

SAN FRANCISCO WATERFRONT COASTAL FLOOD STUDY, CALIFORNIA

FINAL INTEGRATED FEASIBILITY REPORT AND ENVIRONMENTAL IMPACT STATEMENT

JULY 2026



USACE TULSA DISTRICT | THE PORT OF SAN
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US Army Corps
of Engineers



COVER SHEET

San Francisco Waterfront Coastal Flood Study Final Integrated Feasibility Report and Environmental Impact Statement

City and County of San Francisco, California

Lead Agency: U.S. Army Corps of Engineers, Tulsa District

Cooperating Agencies: U.S. Environmental Protection Agency Region 9 (Formally Accepted), Federal Emergency Management Agency Region IX (Planning and Implementation Branch), National Marine Fisheries Service (Formally Accepted), National Park Service, U.S. Fish and Wildlife Service

Participating Agencies: California Department of Fish and Wildlife, California Regional Water Quality Control Board, California State Lands Commission, San Francisco Bay Conservation and Development Commission, and San Francisco Planning Department

Abstract: Low-lying assets and economic activity along the San Francisco waterfront are at risk of flooding from coastal storms, extreme high tides, and changing sea levels. The frequency and depth of tidal flooding along the shoreline is only expected to increase as sea levels continue to rise. The San Francisco Waterfront Coastal Flood Study, California is authorized to investigate the feasibility of managing tidal and fluvial flooding and changing sea levels along 7.5 miles of the San Francisco waterfront, from Aquatic Park to Herons Head Park, in the city of San Francisco, San Francisco County, California. This report has been prepared by the Tulsa District, Southwestern Division of the U.S. Army Corps of Engineers, in partnership with the Port of San Francisco to document the study results and findings, including the formulation of alternatives, the costs and benefits of alternatives considered, the selection process of the Recommended Plan and to disclose the impacts the alternatives may have on the human and natural environment. Short- and long-term impacts to existing aquatic habitats, fish and wildlife including Federally protected species and their habitat, water, air, aesthetics, noise, transportation corridors, recreation, historic, and socioeconomic resources are expected. Many of the impacts to other resources will be minimized or avoided through project design. Compensatory mitigation is needed to offset unavoidable impacts to aquatic habitats and may be required for impacts to air quality. Long-term benefits are anticipated to each of the socioeconomic resources such as life safety, critical infrastructure, utilities, historic resources, at-risk communities, recreation, and the local economy through the management of coastal flooding and relative sea level change.

For more information on this Final Integrated Feasibility Report and Environmental Impact Statement and the tribal, agency, and public involvement process conducted in conjunction with its preparation, write or call:

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Executive Summary

Introduction

The U.S. Army Corps of Engineers (USACE) Tulsa District prepared a Final Integrated Feasibility Report (IFR) and Environmental Impact Statement (EIS) for the San Francisco Waterfront Coastal Flood Study (SFWCFS) in conjunction with the Non-Federal Sponsor (NFS), the Port of San Francisco (POSF), acting as lead agency for the City and County of San Francisco (CCSF). It is a requirement of USACE planning policy and the National Environmental Policy Act (NEPA) of 1969 to make the report available for public review that describes the analysis of alternatives, risks, assumptions, and decisions made by the Project Delivery Team (PDT) during the planning process.

While this feasibility study final report identifies a Recommended Plan for the study area, current USACE policy precludes advancing the plan for Administration review and Congressional authorization until it reaches 35% design maturity. Currently at 20% design maturity, the Recommended Plan is justified by its “Total Net Benefits” across the entire Recommended Plan. The Recommended Plan provides a framework for implementation and includes early resilience actions formulated to mitigate coastal flood risk along the San Francisco Bay waterfront.

The Secretary of the Army’s recommendation to Congress to authorize Civil Works projects requires an assessment of compliance with Army Civil Works policies and technical requirements, including design maturity. Given the Recommended Plan is at 20% level of design, further design development is needed during the feasibility study phase to mitigate an unacceptably high risk of future cost growth. Moving forward, the NFS may undertake additional design and other implementation actions for elements of the recommended plan and advance those for Congressional authorization.

Purpose and Need

This study is being conducted in partial response to the study authority, investigating 7.5 miles of the San Francisco Bay shoreline. San Francisco faces multiple flood and other hazards (including seismic) now and over the next 50 to 100 years threatening its economy, communities, infrastructures, and environment. The purpose of this feasibility study is to frame those multiple risks and make specific recommendations for providing a resilient coastline that can withstand the uncertainties of changing physical conditions. The project area is at risk of flooding from bay water during coastal storms, extreme tides, and future relative sea level change (RSLC). Flooding along the waterfront could cause extensive damage to public infrastructure and private property, loss of life and deterioration of public health and safety, degradation of the natural environment, and adverse changes to the social and economic character of the waterfront community. The risk is expected to increase over time as sea levels change in the bay. Additionally,

the study area is in a high seismic hazard region and coastal flood risk measures will be designed in accordance with USACE seismic criteria.

Study Area

The study area extends approximately 7.5 miles from Aquatic Park in the northeast to just past Heron's Head Park in the south. The study area is divided into four reaches for conducting and evaluating coastal process and economic analyses. The reaches were originally defined based on several criteria including hydrologic separability, identifiable geographic references, specific wave action within each reach, and major differences in physical structure inventory within the reach. This separability depends upon the amount of RSLC, with lower levels of RSLC meaning that the reaches are more separable, while higher levels of RSLC require physical measures to separate several of the reaches. Infrastructure systems such as the combined sewer system, pass through all reaches and provide a hydraulic path that makes hydraulic separability at the reach level difficult, especially at higher levels of RSLC. However, the implementation plan has separable elements within the reaches, but those separable elements would require additional measures, such as outflanking. These reaches also provide a neighborhood-scale approach to communicate risks, impacts, and alternatives. Reach delineations include the following:

- **Reach 1:** Covers Aquatic Park, Fisherman's Wharf, Pier 31 to Pier 35, and the North Beach neighborhood.
- **Reach 2:** Includes the Northeast Waterfront and Financial District.
- **Reach 3:** Contains South Beach, Mission Creek, Mission Rock, Mission Bay, and Pier 70, and includes the South Beach, South of Market Street, and Mission Bay neighborhoods.
- **Reach 4:** Encompasses Pier 80, Islais Creek, Cargo Way, Pier 96, and Heron's Head Park.

Study Area Problems

Low-lying assets and economic activity along the San Francisco waterfront are at risk of flooding from coastal storms and extreme high tides, and from the potential failure of the century-old San Francisco seawall, which could result from structural instability of underlying soils.

The waterfront is currently at risk of coastal overtopping and damages to property and critical infrastructure because of coastal storms, including the contribution of stillwater, waves, and wave runup. Rising sea levels will result in regularly occurring tides that exceed existing Bay shoreline elevations and cause extensive flooding, impacting public infrastructure and private development. The rate of RSLC is uncertain and could rise from 1 to 10 feet by 2140.

Absent any Federal action, coastal storm risk to the study area will increase. The rate and severity of increasing risks is directly connected to rates of RSLC (**Figure ES-1**). Without any Federal action, the study area may be subject to intense inundation by a

1% annual exceedance probability (AEP) flood event by 2140, though the extent of inundation is dependent on the rate of RSLC (Figure ES-2).

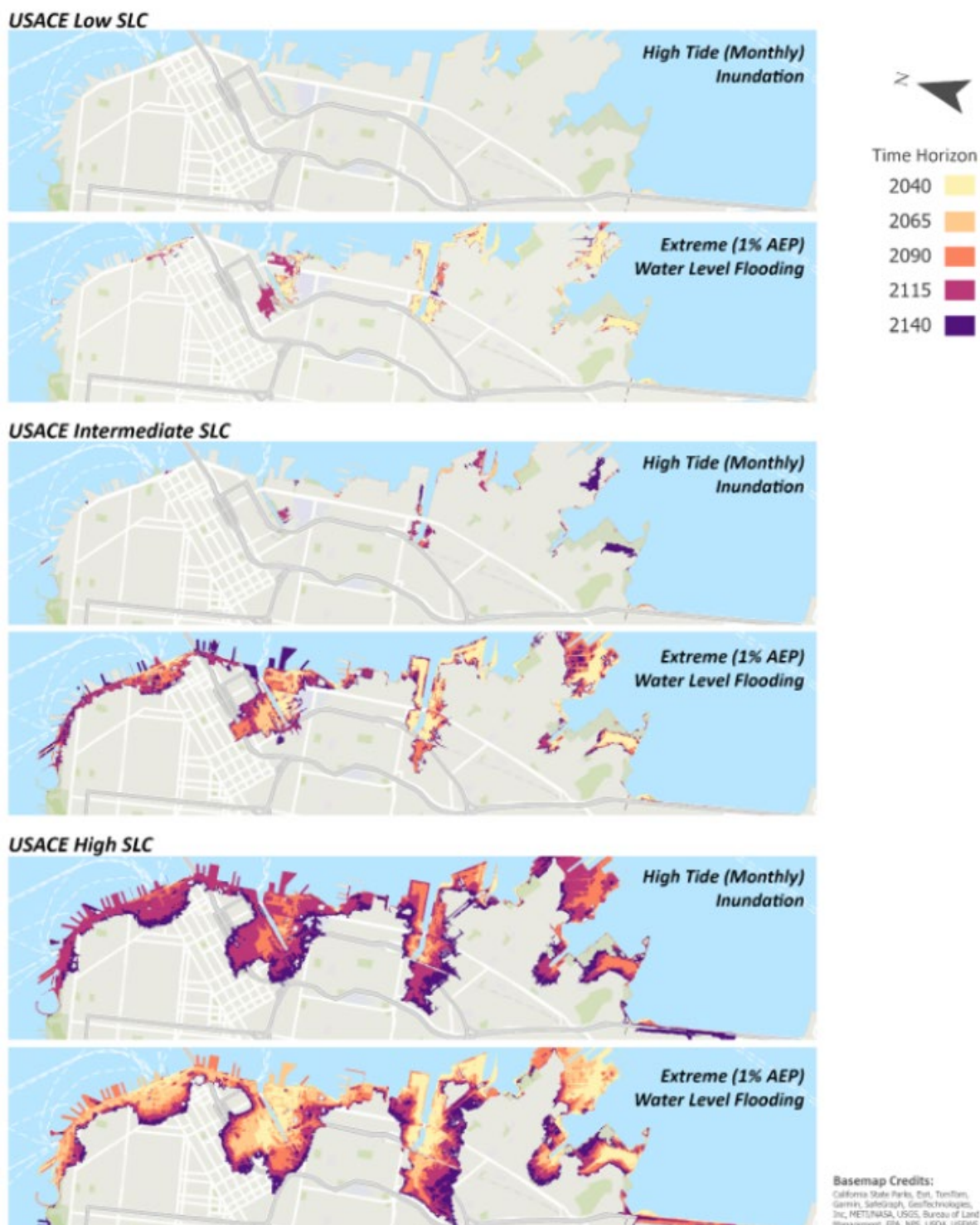
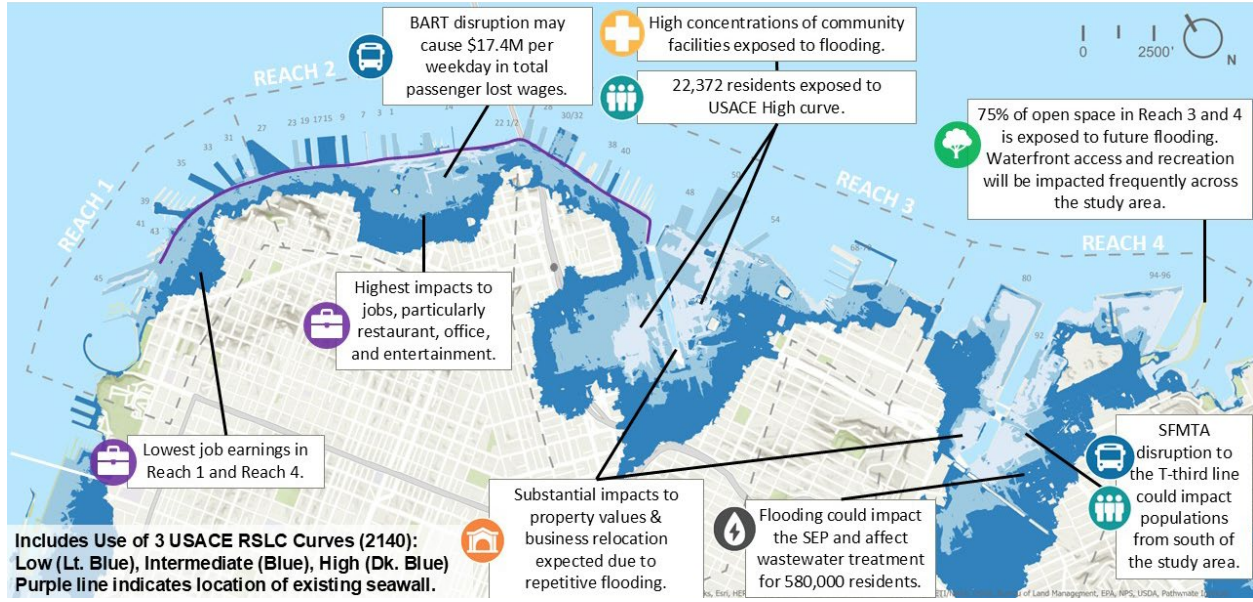


Figure ES-1: High Tide (Monthly) and Extreme (1% AEP) Water Level Flood Extents with USACE Low, Intermediate, and High RSLC (relative to 1992)



Note: The shades of blue reflect the three RSLC curves, with the lightest blue being the USACE Low curve, and darkest the High curve.

Figure ES-2: Extent of Inundation Per Reach Expected Under 1% AEP Flood Event in Future Without Project Conditions Under the Three RSLC Curves

Soil conditions in fill areas along the 7.5-mile waterfront study area could cause the ground to liquefy during an earthquake, as occurred in major earthquakes in 1906 and 1989. Settlement as a result of liquefaction is likely to moderately lower the elevation along the waterfront, exposing segments of the critical shoreline infrastructure to greater risk of flooding.

Planning Objectives and Constraints

As part of the USACE planning process, the PDT and stakeholders identified planning objectives and constraints. The planning objectives and constraints describe what a successful plan will accomplish. The following study-specific planning objectives for the 100-year period of analysis (POA), from 2040 to 2140, were identified for this study:

- Reduce risk to human health and safety from coastal hazards and flooding due to sea level rise, wave run up, and precipitation (combined flooding) in the study area
- Reduce costs and risks to the national, regional, and local economy associated with coastal hazards and combined flooding to business, residents, and infrastructure in the study area
- Increase community resilience opportunities from coastal hazards and combined flooding in the study area
- Reduce disruption to maritime facilities and functions caused by coastal hazards and combined flooding through resilience strategies that support cargo shipping,

cruise, ferry and water taxis, excursion boats, fishing, ship repair, berthing, harbor services, recreational boating, and other water-dependent activities

- Manage risk from coastal hazards and combined flooding to historic resources and preserve the maritime history of the waterfront
- Increase the ability and flexibility to respond to uncertain rates of RSLC

Planning constraints represent restrictions that limit the extent of the planning process and potential solutions. Plans should be formulated to meet the objectives and avoid violating the constraints. The following study-specific constraints for the 100-year POA, from 2040 to 2140, were identified for this study:

- Avoid actions that may violate the authority of the Port Commission to fulfill its public trust responsibilities consistent with the Burton Act (Chapter 1333 of the California Statutes of 1968)
- Minimize disruption to permitted public access, including the San Francisco Bay Trail, San Francisco Bay Water Trail, Blue Greenway, bike paths, harbor walks, and pedestrian walkways
- Maintain ecological functions and minimize ecological disruptions in the Bay
- Avoid removing vital community infrastructure in at-risk communities such as libraries, community centers, health centers, and homeless shelters
- Avoid major loss of existing housing

Planning Framework

The USACE Civil Works planning process follows a standard approach to formulate potential water resource solutions to ensure Federal projects comply with applicable laws and guidance. The 1983 Economic and Environmental Principles and Guidelines for Water and Related Land Implementation Studies (P&G) established by the U.S. Water Resources Council on March 10, 1983, were developed to guide the formulation and evaluation studies of the major Federal water resources development agencies.

The P&G established four accounts to facilitate the evaluation and display of the economic benefits and effects of alternative plans. These four accounts are: National Economic Development (NED), Regional Economic Development (RED), Other Social Effects (OSE), and Environmental Quality (EQ). Benefits and effects of all four accounts (WRC 1983) were considered during the plan formulation process. The four benefits categories are summarized below:

- **NED account:** Includes consideration of a measure's potential to meet the planning objective to reduce storm damage, as well as decrease costs of emergency services, lower flood insurance premiums, and evaluate project costs.

- **RED account:** Includes consideration of the potential regional economic impacts of flooding along the San Francisco waterfront, the Bay Area, and the larger California economy.
- **OSE account:** Includes considerations for the preservation of life, health, and public safety; community cohesion and growth; tax and property values; and the displacement of businesses and public facilities.
- **EQ account:** Displays non-monetary benefits and costs regarding significant ecological, cultural and aesthetic resources.

Planning Horizon and Period of Analysis

The effects of alternative plans are evaluated based on a comparison between the most likely future conditions with and without those plans in place, called the future with project (FWP) and the future without project (FWOP), respectively. The planning horizon encompasses the study period, the implementation period, the economic POA, and the effective life of the project. The timeframe used when forecasting FWOP and FWP conditions is the POA, or the period over which plan effects are measured.

The POA for water resources projects typically extends 50 years following construction. Although project structures will often function for longer than 50 years, forecasting economic and physical conditions and impacts beyond 50 years becomes uncertain because conditions may change considerably over that length of time.

As directed by the USACE guidance for this study, the POA for this study extends 100 years from 2040 until 2140 due to actions triggered by coastal and combined flood risk and RSLC and long-life infrastructure investment.

Plan Formulation Strategy

Coastal and combined flood risk will increase at an uncertain rate over the 2040 to 2140 POA. Although flood events may occur in the study area, the scale of flood event is primarily influenced by the water surface elevations that result from a coastal flood event in combination with RSLC. The plan formulation strategy sought to identify different approaches to reduce flood risk now and into the future with an array of alternatives that would inform whether early, phased, or later interventions would be most cost-effective and avoid or minimize study area impacts.

Formulation of alternatives to manage coastal and combined flood risk included:

- An overall approach to defend, accommodate, or retreat from coastal and combined flood risk consisting of structural and nonstructural measures and natural and nature-based features (NNBFs) along different lines of defense including:
 - Alignment along existing shoreline
 - Alignment bayward of existing shoreline
 - Alignment inland of existing shoreline

- Varied scales of features to reflect uncertain timing of RSLC
- Phased implementation of features within most alternatives

Plan formulation in response to the study authority was conducted in two broad phases. An initial planning iteration considered distinctly different conceptual approaches to coastal and combined flood risk management in the region. The PDT then conducted an initial screening of the conceptual approaches. The second and most significant phase of plan formulation assessed cost-effective approaches. The PDT developed a focused array of alternatives and evaluated NED benefits and costs for the three RSLC conditions (USACE Low, Intermediate, and High curves), in accordance with the specific guidance for the study, to identify the NED plan for each condition. The PDT then developed a final array of alternatives as a combination of varied reach-level components of the focused array. A comprehensive benefits analysis of the final array was then conducted across all four P&G accounts to identify the Total Net Benefits Plan (TNBP) as the Tentatively Selected Plan (TSP) for the Draft IFR/EIS. Following public and agency review of the draft report, the TSP was refined and developed further into the Recommended Plan to increase benefits and reduce costs and impacts.

Initial Planning Iteration

As an initial planning iteration, the PDT developed 11 conceptual structural approaches on a horizontal alignment, referred to as the line of defense (LOD) using a range of appropriate measures. These initial conceptual approaches were evaluated and screened based on completeness, effectiveness, efficiency, and acceptability in consultation with representatives from CCSF and regional agencies and resource and regulatory agencies. The conceptual approaches included a deployable water management structure at the Golden Gate Bridge, an offshore wave attenuator, several scales of offshore barriers, perimeter plans along the Bay coastline, and two forms of retreat.

Preliminary evaluation of these conceptual approaches confirmed that the perimeter plan is the most cost-effective approach to coastal and combined flood risk management in the study area over the 100-year POA. The other conceptual approaches were screened from further development or consideration. Consequently, only perimeter alternatives were considered in subsequent plan formulation.

Formulation Elements

Four elements were applied to develop an array of alternatives for this study, which are consistent with the formulation guidance developed for the study:

- Approaches to reduce risk
- LODs and zones
- Varied scaling of features
- Adaptation as Subsequent Actions

Approaches to Reduce Risk

The timing of RSLC is uncertain, so the focused array was formulated to reveal lessons about cost effectively managing flood risk with uncertain timing, whether to retreat or defend, or to build big initially or to build smaller and adapt later. Four broad, conceptual, high-level approaches – Defend, Accommodate, Retreat, and Hybrid – were developed as a basis for formulating plans to address coastal and combined flood risk management. NNBFs can be part of all these approaches. The terms are defined as follows:

- **Defend** means measures will be used to block Bay waters, either at the current shoreline alignment, bayward of the current alignment, or slightly landward of the current shoreline.
- **Accommodate** can include nonstructural measures to live with water, moving the LOD landward as managed retreat to move people and assets away from the water, or a combination of both of these approaches.
- **Retreat** scenarios are designed to “align with watersheds” by advancing the LOD and shoreline landward, while working with natural inland flooding patterns through a series of nonstructural and structural measures. Floodproofing of some buildings and infrastructure would occur in areas of lower risk, while other assets would be moved away from the current Bay shoreline in highest risk areas.
- **Hybrid** means a combination of these approaches could be used throughout the study area based on flood risk and assets.

Lines of Defense and Zones

For each structural alternative, a horizontal alignment, referred to as the LOD, was developed to provide protection against coastal flooding and RSLC. The LOD varies by strategy and by location throughout the waterfront (e.g., the LOD can be further inland in one location, compared to right along the existing shoreline or shifted slightly toward the Bay in other locations). The selection of the LOD for each strategy was informed by a preliminary examination of local space constraints (e.g., is there enough space for a gradual versus steep elevation transition) and based on the public realm and urban design assumptions adopted for this effort.

Varied Scaling of Features

Within the broad conceptual approaches, the PDT formulated alternatives that vary the scale and timing of the structural and nonstructural strategies to support comparison of cost and performance under the uncertain timing of the RSLC component of the inundation risk. Thus, the array of alternatives includes variations of structural and nonstructural features that are scaled to address varying RSLC conditions.

Adaptation as Subsequent Actions

A final aspect of the plan formulation strategy is to identify phased implementation of the features to balance two important criteria for plan selection: cost-effectiveness and

adaptability to uncertainty across the POA. Adaptations were described in sufficient detail to support estimation of benefits and costs of the alternatives, and scales of adaptation correspond to the target level of performance of each alternative. At this initial stage of plan development, implementation was assumed to occur in a two-step process with the First Actions completed around 2040 and Subsequent Actions occurring around 2090 based on risk. However, a Monitoring and Adaptation Plan (MAP) will ultimately be used to model what the forecasted implementation strategy might look like given the associated risks, and to describe the implementation process for the Subsequent Actions.

The measures considered for this study can reduce risk alone or in combination. They were screened for applicability, function and space constraints, and anticipated cost-effectiveness. Smaller scales of NNBFs are considered for their function to reduce risk in specific applications and to replicate natural coastal processes that are displaced by hardened shorelines. The PDT consulted with the USACE National Nonstructural Committee and incorporated lessons learned from current nonstructural policy concerns and recent coastal and combined flood risk management studies conducted by three USACE districts.

Treatment of Seismic Costs

Section 152 of WRDA 2020, as amended by Section 8380 of WRDA 2022, provides for the treatment of certain benefits and costs for flood risk management projects in regions of moderate or high seismic hazard. The study area is in an area of high seismic hazard; thus, alternatives were formulated with full consideration of applicable USACE engineering design standards needed to address seismic hazards in the study area. However, in accordance with the requirements of Section 152, as amended, the costs of the features necessary to address seismic concerns were excluded from the NED cost of alternatives and the benefit-cost ratio. These costs are included in determining the total cost of the Recommended Plan and in determining cost-sharing requirements for the Recommended Plan.

Identification and Screening of Management Measures

Management measures are features or actions that contribute to the planning objectives. Coastal and combined flood risk management measures consist of three basic types: structural measures, nonstructural measures, and NNBFs. Measures were derived from a variety of sources, including the NEPA scoping process and coordination with stakeholders. The measures considered for this study can reduce risk alone or in combination. They were screened for applicability, function and space constraints, and anticipated cost-effectiveness.

Focused Array of Alternative Plans

The screened and retained measures were used to develop a focused array of alternative plans consistent with the broad conceptual approaches of defend, accommodate, retreat, and hybrid; identify a phased adaptation approach; and incorporate NNBFs, as appropriate or possible.

The study area is an urban waterfront that includes housing, POSF working lands, municipal and transit assets, entertainment arenas, medical facilities, commercial corridors, cultural districts, historical assets, and open spaces. Accordingly, alternatives were formulated with consideration of urban design and public realm drivers. The development of the focused array was informed by the POSF's 7-month intensive engagement process with CCSF agencies and the communities in the study area.

The alternatives were formulated to address uncertain timing of RSLC over the POA. **Table ES-1** displays the estimated water surface elevation of the 1% AEP storm in 2011, 2040, 2090, and 2140. The results show that by 2140, water levels will increase by 0.84, 2.75, and 8.82 feet under the low, intermediate, and high USACE RSLC projections, respectively. The table also shows the incremental increases by the year 2090. The PDT used these RSLC calculations to guide the development of project elevations to use in alternative formulation. **Table ES-2** shows how different base years influence the RSLC value due to the statistical variation in water levels over time.

Table ES-1: Change in 1% AEP Water Surface Elevation over Time

Sea Level Change Scenario ^a	1% AEP ^b (feet NAVD88)				RSLC (feet)	
	2011	2040	2090	2140	2011-2090	2011-2140
USACE Low	9.67	9.86	10.18	10.51	0.51	0.84
USACE Intermediate	9.67	10.03	11.00	12.42	1.33	2.75
USACE High	9.67	10.58	13.61	18.49	3.94	8.82

^a9414290 Presidio / San Francisco Tide Gauge

^bPier 22 ½, point 868 from the Federal Emergency Management Agency study (AECOM 2016)

Values reflected in this table include the 1% AEP near Pier 22 ½ and RSLC baselined to 2011 for alignment with the November 15, 2021, revised version of *San Francisco Waterfront Storm Damage Reduction Study (SFWS) Incorporation of Relative Sea Level Change (RSLC) into the Formulation and Evaluation Process White Paper*, which informed early plan formulation discussions (values updated based on the Sea Level Analysis Tool). Further information on how the study eventually established crest elevations for specific alternatives is available in *Appendix B: Engineering, Section 3.3 Setting Crest Elevation*. RSLC values throughout this report are baselined to 2000 unless otherwise noted.

NAVD88 = North American Vertical Datum of 1988

Table ES-2: RSLC Value Comparisons

	RSLC by 2040 (feet)			RSLC by 2090 (feet)			RSLC by 2140 (feet)		
Base year	1992	2000	2011	1992	2000	2011	1992	2000	2011
USACE Low	0.3	0.3	0.2	0.6	0.6	0.5	1.0	0.9	0.8
USACE Int	0.5	0.5	0.4	1.5	1.4	1.3	2.9	2.9	2.8
USACE High	1.2	1.1	0.9	4.2	4.1	3.9	9.1	9.0	8.8
CA Likely	1.0	0.8	0.7	3.0	2.9	2.8	5.5	5.3	5.2
CA 1:200	1.5	1.3	1.3	5.8	5.7	5.6	11.9	11.8	11.7

This table displays USACE and California Ocean Protection Council RSLC values across baseline years 1992, 2000, and 2011. Inputs for analysis were developed in accordance with USACE requirements, detailed in the *Annex B.1.1. Coastal Extreme Water Levels and High Tide Flooding*. State of California projections are provided for contextual reference and did not inform plan formulation.

The PDT identified representative scales of RSLC as building blocks of 1.5 feet, 3.5 feet, and 7 feet of RSLC (**Table ES-3**). These increments were selected because they allowed an alternative to be effective under at least one RSLC scenario while also facilitating a transition to the next scenario. For example, the first increment of 1.5 feet is sufficient to cover a low rate of RSLC for 100 years, while also covering an intermediate rate for 50 years. Similarly, 3.5 feet covers 100 years of Intermediate RSLC, and almost covers 50 years of High RSLC. The PDT stopped at 7 feet because that degree of RSLC creates significant public safety concerns. Retreat is believed to be the safest option in that scenario, but that decision does not need to be made at this time. Stopping at 7 feet allows the evaluation results to show the severe consequences of storms at those levels, highlighting the importance of that future decision. *Appendix A: Plan Formulation, Section 11: Focused Array of Alternative Plans*, provides additional clarification of how this building block approach aligns with *ER 1100-2-8162 Incorporating Sea Level Change in Civil Works Programs* and *EP 1100-2-1 Procedures to Evaluate Sea Level Changes: Impacts, Responses, and Adaptation*.

The formulation strategy also included a simple two-step adaptation framework with First Actions and Subsequent Actions. For purposes of analysis, Subsequent Actions were assumed to be implemented around 2090 when necessary to address increasing risk. Actual implementation of Subsequent Actions would be guided by the MAP (*Appendix G: Monitoring and Adaptation Plan*). The focused array includes seven alternatives, including the No Action Alternative, and are summarized in **Table ES-4**.

Table ES-3: RSLC Building Blocks for Plan Formulation

Building Block		Expected Time Horizon to Maintain Performance Target, per USACE RSLC Scenario ^{a,b}		
Performance Target Considerations ^a	Crest Elevation ^c	Low	Intermediate	High
1.5 feet RSLC + 1% AEP coastal	13.5 feet NAVD88	Entire POA	Through ~2090	Through ~2050
3.5 feet RSLC + 1% AEP coastal	15.5 feet NAVD88	Entire POA	Entire POA	Through ~2080
7.0 feet RSLC + 1% AEP coastal	19.0 feet NAVD88	Entire POA	Entire POA	Through ~2120

^aFor the purposes of this table, the “performance target” assumes defense against the 1% AEP coastal flood event considering RSLC and assuming 1% wave hazards do not occur concurrent with 1% AEP stillwater levels (*Appendix B: Engineering, Section 3.3 Setting Crest Elevation*). Residual risk – due to less frequent, higher magnitude coastal flood events – was considered tolerable. Baseline 2000.

^bTable 2-6 provides a summary of RSLC over time across each USACE scenario.

^cActual crest elevation would vary along the waterfront based on local wave conditions, pending further analysis in preconstruction engineering and design.

AEP = annual exceedance probability

MHHW = mean higher high water

NAVD88 = North American Vertical Datum of 1988

POA = Period of Analysis (2040-2140)

Table ES-4: Focused Array of Alternative Plans

Alternative Name	First Actions		Subsequent Actions			
	Crest Elevation ^a	Description ^b	Crest Elevation ^a			Description ^b
			Low	Int	High	
Alternative A: No Action	--	No actions beyond FWOP	--	--	--	No actions beyond FWOP
Alternative B: Nonstructural	--	Floodproofing buildings in Reaches 1-4, phased over time	--	<i>Only nonstructural actions</i>	<i>Only nonstructural actions</i>	Floodproofing more buildings, phased over time
Alternative C: Defend, Scaled for Lower Risk	13.5 feet NAVD88	Defend at existing shoreline in Reaches 1-4	--	--	--	No actions beyond FWOP
Alternative D: Defend, Scaled for	13.5 feet NAVD88	Defend at existing shoreline in Reaches 1-4	--	15.5 feet NAVD88	15.5 feet NAVD88	Increase crest elevation of defense

San Francisco Waterfront Coastal Flood Study

Alternative Name	First Actions		Subsequent Actions			
	Crest Elevation ^a	Description ^b	Crest Elevation ^a			Description ^b
			Low	Int	High	
Low-Moderate Risk		Designed to support building higher as risk increases				structure along existing shoreline in Reaches 1-4
Alternative E: Defend Existing Shoreline, Scaled for Higher Risk	15.5 feet NAVD88	Defend at existing shoreline in Reaches 1-4 Designed to support building higher as risk increases	--	--	19.0 feet NAVD88	Increase crest elevation of defense structure along existing shoreline in Reaches 1-4
Alternative F: Manage the Water, Scaled for Higher Risk	15.5 feet NAVD88	Defend bayward of existing shoreline in Reaches 1, 2, and 3 north of Mission Creek Water control structures at creeks Defend at existing shoreline in Reach 3 south of Mission Creek Defend inland of industrial piers in Reach 4	--	--	19.0 feet NAVD88	Increase crest elevation of defense structure along existing shoreline in Reaches 1, 2, and parts of Reaches 3 and 4 Raise new inland defense structure in remaining portions of Reaches 3 and 4
Alternative G: Partial Retreat, Scaled for Higher Risk	15.5 feet NAVD88	Defend at existing shoreline in Reaches 1, 2, and 3 Defend inland in Reach 4	--	--	19.0 feet NAVD88	Increase crest elevation of defense structure along existing shoreline in Reaches 1, 2, and parts of Reaches 3 and 4 Raise new inland defense structure in remaining portions of Reaches 3 and 4

NAVD88 = North American Vertical Datum of 1988

^aCrest elevation columns indicate the assumed structural measure crest elevation for purposes of alternatives evaluation. Actual crest elevation would vary along the waterfront based on local wave conditions, pending further analysis in preconstruction engineering and design.

^bAlternatives C-G include a mix of structural measures, nonstructural measures, and NNBFs. The brief description here is intended to highlight key differences in overarching approach. Comprehensive descriptions are available in Section 3.

Alternative A is the No Action Alternative and is the FWOP condition. Alternative B is the nonstructural alternative and was formulated to represent decisions to either floodproof or retreat from assets over time as flood risk increases. Alternatives C and D are scaled to address low to intermediate rates of RSLC. Alternative C does not include considerations for future adaptation. Alternative D includes a Subsequent Action to increase the crest elevation as risk increases. Alternatives E, F, and G were formulated to address intermediate to high rates of RSLC, and they include Subsequent Actions to address increasing risk.

An NED evaluation of the focused array was conducted by the PDT. Consistent with study guidance, the alternative plans were evaluated under three USACE RSLC scenarios. *Appendix E: Economic and Social Considerations* provides additional detail regarding which benefits are captured under which account. For example, while avoided damages related to adjacent infrastructure systems are included in the NED account, the operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) benefits are considered under the OSE account. This does not influence selection of the Recommended Plan because all structural alternatives have similar footprints as a result of shoreline stabilization necessary to meet the requirements of ER 1110-2-1806.

The plans that maximize net NED benefits by reach by RSLC curve are shown in **Table ES-5**. The NED evaluation will likely understate residual risk due to disruption to people and businesses during and after floods (e.g., from a reduction in foot traffic due to streets being flooded) and there will be impacts when high-frequency flooding causes businesses to have to move out of the floodplain that are not currently calculated under the RED account. Finally, the strict NED evaluation misses the real-world significance that the implementation timeline has on a project of this magnitude in a complex, metropolitan area. Future benefits are discounted heavily in the evaluation, but the lengthy timeline to complete construction means that costs are incurred earlier in the evaluation period are not substantially discounted, creating a challenge for justification of large coastal flood studies. The PDT has considered this in selection of the Recommended Plan.

Table ES-5: NED Plan by Reach Under Each RSLC Curve

Reach	Low RSLC	Intermediate RSLC	High RSLC
1	No Action	B Int.	B High
2	B Int.	B Int.	G
3	B Int.	B Int.	B High
4	B Int.	B Int.	B High

Final Array of Alternatives

The alternatives in the focused array were evaluated on a waterfront-wide basis that combined all four reaches. For the final array, these alternatives were evaluated at the reach level to support the comprehensive benefits analysis across all four P&G accounts to develop a TNBP to maximize net benefits across all benefit categories. The PDT quantified a broad array of metrics in the four benefit categories to see how the various plans performed in the different plan dimensions. After the quantification of the NED, RED, OSE, and EQ metrics, the PDT created “decision drivers” matrices to help in the visualization of the metrics by plan, reach, and RSLC curve. The “decision drivers” matrices included only a subset of the RED and OSE metrics quantified.

The TNBP was created by comparing performance of the alternative plans for each reach under each RSLC scenario and across the RSLC scenarios to assess the best series of actions to maximize benefits across all four accounts and meet the study objectives. Adaptability of the plan components over 100 years is the critical study consideration to ensure that a plan can best address risk under uncertain timing of RSLC. Although adaptation has been simplified to reflect implementation in 2090 to model the benefits and costs, a MAP will be developed to define risk triggers to clarify the appropriate scale, alignment, and timing of the adaptation. This resiliency requirement drives the TNBP to include multiple potential adaptations to address many potential risk scenarios over the study period. The TNBP was formulated as a resilience strategy to create a continuum of potential plan adaptations to a changing risk scenario.

Recommended Plan

The TNBP was formulated by combining the features of the initial array of alternatives to create a plan that maximizes total net benefits across all possible RSLC scenarios and was selected as the TSP for the Draft IFR/EIS. Following public and agency review of the Draft IFR/EIS, the TSP was refined and developed into the Recommended Plan for this Final IFR/EIS.

The Recommended Plan manages coastal flood risk through a suite of measures that function as a system, based on rising sea levels, and are implemented over time based on the risk of RSLC.

The Recommended Plan consists of two phases of intervention to reduce risk within the study area over a 100-year POA. For analysis, the years 2040 and 2090 were used as approximate First Actions and Subsequent Actions years. The actual timing and implementation of the First Actions will be dependent upon project funding and preconstruction activities, while the timing of Subsequent Actions will be refined in response to monitoring of RSLC and other changing conditions (*Appendix G: Monitoring and Adaptation Plan*). Recommended Plan First Actions are independent of the rate of RSLC. The Subsequent Actions vary in scale by RSLC (Low, Intermediate, or High) to maintain the performance of the system over the full POA based on changing risk conditions. **Figure ES-3** depicts the conceptual framework for the Recommended Plan First Actions and Subsequent Actions.

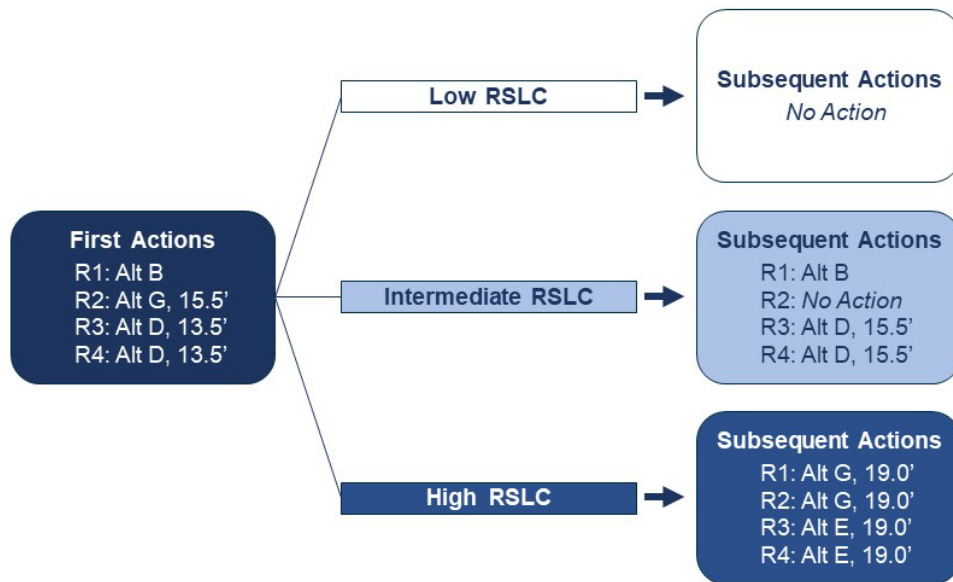


Figure ES-3: Conceptual Framework for Recommended Plan First Actions and Potential Range of Subsequent Actions

The Recommended Plan is a cost-effective, hybridized plan that combines retreat, accommodation, and defend measures, scaled to perform under initial risk and to adapt to risk of a higher rate of RSLC as potential Subsequent Actions. The Recommended Plan is summarized in **Table ES-6**. Each reach has First Actions, assumed to be completed in 2040, and a range of Subsequent Actions, assumed to occur in response to future conditions.

Table ES-6: Recommended Plan First and Potential Subsequent Actions

Reach	First Action		Subsequent Action			
	Crest Elevation ^a	Description ^b	Crest Elevation ^a			Description ^b
			Low	Int	High	
1	--	Floodproofing buildings, phased over time (Alternative B)	--	<i>Only nonstructural actions</i>	<i>New defense structure:</i> 19.0 feet NAVD88	<i>Intermediate:</i> Floodproof more buildings, phased over time (Alternative B) <i>High:</i> Defend at existing shoreline (Alternative G)
2	15.5 feet NAVD88	Defend at existing shoreline (Alternative G)	--	--	19.0 feet NAVD88	<i>High:</i> Increase crest elevation of defense structure along existing shoreline (Alternative G)
3	13.5 feet NAVD88	Defend at existing shoreline (Alternative D)	--	15.5 feet NAVD88	19.0 feet NAVD88	Increase crest elevation of defense structure along existing shoreline (<i>Intermediate:</i> Alternative D; <i>High:</i> Alternative E)
4	13.5 feet NAVD88	Defend at existing shoreline (Alternative D)	--	15.5 feet NAVD88	19.0 feet NAVD88	Increase crest elevation of defense structure along existing shoreline (<i>Intermediate:</i> Alternative D; <i>High:</i> Alternative E)

^aCrest elevation columns indicate the assumed structural measure crest elevation for purposes of alternatives evaluation. Actual crest elevation would vary along the waterfront based on local wave conditions, pending further analysis in preconstruction engineering and design.

^bFirst and Subsequent Actions include a mix of structural measures, nonstructural measures, and NNBFs. The brief description here is intended to highlight key differences by reach. Comprehensive descriptions are available in Section 5.

NAVD88 = North America Vertical Datum of 1988

Recommended Plan First Actions include the following:

- Reach 1: Nonstructural measures, such as dry and wet floodproofing of structures vulnerable to coastal inundation before 2090, and a 2-foot-tall concrete curb around piers.
- Reach 2: Structural measures that raise the shoreline to defend against 3.5 feet of RSLC and a 1% AEP coastal flood event. Measures include raised and rebuilt bulkhead seawalls and wharves, ground improvement to ensure measures meet seismic performance requirements, a closure structure at the transition from

structural to nonstructural measures, a 2-foot-tall concrete curb around piers, regrading and replacement of the Embarcadero roadway and trackway, elevated historic bulkhead buildings and Ferry Building, floodproofing at-risk buildings bayside of the coastal defense, Engineering with Nature features, and green/gray infrastructure compatible with existing combined sewer system to manage interior drainage.

- Reaches 3 and 4: Structural measures that raise the shoreline to defend against 1.5 feet of RSLC (baseline 2000) and a 1% AEP coastal flood event. Measures include features listed for Reach 2 above with the addition of levees and floodwalls.

The Recommended Plan First Actions are shown in **Figure ES-4** and the Recommended Plan Subsequent Actions are shown in **Figure ES-5** and **Figure ES-6**.

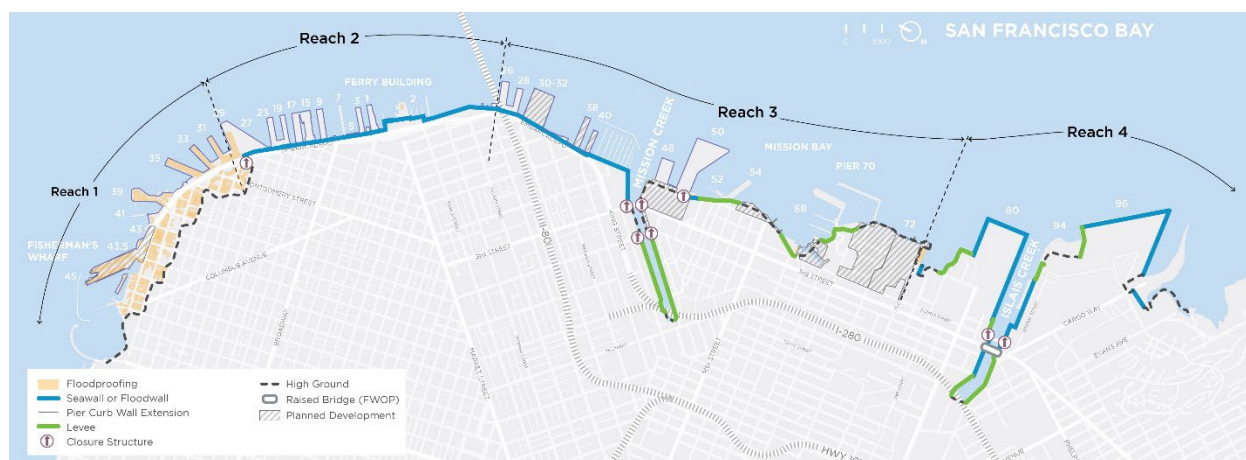


Figure ES-4: Recommended Plan First Actions

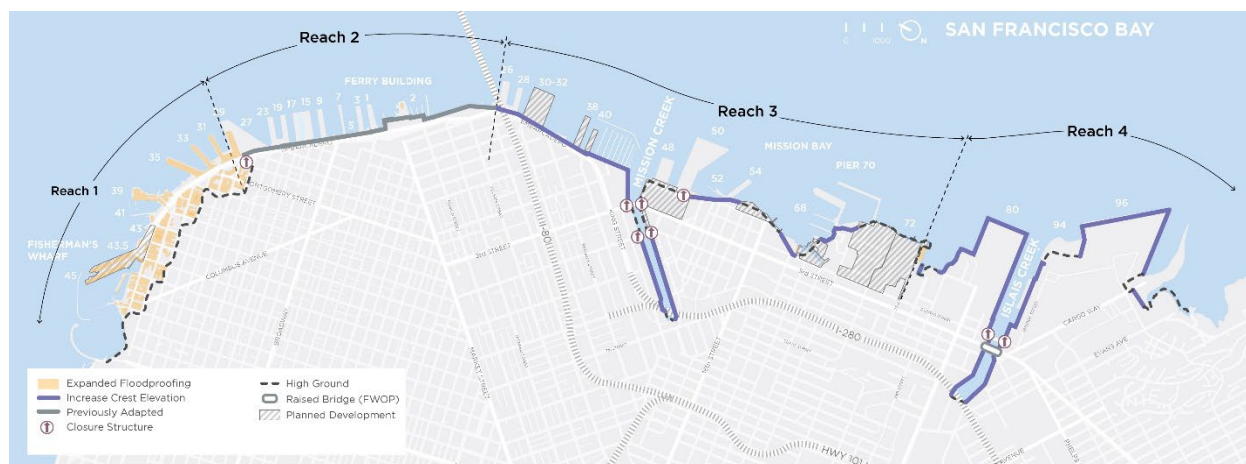


Figure ES-5: Recommended Plan Subsequent Actions (Intermediate RSLC)

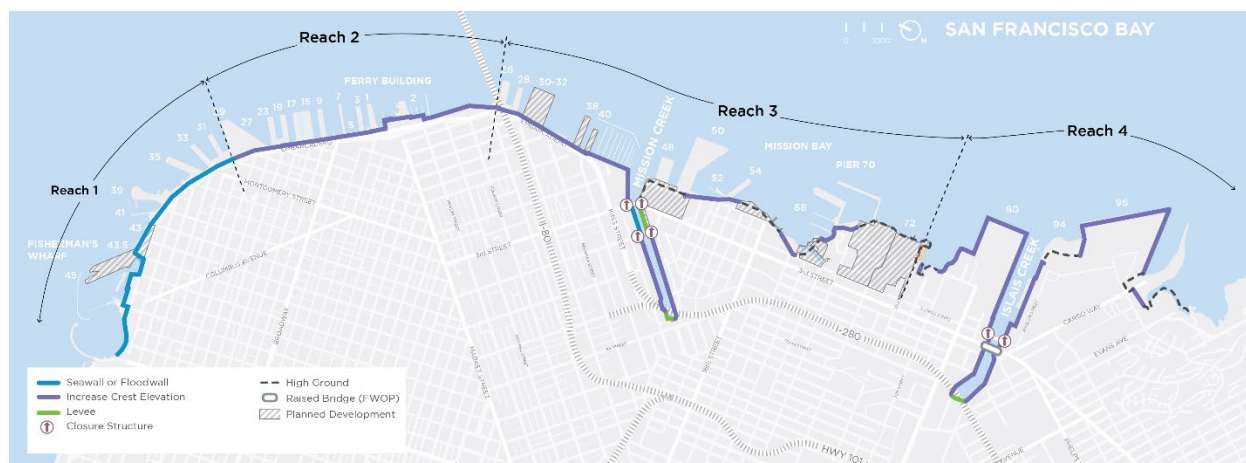


Figure ES-6: Recommended Plan Subsequent Actions (High RSLC)

Pertinent Data

The physical quantities and extents of the Recommended Plan features are summarized in **Table ES-7**.

