	476.4	No	No	No	No
San Carlos	366.1	No	No	No	No
Redwood City	181.1	No	No	No	**Yes**

2.2.3 Right of Way Inundation Vulnerability

Caltrain's track ROW was assessed under 24″, 66″, and 108″ of inundation (Table 6). The start and end mile posts for each segment of track inundated were determined by assessing the cross sections of the ROW. Segments are included in the below if any point of the segment is projected to be inundated under each scenario; the entire segment is not necessarily inundated.

In the 24″ scenario, only one segment of track is projected to be inundated with a total length of 0.1 miles. In the 66″ scenario, 5.7 miles of track is projected to be inundated and in the 108″ scenario approximately 12.4 miles is projected to be inundated. Detailed maps of each of these segments are shown in Appendix A.

Table 6. Track ROW Inundated at 24″ scenario, 66″ scenario, and 108″ Scenarios

Inundated at 24″ Scenario		Inundated at 66″ Scenario		Inundated at 108″ Scenario	
Mile Post Start	Mile Post End	Mile Post Start	Mile Post End	Mile Post Start	Mile Post End
9.6	9.7	0.0	0.7	0.0	1.1
		2.2	2.4	2.1	2.5
		7.9	8.2	2.7	2.8
		9.4	9.5	5.1	8.5
		9.6	10.1	9.4	9.5
		12.0	12.6	9.6	10.2
		13.2	13.7	11.1	11.4
		14.0	14.9	11.5	12.7
		15.2	15.6	13.1	15.8
		18.7	19.7	18.3	19.8
		20.8	20.9	20.7	20.9
		25.4	25.5	25.0	25.8
Total	**0.1 miles**	**Total**	**5.7 miles**	**Total**	**12.4 miles**

2.2.4 Overtopping Vulnerability

Shoreline overtopping refers to the condition where the total water level associated with a particular flood scenario exceeds the elevation of the shoreline, allowing water to flow inland. Table 7 summarizes Caltrain's vulnerabilities to overtopping at 24'', 66'', and 108'' scenarios.

Key asset PS-3 is projected to experience overtopping at the 66'' scenario, and Hayward Park station is projected to experience overtopping at the 108'' scenario. The total track ROW miles are listed below in Table 7 and are listed in more detail by mile post in Table 8. Any area that has overtopping at 24'' also overtops at 66'' and 108'' flooding scenarios, similar if any area overtops at 66'', then it also overtops at 108''

Table 9 lists the total length, as well as by shoreline type, and the maximum depth of overtopping at each scenario (24", 66", and 108"). Figure 3 below maps Caltrain's vulnerabilities to overtopping, including assets, stations, and track ROW.

Table 7. Summary of Caltrain's Vulnerabilities to Overtopping

Overtopping at 24" Scenario	Overtopping at 66" Scenario	Overtopping at 108" Scenario
Track ROW: 0.2 miles	**Key Asset:** Parallel Station 3	**Station:** Hayward Park
	Track ROW: 0.8 miles	**Track ROW:** 2.3 miles

Table 8. Track ROW Overtopping at 24", 66", and 108" Scenarios

Overtopping at 24" Scenario		Overtopping at 66" Scenario		Overtopping at 108" Scenario	
Mile Post Start	Mile Post End	Mile Post Start	Mile Post End	Mile Post Start	Mile Post End
8.0	8.1	7.9	8.0	2.2	2.3
9.6	9.7	14.4	14.6	6.5	7.6
		14.7	14.8	9.5	9.6
		18.8	18.9	14.7	14.9
		19.1	19.4	18.5	18.8
				18.9	19.1
				19.4	19.7
Total	**0.2 miles**	**Total**	**0.8 miles**	**Total**	**2.3 miles**

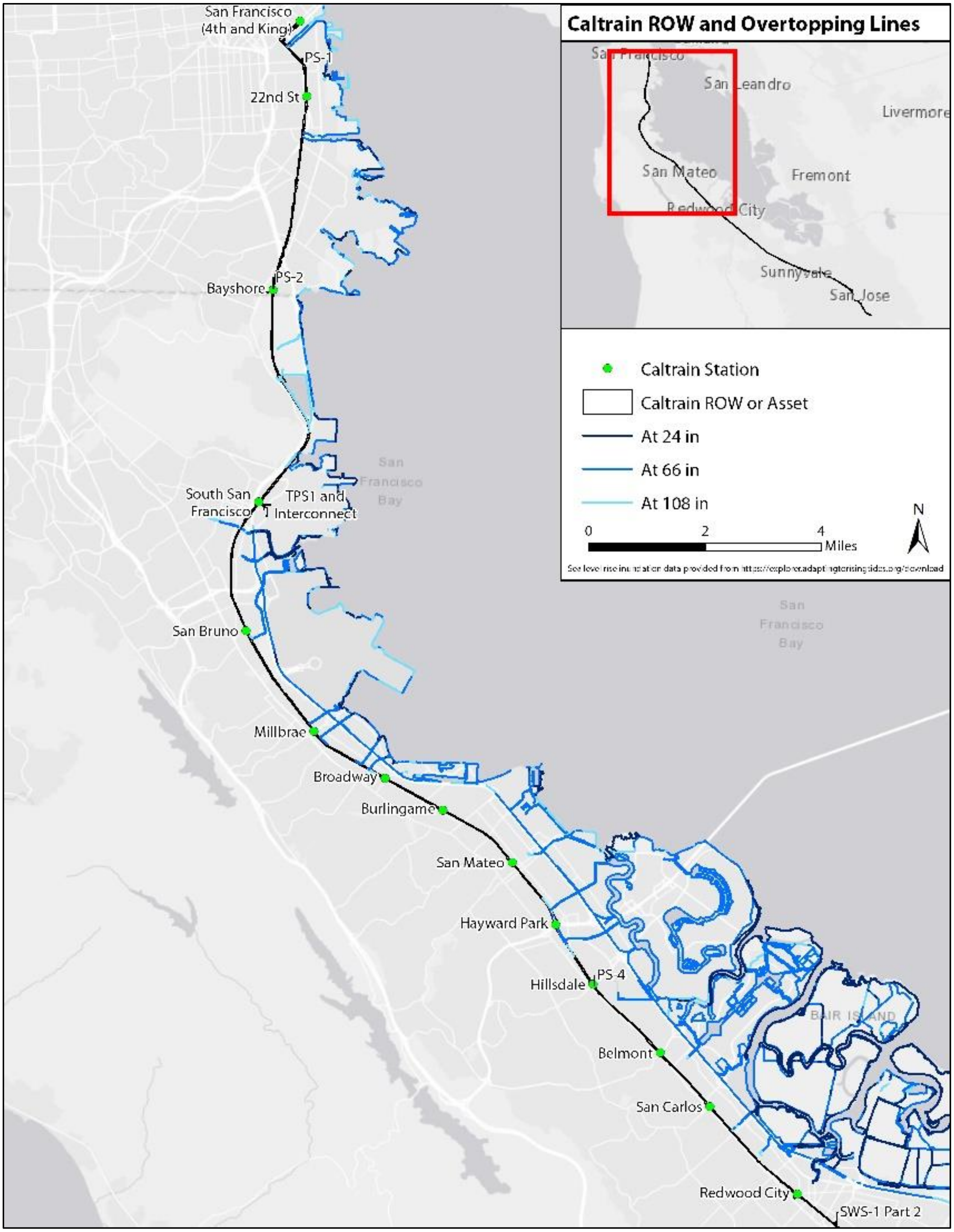

Figure 3. Caltrain's key assets, stations, ROW and overtopping lines at 24", 66", and 108" of inundation.

Table 9. Overtopping Length and Maximum Depth at 24", 66", and 108" Scenarios

	Overtopping at 24″ Scenario	Overtopping at 66″ Scenario	Overtopping at 108″ Scenario
Length of Linear Overtopping (feet)			
Shoreline Type: Berm	-	748	1,823
Shoreline Type: Channel or Opening	90	253	412
Shoreline Type: Embankment	70	830	1,576
Shoreline Type: Shoreline Protection Structure	-	103	103
Shoreline Type: Transportation Structure	-	1,350	11,805
Total Length (feet)	**160**	**3,284**	**15,719**
Height (Depth) of Overtopping (feet)			
Maximum Overtopping Depth (feet)	**7.8**	**11.3**	**14.8**

2.3 Key Takeaways

ICF projected vulnerabilities to sea level rise and overtopping at each scenario assessed, 24″, 66″, and 108″. Key locations of vulnerability include San Francisco, Islais Creek, Brisbane Lagoon, Oyster Point, west of San Francisco International Airport, and San Mateo (Hayward Park area). These locations especially, along with others, should be protected and invested in to reduce vulnerabilities to inundation.

3 Adaptation Action Plan

Caltrain can reduce vulnerability to inundation by developing adaptations for the future. Many inundation adaptation strategies already exist and are being implemented in California and beyond; Caltrain can look to these and assess what strategies are most relevant for their system.

To develop a potential plan for Caltrain to implement to reduce vulnerabilities to sea level rise, ICF completed a desktop review of relevant local/regional efforts, with a focus on existing adaptation projects near Caltrain assets. ICF proposed entities that Caltrain could potentially coordinate with to ensure Caltrain assets are protected from future sea level rise inundation. Additionally, ICF compiled potential adaptation strategies that Caltrain could implement in areas that are not yet addressed by local/regional efforts. These strategies were rated using criteria such as cost, effectiveness, and feasibility to determine which actions Caltrain should prioritize.

3.1 Local/Regional Efforts Relevant for Caltrain

There are local and regional efforts to adapt to sea level rise inundation around the Bay Area. These efforts are in development by different types of entities, and Caltrain should consider coordinating with other entities in the region carrying out sea level rise adaptation projects where collaboration can protect Caltrain's assets. Caltrain owns and operates a thin and narrow right of way, relative to other planning and development entities, and this geographic exposure is prime for a coordinated approaches. Sea level rise inundation threatens extensive areas of development and infrastructure in the Bay Area, and one entity's efforts to protect against inundation may also protect another entity's assets. Coordination can also allow more optimal and cost-effective solutions which are only possible through joint collaboration. Coordination with other entities ensures that Caltrain is making investments that are complementary to other adaptation efforts underway. It also allows Caltrain's perspective to be represented when these other entities are making decisions about investments.

Caltrain's assets do not exist in a vacuum, and ongoing adaptation initiatives along the Bay shoreline can help protect Caltrain's vulnerable assets, stations, and track ROW. For example, the Islais Creek Southeast Mobility Adaptation Strategy is exploring strategies to protect the Islais Creek Shoreline and surrounding district from inland and coastal flooding and sea level rise through 2080 that could also benefit Caltrain. In addition to this project, a detailed list of other ongoing adaptation initiatives relevant to Caltrain can be found below.