Table ES-7: Physical Quantities and Extents of Recommended Plan First Actions

Measure	Total Project		
	Linear Feet	Square Feet	Acres
Floodproofing	--	2,835,000	65
Deployable	--	50,000	1
Elevate Structures	--	750,000	17
Relocate Structures	--	175,000	4
Remove Structures	--	195,000	4
Curb Wall	51,200	--	--
Elevate Shoreline	11,500	1,030,000	24
Seawall	21,000	--	--
T-wall	1,000	--	--
Elevate/Rebuild Wharf	10,900	660,000	15
Paved Levee	1,800	80,000	2

Measure	Total Project		
	Linear Feet	Square Feet	Acres
Planted Levee with EWN Features	11,800	865,000	20
Sheet-Pile Wall with EWN Features	2,900	20,000	0
EWN – Marsh/Coarse Beach Restoration	--	225,000	5
EWN – Rocky Intertidal Bluff	--	85,000	2
Living Seawalls	TBD	--	--
Bay Fill	--	395,000	9
Ground Improvements	38,400		

Linear feet is rounded to the nearest 100 feet, square feet is rounded to the nearest 5,000 square feet, and acres are rounded to the nearest whole number. Values denoted as "--" indicate the measurement was not calculated or applicable

EWN = Engineering With Nature

Costs and Comprehensive Benefits

At Fiscal Year (FY) 2026 price levels, the Recommended Plan has an estimated project first cost of \$17,812,115,000 for the First Actions (**Table ES-8**) and an annualized cost of \$672,477,000 based on a 3.25% discount rate (**Table ES-9**). The annualized cost includes planning, engineering and design, construction management, interest during construction, and OMR&R, including contingencies.

In compliance with Section 152 of WRDA 2020, as amended by Section 8380 of WRDA 2022, the project costs have been allocated into “seismic” and “non-seismic” for the purposes of economic evaluation. The “seismic” cost is equivalent to the total project cost, while the “non-seismic” cost deducts the cost of elements of the plan that would not be required in a low seismic hazard region. For the purposes of this study, the cost of ground improvement required to meet the seismic design requirements of ER1110-2-1806 are allocated as “seismic” costs and constitute approximately 22% of the total project cost. The remaining 78% of the total project cost consists of real estate, Coastal Flood Risk Management features, preconstruction engineering and design, and construction management activities.

Table ES-10 shows the range of costs of the Recommended Plan First and Subsequent Actions for the Low to High RSLC.

Table ES-8: Recommended Plan First Actions Cost Summary
(FY 2026 Price Level)

WBS Code	Item	Cost
02	Relocations	\$1,253,390,000
06	Fish and Wildlife Facilities (Mitigation)	\$67,211,000
10	Breakwaters and Seawalls	\$5,953,057,000
13	Pumping Plant	\$1,388,466,000
18	Cultural Resource Preservation (Mitigation)	\$108,525,000
19	Buildings, Grounds, and Utilities	\$1,938,131,000
19	Buildings, Grounds, and Utilities (Reach 1 2065)	\$157,123,000
01	Lands and Damages ^a	\$3,689,028,000
30	Planning, Engineering and Design	\$2,158,866,000
31	Construction Management	\$1,098,318,000
	Total First Cost	\$17,812,115,000

^aLands and Damages costs are referenced from *Appendix F: Real Estate Plan*

Values rounded

WBS = work breakdown structure

Table ES-9: Recommended Plan First Actions Annual Costs
(FY 2026 Price Level; 3.25% Discount Rate)

Item	Cost
First Cost	\$17,812,115,000
Interest During Construction	\$1,099,833,000
Annual OMRR&R	\$31,674,000
Average Annual Cost	\$672,477,000

Values rounded

Table ES-10: Recommended Plan - First and Subsequent Actions Cost
(FY 2026 Price Level)

Item	First Actions	Subsequent Actions			Total Cost Range		
		Low RSLC	Intermediate RSLC	High RSLC			
Lands & Damages ^a	\$3,689,028,000	\$0	\$0	\$3,144,700,000	\$3,689,028,000	to	\$6,833,728,000
Relocations	\$1,253,390,000	\$0	\$757,700,000	\$3,102,400,000	\$1,253,390,000	to	\$4,355,790,000
Construction	\$9,612,513,000	\$0	\$814,600,000	\$7,520,200,000	\$9,612,513,000	to	\$17,132,713,000
Planning, Engineering and Design	\$2,158,866,000	\$0	\$166,400,000	\$1,220,700,000	\$2,158,866,000	to	\$3,379,566,000
Construction Management	\$1,098,318,000	\$0	\$88,400,000	\$649,100,000	\$1,098,318,000	to	\$1,747,418,000
Total First Cost	\$17,812,115,000	\$0	\$1,827,100,000	\$15,637,100,000	\$17,812,115,000	to	\$33,449,215,000

^aLands and Damages costs are referenced from *Appendix F: Real Estate Plan*. These costs are assumed to be zero under the Intermediate RSLC curve because (1) the Reach 1 footprint will be covered with First Actions, (2) there are no Reach 2 Subsequent Actions with Intermediate RSLC, and (3) Reach 3 and 4 Subsequent Actions require no change to the structure footprint. It is possible that raising the elevation of the protective structure in Reaches 3 and 4 may incur Relocation Assistance Benefits costs that have not been quantified.

Values rounded

In accordance with USACE guidance, the PDT used a comprehensive benefits approach in evaluating alternatives and developing the Recommended Plan. The Recommended Plan maximizes total net benefits across all benefit categories. It has an economic benefit-cost ratio range of 0.13-0.83 with average annual benefits ranging from \$70 million to \$583 million across the range of future sea level conditions as defined in USACE guidance. The Recommended Plan achieves additional benefit streams within the RED, OSE, and EQ accounts. The suite of benefits include reduction in flood risk damages and disruption, life safety, increasing transportation infrastructure resilience, maintaining economic activity, maritime function, and other community and ecological benefits.

Lands, Easements, Rights-of-Way, Relocations, and Disposal Areas

The NFS will be responsible for acquiring and furnishing all land, easements, rights-of-way, relocations (i.e., P.L 91-646 relocations and utility/facility relocations), and disposal areas (LERRDs) for the project areas, as required for the construction, operation, and maintenance of the proposed project. A Real Estate Plan (Appendix F) was developed to present the Real Estate requirements for the Recommended Plan. The standard estates were reviewed and were found to be acceptable for the project.

Cost Sharing

Project first cost is the constant dollar cost of the First Actions of the Recommended Plan at current price levels and is the cost used in the authorizing document for a project. The “Total Project Cost” is the constant dollar fully funded cost with escalation to the estimated midpoint of construction (2045). Total Project Cost is the cost estimate used in Project Partnership Agreements (PPAs) for implementation of design and construction of a project. Total Project Cost is the cost estimate provided to the NFS for their use in financial planning because it provides information regarding the overall non-Federal cost-sharing obligation. For this project, the First Cost of the Recommended Plan First Actions was estimated to be \$17,812,115,000, while the Total Project Cost of the Recommended Plan First Actions (Fully Funded) was estimated to be \$32,312,093,000.

In accordance with the cost share provisions in Section 103 of WRDA 1986, as amended (33 United States Code 2213), project design and implementation are cost shared 65% Federal and 35% non-Federal, with the NFS responsible for providing all LERRDs. The estimated Federal first cost is \$11,577,875,000, and the estimated non-Federal first cost of \$6,234,240,000. The non-Federal costs include credit for the value of LERRDs. Total LERRDs are estimated to be \$4,942,418,000, which is less than 35% of the Project First Costs as shown in **Table ES-11**. The fully funded Total Project Cost also has a LERRDs value that is less than 35%. The cost share apportionments for the Project First Costs and Total Project Costs are provided in **Table ES-11** and **Table ES-12**, respectively.

Table ES-11: Apportionment of First Actions Costs
(FY 2026 Price Level)

Item		Cost
Total Project Cost (First Costs)		\$17,812,115,000
Federal Share (65%)		\$11,577,875,000
Non-Federal Share (35%)		\$6,234,240,000
	<i>Lands and Damages</i>	<i>\$3,689,028,000</i>
	<i>Relocations</i>	<i>\$1,253,390,000</i>
	<i>Non-Federal Cash Contribution</i>	<i>\$1,291,822,000</i>

Table ES-12: Total Project Cost (Fully Funded Cost) - Apportionment of First Actions

Item	Cost
Total Project Cost (Fully Funded)	\$32,312,093,000
Federal Share (65%)	\$21,002,860,000
Non-Federal Share (35%)	\$11,309,233,000
<i>Lands and Damages</i>	<i>\$6,048,984,000</i>
<i>Relocations</i>	<i>\$2,306,593,000</i>
<i>Non-Federal Cash Contribution</i>	<i>\$2,953,656,000</i>

Operations, Maintenance, Repair, Replacement, and Rehabilitation

OMRR&R includes actions to sustain the completed project and to maintain the stated level of benefits at the completion of construction and into the future. The NFS is responsible for OMRR&R costs and actions. Generally, the NFS is required to repair, rehabilitate, or provide replacement of components to maintain the original project benefits. A detailed OMRR&R manual will be developed during the design phase to outline the expected OMRR&R requirements for each project component. Preliminary OMRR&R estimates are estimated as a percentage of the project cost and are subject to refinement as design proceeds.

The total estimated annual OMRR&R cost is \$31,674,000. OMRR&R requirements would also include but are not limited to, annual exercising of gates and closure structures, grass mowing of levee and floodwall right-of-way, painting of metal surfaces, pump station operations and maintenance, and general maintenance of drainage structures.

Compensatory Mitigation

Mitigation needs are currently estimated to be fairly low for the Recommended Plan, pending further consultation with the Regulatory Agency Working Group and consulting parties in the Section 106 process. The Recommended Plan proposes 9 acres of bay fill that would require compensatory mitigation for the loss of 9 acres. The compensatory mitigation provides a few options to compensate for the loss and includes various combinations of pier removal and pile removal. Pier removal is compensated on 1 acre of injury for 1 acre of restoration (1:1) basis while pile removal is compensated on a 1:1.67 basis. The most cost-effective mitigation plan proposes removal of 9.1 acres of abandoned, derelict, or unnecessary piers from the San Francisco waterfront between Aquatic Park and Heron's Head. Currently, proposed available locations provide a total of 5.5 acres. Thus, to implement this plan, an additional 3.6 acres (1,799,996 discounted-service-acre-year) of pier removal options along the waterfront or outside the study area would need to be identified to meet the offset. This would be true for any mitigation alternative implemented.

The mitigation plan recommends the most cost-effective plan based on the information available but primarily serves as a conceptual plan that would be modified and finalized during the design phase. For feasibility, the NNBFs in the Recommended Plan were not considered when calculating offset of project impacts. Instead, the mitigation plan was developed to account for offset that may be required if NNBFs cannot be constructed at the same time as the impact is incurred or, if when constructed, the NNBFs did not fully offset the impacts. During the design phase, the need for compensatory mitigation will need to be reassessed, and, if the NNBFs are included, the compensatory mitigation documented in this IFR/EIS may not be required.

Avoidance and minimization measures, as well as best management practices, would be used during construction and in the final designs to avoid permanent adverse impacts that would require additional compensatory mitigation.

Preliminary analysis suggests the Recommended Plan is measuring below de minimis for the Clean Air Act and would not require compensatory mitigation for air quality. The PDT will continue to work with resource agencies to determine the most applicable models for use and level of mitigation needed to offset impacts.

Implementation of the Recommended Plan

As a multi-billion-dollar project, significant Federal and local resources will be allocated to implement the Recommended Plan components and adaptations that address risk ahead of its arrival. The implementation strategy is flexible but structured to support responsive action under changing conditions. It allows for adjusting implementation based on available funding while addressing areas with highest impact first. The implementation strategy is informed by four components: Phasing Approach, Early Resilience Actions (ERAs), the MAP, and the Authorization Recommendations.

Phasing Approach

The Phasing Approach creates a decision framework to enable prioritized, incremental construction of the First Actions of the Recommended Plan. It supports decision-making under scenarios where local or Federal funding for design and construction is received in increments rather than a funding stream to construct all First Actions at once. The Phasing Approach also affords flexibility under circumstances that may support phased construction to increase cost-effectiveness or reduce disruption by aligning construction with other investments in the project area. The ultimate order of phases and sequencing of specific actions will be developed in the design phase.

Early Resilience Actions

The ERAs, or early actionable elements, are segments of the Recommended Plan that meet the guiding principles and will facilitate its construction under constrained implementation conditions. These segments may be initiated first, reducing near-term risk and delivering other early benefits. While the Phasing Approach establishes criteria to successfully carry out the project through design and construction, ERAs support expedited risk reduction when implementation is constrained in any way (e.g., funding and acquisitions). One or more ERAs may be comparable to the first few actionable

elements of the Phasing Approach. ERAs also reflect the PDT's recognition of the need to identify areas that can move quickly to design and construction to address near-term flood risk to critical infrastructure and facilities and provide early opportunities to pilot innovative approaches to address complex challenges.

The PDT identified three candidate ERAs to be further refined and confirmed during preconstruction engineering and design (PED). From north to south, these include:

- Rincon Park / Embarcadero Shoreline (approximately Pier 14 to Pier 22.5)
- Portion(s) of Mission Bay and Creek
- Portion(s) of Islais Creek

These potential ERAs are subject to change through ongoing discussion and potentially public input. Any ERAs selected in PED remain subject to all requirements related to environmental compliance and permitting processes as well as any necessary agreements between USACE and POSF.

Monitoring and Adaptation Plan

The MAP establishes a process to monitor risk and support decision-making for successful implementation of Subsequent Actions, delivering the benefits of the Recommended Plan over time. It includes the creation of an Adaptation Management Team (AMT), a monitoring program with associated metrics and decision thresholds, assessment and reporting guidance, and a decision-making framework. The MAP is primarily designed to support decision-making for Subsequent Actions. However, the monitoring program may inform design and implementation of First Actions, especially if RSLC is trending high.

The process begins with the AMT monitoring the study area to determine when the combination of physical and social conditions warrant action, acting like a trigger point in the overall process.

The AMT will be a multidisciplinary, technical body responsible for monitoring, synthesizing results, and reporting to USACE and POSF leadership. The AMT will be chartered at the start of the design phase and led by USACE and POSF. USACE and POSF may invite other agencies to serve on the AMT.

The AMT will coordinate monitoring, assist in the evaluation of monitoring data and adaptation planning, and provide technical expertise and recommendations to USACE and POSF. USACE and POSF leadership have final determination on all actions and adaptations recommended by the AMT. USACE and POSF staff are responsible for ensuring that monitoring data and assessments are properly used in the decision-making process. They are also responsible for project documentation, reporting, and external communication.

Monitoring Program

The monitoring program includes monitoring objectives, a monitoring period, a suite of monitoring metrics and associated risk equation to determine when to act, and reporting requirements.

Design and Construction Sequencing

At the completion of this feasibility study, and upon approval by the USACE Chief of Engineers, the Recommended Plan would be provided to the U.S. Congress for authorization and funding. If authorized and funded by Congress, subsequent phases of the project would include PED, construction, and operations and maintenance.

Completion of design and construction of the Recommended Plan, specifically the pace of construction, is highly dependent on Congressional approval and funding. Assuming an ample funding stream, the First Actions of the Recommended Plan could be designed and then constructed over a period of about 32 years. Phased implementation will consider the priorities of the NFS, communities benefitted by the project, resource agencies, and efficiencies in the construction and/or contracting process. Ultimately, implementation activities will be optimized to consider the size and frequency of funding infusions, environmental clearance of individual components including the requirements of the California Environmental Quality Act, and beneficial sequencing.

Public Coordination and Views

Coordination with stakeholders has been a critical component of the SFWCFS. Since 2018, USACE and POSF have held numerous workshops and meetings with Cooperating/Participating Agencies and other Federal, State, and local stakeholders to share information on the study scope, purpose, and formulation of alternatives, as well as to exchange ideas and information on natural and marine resources within the study area.

Views of the Public, Agencies, Stakeholders, and Tribes

A Notice of Intent to prepare an IFR and EIS for the SFWCFS was published in the Federal Register on July 27, 2023. A Notice of Availability for the Draft IFR/EIS was published in the Federal Register on January 26, 2024. The public and agencies were invited to participate in public meetings and submit comments during the comment period that ended March 29, 2024.

Four in-person public meetings were held in San Francisco during the comment period from February 26 to 29, 2024. A total of 154 comments were received during the review period. Public feedback was reviewed and considered in preparation of this Final IFR/EIS. Key themes included sea level rise, groundwater, and hydrology; infrastructure, flood protection, and relation to other studies; coordination and planning; nature-based solutions/Engineering with Nature; hazardous materials and contamination; historic resources; socioeconomic and environmental justice; recreation and inclusion of recreational space; transportation, access, safety, and public health; and study area and authority.

Views of the Non-Federal Sponsor

The POSF, as lead agency for CCSF, fully supports the Recommended Plan as outlined in the SFWCFS Final IFR/EIS. The Recommended Plan closely aligns with the POSF's mission to manage the waterfront as the gateway to a world-class city, and

advance environmentally and financially sustainable maritime, recreational, and economic opportunities to serve the city, Bay Area region, and California.

In particular, the Recommended Plan advances the POSF's Strategic Plan resilience goal to protect people, San Francisco neighborhoods, and critical infrastructure from flooding and other hazards. The Recommended Plan will support POSF initiatives and investments, such as improvement of maritime facilities, historic piers rehabilitation, and waterfront parks and open space by investing in a stable and resilient shoreline and protect city infrastructure and assets, public and private lands, and buildings from coastal flooding.

We view the Recommended Plan as a foundational element for CCSF's overall plan to address flooding through the end of the century and beyond. CCSF appreciates the time and effort invested by community members and groups to shape the Recommended Plan during the feasibility study (*Appendix H: Public Involvement*), and we encourage participation in future opportunities to engage the public during the design stage.

CCSF values the opportunity to continue to engage with USACE to complete the feasibility study and continue to advance toward design and construction. We anticipate playing a significant role in waterfront design, facilitated in part by the Memorandum of Understanding (MOU) signed by CCSF and USACE in February 2025. The MOU references WRDA Section 221 and allows for CCSF to advance design and construction prior to the execution of the Project Partnership Agreement.

The POSF has provided a letter of support on behalf of CCSF, which is included in *Appendix H: Public Involvement*.

Table of Contents

*Items marked with an asterisk are applicable to the satisfaction of National Environmental Policy Act (NEPA) requirements

Acronyms and Abbreviations.....	xii
Section 1.0 Introduction	1
1.1. Introduction	1
1.2. USACE Planning Process	1
1.3. Study Authority	3
1.4. Non-Federal Sponsor	4
1.5. Study Area	5
1.6. Prior and Existing Reports, Studies, and Projects	9
1.7. Purpose and Need*	11
1.8. Problems and Opportunities	11
1.9. Planning Objectives and Constraints	13
1.10. Study Scope	15
Section 2.0 Existing and Future Without Project Conditions*	16
2.1. General Setting	16
2.2. Natural Environment	17
2.2.1. Aquatic Resources	17
2.2.2. Upland Resources	21
2.2.3. Special Status Species	21
2.3. Physical Environment	30
2.3.1. Air Quality	30
2.3.2. Meteorological Conditions	32
2.3.3. Soils and Minerals	33
2.3.4. Hydrology and Hydraulics	34
2.3.5. Relative Sea Level Change	42
2.3.6. Water Quality	45
2.3.7. Groundwater	46
2.3.8. Geology and Geomorphology	51
2.3.9. Seismic	52

2.3.10.	Noise and Vibration	55
2.3.11.	Cultural Resources	59
2.3.12.	Hazardous, Toxic, and Radioactive Waste	66
2.4.	Built Environment	68
2.4.1.	Utilities	68
2.4.2.	Transportation	71
2.4.3.	Recreation and Access	72
2.4.4.	Aesthetics	73
2.4.5.	Port and Maritime Facilities	74
2.4.6.	Existing and Planned Federal and Local Projects	74
2.5.	Human Environment	79
2.5.1.	Socioeconomics and Community	79
2.5.2.	Public Health and Safety	83
2.5.3.	At-Risk Communities	86
Section 3.0	Plan Formulation and Evaluation*	88
3.1.	Planning Framework	88
3.2.	Planning Horizon and Period of Analysis	91
3.3.	Plan Formulation Strategy	92
3.4.	Initial Planning Iteration	94
3.5.	Formulation Elements	95
3.5.1.	Approaches to Reduce Risk	95
3.5.2.	Lines of Defense and Zones	100
3.5.3.	Adaptation Space Considerations for the LOD	100
3.5.4.	Varied Scaling of Features	100
3.5.5.	Adaptation as Subsequent Actions	101
3.6.	Treatment of Seismic Costs	101
3.7.	Identification and Screening of Management Measures	102
3.8.	Focused Array of Alternative Plans	105
3.8.1.	Alternative A: No Action (FWOP Condition)	114
3.8.2.	Alternative B: Nonstructural	114
3.8.3.	Alternative C: Defend, Scaled for Lower Risk	117
3.8.4.	Alternative D: Defend, Scaled for Low-Moderate Risk	118
3.8.5.	Alternative E: Defend Existing Shoreline, Scaled for Higher Risk	119

3.8.6.	Alternative F: Manage the Water, Scaled for Higher Risk	120
3.8.7.	Alternative G: Partial Retreat, Scaled for Higher Risk	122
3.9.	Evaluation of Focused Array	123
3.9.1.	Costs	123
3.9.2.	NED Evaluation	126
3.9.3.	Insights Gained from NED Evaluation	132
3.10.	Refinement of Net NED Plans Using Insights Gained	133
3.11.	Final Array of Alternatives	136
3.12.	Evaluation of the Final Array	136
3.12.1.	Comprehensive Benefits Analysis Approach.....	138
3.12.2.	Decision Drivers	141
3.12.3.	Comprehensive Benefits Analysis	141
3.12.4.	Maximizing Total Net Benefits.....	141
3.12.5.	Selecting a Total Net Benefits Plan.....	143
3.12.6.	Total Net Benefits Plan.....	146
3.13.	Tentative Plan Selection	149
3.14.	Independent Measures	149
3.15.	Refinements Following Draft Report Review.....	150
Section 4.0	Effects and Consequences of Alternative Plans*	153
4.1.	Methodology for Describing Environmental Consequences	154
4.1.1.	Types of Potential Impact.....	154
4.1.2.	Duration of Potential Impact	155
4.1.3.	Geographic Extent of Potential Impacts	155
4.1.4.	Significance	155
4.2.	Natural Environment	156
4.2.1.	Aquatic Resources	156
4.2.2.	Upland Resources.....	158
4.2.3.	Special Status Species.....	159
4.3.	Physical Environment.....	161
4.3.1.	Air Quality.....	161
4.3.2.	Meteorological Conditions	161
4.3.3.	Soils and Minerals	162
4.3.4.	Hydrology and Hydraulics	163

4.3.5.	Relative Sea Level Change	164
4.3.6.	Water Quality	165
4.3.7.	Groundwater	166
4.3.8.	Geology and Geomorphology	167
4.3.9.	Seismic.....	168
4.3.10.	Noise and Vibration.....	168
4.3.11.	Cultural Resources.....	169
4.3.12.	Hazardous, Toxic, and Radioactive Waste.....	171
4.4.	Built Environment	171
4.4.1.	Utilities.....	171
4.4.2.	Transportation	172
4.4.3.	Recreation and Access	173
4.4.4.	Aesthetics.....	174
4.4.5.	Port and Marine Facilities.....	175
4.5.	Human Environment	176
4.5.1.	Socioeconomics and Community	176
4.5.2.	Public Health and Safety	176
4.5.3.	At-Risk Communities.....	177
4.6.	Cumulative Impacts.....	177
4.6.1.	Past or Present Projects.....	178
4.6.2.	Reasonable and Foreseeable Actions.....	179
4.6.3.	Cumulative Impact Analysis	179
4.7.	Probable, Unavoidable Adverse Environmental Effects	182
4.7.1.	Air Quality.....	182
4.7.2.	Aquatic Resources	183
4.7.3.	Noise	183
4.7.4.	Transportation	183
4.8.	Irreversible or Irretrievable Commitments of Resources	184
4.9.	Relationship Between Short-Term Uses of Environment and the Maintenance and Enhancement of Long-Term Productivity	184
Section 5.0	The Recommended Plan*	186
5.1.	Recommended Plan Components	186
5.1.1.	Fisherman’s Wharf (Reach 1)	190

5.1.2.	Embarcadero (Reach 2).....	191
5.1.3.	Mission Creek / Mission Bay (Reach 3).....	194
5.1.4.	Islais Creek / Bayview (Reach 4)	197
5.1.5.	First Actions - Physical Quantities and Extents	200
5.2.	Plan Accomplishments	201
5.2.1.	Flood Risk Reduction	201
5.2.2.	Economic Benefits.....	207
5.2.3.	Environmental and Social Benefits.....	209
5.2.4.	Plan Performance with Changing Conditions	209
5.3.	Monitoring and Adaptation	210
5.4.	Costs	210
5.5.	Project Risk	213
5.5.1.	Life-Safety Risk	213
5.5.2.	Economic Risk	214
5.5.3.	Residual Risk	216
5.5.4.	Adaptation	216
5.5.5.	Implementation Risk.....	216
5.5.6.	Construction and Engineering Risk	217
5.6.	Lands, Easements, Rights-of-Way, Relocations, and Disposal Areas	217
5.7.	Cost Sharing	218
5.8.	Non-Federal Sponsor Responsibilities	219
5.9.	Operations, Maintenance, Repair, Replacement, and Rehabilitation	221
5.10.	Compensatory Mitigation.....	221
5.11.	USACE Environmental Operating Principles.....	222
5.12.	Least Environmentally Damaging Practicable Alternative Plan	223
5.13.	National Flood Insurance Program Compliance.....	223
5.14.	Views of the Non-Federal Sponsor	224
Section 6.0	Implementation of the Recommended Plan	226
6.1.	Phasing Approach.....	228
6.2.	Early Resilience Actions.....	228
6.3.	Monitoring and Adaptation Plan	231
6.3.1.	MAP Process Overview.....	231
6.3.2.	Adaptation Management Team	232

6.3.3. Monitoring Program.....	233
6.3.4. MAP Costs	233
6.4. Design and Construction Sequencing	233
Section 7.0 Environmental Compliance*	235
7.1. Compliance Status	236
7.2. Compensatory Mitigation Plan	239
Section 8.0 Public Coordination and Views	240
8.1. Scoping	240
8.2. Agency Coordination	240
8.3. Tribal Consultation	241
8.4. Public Comments Received	242
Section 9.0 Findings	243
Section 10.0 List of Report Preparers*	244
Section 11.0 References*	248

List of Tables

Table 2-1: Federal Threatened, Endangered, or Candidate Species Identified By USFWS and NMFS That May Occur in the Study Area	22
Table 2-2: State-Listed Threatened and Endangered Species Potentially Occurring in the Study Area	26
Table 2-3: Managed Fish Species in the Study Area Under the Magnuson-Stevens Fishery Management Act	28
Table 2-4: Federal Pollutant Attainment Status of Study Area	31
Table 2-5: Existing Water Levels for Frequent to Extreme Recurrence Intervals	38
Table 2-6: Increase in Sea Level (in Feet) Across Time Horizons and RSLC Curves...	44
Table 2-7: Ambient Noise Levels for Projects Along the San Francisco Waterfront.....	55
Table 2-8: Archaeological Resources Summary	60
Table 2-9: NRHP-Listed Districts in the Study Area	62
Table 2-10: NRHP-Listed Individual Properties in the Study Area	62
Table 2-11: NRHP-Eligible Districts in the Study Area	64
Table 2-12: Additional NRHP-Eligible Properties in the Study Area.....	65
Table 2-13: Population Impacts by Reach.....	82
Table 2-14: Exposed Disaster Response Sites by Reach.....	86

Table 3-1: Screening of Measures	103
Table 3-2: Change in 1% AEP Water Surface Elevation over Time	106
Table 3-3: RSLC Value Comparisons	107
Table 3-4: RSLC Building Blocks for Plan Formulation	108
Table 3-5: Focused Array of Alternative Plans	108
Table 3-6: Focused Array of Alternatives Features Summary	111
Table 3-7: Reach-level First Costs, Without Seismic Design Requirements, First Actions	124
Table 3-8: Reach-level First Costs, Without Seismic Design Requirements, All Actions	124
Table 3-9: Reach-Level First Costs, Including Seismic Design Requirements, First Actions	125
Table 3-10: Reach-Level First Costs, Including Seismic Design Requirements, All Actions	125
Table 3-11: NED Evaluation by Alternative, Low RSLC	126
Table 3-12: NED Evaluation by Alternative, Intermediate RSLC	127
Table 3-13: NED Evaluation by Alternative, High RSLC	129
Table 3-14: NED Plan by Reach Under Each RSLC Curve	132
Table 3-15: First and Potential Subsequent Actions, Hybrid Plan	135
Table 3-16: Overview of OSE Categories and Metrics	139
Table 3-17: TNBP First and Subsequent Actions	147
Table 3-18: Cost of First Actions, TNBP	148
Table 3-19: Additional Cost of Subsequent Actions, Intermediate RSLC Curve	148
Table 3-20: Additional Cost of Subsequent Actions, High RSLC Curve	148
Table 3-21: TSP First and Subsequent Actions	149
Table 3-22: Summary of Refinements	152
Table 4-1: Comparison of Measures Impacting Aquatic Resources by Alternatives for First Actions	158
Table 4-2: Greenhouse Gas Emission Comparison Amongst Action Alternatives	162
Table 4-3: In-Water Activity Quantity Estimates for Alternative First Actions	164
Table 4-4: Estimated Ground Improvement Quantities for Alternative First Actions....	168
Table 4-5: Estimated Construction Equipment Noise Levels for Action Alternatives 100 Feet from the Construction Area	169
Table 4-6: Transportation Corridors Affected from First Actions Construction Activities	173

Table 5-1: First and Potential Subsequent Actions, Recommended Plan	188
Table 5-2: Physical Quantities and Extents of Recommended Plan First Actions	200
Table 5-3: FWOP Total Present Value NED Damages by Reach	202
Table 5-4: Total FWOP Damages by 25-Year Period, Low RSLC	202
Table 5-5: Total FWOP Damages by 25-Year Period, Intermediate RSLC	203
Table 5-6: Total FWOP Damages by 25-Year Period, High RSLC	203
Table 5-7: Recommended Plan Results, Present Value, FY26 Dollars	204
Table 5-8: Recommended Plan Results, Average Annual Value, FY26	205
Table 5-9: Summary of RED Damages for FWOP Condition	206
Table 5-10: How the Recommended Plan Addresses Risk	207
Table 5-11: Recommended Plan Damages by Damage Type, Low RSLC	208
Table 5-12: Recommended Plan Damages by Damage Type, Intermediate. RSLC ...	208
Table 5-13: Recommended Plan Damages by Damage Type, High RSLC	208
Table 5-14: Recommended Plan First Actions Cost Summary	211
Table 5-15: Recommended Plan - First Actions Annual Costs	212
Table 5-16: Recommended Plan - First and Subsequent Actions Cost	212
Table 5-17: Real Estate Requirements for the Recommended Plan	218
Table 5-18: Apportionment of First Actions Costs	219
Table 5-19: Total Project Cost (Fully Funded Cost) - Apportionment of First Actions .	219
Table 6-1: Implementation Strategy Overview	227
Table 7-1: Regulatory Compliance Status	236
Table 7-2: Executive Order Compliance Status	239

List of Figures

Figure 1-1: San Francisco Waterfront Coastal Flood Study Area	7
Figure 1-2: San Francisco Waterfront Coastal Flood Study Reaches	8
Figure 2-1: Inundation of Heron's Head and Pier 96 Wetlands under the Intermediate RSLC Scenario for the Period of Analysis	20
Figure 2-2: Green Sturgeon Critical Habitat Within the Study Area	24
Figure 2-3: Chinook Salmon Sacramento River Winter-Run Critical Habitat Within the Study Area	25

Figure 2-4: HAPC Within the Study Area	28
Figure 2-5: High Tide (Monthly) and Extreme (1%AEP) Water Level Flood Extents with USACE Low, Intermediate, and High RSLC (relative to 1992).....	36
Figure 2-6: Overtopping of Seawall in March 2023	37
Figure 2-7: San Francisco FEMA Flood Insurance Rate Map	39
Figure 2-8: USACE and State of California RSLC Scenarios.....	43
Figure 2-9: Extent of Inundation Per Reach Expected Under 1% AEP Flood Event in Future Without Project Conditions Under the Three RSLC Curves.....	45
Figure 2-10: Depth to Groundwater in San Francisco, Current Conditions	48
Figure 2-11: Future Groundwater Conditions, 9 feet (108 Inches) of Relative Sea Level Change Scenario	50
Figure 2-12: Regional Topography and Faults	53
Figure 2-13: Sensitive Receptors within and 1,000 Feet from the Zones of Construction	57
Figure 2-14: Hazardous Materials Sites Within the Project Footprint.....	67
Figure 2-15: Planned Development along the Waterfront on POSF Property	77
Figure 3-1: Planning Horizon.....	92
Figure 3-2: Plan Formulation Strategy.....	94
Figure 3-3: Approaches to Reduce Risk.....	96
Figure 3-4: Low RSLC 1% AEP Floodplains Over Time.....	97
Figure 3-5: Intermediate RSLC 1% AEP Floodplains Over Time	98
Figure 3-6: High RSLC 1% AEP Floodplains Over Time.....	99
Figure 3-7: Alternative B Floodproof and Retreat by Time Step for Lower-Risk Scenario	116
Figure 3-8: Alternative B Floodproof and Retreat by Time Step for Higher-Risk Scenario	116
Figure 3-9: Alternative C	118
Figure 3-10: Alternative D	119
Figure 3-11: Alternative E.....	120
Figure 3-12: Alternative F.....	121
Figure 3-13: Alternative G	123
Figure 5-1: Conceptual Framework for Recommended Plan First Actions and Potential Range of Subsequent Actions.....	187
Figure 5-2: Recommended Plan First Actions.....	189
Figure 5-3: Recommended Plan Subsequent Actions (Intermediate RSLC).....	189

Figure 5-4: Recommended Plan Subsequent Actions (High RSLC)	189
Figure 5-5: Recommended Plan First Actions: Fisherman’s Wharf to Telegraph Hill (Reach 1), Typical Cross Section within Embarcadero Historic District.....	190
Figure 5-6: Recommended Plan First Actions: Telegraph Hill to Bay Bridge (Reach 2), Typical Cross Section within Embarcadero Historic District	193
Figure 5-7: Recommended Plan First Actions: Telegraph Hill to Bay Bridge (Reach 2), Ferry Building	193
Figure 5-8: Recommended Plan First Actions: Telegraph Hill to Bay Bridge (Reach 2), Rincon Park.....	194
Figure 5-9: Recommended Plan First Actions: Bay Bridge to Potrero Point (Reach 3), Pier 30/32.....	196
Figure 5-10: Recommended Plan First Actions: Bay Bridge to Potrero Point (Reach 3), Mission Creek	196
Figure 5-11: Recommended Plan First Actions: Bay Bridge to Potrero Point (Reach 3), Terry Francois Boulevard	197
Figure 5-12: Recommended Plan First Actions: Potrero Point to Heron’s Head Park (Reach 4), Pier 80	199
Figure 5-13: Recommended Plan First Actions: Potrero Point to Heron’s Head Park (Reach 4), Islais Creek.....	199
Figure 5-14: Recommended Plan First Actions: Potrero Point to Heron’s Head Park (Reach 4), Pier 92	200
Figure 6-1: Areas with Higher Near-Term Flood Hazard	230
Figure 6-2: Candidate ERAs	231
Figure 6-3: MAP Process (1 of 2): Monitoring and the ACT	232
Figure 6-4: MAP Process (2 of 2): Process to Implement Subsequent Actions.....	232

Appendices

Appendix A: Plan Formulation

Appendix B: Engineering

Appendix C: Cost Engineering

Appendix D: Environmental and Cultural Resources

Appendix E: Economic and Social Considerations

Appendix F: Real Estate Plan

Appendix G: Monitoring and Adaptation Plan

Appendix H: Public Involvement

Appendix I: Engineering with Nature

Appendix J: Changing Hydrologic and Meteorological Conditions

Appendix K: Compensatory Mitigation Plan

Appendix L: Nonstructural Implementation Plan

Acronyms and Abbreviations

Acronym	Definition
ACT	Adaptation Confirmation Threshold
AEP	Annual Exceedance Probability
AMM	avoidance and minimization measure
AMT	Adaptation Management Team
AR	Atmospheric River
ASA(CW)	Assistant Secretary of the Army (Civil Works)
ASP	Agency Specific Procedure
BAAQMD	Bay Area Air Quality Management District
BART	Bay Area Rapid Transit
BCDC	San Francisco Bay Conservation and Development Commission
BCR	Benefit-Cost Ratio
BMP	best management practice
CCSF	City and County of San Francisco
CEQ	Council on Environmental Quality
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CFRM	Coastal Flood Risk Management
CSD	Combined Sewer Discharge
CWA	Clean Water Act

Acronym	Definition
CZMA	Coastal Zone Management Act
dBA	decibel(s)
DO	Dissolved Oxygen
DSAY	Discounted-Service-Acre-Year
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EO	Executive Order
EPA	U.S. Environmental Protection Agency
EQ	Environmental Quality
ER	Engineer Regulation
ERA	Early Resilience Action
ESA	Endangered Species Act
EWN	Engineering With Nature
EWNWG	Engineering with Nature Working Group
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FWOP	Future Without Project
FWP	Future With Project
FY	Fiscal Year
GIS	Geographic Information System
G2CRM	Generation II Coastal Risk Model
GHG	Greenhouse Gas
HAP	Hazardous Air Pollutant

Acronym	Definition
HAPC	Habitat of Particular Concern
HCR	Hazards and Climate Resilience Plan
HTRW	Hazardous, Toxic, and Radioactive Waste
IFR	Integrated Feasibility Report
IMPLAN	Impact Analysis for Planning
IPaC	Information for Planning and Consultation
IPCC	Intergovernmental Panel on Climate Change
IWR	(USACE) Institute for Water Resources
LBE	Local Business Enterprise
LEDPA	Least Environmentally Damaging Practicable Alternative
LERRD	Lands, Easements, Rights-of-Way, Relocations, and Disposal Areas
LF	linear feet (foot)
LOD	Line of Defense
LPP	Locally Preferred Plan
LUST	Leaking Underground Storage Tank
MAP	Monitoring and Adaptation Plan
MCACES/MII	Micro-Computer Aided Cost Estimating System, Second Generation
Mgd	million gallon(s) per day
MHHW	Mean Higher High Water
MHRA	Multi-Hazard Risk Assessment
mi ²	square mile(s)
mm/yr	millimeter(s) per year

Acronym	Definition
MMPA	Marine Mammal Protection Act
MOU	Memorandum of Understanding
MPA	Marine Protected Area
Muni	San Francisco Municipal Railway
NAVD88	North American Vertical Datum of 1988
NED	National Economic Development
NEPA	National Environmental Policy Act
NFIP	National Flood Insurance Program
NFS	Non-Federal Sponsor
NHL	National Historic Landmark
NHPA	National Historic Preservation Act of 1966
NMFS	National Marine Fisheries Service
NNBF	Natural and Nature-Based Feature
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRC	National Research Council
NRHP	National Register of Historic Places
OMRR&R	Operations, Maintenance, Repair, Rehabilitation and Replacement
OPC	California Ocean Protection Council
OSE	Other Social Effects
P&G	Economic and Environmental Principles and Guidelines for Water and Related Land Implementation Studies
PAR	Project Adaptation Report

Acronym	Definition
PDT	Project Delivery Team
PED	Preconstruction Engineering and Design
PFM	Potential Failure Mode
PG&E	Pacific Gas and Electric
POA	Period of Analysis
POSF	Port of San Francisco
PPA	Project Partnership Agreement
PR&G	Principles, Requirements, and Guidelines
PV	Present Value
RAWG	Regulatory Agency Working Group
RED	Regional Economic Development
ROD	Record of Decision
RSLC	Relative Sea Level Change
RWQCB	Regional Water Quality Control Board
SAV	Submerged Aquatic Vegetation
SFBAAB	San Francisco Bay Area Air Basin
SFFD	San Francisco Fire Department
SFHA	Special Flood Hazard Area
SFMTA	San Francisco Municipal Transportation Agency
SFPD	San Francisco Police Department
SFPUC	San Francisco Public Utilities Commission
SFWCFS	San Francisco Waterfront Coastal Flood Study
SHPO	State Historic Preservation Officer

Acronym	Definition
SOMA	South of Market
SQRA	Semi-Quantitative Risk Assessment
T&E	Threatened and Endangered
TAC	Toxic Air Contaminant
TNBP	Total Net Benefits Plan
TOL	Top of Levee
TRG	Tolerable Risk Guideline
T/S	Transport/Storage
TSP	Tentatively Selected Plan
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WETA	Water Emergency Transportation Authority
WRDA	Water Resources Development Act
WSE	Water Surface Elevation

Section 1.0 Introduction

1.1. Introduction

The U.S. Army Corps of Engineers (USACE) Tulsa District prepared a Final Integrated Feasibility Report (IFR) and Environmental Impact Statement (EIS) for the San Francisco Waterfront Coastal Flood Study (SFWCFS) in conjunction with the Non-Federal Sponsor (NFS), the Port of San Francisco (POSF), acting as lead agency for the City and County of San Francisco (CCSF). It is a requirement of USACE planning policy and the National Environmental Policy Act (NEPA) of 1969 to make the report available for public review that describes the analysis of alternatives, risks, assumptions, and decisions made by the Project Delivery Team (PDT) during the planning process.

While this feasibility study final report identifies a Recommended Plan for the study area, current USACE policy precludes advancing the plan for Administration review and Congressional authorization until it reaches 35% design maturity. Currently at 20% design maturity, the Recommended Plan is justified by its “Total Net Benefits” across the entire Recommended Plan. The Recommended Plan provides a framework for implementation and includes early resilience actions formulated to mitigate coastal flood risk along the San Francisco Bay waterfront.

The Secretary of the Army’s recommendation to Congress to authorize Civil Works projects requires an assessment of compliance with Army Civil Works policies and technical requirements, including design maturity. Given the Recommended Plan is at 20% level of design, further design development is needed during the feasibility study phase to mitigate an unacceptably high risk of future cost growth. Moving forward, the NFS may undertake additional design and other implementation actions for elements of the recommended plan and advance those for Congressional authorization.

1.2. USACE Planning Process

The 1983 “Economic and Environmental Principles and Guidelines for Water and Related Land Implementation Studies” (P&G), the Planning Guidance Notebook at Engineering Regulation (ER) 1105-2-100, and ER 1105-2-103 provide an iterative six step planning process for USACE teams to use in developing and evaluating alternatives. The steps are:

- **Step 1:** Specification of problems and opportunities, along with identification of objectives and constraints
- **Step 2:** Inventory, forecast, and analysis of relevant conditions within the planning area
- **Step 3:** Formulation of alternative plans
- **Step 4:** Evaluation of the effects of the alternative plans

- **Step 5:** Comparison of alternative plans
- **Step 6:** Selection of a plan based upon the comparison of alternative plans

This process is iterative and was repeated as the PDT focused on the alternatives, bringing in new data, information, and stakeholder input as the study progressed. Risk analysis was incorporated in the process by acknowledging uncertainty and developing only the level of detail needed to make a risk-informed decision at each stage of the study.

This report was prepared in compliance with NEPA, the Council on Environmental Quality's (CEQ) NEPA Regulations, and USACE's Procedures for Implementing NEPA (Title 33 Code of Federal Regulations [CFR] Part 230 [33 CFR Part 230]). This EIS was prepared prior to rescission of the CEQ's NEPA regulations and USACE's Procedures for Implementing NEPA. As such, the procedures and guidelines in developing this document followed those preceding regulations. Sections of the report that are required to meet the requirements of NEPA are marked with an asterisk (*) in the headings.

NEPA requires Federal agencies to integrate the environmental review into their planning and decision-making process. This IFR/EIS is consistent with NEPA statutory requirements. The report reflects an integrated planning process.

This Final IFR/EIS provides a site-specific NEPA review of the First Actions and general overview of the impacts anticipated for the Subsequent Actions. This Final IFR/EIS includes an analysis of both the recommended First and Subsequent Actions even though only the First Actions are being recommended for authorization. The purpose of including both actions is to present sufficient information regarding overall impacts of the Subsequent Actions so that decision-makers can make a reasoned judgment on the merits of the overall potential flood defense system being considered (e.g., "hard look requirement") and make a reasoned choice among alternatives in consideration of potential adaptation in the future. This follows the CEQ guidance to consider connected actions or reasonably foreseeable actions. The authorization would not include the Subsequent Actions, thus the Record of Decision (ROD) would only cover the First Actions. Once the triggers for adaptation are reached, USACE will begin subsequent NEPA reviews of any proposed Subsequent Actions, which would involve preparation of one or more additional NEPA documents (either an EIS or Environmental Assessment) prepared in accordance with applicable implementing regulations, procedures, and guidance in place at that time, which would include providing for additional public review periods and resource agency coordination.

If during the design phase, project changes are found to be outside the scope of the Recommended Plan and the Chief's Discretionary Authority, a re-review of the original decision and authority will need to be completed following USACE policies at the time the change is identified. If design changes induce impacts greater than those described in this Final IFR/EIS, supplementation of the Final IFR/EIS may be required following the applicable implementing regulations, procedures, and guidance at the time the change is identified, and a new ROD or Finding of No Significant Impact signed.

1.3. Study Authority

This study is being conducted in partial response to the authority of Section 110 of Rivers and Harbors Act of 1950 (Pub. L. No. 81-516, 64 Stat. 163 [1950]), Section 142 of the Water Resources Development Act (WRDA) of 1976 (Pub. L. No 94-587, 90 Stat. 2930 [1976]), as amended by Section 705 of WRDA 1986 (Pub. L. No 99-662, 100 Stat. 4158 [1986]) and Section 8325(b) of WRDA 2022 (Pub. L. No 117-263, 136 Stat. 3787 [2022]), and Section 203 of WRDA 2020 (Pub. L. No 116-260, 134 Stat. 2675 [2020]), as amended by Section 8325(a) of WRDA 2022 that authorize an investigation of the feasibility of providing protection against tidal and fluvial flooding and measures to adapt to rising sea levels in the city and county of San Francisco.

Section 110 of the Rivers and Harbors Act of 1950 states:

“The Secretary of the Army is hereby authorized and directed to cause preliminary examinations and surveys to be made at the following-named localities, the cost thereof to be paid from appropriations heretofore or hereafter made for such purposes: Provided, That no preliminary examination, survey, project, or estimate for new works other than those designated in this title or some prior Act or joint resolution shall be made: Provided further, That after the regular or formal reports made as required by law on any examination, survey, project, or work under way or proposed are submitted, no supplemental or additional report or estimate shall be made unless authorized by law: Provided further, That the Government shall not be deemed to have entered upon any project for the improvement of any waterway or harbor mentioned in this title until the project for the proposed work shall have been adopted by law: Provided further, That reports of surveys on beach erosion and shore protection shall include an estimate of the public interests involved, and such plan of improvement as is found justified, together with the equitable distribution of costs in each case: And provided further, That this section shall not be construed to interfere with the performance of any duties vested in the Federal Power Commission under existing law:...San Francisco Bay, including San Pablo Bay, Suisun Bay, and other adjacent bays, and tributaries thereto, California.”

Section 142 of WRDA 1976, as amended by Section 705 of WRDA 1986, states:

“The Secretary of the Army, acting through the Chief of Engineers, is authorized and directed to investigate the flood and related problems to those lands lying below the plane of mean higher high water along the San Francisco Bay shoreline of San Mateo, Santa Clara, Alameda, Napa, San Francisco, Marin, Sonoma and Solano Counties to the confluence of the Sacramento and San Joaquin Rivers with a view toward determining the feasibility of and the Federal interest in providing protection against tidal and fluvial flooding. The investigation shall evaluate the effects of any proposed improvements on wildlife preservation, agriculture, municipal and urban interests in coordination with Federal, State, regional, and local agencies with particular reference to preservation of existing marshland in the San Francisco Bay region.”