3.1.1 San Francisco Waterfront Flood Study

The U.S. Army Corps of Engineers (USACE) in collaboration with the City of San Francisco, conducted a Flood Study to analyze coastal flood risk and impacts of sea level rise for the 7.5 miles of Port of San Francisco's waterfront from Aquatic Park to Heron's Head Park. In January 2024, a Draft Integrated Feasibility Report and Environmental Impact Statement was released that outlined possible adaptation measures the City of San Francisco could take to build resiliency to coastal flooding. The Draft Plan is a critical milestone in San Francisco's continued, long-term efforts to defend the waterfront against flood risk and sea level rise, while also enhancing the seismic stability of the waterfront's flood management structures and complementing waterfront improvements.

The Draft divides the area into four reach locations, including Reach 1: Fisherman's Wharf, Reach 2: Embarcadero, Reach 3: South Beach/Mission Bay, and Reach 4: Isais Creek/Bayview. Reach 3 (South Beach/Mission Bay) and Reach 4 (Islais Creek/Bayview) are the most relevant for Caltrain due to the proximity of Caltrain's track ROW. Both Reach 3 and Reach 4 propose actions to defend against 1.5 feet of sea level rise by using a combination of berms/levees, seawalls, nature-based features such as creek enhancements, and closure structures for bridges to provide coastal flooding resiliency. The Draft Plan also proposes adding short floodwalls on piers in the area. Figure 4 maps each Reach and summarizes the proposed adaptation strategies.

The Draft Plan is open to public comment until the end of March 2024 and will help to further refine the plan, with construction estimated to occur from approximately 2026 to 2030.

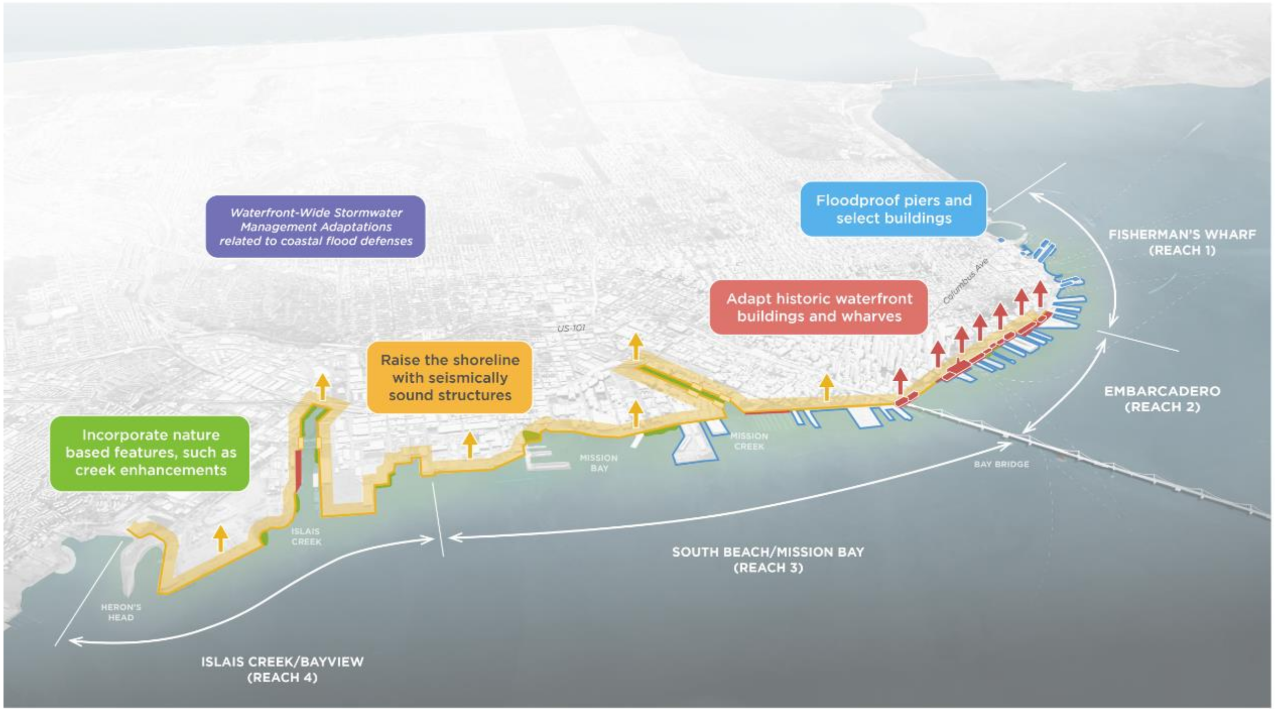

Figure 4. San Francisco Waterfront Flood Study Draft Plan Reaches. Source: [San Francisco Waterfront Flood Study]

3.1.2 San Francisco Railyards Project[9]

The Railyards Project builds off the 2018 Rail Alignment and Benefits Study (RAB), which explores how reconfiguring or relocating infrastructure at the SF Railyards could yield significant public benefits. The project team consists of Caltrain, Prologis (the railyards site owner and development lead), SF Planning, Office of Economic and Workforce Development, the Mayor's Office of Transportation, SF County Transportation Authority, CA High Speed Rail Authority, and Transbay Joint Powers Authority. The SF Railyards Project envisions the Caltrain railyards at 4th and King as a regional transit center with a new underground rail station, added Caltrain service, and new development. Redesigning the SF Railyards is an opportunity to increase the resilience of the station and neighborhood in preparation for sea level rise and could help protect the San Francisco 4th and King Street station nearby track ROW.

The project currently consists of two inter-related efforts that will identify potential new track layouts and development concepts for the SF Railyards site.

1. Caltrain/Prologis "Business Case"
    - By 2040, Caltrain envisions running trains every 7.5 minutes at rush hour and express service all day. Caltrain and Prologis are now evaluating track layout options for the Railyards site that can meet the operational needs of this vision, while also supporting feasible development at the Railyards.

[9] As of March 2024, the Preliminary Business Case Concept and Draft Zoning and Concept Development for the San Francisco Railyards Project is wrapping up and will be submitted for Environmental Review sometime in 2024.

2. SF Railyards

    - In partnership with public agencies, Prologis will propose a design and development concept for the SF Railyards and nearby rail tracks. The concept will include housing, office, commercial spaces; open space and community facilities; and connections between Soma, Mission Bay, and Mission Creek.

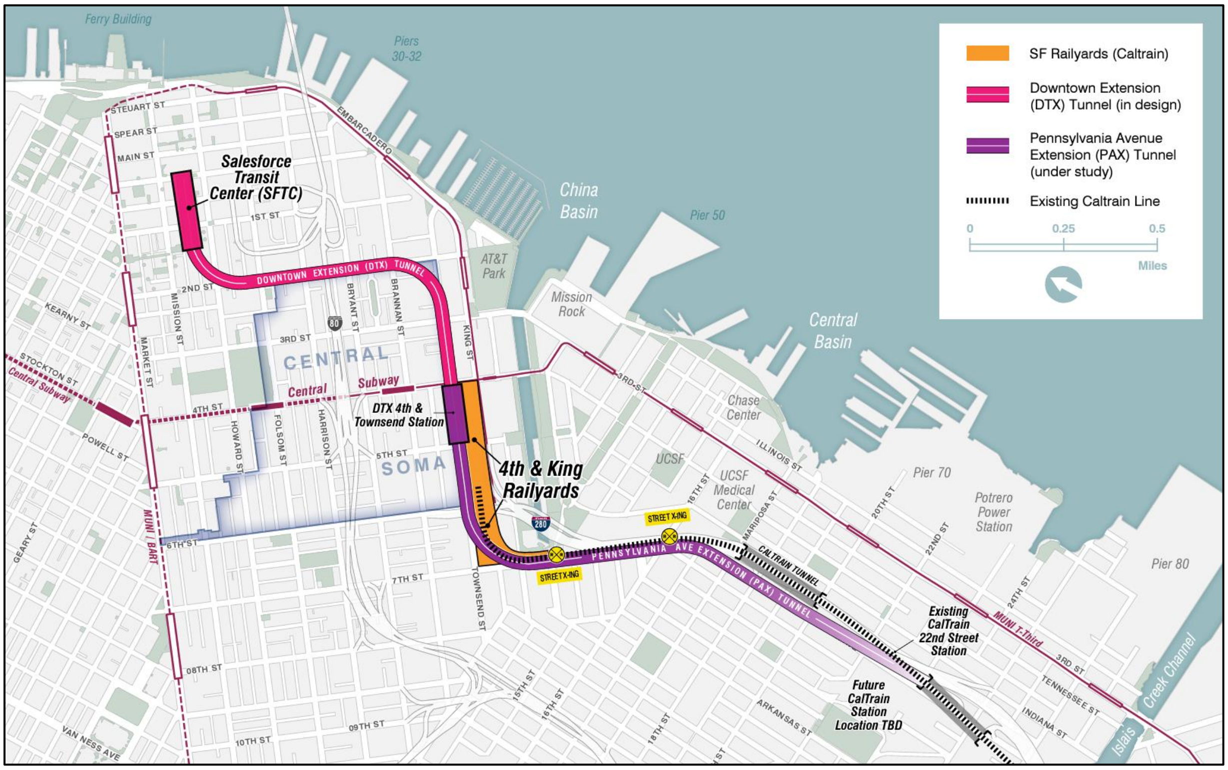

Figure 5. Map of SF Railyards Project. Source: San Francisco Planning.

3.1.3 Islais Creek Southeast Mobility Adaptation Strategy (ICSMAS)

The ICSMAS provides a comprehensive set of adaptation pathways to protect the Islais Creek shoreline and surrounding district from inland and coastal flooding and sea level rise through 2080. The project is led by the San Francisco Planning Department (Planning), Municipal Transportation Agency (SFMTA), Port of San Francisco (the Port), and the San Francisco Public Utilities Commission (SFPUC). The ICSMAS Team reviewed existing conditions and explored several scenarios for flood adaptation that protect the creek and assets vulnerable to flooding. From those scenarios, a robust set of district and asset scale strategies were developed and grouped into five Reaches. Two of those Reaches are the most relevant for Caltrain: Reach 3-Northwestern Creek Bank and Reach 4-Southwestern Creek Bank. Reach 3 and Reach 4 would protect Caltrain's track ROW from approximately mile post 2.1 to 2.5.

Reach 3 includes the following strategies for the near term (2050) that will protect segments of the track.

- Installing flood protection measures at the Islais Creek Bus Facility (which is located east of the Caltrain track mile post 2.2) by either managing local stormwater issues or by separating the stormwater drainage system.