Section 8325(b) of WRDA 2022 states:

“(b) IMPLEMENTATION. - In carrying out a study under section 142 of the Water Resources Development Act of 1976 (90 Stat. 2930; 100 Stat. 4158), pursuant to section 203(a)(1)(A) of the Water Resources Development Act of 2020 (as amended by this section), the Secretary shall not differentiate between damages related to high tide flooding and coastal storm flooding for the purposes of determining the Federal interest or cost share.”

Section 203 of WRDA 2020, as amended by Section 8325(a) of WRDA 2022, states:

“a) the Secretary shall expedite the completion of the following feasibility studies, as modified by this section, and if the Secretary determines that a project that is the subject of the feasibility study is justified in a completed report, may proceed directly to preconstruction planning, engineering, and design of the project”

(1) San Francisco Bay, California – The study for flood risk reduction authorized by section 142 of the Water Resources Development Act of 1976 (90 Stat. 2930), is modified to authorize the Secretary to—

(A) investigate the bay and ocean shorelines of San Mateo, San Francisco, and Marin Counties for the purposes of providing flood protection against tidal and fluvial flooding;

(B) with respect to the bay and ocean shorelines of San Mateo, San Francisco, and Marin Counties, investigate measures to adapt to rising sea levels; and

(C) with respect to the bay and ocean shorelines, and streams running to the bay and ocean shorelines, of San Mateo, San Francisco, and Marin Counties, investigate the effects of proposed flood protection and other measures or improvements on—

(i) the local economy;

(ii) habitat restoration, enhancement, or expansion efforts or opportunities;

(iii) public infrastructure protection and improvement;

(iv) stormwater runoff capacity and control measures, including those that may mitigate flooding;

(v) erosion of beaches and coasts; and

(vi) any other measures or improvements relevant to adapting to rising sea levels.”

1.4. Non-Federal Sponsor

POSF is the NFS for this study. The POSF oversees the administration of the public trust for the State of California under the Burton Act, ensuring that public trust uses such as maritime, public access, historic resources, visitor-serving uses, and water-related and dependent uses are preserved and maintained along the waterfront. The POSF is

also an enterprise agency of CCSF. They raise funds by leasing property and charging fees within their jurisdiction to preserve and enhance uses that are important to the public trust and to the city of San Francisco.

1.5. Study Area

The study area extends approximately 7.5 miles from Aquatic Park in the northeast to just past Heron's Head Park in the south (**Figure 1-1**). The study area is divided into four reaches for conducting and evaluating coastal process and economic analyses, as shown in **Figure 1-2**. The reaches were originally defined based on several criteria including hydrologic separability, identifiable geographic references, specific wave action within each reach, and major differences in physical structure inventory within the reach. This separability depends upon the amount of relative sea level change (RSLC), with lower levels of RSLC meaning that the reaches are more separable, while higher levels of RSLC require physical measures to separate several of the reaches. Infrastructure systems, such as the combined sewer system, pass through all reaches and provide a hydraulic path that makes hydraulic separability at the reach level difficult, especially at higher levels of RSLC. However, the implementation plan has separable elements within the reaches, but those separable elements would require additional measures, such as outflanking. These reaches also provide a neighborhood-scale approach to communicate risks, impacts, and alternatives. Reach delineations include the following:

- **Reach 1:** Covers Aquatic Park, Fisherman's Wharf, Pier 31 to Pier 35, and the North Beach neighborhood. This reach contains unique open space, recreational opportunities, historic resources, and tourism attractions that are recognized as global icons.
- **Reach 2:** Includes the Northeast Waterfront and Financial District. This area comprises a significant portion of the Embarcadero Historic District from Pier 27 to the Bay Bridge and includes popular sites such as the Exploratorium, Embarcadero promenade, and the San Francisco Ferry Building. Through this reach, many transportation hubs and businesses in the Financial District make this area central to San Francisco's economy.
- **Reach 3:** Contains South Beach, Mission Creek, Mission Rock, Mission Bay, and Pier 70, and includes the South Beach, South of Market Street (SOMA), and Mission Bay neighborhoods. This area is known for the Giants' baseball stadium, Chase Center, and access to Mission Creek and the Bay. It is one of the densest residential areas within the study area, with high numbers of at-risk populations and a number of community facilities such as the Delancey Street Foundation and SOMA Recreation Center. This reach is also the site of new mixed-use waterfront development projects such as Mission Rock and Pier 70 aimed to provide greater public access, jobs, services, and affordable housing opportunities.

- **Reach 4:** Encompasses Pier 80, Islais Creek, Cargo Way, Pier 96, and Heron's Head Park. This area consists of industrial uses along the waterfront and provides critical industrial, maritime, and commercial POSF functions. The area surrounding Islais Creek and adjacent Potrero Hill, Bayview, and Hunters Point neighborhoods are ethnically diverse. Reach 4 also has strong economic and cultural life, with high rates of women- and minority-owned businesses, numerous community benefit organizations, worship centers, and arts and culture organizations.

San Francisco Waterfront Coastal Flood Study

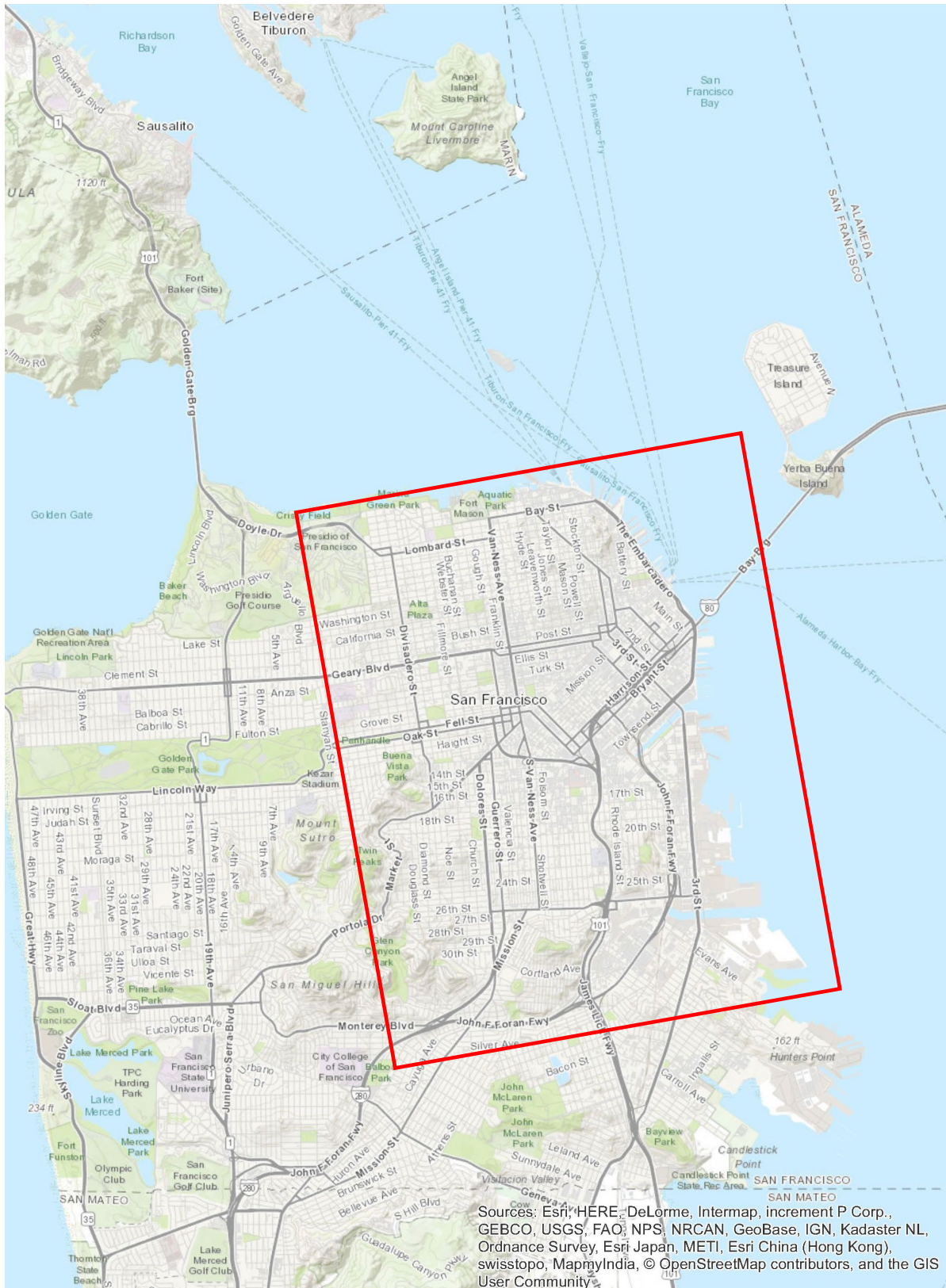


Figure 1-1: San Francisco Waterfront Coastal Flood Study Area



Figure 1-2: San Francisco Waterfront Coastal Flood Study Reaches

1.6. Prior and Existing Reports, Studies, and Projects

This study is one of many ongoing efforts to improve coastal flood and disaster resilience along the San Francisco waterfront. The San Francisco Waterfront Plan and the Waterfront Resilience Program are led by the POSF and include the study area, as well as areas both north and south of this study boundary.

The POSF is using funds from the 2018 voter-approved Seawall Earthquake Safety General Obligation Bond to improve earthquake safety and performance of the Embarcadero seawall and align with this study to address near-term flood risk while planning for long-term resilience and RSLC adaptation along the city's waterfront. These efforts include but are not limited to:

- CCSF. (2016). *San Francisco Sea Level Rise Action Plan*
- POSF. (1997). *Waterfront Land Use Plan*
- POSF. (2012). *Sea Level Rise and Adaptation Study*
- POSF. (2015). *Waterfront Land Use Plan Review, 1997- 2014*
- POSF. (2016). *Presentation to the San Francisco Port Commission on the Preliminary Results of the Earthquake Vulnerability Study of the Northern Waterfront Seawall*
- POSF (2020). *Multi-Hazard Risk Assessment (MHRA)*
- CCSF (2020). *Sea Level Rise Vulnerability and Consequences Assessment*
- CCSF (2020). *Islais Creek Southeast Mobility Adaptation Strategy*

Other pertinent Federal studies and projects are described in the following paragraphs.

San Francisco Harbor Project. San Francisco Bay is one of the critical maritime thoroughfares in the nation, supporting international trade, commercial and recreational fishing, and recreation. Over 60 million tons of waterborne commerce traverse the San Francisco Bar entrance channel annually. The San Francisco Bay Harbor project consists of a deep-draft navigation channel (the Main Ship Channel) immediately offshore of San Francisco Bay on the San Francisco Bar and in-Bay components. The original project was adopted by various U.S. Congressional Acts from 1868 to 1922 and provided for channel dredging and rock removal. The project was modified to existing dimensions by the Rivers and Harbors Acts of 1927, 1935, 1937, 1939, and 1965. The San Francisco Bar entrance is located approximately 5 miles west of the Golden Gate Bridge in the waters leading into San Francisco Bay. The Rivers and Harbors Act of 1965 authorized a 55-foot project depth at mean lower low water. This high use, deep-draft channel requires annual maintenance dredging to be performed to maintain the 55-foot project depth. This critical channel, which is the gateway to San Francisco Bay, is 2,000 feet wide by 16,000 feet long (USACE and RWQCB, 2015). In addition to the San Francisco Bar entrance channel, there are 11 in-Bay components. These components are dredged infrequently.

The Islais Creek entrance channel is located 2.5 miles south of the Bay Bridge. The original channel was adopted by the Rivers and Harbors Act of 1927 and modified by the Rivers and Harbors Act of 1935 and consists of a flared channel approaching the mouth of Islais Creek, 3,300 feet wide at the Bay end and 500 feet wide at the U.S. Pipehead Line end, and 35 feet deep. The primary users of the channel were commercial shipping firms operating out of Piers 80, 84, 86, 88, 90, 92, and 96 (USACE, 1975). Dredging of the channel was very infrequent. Enlargement of the entrance channel was considered, and a draft EIS was issued in October 1973.

According to the Final Environmental Assessment/Environmental Impact Report for Maintenance Dredging of the Federal Navigation Channels in San Francisco Bay, 2015-2024, sediment accumulation in these channels can impede navigability. Maintenance dredging removes this sediment and returns the channels to regulatory depths to provide safe, reliable, and efficient waterborne transportation systems (channels, harbors, and waterways) for the movement of commerce, national security needs, and recreation. Therefore, USACE's purpose in this project is to continue maintenance dredging of the Federal navigation channels in San Francisco Bay consistent with the goals and adopted plans of the Long-Term Maintenance Strategy while adequately protecting the environment, including listed species.

Fisherman's Wharf. This project provides protection to the existing fishing fleet and the Federally owned (National Park Service [NPS]) historic fleet at Fisherman's Wharf. Originally constructed in 1988, the project includes a 1,509-foot-long solid concrete sheet-pile breakwater, which is located along the west side of Pier 45, and a segmented concrete sheet-pile breakwater, which is located on the northeastern side of Pier 45. The latter has one 252-foot-long segment and one 150-foot-long segment. A Section 216 study was conducted in Fiscal Year (FY) 2007 to identify relationships and impacts between the USACE project and the NPS's San Francisco Municipal Pier.

San Francisco Waterfront Seawall Section 103 Study. This study was initiated in 2013 under the continuing authority of Section 103 of the River and Harbor Act of 1962, as amended. The study included a portion of the Embarcadero along the San Francisco waterfront. The study focused on two areas of concern – a low point approximately 40 feet wide between two buildings near Pier 5 and a half-mile low section of seawall between the Agricultural Building and Pier 22 1/2. The study was put on hold in 2018 due to the funding and initiation of this Congressionally authorized feasibility study under the Investigations account that includes the entire 7.5-mile waterfront.

Pier Repair/Removal Program. Section 5051 of WRDA 2007 provides discretionary authority to the Secretary of the Army, in cooperation with POSF, to carry out a project for repair and removal, as appropriate, of Piers 30-32, 35, 36, 70 (including Wharves 7 and 8), and 80 in San Francisco, California, substantially in accordance with POSF's Redevelopment Plan. The first phase of the project consisted of removing the deteriorated and partially collapsed Pier 36 using funding provided in FY 2010. Built in 1909 of both reinforced concrete and wood elements, Pier 36 was originally 721-feet long and 201-feet wide. Removal of Pier 36 made way for construction of the Brannan Street Wharf public park, the centerpiece of the South Beach Waterfront neighborhood redevelopment plan. A letter report on the removal of Pier 70 was completed in 2016, but the work was not undertaken due to the redevelopment of Pier 70.

Pier 70 Central Basin Section 107 Study. This study was conducted under the continuing authority of Section 107 of the Rivers and Harbors Act of 1960, as amended. The purpose of the study was to determine the feasibility of dredging the central basin at Pier 70 to an increased depth to reduce the impacts of shoaling to allow vessels to access the Pier 70 shipyard safely and efficiently without the use of high tide. A draft integrated Detailed Project Report and Environmental Assessment was completed in 2017, but the study was terminated after the dry dock closed.

1.7. Purpose and Need*

This study is being conducted in partial response to the study authority, investigating 7.5 miles of the San Francisco Bay shoreline. San Francisco faces multiple flood and other hazards (including seismic) now and over the next 50 to 100 years threatening its economy, communities, infrastructures, and environment. The purpose of this feasibility study is to frame those multiple risks and make specific recommendations for providing a resilient coastline that can withstand the uncertainties of changing physical conditions. The project area is at risk of flooding from bay water during coastal storms, extreme tides, and future RSLC. Flooding along the waterfront could cause extensive damage to public infrastructure and private property, loss of life and deterioration of public health and safety, degradation of the natural environment, and adverse changes to the social and economic character of the waterfront community. The risk is expected to increase over time as sea levels change in the bay. Additionally, the study area is in a high seismic hazard region and coastal flood risk measures will be designed in accordance with USACE seismic criteria.

1.8. Problems and Opportunities

Problems are undesirable conditions to be changed through the implementation of an alternative plan. Problem statements were developed at the start of the study and led to the identification of the study objectives. The problems to be addressed in this study are:

- Low-lying assets and economic activity along the San Francisco waterfront are at risk of flooding from coastal storms and extreme high tides, and from the potential failure of the century-old San Francisco seawall, which could result from structural instability, land subsidence, or an earthquake.
- Without Federal action, it is expected that future RSLC will increase the frequency and depth of tidal flooding along the shoreline, thereby increasing economic damages and coastal storm risk to one of the nation's most iconic waterfronts. The POSF and CCSF partners do not have the financial resources to reduce risks to people, property, and critical infrastructure assets without Federal assistance.
- The waterfront is currently at risk of coastal overtopping and damages to property and critical infrastructure because of coastal storms, including the contribution of stillwater, waves, and wave runoff. Rising sea levels will result in regularly

occurring tides that exceed existing Bay shoreline elevations and cause extensive flooding, impacting public infrastructure and private development. The rate of RSLC is uncertain and could rise from 1 to 10 feet by 2140.

- San Francisco relies on a combined sewer system designed to handle stormwater from up to a 5-year storm, with gravity drainage of treated combined sewer discharge (CSD) to the Bay. A 5-year rainfall event has a 20% chance of happening in a given year. Rising sea levels will impact the functioning of the combined sewer system and impede the ability of overland stormwater to drain to the Bay. These hazards will impact critical utility service and cause flooding for a broad segment of residents and businesses.
- Extreme precipitation events including atmospheric rivers and extratropical cyclones are projected to occur more frequently and yield more rain in shorter periods due to changing meteorological conditions, exacerbating combined flooding problems at the shoreline.
- Rising sea levels and coastal storms will inundate POSF maritime facilities and visitor-serving attractions, including the Ferry Building and historic finger piers that were built before World War II and have historical significance. Many are listed on the National Register of Historic Places (NRHP) and are more vulnerable to damage due to their age. Some structures are listed in the NRHP as historic properties with individual historic significance, such as the Ferry Building. Other buildings and structures within the waterfront area are contributing elements to listed historic districts, such as the Embarcadero Historic District or Central Embarcadero Piers Historic District.
- Rising sea levels will elevate groundwater levels, which increases flood risk to the study area damaging utility and transportation infrastructure and potentially mobilizing contaminants, causing public health concerns. Coastal storms could cause significant damage and disrupt services to public and private infrastructure, housing and commercial development, community services, and transportation linkages.
- Soil conditions in fill areas along the 7.5-mile waterfront study area could cause the ground to liquefy during an earthquake, as occurred in major earthquakes in 1906 and 1989. Settlement because of liquefaction is likely to moderately lower the elevation along the waterfront, exposing segments of the critical shoreline infrastructure to greater risk of flooding.
- Access to critical infrastructure, emergency services, and evacuation routes is expected to be limited or cut off entirely during floods, posing a severe risk to life safety.
- Hardened shorelines have replaced coastal habitat and impeded or eliminated natural coastal processes that occur along natural edges that provided natural erosion reduction. Lack of coastal features along these hardened shorelines

impairs natural coastal processes and decreases coastal resilience from erosion and wave attenuation.

Opportunities are instances when the implementation of a plan has the potential to create a desirable future condition and provides ways to address the specific problems within the study area. This study presents opportunities to:

- Provide resilience and related benefits fairly.
- Design coastal flood defenses that are more resilient to earthquake risk.
- Align multiple Federal and regional agencies resilience investment in infrastructure sustainability and hardiness over multiple scenarios and conditions to coordinate efficient actions and expenditures.
- Educate the public and stakeholders about current and future flood risk and create incentives for residents and businesses in the future floodplain to take individual action to reduce flood risk exposure.
- Design coastal flood defenses that also improve wildlife habitat and reduce shoreline erosion through addition of natural and nature-based features (NNBFs) that mimic coastal processes.
- Develop innovative strategies for adapting at-risk historic maritime resources to RSLC consistent with the Secretary of the Interior Standards for Treatment of Historic Properties.
- Recognize the cultural experiences and traditions of waterfront communities and incorporate them into the planning and design of alternatives.
- Redesign streets and open space for water retention and storage and green infrastructure to address overland flooding issues and reduce transport of land-based pollutants into the Bay.
- Increase resilience of city transportation infrastructure from coastal hazards and combined flooding in the study area.
- Promote and enhance public access to the San Francisco waterfront and the Bay, including the San Francisco Bay Trail and San Francisco Bay Water Trail.
- Minimize carbon emissions from major construction by exploring and utilizing proven technology in materials and landscape design.

1.9. Planning Objectives and Constraints

As part of the USACE planning process, the PDT identified planning objectives and constraints to describe what a successful plan will accomplish. Planning objectives are specific statements that describe the desired measurable results of the planning process. The objective and constraint statements are used to guide the planning efforts to formulate solutions that solve the identified problems and attain the identified

opportunities. The metrics used to evaluate alternative plans against these objectives can be found in *Appendix A: Plan Formulation*. The following study-specific planning objectives for the 100-year period of analysis (POA), from 2040 to 2140, were identified for this study:

- Reduce risk to human health and safety from coastal hazards and flooding due to sea level rise, wave run up, and precipitation (combined flooding) in the study area
- Reduce costs and risks to the national, regional, and local economy associated with coastal hazards and combined flooding to business, residents, and infrastructure in the study area
- Increase community resilience opportunities from coastal hazards and combined flooding in the study area
- Reduce disruption to maritime facilities and functions caused by coastal hazards and combined flooding, through resilience strategies that support cargo shipping, cruise, ferry and water taxis, excursion boats, fishing, ship repair, berthing, harbor services, recreational boating, and other water-dependent activities
- Manage risk from coastal hazards and combined flooding to historic resources and preserve the maritime history of the waterfront
- Increase the ability and flexibility to respond to uncertain rates of RSLC

Planning constraints represent restrictions that limit the extent of the planning process and potential solutions. Plans should be formulated to meet the objectives and avoid violating the constraints. Constraints can be divided into two categories: general and study specific. General planning constraints are the technical, legal, and policy constraints that are included in every planning study. Study-specific planning constraints are statements unique to a specific study. All studies must avoid conflict with Federal regulations, as stated in Federal law, USACE regulations, and executive orders (EOs). These include NEPA, Section 106 of the National Historic Preservation Act of 1966 (NHPA), Clean Water Act (CWA), Coastal Zone Management Act (CZMA), EOs such as EO 1988, and USACE policies for planning, engineering, and design. The following study-specific constraints for the 100-year POA, from 2040 to 2140, were identified for this study:

- Avoid actions that may violate the authority of the Port Commission to fulfill its public trust responsibilities consistent with the Burton Act (Chapter 1333 of the California Statutes of 1968)
- Minimize disruption to permitted public access, including the San Francisco Bay Trail, San Francisco Bay Water Trail, Blue Greenway, bike paths, harbor walks, and pedestrian walkways
- Maintain ecological functions and minimize ecological disruptions in the Bay

- Avoid removing vital community infrastructure in at-risk communities such as libraries, community centers, health centers, and homeless shelters
- Avoid major loss of existing housing

1.10. Study Scope

USACE and POSF have partnered to study coastal and combined flood risk management along 7.5 miles of San Francisco's bayside shoreline including areas between Aquatic Park and Heron's Head Park. The study is one of several coordinated waterfront resiliency efforts being undertaken by the POSF in partnership with other Federal, State, and local agencies to plan and reduce the risk of anticipated seismic activity, coastal flood damages, and RSLC along the waterfront.

Section 2.0 Existing and Future Without Project Conditions*

This section presents a summary of existing conditions and future without project (FWOP) conditions in the study area. The existing conditions also represent the affected environment for the purposes of NEPA. The FWOP condition is a forecast of future conditions without construction of a Federal project. The FWOP condition is the consequence of taking no Federal action during the POA. The FWOP is used as a baseline for the analysis and comparison of alternatives developed for this study. For the purposes of simplicity in this report and to serve multiple audiences, the term “no action” will be used in combination with “future without project condition” and understood as described in the sentence above. A description of future actions that may occur within the study area used for the FWOP evaluation of resources is provided in Section 2.4.6.

This section is organized by four types of resources: (1) Natural Environment, (2) Physical Environment, (3) Built Environment (Infrastructure), and (4) Economic Environment (Demographics and Socioeconomics). Each of these resources are described in this section.

2.1. General Setting

The San Francisco waterfront study area extends for 7.5 miles from Hyde Street Pier in the north to India Basin in the south. The POSF holds this land in public trust for the use and enjoyment of the people of California, and develops, markets, leases, administers, manages, and maintains over 1,000 acres of land. This land adjacent to San Francisco Bay includes some of the region’s most popular open spaces and attractions, two national historic districts, hundreds of small businesses, nearby housing, and maritime and industrial uses. The POSF’s jurisdiction also includes important regional and citywide assets, including transportation networks like Bay Area Rapid Transit (BART) and San Francisco Municipal Railway (Muni); critical utilities, including drinking water and wastewater; key disaster response facilities; and state and regional maritime assets and functions.

The San Francisco shoreline has been altered considerably since the late 18th century. Yerba Buena Cove, Mission Bay, and the marshlands of Islais Creek have all been filled over time to create more developable land (termed “bay fill”) and maritime access. As the Bay water rises, the low-lying areas that have been previously filled will be the first to flood.

The waterfront lies within the San Andreas Fault system, which accommodates a significant fraction of the tectonic motion between the Pacific and North American plates. Although active faults of the San Andreas Fault system do not transect city boundaries, the inevitable slip on these nearby faults will cause future large earthquakes that could produce strong ground motions damaging to buildings, lifelines, and other infrastructure, and cause economic losses and fatalities. The shaking caused by these earthquakes would also induce liquefaction and landslides, with the most extensive ground failure likely to be caused by liquefaction around the margins of the city, which includes all the project extent.

2.2. Natural Environment

This subsection discusses the natural environment including wildlife, special status species, special status areas, and other relevant environmental resources within the study area. The affected environment for natural resources includes the San Francisco Bay Area and San Francisco Bay watershed located in the city and county of San Francisco.

2.2.1. Aquatic Resources

2.2.1.1. Existing Conditions

Aquatic resources refer to a range of habitats and natural water resources that are of potential use to humans including, but not limited to, wetlands, streams, lakes, rivers, springs, seeps, reservoirs, and ponds (Britannica 2023).

Intertidal habitats are the regions of the bay that lie between low and high tides (NOAA 2022b). The Central Bay basin includes natural and artificial intertidal habitats such as sandy beaches; natural and artificial rock (quarried riprap); concrete bulkheads; concrete, composite, and wood pier pilings; and mud flats. These habitats provide highly diverse locations for marine flora and fauna to forage, rest, reproduce, and refuge. Typical invertebrate and algae species inhabiting these zones include sea lettuce (*Ulva* spp.), rockweed (*Fucus gardeneri*), the red algae species (*Polysiphonia latisima* and *Gelidium* spp.), and the non-native brown algae species (*Sargassum muticum*) (AMS 2009). The Central Bay basin's proximity to the Pacific Ocean has resulted in an intertidal zone inhabited by many coastal and estuarine species.

The study area includes limited areas of sandy beaches (e.g., Aquatic Park) and mudflats (e.g., Heron's Head), which are mainly composed of sandy substrates and other soft-bottom material (SFPUC 2014). These habitats support benthic fauna including amphipods, polychaetes, and flies of the intertidal zone, providing food for shorebirds.

Subtidal habitats are submerged areas beneath the San Francisco Bay water surface and include mud, shell, sand, rocks, artificial structures, shellfish beds, eelgrass beds, macroalgal beds, and the water column above the bay bottom (Cosentino-Manning et al. 2010). Soft substrate comprises the majority of the bay's bottom (approximately 90%) and ranges between soft mud with high silt and clay content and areas of coarser sand. These latter tend to occur in locations subjected to high tidal or current flow. Soft mud locations are typically located in areas of reduced energy that enable deposition of sediments that have been suspended in the water column, such as in protected slips, under wharves, and behind breakwaters and groins. Artificial structures include a variety of constructed objects designed to protect shorelines and shoreline structures, for transportation, recreation, and restoration (oyster shell and artificial reefs) (Cosentino-Manning et al. 2010). In the intertidal and subtidal zones, barnacles (*Balanus glandula*, *Amphibalanus amphitrite*, *A. improvisus*), Bay mussel (*Mytilus trossulus/galloprovincialis*), and Olympia oyster are commonly present on hard substrate, as well as the invasive Asian mussel (*Musculista senhousia*). Red and brown algae are found attached to submerged intertidal hard substrate, including pier pilings.

Subtidal habitats provide diverse structure and function as an important habitat in the bay for various wildlife including fish (herring and salmon), vegetation (eelgrass and seaweed), shellfish, invertebrates, marine mammals, and birds (diving ducks and shorebirds) that forage, rest, refuge, and reproduce in the subtidal areas (Cosentino-Manning et al. 2010).

Submerged aquatic vegetation (SAV) refers to all underwater flowering plants. In San Francisco Bay, SAV includes sago pondweed (*Stuckenia pectinata*), eelgrass (*Zostera marina*), surfgrasses (*Phyllospadix torreyi* and *P. scouleri*), and widgeongrass (*Ruppia maritima*). Eelgrass is the most extensive SAV in San Francisco Bay (Cosentino-Manning et al. 2010), albeit very few beds are documented or known to occur within the study area (Merkel and Associates 2014). Small, isolated beds are known to occur along the southern extent of the study area, such as Heron's Head Park.

The open water (pelagic) environment of the San Francisco Bay is near the Pacific Ocean and is very similar to the open water coastal environment. Pelagic habitat is the predominant marine habitat in the Bay and includes the area between the water surface and the seafloor, which can be further subdivided into shallow water/shoal and deep water/channel areas. The water column is predominantly inhabited by planktonic organisms that float or swim in the water, fish, marine birds, and marine mammals.

Fisherman's Wharf is the central hub of Northern California's commercial and recreational fishing fleets, while Pier 45 is the West Coast's largest concentration of commercial fish processors and distributors (POSF 2022). The San Francisco Bay, adjacent to the study area, once supported several commercial fisheries including salmon, sardines, herring, halibut, sturgeon, oysters, crabs, and shrimp; however, presently only the Pacific herring (*Clupea pallasii*) fishery has survived (Mann n.d.). Annual herring landings have ranged up to 11,000 metric tons since 1980 (Thayer et al. 2020). Herring is found offshore in California during the spring and summer foraging in the open ocean and then forms spawning aggregations starting in the fall. San Francisco Bay hosts the largest spawning aggregation, along with Tomales Bay, for Pacific herring with the greatest concentrations between October and April (CFW 2022). Many of the once productive commercial fisheries collapsed due to overharvesting and a myriad of environmentally damaging practices such as water consumption and diversion, modification of the sediment supply, introduction of non-native species, and sewage input, as well as climate shifts and environmental policy that did not effectively protect the resources (Cloern and Jassby 2012).

The bay supports a variety of important recreational fisheries including groundfish, salmon, sharks, sportfish, shellfish, and kelp. Although recreational fisheries are popular in San Francisco Bay, many of the fish are under a consumption advisory from the California Office of Environmental Health Hazard Assessment including sharks, white sturgeon, surfperches, striped bass (do not eat), and California halibut and white croaker (limit consumption to one serving per week (OEHHA 2018).

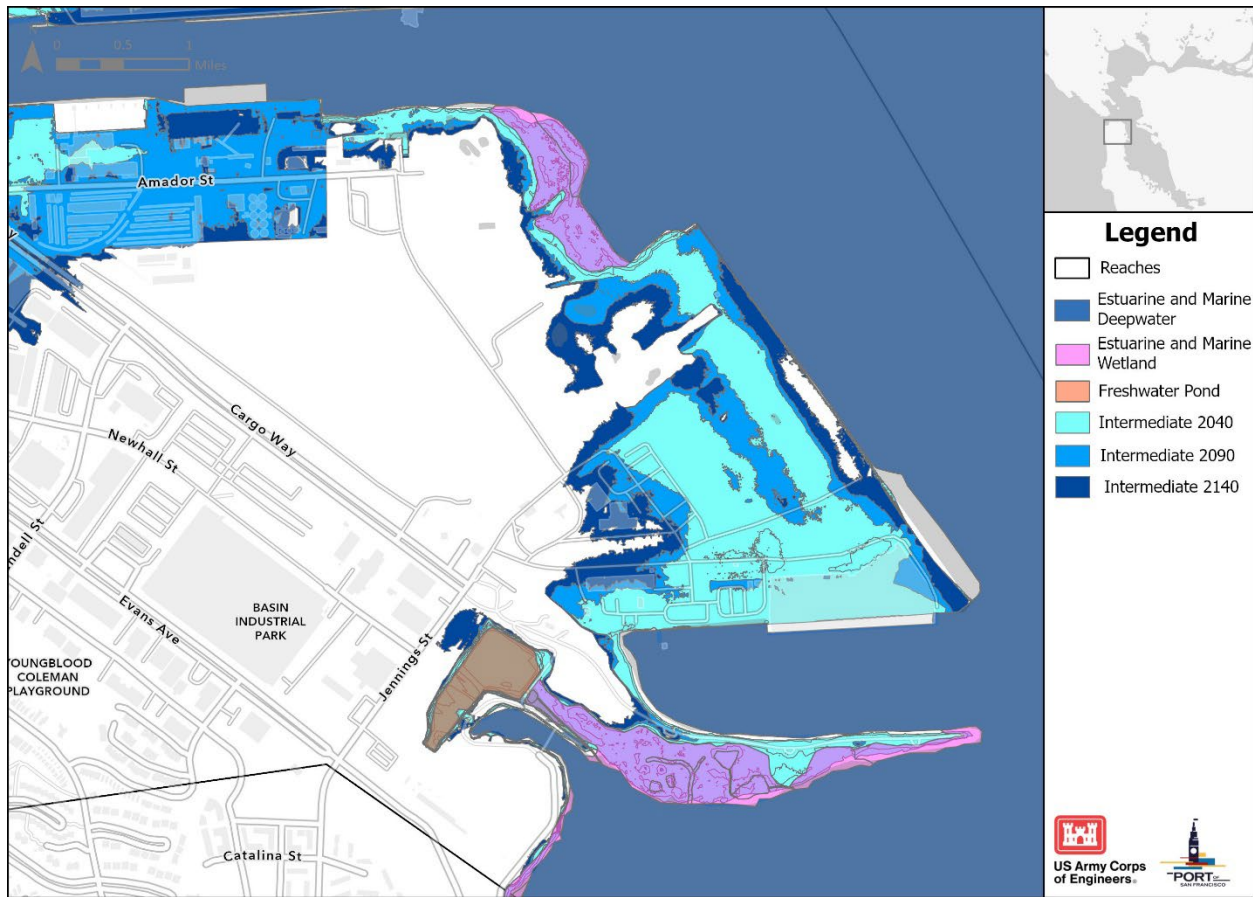
Wetlands are important aquatic habitats for fish, invertebrates, birds, and mammals. In the study area, wetlands are located predominantly in Reaches 3 and 4 at Pier 94, Heron's Head Park, Warm Water Cover, and on the north and south banks of Islais Creek.

2.2.1.2. Future Without Project

Intertidal and subtidal habitats are expected to continue given that most of these habitats in the study area are artificial. With changing meteorological conditions and RSLC, there could be an increase in intertidal and subtidal habitats as fringe marshes, low-lying vegetated areas, and artificial structures such as piers, wharves, and bulkheads become inundated or are permanently covered by water. RSLC could adversely impact existing intertidal and subtidal suitability by increasing water depths, resulting in reduced productivity and exposure to tidal exchange. This would most likely occur with natural habitats such as shellfish beds, eelgrass beds, and macroalgal beds that are vulnerable to these conditions and are predominantly sessile.

Pelagic habitat could be degraded over time with changes in water quality (e.g., temperature, salinity, and dissolved oxygen [DO]), flow patterns, and habitat composition following extreme events. In general, as RSLC rises, it would be assumed the pelagic environment would increase in volume with additional water depth. However, changing meteorological conditions could cause a shift in plankton and benthic communities, which are food sources for pelagic fish and mammalian species. A shift in the composition, abundance, or distribution of food sources could result in similar shifts to pelagic fish and mammals, such that these species seek forage grounds elsewhere in the bay or Pelagic Ocean.

Wetland degradation and loss would be expected to occur under the Intermediate RSLC scenarios (**Figure 2-1**). Thorne et al. 2024 estimated an accretion rate approximately of 6-7 millimeters per year (mm/yr) for San Francisco Bay, albeit north of the project area. Sediment accretion could alleviate impacts of RSLC when surface elevation increases at or exceeds the rate of RSLC (Anisfeld et al. 2016; Ouyange et al. 2022). Under current projections of Intermediate RSLC, sea level rise outpaces the accretion rate for San Francisco Bay, and thus, already leads to sediment loss. This would continue in the future, with the majority of marsh in the study area being inundated during daily mean higher high water (MHHW) conditions by 2040 (**Figure 2-1**). It is plausible marsh in the study area would be lost by 2140.



San Francisco Waterfront Resiliency Study
Integrated Feasibility Report/Environmental Impact Statement

Figure 2-1: Inundation of Heron's Head and Pier 96 Wetlands under the Intermediate RSLC Scenario for the Period of Analysis

Marine biodiversity has experienced significant alterations due to changing meteorological conditions, linked, in part, to changing physical and biogeochemical conditions that have directly or indirectly led to shifts in species distribution and abundances (Liu et al. 2024). These changes have resulted in shifts in community composition, which has the potential to lead to widespread change in ecosystem structure and function (Lui et al. 2024). Widespread shifts in distribution and abundances in planktonic, benthic, and fish species is likely to occur in the future in the study area as changing meteorological conditions continues, as evident through declines in Atlantic and Pacific salmon and steelhead populations, for example. With the loss or change in distribution of important fish, it is also likely to result in fishery declines, of commercial and recreational importance, as well as negatively affect culturally important practices and marine mammals (Crozier et al. 2021).

Over the POA, loss of these habitats would be **significant** given their rare nature in the project area.

2.2.2. Upland Resources

2.2.2.1. Existing Conditions

The California annual grassland community, also known as non-native grassland, is typically composed of a dense cover of introduced annual grasses and ruderal (woody) forbs (broad-leaved plants) adapted to colonizing and persisting in disturbed upland habitats. The California annual grassland community can provide cover, foraging, and nesting habitat for a variety of bird species, as well as reptiles and small mammals. Coastal scrub is present only at the easternmost portion of the study area, within India Basin Open Space. Coastal scrub commonly includes buckwheat (*Eriogonum spp.*), sage (*Salvia spp.*), bush monkeyflower (*Mimulus aurantiacus*) and poison oak (*Toxicodendron diversilobum*). Coastal saltmarsh is a wetland type flood and drained by saltwater between high and low tides and is composed of a variety of terrestrial and aquatic species (NOAA 2022c). Coastal saltmarshes can be fully tidal, or brackish if they occur near the mouth of a freshwater source. Coastal saltmarshes in the Central and South Bay are remnants of their former extent. Where salt marshes are still present, they support high densities and high diversity of wildlife. Additionally, they provide habitat for the Ridgway's rail (*Rallus obsoletus*) and salt marsh harvest mouse (*Reithrodontomys raviventris*), both of which are Federally and State-endangered and state fully protected species.

2.2.2.2. Future Without Project

The study area is highly urbanized with limited availability of terrestrial vegetation, particularly native species. This is not anticipated to change in the future, rather the study area will continue to be an urbanized region predominated with non-native and ornamental plants. RSLC would likely convert lower lying upland areas to wetlands or subtidal and/or intertidal habitats as they became regularly inundated.

2.2.3. Special Status Species

2.2.3.1. Existing Conditions

Special status species are plant and wildlife species considered sufficiently rare, such that they require special consideration and/or protection and should be, or currently are, listed as rare, threatened, or endangered by the Federal and/or State governments. Such species are legally protected under the Federal and/or State Endangered Species Act (ESA) or other regulations listed below, or are species considered sufficiently rare by the regulatory and scientific community to qualify for protection. The U.S. Fish and Wildlife Service's (USFWS's) Information for Planning and Consultation (IPaC) database lists the threatened and endangered (T&E) species and trust resources that may occur within the study area boundary, while National Marine Fisheries Service (NMFS) provided a list of species with an official letter. Based on the IPaC report and species directory, there are 27 USFWS listed species (threatened, endangered, or candidate), 14 additional NMFS listed species, and two designated critical habitats found to potentially occur within the study area (**Table 2-1**).

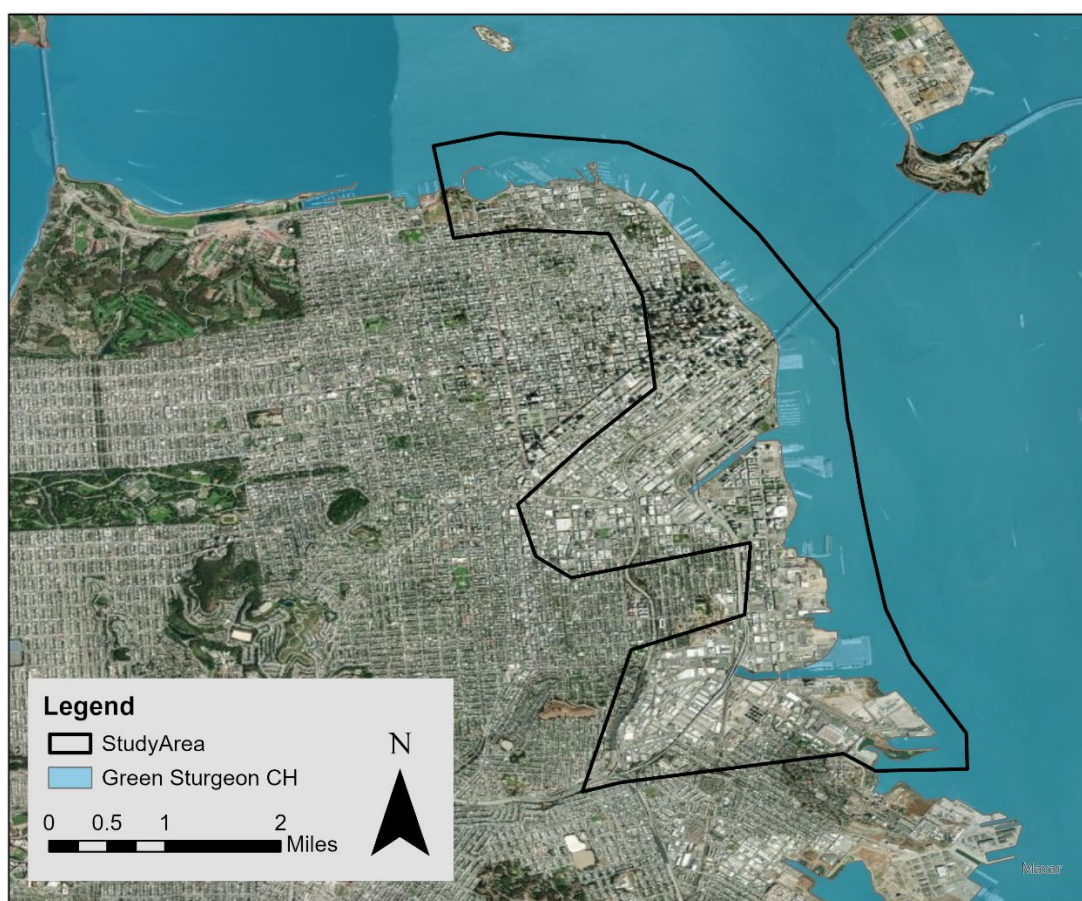
Table 2-1: Federal Threatened, Endangered, or Candidate Species Identified By USFWS and NMFS That May Occur in the Study Area

Common Name and Scientific Name	Federal Status	Jurisdiction
Salt marsh harvest mouse <i>Reithrodontomys raviventris</i>	Endangered	USFWS
California Ridgeway's Rail <i>Rallus obsoletus</i>	Endangered	USFWS
California least tern <i>Sterna antillarum browni</i>	Endangered	USFWS
Marbled murrelet <i>Brachyrampus marmoratus</i>	Threatened	USFWS
Western snowy plover <i>Charadrius nivosus</i>	Threatened	USFWS
Alameda whipsnake <i>Masticophis lateralis euryxanthus</i>	Threatened	USFWS
San Francisco garter snake <i>Thamnophis sirtalis tetrataenia</i>	Endangered	USFWS
Green sea turtle <i>Chelonia mydas</i>	Threatened	USFWS
California red-legged frog <i>Rana draytonii</i>	Threatened	USFWS
Delta smelt <i>Hypomesus transpacificus</i>	Threatened	USFWS
Tidewater goby <i>Eucyclogobius newberryi</i>	Endangered	USFWS
Sacramento River Chinook salmon critical habitat, winter-run Evolutionary Significant Unit (ESU) <i>Oncorhynchus tshawytscha</i>	Endangered	NMFS
Central Valley Chinook salmon, spring-run ESU <i>O. tshawytscha</i>	Threatened	NMFS
Central California Coast Steelhead trout, Distinct Population Segment (DPS) <i>Oncorhynchus mykiss</i>	Threatened	NMFS
California Central Valley Steelhead trout DPS <i>O. mykiss</i>	Threatened	NMFS

Common Name and Scientific Name	Federal Status	Jurisdiction
North American Green sturgeon, southern DPS critical habitat <i>Acipenser medirostris</i>	Threatened	NMFS
Longfin smelt, San Francisco Bay-Delta DPS <i>Spirinchus thaleichthys</i>	Endangered	USFWS
Monarch butterfly <i>Danaus plexippus</i>	Candidate	USFWS
California seablite <i>Suaeda californica</i>	Endangered	USFWS
Franciscan manzanita <i>Arctostaphylos franciscana</i>	Endangered	USFWS
Marin dwarf-flax <i>Hesperolinon congestum</i>	Threatened	USFWS
Marsh sandwort <i>Arenaria paludicola</i>	Endangered	USFWS
Presidio clarkia <i>Clarkia franciscana</i>	Endangered	USFWS
Presidio manzanita <i>Arctostaphylos hookeri</i> var. <i>ravenii</i>	Endangered	USFWS
Robust spineflower <i>Chorizanthe robusta</i> var. <i>robusta</i>	Endangered	USFWS
San Francisco lessignia <i>Lessingia germanorum</i>	Endangered	USFWS
Showy Indian clover <i>Trifolium amoenum</i>	Endangered	USFWS
Sonoma sunshine <i>Blennosperma bakeri</i>	Endangered	USFWS
White-rayed pentachaeta <i>Pentachaeta bellidiflora</i>	Endangered	USFWS

Two critical habitats occur within the study area – green sturgeon and chinook salmon. Green sturgeon critical habitat spans approximately 320 miles of freshwater river habitat, 897 square miles (mi²) of estuarine habitat, 11,421 mi² of marine habitat, 487 miles of the Sacramento-San Joaquin Delta, and 135 mi² of the Yolo and Sutter bypasses in the Sacramento River (50 CFR 226). All of San Francisco Bay adjacent to the study area is considered critical habitat for green sturgeon (**Figure 2-2**).

There are several chinook salmon critical habitats throughout California; however, only one intersects the study area – the Sacramento River winter-run chinook salmon. The critical habitat includes the Sacramento River from Keswick Dam, Shasta County (river mile 302) to Chipps Island (River Mile 0) at the westward margin of the Sacramento-San Joaquin Delta; all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge; and all waters of San Francisco Bay from San Pablo Bay to the Golden Gate Bridge (50 CFR 226). Chinook salmon critical habitat includes waters in the northern two reaches of the study area (**Figure 2-3**).