- Diverting storm runoff from adjacent areas of Marin Yard (located at the track mile post 2.2) by raising adjacent streets, deploying temporary flood barriers, constructing a temporary floodwall, and by removing rubble and debris along the shoreline.
- Installing backflow prevention by 2030 (12" of sea level rise at the Islais Creek North combined sewer discharge.
- Restoring the shoreline along Islais Creek in front of the bus facility by removing rubble and debris and constructing a living shoreline by 2030 (12" of sea level rise) and raising the shoreline edge and constructing a higher floodwall setback from the shoreline.

Reach 4 includes the following strategies for the near term (2050) that will also protect segments of the track.

- Converting the western shoreline into tidal marsh to protect from sea level rise and construct a new shoreline floodwall to provide limited flood mitigation through 24" of sea level rise.
- Improve stormwater management in coordination with SFPUC and improve nearby streets with green infrastructure.

Caltrain's assets near Islais Creek are expected to be inundated at 66" and 108", so these measures do not protect against higher levels of inundation for Caltrain.

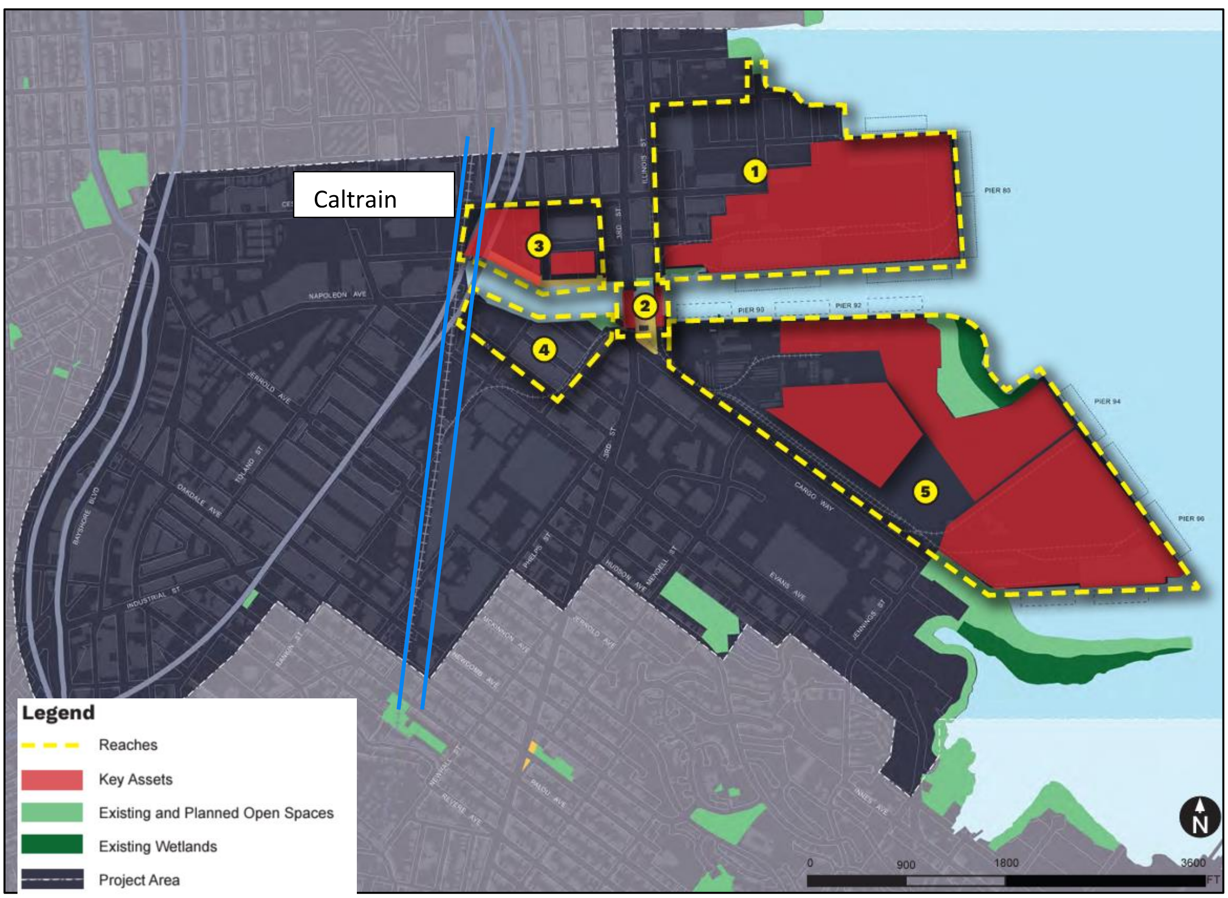

Figure 6. Islais Creek adaptation project area. Source: San Francisco Planning.

3.1.4 San Francisco International Airport Shoreline Protection Program

San Francisco International Airport (SFO) has developed the Shoreline Protection Program (SPP) to protect the Airport's assets and operations from flooding from a 100-year storm surge and future sea level rise events. The SPP would remove existing shoreline protection and install a contiguous system of concrete-capped steel sheet pile walls and steel king pile walls along the 8 miles of the Airport's shoreline. The system incorporates up to 42 inches of future sea level rise in addition to the existing 100-year flood event protection FEMA requirements. Depending on the location along the shoreline, the design elevation of the protection could range from 15 to 20 feet above current mean sea level. In addition, rip rap would be added to the front of sheet pile walls to break up the waves. Sheet piles could be as deep as 27 – 79 feet below grade, depending on the location, and king pile walls would be as deep as roughly 80 feet below grade.

The system will protect Caltrain's track ROW located to the west of SFO from approximately mile post 11.1 to 13.4.

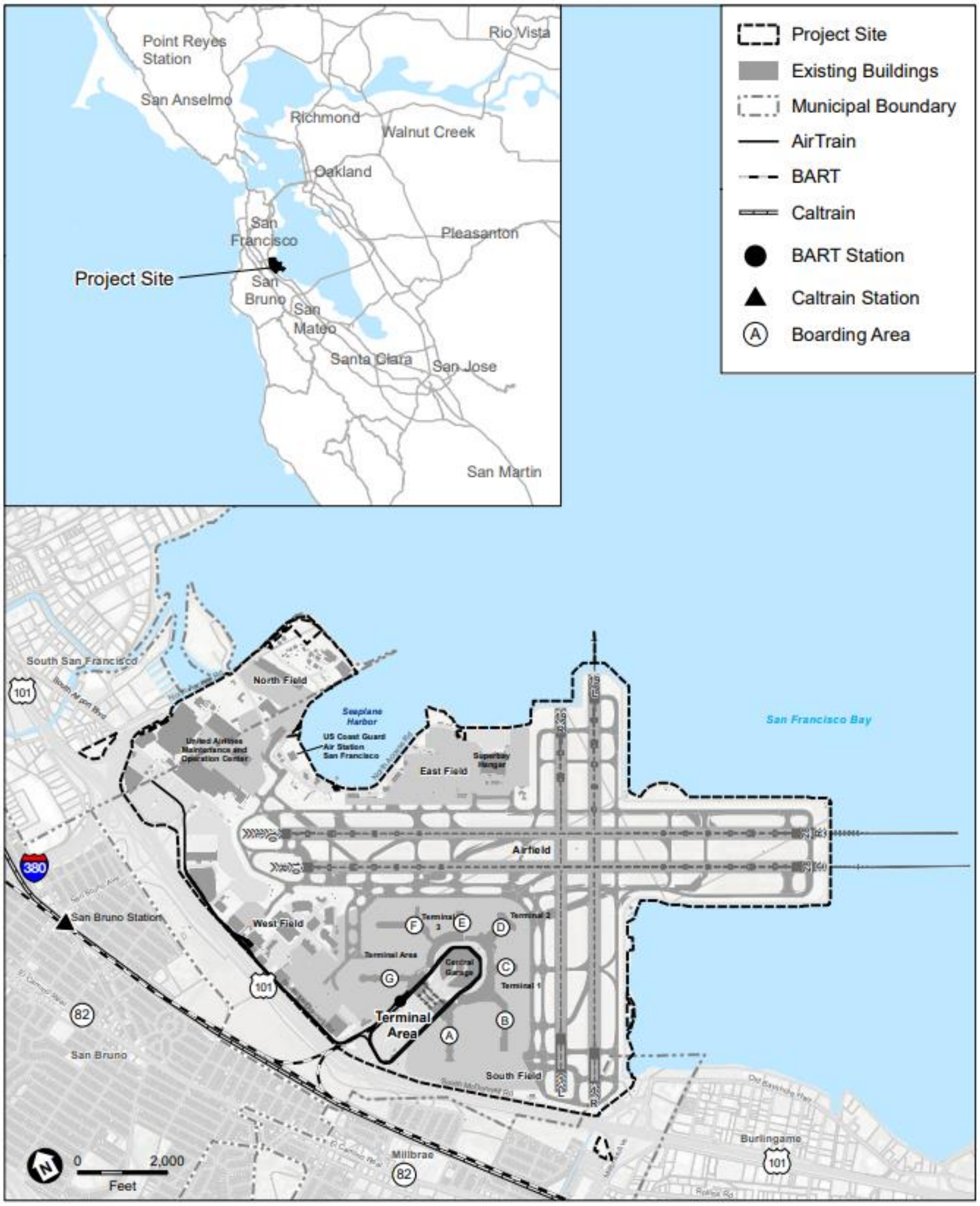

Figure 7. Proposed SFO Shoreline Protection Program. Source: [Fly SFO]

3.1.5 OneShoreline Projects

OneShoreline is the San Mateo County Flood and Sea Level Rise Resiliency District which works across jurisdictional boundaries to secure and leverage public and private resources for the long-term resilience of the region. The projects under OneShoreline plan to build solutions to the climate change impacts of sea level rise, flooding, and coastal erosion. Two of these projects, Millbrae and Burlingame Shoreline Area Protection and Enhancement Project and Colma Creek, San Bruno Creek, Navigable Slough and nearby areas of the shoreline, will help protect Caltrain's assets and are summarized below.

3.1.5.1 Millbrae and Burlingame Shoreline Area Protection and Enhancement Project[10]

Millbrae and Burlingame are located along San Mateo County's Bay shoreline and are low-lying and densely-developed lands, vulnerable to inundation from sea level rise, storm surge, and high tides. Burlingame and Millbrae separately completed studies that evaluated alternatives to build resilience to hazards along the shoreline. Soon after the San Mateo County Flood and Sea Level Rise Resiliency District (OneShoreline) was established, it brought together these three entities to advance their efforts and foster coordination.

Since then, the Project now has three primary objectives: 1) protect areas within the cities of Millbrae and Burlingame along the Bay shoreline, creeks, and lagoons against current coastal hazards and future sea level rise as defined by OneShoreline's Bay Protection Standard; 2) enhance recreation and trails; and 3) promote healthy and sustainable ecosystems proximate to the Bay shoreline. To achieve these goals, the project will create a tidal lagoon capable of controlling the offshore water level through an offshore barrier composed of both hardened and natural materials that include habitat features, known as a living shoreline. The living shoreline would extend approximately 2.65 miles from southernmost coastal SFO location just north of Highline Canal to the southeast corner of the shoreline of Burlingame (**Error! Reference source not found.**) and provide coastal flood protection from tidal waters at an elevation of 16 feet NAVD (100-year stillwater plus six feet of future sea level rise). This Project will protect the track's ROW from approximately mile post 13.5 to 15.8, stations Millbrae and Broadway, as well as asset PS-3. maps the coastal protection area from the project as well as the Caltrain track.

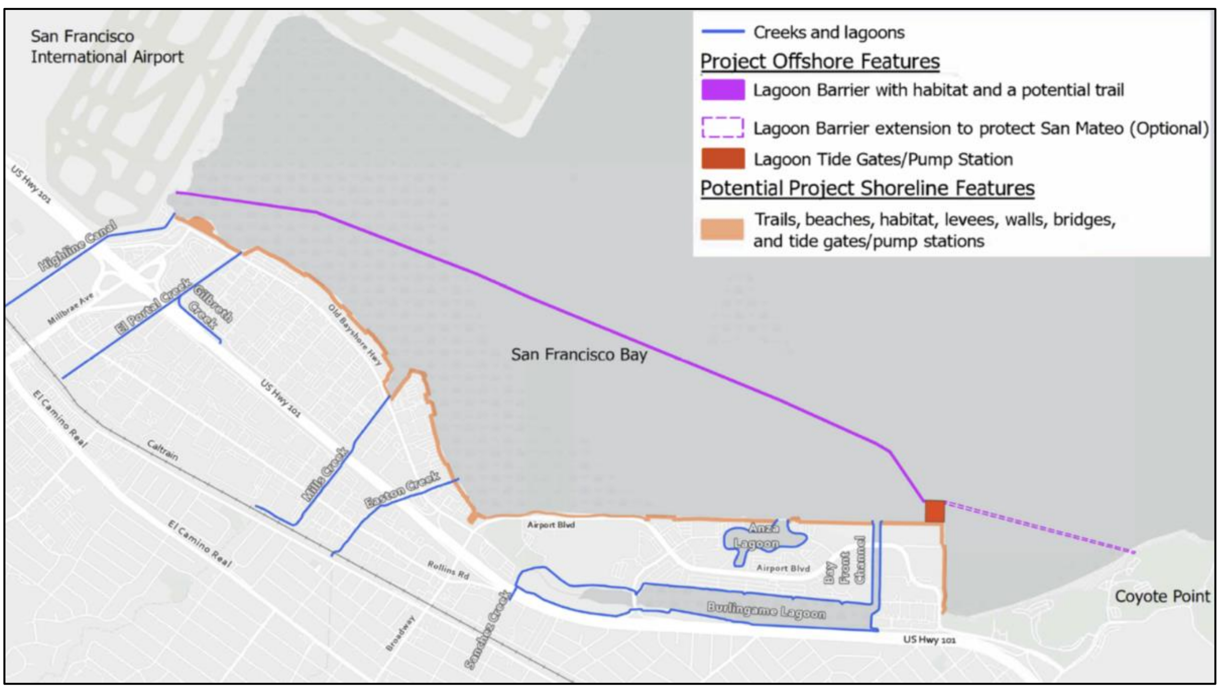

Figure 8. Proposed project scope for Millbrae and Burlingame Shoreline Area Protection and Enhancement Project. Source: OneShoreline.

[10] A Draft Environmental Review for public review and comment is expected in the fall of 2024. https://oneshoreline.org/projects/millbrae-burlingame/

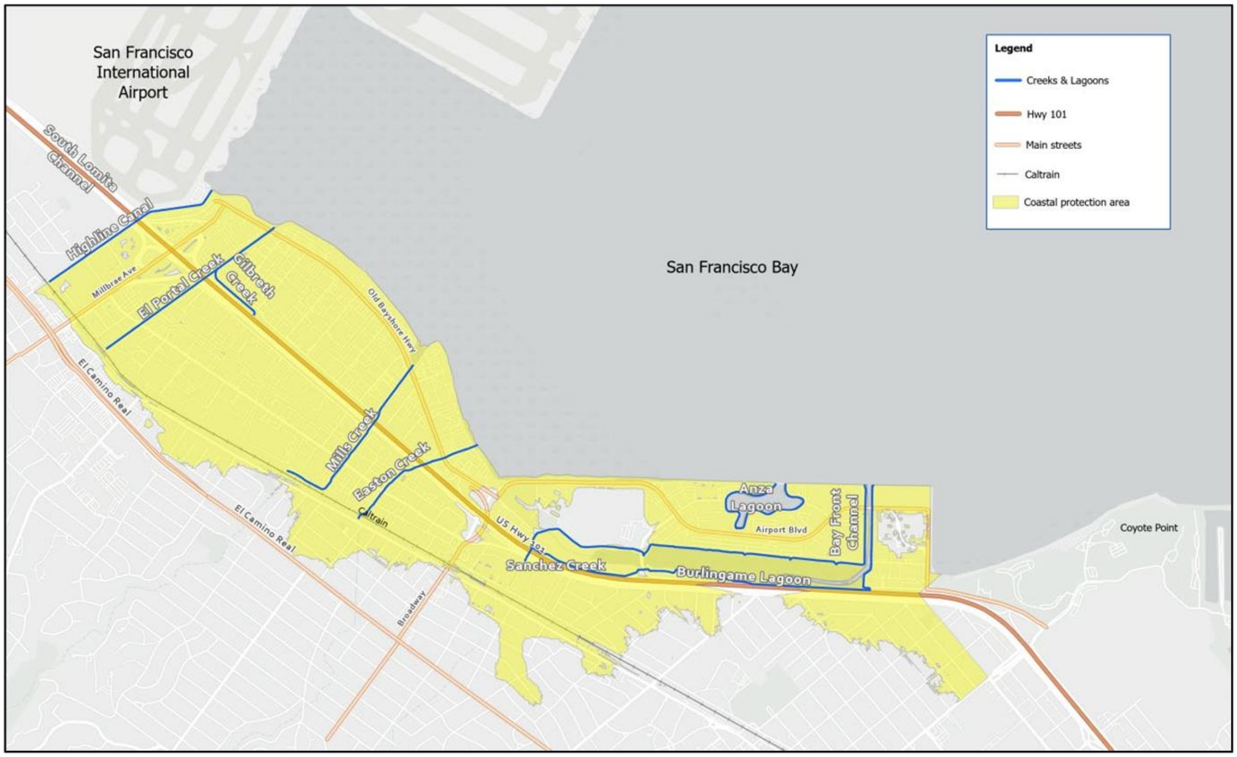

Figure 9. Coastal Protection Area for Millbrae and Burlingame Shoreline Area Protection and Enhance Project. Source: OneShoreline.

In October 2023, the Project initiated the California Environment Quality Act (CEQA) process by releasing a Notice of Preparation for an Environmental Impact Report (EIR). The Project team has received comments from stakeholders on the scope and are currently reviewing them.

3.1.5.2 Colma Creek, San Bruno Creek, Navigable Slough and nearby areas of the shoreline

Colma Creek, San Bruno Creek, and Navigable Slough are connected waterways within the cities of South San Francisco and San Bruno that are prone to flooding, especially during high tide levels in the San Francisco Bay.

Along Colma Creek, an assessment of future priorities is being completed in close coordination with the City of South San Francisco's planning efforts and the City's General Plan.

Along San Bruno Creek, three potential project components have been identified – but not yet selected or approved – that could address significant flooding issues in the region:

1. A pump station that would carry the excess flows around the existing tide gate where the San Bruno Creek meets the San Francisco Bay, along with a backup generator to ensure continued function during a storm event;
2. The rehabilitation of two existing pump stations, built in the 1960s and owned/operated by OneShoreline, that facilitate stormwater drainage from San Bruno to the San Francisco Bay;
3. The design and construction of a detention basin at an existing low elevation site along 7th Avenue to increase capacity at the site to store water during high-intensity rainfall events, especially those that occur during high tide.

3.1.6 Foster City Levee Protection Planning and Improvement Project

In 2014, the Federal Emergency Management Agency (FEMA) determined that Foster City's levee system does not meet minimum requirements for flood protection. To retain FEMA accreditation for the levee system, Foster City developed the Foster City Levee Protection Planning and Improvement Project to increase the height and width of the system, protect against flooding and protect against sea level rise projections through 2050.

In 2017, the Foster City Planning Commission adopted the Final Environmental Impact Report (EIR). The project site is within the 43,000 linear foot (8 miles) existing levee system surrounding Foster City and will include a combination of three different levee improvement types, sheet pile floodwall, earthen levee, and conventional floodwall. The new levee is described in eight segments (as seen in Figure 10) with a height range of 13.5-19 feet NAVD 88 for a 2050 sea level rise scenario.

Construction was completed in February 2024 and will help protect Caltrain's track ROW from milepost 18.3 to 19.8, from 20.7 to 20.9, and Hayward Park Station.

Figure 10. Foster City Levee Improvements Project. Source: [Foster City]

3.2 Potential Adaptation Strategies for Caltrain

In addition to coordinating with existing local/regional efforts, Caltrain can implement adaptation strategies to reduce the vulnerability to inundation from sea level rise, storm surge, and tides which result in damage to Caltrain infrastructure or affect reliability of service. The adaptation options presented here fall into four categories: 1) engineering, 2) nature-based, 3) policy, and 4) operational strategies. Each strategy comes with a description of what the strategy entails, the benefits it provides, and considerations for Caltrain for applicability. Table 10 provides a summary of the strategies, their pros and cons, and areas where they are most suitable.

Table 10. Potential adaptation strategies summary.