Source: NMFS 2021

Figure 2-2: Green Sturgeon Critical Habitat Within the Study Area

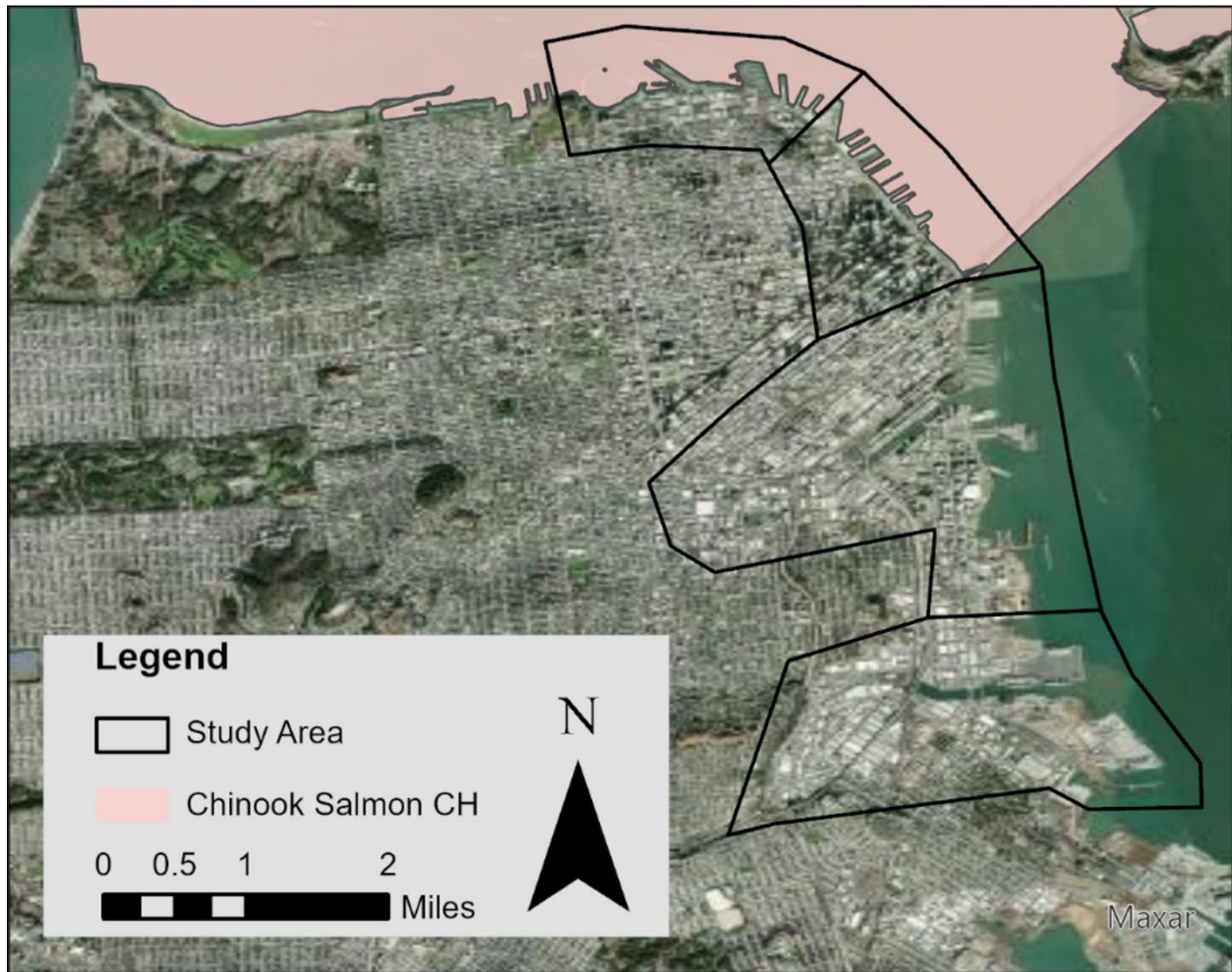


Figure 2-3: Chinook Salmon Sacramento River Winter-Run Critical Habitat Within the Study Area

In California, animal or plant species of conservation concern may be listed as threatened or endangered under the authority of the California ESA of 1984 (CESA; Cal. Code Regs. tit. 14 §§ 783.0-787.9). The California Natural Diversity Database online BIOS Quicktool was used to evaluate the state-protected T&E species likely present in the study area. It was determined the study area provided suitable habitat for seven CESA protected animal and plant species that include California Ridgeway's rail, bank swallow (*Riparia riparia*), California black rail (*Laterallus jamaicensis coturniculus*), longfin smelt (*Spirinchus thaleichthys*), Chinook salmon – Central Valley spring-run, marsh sandwort, and marine dwarf-flax (*Hesperolinon congestum*). Of these, three of the animal and plant species, respectively, also are Federally listed (**Table 2-2**).

Table 2-2: State-Listed Threatened and Endangered Species Potentially Occurring in the Study Area

Common Name and Scientific Name	State Status	Federal Status	Habitat Requirements
BIRDS			
California Ridgeway's rail <i>Rallus obsoletus obsoletus</i>	Endangered	None	Reside in the San Francisco Bay Area; lives in dense vegetation in saltwater marshes, freshwater marshes, and mangrove swamps
Bank swallow <i>Riparia riparia</i>	Threatened	None	Breed in open lowland areas near bodies of water; avoid forests, woodlands, or areas that lack appropriate nesting
California black rail <i>Laterallus jamaicensis coturniculus</i>	Threatened	None	Live in tidal and freshwater marshes in California
FISH			
Longfin smelt <i>Spirinchus thaleichthys</i>	Threatened	Endangered	Reside in San Francisco Estuary; use a variety of habitats including nearshore waters, estuaries, lower portions of freshwater streams
Chinook salmon - Central Valley spring-run <i>Oncorhynchus tshawytscha</i>	Threatened	Threatened	Spend early life growing and feeding in freshwater streams, estuaries, and wetlands; transition to open ocean and estuaries, then return to freshwater to spawn
PLANTS			
Marsh sandwort <i>Arenaria paludicola</i>	Endangered	Endangered	Reside in freshwater marshes, swamps, and areas that are wet year-round
Marin dwarf-flax <i>Hesperolinon congestum</i>	Threatened	Threatened	Endemic to San Francisco County; occur in serpentine soils, in dry native bunch grasses

Few marine mammal species occur in the San Francisco Bay within the study area. Pacific harbor seals (*Phoca vitulina richardsi*) are the only resident in the Bay year-round with the highest numbers sighted during the pupping (March to May) and molting (June to July) seasons (SFBAWT 2022). Harbor seals congregate on “haul-out” terrestrial sites annually, which are typically located in areas with easy access to the

water, proximity to food, and experiences minimal disturbances. Haul-out sites can be used annually or seasonally, with some being important for providing shelter during pupping and molting (SFBAWT 2022).

California sea lions (*Zalophus californianus*) use the Bay for foraging but breed elsewhere. Pier 39 in the study area is a common haul-out site for California sea lions where they are often observed loafing. The greatest number of sea lions are observed in the Bay during the winter herring run (December to February). Sea lions are opportunistic feeders and will prey mostly on schooling species, but have also been known to consume leopard sharks, shrimp, and crabs (SFBAWT 2022).

Harbor porpoises (*Phocoena phocoena*) are sighted year-round in harbors, bays, and estuaries of the San Francisco Bay. The porpoise is elusive and typically solitary, or may travel in small pods of two to five individuals (MMC 2022). Individuals traditionally feed on schooling fish (herring, capelin, and hake) and will occasionally eat squid or octopus. They were believed to have disappeared from the San Francisco Bay in the 1940s during World War II and because of environmental contaminants from industrialization; however, they returned in the 1990s following restoration attributed to the Clean Air and Water Act (MMC 2022).

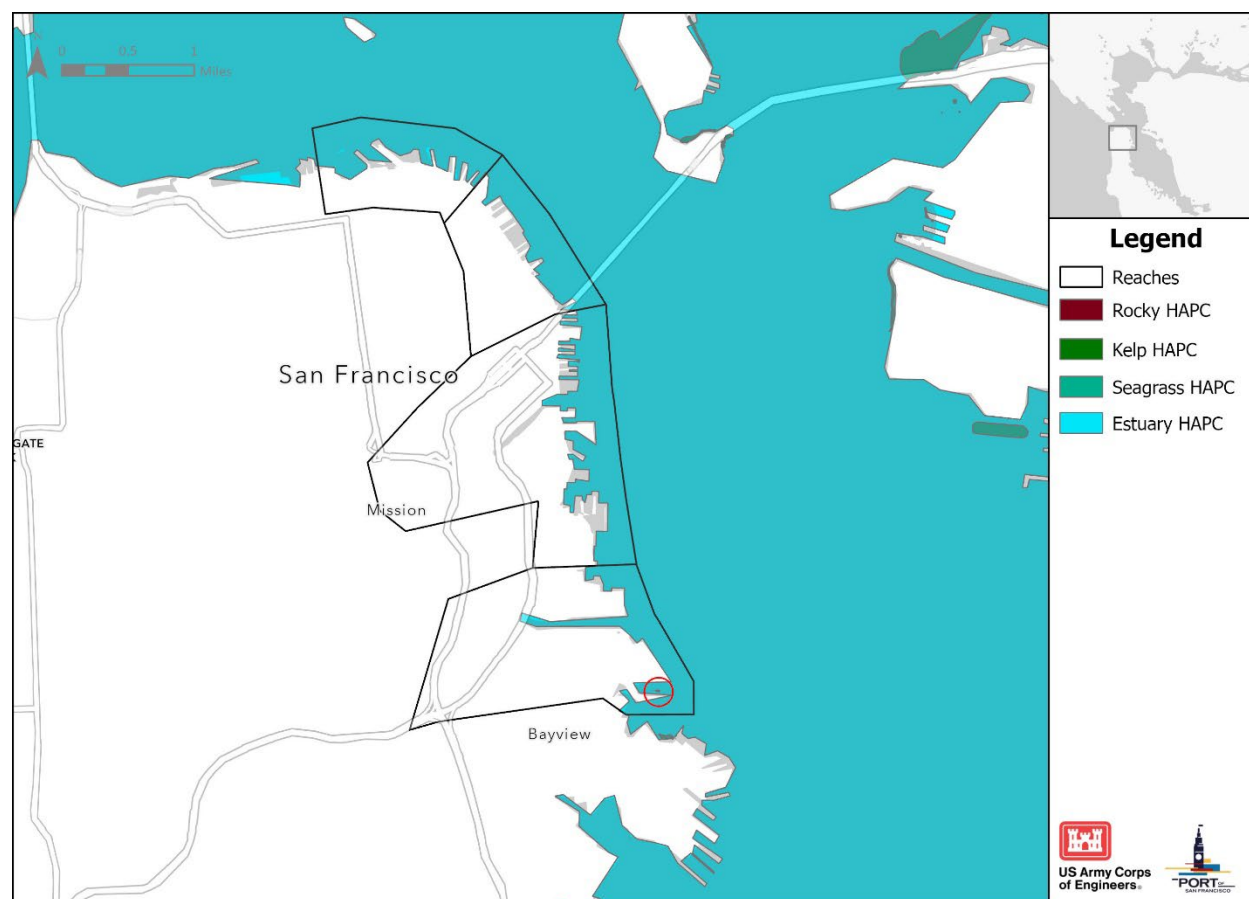
Most cetacean sightings occur in the Central Bay basin, outside of the study area. Marine mammal presence is predominantly dependent on distribution and presence of prey species and foraging habitat (SFBAWT 2022).

San Francisco Bay is a migration highway for over 250 species of birds, many of which are small songbirds (e.g., warblers, thrushes, tanagers, and sparrows) and some threatened species (GGAS 2023). A variety of birds use this area to forage in the many microclimates while others use the Bay Area as a resting stop over. The San Francisco Bay is the largest estuary on the Pacific Coast, thus, is an ideal refuge for shorebirds, raptors, and songbirds.

Populations of bald and golden eagles are found in the less urbanized areas of San Francisco Bay and coastal range. While individual eagles may migrate through the area, the study area does not support nesting habitat for eagles because it generally lacks large mature trees. If nesting were to occur, the nest would need to be placed on constructed structures, which would present its own set of challenges to survival, although not unheard of in other parts of the county. The chance of this occurring is relatively low because more suitable nesting habitat is available throughout the Bay or in more vegetated areas of the city.

Essential fish habitat (EFH) includes “waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity” (NMFS 2021; GMFMC & NMFS 2016). The study area falls within EFH for 20 species of commercially important fish and sharks managed under the Pacific Groundfish, Coastal Pelagic, and Pacific Coast Fisheries Management Plans. Of the fish species considered by NMFS to potentially occur within the study area, EFH habitat for these species consists of all waters and substrate from MHHW to 3,500 water depth, seamounts, and areas designated as Habitats of Particular Concern (HAPCs). There are four HAPCs within the study area, including the San Francisco Estuary (estuary HAPC), seagrass, rocky reef, and marine and estuarine SAV HAPC, as shown on **Figure 2-4**. The study area includes 0.29 acre

of seagrass HAPC, and the entire in-water study area is considered salmon EFH and estuary HAPC (Hanshew 2019; NOAA 2016).



San Francisco Waterfront Resiliency Study
Integrated Feasibility Report/Environmental Impact Statement

Source: Hanshew 2019

Figure 2-4: HAPC Within the Study Area

Table 2-3 identifies the fish species covered by the fishery management plans as utilizing the study area, along with the life stage and relative occurrence.

Table 2-3: Managed Fish Species in the Study Area Under the Magnuson-Stevens Fishery Management Act

Fmp	Common Name	Scientific Name	Life Stage	Abundance
Coastal Pelagic	Northern anchovy	<i>Engraulis mordax</i>	J, A	A
	Jack mackerel	<i>Sardinops sagax</i>	E, L	P
	Pacific sardine	<i>Trachurus symmetricus</i>	J, A	P

Fmp	Common Name	Scientific Name	Life Stage	Abundance
Pacific Groundfish	English sole	<i>Parophrys vetulus</i>	J, A	A
	Sand sole	<i>Psettichthys melanostictus</i>	L, J, A	P
	Curlfin sole	<i>Pleuronichthys decurrens</i>	J	R
	Pacific sanddab	<i>Citharichthys sordidus</i>	E, L, J, A	P
	Starry flounder	<i>Platichthys stellatus</i>	J, A	P
	Lingcod	<i>Ophiodon elongatus</i>	J, A	P
	Brown rockfish	<i>Sebastes auriculatus</i>	J	P
	Pacific whiting	<i>Merluccius productus</i>	E, L	P
	Kelp greenling	<i>Hexagrammos decagrammus</i>	J, A	P
	Leopard shark	<i>Triakis semifasciata</i>	J, A	P
	Spiny dogfish	<i>Squalus acanthias</i>	J, A	P
	Skates	<i>Raja</i> spp.	J, A	P
	Soupfin shark	<i>Galeorhinus galeus</i>	J, A	R
	Bocaccio	<i>Sebastes paucispinis</i>	J	R
	Cabazon	<i>Scorpaenichthys marmoratus</i>	J	P
Pacific Coast Salmon	Chinook salmon	<i>Oncorhynchus tshawytscha</i>	J, A	Seasonally P
	Coho salmon	<i>O. kisutch</i>	J, A	Historically P

Life stage is indicated with A = adult, J = juvenile, L = larvae, and E = egg. Abundance is recorded as A = abundant, P = present, and R = rare.

2.2.3.2. Future Without Project

RSLC and flooding exacerbated by changing meteorological conditions is likely to negatively impact special status species including ESA-listed, State protected, migratory birds, marine mammals, EFH and EFH-designated species, HAPC, and SAV through habitat loss or conversion, and water quality degradation.

RSLC may convert low-lying upland areas to wetlands or subtidal and/or intertidal habitats that would reduce available nesting and foraging for Ridgway's rail, diminish or eliminate necessary transition zones and refuge for salt marsh harvest mice, and further limit adequate habitat for California seablite. Warming water temperatures can influence egg development and hatching rate for green sturgeon, which may have more detrimental effects to the overall recovery of the species (NMFS 2022). Changes in flow patterns or currents may change the behavior of green sturgeon in marine environments

that could make them more susceptible to human activities such as dredging and bottom disturbances (NMFS 2022). Changing meteorological conditions and warming water temperatures could shift prey availability for salmon and steelhead trout, as well as endangered marine mammals and state-listed aquatic species, while ocean acidification could have negative impacts on protected shellfish. The study area includes critical habitat for green sturgeon and chinook salmon that is likely to degrade with reduced water quality (e.g., lowered DO and contaminants), which may contribute to loss or shift in distribution of these species.

San Francisco Bay is a critical stop over habitat for migratory bird species. Wetland loss and water quality degradation may exacerbate ongoing critical habitat loss for migratory birds that could require shifts in migratory patterns over time.

EFH impacts would be focused on loss of shallow nearshore areas including SAV. The study area supports a diverse fish community including EFH. HAPC impacts would be focused on degradation of the quality of habitat through ocean acidification driven by changing meteorological conditions. More frequent flooding would increase contaminants delivery to HAPC, which would reduce water quality. Due to the urbanized nature of the shoreline and water quality degradation, the amount of SAV has been greatly diminished in the study area over time. Changing meteorological conditions and RSLC introduce greater uncertainty of continued trends where changes in temperature, precipitation, flooding patterns, and chemical composition could impose additional impacts on water quality, algal blooms, and SAV/macroalgae distribution and abundance. RSLC could also potentially impact habitat suitability for seagrasses by increasing water depths resulting in reduced light penetration, photosynthesis, and productivity (Strange 2008; USACE 2014).

2.3. Physical Environment

This subsection discusses the physical environment within the study area, including air quality, climate, geology and geomorphology, soils and minerals, hydrology and hydraulics, water quality, groundwater, noise and vibration, cultural resources, and hazardous, toxic, and radioactive waste (HTRW).

2.3.1. Air Quality

2.3.1.1. Existing Conditions

The study area is in the San Francisco Bay Area Air Basin (SFBAAB), which is regulated primarily by the Bay Area Air Quality Management District (BAAQMD). The determination of the criteria air pollutants relevant to the action was based on an assessment of existing air quality conditions in the SFBAAB. The determination of toxic air contaminants (TACs; also known as hazardous air pollutants [HAPs]) relevant to the action was based on BAAQMD guidance and study conditions.

The attainment status for criteria air pollutants in the study area varies and is summarized in **Table 2-4**.

Table 2-4: Federal Pollutant Attainment Status of Study Area

Source: EPA 2020

Pollutant	Attainment Status
Ozone (8 hours)	Nonattainment (marginal)
CO	Attainment
PM ₁₀	Attainment/Unclassified
PM _{2.5}	Nonattainment (moderate)

The U.S. Environmental Protection Agency (EPA) defines the HAPs as pollutants that are known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects (EPA 2017). California law uses the term TAC, which is defined as an air pollutant that “may cause or contribute to an increase in mortality or an increase in serious illness or pose a present or potential hazard to human health.” Controlling air toxic emissions became a national priority whereby Congress mandated that EPA regulate 187 air pollutants. HAPs can be emitted from stationery and mobile sources, such as refineries and heavy-duty vehicles. The primary source of TACs in the study area are diesel-powered on-road haul trucks and off-road construction equipment.

2.3.1.2. Future Without Project

It was assumed no actions would be taken to reduce flood risks beyond projects already approved along the San Francisco waterfront; thus, the No Action Alternative has the potential to result in significant air quality and greenhouse gas (GHG) emissions from increased maintenance, emergency response, and recovery activities to address coastal flooding including demolition and relocation of buildings within inundation areas. In addition, disruptions to the electrical grid could also generate emissions, especially if replacement power sources are fossil fueled. The FWOP scenario also poses potential health risks to individuals displaced from their homes due to flooding if they are relocated to areas with higher ambient air pollution or if they become unhoused.

Identifying the specific emissions activities under the FWOP involves a high degree of uncertainty because the timing, types, and magnitude of maintenance, construction, response, and relocation would be strongly influenced by the specific nature, timing, and severity of storm surges, which are unpredictable. While it is improbable to fully estimate all emissions, a rough estimate of fuel expenditures for the San Francisco Public Utilities Commission (SFPUC) anticipated storm and sewer upgrades was made. The fuel estimated for SFPUC work was approximately 3,846,000 gallons. CO₂ emissions are highly correlated to fuel use with approximately 99% of carbon in diesel fuel emitted in the form of CO₂ (EPA 2023b). EPA published a CO₂ emission factor of 10.18 kilograms per gallon. Using these assumptions, CO₂ emissions from the SFPUC storm and sewer upgrades were estimated to equate to approximately 3,920 metric tons

CO₂ per year over the construction period (120 months). This is equivalent to 914 gasoline-powered passenger vehicles driven for 1 year (EPA 2024).

While criteria pollutants are generated from fossil fuel combustion in construction equipment and vehicles, compared to GHGs, the magnitude of criteria pollutants released is more strongly influenced by types and efficiency of equipment-specific control technologies. Because criteria pollutants cannot be reliably calculated from fuel use alone, a criteria pollutant emissions inventory cannot be generated at this time for the FWOP scenario.

Another substantial source of emissions would be repairs, recovery, demolition, and potential relocation of damaged and unusable buildings and facilities. Based on RSLC inundation, 2,430 housing units, 38 Local Business Enterprise (LBE) businesses, 25 city facilities, 4 miles of Muni routes, and 10 miles of streets would be impacted under the 2040 1% annual exceedance probability (AEP). For the 2090 1% AEP, 13,248 housing units, 174 LBE businesses, 237 city facilities, 22 miles of Muni routes, and 42 miles of streets would be inundated.

The lack of ability to precisely estimate storm event response precludes a comprehensive and accurate analysis of expected emissions. The fuel and GHG emissions estimates for the SFPUC storm and sewer upgrades highlight the substantial GHG output associated with a single component of the FWOP scenario. Substantial additional emissions would be generated by other activities under the FWOP scenario, including but not limited to maintenance, sea wall repairs, demolition, relocation, and road reconstruction. Given the damage expected and the associated magnitude of repairs, it is likely air quality impacts would be significant.

2.3.2. Meteorological Conditions

2.3.2.1. Existing Conditions

Meteorology or climate refers to the long-term weather conditions that describe a region, whereas weather relates to short-term changes in the atmosphere (NOAA 2020).

San Francisco is straddled by sharp topography and marine environments that create a unique variety of microclimates. The San Francisco Bay Area climate is classified as Mediterranean and is characterized by relatively dry, cool summers and mild winters (Null 1995). In the summertime, San Francisco experiences cool marine air and persistent coastal stratus and fog, with average temperatures between 60 and 70 degrees Fahrenheit (Null 1995). The cool marine air is influenced by the upwelling of cold water along the California coast, driven by oceanographic conditions that cause a net transport of surface water away from the shore that are consequently replaced by cold, upwelled water (Null 1995, Ahrens 1991). Winter temperatures are temperate with highs between 55 and 60 degrees Fahrenheit and lows between 45 and 50 degrees Fahrenheit (Null 1995).

Rainfall in San Francisco is seasonal, with over 80% occurring between November and March (Null 1995). Winter rains typically occur because of fronts primarily from the west-northwest and occasionally from the Gulf of Alaska. Spring and fall rain are

infrequent, with most storms producing light precipitation during these periods (Null 1995). In general, hydrometeorological patterns in California are often associated with phenomena known as atmospheric river (AR) events. ARs are narrow bands of low-level systems with high precipitable water content that extend from the tropics into the mid-latitudes (Climate 2015). In general, California's hydrometeorological data indicate robust patterns of AR events promote heavy rains and flooding. Conversely, drought conditions prevail when ARs are persistently low or weak (Climate 2015). Annual precipitation has been cyclical in the Bay Area, varying from approximately 5 inches to 37 inches over the last century. On average, the region receives 20 to 23 inches of rain annually. Droughts are also common in the San Francisco Bay Area, which can be tracked in the U.S. Drought Monitor. Over the last two decades, drought intensity has become more prevalent in the San Francisco Bay Area.

The San Francisco Bay is a large estuary with varying salinity, influenced by seasonality, local bathymetry, proximity to the Pacific Ocean, precipitation, and river discharge. In 2016, the U.S. Geological Survey (USGS) released water quality data including water temperature and salinity measurements sampled from discrete locations across the San Francisco Bay over the course of nearly 47 years (1969 – 2016). Water temperatures have been recorded in the range of roughly 48.5 to 67.5 degrees Fahrenheit. Salinity at this location is most often in the range of 25 – 33 parts per thousand.

2.3.2.2. Future Without Project

The potential for emergency maintenance activities is expected to increase because of coastal flooding. Equipment and vehicles used for emergency maintenance activities would generate GHG emissions. Disruption of the electrical grid could also generate GHGs, particularly if replacement power sources, such as diesel generators, are fossil fueled. A FWOP condition likely includes increased risk from meteorological conditions such as extreme precipitation, drought, and heat waves within the POA (NCA 2014, 2018; Ault et al. 2014; Ault et al. 2016; Cook et al. 2016; Jones and Gutzler 2016). This is likely to cause flooding, erosion, and increases in the rate and amount of nutrients and sediments entering the bay.

2.3.3. Soils and Minerals

2.3.3.1. Existing Conditions

The San Francisco Bay Area consists of a combination of residual (i.e., have formed in place) and depositional (i.e., transported from somewhere else) soils that are predominately clay, sand, loam, and peat-like organic matter (Hayes 2005). Much of the residual soil is fine in texture and formed from sedimentary rocks, which over time weathered to clay minerals and clay-like soils rich in nutrients. Depositional soils occur along the wetlands where fine, clay-sized sediments were transported via marine currents or streams, and large-particle sand that were deposited by streams or carried by wind. Loamy soils are an optimal blend of sand, silt, and clay and are typically found in alluvial or depositional valley and bay fronts around the bay. Soils along the California

coast contain approximately 4% organic material, while this lowers with inland soils to about 1 to 2% (Hayes 2005).

California hosts a diversity of mineral resources that can be categorized into metals, industrial minerals, and construction aggregate. Metals include gold, silver, iron, and copper. Industrial minerals include boron compounds, rare-earth elements, clay, limestone, gypsum, salt, and dimension stone. Construction aggregate consists of sand, gravel, and crushed stone (CGS 2019).

2.3.3.2. Future Without Project

Soils and mineral resources are expected to continue as described in existing conditions. Future exploration and production of oil, gas, and minerals within the study area is highly dependent on market conditions, value of existing resources, presence of production fields, and future development. It is unlikely that urbanized areas would see any increase in oil and gas production.

2.3.4. Hydrology and Hydraulics

2.3.4.1. Existing Conditions

San Francisco Bay is the largest estuary in the western U.S., with a 300-foot-deep Golden Gate inlet that connects the Bay with the Pacific Ocean. The tides, ocean-driven swells, and extreme ocean water levels all enter the Bay through this single inlet. San Francisco Bay is characterized by broad narrow shoals and narrow channels that result in a complex tidal system with a complex bathymetry that contribute to large spatial variability in flow properties. The interactions among tidal processes, bathymetric complexities, and shoreline orientation amplify tidal ranges, with tides increasing with the spatial distance from the Golden Gate inlet (Conomos 1979). The large expanse of the Bay combined with the complex topography surrounding the Bay can transform storm-driven winds in a multitude of directions depending on the primary driver of the onshore or offshore winds or the track of the large storm system descending on the Bay Area. The water levels and wave heights of the Bay exhibit a high degree of variability driven by many factors, including the bathymetry, astronomical and oceanic cycles (e.g., El Niño Southern Oscillation and Pacific Decadal Oscillation), windspeeds and direction, and atmospheric events such as extratropical cyclones and ARs. In the Bay, no single storm event produces the highest water level and highest wave hazard along the entire 400-mile shoreline of the Bay.

The elevation of tidal ranges along the study area varies by approximately 0.5 foot between Aquatic Park and Heron's Head (*Annex B.1.1: Coastal Extreme Water Levels and High Tide Flooding*). The Bay is a partially to well mixed estuary with substantial longitudinal density gradients (Walters et al. 1985) dominated by seasonally varying river inflow (Conomos et al. 1985). Tidal currents are generated by mixed semidiurnal and diurnal tides with the bay experiencing two tidal cycles daily with two high and two low tides of unequal height. Additionally, the bay experiences pronounced spring-neap tidal variability (Rajasekar 2016). The National Oceanic and Atmospheric Administration (NOAA) tidal gauge near the Presidio (Station ID: 9414290) reports a mean tidal range

of 4.09 feet and diurnal range of 5.84 feet (NOAA 2023b). Water level variations in the bay are driven primarily by five tidal and oceanic cycles including the mixed semidiurnal tidal cycle, two-week spring-neap cycle, seasonal spring/summer (low levels) and fall/winter (higher levels) cycles, El Niño and La Niña, and the Pacific Decadal Oscillation (atmospheric shift on decadal time scale).

As described in *Annex B.1.1: Coastal Extreme Water Levels and High Tide Flooding*, the wave climate in San Francisco Bay is predominantly driven by wind and ocean swells from the Pacific Ocean. The steep topography, hills, and valleys throughout the San Francisco Bay Area drive complex wind patterns and because of the large size of the Bay, those winds can sufficiently generate wind-driven waves ranging from 3 to 5 feet high in vulnerable (i.e., exposed) areas of the shoreline. The most impactful waves to the study area shoreline are those driven by easterly (i.e., offshore; Ferry Building and southward), north and northeasterly (northern waterfront), and southeasterly winds (southern waterfront). The strongest winds occur during the spring and the lowest are typically experienced in the fall, while the winter produces the most variable wind directions. In general, wind-driven waves can impact shorelines across the study area.

Coastal flooding hazards in the study area can be organized into four interrelated categories: coastal flooding, inundation, waves, and erosion.

Coastal flooding occurs when Bay water levels rise above the shoreline along the waterfront, overtopping the shoreline and temporarily flooding inland areas. **Figure 2-5** provides a snapshot of five different times within the study period, for both monthly and 1% AEP coastal events, in accordance with each RSLC scenario starting in 2040. A more detailed discussion on the tidal conditions for each reach can be found in *Annex B.1.1: Coastal Extreme Water Levels and High Tide Flooding*. Additional inundation maps can be found in *Annex B.1.2: Inundation Maps*.

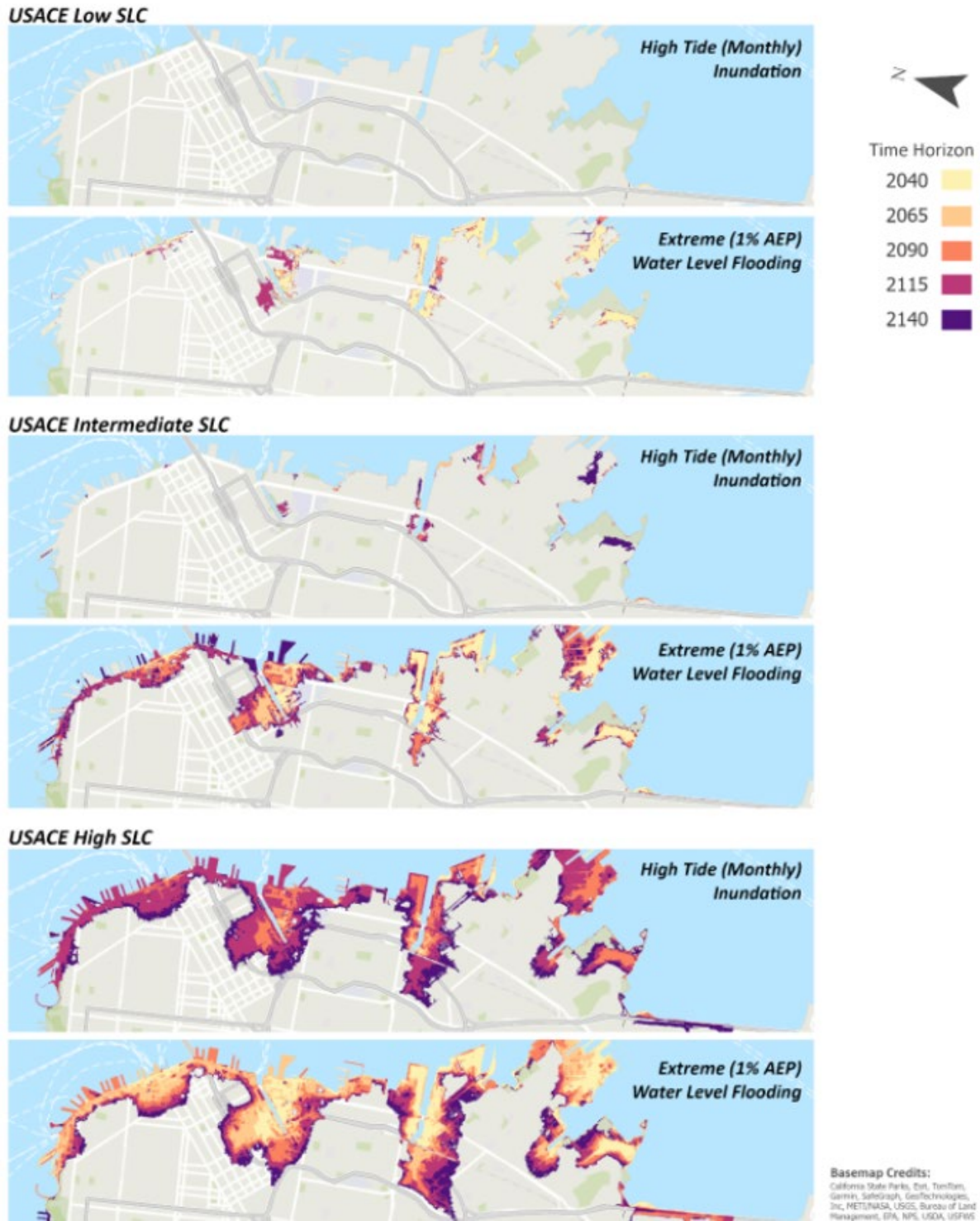


Figure 2-5: High Tide (Monthly) and Extreme (1%AEP) Water Level Flood Extents with USACE Low, Intermediate, and High RSLC (relative to 1992)

Most of the developed areas along the shoreline are built on bay fill, are generally low-lying and flat, and only a few inches to a few feet above the Bay's existing highest

annual tides (Port of San Francisco 2020). Because of this, the extent of flooding and the potential damage and disruption that can occur are sensitive to small changes in Bay water level elevation (e.g., ± 6 inches) once the shoreline is overtopped.

The existing risk of coastal storm damages are currently isolated to low-lying areas along the waterfront where land elevations are less than +10 feet North American Vertical Datum of 1988 (NAVD88), which is the average height of the seawall. The height of the seawall varies, as do heights along the entire waterfront. Specific low points along each reach are as follows: Reach 1 (9.7 feet); Reach 2 (8.1 feet); Reach 3 (6.6 feet); and Reach 4 (6.9 feet). Relatively small coastal flooding events occur several times a year during the perigean spring tides, or king tides, where water levels exceed 7 feet NAVD88, which is the local community classification of a high tide being a “king” tide. Isolated coastal flooding caused by these exceptionally high tides, plus typical wave or vessel wake, can occur in several locations along the southern waterfront in Reaches 3 and 4, as well as in Reach 2 just south of the Ferry Building, such as Pier 14 by the Agricultural Building, where pedestrian, bike, and vehicular traffic can be disrupted by the flooding.

Storm events add a dynamic component to the flooding with waves overtopping the existing shoreline in discrete locations. An example of past overtopping of the seawall occurred during an extreme tide in November 2015, resulting in Bay waters flooding the Embarcadero promenade along the waterfront near the Ferry Building. This event damaged steel plate joints, shut down at least one lane of traffic along the Embarcadero corridor, and posed a safety hazard to pedestrians. Additionally, in March 2023, a winter storm with high winds led to extreme wave activity causing substantial shoreline overtopping at low tide (**Figure 2-6**). In recent memory, large storm events have not coincided with exceptionally high tides, so damages have been minimal.



Figure 2-6: Overtopping of Seawall in March 2023

Table 2-5 presents a range of frequent to extreme water levels for the Presidio tide gauge, located off the San Francisco shoreline near the Golden Gate Bridge, and two locations near the northern and southern ends of the study area. Extreme High Bay water levels (e.g., the 1% AEP water level) are only about 1 foot above the 10% AEP water level, 2.5 feet above the monthly high tide water levels, and 3.5 feet above MHHW.

This tight range in water level elevations from frequent to extreme recurrence intervals makes San Francisco very sensitive to RSLC. With 1 foot of RSLC, coastal flood risk increases by a factor of 10. With 3.5 feet of RSLC, areas exposed to rare (but foreseeable) coastal flooding will experience flooding with daily high tides.

Table 2-5: Existing Water Levels for Frequent to Extreme Recurrence Intervals

AEP	Recurrence	Presidio ^a (feet NAVD88)	Pier 39 ^b (feet NAVD88)	Pier 94 ^c (feet NAVD88)
99.9994%	1-month	6.89	6.92	7.24
98.17%	3-month	7.07	7.11	7.53
86.47%	6-month	7.24	7.34	7.74
63.21%	1-year	7.44	7.63	8.02
18.13%	5-year	7.99	8.18	8.46
9.52%	10-year	8.09	8.43	8.72
3.92%	25-year	8.36	8.80	9.09
1.98%	50-year	8.57	9.09	9.40
1.00%	100-year	8.78	9.40	9.67

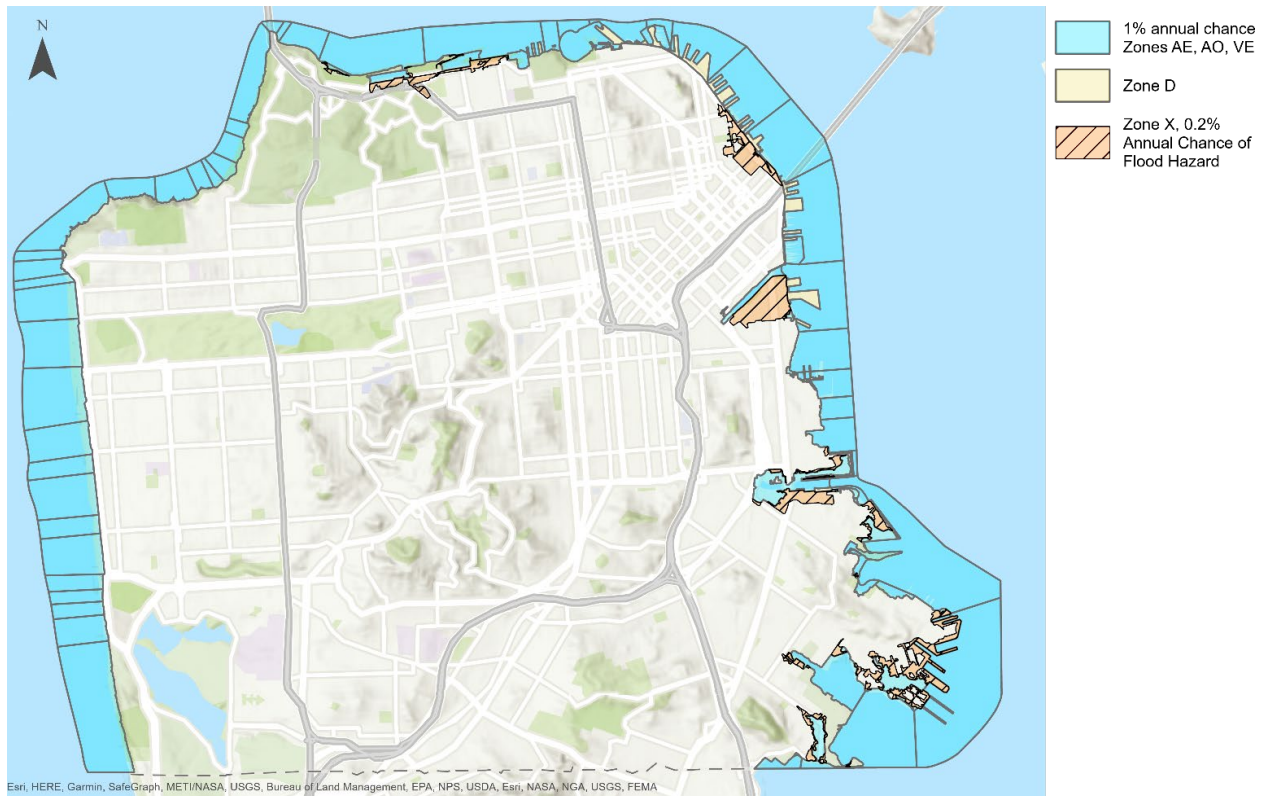
^a Calculated from Presidio tide gauge data from 1974 – 2003 to match modeled time horizon.

^b Calculated from two-dimensional hydrodynamic model output near the northern edge of the study area, offshore of Pier 39.

^c Calculated from two-dimensional hydrodynamic model output near the southern edge of the study area, offshore of the Pier 94 wetlands.

Figure 2-7 presents the Special Flood Hazard Areas (SFHAs), which are areas at risk of flooding during a 1% AEP water level event according to the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs). In coastal areas, SFHAs are primarily designated as VE or AE zones with an associated flood inundation elevation, and the two zones are distinguished by wave height. VE and AE zones represent areas where wave heights are greater than 3 feet and less than 3 feet, respectively. While VE zones are designated due to the potential for significant wave damage, FEMA guidance recommends consideration of wave heights as low as 1.5 feet as posing significant risks to structures when constructed without consideration of

coastal hazards. Much of the port's shoreline is mapped as Zone D, which indicates possible but undetermined flood risks.



Source: (FEMA 2021)

Zones AE and VE are within the SFHA and are subject to flooding during the 1% annual chance event. Zone D includes waterfront piers, which is an area of possible but undefined flood risk. Zone X is subject to inundation during a 0.2% annual chance event.

Figure 2-7: San Francisco FEMA Flood Insurance Rate Map

Coastal inundation refers to the permanent inundation of land by high tides, such as areas that are below MHHW. Under existing conditions, only the wetland areas, including fringe wetland areas along Islais Creek and Mission Creek, are inundated on a regular basis. However, as sea levels rise, the area inundated by the high tides will increase.

Waves in the Bay include both longer period ocean-driven swell propagating through the Golden Gate, and locally generated, wind-driven waves. Ocean-driven swell waves propagate parallel to the northern San Francisco shoreline and may pose a hazard to the Aquatic Park municipal pier and the port's finger piers. Although these waves temporarily increase Bay water levels, they are not a significant direct wave hazard along the shoreline.

Wind-driven waves within the Bay are the dominant wave hazard. The wind climate above the Bay and the larger Bay Area is highly variable, and the steep topography, hills, and valleys throughout the Bay Area drive complex local wind patterns. Due to the

large size of the Bay, the winds have sufficient fetch to generate wind-driven waves that are 3 to 5 feet high along the most exposed sections of the Bay shoreline when windspeeds are high and the wind is blowing toward the shoreline. Strong windspeeds in almost any direction will impact a section of the Bay shoreline.

Understanding waves and local wave conditions is a crucial part of coastal and combined flood risk management along the shoreline, both with respect to infrastructure design (including coastal defense structures) and understanding residual risk. Waves are essentially energy passing through a fluid (in this case, water). They can be measured and experienced as wave runup; as splashing and overtopping; as a dynamic force on piers, wharves, and other coastal structures; and as waves that propagate inland once a shoreline is overtopped.

Wave runup is the culmination of the wave breaking process as waves approach sloped or vertical shorelines. Wave runup includes both wave setup (the mean increase in water level as waves get slower and increase in height near the shoreline) and swash (the decelerating water that surges up the shoreline during and after the wave breaks). The slope and roughness (e.g., smooth, cobbled rock, or vegetated) of the natural shoreline or engineered structures are key parameters in defining how high the waves can run up the shoreline. Smooth vertical walls have the highest potential wave runup elevations, whereas a sloped shoreline with riprap armoring will dissipate wave energy and reduce the wave runup potential.

Wave overtopping occurs when the wave runup elevation exceeds the height of the shoreline (e.g., the top of a naturalized or embankment shoreline or floodwall) potentially flooding inland areas. Overtopping can range from a spray to a splash to a stream of water, depending on shoreline, Bay water level, and wave characteristics. Waves overtop low spots along the shoreline under existing conditions. Marginal wharves along parts of the San Francisco shoreline act as a barrier, blocking waves from overtopping the adjacent bulkhead wall.

Overland wave propagation occurs along natural, gently sloped shorelines when water levels are high enough to allow waves to travel inland across the shoreline as opposed to breaking and running up the face of a more sloped or vertical structure. Under existing conditions, overland wave propagation only occurs in small areas where the shoreline is not hardened, for example, along the Pier 94 wetlands and portions of Heron's Head Park. As waves propagate inland over wetlands and vegetated areas, they generally decrease in height due to wave energy dissipation. However, waves may regenerate or intensify over inundated areas with sufficient water depth with favorable wind energy.

Waves are also a powerful and dynamic force that can cause significant structural damage. Along the shoreline, waves crash into the piers and wharves causing them to shake and vibrate. This contributes to wear and tear on the structures. Direct wave/wharf deck interaction could be and likely would be the most damaging. Waves can cause damage gradually over time, and they can cause abrupt damage during an

extreme storm event. The degree of damage depends on the storm conditions, the direction of the waves, and the structure's condition.

Coastal erosion occurs when currents and waves wear down and carry away earthen or engineered materials along the shoreline. In areas with a natural or naturalized shoreline, like the Pier 94 wetlands or Heron's Head Park, erosion can lead to inland migration of the shoreline. For engineered coastal defenses (e.g., a floodwall or seawall), erosion is of particular concern at the toe of the structure, because erosion can weaken the foundation of the structure and increase the risk of failure. With erosion causing increased depths in front of a structure, the wave height may increase, and therefore lead to increased overtopping and flooding.

In addition to the coastal flooding hazards described above, groundwater shoaling and groundwater emergence are also concerns. **Groundwater shoaling** occurs when a water table gains elevation and becomes shallower from the land surface.

Groundwater emergence occurs when the water table intersects the land surface, resulting in either the formation of a new spring, seep, ponding, or evaporative deposit, depending on the nearby climate and topography. With sea level rise, the water table at the shoreline would rise to meet the new sea level. This is because the lowest elevation of the coastal water table is likely on average near or above mean sea level in most coastal areas, unless losses other than discharge to the coast reverse flow such that saline water flows inland and causes intrusion (e.g., pumping or evaporation). Shallow and emergent groundwater represent hazards for surficial flooding, water quality, transportation, and shallow buried infrastructure. Understanding the characteristics of groundwater and influence that RSLC and the 6-foot tidal range will have on the existing condition is important to ensure coastal and combined flood risk management solutions do not exacerbate flood risk from another source.

2.3.4.2. Future Without Project

The study area would continue to be at risk of flooding and could become more at risk due to RSLC and changing meteorological conditions. Without local or non-Federal interventions, it is expected that nuisance flooding in low-lying areas would continue where the potential impacts from tidal and/or rainfall flooding would likely increase and worsen over time. Coastal hazards such as wave overtopping and storm surge is expected to increase over time with changing meteorological conditions and RSLC, which would lead to more catastrophic flooding. RSLC would likely increase flooding and wave hazards, resulting in increased soil erosion, modifications to the shoreline, and release of contaminants. RSLC rates may also exceed normal sediment accretion rates in saline marshes, resulting in increased inundation and subsidence. Hydrology patterns may be impacted as continued water temperatures rise and trends in the Pacific Ocean circulation patterns change. No significant impact to tides is expected. Tidal exchange and range, and wave hazards may be impacted based on RSLC whereby threats from wave hazards increase.

Changing meteorological conditions, including more frequent and intense storms and flooding events, can increase stormwater runoff. An increase in stormwater runoff can exacerbate existing, or introduce new, contaminants into water sources and soils.

Increased precipitation could overwhelm the study area's municipal stormwater management system, which can lead to backups that cause localized flooding or greater runoff of contaminants (e.g., trash, nutrients, and bacteria) in waterways and soils (EPA 2023).

2.3.5. Relative Sea Level Change

RSLC is a primary impact of globally changing hydrologic and meteorological conditions (Knowles 2010) and is a present and future risk to the United States (Hall et al. 2019). This combined with land subsidence, and other coastal flood factors such as storm surge, waves, rising water tables, river flows, and rainfall are likely to result in a dramatic net increase in the exposure and vulnerability of coastal populations (USGCRP 2017; Sweet et al. 2022). It is generally accepted that increasing global temperatures will increase rates of RSLC; however, the range in projected rates is wide due mainly to uncertainty in the amount of meltwater from land-based ice in Greenland and Antarctica (Knowles 2010).

The NOAA San Francisco Presidio tide gauge was selected to formulate the RSLC strategy based on its proximity to the study area. The observed RSLC trend for the gauge from 1897 to 2020 is 1.97 mm/yr with a 95% confidence interval of ± 0.17 mm/yr (NOAA 2022).

Five RSLC curves were considered in this study (**Figure 2-8**) to address USACE requirements, as well as the requirements of the State of California and CCSF (Port of San Francisco 2020; CPC 2020). The three USACE RSLC curves were used in formulating alternatives and are based on science presented in the National Research Council (NRC) 2012 report, using best available science at the time of publication, including local tide gauge and other information to develop regional projections based on the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment (IPCC 2007; NRC 2012; USACE 2019a). The three USACE curves were derived using the guidance provided in ER 1100-2-8162 (USACE 2019b; 2020).