Strategy	Description	Advantages	Disadvantages	Suitability
Engineering Strategies				
Track elevation	Elevate the track bed above projected flood inundation depth to achieve flood protection.	• Highly effective	• High costs • Low adaptability • High impact on surrounding areas	ROW segments with sufficient area for fill placement
Flood barriers	These structures separate a body of water or flood zone from the asset or area intended to be protected. This includes seawalls, floodwalls, dikes, levees, revetments, and other similar structures.	• Effective at protecting against multiple hazards, including erosion and scour	• High costs • Requires large area • Requires ongoing maintenance • Can worsen drainage • Low adaptability	Single or multiple structures
Deployable barriers	These structures can be moved or closed to prevent flooding. This includes storm surge and tidal barriers, stop logs, flood doors/gates, and other similar structures.	• Effective at protecting against storm surge and tides • Lower upfront construction costs compared to other strategies • High adaptability	• Best areas for implementation are outside Caltrain's jurisdiction • Not as effective at protecting against permanent SLR inundation • High maintenance and operation costs • High impact on surrounding areas	Placed at mouth of river, waterway, or tidal inlet

Strategy	Description	Advantages	Disadvantages	Suitability
Wet and dry floodproofing	Measures to floodproof structures, including the use of flood resistant materials, elevation of electrical/mechanical equipment, flood vents and pumps, and design that resists water loads and infiltration.	• Lower costs compared to larger engineering projects • Do not require large amounts of land	• Less effective against permanent SLR inundation and wave action	Structures
Floodwater management	Install and/or upgrade floodwater management infrastructure and equipment to improve drainage of floodwaters. Includes pervious surfaces.	• Effective against temporary inundation • Co-benefits related to increasing water storage and reducing runoff	• Can worsen flooding in other areas • May lie outside Caltrain's jurisdiction • High costs	Stormwater system surrounding vulnerable assets
Nature-based Strategies				
Floodable natural areas	Natural spaces designed to be flooded that can protect upland areas from flooding. These could include creating/restoring coastal wetlands and waterfront parks.	• Effective at reducing coastal flooding, wave and tidal energy • High adaptability	• Potentially high costs • May require permits	Natural spaces between assets and shore
Living shorelines	Living shorelines retain land and resist erosion while also providing for intertidal habitat and coastal vegetation	• Co-benefits related to green space • Effective at reducing erosion, storm surge impacts	• Requires large amounts of land • Lower adaptability	Along Bay shoreline
Beaches and dunes	Involves placing more sand on beaches to increase the amount of land buffer that can dissipate wave energy and reduce inundation of upland areas	• Effective at protecting against flooding, waves, erosion, storm surge • High scale of protection • Co-benefits related to provision of recreational land	• High maintenance costs • Requires permits and coordination • May be less suitable along Bay shoreline	Along ocean shorelines

Strategy	Description	Advantages	Disadvantages	Suitability
Policy Strategies				
Redevelopment policies	Incorporate sea level rise adaptation into redevelopment policies, such as by not expanding into flood zones.	• High effectiveness • Feasible within Caltrain's jurisdiction	• Cannot protect existing infrastructure	System-wide
Climate emergency plans	Develop plans to prepare for, respond to, and recover from climate emergencies related to coastal flooding.	• Can address non-SLR hazards • Protect employee and passenger safety	• Unable to protect assets on its own	System-wide
Adaptive management plan	Develop an adaptive management plan to consider long-term impacts of sea level rise; for example, this could include options to elevate or relocate assets in later years.	• Considers variety of adaptation options	• Potential high costs to carry out in long term	System-wide
Zoning	Update zoning requirements to allow construction of infrastructure that can protect against sea level rise and flooding.	• Increases feasibility of engineering and nature-based strategies	• Requires coordination with other entities	System-wide
Operational Strategies				
Climate hazard notification system	Develop a climate hazard notification system that provides early warnings and evacuation notifications, which can trigger operational procedures during a flood event.	• Protect employee and passenger safety	• Unable to protect assets on its own	System-wide

Strategy	Description	Advantages	Disadvantages	Suitability
Redundant transportation routes	Coordinate redundant transportation access, such as shuttles that can temporarily replace flooded rail segments.	• Immediately addresses service gaps	• Unable to protect assets on its own • May require coordination with other entities	System-wide
Monitoring and maintenance	Carry out regular monitoring and inspections of seas levels and vulnerable assets, and carry out maintenance when needed (e.g., reinforcing infrastructure damaged by sea level rise or coastal erosion).	• Can be paired with many other strategies	• Unable to protect assets on its own	System-wide

3.2.1 Engineering

Engineering strategies include hard infrastructure projects that can prevent inundation by either raising the asset out of the vulnerable area or preventing floodwater from reaching the asset. These include raising the track elevation, permanent and deployable flood barriers, wet and dry floodproofing, and floodwater management.

3.2.1.1 Raising the Track Elevation[11]

This strategy involves elevating the track bed above the projected flood inundation depth in order to prevent inundation. This is often completed through the placement of fill below and around the track. Tracks can be raised to different elevations depending on the vulnerability and risk tolerance and may be best suited for long stretches of right of way that are vulnerable rather than point locations of inundation vulnerability.

Track elevation is an effective strategy for reducing flood risk for specific elevations. The higher a track is elevated, the more flood protection it provides. However, this strategy can be costly, and larger elevations are more expensive. Additionally, track elevation may be difficult to adapt in the future as sea levels continue to rise. The project area for track elevation includes the track segment itself plus a sloped area around the track for the fill. The higher the elevation, the greater the additional area surrounding the track is needed. Otherwise, more advanced and expensive structures like concrete retaining walls will be needed. As a result, available space around the track can be a significant limiting factor for elevation. Additionally, track elevation can have an adverse impact on the surrounding environment if a large area requires fill placement. For example, undeveloped areas and natural areas or wetlands can be disrupted by fill placement. Track elevation may also impact local drainage, requiring additional culverts or bypasses to manage excess runoff.

Caltrain may consider implementing track elevation in locations with sufficient area available for fill placement. For instance, the area around Brisbane Lagoon appears to have available land for raising the elevation based on satellite imagery. Additionally, there is a long stretch of track along the lagoon that is vulnerable to flooding, therefore raising the elevation could provide significant advantages.

3.2.1.2 Permanent Flood Barriers[12, 13]

These structures separate a body of water or flood zone from the asset or area intended to be protected. This includes seawalls, floodwalls, dikes, levees, revetments, and other similar structures. A

[11] British Columbia Ministry of Environment. 2013. Sea Level Rise Adaptation Primer. https://www2.gov.bc.ca/assets/gov/environment/climate-change/adaptation/resources/slr-primer.pdf
[12] British Columbia Ministry of Environment. 2013. Sea Level Rise Adaptation Primer. https://www2.gov.bc.ca/assets/gov/environment/climate-change/adaptation/resources/slr-primer.pdf.
[13] FEMA. 2007. Selecting Appropriate Measures for Floodprone Structures. https://www.govinfo.gov/content/pkg/GOVPUB-HS5-PURL-LPS93623/pdf/GOVPUB-HS5-PURL-LPS93623.pdf.

flood barrier can either be a compacted earthen structure (dikes, levees) or an engineered concrete structure (seawalls, floodwalls).

Flood barriers are effective for protecting either a single structure or multiple structures from inundation and other inundation impacts, such as erosion and scour. Flood barriers made of concrete or masonry are often more resistant to erosion and require less space than those made of compacted earth but are more expensive. Overtopping is also a greater concern for earthen flood barriers as they can erode at the top and subsequently fail. Many of Caltrain's assets exist along the linear ROW, so significant lengths of flood barriers will be needed to protect assets. Other assets, such as electrical sub-stations or stations, may be easier to flood proof.

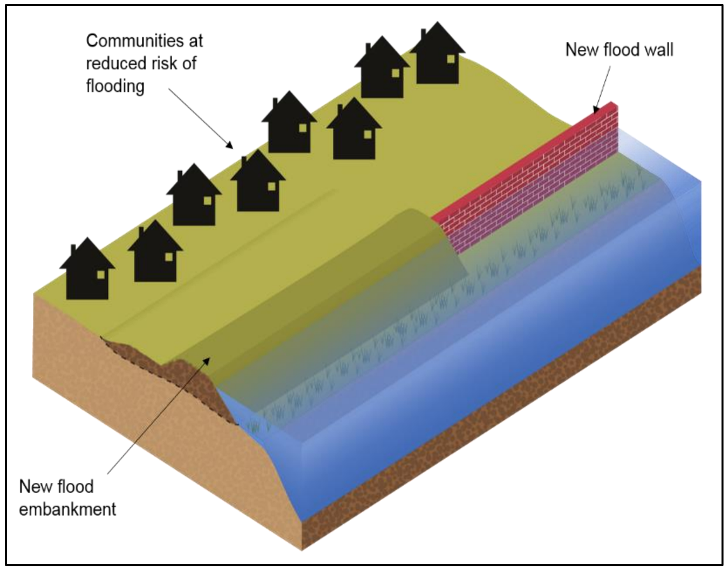

Figure 11. Example diagram of permanent flood barriers. Source: Environment Agency.

Constructing flood barriers is often costly and requires a large area of land. Flood barriers also require ongoing maintenance and investment in the future as they absorb wave energy and can be damaged. The implementation of flood barriers should consider existing drainage systems at the site, as flood barriers can affect local drainage and potentially create or worsen flooding. Flood barriers can adversely affect intertidal areas and reduce access to the shoreline. Flood barriers are typically permanent structures that do not change significantly in the future. However, if required, certain structures can be adapted to accommodate higher sea levels, though this is often costly or unfeasible.

The height of flood barriers is typically limited to 4 to 6 feet, as constructing beyond this range is often impractical and/or not cost-effective. Certain Caltrain assets and locations are expected to be inundated at 108", or 9 feet, therefore flood barriers may not be cost-effective or practical in these cases. This is true for Redwood City Station and the track along Brisbane Lagoon, which will both be flooded at 108" by 2070.

3.2.1.3 Deployable Barriers[14, 15]

These structures can be moved or closed to prevent flooding in the event of extreme water levels. This includes storm surge and tidal barriers, stop logs, flood doors/gates, and other similar structures. Deployable barriers are typically placed at the mouth of a river, waterway, or a tidal inlet. To address

[14] British Columbia Ministry of Environment. 2013. Sea Level Rise Adaptation Primer. https://www2.gov.bc.ca/assets/gov/environment/climate-change/adaptation/resources/slr-primer.pdf.
[15] Chen et al. 2020. Storm Surge Barrier Protection in an Era of Accelerating Sea-Level Rise: Quantifying Closure Frequency, Duration and Trapped River Flooding. https://www.mdpi.com/2077-1312/8/9/725.

specific vulnerabilities, Caltrain could deploy these barriers in areas such as Islais Creek and Oyster Point, however, the best areas for implementation are outside of Caltrain's jurisdiction.

Deployable barriers can help reduce temporary inundation from storm surge or tides rather than permanent inundation due to sea level rise. These structures are effective and cost-effective for reducing temporary coastal flooding provided they are implemented before an extreme event occurs. As a result, implementing deployable barriers requires advanced flood forecast and early warning systems to ensure gates and barriers are activated in time. Deployable barriers are costly to construct, require consistent maintenance, and have high operating costs. Although permanent flood protection structures have higher upfront construction costs, deployable barriers may have more costs associated with maintenance and operation.

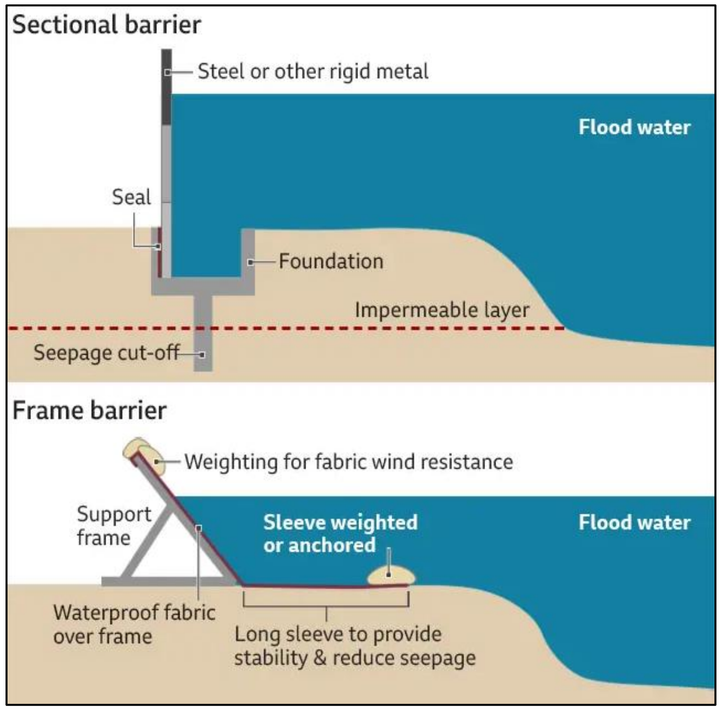

Figure 12. Examples of temporary flood barriers. Source: [BBC News]

Unlike permanent flood protection structures, deployable barriers provide more opportunities for adaptive management in the future. For example, deployable barriers now can be upgraded in the future to more permanent structures depending on future growth and development, risk tolerance, and resource availability. Deployable barriers can also be operated more flexibly, as operators can decide whether to engage them based on the scenario. However, deployable barriers can potentially worsen flooding in other areas during extreme water levels. Deploying the barriers/gates can also have adverse effects on water quality and ecological processes in the surrounding estuary, especially if they are deployed more frequently as extreme inundation events increase in the future.

3.2.1.4 Wet and Dry Floodproofing[16, 17]

These are measures designed to allow structures to be exposed to floodwaters. Wet floodproofing includes measures that allow water to enter and exit a structure without causing significant damage, such as with flood-resistant materials, the elevation of electrical and mechanical equipment, and the use of opening for drainage. Dry floodproofing includes measures to make the structure watertight, such as by sealing walls with waterproof coatings, adding flood vents and pumps, and designing structures to reduce water loads and infiltration.

[16] FEMA. 2007. Selecting Appropriate Measures for Floodprone Structures. https://www.govinfo.gov/content/pkg/GOVPUB-HS5-PURL-LPS93623/pdf/GOVPUB-HS5-PURL-LPS93623.pdf.
[17] British Columbia Ministry of Environment. 2013. Sea Level Rise Adaptation Primer. https://www2.gov.bc.ca/assets/gov/environment/climate-change/adaptation/resources/slr-primer.pdf.

Wet and dry floodproofing are both less costly than larger engineering projects such as track elevation and permanent or deployable flood barriers. They also do not require additional land, which may be needed for some flood barriers. However, floodproofing measures generally have less applicability for sea level rise and are not frequently used as a solution for permanent inundation. Additionally, floodproofing measures are not effective for minimizing damage from high-velocity flood flow and wave action.

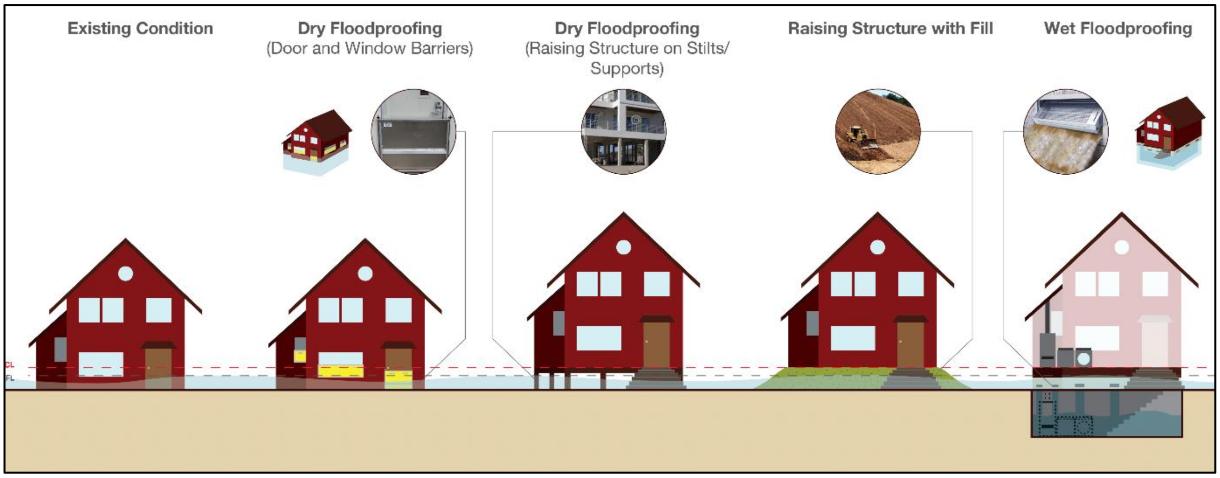

Figure 13. Examples of wet and dry floodproofing techniques for existing structures. Source: [Floodwise](#).

3.2.1.5 Floodwater Management[18]

This includes the installation and/or upgrade of floodwater management infrastructure and equipment (i.e., culverts, drains, etc.) to improve the drainage of floodwater during extreme events. Floodwater management measures can also include the implementation of pervious surfaces to capture or redirect floodwaters.

These measures are effective for increasing water storage capacity and reducing surface runoff and temporary inundation around the site of concern. However, floodwater management measures can potentially worsen flooding issues upstream or downstream of the site. Additionally, depending on the location, Caltrain may not have jurisdiction to install or upgrade larger infrastructure like culverts. The cost of the floodwater management project can vary significantly depending on the size and scope of the project and the materials required. In general, installing or constructing new infrastructure will be more costly than upgrading or retrofitting existing infrastructure/equipment.

3.2.2 Nature-Based

Nature-based strategies use natural materials to help reduce inundation. These include floodable natural areas, living shorelines, and beaches and dunes.

[18] FEMA. 2007. Selecting Appropriate Measures for Floodprone Structures. https://www.govinfo.gov/content/pkg/GOVPUB-HS5-PURL-LPS93623/pdf/GOVPUB-HS5-PURL-LPS93623.pdf.

3.2.2.1 Floodable Natural Areas[19]

Floodable natural areas are natural spaces designed to be inundated that can protect upland areas from flooding. Examples include creating/restoring coastal wetlands and waterfront parks.

Floodable natural areas are effective for reducing coastal flooding. They can also help reduce incoming wave and tidal energy in addition to stabilizing shorelines. Additionally, floodable natural areas can provide a range of positive environmental benefits through the creation/provision of new habitats and improved water quality. Another benefit of floodable natural areas is that they can generally adapt to rising sea levels without additional intervention/investment, provided that sea level rise rates are not too rapid, and the area is not subjected to coastal squeeze.[20]

The costs associated with restoring or creating floodable natural areas depend significantly on the scale of the project. Jurisdiction and permitting requirements in the Bay Area such as the California Environmental Quality Act (CEQA), Environmental Social Impact Assessment (EISA), and the San Francisco Bay Plan, can present significant limiting factors to implementing this strategy.

3.2.2.2 Living Shorelines[21]

Living shorelines retain land, resist erosion, and provide for intertidal habitat and coastal vegetation. This strategy stabilizes the shoreline while also incorporating ecological function and is mostly effective for controlling erosion, but it could also reduce risk of damage from frequent inundation and periodic storm surge.

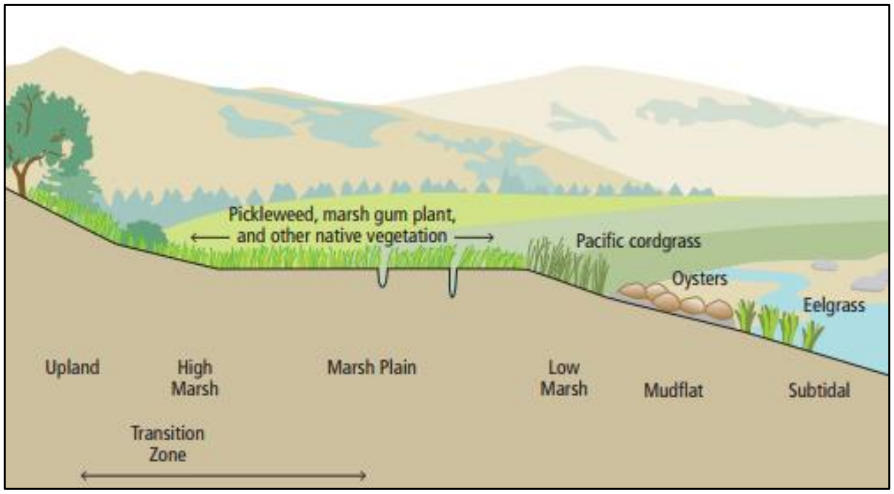

Figure 14. Living shoreline example. Source: [Southern California Wetlands Recovery Project](#).

Living shorelines may be less suitable in environments with high wave energy, as currents may be too strong to allow vegetation to be established; this means living shorelines could be suitable along the San Francisco Bay. Living shorelines may also require more space than other strategies (such as bulkheads), which could affect feasibility depending on availability of space along the shoreline near Caltrain's assets. Furthermore, shoreline areas may change with sea level rise, so living shorelines may need to be adapted in the future to accommodate changes in sea level. Because this strategy incorporates ecological function, it can

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[19] British Columbia Ministry of Environment. 2013. Sea Level Rise Adaptation Primer. https://www2.gov.bc.ca/assets/gov/environment/climate-change/adaptation/resources/slr-primer.pdf.

[20] Coastal squeeze is when coastal natural areas such as wetlands are blocked by hardened shoreline structures and are therefore unable to retreat landward.

[21] NYC Department of City Planning. 2013. Coastal Climate Resilience: Urban Waterfront Adaptive Strategies. https://www.nyc.gov/assets/planning/download/pdf/plans-studies/sustainable-communities/climate-resilience/urban_waterfront.pdf.

have co-benefits such as nurturing diverse habitats, nursey habitat for aquatic, avian, and estuarine species, maintaining natural shoreline dynamics, improving water quality by filtering nutrients and pollutants, and carbon sequestration. In urban areas with limited space, living shorelines can also create some naturalized areas if full restoration is not possible. As this strategy is still a relatively new technology, there may be a lack of clear guidelines around design and implementation, so further research and discussion with practitioners may be needed.