The State of California curves considered in this study reflect the likely projection and 1-in-200 projection for San Francisco (OPC and CNRA 2018). These 2018 California RSLC projections are based on NOAA's 2017 report (W.V. Sweet et al. 2017), which relies on the IPCC Fifth Assessment (IPCC 2014). The State of California has since updated its recommendations based on the 2022 Federal Interagency Sea Level Rise Report (Sweet et al. 2022), which relies on the IPCC Sixth Assessment (IPCC 2021). State of California projections are provided for contextual reference and did not inform plan formulation. The IPCC revised the approach for estimating potential changing meteorological conditions between the Fourth, Fifth, and Sixth Assessments. No simple comparison is available to translate the previous NRC (2012) scenarios used to compute the USACE RSLCs to the IPCC (2014) or IPCC (2021) scenarios that form the basis of the State of California's recommendations. For context, collectively, the three USACE RSLC curves and two California RSLC curves are similar to the RSLC scenarios recently updated by the Federal Interagency Sea Level Rise Task Force (Sweet et al. 2022). *Appendix J: Changing Hydrologic and Meteorological Conditions* provides further information regarding RSLC scenarios.

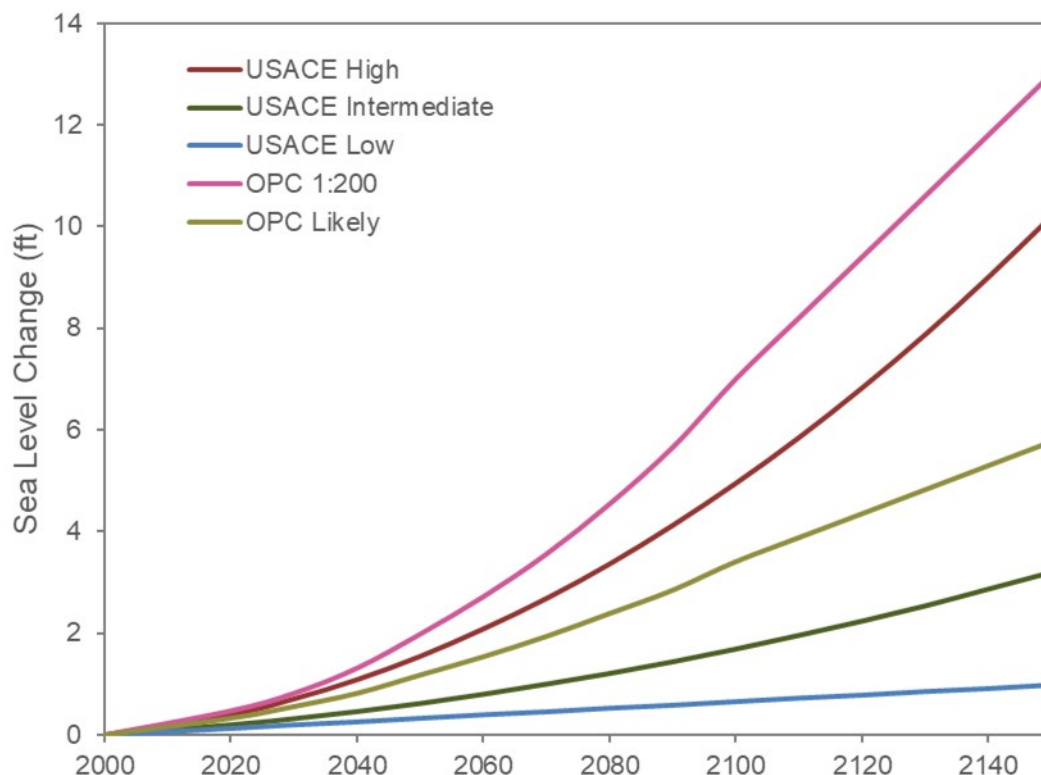


Figure 2-8: USACE and State of California RSLC Scenarios

Figure 2-8 displays both California Ocean Protection Council (OPC) and USACE RSLC Curves baselined to the year 2000 for the purposes of illustration. Inputs for analysis were developed in accordance with USACE requirements, detailed in *Annex B.1.1: Coastal Extreme Water Levels and High Tide Flooding*.

Table 2-6 shows the increase in sea level (in feet) under various projections for the time horizons evaluated. The table is organized from most conservative (swift) to least conservative (slow) RSLC projections. For example, the State of California 1-in-200 projection predicts 1.4 feet of RSLC by 2040, whereas the USACE Low projection predicts that 1.4 feet of RSLC may not occur until later in the next century, after the 100-year POA.

Table 2-6: Increase in Sea Level (in Feet) Across Time Horizons and RSLC Curves

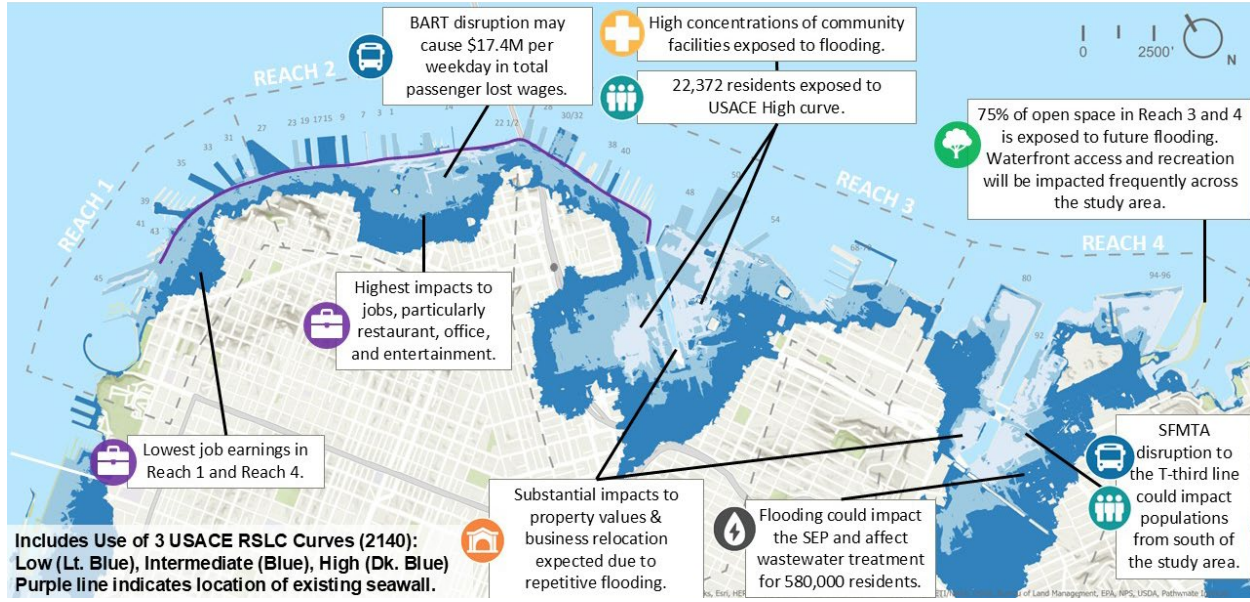
Time Period	USACE Low	USACE Intermediate	State of CA Likely	USACE High	State of CA 1-in-200
2040	0.3	0.5	0.8	1.1	1.4
2065	0.4	0.9	1.8	2.4	3.3
2090	0.6	1.4	2.9	4.1	5.8
2115	0.8	2.1	4.1	6.3	8.6
2140	0.9	2.9	5.3	9.0	11.7

Note: Cell color scheme identifies similar RSLC increments. Darker colors indicate greater increases in sea level. This table displays both California OPC (baseline 2000) and USACE (baseline 1992) RSLC Curves. Inputs for analysis were developed in accordance with USACE requirements, detailed in the *Annex B.1.1. Coastal Extreme Water Levels and High Tide Flooding*. State of California projections are provided for contextual reference and did not inform plan formulation.

Most analyses of flooding, and flood-related damage and loss, focus on extreme events with relatively rare occurrence frequencies, such as the 1% AEP water level (**Figure 2-9**). The San Francisco waterfront required analysis of increasing event frequency and flood risk as a potential as lead driver for this study, given the characteristics of this study area and the RSLC rates considered. In the Bay, the difference between MHHW and the 1% AEP water level is on the same order of magnitude as future RSLC by the year 2100.

Future flooding by lower magnitude, high-frequency events could result in more damage and disruption to shoreline communities and infrastructure than higher magnitude, lower frequency events (William V. Sweet et al. 2016; Ghanbari et al. 2019; Taherkhani et al. 2020). High-frequency events include very frequent events (such as the 6-month to 1-month water level), and near-daily events or high tide flooding.

For example, if sea level rises by 6 inches, a 1% AEP water level will become about a 4% AEP water level in the Bay (Vandever et al. 2017; CCSF 2020). If sea levels rise by 24 inches, Bay Area coastal communities could experience multiple flood events, in addition to 90 to 150 days of high tide flooding, each year (Ghanbari et al. 2019; Sidder 2019). With RSLC, the same flooding thresholds could be overtopped frequently throughout the entire year. This more frequent flooding will cause chronic and cumulative damages (FEMA 2015; Sievanen et al. 2018; Sidder 2019), and ultimately the frequent flooding will transition to permanent inundation by regular high tides.



Note: The shades of blue reflect the three RSLC curves, with the lightest blue being the USACE Low curve, and darkest the High curve.

Figure 2-9: Extent of Inundation Per Reach Expected Under 1% AEP Flood Event in Future Without Project Conditions Under the Three RSLC Curves

2.3.6. Water Quality

2.3.6.1. Existing Conditions

Water quality describes the condition of water, including chemical, physical, and biological characteristics typically with respect to suitability for a purpose, and is measured by several factors including salinity, turbidity, bacteria, DO, and contaminants (NOAA 2023a). Water quality in the San Francisco Bay Region is saline and predominated by ocean influences; however, substantial runoff from freshwater during heavy rains is also prevalent. The freshwater inundation can temporarily reduce salinity in the study area (Bay Institute 2003). Physical barriers, such as the Golden Gate Bridge, influence sedimentation and water quality characteristics by altering the behavior of currents that affect circulation, flushing, and water exchange.

Suspended sediments are a key component of the estuarine system, which tend to have higher levels of turbidity or suspended sediment loads due to discharges from rivers, drainages, and their shallow nature. Suspended sediment concentrations are variable in San Francisco Bay and strongly correlate to season and water depth (Buchanan and Ganju 2006; Buchanan and Ganju 2005; McKee et al. 2006), ranging from 1,000 milligrams per liter near the bottom to 10 milligrams per liter near the surface (Buchanan and Ganju 2006).

Contaminants are prominent in the bay and are transported by a variety of sources including, but not limited to, urban uses, industrial outfalls, municipal wastewater outfalls, municipal stormwater, upstream farming, upstream historic and current mining

discharges, and legacy pollutants. Approximately 40% of California drains into San Francisco Bay including point and non-point source pollutants that distribute up to 40,000 metric tons of at least 65 different pollutants (BCDC 2020). The study area is listed as an impaired water body by the San Francisco Regional Water Quality Control Board (RWQCB). The pollutants recorded in the Central San Francisco Bay, including the study area, are chlordane, dichlorodiphenyltrichloroethane, dieldrin, hydrogen sulfide, lead, mercury, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, selenium, silver, furans, and dioxins. Pollutant concentrations vary seasonally and annually, dependent on the source and degradation characteristics.

2.3.6.2. Future Without Project

Current water quality trends could improve with changes in land use or improve through implementation of new water quality improvement programs such as total maximum daily loads administered by Federal, State, and local agencies. However, with the existing status of water quality in the study area, it is more likely that conditions would worsen with increased flooding associated with changing meteorological conditions and RSLC. Increased flooding would lead to more runoff, potentially carrying contaminants, thereby lowering water quality. Changing meteorological conditions and RSLC introduce uncertainty of continued trends where changes in temperature, precipitation, chemical composition (e.g., ocean acidification), and increases in salinity could also impact water quality.

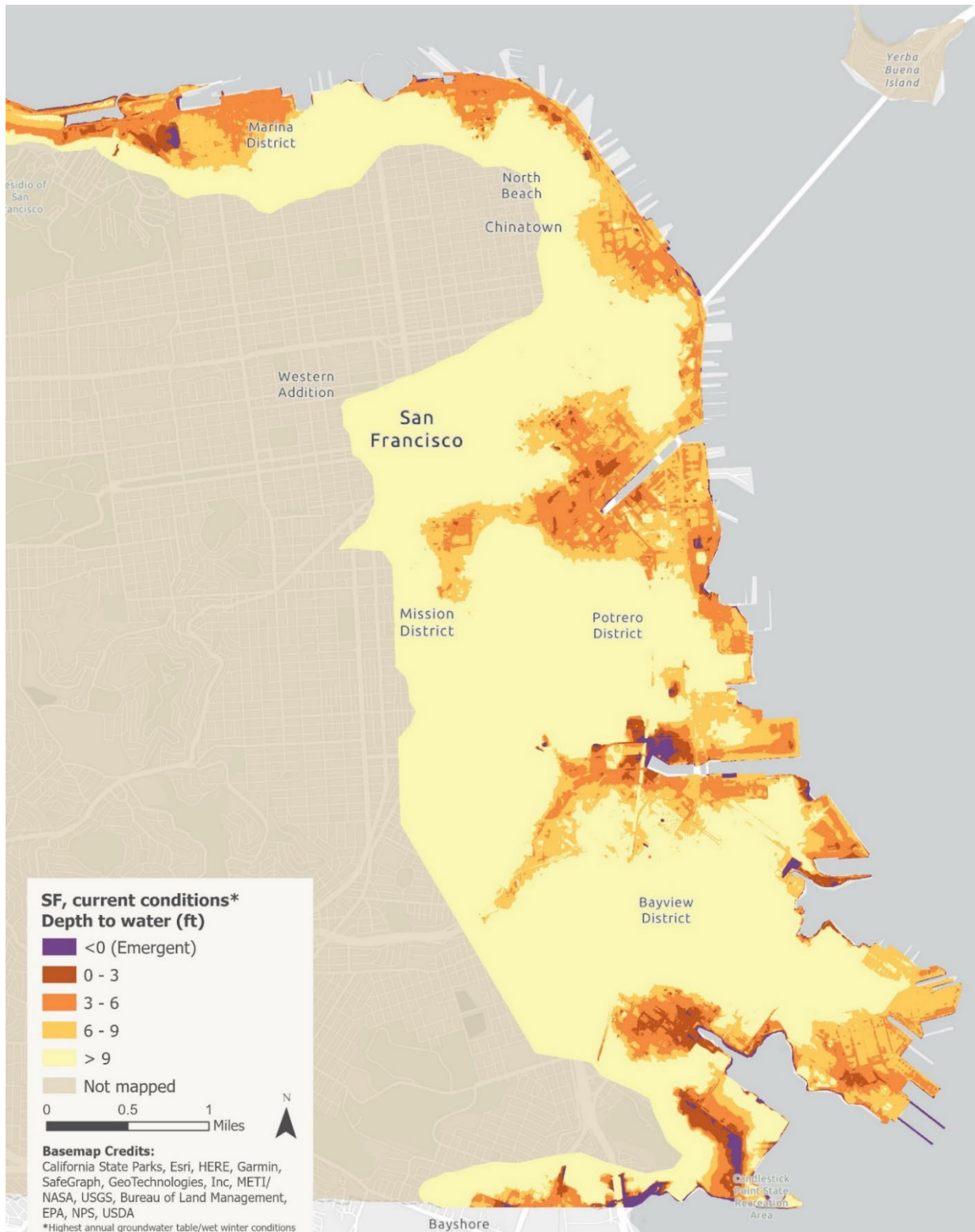
2.3.7. Groundwater

2.3.7.1. Existing Conditions

The study area overlies seven small groundwater basins. Local groundwater supply comes from the Westside Basin, a series of aquifers extending from Golden Gate Park southward to San Bruno. Groundwater is pumped from the Westside Groundwater Basin from depths of approximately 400 feet below the surface, blended with surface water supplies from San Francisco, treated, and distributed to the city for drinking water (SFPUC 2021a). Most of the groundwater supplies in the study area are confined between two substantial layers of clay that act as aquitards. Aquitards have low permeability, which allow groundwater to be confined and under high pressure. Shallow groundwater in the study area is poor quality and is not used for supplying drinking water. Young Bay Mud acts as an aquitard, separating shallow groundwater from deeper aquifers used for municipal water supply and generally acts as a barrier to the vertical migration of contaminants. Shallow groundwater levels are influenced by seasonal variations in precipitation, tidal levels, local irrigation, groundwater pumping, and other factors, and vary across the study area.

Figure 2-10 shows the existing depth to groundwater mapping for San Francisco, including the study area, representing the highest annual groundwater table during a wet winter. The groundwater table is within 6 feet of the ground surface across most of the shoreline and nearby low-lying areas. Most underground infrastructure is located within 6 feet of the ground surface, and while underground infrastructure has been designed to account for the historical highest annual groundwater table, it may not have

been designed to account for increases in the groundwater table. **Figure 2-10** highlights an area along the northern Islais Creek shoreline with the potential for emergent groundwater under existing conditions. This area floods regularly during rainfall events, with more severe flooding observed when Bay water levels are high. **Figure 2-11** identifies the potential for emergent groundwater under an extreme RSLC scenario where relative sea levels have increased by 9 feet. This scenario occurs toward the end of the 100-year POA for the USACE High RLSC and the First Actions of coastal flood defense system are not intended to alter the flow of groundwater between the upper watershed and the Bay. This is equivalent to the RSLC expected under the USACE High curve by the end of the study period (2140) shown in **Table 2-6**.



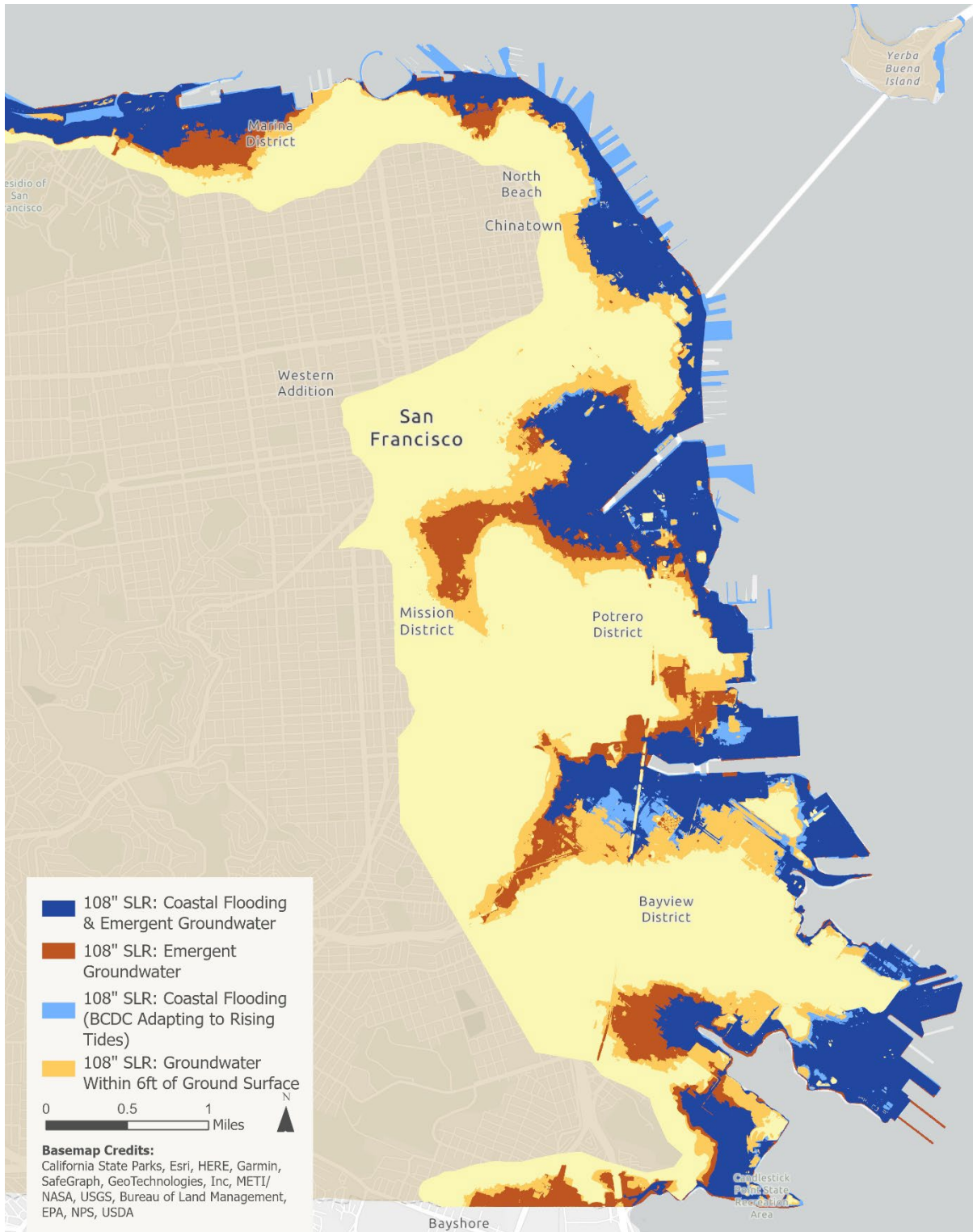
Source: (May et al. 2022)

Figure 2-10: Depth to Groundwater in San Francisco, Current Conditions

2.3.7.2. Future Without Project

In nearshore coastal areas like San Francisco, where shallow aquifers are unconfined, the groundwater table will rise as sea levels rise. This threat can flood communities from below, damaging buried infrastructure and roadway subgrades, increasing infiltration into sewer systems, flooding below grade structures, mobilizing contaminants, and emerging above ground as an urban flood hazard, even before coastal floodwaters overtop the shoreline. Several studies have identified various locations where emergent groundwater is happening today and is projected in the Bay Area (Plane et al. 2019; May 2020; May et al. 2022).

In San Francisco, as sea levels rise, the extent of emergent groundwater could increase, with emergent groundwater found further inland. This could impact essential services, critical infrastructure, and reduce access to and from several locations within the city and region.



Source: (Pathways and SFEI 2022)

Figure 2-11: Future Groundwater Conditions, 9 feet (108 Inches) of Relative Sea Level Change Scenario

2.3.8. Geology and Geomorphology

2.3.8.1. Existing Conditions

Geology is the study of the structure, evolution, and dynamics of Earth and its natural mineral and energy properties (USGS 2022a), while geomorphology is the study of the physical features of the Earth's surface and their relation to the geological structure (Stetler 2014). San Francisco is part of the California Coast Ranges geomorphic provinces and is characterized by a series of northwest-trending ridges and valleys that run nearly parallel to the San Andreas Fault zone (Norris and Webb 1990). The San Francisco Bay lies within a depression created by an expansion between the San Andreas and Hayward fault systems. Much of the province is composed of marine sedimentary deposits and volcanic rocks (Norris and Webb 1990). Within this province, the Northern Coast Ranges, where project activities would occur, the geologic structure contains the Alcatraz terrane. The Alcatraz terrane is an amalgamation of semi-coherent blocks that consists of shale, greenstone, basalt, chert, sandstone, graywacke, and serpentine. Many of these units originated from ancient seafloor sediments that were displaced and deformed through tectonic forces (CCSF 2017).

The sediments within San Francisco Bay originate from erosion of surrounding hills or from later marine and riverine deposits. Generally, the upper several feet of the sediment profile in San Francisco Bay consists of more recently deposited marine and riverine sediments. The thickness of various underlying historic sediment formations varies throughout the San Francisco Bay/Delta Estuary, and it can be several hundred feet thick. Large areas of San Francisco Bay contain Bay Mud, a marine clay-silt deposit, which lies beneath softer, more recently deposited muds (USACE 2015). Bay Mud is prone to cyclic softening during an earthquake, which can lead to lateral spreading and vertical settlement along the shoreline during a seismic event. Bay Mud can be divided into younger and older, varying in engineering properties, dependent on thickness and consolidation (CCSF 2017). The deposit known as Young Bay Mud is generally less than 165 feet thick. Within the San Francisco city limits, Young Bay Mud is located along the margins of the Bay, between the modern shoreline and historical limit of the tidal marsh and generally buried by artificial fill. During construction of the Embarcadero seawall in the late 1800s and early 1900s, a wedge along the wall alignment of this deposit was dredged to approximately elevation -35 feet and backfilled with rock or sand upon which the seawall was constructed.

Since the 1800s, the northeastern and eastern margins of the city have undergone significant landscape modification through multiple episodes of fill placement. Areas receiving the most extensive artificial fill include inlets, coves, and saltwater marshes. Filling of the bay margins included a variety of fill placement methods ranging from dumping to hydraulic filling, as well as the intentional sinking of abandoned wooden sailing vessels. Artificial fill in the city contains a combination of local native sediments, including hydraulically placed dune sand and bay sediments, and miscellaneous construction debris, such as brick, concrete rubble, metal, glass, and timber - all of which were typically placed on top of weak Young Bay Mud. More information on the geology and geomorphology of the area may be found in *Appendix B: Engineering*.

2.3.8.2. Future Without Project

No significant impacts are expected on the underlying geology or geologic processes, thus only minimal changes to the topographic features, geologic formations, and soils in the study area would be expected. Sediment quality would continue to be impacted due to coastal flooding, which potentially introduces contaminants into surface waters and nearby waterbodies. There is also the potential for contaminants to become trapped in sediments over time as flooding and RSLC may expose or flush debris and contaminants onto soils/sediments that become buried.

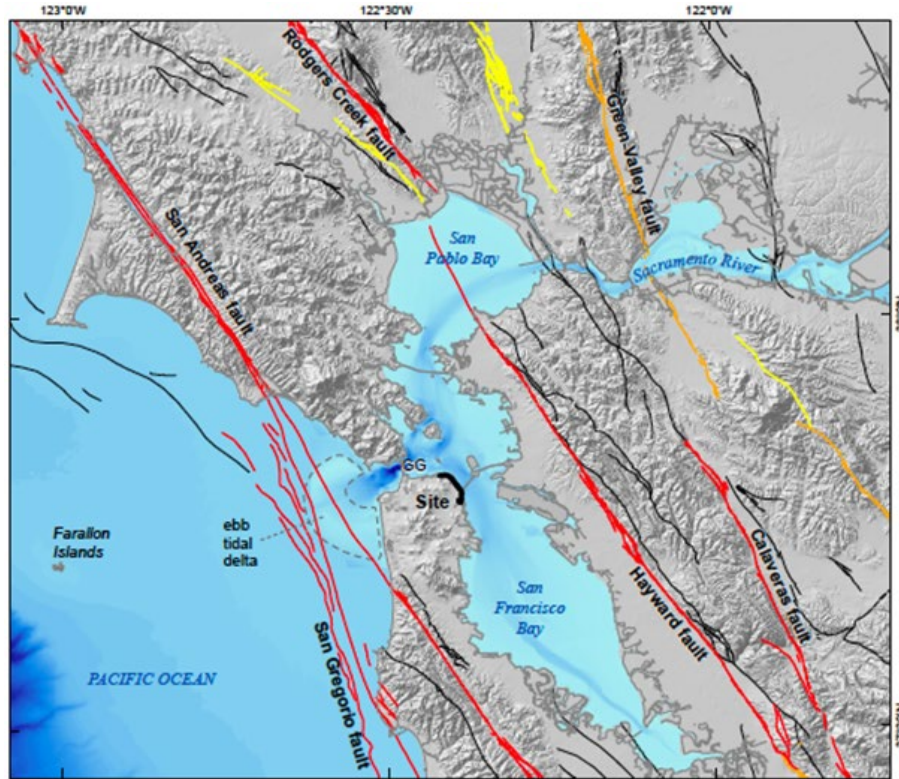
2.3.9. Seismic

2.3.9.1. Existing Conditions

The Bay Area is a seismically active region (**Figure 2-12**). A major earthquake could happen at any time. The 1906 earthquake that shook San Francisco lasted less than 1 minute, yet the impact was disastrous. In addition to the immediate damage, the earthquake ignited fires that burned across the city for 3 days, destroying nearly 500 city blocks. The 1989 Loma Prieta earthquake is the largest seismic event to occur in the Bay Area since 1906. It shook for only 15 seconds and resulted in over \$6 billion in damages across the greater Bay Area and Monterey Bay.

There are numerous fault lines crossing the Bay Area, most from northwest to southeast, with the San Andreas and the Hayward faults being the most active and well-known. The POSF's waterfront is located between the two faults. Both the 1906 earthquake (magnitude 7.9)¹ and 1989 earthquake (6.9) were located along the San Andreas Fault. The Hayward Fault located across the Bay has not experienced a major earthquake since the 1868 Hayward earthquake (6.5). This fault can produce a magnitude 7.3 earthquake, and because it has not experienced major activity for over 150 years, it is considered the fault most likely to generate a strong earthquake in the near future (USGS, 2015). The most recent USGS earthquake forecast for the Bay Area indicates a 72% probability of at least one magnitude 6.7 or greater earthquake striking the region before 2043 (Working Group California Earthquake Probabilities, 2014).

¹ For each increment of 1 on the Richter scale, an earthquake feels 10 times stronger. So, a 7.9 magnitude earthquake is nearly 4 orders of magnitude stronger than a 3.0 earthquake, or 10,000 times stronger.



Basemap source: Topographic and bathymetric data from U.S. Geological Survey

Figure 2-12: Regional Topography and Faults

Along the waterfront, the ground's earthquake response will vary based on how far below the ground bedrock is located, as well as the type and thickness of the layers of soil and mud, pockets of sand, the presence of bay fill above the bedrock, and the depth of the groundwater table. There are three main ways that the ground responds to an earthquake: ground shaking, liquefaction, and lateral spreading.

Ground motion / shaking is produced by waves of energy that are generated by a sudden slip on a fault (i.e., fractures in the earth's crust) or by a sudden release of pressure along the fault that travels through the earth and along its surface. Ground shaking could affect POSF facilities along the waterfront more than buildings built inland on firmer soil. Softer ground, such as Bay Mud, can amplify the shaking. For example, along the Embarcadero, this effect is greatest near the Ferry Building where the layer of Bay Mud is thick, and the bedrock is more than 240 feet below the surface. The ground shaking intensity could be more than double that observed in areas underlain with shallow rock, such as found near Telegraph Hill. Tall and flexible structures, such as the Ferry Building clock tower, may resonate with the soft soil and experience higher levels of shaking than stiff structures (CH2M/Arcadis Team 2020e).

Liquefaction occurs when water-saturated sediment (like sand) temporarily loses strength and acts like a fluid. Strong ground shaking during an earthquake can trigger this effect across large geographic areas. As a result of liquefaction, buildings, roads, and utility lines may lose their foundational support and the likelihood of significant

damage increases. The Marina neighborhood in San Francisco experienced significant liquefaction during the 1989 Loma Prieta earthquake and filled areas of the Embarcadero and Mission Bay waterfronts experienced liquefaction in the 1906 earthquake.

Lateral Spreading occurs when gently sloping or retained slopes experience strength loss and acceleration during an earthquake and the ground moves horizontally and vertically in the downslope or retained direction. This can cause large areas of land to separate from each other, creating cracks in the ground surface, and rapid settlement of the ground as it moves. Lateral spreading poses a significant risk to the Embarcadero roadway and adjacent POSF marine structures and increases the likelihood that buried utilities, such as water, sewer, wastewater, and gas pipelines will rupture. Filled areas of the Embarcadero waterfront experienced lateral spreading in the 1906 earthquake.

The POSF completed a MHRA in 2020 (CH2M/Arcadis Team 2020i) along the Embarcadero waterfront from Hyde Street Pier to South Beach Harbor to better understand the earthquake risks and how they vary along the oldest stretches of the aging Embarcadero seawall. Along the Mission Creek / Mission Bay and Islais Creek / Bayview waterfront, earthquake risk findings are drawn from the Initial Southern Waterfront Earthquake Assessment and best available science USGS studies (USGS, CGS, 2014).

The MHRA found that up to 40,000 people could be at risk on POSF property if an earthquake occurs during the day (CH2M/Arcadis Team 2020). The Ferry Building area and Embarcadero roadway were identified as having particularly high earthquake risk, notably with respect to threatening life safety, disaster response efforts, and day-to-day functions along this waterfront. The Embarcadero-related earthquake losses are a near-term problem with over \$0.9 billion in losses estimated by 2050 and \$1.5 billion estimated by 2100 (CH2M/Arcadis Team 2020).²

The Initial Southern Waterfront Earthquake Assessment examined earthquake hazards and potential vulnerabilities from Pier 48 to Heron's Head Park. The assessment was targeted toward specific POSF facilities, including Piers 50, 80, 92, and 94-96. Piers 80 and 94-96 are filled piers primarily with perimeter sand dikes and pile-supported bulkhead wharves with high liquefaction and lateral spreading risk. Liquefaction and lateral spreading are also expected at Pier 92, with potential damage to landside equipment and buildings. This study estimates the scale of construction funding to fully mitigate seismic risk at Piers 50, 80, and 94-96 to be greater than \$100 million per facility as estimated in 2022.

2.3.9.2. Future Without Project

The current risk from a seismic event would continue into the future, which could affect life safety, infrastructure disaster response and recovery, maritime commerce,

² These economic estimates include direct damages, disruption, supply chain impacts, and income spending impacts throughout the Bay Area. However, they are limited to economic impacts triggered by damage to POSF buildings and marine structures as well as mobility infrastructure within POSF's jurisdiction. The estimates do not include economic impacts to other buildings and infrastructure throughout the entire study area along the Embarcadero or beyond.

commerce, utilities, transportation, historic resources, environment (contamination), land use, recreational areas, and the economy (MHRA 2020). However, current zone, building codes, and policies would minimize some of the risk for buildings/constructions subject to those policies.

2.3.10. Noise and Vibration

2.3.10.1. Existing Conditions

Noise levels in the study area are influenced by traffic, transit vehicles, construction, aircraft, watercraft, industrial, commercial, and other sources associated with a densely populated urban environment. The influence of each of these sources of noise on ambient levels depends on the proximity of receivers to transportation corridors and developed areas.

Ambient noise levels have been measured for previous environmental studies of projects along the San Francisco waterfront (**Table 2-7**).

Table 2-7: Ambient Noise Levels for Projects Along the San Francisco Waterfront

Project Title	Noise Measurement	Year	Project Reach	Source
Better Market Street	75 Ldn	2018	Reach 2	San Francisco Planning Department, 2019
Pier 70	58-68 Ldn Average: 64 Ldn	2012, 2015	Reach 3	San Francisco Planning Department, 2016.
Chase Center	75 Ldn	2014	Reach 3	San Francisco Planning Department 2015
Mission Rock Development	64-83 Ldn Average: 71 Ldn	2015	Reach 3	San Francisco Planning Department 2015

These levels are typical of an urban or a dense urban environment, based on historical measured levels taken in these settings (U.S. Environmental Protection Agency 1971).

Sources of vibration include heavy trucks and transit vehicles producing vibration from contact between the moving wheel and the travel surface (rail or road). The levels of vibration associated with these sources are generally perceptible only within short distances, generally less than 100 feet from the source. Construction activities that require pile driving can produce vibration at distances greater than 100 feet from the source, depending on the method of installation and the size of pile used.

Noise- and vibration-sensitive land uses are generally defined as locations where people reside or where the presence of elevated noise could significantly affect use of the land. Typical sensitive land uses include residences, schools, hospitals, places of worship, and hotels. In general, in all reaches, the area surrounding the zones of construction consists of a mix of residential, recreational, commercial, and industrial

uses. The area is generally densely populated with multi-family, condominium, and transient lodging uses that face the POSF waterfront areas. Outdoor noise-sensitive receptors in the area also include parks, recreational uses, and outdoor dining areas. Outdoor areas are generally not considered to be sensitive to vibration. **Figure 2-13** shows the sensitive receptors within and up to 1,000 feet from the zones of construction.

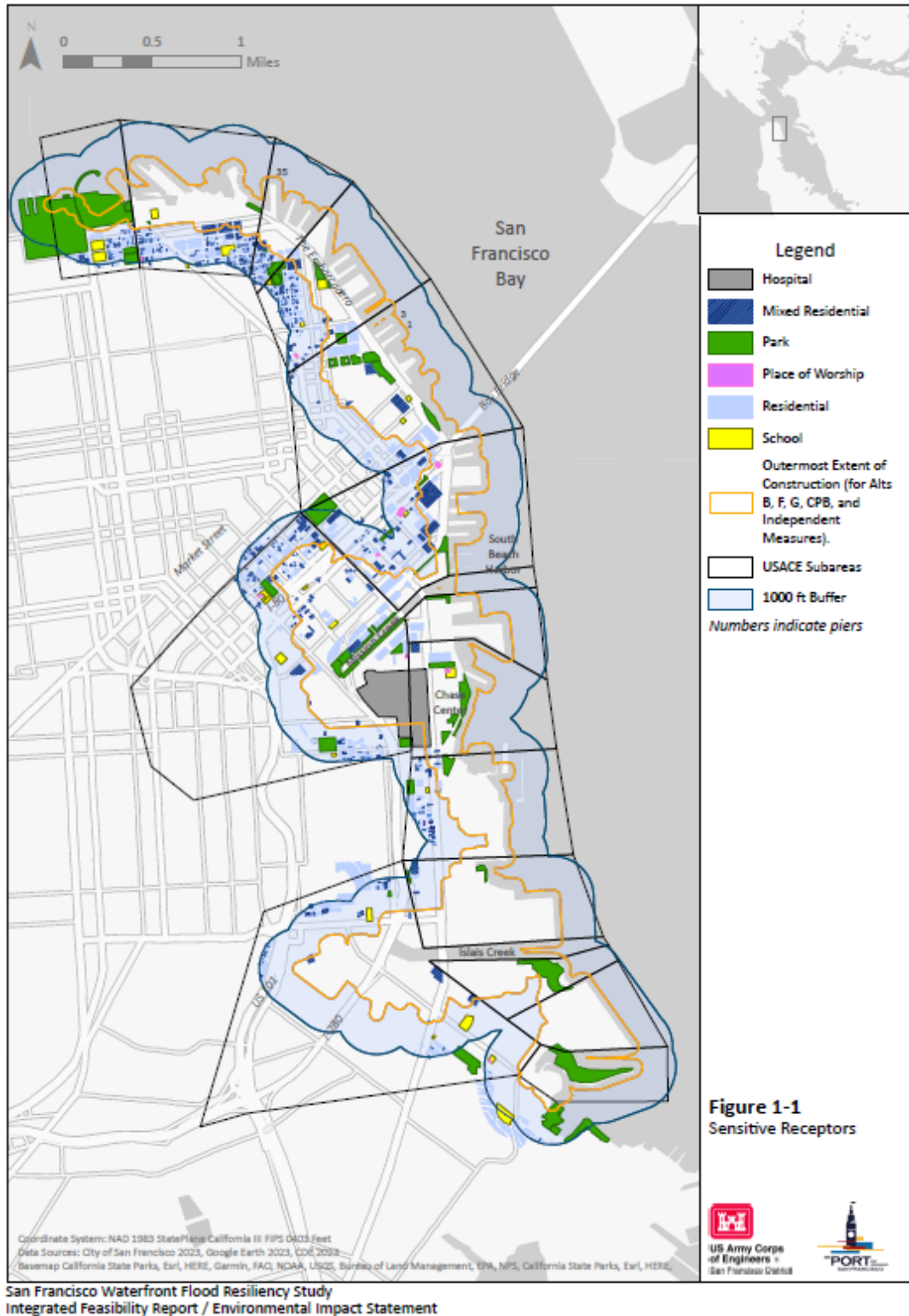


Figure 2-13: Sensitive Receptors within and 1,000 Feet from the Zones of Construction

2.3.10.2. Future Without Project

As described in Section 2.3.10.1, the study area is characteristic of an urban environment with consistent ambient noise and vibration disturbances. This is anticipated to continue under FWOP, with potential noise and vibration impacts from normal construction and operation for existing and planned projects, such as housing development, road and utility maintenance, etc.

Identifying the specific noise and vibration generating activities under the FWOP involves a high degree of uncertainty because the timing, type, and magnitude of maintenance, construction, response, and relocation would be strongly influenced by the severity of storms, which are unpredictable. While it is improbable to fully estimate all noise and vibration levels, an estimate of the ranges of noise and vibration generating equipment was made for the potential construction projects in Section 2.4.6. Construction equipment noise at 50 feet is estimated to be 80-117 A-weighted decibel (dBA) and at 100 feet is estimated to be 74-111 dBA. Construction equipment vibration in Peak Particle Velocity is estimated to be 0.003-1.518 inches per second at 25 feet and 0.000-0.190 inches per second at 100 feet. It is likely noise and vibration impacts would be significant.

Emergency flood defense and response, and cleanup actions would require the use of a considerable amount of heavy equipment, which would generate noise. Buildings and infrastructure damaged by flooding would need to be demolished and the services provided would need to be relocated to other areas of the city, requiring new construction. The use of heavy equipment for flood defense on an emergency basis would very likely be substantial and could be any hour of the day or night. As such, there is a high potential for sleep interference due to emergency flood defense and response activities. Equipment noise from redevelopment could occur at any scale or location within the city and, as such, impacts of construction noise would be expected.

Heavy equipment noise during flood defense and response, and cleanup actions could occur at any location for an unknown span of time, affecting receptors within and surrounding areas of inundation. For all types of land uses needing to be relocated due to flooding events, redevelopment of zones to accommodate residents and businesses displaced by flooding could potentially occur at any location within the city. These redevelopment projects would involve all phases of building construction, including demolition, grading, building construction, and paving. The extents of redevelopment areas would be commensurate to the scale of losses from flooding, and the duration and intensity of construction noise would vary widely relative to specific receptors.

Heavy equipment types used for flood defense and demolition would create a perceptible level of vibration in the immediate vicinity of the equipment. It is unlikely that high-impact equipment, such as pile drivers, would be used for these types of activities, although jackhammers and hoe rams may be used for demolition. The relocation of services and properties would use heavy equipment that may potentially produce vibration near sensitive receptors and historic buildings that are more susceptible to building damage. The frequency and duration of these activities would be commensurate with flooding events, which could occur on an emergency basis within

residential areas with a high risk for flooding. In situations where deep support systems are needed for building foundations, vibratory or impact pile driving may be used.

Demolition and reconstruction activities could potentially exceed California Department of Transportation (Caltrans) vibration criteria for building damage and/or FTA criteria for construction vibration in situations where heavy equipment is operated within 50 feet of existing buildings. Due to the nature of emergency response to natural disasters and potential for large areas of the city to be inundated without a line of defense (LOD), heavy equipment would be required within city neighborhoods and close to structures.

2.3.11. Cultural Resources

2.3.11.1. Existing Conditions

Federal agencies are required under Section 106 of the NHPA (54 United States Code [U.S.C.] § 306108), as amended, and its Implementing Regulations (36 CFR Part 800) to consider the effect of any Federal or Federally assisted undertaking upon any site, building, structure, district, or object that is listed or eligible for listing in the NRHP and consider alternatives “to avoid, minimize or mitigate the undertaking’s adverse effects” in consultation with the State Historic Preservation Officer (SHPO), Native American Tribes/Nations, and consulting parties. Cultural resources must first be identified and evaluated for the NRHP. Procedures for identification and evaluation are detailed in a Programmatic Agreement included in *Appendix D: Environmental and Cultural Resources*.

Cultural resources are divided here into aboveground and archaeological properties. Cultural resources may be any prehistoric/precontact or historic district, site, building, structure, or object. Regardless of whether a resource is prehistoric/precontact or historic, it is referred to in the NHPA and NRHP as a Historic Property if it is included in, or eligible for inclusion in, the NRHP (which is maintained by the Secretary of the Interior). Historic properties include artifacts, records, and remains that are related to and located within such properties, and may be, but are not limited to, aboveground historic, architectural, terrestrial and marine archaeological resources, and Traditional Cultural Properties (TCPs). Identified resources are evaluated for eligibility for inclusion in the NRHP individually or as a contributing element to an archaeological, historic, or other district.

The following subsection provides summary information on the buildings, structures, objects, sites, and districts identified in the study area. Details of methods are described in Sub-Appendix D.3. Cultural Resources are categorized as NRHP-eligible, listed, unevaluated, or not eligible. Because the term Historic Property (defined as listed in or eligible for listing in the NRHP regardless of age) is often taken to mean properties solely from the Historic Period, historic properties are divided into aboveground resources and archaeological resources.

2.3.11.1.1. Archaeological Resources

Table 2-8 summarizes the key attributes of known archaeological resources. Due to the sensitive nature of some archaeological sites, each archaeological resource is

categorized by reach and ordered north to south in the table. Each archaeological resource is further categorized by NRHP eligibility.

Based on the records searches, a total of 39 previously identified archaeological resources are located in or adjacent to the study area. Of these, 32 are historic-age archaeological resources, four are precontact age, and three are multi-component with precontact and historic-age components.

Table 2-8: Archaeological Resources Summary

Reach	State Resource Identifier (P#)	Period	Name or Description	NRHP Eligibility
1	P-38-000023	Precontact/ Historic	Circular, fire-burnt rock, with quantities of decayed fish bones and crushed shells.	Undetermined
1	P-38-000030	Precontact/ Historic	Shell midden with hearths, bone, fire affected rock.	Undetermined
1	P-38-000031	Precontact	Black, sandy midden	Undetermined
1	P-38-005444	Historic	N-5 Dump	Undetermined
1	P-38-005647	Precontact	Franklin Street Midden	Undetermined
2	P-38-000095	Historic	Frederick Griffing's ship	Listed
2	P-38-000126	Historic	Mid-Embarcadero Roadway Project	Eligible
2	P-38-002324	Historic	The site includes two early wharf piles from the 1850s and a historic-era domestic artifact deposit from the mid-1860s.	Undetermined
2	P-38-004493	Historic	300 Spear Street	Undetermined
2	P-38-004926	Historic	333 Fremont Street Feature 100	Undetermined
2	P-38-004965	Historic	Thompson's Cove	Undetermined
2	P-38-005247	Precontact/ Historic	201 Folsom Street	Potentially Eligible
2	P-38-005499	Historic	240 Pacific Avenue	Undetermined
2	P-38-005683	Historic	Broadway-Vallejo Street Block (Temp No. 17-124-01)	Undetermined
3	P-38-000085	Historic	The Lydia	Eligible
3	P-38-000163	Historic	Three archaeological features associated with the marine railway operated by Henry Tichenor from 1851 to 1868.	Undetermined
3	P-38-004294	Historic	San Francisco Glass Works	Ineligible

San Francisco Waterfront Coastal Flood Study

Reach	State Resource Identifier (P#)	Period	Name or Description	NRHP Eligibility
3	P-38-004304	Historic	Bayshore Viaduct Block 5	Undetermined
3	P-38-004306	Historic	Buried remains of a historic city block, developed as Butchertown in 1853, used for industrial purposes through 1950.	Undetermined
3	P-38-004307	Historic	Bayshore Viaduct Block 8	Undetermined
3	P-38-004308	Historic	Bayshore Viaduct Block 9	Undetermined
3	P-38-004309	Historic	Bayshore Viaduct Block 10	Undetermined
3	P-38-004327	Historic	SFWBA Block 7; St. Mary's Hospital	Undetermined
3	P-38-004367	Historic	Coal Gasification Facility	Undetermined
3	P-38-004368	Historic	Built between 1887 and 1889, a brick foundation wall and office floor at 170 King Street, San Francisco.	Undetermined
3	P-38-004884	Historic	Rincon Point South Beach	Undetermined
3	P-38-005033	Historic	399 Fremont Street Privy 1	Undetermined
3	P-38-005102	Historic	Pier 68, Pier 3	Ineligible
3	P-38-005103	Historic	Pier 68, Pier 4	Undetermined
3	P-38-005151	Historic	The Crystal Hotel Site	Undetermined
3	P-38-005452	Historic	1913 Potrero Power Plant Wharf	Undetermined
3	P-38-005453	Historic	Sugar Refinery East Wharf	Undetermined
3	P-38-005501	Historic	Mission Bay Fourth Street Streetscape	Ineligible
3	P-38-005517	Historic	Abandoned Railroad Spurs	Undetermined
3	P-38-005641	Historic	Chase Center Railcar	Undetermined
4	P-38-004361	Historic	Middle Point War Dwellings	Undetermined
4	P-38-004638	Precontact	Quint Street Site	Undetermined
4	P-38-005445	Precontact	Submerged Flake	Undetermined
4	P-38-005504	Historic	Core 17 historic dump	Undetermined

2.3.11.1.2. NRHP-Listed Aboveground Resources

Examples of the types of aboveground resources within the study area include maritime infrastructure such as piers, wharves, bulkheads, and seawalls; boats; commercial and industrial buildings; transportation infrastructure; utility infrastructure; a military landscape; and recreational facilities.