3.2.2.3 Beaches and Dunes[22]

Beach nourishment involves placing more sand on beaches to increase the amount of land buffer that can dissipate wave energy and reduce inundation of upland areas. While the beach may erode, the sand can continue to be replenished. The addition of dunes can provide more protection, while including vegetation can stabilize sediment and provide habitat. Beaches and dunes in combination are effective at protecting against flooding, waves, erosion, and storm surge, and can protect a large area rather than a single, specific site.

Beaches are more suitable for oceanfront areas with existing sand, which could make them more difficult to implement along the Bay. Furthermore, nourishment requires continual maintenance to replenish sand, which could be costly if erosion rates in the area are high. Beach nourishment projects may also require permits or coordination with other entities like the U.S. Army Corps of Engineers. Co-benefits of this strategy include the expansion of areas for recreation and public access, which promotes equity.

3.2.3 Policy

Policy strategies are initiatives Caltrain can undertake to incorporate sea level rise into their policies and long-term planning. These tend to be system-wide actions that can be implemented and refined over a long period of time, offering high flexibility and the ability for Caltrain to tailor these strategies to their needs. Policy strategies include developing redevelopment policies, climate emergency plans, adaptive management plans, and updating zoning restrictions.

3.2.3.1 Redevelopment policies[23]

Incorporation of sea level rise adaptation into redevelopment policies can reduce future flood risk should Caltrain choose to expand, add, or renovate part of its infrastructure in the future. This can include policies to limit redevelopment in flood zones or limit additions to structures that currently lie in flood zones.

This strategy could have high effectiveness to prevent inundation of future changes to Caltrain's infrastructure; however, it is less able to provide protection for the assets that are already built. Furthermore, while this strategy is mostly feasible under Caltrain's jurisdiction, Caltrain may have to coordinate with other entities if avoiding flood zones requires Caltrain to develop outside its current right-of-way.

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[22] NYC Department of City Planning. 2013. Coastal Climate Resilience: Urban Waterfront Adaptive Strategies. https://www.nyc.gov/assets/planning/download/pdf/plans-studies/sustainable-communities/climate-resilience/urban_waterfront.pdf.

[23] California Coastal Commission. 2018. Sea Level Rise Policy Guidance. https://documents.coastal.ca.gov/assets/slr/guidance/2018/0_Full_2018AdoptedSLRGuidanceUpdate.pdf.

3.2.3.2 Climate emergency plans[24,25]

Develop plans to prepare for, respond to, and recover from climate emergencies related to coastal flooding. This could be paired with operational strategies like development of a climate hazard notification system. These plans could include actions such as training employees and educating passengers on how to respond to climate events and partner with emergency response organizations.

This strategy could be incorporated with a more general emergency plan for Caltrain that is not limited to sea level rise or climate change. While this strategy could enhance employee and passenger safety, it is unlikely to protect Caltrain assets unless paired with a strategy like deployable flood barriers.

3.2.3.3 Adaptive management plan[26]

Develop an adaptive management plan to consider long-term impacts of sea level rise. This could include less costly adaptation options in the short term and more robust and expensive options in the long term. As an example, Caltrans developed flexible adaptation pathways for the Eureka-Arcata Corridor in 2019 that consider first addressing low points in dikes and increasing maintenance, and then considering regrading or raising the elevation of assets in later years.[27]

3.2.3.4 Zoning

Update zoning requirements to allow construction of infrastructure that can protect against sea level rise and flooding. This infrastructure can include the engineering or nature-based solutions described above. As Caltrain lacks jurisdiction over zoning requirements, this would require coordination with local and regional planning entities.

3.2.4 Operational

Operational strategies are actions that Caltrain can implement to ensure continuous service during coastal flooding events. While these strategies may not all necessarily protect Caltrain assets, they support Caltrain's mission to offer safe, reliable, accessible, and sustainable transportation services and focus on protecting the safety of passengers and employees. Operational strategies include developing a climate hazard notification system, implementing redundant transportation routes, and incorporating sea level rise indicators into monitoring and maintenance.

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[24] ICF. 2021. Handbook for Analyzing Greenhouse Gas Emission Reductions, Assessing Climate Vulnerabilities, and Advancing Health and Equity. https://www.airquality.org/ClimateChange/Documents/Handbook%20Public%20Draft_2021-Aug.pdf.

[25] Federal Transit Administration. 1999. Recommended Emergency Preparedness Guidelines for Rail Transit Systems. https://www.transit.dot.gov/regulations-and-guidance/safety/recommended-emergency-preparedness-guidelines-rail-transit-systems.

[26] ICF. 2021. Handbook for Analyzing Greenhouse Gas Emission Reductions, Assessing Climate Vulnerabilities, and Advancing Health and Equity. https://www.airquality.org/ClimateChange/Documents/Handbook%20Public%20Draft_2021-Aug.pdf.

[27] https://digitalcommons.humboldt.edu/cgi/viewcontent.cgi?article=1007&context=hsuslri_state

3.2.4.1 Climate hazard notification system[28]

Develop a climate hazard notification system that provides early warnings and evacuation notifications, which can trigger operational procedures during a flood event. This could be paired with policy strategies like development of a climate emergency plan.

This strategy could be incorporated with a more general hazard notification system for Caltrain that is not limited to sea level rise or climate change. While this strategy could enhance employee and passenger safety and convenience, it is unlikely to protect Caltrain assets unless paired with a strategy like deployable flood barriers.

3.2.4.2 Redundant transportation routes[29]

Coordinate redundant transportation access, such as shuttles that can temporarily replace flooded rail segments. This strategy provides a way to quickly respond to emergencies by continuing to serve passengers if the rail system becomes inoperable. The strategy could be paired with a climate hazard notification system and outreach to ensure passengers are notified of the change.

This strategy would not protect assets from the impacts of sea level rise and storm surge events. If Caltrain does not already own vehicles that could serve as temporary shuttles, it may need to coordinate with other entities, such as public transit agencies.

3.2.4.3 Monitoring and maintenance

Carry out regular monitoring and inspections of sea levels and vulnerable assets, and carry out maintenance when needed (e.g., reinforcing infrastructure damaged by sea level rise or coastal erosion). This could be paired with many other strategies, such as development of an adaptive management plan or climate hazard notification system. Information from monitoring and inspections could inform which areas along Caltrain's right-of-way may sooner require an engineering or nature-based strategy to protect assets from inundation and erosion.

3.3 Recommended Adaptation Strategies

In this section, ICF recommends specific strategies for reducing vulnerabilities of stations, assets, ROW segments. ICF also makes recommendations of policy and operational strategies to reduce the system's vulnerabilities. ICF selected the recommended strategies using the adaptation strategy prioritization approach described below.

3.3.1 Adaptation Strategy Prioritization

Strategies were rated based on how they meet criteria related to cost, criticality, environmental and social benefits, and temporal considerations. These criteria ratings can help Caltrain choose specific strategies depending on Caltrain's priorities for adaptation.

The rating scale differs for each criteria category. Rating scales were either *low/medium/high* or *negative/neutral/positive* depending on the criteria category. The color code highlights which criteria ratings are preferable, with more preferable ratings in **green** and less preferable ratings in **red**. For

[28] ICF. 2021. Handbook for Analyzing Greenhouse Gas Emission Reductions, Assessing Climate Vulnerabilities, and Advancing Health and Equity. https://www.airquality.org/ClimateChange/Documents/Handbook%20Public%20Draft_2021-Aug.pdf.

[29] ICF. 2021. Handbook for Analyzing Greenhouse Gas Emission Reductions, Assessing Climate Vulnerabilities, and Advancing Health and Equity. https://www.airquality.org/ClimateChange/Documents/Handbook%20Public%20Draft_2021-Aug.pdf.

“Implementation time period”, the scale used was *near-term/mid-term/long-term*. These were not assigned a preference color code because different implementation time periods can be useful depending on Caltrain’s priorities. Table 11 shows the rating scales for each criteria and Table 12 shows how each adaptation strategy was rated for these criteria.

Table 11. Adaptation Strategy Criteria Rating Scale

Category	Rating Scale and Definitions		
Cost	Low	Medium	High
Capital Costs	Coordination, outreach, and research-based tasks	Implementation of new polices and minor construction	Large infrastructure projects (e.g. sea wall)
Operating Costs	One-time policy changes, research, or infrastructure that does not need to be maintained	Ongoing "soft" adaptation measures (i.e., smaller infrastructure projects and nature-based solutions)	Large infrastructure changes that will have to be maintained/replaced
Funding Sources	Caltrain can implement with existing budget	Caltrain might need to use of existing and new funding	Caltrain must seek external funding sources
Criticality	Low	Medium	High
Effectiveness and Co-benefits	Research tasks to feed into future/additional adaptation design	Policies or programs that gradually increase resilience over time OR strategies that reduce inundation risk at a specific location or asset OR strategies that only partially reduce inundation risk (e.g., floodproofing or track elevation)	Strategies that will physically reduce inundation risk and protect a large number of Caltrain assets
Scale	Asset scale (helps just one location)	Redundancy (helps protect multiple Caltrain assets)	System wide (helps protect assets across Caltrain systems)
Level of Urgency	Non-priority strategies whose implementation can wait until late-century	Strategy can be implemented by mid-century and still deliver benefits	Strategy would provide immediate benefits
Feasibility	Other entities have primary jurisdiction or Caltrain is unable to effectively protect against inundation	Caltrain has autonomy but there are physical challenges for implementation OR other entities have primary jurisdiction but the strategy is straightforward and effective.	Caltrain has complete autonomy to implement this adaptation strategy

Category	Rating Scale and Definitions		
Environment/ Social	**Negative**	**Neutral**	**Positive**
Access to Green Space and Recreation	Removes access to recreation and green space	No impact on access to green space	Increases or protects access to green space
Impact on Wildlife Habitat, Rare Species, or Water Quality	The action builds over existing habitats or increases storm water runoff (increases pavement)	The action has no impact on wildlife habitat, rare species, or water quality	The action increases habitats or improves water quality
Temporal	**Low**	**Medium**	**High**
Implementation Time Period	Near-term	Mid-term	Long-term
Protection Time Period	0-5 years	5-30 years	30+ years
Adaptability	No – Hard changes in infrastructure that do not have plans for phased adaptation	Partially – Policies that impact the construction of many things over time	Yes – Plans, outreach, and research-based strategies.