There are 41 aboveground historic properties in the study area that are listed in the NRHP, including 9 historic districts and 32 individual historic properties. **Table 2-9** and **Table 2-10** provide summaries of these resources.

Several NRHP-listed properties are located within NRHP-listed districts. Furthermore, there are five maritime National Historic Landmarks (NHLs) (i.e., ships) within the San Francisco Maritime National Historical Park and two within the POSF Embarcadero Historic District that are individually listed in the NRHP.

Fourteen of the NRHP-listed or NRHP-eligible properties in the study area are historic districts. Four of the NRHP-listed districts are also designated as NHLs.

Table 2-9: NRHP-Listed Districts in the Study Area

Historic Property Name	NRIS Number	Number of Significant Features
Aquatic Park Historic District (NHL)	84001183	9
Central Embarcadero Piers Historic District	02001390	5
Fort Mason Historic District ^a	72000109	9
Port of San Francisco Embarcadero Historic District	06000372	47
San Francisco Cable Car Historic District (NHL)	66000233	48
San Francisco Maritime National Historical Park (NHL)	01000281	11
San Francisco Port of Embarkation, U.S. Army Historic District (NHL)	85002433	19
South End Historic District	4101-2500-9999	55 contributors ^b
Union Iron Works Historic District	14000150	33

^aThe Fort Mason Historic District was formerly known as the Black Point Historic District.

^bPage & Turnbull, South End Historic District National Register Certification, June 2008.

NRIS = National Register Information System

Table 2-10: NRHP-Listed Individual Properties in the Study Area

Aboveground Historic Property Name	NRIS Number	Year Built	Resource Type	NRHP Area of Significance
San Francisco–Oakland Bay Bridge	00000525	1935	Bridge	Architecture; Engineering
Baker and Hamilton	05000001	1905	Property	Architecture
Haslett Warehouse	75000172	1907	Property	Industry, Community Planning and Development, Commerce, Architecture

San Francisco Waterfront Coastal Flood Study

Aboveground Historic Property Name	NRIS Number	Year Built	Resource Type	NRHP Area of Significance
Audiffred Building	79000528	1889	Property	Commerce, Architecture
Coit Memorial Tower	07001468	1933	Property	Art
Armour & Co. Building	09001117	1900	Property	Commerce, Architecture
Fuller Co. Glass Warehouse	01001101	1907	Property	Architecture
Daniel Gibb & Co. Warehouse/Gibb-Sanborn Warehouse	97001189	1906	Property	Architecture, Commerce, Community Planning and Development
1254–1256 Montgomery Street	79000532	1962	Property	Architecture
Merchant's Ice and Cold Storage Co.	09001300	1904	Property	Architecture
Otis Elevator Company Building	99001265	1971	Property	Engineering, Industry
Pioneer Woolen Mills and D. Ghirardelli Company	82002249	1858; 1893; 1962	Property	Industry, Landscape Architecture, Commerce, Art, Conservation, Architecture
Pumping Station No. 2, San Francisco Fire Department AWSS	76000177	1900	Property	Community Planning and Development, Engineering
Rincon Annex	79000537	1925	Property	Art, Architecture
Irving Murray Scott School	85000714	1900	Property	Education
U.S. Customhouse	75000476	1974	Property	Architecture
Matson Building and Annex	95001384	1921	Property	Transportation, Architecture
Folger Coffee Co. Building	96000679	1903-05	Property	Architecture, Commerce, Community Planning/Development, Engineering
Tubbs Cordage Co. Building	79000254	1890	Property	Architecture, Commerce, Industry
<i>Balclutha</i>	76000178	1886	Ship	Commerce, Education, Transportation
<i>Eureka</i> (Ferry Boat)	73000229	1890	Ship	Commerce, Transportation
<i>C.A. Thayer</i>	66000229	1895	Ship	Commerce, Industry
<i>Alma</i> (Scow Schooner)	75000179	1891	Ship	Commerce, Transportation
<i>Hercules</i> (Tugboat)	75000225	1906	Ship	Commerce, Industry

Aboveground Historic Property Name	NRIS Number	Year Built	Resource Type	NRHP Area of Significance
<i>S.S. Jeremiah O'Brien</i>	78003405	1943	Ship	Commerce, Engineering, Military, Transportation
<i>U.S.S. Pampanito</i>	86000089	1943	Submarine	Military
<i>M.V. Santa Rosa</i>	79000469	1926	Ship	Transportation, Maritime History
Ferry Building/Union Ferry Depot	78000760	1895	Property	Architecture, Engineering, Transportation
Ferry Station Post Office	78000756	1915	Property	Architecture, Commerce
Beltline Railroad Roundhouse Complex/Belt Railroad Engine House and Sandhouse	86000207	1913-14	Property	Commerce, Engineering, Transportation
Pier One	98001551	1931	Property	Commerce, Transportation, Architecture
Sinton House, 1020 Francisco Street	11000944	1927	Property	Art, Architecture

NRIS = National Register Information System

NRHP-Eligible Properties in the study area

There are five districts and six individual aboveground historic properties in the study area that are determined eligible for listing in the NRHP. All are considered historic properties under Section 106. **Table 2-11** and **Table 2-12** provide summaries of these resources.

Table 2-11: NRHP-Eligible Districts in the Study Area

Historic Property Name	Documentation	Number of Significant Features
Bluxome Townsend Historic District	DPR 523 form set (Page & Turnbull 2009)	9
Auxiliary Water Supply System (discontiguous)	Historical Resources Evaluation (Tetra Tech, Inc. 2009)	5
South End Historic District Addition	DPR 523 form set (Page & Turnbull 2009)	12
Bridges and Tunnels	DPR 523 form set (San Francisco Planning Department 2001)	N/A
Market Street Cultural Landscape District	Better Market Street Project Cultural Landscape Evaluation (ICF 2016)	Numerous

Table 2-12: Additional NRHP-Eligible Properties in the Study Area

Historic Property Name	Documentation	Year Built	Significance
Embarcadero Plaza/Justin Herman Plaza	Better Market Street EIR (San Francisco Planning Department 2019)	1971–72	
Army-Navy YMCA (161–169 Steuart Street)	National Register survey (2019)	1925	Appears individually eligible for NRHP
Oriental Warehouse (650 Delancey Street)	South of Market Area Historic Resource Survey (San Francisco Planning Department 2011)	1867	Contributor to the NRHP-listed South End Historic District
Fireboat House/Fire Station No. 35 (Pier 22 ½)	Waterfront Plan EIR (San Francisco Planning Department 2023)		Determined eligible for NRHP (criteria and period of significance are not identified).
Kneass Boatworks Building (671 Illinois Street)	Pier 70 Mixed-Use District Project EIR (San Francisco Planning Department 2016)	Ca. 1870s	Determined eligible for NRHP under Criterion A with a period of significance of 1854–1948.
Fire House No. 25 (3305 Third Street)	Waterfront Plan EIR (San Francisco Planning Department 2023)		Determined eligible for NRHP under Criterion C (period of significance is not identified).

EIR = environmental impact report

2.3.11.2. Future Without Project

Access and use of aboveground historic properties along the San Francisco waterfront would likely be impeded in the future as RSLC leads to overtopping, increased precipitation results in additional flooding, etc. Physical impacts, such as erosion from wave energy and inundation, and potential loss could also occur with water intrusion associated with RSLC and flooding events. Resources in low-lying areas are at highest risk for adverse effects. Resources along the waterfront in the Marina and Northeast planning districts would be at risk of flooding, particularly Fisherman’s Wharf and the Embarcadero. Identified resources in the Mission, SOMA, and South Bayshore planning district are at the highest risk for adverse effects because they are currently the lowest-lying areas and already experience flooding.

The San Francisco shoreline has been altered considerably since the late 18th century. Yerba Buena Cove, Mission Bay, and the marshlands of Islais Creek have all been filled over time to create more developable land (termed “bay fill”) and maritime access. Deep and/or extensive areas of bay fill likely cover unknown archaeological resources. If RSLC outpaces alluvial deposition, sediments will be lost, potentially exposing sensitive archaeological resources to the elements and effects of future flooding, as well as

human impacts such as development, remediation, trespass, or looting. Alternately, sediment accretion would further protect buried archaeological resources.

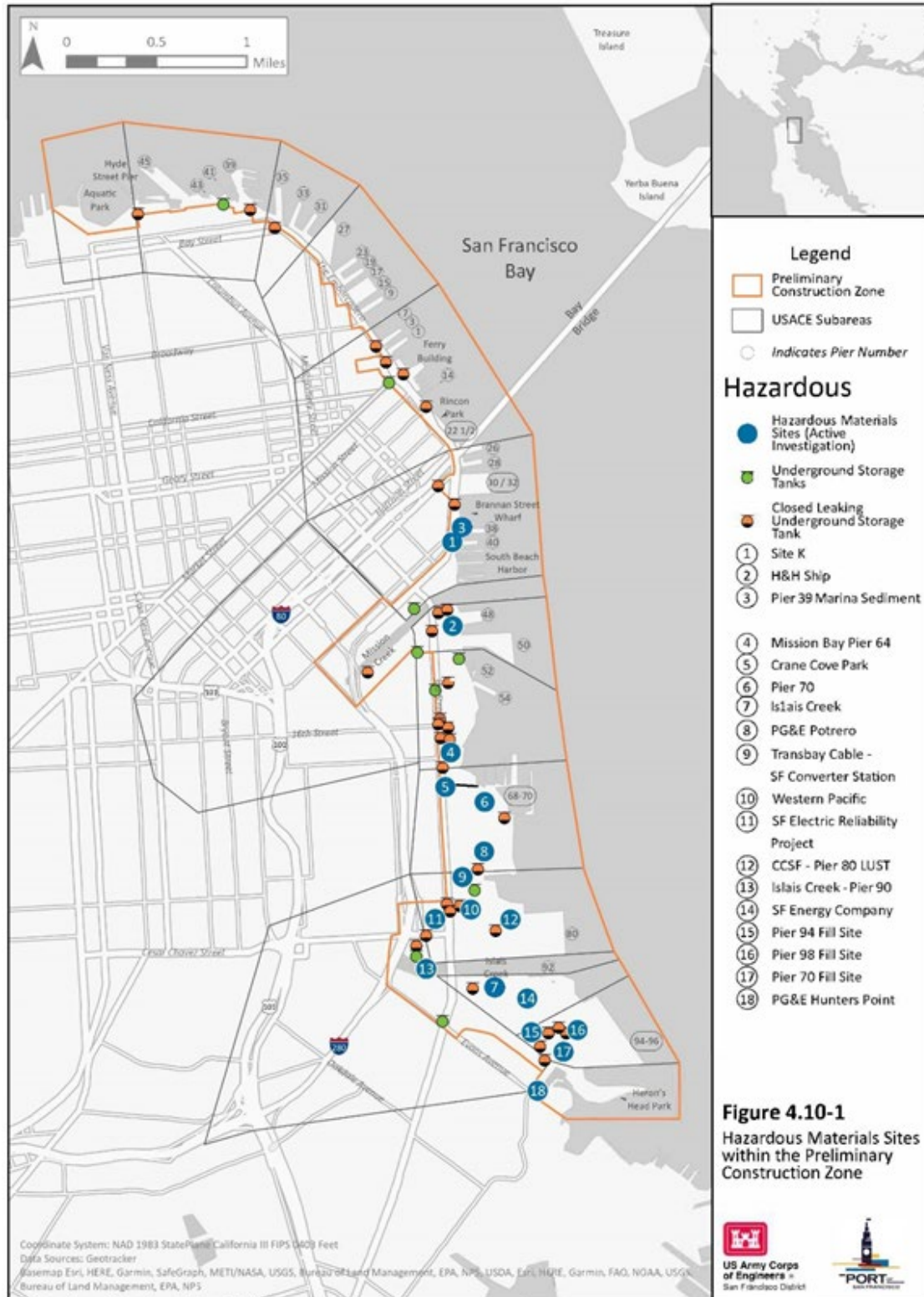
Changing conditions resulting in expected increases in nuisance flooding and more catastrophic flooding are expected. In the absence of intervention, emergency flood response and cleanup would continue to require the use of heavy equipment. In emergency situations, damages lead to removal of contaminated sediments, debris, and damaged structures, potentially damaging or destroying archaeological and aboveground cultural resources. Unknown buried archaeological resources would be at risk of destruction, contingent on depth of disturbance. Construction equipment operated near to cultural resources produces potentially damaging vibrations. Should buildings be demolished and reconstructed in place or elsewhere, construction activities could impact unknown or previously recorded cultural resources. Increasing frequency and scale of inundation would cause varying impacts.

Changes to the surrounding viewshed due to flooding, emergency cleanup, and demolition or construction may adversely affect historic properties by altering the setting and feeling that contribute to the property's NRHP eligibility. Emergency repairs to structures may alter contributing factors to NRHP eligibility, and impact surrounding cultural resources and districts. Historic Districts and NHLs would be adversely impacted by repairs or demolition to contributing resources or to viewshed and setting.

2.3.12. Hazardous, Toxic, and Radioactive Waste

2.3.12.1. Existing Conditions

The study area was evaluated for HTRW through a records search of Federal, State, and local databases to identify sites that include locations where releases of hazardous substances or petroleum products have occurred into the soil, groundwater, or surface water. No environmental sampling of soil or groundwater was performed as part of this evaluation. The results of the records search identified over 157 potential environmental contamination sites within the study area. Of the potential sites identified, approximately 61 are located within the project area with known impacts to the soil or groundwater due to hazardous substances. For the sites located within the study area, additional information was obtained from the EnviroStor and GeoTracker databases for the purpose of determining potential impacts from these sites in relation to potential future construction activities. The potential for these sites to impact the construction activities was determined based on the presence of suspected soil and/or groundwater contamination, mobility within the soil-groundwater-air matrix, and the potential for construction activities to affect the contaminated media. As a result, 18 sites were identified within the study area with the potential to impact future construction activities (**Figure 2-14**). An additional 34 leaking underground storage tank (LUST) sites that have received regulatory closure were identified within the project footprint. Although these LUST sites have received regulatory closure, there is potential for waste/contamination to remain in the soil and groundwater that may require special management and disposal related to future construction activities. Additional details on the HTRW sites can be found in *Annex D.1.6: Hazardous, Toxic and Radioactive Waste*, located within *Appendix D: Environmental and Cultural Resources*.



San Francisco Waterfront Flood Resiliency Study
Integrated Feasibility Report / Environmental Impact Statement

1.09.11/12/29/20/revision 1/Dave Golles/DRAFT

Figure 2-14: Hazardous Materials Sites Within the Project Footprint

2.3.12.2. Future Without Project

Capped and un-capped HTRW areas would be exposed to flooding and erosion from RSLC, which could result in releasing contaminants that impact water, soil, and sediment quality, as well as human health.

2.4. Built Environment

The built environment is defined broadly as constructed resources and infrastructure that define the urban fabric, support communities, and enable economic activity. This definition includes transportation infrastructure, utilities, recreation, aesthetics, land use planning, ports and marine facilities, and existing coastal defenses.

2.4.1. Utilities

Utilities include low-pressure (potable) water, combined sewer system, waste management, and energy.

2.4.1.1. Potable Water

2.4.1.1.1. Existing Conditions

Potable, or low-pressure water is vital to the community's development and daily functions. All types of businesses, such as office buildings, hotels, restaurants, and industry, depend on potable water to stay open. The SFPUC Water Enterprise operates San Francisco's water distribution system, which includes reservoirs and storage tanks, pump stations, fire hydrants, distribution pipelines, isolation valves, and automatic air valves. In the study area, critical low-pressure water assets include the Bay Bridge Pump Station, water mains, low-pressure fire hydrants, and automatic air valves (CH2M/Arcadis 2020h).

From a coastal flooding perspective, the Bay Bridge Pump Station is most vulnerable to flood damage (and service disruption) while underground pipes are vulnerable to rising ground water. The Bay Bridge Pump Station, located in Reach 3, is the sole provider of potable water to Treasure Island and Yerba Buena Island. If the facility is damaged, around 3,200 residential customers could lose potable water service (U.S. Census 2020).

2.4.1.1.2. Future Without Project

The reliability of potable water is necessary for many industries in the study area. Changing meteorological conditions could lead to a short-term or long-term water shortage, which could significantly impact potable water-dependent industries. RSLC would continue to stress the water main system, likely requiring increased investment into utilities such as potable water. Corrosion from rising groundwater could shorten life expectancy of buried pipes and require more frequent inspection or replacement. If buried pipelines are compromised, saltwater infiltration from increased groundwater levels may occur and affect the quality of drinking water.

2.4.1.2. Combined Sewer System

2.4.1.2.1. Existing Conditions

Through the SFPUC, CCSF operates and maintains a predominantly combined sewer system with major infrastructure including three treatment plants, 25 pump stations, 1,000 miles of sewer mains, 17 miles of transport/storage (T/S) structures, 35 CSD structures, and over 85 green infrastructure facilities.

The combined sewer system collects both wastewater and stormwater for most of the city. The wastewater is collected, stored, conveyed to, and treated at one of three treatment plants, two of which are located in the study area. The Southeast Treatment Plant is the city's largest wastewater treatment facility (43 million gallons per day [mgd] average dry weather capacity in 2022, and 250 mgd peak wet weather capacity) and is located within the study area. The North Point Wet Weather Treatment Plant is also located in the study area, is used only during wet weather, and has a peak wet weather treatment capacity of 150 mgd. Local gravity sewers convey combined wastewater flows to T/S boxes, which meter to the treatment plants. Once system capacity is exceeded during wet weather events, discharges through one of the CSD structures occur with equivalent to primary treatment. Generally, only during the most prolonged intense rainstorms is the combined capacity of the treatment plants and T/S boxes exceeded. Instead of allowing the excess water to back up through the sewers into homes and streets, water is discharged into either the Bay or Pacific Ocean through CSD structures.

Wastewater service is critical in supporting residents, commerce, and industries. In addition to providing wastewater service to SFPUC customers, the combined sewer system is also an essential stormwater drainage system for the city; together, the collection system and outfalls provide drainage for public streets, sidewalks, parks, and public/private facilities during wet weather events.

Some of the city's most critical wastewater conveyance and treatment facilities are in the waterfront area. This includes several miles of local gravity sewer systems, T/S boxes, tunnels, a force main, combined sewer gravity mains, CSD structures, pump stations, and two treatment facilities. These assets are arranged by reach as follows:

- Reach 1 critical wastewater assets consist of the North Shore Pump Station, the North Point Wet Weather Facility, the North Beach Tunnel, a part of the Jackson T/S Box, and one CSD outfall structure.
- Reach 2 includes the Jackson T/S Box, the North Shore Force Main, a part of the Channel T/S Box, and one CSD outfall structure.
- Reach 3 includes the Channel T/S Box; the Channel Pump Station; the Channel Force Main; the smaller Mission Bay, Berry Street, Harriet Street and Mariposa Pump Station; the Mariposa T/S Box; and several CSD structures.
- Reach 4 encompasses part of the Channel Force Main, the Bruce Flynn Pump Station, the Booster Pump Station, the Southeast Bay Outfall, the Islais Creek

T/S Box, the Southeast Treatment Plan and Bay Outfall, and several CSD structures.

2.4.1.2.2. Future Without Project

High coastal water levels could impact the city's combined sewer system. Potential impacts of high coastal waters in the Bay Area (with or without coincident rain events) include overtopping seawalls, water backing up into storm drains, ponding, delays in stormwater drainage to receiving bodies, surface flooding, pressurization of storm drains, damage to underground pipes, and sinkholes. CCSF's impact assessment states that discharge capacity of outfalls would be reduced under rising sea level scenarios (CCSF 2020). As sea level rises, the ability for the system to discharge to the Bay and creek by gravity would be hampered by the hydraulic gradient. Changing meteorological conditions effects and altered sea levels would affect the operation and viability of the current system. Increased precipitation would challenge the study area's combined stormwater and wastewater drainage system, potentially leading to more combined sewer overflows. An increase in sewer overflows can reduce water quality (EPA 2023).

2.4.1.3. Waste Management

2.4.1.3.1. Existing Conditions

Recology, or Recycle Central, is located on Pier 96 (Reach 4), and provides collection and sorting of recyclable materials including containers, mixed paper, and cardboard to commercial and residential customers in San Francisco. The facility, which opened in 2002, was designed and constructed in partnership with the CCSF and is a key asset to the CCSF's zero waste goal. Recology covers over 185,000 square feet and processes about 750 tons of material each day, employing over 180 people, many from the nearby Bayview Hunters point neighborhood.

2.4.1.3.2. Future Without Project

Recycle Central would be at risk of repeated damage to the facility at Pier 96 in the absence of a Federal project. Under the Intermediate RSLC scenario, the facility would likely be repeatedly inundated during daily MHHW with a 1% AEP event. Additionally, the facility would be subject to regular flooding with high tide or rainfall events over time. This is likely to render the center temporary unusable at times following an event, but may require replacement, refurbishment, or relocation at a later time when frequent flooding exacerbates.

2.4.1.4. Energy

2.4.1.4.1. Existing Conditions

SFPUC and Pacific Gas and Electric Company (PG&E) provide energy to the study area and the city of San Francisco. The SFPUC manages two retail electric service programs: Hetch Hetchy Power and CleanPowerSF. Together, these programs provide

more than 70% of the electricity consumed in San Francisco today. For over 100 years, Hetch Hetchy Power has generated clean, 100% GHG-free electricity for San Francisco. It powers critical municipal services such as Muni and San Francisco General Hospital, affordable and public housing sites, and new developments like The Shipyard and Salesforce Transit Center.

Launched in 2016, CleanPowerSF is San Francisco's community choice aggregation program and serves more than 380,000 residential and commercial customers with clean, renewable electricity at competitive rates. CleanPowerSF's current resource portfolio includes solar, wind, hydroelectric, and geothermal power.

PG&E provides power through a combination of energy resources, including natural gas, nuclear, biomass and waste, geothermal, small and large hydroelectric, solar, and wind resources (PG&E 2019).

2.4.1.4.2. Future Without Project

The PG&E building may succumb to periodic flooding during major events over the study period; however, the greatest impact under FWOP is likely to be to energy services provided to transportation, residents, businesses, and emergency response efforts. Nuisance flooding would strain energy services to the extent power outages would likely increase due to damage to supporting infrastructure. As sea levels rise, flooding frequency, duration, and magnitude would likely increase, thereby worsening the strain to energy infrastructure. It is probable that infrastructure would undergo repairs throughout the study period and/or would need to be replaced or relocated as flooding became more problematic.

2.4.2. Transportation

2.4.2.1. Existing Conditions

The study area provides a variety of transportation facilities and services, both on the water and throughout the city. Transportation is overseen primarily by the San Francisco Municipal Transportation Agency (SFMTA), with additional responsibilities overlapping with San Francisco Public Works, the San Francisco County Transportation Authority, and POSF. Additional regional transportation provide service to, from, and within San Francisco, including Alameda-Contra Costa Transit District, BART, Caltrain, Golden Gate Transit, Water Emergency Transportation Authority (WETA), and San Mateo County Transit. The transportation network consists of roadways, local and regional transit facilities, and bicycle and pedestrian networks.

The roadway network includes freeways, major arterials, transit preferential streets, secondary arterials, recreational streets, collector and local streets, primary emergency priority routes, and freight truck routes. Detailed descriptions of these functional classifications are provided in the Transportation Element of the General Plan (CCSF 2014b). The study area includes the Embarcadero, Jefferson Street, Beach Street, Broadway, Washington Street, Harrison Street, Bryant Street, Third Street, Fourth Street, Terry A. Francois Boulevard, Cesar Chavez, Cargo Way, Evans Avenue, Amador Road, and Illinois Street.

The city has designated on-street bicycle facilities in the study area that are part of the San Francisco Bicycle Network. On-street bicycle facilities include Class I bikeways (bike paths with an exclusive right-of-way for use by bicyclists or pedestrians), Class II bike lanes (bike lanes striped within the paved areas of roadways and established for the preferential use of bicyclists), Class III bikeways (signed bike routes that allow bicycles to share travel lanes with vehicles), and Class IV cycle tracks (areas for exclusive use by bicyclists that include physical separation from motor vehicle traffic). There are one Class I bikeway, six Class II bike lanes, seven Class III bike routes, and four Class IV bikeways in the study area.

2.4.2.2. Future Without Project

Several important transportation corridors would be impacted by rising sea levels and flooding that carry or provide access to vehicles, transit users (rail, bus, and ferry), bicyclists, and pedestrians. Nuisance flooding impacts and major storms pose flood risk to the Muni and BART underground transit systems and to core transportation corridors such as the Embarcadero and Third Street transit corridor. As sea levels continue to rise, flooding frequency, magnitude, and duration will likely increase, which exacerbates risk to the BART Transbay Tube, Muni light rail, key utility infrastructure, WETA and Golden Gate Ferry service, and waterfront businesses and neighborhoods that depend on the seawall. Flooding and associated freeway on- and off-ramp, road, sidewalk, and bike path closures and repairs would become increasingly common and gradual retreat of these facilities is expected to occur over time as RSLC continues. There would also be several transportation facilities for maintenance and operations such as the Muni Municipal East facility that would be subject to flooding and infrastructure affected that would lead to a high degradation of transit by the end of century (SFMTA 2022).

2.4.3. Recreation and Access

2.4.3.1. Existing Conditions

The San Francisco Bay is a major destination for recreationists, including water-based activities such as cruising, wakeboarding, sailing, windsurfing, and kiteboarding as well as fishing both from land and boat, and land-based tourism and recreation at public parks and open spaces. In total, the city is home to approximately 5,890 acres of parkland and open space areas (San Francisco 2014).

The POSF oversees public access, parks and open spaces, natural and cultural resources, and much of the city's last remaining critical industrial uses. The Exploratorium, Oracle Park, the Ferry Building, Chase Center, Heron's Head Park and EcoCenter, and Fisherman's Wharf are all within the study area. The Embarcadero promenade and the Blue Greenway, both elements of the San Francisco Bay Trail, are significant recreation resources for the city. These are among the most heavily used trails for walking, jogging, and cycling in the city, providing miles of access along San Francisco Bay.

2.4.3.2. Future Without Project

The study area would continue to be at risk of flooding and could become more at risk due to RSLC and changing meteorological conditions, which may impede the public's access to recreation areas. Access to the waterfront is critical for the public in the study area but flooding under RSLC may render it inaccessible. Additionally, loss of important natural recreation areas would be expected due to erosion and subsidence. Access to local piers and wharves may be temporarily inaccessible with nuisance flooding or lost with repeated storms and RSLC.

2.4.4. Aesthetics

2.4.4.1. Existing Conditions

POSF maritime and water-dependent uses stretch along the entire waterfront, preserving San Francisco's working waterfront character and heritage. The POSF waterfront is distinctly urban in character. The POSF's linear stretch of property extends through a diverse cross section of San Francisco districts and neighborhoods that define much of the urban character and scale. Distinguishing features of the waterfront include the pier facilities and maritime operations that connect to the larger San Francisco urban landscape. San Francisco's street grid provides a direct connection from the city's neighborhoods to the network of historic piers, maritime facilities, and open spaces that extend along and over the Bay. This juxtaposition creates what is generally considered a visually pleasing waterfront experience.

The Embarcadero and Terry A. Francois Boulevard form a break in the city landscape that creates two distinct identities: city neighborhoods on the west side and the POSF waterfront features on the east side. The Bay and piers create visual contrasts to the city streets and upland neighborhoods that adjoin the Embarcadero and Terry A. Francois Boulevard. These contrasts help give the San Francisco waterfront its unique identity.

The POSF waterfront has distinct land use and architectural characteristics. Fisherman's Wharf is characterized by many simply detailed one-story industrial buildings. The bulkhead buildings and piers along the Embarcadero, with the Ferry Building as the centerpiece, reflect the port's historic civic significance. The South Beach and Rincon Hill neighborhoods and entertainment venues such as Oracle Park and Chase Center highlight the transformation of former industrial areas to new residential neighborhoods and city attractions. Mission Rock is an emerging new mixed-used neighborhood in Mission Bay with parks, commercial, and residential uses. Pier 70 is an emerging mixed-use district in the Dogpatch neighborhood with parks, commercial, and residential uses and is home to the Union Iron Works Historic District which showcases the architectural, maritime, and labor history of the area. The Islais Creek area in the Bayview community is characterized by large industrial buildings and facilities.

The open spaces along the POSF waterfront within the study area vary in character, largely related to the physical form of the waterfront's edge. From Fisherman's Wharf to just south of China Basin Channel, the waterfront is a built edge supported by the

Embarcadero seawall and pile-supported pier decks. The built seawall ends at the Mission Bay waterfront, transitioning to a solid landform that meets the water. The natural shoreline areas include those along Mission Creek, along the northeast shoreline of Pier 94, and at Heron's Head Park.

2.4.4.2. Future Without Project

The aesthetics are expected to continue as described in the existing conditions over time. No significant impacts are expected to the aesthetics in the study area, though changing meteorological conditions and/or RSLC could cause damage to structures that contribute to the aesthetics of the waterfront from repeated nuisance flooding or more significantly from storms.

2.4.5. Port and Maritime Facilities

2.4.5.1. Existing Conditions

The POSF is an enterprise agency within CCSF, meaning that revenues generated through rent, maritime fees, and other income streams are used to fully fund POSF's annual budget (Operating & Capital). San Francisco port and maritime facilities encompass several different types of infrastructure along the waterfront, including piers, wharves, and bulkhead and shed buildings.

The POSF's seven maritime industries – fishing, cruise, harbor services, temporary and ceremonial, excursion, water recreation, and ferry and water taxi – serve State purposes and have important regional economic and social value.

2.4.5.2. Future Without Project

As described in Section 2.3.5, port and maritime facilities would likely be damaged or deemed inaccessible with rising sea levels, such that it could impede regular use for recreation, transportation, and operational purposes.

2.4.6. Existing and Planned Federal and Local Projects

2.4.6.1. Embarcadero Seawall

The existing Embarcadero seawall was constructed by the State of California in segments from 1878 to 1929 and transferred to CCSF in 1968. The seawall was built by dredging a trench through the "young Bay mud" formation, filling that trench with rock and rubble, capping the fill with a timber pile bulkhead wall and wharves, and then filling the tidal marshland area behind the seawall. Spanning 3 miles from Fisherman's Wharf to Mission Creek, the seawall is one of San Francisco's oldest pieces of infrastructure. The seawall helped create over 500 acres of new land between San Francisco Bay and 1st Street.

The Embarcadero seawall generally reduces coastal flooding along San Francisco's shoreline when coastal storms or extremely high tides occur. It is largely invisible as it underpins the waterfront adjacent to San Francisco Bay. The seawall acts as a retaining

wall and stabilizes the land that was filled (created) behind it. Portions of the seawall that existed at the time of the 1906 earthquake settled and moved several feet toward the Bay.

POSF has a long-term seawall rehabilitation program that includes the incorporation of limited coastal and combined flood risk management measures independent of this study. However, any actions are considered to be limited in scope and scale for the FWOP and only implemented in areas that are at high risk of failure or will have sustained damage due a future coastal storm or seismic event. Available funding for such repairs is limited. The FWOP condition includes the following actions:

- POSF will make life-safety improvements along portions of the waterfront through retrofit of existing marine structures, but these projects are not expected to significantly change elevations.
- The first phase of the Waterfront Resilience Program will address the most critical life-safety upgrades to the seawall and is estimated to cost \$500 million. The proposed Seawall Earthquake Safety and Disaster Prevention Program Bond will fund the majority of this work and leverage other funding sources including private, state, and Federal funds.
- Possible improvements include strengthening the ground below and landside of the seawall, constructing new seawall segments along limited extents of the waterfront, strengthening, or replacing bulkhead walls and wharves along the Embarcadero promenade, and relocating or replacing critical utilities.

2.4.6.2. Hazards and Climate Resilience Plan

This feasibility study is one critical piece of a larger CCSF commitment to resiliency planning and proactive coordination of CCSF agencies to build and maintain vital city and community functions over the next 100 years.

The climate resilience goals of POSF are formalized in the CCSF's Hazards and Climate Resilience Plan (HCR) (CCSF 2025). The HCR was developed to serve as a roadmap to address the impacts of natural hazards and changing meteorological conditions on the assets and people within the city of San Francisco. It identifies the hazards and risks San Francisco faces and proposes multiple strategies to reduce risks and adapt to the impacts of changing meteorological conditions.

The 2025 HCR was adopted as San Francisco's 2025 Hazard Mitigation Plan by the Board of Supervisors on July 22, 2025, and the Mayor on August 1, 2025. It was approved by FEMA on August 14, 2025. The plan updated the 2020 HCR, which served as an update to CCSF's 2014 Hazard Mitigation Plan, coordinated with FEMA to encourage proactive risk reduction efforts are implemented to mitigate post-disaster consequences where possible and to increase efficiency of post-disaster response and recovery programs at the Federal and local level. The 2025 Hazard Mitigation Plan reflects the proactive efforts of the CCSF to reduce FEMA post-disaster response costs.

2.4.6.3. Waterfront Development Projects

This subsection describes the actions that CCSF, as well as individual public and private property and asset owners, would take to address RSLC and coastal flood hazards in the study area in the absence of a federal project. CCSF would be expected to act rationally within the constraints of available funding sources to continue operation of essential services within and outside of the flooded areas. Individual actors (property owners, agencies, business owners, and residents) are expected to dynamically react to the increasing risk of flood damage, thereby repairing damage from infrequent flood events and eventually taking proactive steps to prevent repetitive damage through floodproofing actions. When the frequency of flooding becomes too great and impacts too disruptive to commerce within the urban study area, it is reasonable to assume zones within the floodplain will be abandoned and converted to land uses compatible with frequent inundation.

There are many development projects underway up and down the waterfront on POSF-owned land, as shown on **Figure 2-15**. These new projects not only bring new investment to the city but also will provide more places for people to live, work, shop, and visit. Some of these projects are in the planning phase, such as those proposed at Pier 45/Seawall Lot 301, Piers 19-31, Piers 30-32/Seawall Lot 330, and Piers 94-96/Backlands. These projects are not included in the FWOP condition.

Others are approved and are either under construction or waiting for improved real estate market conditions, such as Mission Rock, Pier 70 Brookfield, and Teatro ZinZanni. These projects are included in FWOP condition.

POSF requires consideration of RSLC for all new developments. CCSF requires a similar assessment for all projects along the shoreline. As a result, all new projects along the San Francisco shoreline will incorporate coastal and combined flood risk management measures that include raising grades, raising shorelines, creating adaptation spaces along the shoreline, monitoring flood events/coastal storms, requiring funds to be set aside and used for RSLC adaptation, when needed, and flood proofing at specific sites.

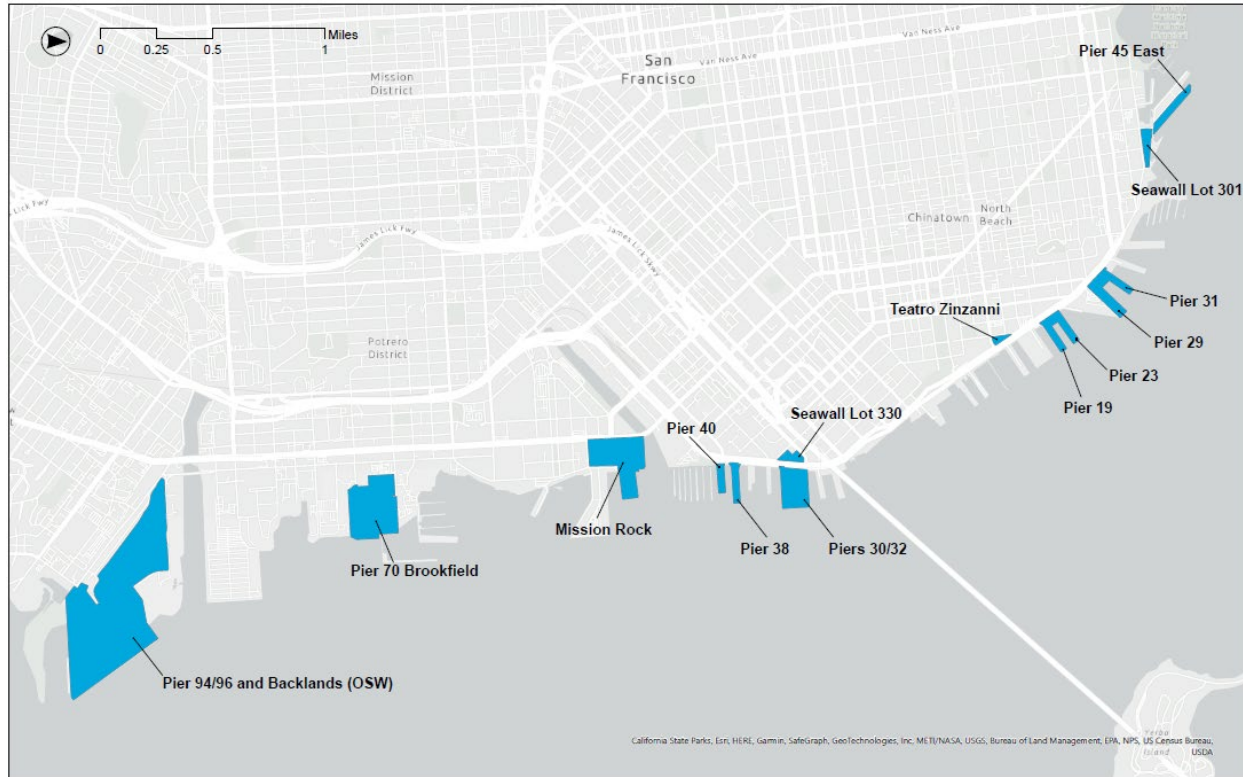


Figure 2-15: Planned Development along the Waterfront on POSF Property

2.4.6.4. Planned Resilience Projects

In 2018, San Francisco voters passed Proposition A, a \$425 million municipal bond measure, to fund seawall earthquake safety and resilience projects along the Embarcadero waterfront. This money is being used for planning, design, and implementation of Early Projects along the Embarcadero, focused on immediate life safety, disaster response, and earthquake resilience.

POSF identified 23 Embarcadero Early Projects to reduce earthquake and flood risk focused on improving earthquake safety, building CCSF and regional disaster response capability, and managing near-term coastal and combined flood risk. The estimated total cost range to deliver all 23 projects is estimated to be between \$650 million and \$3 billion, more than the current funding available from Proposition A and other available funding sources.

POSF prioritized seven Embarcadero Early Projects to move forward through pre-design. The projects include earthquake safety projects to reduce loss of life in an earthquake, earthquake resilience projects to reduce damages to buildings and structures, and a near-term flood improvement project, the Downtown Coastal Resilience Project.

The seven projects are:

- Wharf J9 Replacement and Resilient Shoreline Project

- Pier 15 Bulkhead Wall and Wharf Substructure Earthquake Safety Retrofit Project
- Pier 9 Bulkhead Wall and Wharf Substructure Earthquake Safety Retrofit Project
- Ferry Building Seawall and Substructure Earthquake Reliability Project
- Downtown Coastal Resilience Project
- Pier 24½ to Pier 28½ Bulkhead Wall and Wharf Substructure Earthquake Safety Project
- Emergency Fire Water System Fireboat Manifold Earthquake Resilience Project

These projects are not included in the FWOP condition because CCSF has not completed analysis of these projects under the California Environmental Quality Act (CEQA) nor approved funding for construction. As plan refinement progresses, the PDT will continue to evaluate how projects such as the Wharf J9 Replacement and Resilient Shoreline Project and the Downtown Coastal Resilience Project will align with elements of the Recommended Plan. At this time, targeted components of the Downtown Coastal Resilience Project have been identified as potential ERAs for implementation as part of the Recommended Plan (Section 6.2). POSF does not have other significant sources of funding to pay for flood resilience projects, outside of the SFWCFS Recommended Plan. POSF has a significant maintenance capital backlog of \$1.1 billion, with an annual budget of \$10-20 million for port upkeep and capital state of good repair. Projects that are completed or are scheduled to be completed by 2040 were not included in the flood damage modeling but were included in the FWOP condition utilized during formulation of measures and alternatives in the study.

With any available funds, POSF will continue to prioritize immediate life safety and resilience projects over time, similar to the Embarcadero Early Projects. While CCSF and POSF have a demonstrated commitment to managing flood risk, the coastal flood resilience structures required to manage flood risk along the POSF's 7.5-mile shoreline over the 100-year POA exceeds the capacity of CCSF or POSF to implement without Federal participation.

The Heron's Head Park Shoreline Resilience Project aims to bring a living shoreline approach to address significant subsidence and erosion since the park's creation over 20 years ago. POSF completed planning, design, and permitting of a nature-based solution to shoreline erosion at Heron's Head Park in 2021. The Heron's Head Park Shoreline Resilience Project will restore the former type and extent of habitat and provide new habitat in the form of coarse sand/gravel beach, new wetland vegetation to reinforce shoreline and pond edges, and subtidal oyster reefs. The coarse material shoreline will enable wetlands to migrate with rising sea level so that some wetland habitat and public access areas remain through mid-century. This project was considered as an existing/FWOP condition and utilized during formulation of measures and alternatives in the study.

The objectives of the Heron's Head Park Shoreline Resilience Project are:

- Protect the southern shoreline from continued erosion
- Restore native wetland plant habitat by growing, planting, and caring for key wetland species
- Create capacity for adaptation to RSLC
- Create youth employment and community engagement opportunities

To achieve these objectives, the project includes the following elements:

- Dynamically stable sand and gravel beach
- Oyster reef balls, which are structures fabricated of special concrete, sand, rock, and shell
- Wetland revegetation
- Youth employment in hands-on habitat restoration and community outreach
- Post-construction monitoring and habitat stewardship

2.5. Human Environment

The economic environment describes the socioeconomic and community profile, public health and safety, at-risk communities, and flood damages in the study area.

2.5.1. Socioeconomics and Community

2.5.1.1. Existing Conditions

The study area is highly developed and characterized by multiple land uses. It encompasses several neighborhoods, including North Beach/Fisherman's Wharf, the Financial District, SOMA/Mission Bay, Potrero Hill/Central Waterfront, and Bayview North/Islands Creek (City and County of San Francisco Planning Department 2020). Neighborhoods in the study area include commercial land uses, residential buildings, tourist attractions, high-density housing, mixed-use spaces, and mixed industrial and residential use. Occupied housing units in the city and study area are occupied primarily by renters, approximately 62.4% and 70.9%, respectively.

The North Beach and Fisherman's Wharf neighborhoods are located along the northeast edge of the city's waterfront. These neighborhoods include mainly commercial land uses, with some residential buildings, as well as large tourist attractions. The Financial District is the Bay Area's largest and densest job center, comprising large areas of high-density housing, commercial, and mixed-use space near the Embarcadero and Market Street.

Next, the SOMA and Mission Bay neighborhoods comprise developing mixed-use neighborhoods as well as large commercial buildings on both sides of Mission Creek; Mission Bay includes health industry uses, as well as residential and other commercial

uses. The Potrero Hill and Central Waterfront neighborhoods include residential areas along the hillside as well as mixed industrial and residential uses along the shoreline in an area known as Dogpatch. This neighborhood is located along the east edge of the city, between the SOMA and Bayview neighborhoods.

Finally, the Bayview North/Islais Creek neighborhood, located along the southeast edge of the city, includes the industrial areas surrounding Islais Creek, as well as residential areas and developments.

Community resources and services within the study area include:

- Emergency water system for firefighting
- San Francisco Fire Department (SFFD) stations 4, 8, 9, 13, 25, and 35
- San Francisco Police Department (SFPD) headquarters and county jail
- Open space, trails, and parks
- POSF facilities and several piers

Additional community resources and services include regional and local transportation infrastructure (e.g., the Bay Bridge, BART, Muni, and Caltrain); wastewater infrastructure (e.g., pump stations, the Southeast Wastewater Treatment Plant, the North Point Wet Weather Treatment Plant); the Recology Recycle Center; University of California, San Francisco Medical Center at Mission Bay; Oracle Park and Chase Center; and tourist attractions (e.g., the Ferry Building, the Embarcadero promenade, Fisherman's Wharf, the Exploratorium, historic buildings and piers, restaurants, hotels); Mission Bay branch of the San Francisco Public Library; childcare facilities; and recreation centers (EcoCenter at Heron's Head Park).

2.5.1.1.1. Population Characteristics

Racial and ethnic data were collected for 883,305 persons in the city of San Francisco (U.S. Census Bureau 2019). Of these, 353,597 (40.0%) identified themselves as White; 301,051 (34.1%) as Asian; 134,664 (15.3%) as Hispanic or Latino; 43,953 (5.0%) as Black or African American; 1,187 (0.1%) as American Indian and Alaska Native; 2,085 (0.2%) as Native Hawaiian and Other Pacific Islanders; 3,259 (0.4%) as "Some Other Race"; and 43,599 (4.9%) as "Two or More Races."

The study area has a total population of 58,876 resident within 12 census tracts. Residents in the study area identify themselves as White (43.0%), Asian (24.4%), Hispanic or Latino (16.0%), Black or African American (10.6%), Native Hawaiian and Other Pacific Islanders (0.6%), American Indian and Alaskan Native (0.1%), "Some Other Race" (0.1%), and "Two or More Races" (4.6%).

2.5.1.1.2. Housing

There are 401,478 housing units in the city of San Francisco, of which 362,827 (90.4%) are occupied and 38,651 (9.6%) are vacant (U.S. Census Bureau 2019). The average household size within the occupied housing units is 2.4 persons; 136,242 (37.6%) of the housing units are owner occupied, and 226,585 (62.4%) are renter occupied.

Overall, the study area has a slightly lower percentage of occupied units (86.8%) than the city (90.4%). Of the occupied units, the study area has a lower percentage of owner-occupied housing units (29.1%) compared to the city (37.6%) but a greater proportion (70.9%) of renter-occupied housing units (62.4%). In addition, the average household size within the study area (2.1 persons) was slightly smaller than that of the city (2.4 persons).

2.5.1.1.3. Employment and Income

Per capita income in city of San Francisco is \$71,606, and the median household income is \$112,376 (U.S. Census Bureau 2019). As of 2019, 10.0% of the citizens within the city were living below the poverty level, which equates to 87,087 residents.

2.5.1.2. Future Without Project

Flooding events would physically divide the waterfront neighborhoods, inhibiting community function and interaction, cause the displacement of various structures including residences, commercial and industrial businesses, and community and public facilities in each reach. These events would have a substantial adverse effect on economics, with the coastal neighborhoods experiencing loss in employment, school district funding, and county and city property and sales tax revenues.

Population exposure to coastal flooding and RSLC is an important indicator of the extent that health and safety may be impacted after a flood event. The highest flooding impact to residential populations could be around Mission Creek in Reach 3. Islais Creek in Reach 4 is also impacted early and broadly; however, this area is less densely populated with industrial use being the most prevalent in the flood inundation extent.

Table 2-13 presents population impacts as counts of temporarily displaced residents, shelter needs, and homeless population exposure. These are additional social effects which are important to consider:

- Temporarily displaced residents counts include a factor of flood depth in addition to exposure. It is assumed that more than 1 foot of flood depth within a residential structure could require disruptive repairs that would impact the use of the building. The displaced residential population is approximately 30 to 40% of the exposed population counts in the near to medium time horizon (2040 to 2065), rising to nearly 70% of the exposed population by 2090, and 90% of the exposed population by 2140.
- Of the temporarily displaced population, a portion may require access to public shelter. Low-income households, minority populations, homeownership status, and young families and the elderly are more likely to seek emergency short-term shelter according to FEMA (2022). Additionally, homeless populations may also require shelter in a flood event. Over 2,300 people in the SFWCFS may require public shelter by 2090 for a 1% AEP event, including residents and homeless populations alike. Shelter needs range from 6 to 13% of the exposed population throughout the study area.

- Monthly flooding will influence both permanent and temporary displacement expectations. The PDT assumed that in the FWOP scenario, people subject to monthly flooding will leave the floodplain. This may pose additional challenges for at-risk communities. Over time, population exposure to extreme events such as the 1% AEP will lessen as those at high-risk retreat from the waterfront. **Table 2-13** does not reflect this occurrence.

Reach 3 has the greatest exposure, residential displacement, and shelter needs across the waterfront, indicating a greater need for emergency and housing recovery services in Mission Bay in the future.