Table 12. Adaptation Strategy Criteria Ratings

		Criteria											
		Costs			Criticality				Environment/Social		Temporal		
Category	**Strategy**	Capital Costs	Operating Costs	Funding sources required?	Effectiveness/ co-benefits	Scale	Level of Urgency	Feasibility of implementation	Access to Green Space and Recreation	Impact on Wildlife Habitat, Rare Species, or Water Quality	Implementation time period	Protection time period	Can Caltrain adapt the strategy over
Engineering	Track elevation – **low** protection	Medium	Low	Medium	Medium	Medium	High	High	Negative	Negative	Near-term	Medium	Low
Engineering	Track elevation – **high** protection	High	Medium	High	High	High	High	Medium	Negative	Negative	Mid-term	High	Low
Engineering	Flood barriers – **low** protection	Medium	Low	Medium	Medium	Low	High	Medium	Neutral	Neutral	Near-term	Medium	Low
Engineering	Flood barriers – **high** protection	High	Medium	High	High	Medium	High	Medium	Neutral	Neutral	Mid-term	High	Low
Engineering	Deployable barriers	High	High	Medium	Medium	Medium	High	Medium	Neutral	Negative	Mid-term	High	High
Engineering	Wet and dry floodproofing	Medium	Low	Low	Medium	Low	High	High	Neutral	Neutral	Near-term	Medium	Medium
Engineering	Floodwater management – **low** protection	Medium	Low	Medium	Medium	Medium	High	Medium	Neutral	Neutral	Near-term	Medium	Low
Engineering	Floodwater management – **high** protection	High	Medium	High	High	Medium	High	Low	Neutral	Neutral	Mid-term	High	Low
Natur e-	Floodable natural areas	Medium	Low	Low	High	Medium	Medium	Low	Positive	Positive	Mid-term	Medium	Medium

		Criteria											
		Costs			Criticality				Environment/Social		Temporal		
Category	Strategy	Capital Costs	Operating Costs	Funding sources required?	Effectiveness/ co-benefits	Scale	Level of Urgency	Feasibility of implementation	Access to Green Space and Recreation	Impact on Wildlife Habitat, Rare Species, or Water Quality	Implementation time period	Protection time period	Can Caltrain adapt the strategy over
	Living shorelines	Medium	Medium	Medium	Medium	High	Medium	Medium	Positive	Positive	Mid-term	Medium	Medium
	Beaches and dunes	High	Medium	Medium	High	High	Medium	Low	Positive	Positive	Mid-term	Medium	Low
Policy	Redevelopment policies	Low	Low	Low	High	High	High	High	Neutral	Neutral	Long-term	High	High
	Climate emergency plans	Low	Medium	Low	Medium	High	High	High	Neutral	Neutral	Long-term	Medium	High
	Adaptive management plan	Low	High	Low	Medium	High	High	High	Neutral	Neutral	Long-term	High	High
	Zoning	Low	Low	Low	Medium	High	Medium	Medium	Neutral	Neutral	Long-term	High	High
Operational	Climate hazard notification system	Medium	Low	Medium	Low	High	High	High	Neutral	Neutral	Near-term	Medium	High
	Redundant transportation routes	Medium	Medium	Medium	Medium	Medium	High	High	Neutral	Neutral	Near-term	Low	High
	Monitoring and maintenance	Medium	Medium	Low	Low	High	High	High	Neutral	Neutral	Near-term	Medium	High

Recommended strategies, or combinations of strategies, that Caltrain could implement to address vulnerable stations, assets, and ROW segments are described below. These recommendations were developed based on the vulnerabilities described in Section 2.2 and the criteria ratings in Table 12.

One limiting factor to implementing adaptation strategies is Caltrain's lack of jurisdiction in certain areas, especially when carrying out projects outside their ROW. For example, Caltrain is unlikely to have the jurisdiction to implement most of the nature-based strategies described in Section 1.1, as many of these must occur on shorelines managed by other entities. However, Caltrain can consider opportunities to collaborate with other entities or organizations in the area that have jurisdiction to implement nature-based strategies. Another factor that limits implementation of specific adaptation strategies is potential pushback Caltrain could face from surrounding communities that may be affected by strategies requiring construction. When carrying out any adaptation strategy that is likely to have a significant impact on surrounding communities, Caltrain can incorporate plans for outreach and community engagement to address this issue.

3.3.2 Strategies to Address Vulnerable Stations

The vulnerability assessment indicates that five stations are projected to be inundated: San Francisco (4th and King Street) at 66", and Millbrae, Broadway, Hayward Park, and Redwood City at 108". As described in Section 3.1, ongoing adaptation efforts are expected to provide protection for all stations except Redwood City. However, Redwood City is currently developing a Sea Level Rise Vulnerability Assessment; this provides an opportunity for Caltrain to collaborate with Redwood City on developing adaptation options that can protect both the city and Caltrain assets. Adaptation strategies for vulnerable rail stations should target parts of the station that are most critical, such as electrical equipment/components, platforms and waiting areas, and access routes to the station.

ICF recommends **deployable barriers** and **flood walls** be constructed in strategic areas to address vulnerable stations because they are effective for reducing inundation risk, have a limited environmental footprint if implemented in small, targeted areas, and can be implemented in the near- or mid-term. Additionally, depending on the height of the barrier or wall, these strategies can provide medium- (5-30 years) or long-term (30+ years) protection. Deployable barriers could have higher operational costs compared to flood walls, but they can also be adapted over time as needed.

3.3.3 Strategies to Address Vulnerable Assets

Two key assets are projected to be inundated under future sea level rise: TPS1 and Interconnected (a traction power substation) at 108" and PS-3 (a parallel station) at 66" and 108". PS-3 may be protected by the Millbrae and Burlingame Shoreline Area Protection and Enhancement Project (Section 3.1.5.1).

ICF recommends **wet and dry floodproofing** be implemented to address vulnerable assets because this strategy is effective for reducing inundation, has high feasibility of implementation, and can be implemented in the near-term. Additionally, this strategy has little to no additional footprint on the surrounding environment because it can be implemented at the existing asset. Examples of floodproofing for Caltrain assets can include elevating assets, constructing walls around assets, using flood-proof materials, and making structures water-tight.

3.3.4 Strategies to Address Vulnerable ROW Segments

In the 24" scenario, only one segment of track is projected to be inundated with a total length of 0.1 miles. In the 66'' scenario, 5.7 miles of track is projected to be inundated and under the 108'' scenario approximately 12.4 miles is projected to be inundated.

Although track elevation is a highly effective adaptation strategy, there are significant barriers to implementing this strategy for Caltrain. These include high capital costs, the large amount of available land required to raise the track, the significant environmental footprint track elevation can have, and potential disruptions to surrounding communities. For example, raising a track segment also requires raising roadway crossings along the track, which can cause significant traffic disruptions to the surrounding area.

ICF recommends implementing **floodwalls with deployable barriers constructed at crossings in the most vulnerable areas** to address vulnerable ROW segments. However, the most vulnerable track segments are located along the Bay, where there are many environmental compliance requirements for new infrastructure projects. To address ROW vulnerabilities, Caltrain should consider opportunities to coordinate with other entities in the area.

3.3.5 Policy/Operational Strategies

For the most part, the policy and operational strategies are less expensive compared to engineering and nature-based strategies, are highly feasible, can have system-wide benefits, can implement changes immediately, and can be adapted over time. Because the operational strategies can be implemented in the near-term while policy strategies take place over the long-term, these two categories of strategies complement each other well by supporting protection at all timeframes. While Caltrain could carry out all these strategies, ICF recommends prioritizing certain strategies due to their higher feasibility and impact.

Amongst the policy strategies, ICF recommends prioritizing **redevelopment policies**. This has high feasibility as it is fully under Caltrain's jurisdiction. Compared to other strategies, this option also has lower costs and high effectiveness since it will affect the majority of future infrastructure changes.

Amongst the operational strategies, ICF recommends prioritizing **redundant transportation routes**. This could be implemented in the near-term to fill gaps in service caused by coastal flooding events, providing immediate benefits for vulnerable ROW segments.

4 Next Steps

While many parts of Caltrain's system are vulnerable to sea level rise, ongoing adaptation efforts can address some of these vulnerabilities. However, coordination with the entities carrying out those efforts is critical to ensuring Caltrain's infrastructure is included under their protection. The adaptation strategies described above can address gaps for currently unprotected infrastructure. Caltrain can carry out the following next steps to address vulnerability for exposed stations, assets, and ROW:

- Addressing station vulnerability:
    - **Carry out a deeper assessment of how ongoing projects in Section 3.1 may provide protection for Caltrain stations and coordinate with entities operating those projects as needed.** In particular, look deeper into the SF Railyards project

(which may protect the San Francisco Station at 4th and King), OneShoreline projects (which may protect Millbrae and Broadway Stations), and the Foster City Levee (which may protect Hayward Park Station). As some of these projects are still in progress, it may be necessary to coordinate with the entities implementing these to check if they do protect Caltrain assets.

  - **Coordinate with Redwood City on their Sea Level Rise Vulnerability Plan.** Redwood City remains the one station exposed to sea level rise inundation that is not currently protected by ongoing efforts. Because Redwood City is currently developing a Sea Level Rise Vulnerability Plan, Caltrain can coordinate with them to work on identifying adaptation strategies that provide protection for Caltrain assets.
  - **For any remaining gaps, evaluate deployable barriers and flood walls as potential adaptation strategies.** Caltrain may carry out further investigations into the feasibility and effectiveness of these strategies to protect exposed stations and begin to invest in them as relevant.
- Addressing asset vulnerability:
  - **Carry out a deeper assessment of how the Millbrae and Burlingame Shoreline Area Protection and Enhancement Project can protect PS-3.** As this project is still in progress, it may be necessary to coordinate with OneShoreline to check if this project will protect Caltrain assets.
  - **To protect TPS1, evaluate floodproofing as a potential adaptation strategy.** Caltrain may carry out further investigations into the feasibility and effectiveness of wet and dry floodproofing to protect TPS1 and begin to invest in this strategy as relevant.
- Addressing ROW vulnerability:
  - **Carry out a deeper assessment of how ongoing projects in Section 3.1 may provide protection for Caltrain ROW and coordinate with entities operating those projects as needed.** The same projects that protect four of Caltrain's stations (San Francisco, San Bruno, Millbrae, Broadway, and Hayward Park) are also expected to protect the ROW surrounding those stations. As some of these projects are still in progress, it may be necessary to coordinate with the entities implementing these to check if they do protect Caltrain assets.
  - **For remaining exposed ROW segments (see Section 2.2.3), evaluate the use of floodwalls with deployable barriers as a potential adaptation strategy.** Caltrain may carry out further investigations into the feasibility and effectiveness of this strategy to protect exposed ROW and begin to invest as relevant.