Table 2-13: Population Impacts by Reach

Time Horizon	Reach 1	Reach 2	Reach 3	Reach 4	Total
<i>Exposed Residential Population (count of people)^a with 1% AEP flooding</i>					
2040	63	832	3,745	305	4,944
2065	786	3,362	10,624	396	15,168
2090	1,283	4,709	15,965	558	22,514
2115	1,864	5,900	20,212	853	28,829
2140	2,604	6,657	23,374	1,435	34,070
<i>Exposed Residential Population (count of people)^a with monthly flooding, subject to permanent relocation</i>					
2040	11	4	45	50	110
2065	20	15	293	135	462
2090	50	633	3,343	292	4,318
2115	1,112	4,120	13,795	450	19,478
2140	1,608	5,610	19,263	713	27,194
<i>Temporarily Displaced Residential Population (count of people)^b with 1% AEP flooding</i>					
2040	0	0	1,837	0	1,837
2065	0	0	4,335	10	4,345
2090	0	3,697	12,570	61	16,327
2115	231	5,327	17,769	66	23,392

Time Horizon	Reach 1	Reach 2	Reach 3	Reach 4	Total
2140	1,232	6,599	22,177	227	30,235
<i>Shelter Needs (count of people)^c with 1% AEP flooding</i>					
2040	0	0	233	0	233
2065	0	0	512	2	514
2090	0	428	1,505	11	1,944
2115	35	682	2,178	12	2,906
2140	199	834	2,787	32	3,852
<i>Homelessness Population in the Study Area exposed to 1% AEP flooding (count of people)^d</i>					
2040	0	7	50	50	105
2065	3	25	125	85	240
2090	5	35	205	120	360
2115	6	40	245	135	425
2140	7	45	275	145	470

^a Limitations on measure. Counts only include residents within the study area and does not capture commuters or homeless populations.

^b Limitations on measure. Counts based on residential building damages. Does not include homeless populations.

^c Limitations on measure. Counts do not include homeless populations requiring shelter.

^d Homeless population source is SFDPH, 2017b. The report uses the 2015 San Francisco Homeless Count.

Exposed, displaced, and shelter needs counts are based on the location and size of residential structures in the SFWCFS, and are based on 2019 ACS data.

2.5.2. Public Health and Safety

2.5.2.1. Existing Conditions

The bayside waterfront is immediately adjacent to the densely populated Financial District and SOMA neighborhoods and is anticipated to serve several critical functions during an emergency. The high number of commuters to the city will require a safe place to congregate and stage medical treatment and evacuation across the bay following an earthquake. Existing ferry terminals and small craft harbors are identified by local disaster response plans as critical facilities for the first 72 hours following a major disaster. Additionally, the deep-draft berths along the port are identified as critical logistic hubs to aid in the CCSF's recovery following a disaster, thus enabling export of debris and import of supplies.

Existing critical disaster response infrastructure along the waterfront includes (north to south):

- Aquatic Park: used as a gathering area for disaster response (storm, seismic, and fire)
- Fisherman's Wharf: police boat dock facility, refueling dock
- Ferry Terminal: staging and regional ferry service
- Pier 41: ferry access – important resource for disaster response/evacuation
- Pier 35: critical for disaster response and evacuation
- Pier 31.5: Alcatraz landing – critical for disaster response and evacuation
- Pier 27: Cruise terminal – critical for disaster response and evacuation
- Pier 9: WETA administrative office – serves as emergency operations center
- Pier 3: critical for disaster response and evacuation
- Pier 22.5: Fireboat station
- Pier 40/South Beach Harbor: critical for disaster response and evacuation
- China Basin: ferry landing – critical for disaster response and evacuation
- Pier 48.5: large event transportation – integral for evacuation
- Pier 50: POSF operations center – critical for disaster response
- Pier 94 and 96: FEMA disaster response area

SFFD and SFPD provide fire protection and emergency services and public safety services, respectively, within the city and the study area. In addition, there are several other public services, including the University of California Mission Bay campus, schools, non-profit organizations, and child centers, within the study area.

SFPD, located on the first floor of the Public Safety Campus, provides public safety services for the study area and CCSF. SFPD is the 11th largest police department in the U.S. and serves a population of approximately 1.5 million, comprising daytime commuters, tourists, and visitors (City and County of San Francisco 2020c). SFPD has 10 districts, each with its own station. Three police districts, Bayview, Southern, and Central, cover the study area. SFPD headquarters, the Southern Police District Station, and SFPD Marine Unit headquarters and berths are located within the study area.

SFFD is responsible for fire protection and emergency medical services for CCSF, including the study area. In addition to SFFD, several privately operated ambulance companies are authorized to provide advanced life support services. SFFD consists of two divisions, divided into 10 battalions and 45 active stations (City and County of San Francisco 2020b). Division 2 serves the northern and western regions of the city and San Francisco County, and Division 3 serves the eastern and southern regions (City

and County of San Francisco 2020b). Fire Stations 4, 8, 9, 13, 25, and 35 are within the study area.

2.5.2.2. Future Without Project

The study area would continue to be at risk of flooding and could become more at risk due to RSLC and changing meteorological conditions, which may impede the public's access to critical safety infrastructures (i.e., hospitals) or the ability of public safety entities (i.e., ambulance, police) to render aid. Currently planned life-safety measures in the event of a major earthquake may not be accessible due to increased flooding. Nuisance flooding would make access to health and safety infrastructure troublesome, while severe flooding from storms may render them inaccessible. Increased flooding and rising groundwater are likely to release contaminants from HTRW sites that pose a risk to human health.

The POSF has some of the city's largest open properties that can serve as disaster response sites, including staging areas in an emergency. Staging areas are typically parking lots or piers, designated for short-term stockpiling of equipment, supplies, or debris. These areas should ideally be relatively flat, paved, and accessible by trucks and forklifts. Several of these disaster response sites are unique and do not have suitable replacement alternatives, and damage to these assets would be particularly disruptive. Due to this lack of redundancy, the Emergency Operations Center, SFPD-POSF Joint Operations Center, and SFFD Station and Fireboat Pier are considered especially critical disaster response assets. Due to San Francisco's dense urban environment, options for additional or new disaster response sites in the city are limited.

While disaster response sites are exposed to severe coastal events such as the 1% AEP, event durations are short, and water typically recedes within a few hours. Prolonged monthly flooding at these sites will likely present challenges for the city in the future. If another incident type (such as an earthquake or a terrorist attack) were to occur during a monthly tide, access to sites for supplies and equipment will be limited. Disaster response sites in Reach 2, Reach 3, and Reach 4 will be exposed to monthly flooding first in 2090. By 2140, 80% of the designated disaster response sites will be exposed to monthly flooding under the USACE High RSLC curve. Relocation of sites may be necessary and increase over time with frequent monthly exposure (**Table 2-14**).

Table 2-14: Exposed Disaster Response Sites by Reach

Time Horizon	Reach 1	Reach 2	Reach 3	Reach 4	Total
<i>Disaster Response Sites Exposed to 1% AEP flooding</i>					
2040	0	2	1	5	8
2065	6	8	8	8	30
2090	11	15	16	9	51
2115	11	15	17	9	52
2140	11	16	17	9	53
<i>Disaster Response Sites Exposed to monthly flooding, indicating access issues and the potential need for relocation</i>					
2040	0	0	0	0	0
2065	0	0	0	1	1
2090	0	1	1	5	7
2115	9	13	15	8	45
2140	11	15	17	9	52

2.5.3. At-Risk Communities

2.5.3.1. Existing Conditions

To evaluate potential issues with at-risk communities within the study area, a demographic profile of the relevant census tracts was developed to identify the low-income and minority populations present. For the purposes of this analysis, a census tract included a population to be evaluated for at-risk issues if:

- The total minority population of the census tract was more than 50% of the total population or substantially higher (i.e., more than 15%) than that of the city or county where it was located or
- The proportion of the census tract population that was 100% below the poverty level was substantially higher (i.e., more than 15%) than of the city or county where it was located.

Because the city has a minority population that totals more than 50%, the “substantially higher” criterion (i.e., more than 15%) was used in this analysis.

Based on census tract information for the study area, the total percentage of individuals living below the poverty threshold is higher in the study area (13.6%) than in the city as a whole (10.0%). However, using the “substantially higher than the city” criterion for population below the poverty level, only census tract 231.03 within the Bayview Neighborhood, which has approximately 32.7% of people below the poverty level, meets the low-income criteria for an at-risk community.

Minorities represent approximately 60.0% of the total population of the city and approximately 56.4% of that of the study area. The 2014–2018 American Community Survey 5-year estimates indicate that the proportion of the populations within the study area composed of minority populations ranges from 21.8% (census tract 102) to 96.2% (census tract 231.03). Using the “substantially higher” criterion, census tracts 231.03 and 612, located within the Bayview Neighborhood, meet the minority criteria for an at-risk community in the study, because the percentage of minority populations is more than 15% greater than the proportion of minority populations in the city.

2.5.3.2. Future Without Project

Overall, while the FWOP would generate adverse effects, the distribution of these effects (displacement and flooding) would be dispersed throughout the study area. Therefore, the adverse environmental effects under FWOP would not be disproportionately felt by a minority or low-income population.

Section 3.0 Plan Formulation and Evaluation*

Plan formulation is an iterative process whereby project measures (specific project features) are conceived, developed, and evaluated to satisfy specific objectives, and then combinations of measures are evaluated to develop comprehensive alternative plans. This section details the identification of problems and opportunities in the study area, planning objectives and constraints, and the development of management measures and alternative plans to provide solutions to the identified problems and opportunities.

3.1. Planning Framework

The USACE Civil Works planning process follows a standard approach to formulate potential water resource solutions to ensure Federal projects comply with applicable laws and guidance. The 1983 Economic and Environmental Principles and Guidelines for Water and Related Land Implementation Studies (P&G) established by the U.S. Water Resources Council on March 10, 1983, were developed to guide the formulation and evaluation studies of the major Federal water resources development agencies. *ER 1105-2-100 Planning Guidance Notebook*, *ER 1105-2-103 Policy for Conducting Civil Works Planning Studies*, and the *Planning Manual Part II: Risk-Informed Planning* lay out an iterative planning process for all USACE Civil Works studies to develop and evaluate alternative plans.

The P&G established four accounts to facilitate the evaluation and display of the economic benefits and effects of alternative plans. These four accounts are: National Economic Development (NED), Regional Economic Development (RED), Other Social Effects (OSE), and Environmental Quality (EQ). Benefits and effects of all four accounts (WRC 1983) were considered during the plan formulation process. The four benefits categories are summarized below:

- NED account: Includes consideration of a measure's potential to meet the planning objective to reduce storm damage, as well as decrease costs of emergency services, lower flood insurance premiums, and evaluate project costs. Effects of RSLC and a measure's adaptability to such change are considered under the NED account.
- RED account: Includes consideration of the potential regional economic impacts of flooding along the San Francisco waterfront, the Bay Area, and the larger California economy. The Institute for Water Resources (IWR) RED Procedures Handbook (2011-RPT-01) defines RED impacts as regional losses in employment and/or income under the FWOP condition. Based on guidance from this handbook, the RED analysis evaluates the regional economic consequences of coastal flooding and RSLC using FEMA benefit-cost analysis methodologies.

- OSE account: Includes considerations for the preservation of life, health, and public safety; community cohesion and growth; tax and property values; and the displacement of businesses and public facilities. For evaluation purposes, the OSE account is inclusive of the planning objectives to maintain recreation and safe evacuation routes, and the planning constraint to avoid conflict with legal requirements.
- EQ account: Considers ecosystem restoration, water circulation, noise level changes, public facilities and services, aesthetic values, natural resources, air and water quality, cultural and historic preservation, and other factors covered by NEPA.

The P&G also require that alternative plans are formulated and evaluated in consideration of four criteria: completeness, effectiveness, efficiency, and acceptability.

- Completeness is the extent to which a given alternative plan provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects.
- Effectiveness is the extent to which an alternative plan solves the specific problems and achieves the specified opportunities.
- Efficiency is the extent to which an alternative plan is the most cost-effective means of solving the water resources problems and realizing opportunities consistent with protecting the nation's environment.
- Acceptability is the workability of the alternative plan with respect to acceptance by State and local entities and the public, and compatibility with existing laws, regulations, and public policies.

ER 1105-2-103 Policy for Conducting Civil Works Planning Studies requires that the array of alternatives include:

- The “No Action” alternative
- An NED or National Ecosystem Restoration plan
- A plan that reasonably maximizes total net benefits across all benefit categories including monetized and non-monetized benefits (Total Net Benefits Plan [TNBP])
- A plan that reasonably maximizes net benefits including monetized and non-monetized benefits consistent with the study purpose only
- The least environmentally damaging practicable alternative (LEDPA), as required by the CWA under Section 404 (40 CFR Part 230)
- For flood risk management studies, a nonstructural plan that includes modified floodplain management practices, elevation, relocation, buyout/acquisition, dry flood proofing, and wet flood proofing

- A locally preferred plan (LPP), if requested by the NFS and approved by the Assistant Secretary of the Army (Civil Works) (ASA(CW)), if the LPP is not one of the other plans

Specific guidance for this study was issued ASA(CW) and USACE on December 15, 2021. This included the following guidance for the formulation process:

- Update FWOP Conditions:
 - Update FWOP conditions for the study area to account for RSLC, and seismic and frequent (storm, tidal, and fluvial) flooding multi-hazard risks.
 - Calibrate and perform independent verification of coastal hydrologic and hydraulic modeling, which will include tidal and storm flooding, with assessments of timing, location, and severity in the study area before detailed economic analysis.
 - Incorporate RSLC scenarios in accordance with USACE policies (ER1100-2-8162, EP1100-2-1).
 - Characterize seismic risks to the existing seawall and other flood risk structures.
 - Assess impacts to the regional economy, at-risk populations, environmental quality, and critical public infrastructure, in addition to NED impacts.
 - Identify reasonable and prudent actions that would be expected to strategically mitigate extreme storm impacts in advance of the base year.
 - Use a 100-year period of economic and engineering analysis, due to actions triggered by sea level and flood risk and long-life infrastructure investment.
- Formulation:
 - Develop multi-hazard formulation strategies that reflect timing, location, and severity differences in risk.
 - Develop at least one stand-alone nonstructural alternative.
 - Incorporate Engineering with Nature (EWN), when practicable.
 - Formulate with all three USACE RSLC projections, plus additional State of California projections if an LPP is requested.
 - Formulate measures and alternatives that can be implemented incrementally for varying topography and locations to address varying degrees of risk. Individually and in combination, they should describe flexibility in scale and timing of actions (initial and future adaptations) for the desired risk management performance, as required under the *Planning Guidance Notebook* (USACE 2000).

- Evaluation:
 - Evaluate and document benefits in accordance with the *Comprehensive Documentation of Benefits in Decision Documents* memorandum, dated January 5, 2021, and subsequently codified in ER 1105-2-103.
 - Conduct the benefit analysis using the three USACE RSLC curves, with a benefit to cost analysis based on initial and future adaptations.
 - Use the California Regional RSLC curves for the LPP.
 - Evaluate differences in timing of actions and scaling of project features to reflect the advantages and disadvantages of adaptability and flexibility of the recommended alternative in regard to realized RSLC.

On December 19, 2024, USACE published the final rule to establish Agency Specific Procedures (ASPs) for USACE to implement the Principles, Requirements, and Guidelines (PR&G), effective January 17, 2025. The Principles and Requirements were released in March 2013, and the Interagency Guidelines were finalized in 2014. The PR&G replace the 1983 P&G. Section 2031 of WRDA 2007 specifies that Federal water resources investments must reflect national priorities, encourage economic development, and protect the environment. The ASPs specify that USACE will accomplish this objective by:

- Seeking to maximize sustainable economic development
- Seeking to avoid the unwise use of floodplains and flood-prone areas and minimizing adverse impacts and vulnerabilities in any case when a floodplain or flood-prone area must be used
- Protecting and restoring the functions of natural systems and mitigating any unavoidable damage to natural systems

The ASPs also require that the array of alternatives include a nonstructural plan, a nature-based solution, an environmentally preferred alternative, and an alternative that seeks to maximize net public benefits. A Recommended Plan that does not maximize net public benefits requires an exception from ASA(CW). ASA(CW) has not issued implementation guidance for the ASPs.

3.2. Planning Horizon and Period of Analysis

The P&G provides instructions and rules for Federal water resources planning timeframes. One P&G requirement is to evaluate the effects of alternative plans based on a comparison between the most likely future conditions with and without those plans in place. To make this type of comparison, descriptions (often called forecasts) must be developed for two different future conditions: the FWOP condition and the future with project (FWP) condition. The FWOP condition describes what is assumed to be in place if none of the study's alternative plans are implemented and is the same as the "No Action" alternative that is required to be considered by the Federal regulations implementing NEPA. The FWP condition describes what is expected to occur as a

result of implementing each alternative plan. The differences between the FWOP and FWP conditions are the effects of an alternative. Measuring these differences across alternative plans supports comparison and, ultimately, plan selection and refinement.

The planning horizon encompasses the study period, the implementation period, the economic POA, and the effective life of the project. The timeframe used when forecasting FWOP and FWP conditions is the POA, or the period over which plan effects are measured (**Figure 3-1**).

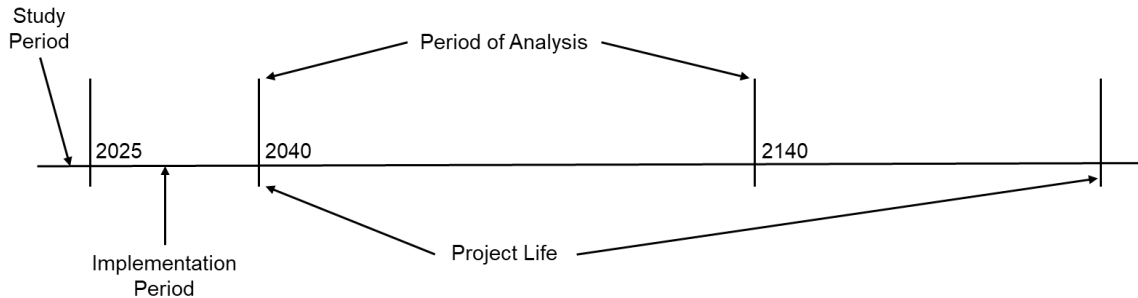


Figure 3-1: Planning Horizon

The POA for water resources projects typically extends 50 years following construction. Although project structures will often function for longer than 50 years, forecasting economic and physical conditions and impacts beyond 50 years becomes uncertain because conditions may change considerably over that length of time. As directed by December 15, 2021, USACE guidance for this study, the POA for this study extends 100 years from 2040 until 2140 due to actions triggered by coastal and combined flood risk and RSLC and long-life infrastructure investment. For this analysis, and depending on the alternative, project implementation is assumed to begin with preconstruction engineering and design (PED) beginning around 2027. The base year is assumed to be 2040, the year the alternative is in place and functioning and benefits are produced. Project performance is quantified by estimating future damages to 2140 for a POA of 100 years. Most alternatives were formulated to assume adaptation to the plan alignment or features at around the midpoint of the POA (2090) and have a subsequent construction phase.

Alternative plans are proposed with First Actions completed around 2040 and Subsequent Actions completed around 2090 as a planning construct to support fair comparison of plan effects. It should be noted that adaptive actions may be taken considerably sooner or later than 2090 depending on the risk conditions.

3.3. Plan Formulation Strategy

Coastal and combined flood risk will increase at an uncertain rate over the POA. Although flood events may occur in the study area, the scale of flood events is primarily influenced by the water surface elevations (WSEs) that result from a coastal flood event in combination with RSLC. The plan formulation strategy sought to identify different

approaches to reduce flood risk now and into the future with an array of alternatives that would inform whether early, phased, or later interventions would be most cost-effective and avoid or minimize study area impacts.

Formulation of alternatives to manage coastal and combined flood risk included:

- An overall approach to defend, accommodate, or retreat from coastal and combined flood risk consisting of structural and nonstructural measures and NNBFs along different LODs including:
 - Alignment along existing shoreline
 - Alignment bayward of existing shoreline
 - Alignment inland of existing shoreline
- Varied scales of features to reflect uncertain timing of RSLC
- Phased implementation of features within most alternatives

Plan formulation in response to the study authority was conducted in two broad phases. An initial planning iteration considered distinctly different conceptual approaches to manage the coastal and combined flood risk in the region. The PDT then conducted an initial screening of the conceptual approaches. The second and most significant phase of plan formulation assessed cost-effective approaches. The PDT developed a focused array of alternatives and evaluated NED benefits and costs for the three RSLC conditions (USACE Low, Intermediate, and High curves), in accordance with the specific guidance for the study, to identify the NED plan for each condition. The PDT then developed a final array of alternatives as a combination of varied reach-level components of the focused array. A comprehensive benefits analysis of the final array was then conducted across all four P&G accounts for each of the three RSLC conditions to identify the Tentatively Selected Plan (TSP) for the Draft IFR/EIS. Following public and agency review of the draft report, the TSP was refined and developed further into the Recommended Plan.

Figure 3-2 illustrates the plan formulation strategy. A detailed summary of the formulation and evaluation process is provided in subsequent subsections.

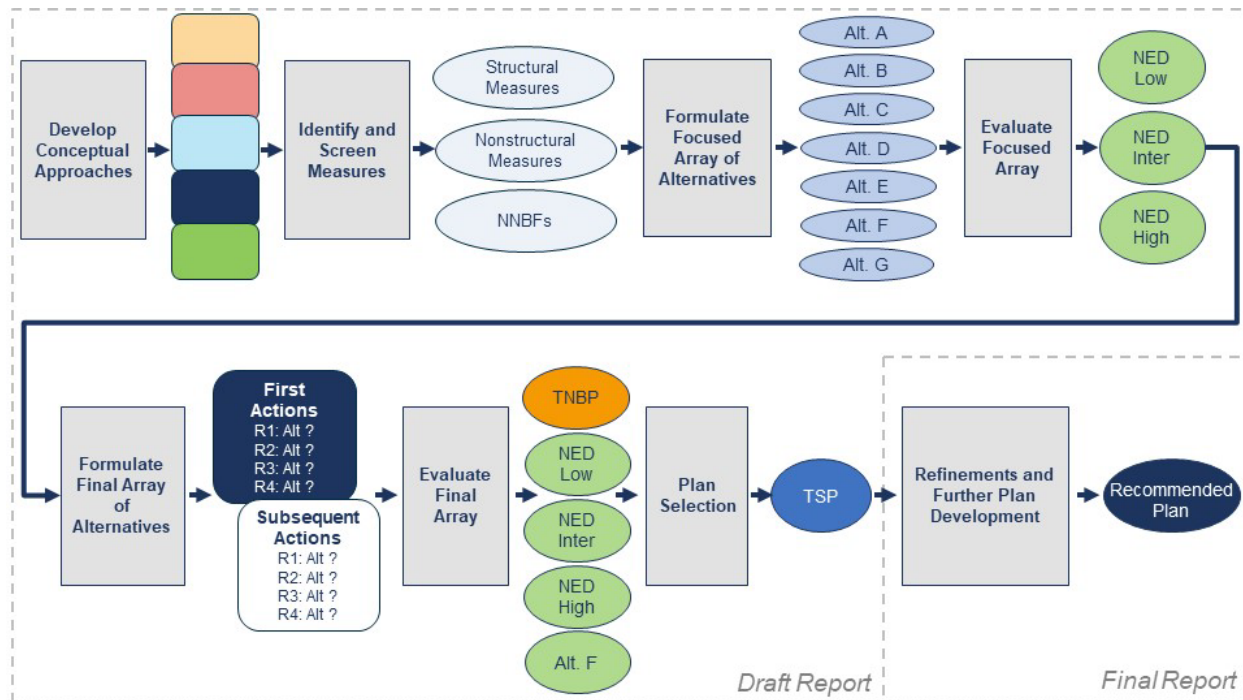


Figure 3-2: Plan Formulation Strategy

3.4. Initial Planning Iteration

As an initial planning iteration, the PDT developed 11 conceptual structural approaches on a horizontal alignment, referred to as the LOD, using a range of appropriate measures. These initial conceptual approaches were evaluated and screened based on completeness, effectiveness, efficiency, and acceptability in consultation with representatives from CCSF and regional agencies and resource and regulatory agencies. The conceptual approaches included a deployable water management structure at the Golden Gate Bridge, an offshore wave attenuator, several scales of offshore barriers, perimeter plans along the Bay coastline, and two forms of retreat.

These conceptual approaches were presented at the Alternatives Milestone Meeting on December 3, 2018, and the Port Commission on February 12, 2019.

In consultation with representatives from CCSF and regional agencies, and resource and regulatory agencies, the PDT began evaluating these conceptual approaches based on the following themes:

- Seismic safety and disaster response
- Historic and cultural preservation
- Transportation-mobility
- Ecological assets and services
- Community cohesiveness
- Nonstructural

Preliminary evaluation of these conceptual approaches confirmed that the perimeter plan is the most cost-effective approach to defend the study area against coastal and combined flood risk over the 100-year POA, and the other conceptual approaches were screened from further development or consideration. Consequently, only perimeter alternatives were considered in subsequent plan formulation, in addition to a nonstructural approach. Details about the initial planning iteration can be found in *Appendix A: Plan Formulation*.

3.5. Formulation Elements

The following four formulation elements were applied to develop an array of alternatives for this study, which are consistent with the formulation guidance to deliver a policy-compliant report and recommendations:

- Overall approach to reduce flood risk consisting of structural and nonstructural measures and NNBFs (in line with the EWN philosophy)
- LODs along the existing shoreline, more bayward, and more inland alignments
- Varied scales of features to reflect uncertain timing of RSLC
- Adaptation as Subsequent Actions (i.e., phased approach) for implementation of features within most alternatives

3.5.1. Approaches to Reduce Risk

Instead of formulating and evaluating a plan under one RSLC rate and assessing its performance under all rates, formulation for this study was conducted using three RSLC rates and adapting the scale or timing of the features to manage risk over 100 years.

The timing of RSLC is uncertain, so the focused array was formulated to reveal lessons about cost effectively managing flood risk with uncertain timing, whether to retreat or defend, or to build big initially or to build smaller and adapt later. Four broad, high-level approaches – Defend, Accommodate, Retreat, and Hybrid – were developed as a basis for formulating plans to manage coastal and combined flood risk. NNBFs can be part of all of these approaches, which are defined as follows:

- **Defend** means measures will be used to block Bay waters, either at the current shoreline alignment, bayward of the current alignment, or slightly landward of the current shoreline.
- **Accommodate** can include nonstructural measures to reduce risk while living with exposure during infrequent, temporary flood events for as long as practicable.
- **Retreat** scenarios are designed to “align with watersheds” by advancing the LOD and shoreline landward, while working with natural inland flooding patterns through a series of nonstructural and structural measures. Floodproofing of some buildings and infrastructure would occur in areas of lower risk, while other assets would be moved away from the current Bay shoreline in highest risk areas.

- **Hybrid** is a combination of these approaches that could be used throughout the study area based on flood risk and assets.

The Defend, Accommodate, and Retreat approaches are illustrated in **Figure 3-3**. For reference, **Figure 3-4**, **Figure 3-5**, and **Figure 3-6** show the 1% AEP floodplains under the three RSLC curves.

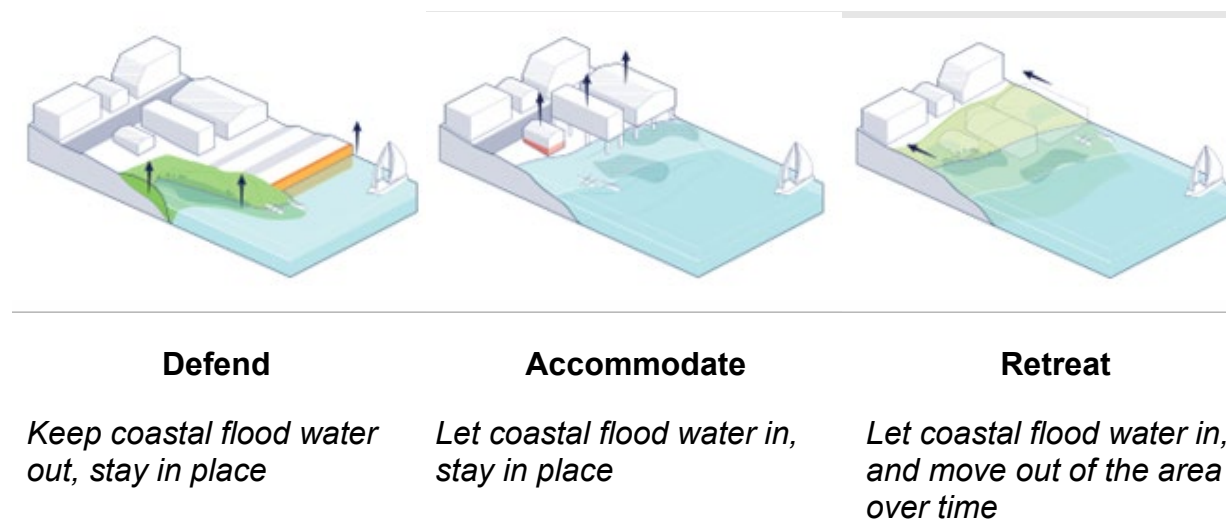


Figure 3-3: Approaches to Reduce Risk



Figure 3-4: Low RSLC 1% AEP Floodplains Over Time

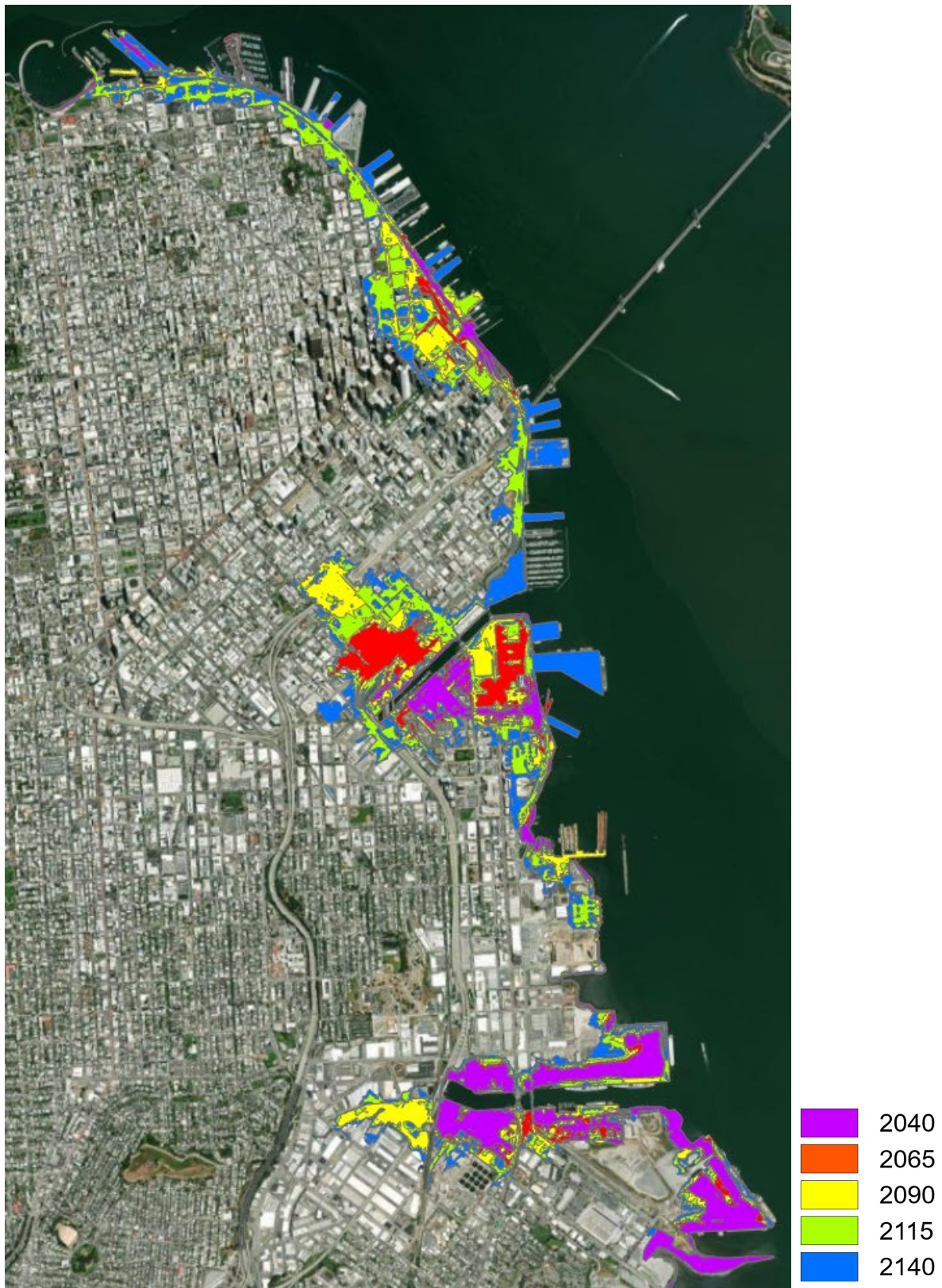


Figure 3-5: Intermediate RSLC 1% AEP Floodplains Over Time

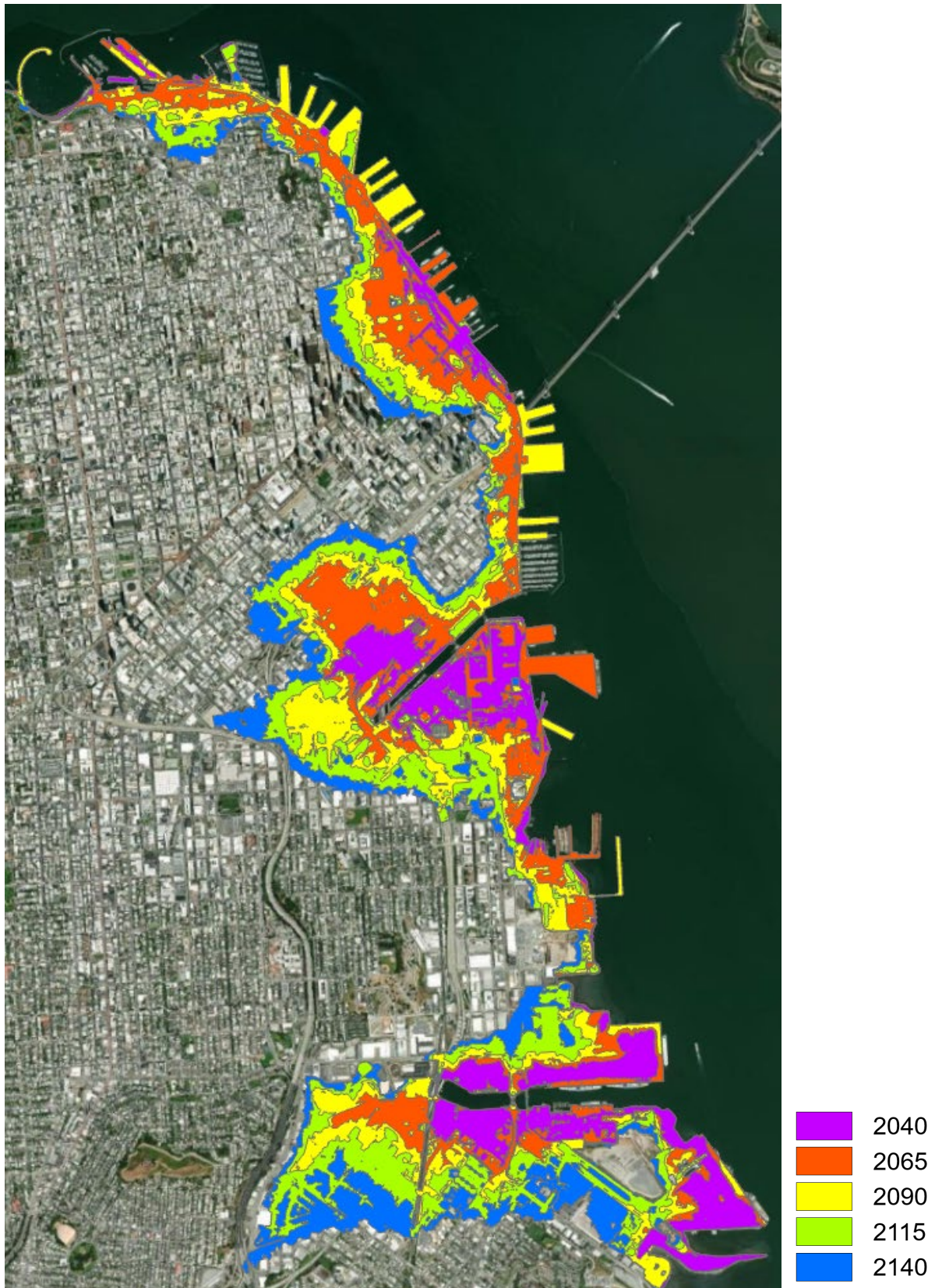


Figure 3-6: High RSLC 1% AEP Floodplains Over Time

3.5.2. Lines of Defense and Zones

For each structural alternative, a horizontal alignment, referred to as the LOD, was developed to provide protection against coastal flooding and RSLC. The LOD varies by strategy and by location throughout the waterfront (e.g., the LOD can be further inland in one location, compared to right along the existing shoreline or shifted slightly toward the Bay in other locations). The selection of the LOD for each strategy was informed by a preliminary examination of local space constraints (e.g., is there enough space for a gradual or steep elevation transition) and based on the public realm and urban design assumptions adopted for this effort.

3.5.3. Adaptation Space Considerations for the LOD

In developing the structural alternatives, the PDT considered the amount of horizontal space required for the project footprint (locally referred to as “adaptation space”) within the context of the planning objectives and constraints, including reducing economic costs and risks, and avoiding disruptions to maritime uses, permitted public access, and historic resources. Based on these planning objectives and constraints, the PDT formulated multiple structural alternatives that include raising ground (e.g., with a seawall or levee) rather than relying on tall, vertical walls, except in targeted locations. The PDT considered vertical wall heights of more than 2 feet along the waterfront to be unacceptable due to local requirements and policies regarding access to maritime uses, public waterfront access, and historic integrity. Where an alternative includes steep steps, or terraces, or gradual slopes, the vertical differential was limited to 3.5 feet. Project footprints are intended to include sufficient space for gradual grade changes and – for structural alternatives with two phases (Alternatives D-G) – adaptability to future elevations with minimal additional utility relocations or real estate acquisitions.

These guidelines help determine how much adaptation space is needed and preserve a buffer to avoid potential future cost and schedule impacts. The footprint of a structural measure is not determined solely by the width of associated ground improvements for structure stabilization. Value engineering to refine the ground improvements for cost savings may not always shrink the overall project footprint if the adaptation space needed to maintain acceptability in terms of access to maritime uses and applicable laws, regulations, and public policies is greater than the footprint of ground improvements.

3.5.4. Varied Scaling of Features

Within the broad conceptual approaches, the PDT formulated alternatives that vary the scale and timing of the structural and nonstructural strategies to support comparison of cost and performance under the uncertain timing of the RSLC component of the inundation risk. Thus, the array of alternatives includes variations of structural and nonstructural features that are scaled to address varying RSLC conditions.

3.5.5. Adaptation as Subsequent Actions

A final aspect of the plan formulation strategy was to identify phased implementation of the features to balance two important criteria for plan selection: cost-effectiveness and adaptability to uncertainty across the POA. Adaptations were described in sufficient detail to support estimation of benefits and costs of the alternatives. Scales of adaptation correspond to the target level of performance of each alternative. At this initial stage of plan development, implementation was assumed to occur in a two-step process with the First Actions completed around 2040 and Subsequent Actions occurring around 2090 based on risk. However, a Monitoring and Adaptation Plan (MAP) will ultimately be used to model what the forecasted implementation strategy might look like given the associated risks, and to describe the implementation process for Subsequent Actions. The MAP will ultimately address how USACE and POSF will manage the risks of RSLC over time through implementation of subsequent Federal actions, in congruence with CCSF plans, and identify triggers for risk assessment, management, and implementation. The MAP builds the framework to:

- Identify thresholds of RSLC that would trigger the need for an adaptation, such as additional height to manage coastal and combined flood risk or changed alignment.
- Evaluate the plan performance required to address the RSLC risk based on those thresholds, considering other factors such as asset life, other planned projects, and disruption from the construction period.
- Develop the governance and executive structure to collaboratively monitor and interpret risk within the study area.
- Describe coordination and involvement of resource agencies, USACE, POSF, CCSF, and the State to manage the risks over time.
- Recommend approaches for Congressional authorization and future design strategies that will allow USACE and POSF to more efficiently implement subsequent adaptation actions given the uncertainty regarding future rates of RSLC.
- Clarify appropriate scale and alignment of features to be constructed in time to reduce risk of flooding in the study area.

3.6. Treatment of Seismic Costs

Section 152 of WRDA 2020, as amended by Section 8380 of WRDA 2022, provides for the treatment of certain benefits and costs for flood risk management projects in regions of moderate or high seismic hazard. The study area is in an area of high seismic hazard; thus, alternatives were formulated with full consideration of applicable USACE engineering design standards needed to address seismic hazards in the study area. In accordance with the provisions of Section 152, as amended, the alternatives were

estimated both with and without the scope of work attributed to seismic design requirements due to the seismic hazard present within the study area. For the purpose of evaluating NED benefits and costs and calculating benefit-cost ratios (BCRs), the cost basis was assumed to be the scope of work that is necessary to produce the same coastal flood risk management benefits in a region that is not subject to seismic hazards. However, the total project cost for the Recommended Plan includes the scope of work and cost to complete the project in this high seismic region.

3.7. Identification and Screening of Management Measures

Management measures are features or actions that contribute to the planning objectives. Measures were formulated based on problems in each of the four reaches. They were derived from a variety of sources, including the NEPA scoping process and coordination with stakeholders. Coastal and combined flood risk management measures consist of three basic types: structural measures, nonstructural measures, and NNBFs.

- **Structural measures** reduce flood risk by modifying the characteristics of the flood. They are physical modifications designed to reduce the frequency of damaging levels of flood inundation. In the context of coastal flooding, structural measures are often employed to defend against overtopping (flood barriers); reduce wave hazards (dissipation); reduce erosion (armoring); and facilitate the flow, storage, or removal of water that has overtopped the shoreline (pumping and drainage). They may be used alone or in combination with other measures.
- **Nonstructural measures** can be grouped into two categories: physical and nonphysical measures. Physical nonstructural measures include actions that require modifications to a property or structure. They include structure elevation, dry and wet floodproofing, basement removal, relocation, and acquisition. Nonphysical nonstructural measures do not modify individual structures but rather focus on behaviors and plans that reduce flood risk. They include evacuation plans, flood warning systems, flood insurance, floodplain mapping, emergency preparedness plans, risk communication, and land use regulations and zoning. Nonstructural measures are permanent or contingent measures applied to a structure and/or its contents that prevent or provide resistance to damage from flooding. Nonstructural measures differ from structural measures in that they focus on reducing the consequences of flooding instead of focusing on reducing the flow of water into portions of the study area.
- **NNBFs** are the intentional alignment of natural and engineering processes to address flooding hazards while also delivering economic, environmental, and social benefits (*Appendix I: Engineering with Nature*). NNBFs refer to the landscape features used to reduce flood risk while restoring natural processes and providing ecosystem benefits. NNBFs may also produce other economic, environmental, and social benefits known as NNBF co-benefits. These landscape

features may be natural (produced purely by natural processes) or nature-based (produced by a combination of natural processes and human engineering) and include such features as beaches, dunes, wetlands, reefs, and islands.

Landscape features can be used alone, in combination with each other, and in combination with conventional engineering measures such as levees, floodwalls, and other structures (USACE 2021b). Within this document, the term “EWN” refers to the philosophy, whereas the term “NNBF” refers to a natural and nature-based feature, measure, or action. NNBFs can be combined across a terrestrial to aquatic transect to provide multiple integrated benefits in one location. The performance of these other benefits enhance coastal and combined flood risk management performance.

The measures considered for this study can reduce risk alone or in combination. They were screened for applicability, function and space constraints, and anticipated cost-effectiveness. Smaller scales of NNBFs are considered for their function to reduce risk in specific applications and to replicate natural coastal processes that are displaced by hardened shorelines. The PDT consulted with the USACE National Nonstructural Committee and incorporated lessons learned from current nonstructural policy concerns and recent coastal flood risk management studies conducted by three USACE districts. More details on the screening of measures can be found in *Appendix A: Plan Formulation* and are summarized in **Table 3-1**.

Table 3-1: Screening of Measures

Measure	Carried Forward ^a
Structural	
Floodwalls	Yes
Levees	Yes
Ringwalls	Yes
Seawalls and Bulkhead Walls	Yes
Breakwaters	Tentatively Yes
Tide Gates	Yes
Deployable Closure Structures	Yes
Pump Stations	Yes
Inland Drainage Infrastructure	Yes
Revetments	Yes
Bridge Raising/Replacement	Yes
Wharf Raising/Replacement	Yes

Measure	Carried Forward ^a
<i>Nonstructural</i>	
Building Elevation (Raising)	Tentatively Yes
Relocation	Yes
Acquisition (Buyout)	Yes
Dry Floodproofing	Yes
Wet Floodproofing	Yes
Flood Warning Systems	Tentatively Yes
Flood Insurance	Tentatively Yes
Floodplain Mapping	Tentatively Yes
Flood Emergency Preparedness Plan	Tentatively Yes
Land Use Regulations and Zoning	Tentatively Yes
Evacuation Plans	Tentatively Yes
Risk Communication	Tentatively Yes
<i>Natural and Nature-Based Features</i>	
Enhancement of Existing Wetlands	Yes
Wetland Creation	Yes
Ecotone Levee	Yes
Coarse Beach	Yes
Living Seawall and Vertical Enhancements	Yes
Naturalized or Embankment Shoreline	Yes
Ecological Armoring	Yes
Creek Enhancements	Yes
Green Stormwater Infrastructure (GSI)	Yes
Mudflat Augmentation	Tentatively Yes
Pier and Piling Habitat Improvement	Tentatively Yes
Subtidal Habitat Improvements	Tentatively Yes
Living Breakwater (new or enhanced)	Tentatively Yes
Afforestation and Urban Corridors	Tentatively Yes
Submerged Breakwater	No
Sandy Beaches (establishment and nourishment)	No
Polder Creation	No

Measure	Carried Forward ^a
Islands	No
Creek Daylighting	No
Watershed and Creek to Baylands Reconnection	No
Wharf Enhancements (Light Penetration)	No

^aYes (green) means retained for further evaluation.

Tentatively yes (yellow) means tentatively retained for further evaluation in future stages of planning and design but not currently included in the alternatives.

No (red) means screened out.

3.8. Focused Array of Alternative Plans

The screened and retained measures were used to develop a focused array of alternative plans consistent with the broad conceptual approaches of Defend, Accommodate, Retreat, and Hybrid; identification of a phased adaptation approach; and incorporation of NNBFs, as appropriate or possible.

The study area is an urban waterfront that includes housing, POSF working lands, municipal and transit assets, entertainment arenas, medical facilities, commercial centers, cultural districts, historical assets, and open spaces. The development of the focused array was informed by POSF’s engagement process with CCSF agencies and the communities in the study area. Accordingly, alternatives were formulated with consideration of the following drivers:

- Maintaining and enhancing connections from city neighborhoods to diverse maritime activities, facilities, and infrastructure
- Providing contiguous and equitable access along the waterfront and to the water including the San Francisco Bay Trail, San Francisco Bay Water Trail, and Blue Greenway, bike paths, harbor walks, and pedestrian walkways
- Maintaining the city’s physical and visual relationship to the Bay, historic structures, and maritime facilities; minimizing the use of new, tall, vertical walls at the water’s edge; and using available landside elevation for gradual adaptation where appropriate
- Demonstrating a quality public realm while adapting the shoreline to sea level change. Some elements of a desirable public realm include generous and continuous pedestrian spaces that are accessible for all ages and abilities, active edges, regular access to open space, views of the water and waterfront activities, and clear wayfinding between different zones
- Maintaining the Embarcadero as a “complete street” with a separate right-of-way for each mode, including a dedicated rail transit corridor, vehicular travel, bike facilities, sidewalks and promenades, and curb uses

- Considering opportunities for multi-benefit solutions including greening, stormwater planting and ecological enhancements wherever possible
- Assessing the viability of maintaining and adapting historic resources while maintaining relationships to their context

The alternatives were formulated to address uncertain timing of RSLC over the POA. **Table 3-2** displays the estimated water surface elevation of the 1% AEP storm in 2011, 2040, 2090, and 2140. The results show that by 2140, water levels will increase by 0.84, 2.75, and 8.82 feet under the Low, Intermediate, and High USACE RSLC projections, respectively. The table also shows the incremental increases by the year 2090. The PDT used these RSLC calculations to guide the development of project elevations to use in alternative formulation. **Table 3-3** shows how different base years influence the RSLC value due to the statistical variation in water levels over time.

Table 3-2: Change in 1% AEP Water Surface Elevation over Time

Sea Level Change Scenario ^a	1% AEP ^b (feet NAVD88)				RSLC (feet)	
	2011	2040	2090	2140	2011-2090	2011-2140
USACE Low	9.67	9.86	10.18	10.51	0.51	0.84
USACE Intermediate	9.67	10.03	11.00	12.42	1.33	2.75
USACE High	9.67	10.58	13.61	18.49	3.94	8.82

^a9414290 Presidio / San Francisco Tide Gauge

^bPier 22 ½, point 868 from the FEMA study (AECOM 2016)

Values reflected in this table include the 1% AEP near Pier 22 ½ and RSLC baselined to 2011 for alignment with the November 15, 2021, revised version of *San Francisco Waterfront Storm Damage Reduction Study (SFWS) Incorporation of Relative Sea Level Change (RSLC) into the Formulation and Evaluation Process White Paper*, which informed early plan formulation discussions (values updated based on Sea Level Analysis Tool). Further information on how the study eventually established crest elevations for specific alternatives is available in *Appendix B: Engineering, Section 3.3 Setting Crest Elevation*. RSLC values throughout this report are baselined to 2000 unless otherwise noted.

Table 3-3: RSLC Value Comparisons

Base year	RSLC by 2040 (feet)			RSLC by 2090 (feet)			RSLC by 2140 (feet)		
	1992	2000	2011	1992	2000	2011	1992	2000	2011
USACE Low	0.3	0.3	0.2	0.6	0.6	0.5	1.0	0.9	0.8
USACE Int	0.5	0.5	0.4	1.5	1.4	1.3	2.9	2.9	2.8
USACE High	1.2	1.1	0.9	4.2	4.1	3.9	9.1	9.0	8.8
CA Likely	1.0	0.8	0.7	3.0	2.9	2.8	5.5	5.3	5.2
CA 1:200	1.5	1.3	1.3	5.8	5.7	5.6	11.9	11.8	11.7

This table displays USACE and California OPC RSLC values across baseline years 1992, 2000, and 2011. Inputs for analysis were developed in accordance with USACE requirements, detailed in the *Annex B.1.1. Coastal Extreme Water Levels and High Tide Flooding*. State of California projections are provided for contextual reference and did not inform plan formulation.

The PDT identified representative scales of RSLC as building blocks of 1.5 feet, 3.5 feet, and 7 feet of RSLC (**Table 3-4**). These increments were selected because they allowed an alternative to be effective under at least one RSLC scenario while also facilitating a transition to the next scenario. For example, the first increment of 1.5 feet is sufficient to cover a low rate of RSLC for 100 years, while also covering an intermediate rate for 50 years. Similarly, 3.5 feet covers 100 years of Intermediate RSLC, and almost covers 50 years of High RSLC. The PDT stopped at 7 feet because that degree of RSLC creates significant public safety concerns. Retreat is believed to be the safest option in that scenario, but that decision does not need to be made at this time. Stopping at 7 feet allows the evaluation results to show the severe consequences of storms at those levels, highlighting the importance of that future decision. *Appendix A: Plan Formulation, Section 11: Focused Array of Alternative Plans*, provides additional clarification of how this building block approach aligns with *ER 1100-2-8162 Incorporating Sea Level Change in Civil Works Programs* and *EP 1100-2-1 Procedures to Evaluate Sea Level Changes: Impacts, Responses, and Adaptation*.

The formulation strategy also included a simple two-step adaptation framework with First Actions and Subsequent Actions. For purposes of analysis, Subsequent Actions were assumed to be implemented around 2090 when necessary to address increasing risk. Actual implementation of Subsequent Actions would be guided by the MAP (*Appendix G: Monitoring and Adaptation Plan*). The focused array includes seven alternatives (**Table 3-5**), including the No Action Alternative.

Table 3-4: RSLC Building Blocks for Plan Formulation

Building Block		Expected Time Horizon to Maintain Performance Target, per USACE RSLC Scenario ^{a,b}		
Performance Target Considerations ^a	Crest Elevation ^c	Low	Intermediate	High
1.5 feet RSLC + 1% AEP coastal	13.5 feet NAVD88	Entire POA	Through ~2090	Through ~2050
3.5 feet RSLC + 1% AEP coastal	15.5 feet NAVD88	Entire POA	Entire POA	Through ~2080
7.0 feet RSLC + 1% AEP coastal	19.0 feet NAVD88	Entire POA	Entire POA	Through ~2120

^aFor the purposes of this table, the “performance target” assumes defense against the 1% AEP coastal flood event considering RSLC and assuming 1% wave hazards do not occur concurrent with 1% AEP stillwater levels (*Appendix B: Engineering, Section 3.3 Setting Crest Elevation*). Residual risk – due to less frequent, higher magnitude coastal flood events – was considered tolerable. Baseline 2000.

^bTable 2-6 provides a summary of RSLC over time across each USACE scenario.

^cActual crest elevation would vary along the waterfront based on local wave conditions, pending further analysis in PED.

AEP = annual exceedance probability

MHHW = mean higher high water

NAVD88 = North American Vertical Datum of 1988

POA = Period of Analysis (2040-2140)

Table 3-5: Focused Array of Alternative Plans

Alternative Name	First Actions		Subsequent Actions			
	Crest Elevation ^a	Description ^b	Crest Elevation ^a			Description ^b
			Low	Int	High	
Alternative A: No Action	--	No actions beyond FWOP	--	--	--	No actions beyond FWOP
Alternative B: Nonstructural	--	Floodproofing buildings in Reaches 1-4, phased over time	--	<i>Only nonstructural actions</i>	<i>Only nonstructural actions</i>	Floodproofing more buildings, phased over time
Alternative C: Defend, Scaled for Lower Risk	13.5 feet NAVD88	Defend at existing shoreline in Reaches 1-4	--	--	--	No actions beyond FWOP
Alternative D: Defend,	13.5 feet NAVD88	Defend at existing	--	15.5 feet NAVD88	15.5 feet NAVD88	Increase crest elevation of

Alternative Name	First Actions		Subsequent Actions			
	Crest Elevation ^a	Description ^b	Crest Elevation ^a			Description ^b
			Low	Int	High	
Scaled for Low-Moderate Risk		shoreline in Reaches 1-4 Designed to support building higher as risk increases				defense structure along existing shoreline in Reaches 1-4
Alternative E: Defend Existing Shoreline, Scaled for Higher Risk	15.5 feet NAVD88	Defend at existing shoreline in Reaches 1-4 Designed to support building higher as risk increases	--	--	19.0 feet NAVD88	Increase crest elevation of defense structure along existing shoreline in Reaches 1-4
Alternative F: Manage the Water, Scaled for Higher Risk	15.5 feet NAVD88	Defend bayward of existing shoreline in Reaches 1, 2, and 3 north of Mission Creek Water control structures at creeks Defend at existing shoreline in Reach 3 south of Mission Creek Defend inland of industrial piers in Reach 4	--	--	19.0 feet NAVD88	Increase crest elevation of defense structure along existing shoreline in Reaches 1, 2, and parts of Reaches 3 and 4 Raise new inland defense structure in remaining portions of Reaches 3 and 4
Alternative G: Partial Retreat, Scaled for Higher Risk	15.5 feet NAVD88	Defend at existing shoreline in Reaches 1, 2, and 3 Defend inland in Reach 4	--	--	19.0 feet NAVD88	Increase crest elevation of defense structure along existing shoreline in Reaches 1, 2, and parts of Reaches 3 and 4 Raise new inland defense structure in remaining

Alternative Name	First Actions		Subsequent Actions			
	Crest Elevation ^a	Description ^b	Crest Elevation ^a			Description ^b
			Low	Int	High	
						portions of Reaches 3 and 4

^aCrest elevation columns indicate the assumed structural measure crest elevation for purposes of alternatives evaluation. Actual crest elevation would vary along the waterfront based on local wave conditions, pending further analysis in PED.

^bAlternatives C-G include a mix of structural measures, nonstructural measures, and NNBFs. The brief description here is intended to highlight key differences in overarching approach. Comprehensive descriptions available in Section 3.

NAVD88 = North American Vertical Datum of 1988

Alternative A is the No Action Alternative and is the FWOP condition. Alternative B is the nonstructural alternative and was formulated to represent decisions to either floodproof or retreat from assets over time as sea levels change flood risk increases. Alternatives C and D are scaled to address low to intermediate rates of RSLC. Alternative C does not include considerations for future adaptation. Alternative D includes a Subsequent Action to increase the crest elevation as risk increases. Alternatives E, F, and G were formulated to address intermediate to high rates of RSLC, and they include Subsequent Actions to address increasing risk.

The RSLC scenarios described in *ER 1100-2-8162 Incorporating Sea Level Change in Civil Works Programs* are not designated as design criteria and were not used as such in this study. The December 15, 2021, study-specific guidance says that the RSLC curves will consider the full range in formulation, not that they will be used as design criteria.

Mean sea level estimates represent a moving average of the recorded date. The USACE RSLC projections are smooth curves, but there is significant uncertainty in these projections, and the white space between each curve is also a plausible future sea level condition. Guidance suggests care in the use of the precise calculations. *EP 1100-2-1 Procedures to Evaluate Sea Level Changes: Impacts, Responses, and Adaptation*, paragraph 2.5b states that

The use of “curves” is mathematically smooth, but it is unlikely that actual variations will have that attribute. The uncertainty is magnified when the responses of coastal systems and processes are considered or when the combined effects of sea level rise and altered storm frequency or intensity are evaluated.

Accordingly, the formulation was done to approximate the differences between the three scenarios without being exact in the use of the calculated estimate and to provide a range of possible solutions that respond to the projected range of RSLC.

The calculated future sea level scenarios have been used in the Generation II Coastal Risk Model (G2CRM) modeling, thus the damage analysis does reflect the precise calculations from the calculators. This allows those damage assessments to be consistent with the evaluations in other CFRM studies.

The PDT recognized that the rate of RSLC is the dominant uncertainty in this study; therefore, it is the most significant risk driver and the driving determination for system crest elevation or optimization. The PDT chose to optimize crest elevations for resiliency rather than through the cost-benefit evaluation to balance First Actions and Subsequent Actions. The First Actions allow the project area to withstand the consequences of RSLC over the early portion of the POA, while a monitoring and adaptation framework, the MAP (*Appendix G: Monitoring and Adaptation Plan*) allows for Subsequent Actions as actual RSLC is observed.

Table 3-6 summarizes the features of the focused array alternatives.

Table 3-6: Focused Array of Alternatives Features Summary

Alternative	First Actions	Subsequent Actions
A – No Action	N/A	N/A
B – Nonstructural	Retreat assets exposed to the monthly coastal flood Floodproof (perimeter walls + dry floodproofing) assets exposed to 1% AEP coastal flood Two scenarios, one scaled for lower risk, the other for higher risk, each including proactive floodproofing and retreat at approximately 25-year increments resulting in four action steps per scenario to span the 100-year POA	
C – Defend, Scaled for Lower Risk <i>LOD primarily along existing shoreline (13.5 feet NAVD88)</i>	Naturalized or embankment shorelines, earthen & paved (R1,2,3,4) Floodwalls (T-walls, sheet-pile walls, concrete curbs) (R1,2,3,4) Ground improvement (R1,2,3,4) Deployable closure structures at: • 3rd Street Bridge (R3) • 4th Street Bridge (R3) • Illinois Street Bridge (R4) NNBFs (R3,4) Perimeter walls on piers (R1,2,3) Raised/rebuilt wharf (R3 - South Beach Harbor only) Floodproof buildings <10 Elevated building <5 Demo buildings <10 Inland drainage modifications	N/A

Alternative	First Actions	Subsequent Actions
D – Defend, Scaled for Low-Moderate Risk <i>LOD primarily along existing shoreline (13.5 feet NAVD88, adapts to 15.5 feet)</i>	Naturalized or embankment shorelines earthen & paved (R3,4) Floodwalls (T-walls, sheet-pile walls, concrete curbs) (R1,2,3,4) Ground improvement (R1,2,3,4) Deployable closure structures at: • 3rd Street Bridge (R3) • 4th Street Bridge (R3) • Illinois Street Bridge (R4) NNBFs (R3,4) Perimeter walls on piers (R1,2,3) Raised/rebuilt wharf (R3 – harbor only, R4 – P90-92 only) Demo buildings <10 Inland drainage modifications	2 feet vertical extension (wall or added naturalized or embankment shoreline height) added to naturalized or embankment shoreline crests and floodwalls (R1,3,4) Raised/rebuilt wharves (R1,2, 3) Elevated bridges: • 3rd Street Bridge (R3) • 4th Street Bridge (R3) • Illinois Street Bridge (R4) NNBFs (R4) Elevated buildings <20 Demo buildings <15
E – Defend Existing Shoreline, Scaled for Higher Risk <i>LOD primarily along existing shoreline (15.5 feet NAVD88, adapts to 19 feet)</i> • <u>some shoreline extension</u> into Bay in R1,2,3 • <u>little/no retreat</u>	Naturalized or embankment shorelines earthen & paved (R1,3,4) Seawalls/bulkhead walls: • w Fill (R1,2,3) • w/o Fill (R4) • at Ferry Building, seawall along bayside edge of bldg Ground improvements (R1,2,3,4) Deployable closure structures at: • 3rd Street Bridge (R3) • 4th Street Bridge (R3) • Illinois Street Bridge (R4) NNBFs (R1,2,3,4) Perimeter walls on piers (R1,2,3) Raised/rebuilt wharves (R1,2,3,4) Elevated buildings <25 Demo buildings <30 Inland drainage modifications	3.5 feet vertical extension (wall or added naturalized or embankment shoreline height) added to naturalized or embankment shoreline crests, floodwalls, and seawalls (R1,2,3,4) Seawalls/bulkhead walls: • w Fill (R2 – Rincon Park only) • Elevated bridges • 3rd Street Bridge (R3) • 4th Street Bridge (R3) • Illinois Street Bridge (R4) NNBFs (R4) Raised/rebuilt wharves (R1,2,3,4) Elevated buildings <25

Alternative	First Actions	Subsequent Actions
F – Manage the Water, Scaled for Higher Risk <i>LOD primarily along existing shoreline (15.5 feet NAVD88, adapts to 19 feet)</i> • <u>more shoreline extension</u> into Bay in R1,2 • <u>retreat</u> mostly on piers in R4	Naturalized or embankment shorelines earthen & paved (R3,4) Floodwalls (R1) Seawalls/bulkhead walls: • w Fill (R1,2,3) – larger shoreline extension compared to E • w/o Fill (R4) • at Ferry Building, seawall further bayward of bldg Ground improvements (R1,2,3,4) Water mgmt. structure (tide gates) (R3,4) NNBFs (R3,4) Perimeter walls on piers (R1,2,3) Raised/rebuilt wharves (R3 - South Beach Harbor only) Floodproof buildings <25 Elevated buildings <20 Demo buildings <15 Inland drainage modifications	3.5 feet vertical extension (wall or added naturalized or embankment shoreline height) added to naturalized or embankment shoreline crests, floodwalls, and seawalls (R1,2,3,4) Ground improvements (R4 – where LOD moved further inland) Water mgmt. structure (permanently close the tide gates, add pumps) (R3,4) NNBFs (R3,4) Raised/rebuilt wharves (R3 - South Beach Harbor only) Demo buildings >45
G – Partial Retreat, Scaled for Higher Risk <i>LOD primarily along existing shoreline (15.5-17' NAVD88, adapts to 19)</i> • <u>little/no shoreline extension</u> • more retreat in R4, esp. by 2090	Naturalized or embankment shorelines* earthen & paved (R3,4) Floodwalls (R1,3,4) Seawalls/bulkhead walls: • little/no fill (R1,2,3) • at Ferry Building, seawall along landside edge of bldg Ground improvements (R1,2,3,4) Elevated bridges: • 3rd Street Bridge (R3) • 4th Street Bridge (R3) • Illinois Street Bridge (R4) NNBFs (R3,4) Perimeter walls on piers (R1,2,3) Raised/rebuilt wharves (R1,2,3) Floodproof buildings >45 Elevated buildings <20 Demo buildings <15 Inland drainage modifications	2 feet-3.5 feet vertical extension (wall or added naturalized or embankment shoreline height) added to naturalized or embankment shoreline crests, floodwalls, and seawalls (R1,2,3,4) Retreat some areas adjacent to creeks and construct new inland naturalized or embankment shorelines and floodwalls (R3,4) Ground improvements (R3,4) NNBFs (R3,4) Demo bridge (R4 – Illinois Street Bridge) – due to retreat of adjacent area Demo buildings >50

3.8.1. Alternative A: No Action (FWOP Condition)

Alternative A is the No Action Alternative, meaning no action is taken by USACE to reduce flood risks beyond projects that have already been implemented or are approved for implementation along the San Francisco waterfront as described in the FWOP condition presented in Section 2.0. The FWOP coastal flood hazard is described in Section 2.3.4, RSLC is described in Section 2.3.5, and future local projects are described in Section 2.4.6. Alternative A represents a baseline for comparison to evaluate the costs and benefits of all other alternatives and is the same as the FWOP condition.

Taking no action would not reduce the risk of coastal flooding that could begin to cause economic damage and interruptions to private property and public assets and impact transportation corridors, the performance of the wastewater and stormwater system, and the stability of the electrical grid. Many areas of the shoreline would be overtopped by frequent high-tide flooding in the absence of large storms. This would occur first in the winter months when king tides could flood roadways, causing road and transit closures. In the long-term, low-lying areas would be subjected to more prolonged flooding, damage, and disruption. Eventually, low-lying areas could be flooded daily by the rise and fall of the Bay tides. Over time, this is projected to result in lower quality of life; lowered property values; and the displacement of businesses, jobs, and homes.

Some public and private projects that are already underway or are planned would address RSLC in those areas (such as Mission Rock and Pier 70 or Islais Creek and 3rd Street Bridge), but these are targeted efforts that address a very small portion of a much larger problem. In some cases, these projects will effectively be stranded as islands if not tied into a broader plan to address RSLC.

3.8.2. Alternative B: Nonstructural

Alternative B is a nonstructural plan that moves people and assets away from flood risk. Nonstructural measures (such as floodproofing) reduce the consequences of flooding and allow water to disperse naturally rather than constructing traditional structural solutions. In Alternative B, buildings and critical city systems could be floodproofed, relocated, or retreated from so that they are not damaged when flood waters enter the area.

As sea levels rise and flood risks change over time, areas of the city that could flood frequently may be good candidates for managed retreat where people and assets are moved out of risk areas to avoid recurring damage and disruption. Alternative B assumes that public and private owners would be assisted to take proactive steps to minimize flood damage to their assets and properties such as floodproofing, modifying, or removing buildings and infrastructure to reduce the risk of flood damage as sea levels rise.

The extent of the infrequent and frequent flood zones will increase such that floodproofing and managed retreat actions sweep inland over time. As many of these actions are occurring on an asset-by-asset basis, they are highly responsive to the expected RSLC trajectory.

The nonstructural alternative was scaled for two different risk scenarios. The lower-risk scenario follows the USACE Intermediate curve trajectory of RSLC and uses the associated flood zones to determine the cost, benefits, and impacts to assess this plan, while the higher risk scenario follows the USACE High curve trajectory, which implicates larger areas of the city at an earlier point in time. Following these two trajectories, proactive actions (floodproofing or retreat) based on expected flood frequency are proposed and quantified at 25-year increments, resulting in four action steps to span the 100-year POA.

As a baseline assumption, buildings and critical city infrastructure within the infrequent flood zone are floodproofed to prevent physical damage but will incur periodic disruption of services whenever a potential coastal flood event is forecast, likely resulting in evacuation and business shutdown for hours to days. Areas within the frequent flood zone would be retreated from. This will require property buyout, asset condemnation, and removal of the built environment. This also presents an opportunity for this space to be re-imagined with nature-based features that would provide ecological habitat and associated benefits. Essential utilities, such as wastewater, water, and the electric grid would be relocated or modified to continue providing service for the inland areas of the city for both floodproofing and retreat scenarios. Major transportation and transit corridors would be permanently disrupted or require network reconfiguration to mitigate this disruption.

This alternative would only involve actions that reduce human exposure and vulnerability to flooding but does not attempt to change flows. In this alternative, the area of potential flooding would not be substantially changed. **Figure 3-7** and **Figure 3-8** visualize the floodproof and retreat zones across timesteps for the lower-risk scenario and higher risk scenario, respectively. *Sub-Appendix B.4 Array of Alternatives (B-G)* provides additional plan view figures for this alternative.

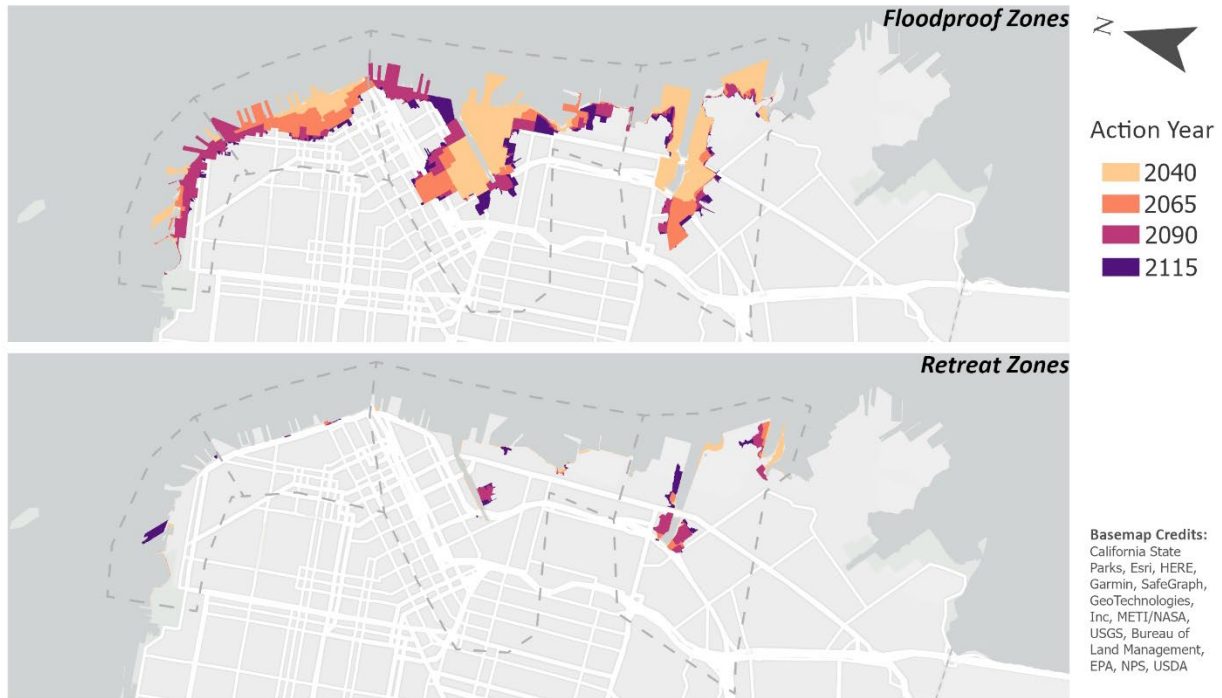


Figure 3-7: Alternative B Floodproof and Retreat by Time Step for Lower-Risk Scenario

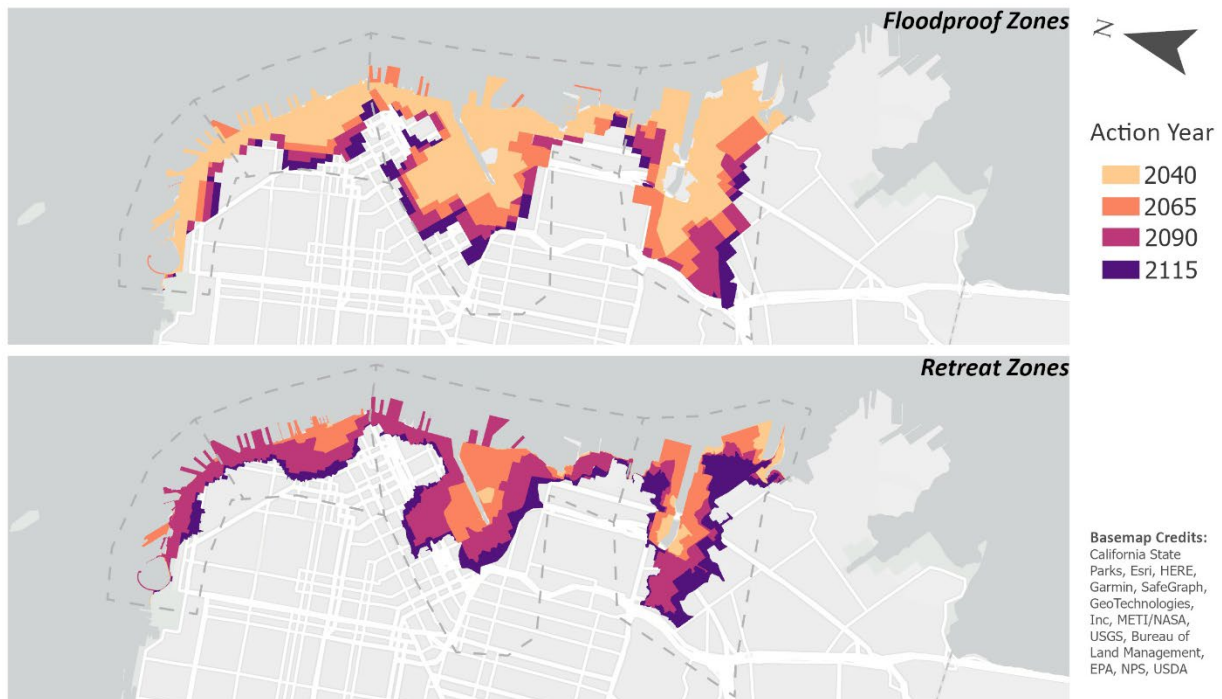


Figure 3-8: Alternative B Floodproof and Retreat by Time Step for Higher-Risk Scenario

3.8.3. Alternative C: Defend, Scaled for Lower Risk

Alternative C is a structural alternative formulated to address lower rates of RSLC, consistent with the USACE Low and Intermediate RSLC curves but may not be consistent with State of California and CCSF RSLC guidance unless it was incorporated within a more robust plan addressing higher rates of RSLC. The design crest elevation for the measures in 2040 is 13.5 feet NAVD88.

To address the lower rates of RSLC, Alternative C is engineered to reduce exposure of the shoreline to significant overtopping with 1.5 feet of RSLC (baseline 2000). The alternative is assumed to be a continuous line of protection with a crest elevation that was established to avoid overtopping caused by wave runup in addition to high water levels in the Bay. This alternative is largely composed of short walls and levees located near the edge of the existing shoreline. Some areas of the shoreline would include nature-based solutions and natural features that can reduce flood risks, while also enhancing Bay ecology and habitat. This alternative was developed without detailed consideration of local urban design standards, which may be addressed in future stages of design.

This alternative is distinct in that it is not envisioned to be easily adaptable to higher rates of RSLC. For example, foundations would not be sized to support adding height at a future date. Where space is readily available, levees were selected due to lower cost. However, within the space-constrained urban right-of-way, floodwalls within the Embarcadero promenade were identified as the most feasible measure. Additionally, the alternative includes short perimeter ring walls constructed along the apron of the existing finger piers to provide added protection from coastal storms and waves.

Foundations are constructed to meet the seismic performance requirements to ensure that higher water levels do not result in a high hazard to life safety during or following an earthquake, especially at the end of the study period when the coastal defenses routinely hold back Bay water.

Figure 3-9 shows the alignment of the LOD for Alternative C. *Sub-Appendix B.4 Array of Alternatives (B-G)* provides additional plan view figures for this alternative.

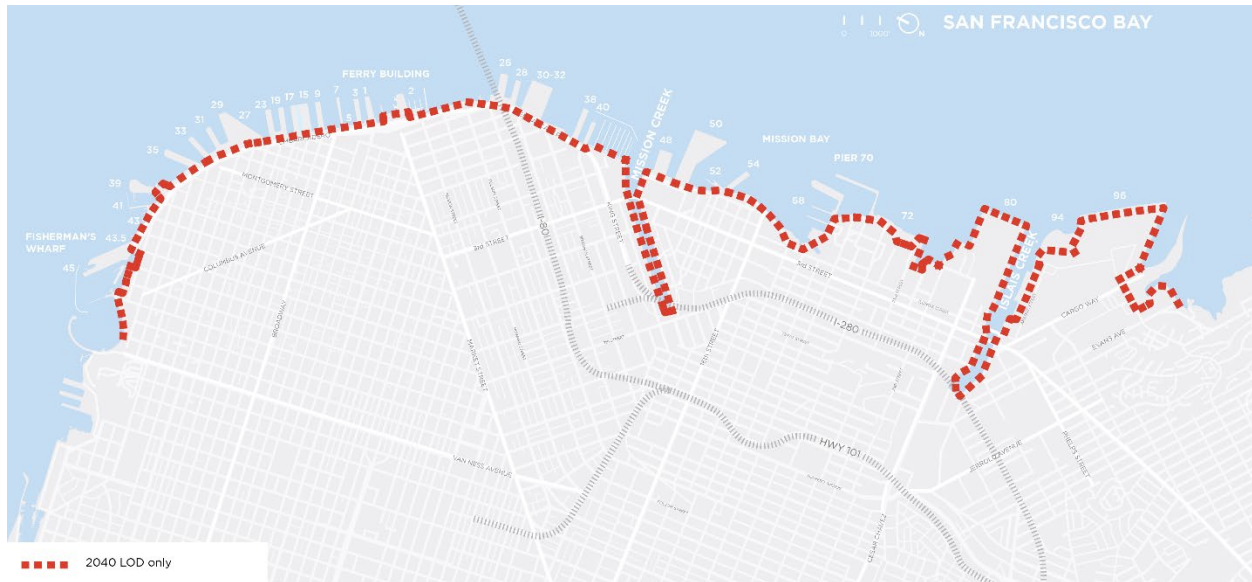


Figure 3-9: Alternative C

3.8.4. Alternative D: Defend, Scaled for Low-Moderate Risk

Alternative D is designed to adapt the shoreline to withstand 1.5 feet of RSLC (baseline 2000), with the possibility of building higher (up to an additional 2 feet of RSLC) closer to 2090 if RSLC is projected to increase beyond the first line of protection. Alternative D addresses lower rates of RSLC, consistent with the USACE Low and Intermediate RSLC curves, but may not be consistent with State of California and CCSF RSLC guidance unless it was incorporated within a more robust plan addressing higher rates of RSLC. The design crest elevation for the First Actions measures is 13.5 feet NAVD88.

Alternative D is engineered to protect the shoreline from significant overtopping with 1.5 feet of RSLC, while providing adaptability to RSLC up to 3.5 feet. While 1.5 feet of RSLC will only cause shoreline overtopping in discrete segments of the waterfront, the alternative is assumed to be a continuous line of protection with a crest elevation that was established to avoid overtopping caused by wave runup in addition to high water levels in the Bay.

This alternative proposes construction of short floodwalls and levees near the edge of the existing shoreline and adding a 2-foot-high concrete curb around the perimeter of piers as a First Action. Some areas of the shoreline would include NNBFs that can reduce flood risks, while also enhancing Bay ecology and habitat. This alternative was initially developed without detailed consideration of local urban design standards, which may be addressed in future stages of design. This alternative includes foundation elements that allow adaptation up to 3.5 feet of RSLC.

Foundations would be constructed to meet the seismic performance requirements to ensure that higher water levels do not result in a high hazard to life safety during or

following an earthquake, especially at the end of the study period when the coastal defenses routinely hold back Bay water.

The First Actions structures are adaptable to perform under higher water levels as sea levels continue to rise. In most cases, the Subsequent Actions adaptive measure is the construction of a 2-foot-tall vertical extension wall added to levees and walls constructed as the First Actions. For the Subsequent Actions, this alternative includes reconstructing bulkhead wharves and buildings at a higher elevation to address 3.5 feet of RSLC. New wharves will be constructed from Fisherman's Wharf to South Beach Harbor. The bridges over Mission Creek and the Illinois Street Bridge over Islais Creek would be raised with regrading of the vehicle and rail approaches to accommodate higher water levels while maintaining transportation connections across the creek.

Figure 3-10 shows the alignment of the LOD for Alternative D. *Sub-Appendix B.4 Array of Alternatives (B-G)* provides additional plan view figures for this alternative.

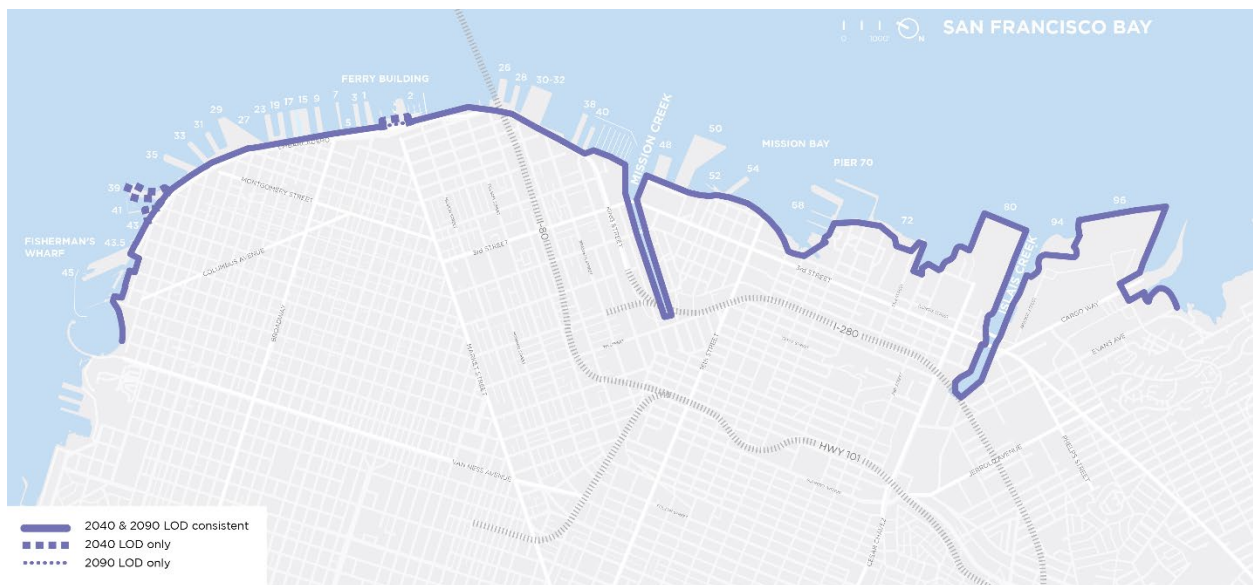


Figure 3-10: Alternative D

3.8.5. Alternative E: Defend Existing Shoreline, Scaled for Higher Risk

Alternative E is designed to adapt the shoreline to withstand 3.5 feet of RSLC, with the possibility of building higher (up to an additional 3.5 feet of RSLC) closer to 2090 if RSLC is projected to increase beyond the first LOD. Alternative E addresses higher rates of RSLC, consistent with the USACE High RSLC curve, and is consistent with State of California and CCSF RSLC guidance. The design crest elevation for the measures for the First Actions is 15.5 feet NAVD88.

Alternative E was designed to “hold the line” by preserving a waterfront that looks and functions much as it does today by adapting along the shoreline. Alternative E raises the shoreline using a combination of levees, seawalls, bulkhead wharves, and

deployable closure structures. Where appropriate, the LOD ties into existing high ground. The shoreline is extended into the Bay along the Embarcadero and portions of Mission Bay to accommodate the new coastal flood defense structures to minimize disruption to key transportation facilities, emergency services, and other important city features.

Foundations are constructed to meet the seismic performance requirements to ensure that higher water levels do not result in a high hazard to life safety during or following an earthquake, especially at the end of the study period when the coastal defenses routinely hold back Bay water.

The First Actions structures are adaptable to perform under higher water levels as sea levels continue to rise. The subsequent adaptations mostly include increasing the elevation of the First Actions measures, with one instance of extending the shoreline into the Bay at Rincon Park to provide additional space for the elevation gains required. The bridges over Mission Creek and the Illinois Street Bridge over Islais Creek would be raised with regrading of the vehicle and rail approaches to accommodate higher water levels while maintaining transportation connections across the creek.

Figure 3-11 shows the alignment of the LOD for Alternative E. *Sub-Appendix B.4 Array of Alternatives (B-G)* provides additional plan view figures for this alternative.

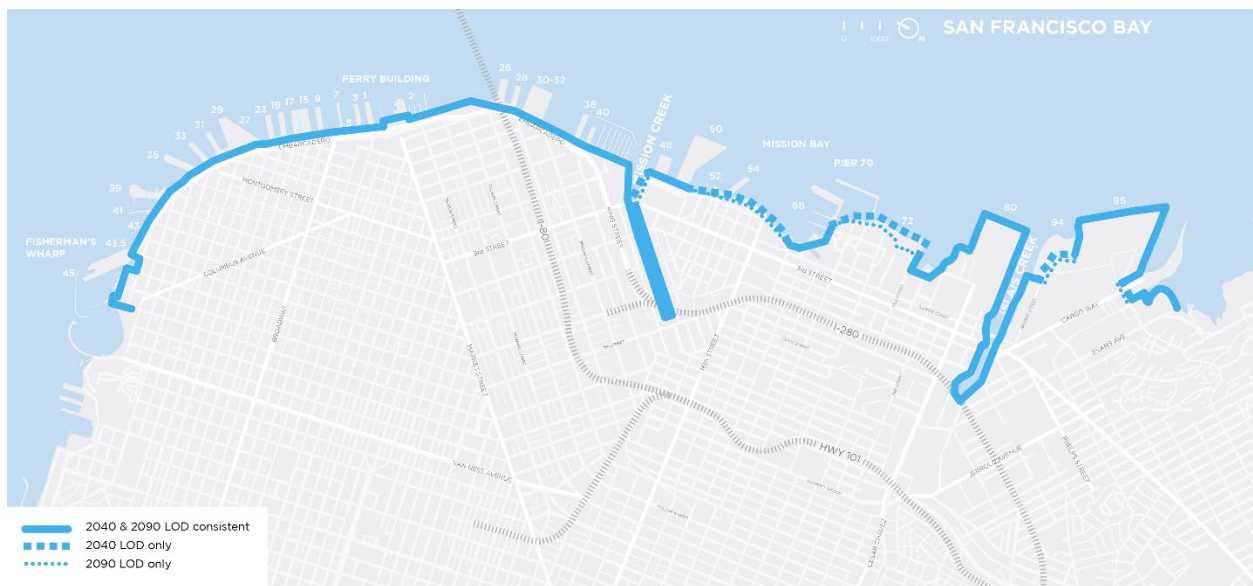


Figure 3-11: Alternative E

3.8.6. Alternative F: Manage the Water, Scaled for Higher Risk

Alternative F is designed to adapt the shoreline to withstand 3.5 feet of RSLC, with the possibility of building higher (up to an additional 3.5 feet of RSLC) closer to 2090 if RSLC is projected to increase beyond the first LOD. Alternative F addresses higher rates of RSLC, consistent with the USACE High RSLC curve and is consistent with State of California and CCSF RSLC guidance. The design crest elevation for the First Actions measures is 15.5 feet NAVD88.

Alternative F is designed to “manage the water” by integrating typical passive flood protection measures (levees and floodwalls) along a large portion of the project length, managed retreat in select locations with new setback passive protection measures, and new water control structures near the mouths of Mission and Islais Creeks. For the First Actions, the water control structures would consist of tide gates near the mouths of Mission and Islais Creeks that when closed would protect against coastal floodwaters entering the protected creek channels. The protected creek channels would become engineered lagoons that would hold some stormwater to manage inland floodwaters until the gates can be opened when the Bay water level recedes. The tide gates are intended to be designed as part of an integrated inland drainage system that balances stormwater storage within the separated lagoon with active pumping to manage the runoff trapped landward of the coastal defense.

Foundations are constructed to meet the seismic performance requirements to ensure that higher water levels do not result in a high hazard to life safety during or following an earthquake, especially at the end of the study period when the coastal defenses routinely hold back Bay water.

Most First Actions structures are adaptable to perform under higher water levels as sea levels continue to rise, except for portions of Reach 3 and Reach 4, where the Subsequent Actions LOD would shift inland. The Subsequent Actions adaptations include increasing the elevation of the First Actions measures and converting the tide gates to pump stations, permanently separating the engineered lagoons from the Bay. For the Subsequent Actions, Alternative F would require floodproofing and accommodation of some flood waters on industrial and commercial land uses east of Illinois Street. These areas would require flood monitoring and warning systems.

Figure 3-12 shows the alignment of the LOD for Alternative F. *Sub-Appendix B.4 Array of Alternatives (B-G)* provides additional plan view figures for this alternative.

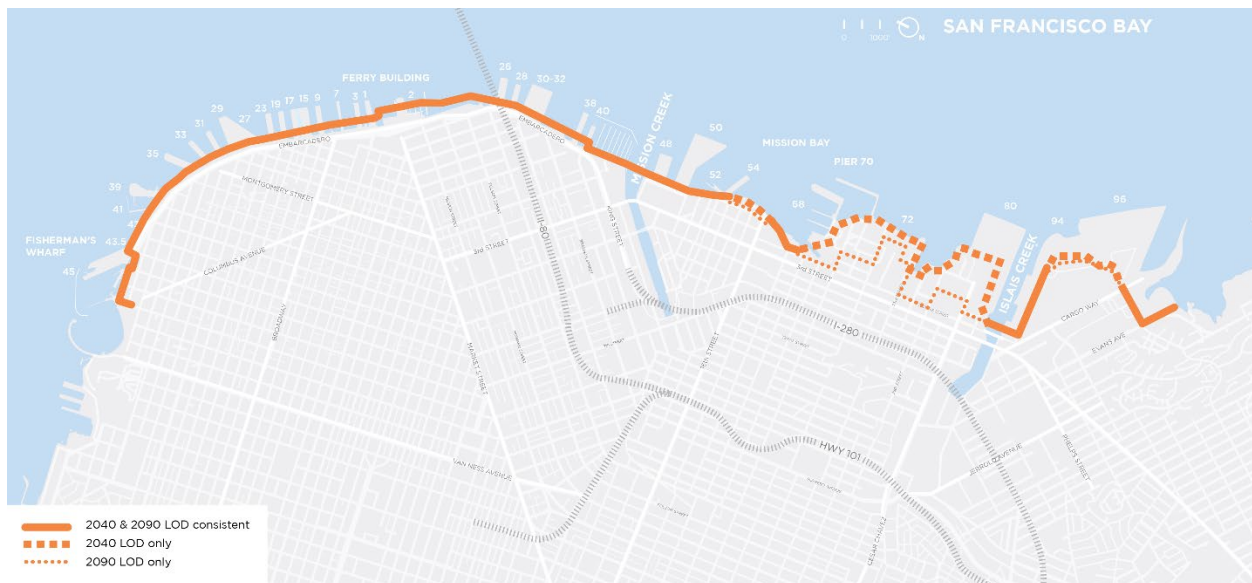


Figure 3-12: Alternative F

3.8.7. Alternative G: Partial Retreat, Scaled for Higher Risk

Alternative G is designed to adapt the shoreline to withstand 3.5 feet of RSLC, with the possibility of building higher (up to an additional 3.5 feet of RSLC) around 2090 if RSLC is projected to increase beyond the first line of protection. Alternative G addresses higher rates of RSLC, consistent with the USACE High RSLC curve and is consistent with State of California and CCSF RSLC guidance. The design crest elevation for the First Actions measures is 15.5 feet NAVD88.

Alternative G is designed to “align with watersheds” by advancing shoreline adaptation while working with natural inland flooding patterns, floodproofing some buildings and infrastructure, and gradually retreating from the highest risk areas. For the First Actions, buildings and infrastructure throughout the waterfront, including those within the future retreat areas, will be protected using a combination of floodproofing and coastal defense structures including levees, floodwalls, seawalls, and bulkhead wharves. The bridges over Mission Creek and the Illinois Street Bridge over Islais Creek would be raised with regrading of the vehicle and rail approaches to accommodate higher water levels while maintaining transportation connections across the creek.

This alternative has the potential to significantly transform geographies in the long-term by providing new floodable open spaces, relying less on inland drainage infrastructure, and restoring portions of the historic natural watersheds at the creeks. This alternative would rely heavily on policy actions in the near-term for a successful, gradual transformation.

Foundations are constructed to meet the seismic performance requirements to ensure that higher water levels do not result in a high hazard to life safety during or following an earthquake, especially at the end of the study period when the coastal defenses routinely hold back Bay water.

Many First Actions are adaptable to manage risk from higher water levels as sea levels continue to rise, except for portions of Reach 3 and Reach 4, where the 2090 LOD would shift inland. The subsequent adaptive measures include increasing the elevation of some First Actions, constructing new inland levees, and floodproofing and gradually retreating high-risk areas.

Gradual retreat along the creek banks is a defining feature of Alternative G subsequent adaptations in Reach 3 and Reach 4. Over time, this alternative would move toward a future waterfront more closely aligned with the natural watersheds to reduce both coastal and inland flood risk. In these future retreat areas, the shoreline would be converted to NNBFs.

As the shoreline moves landward, the volume of inland drainage trapped behind the coastal defense decreases such that this alternative will require less stormwater management infrastructure than Alternatives E and F. However, there will still be a need to modify the existing wastewater system to manage inland drainage that has been transformed with the new LOD and rising Bay water levels. These modifications could include a combination of measures such as consolidation of CSD outfalls, new pumps, expanded pump capacity, green infrastructure, and other resilient building and street design opportunities.

Figure 3-13 shows the alignment of the LOD for Alternative G. *Sub-Appendix B.4 Array of Alternatives (B-G)* provides additional plan view figures for this alternative.

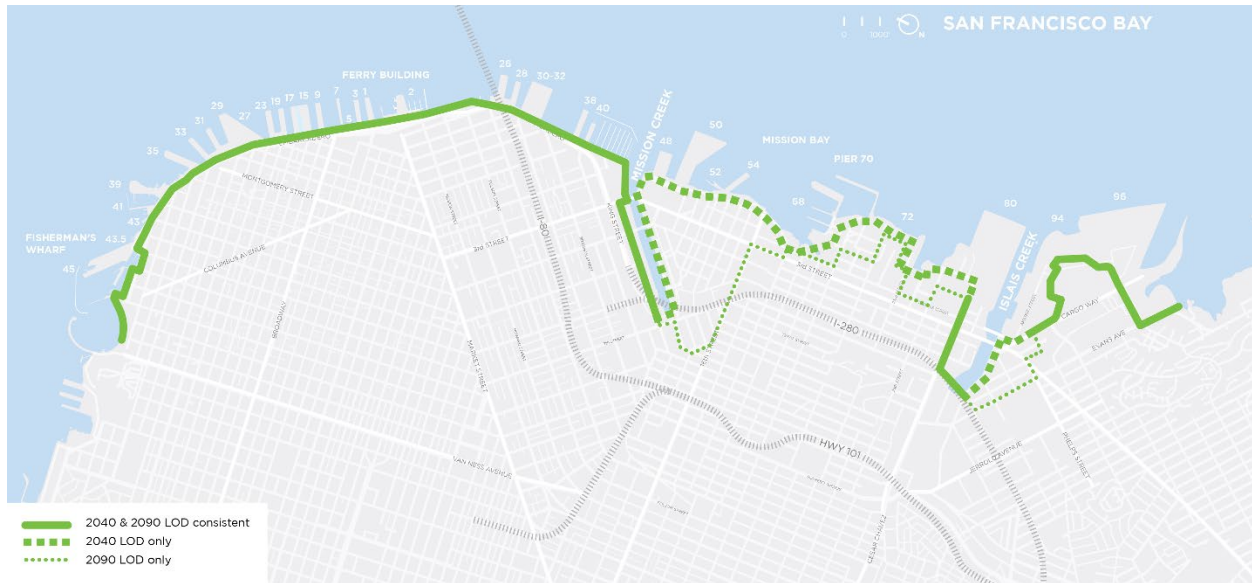


Figure 3-13: Alternative G

3.9. Evaluation of Focused Array

An NED evaluation of the focused array was conducted by the PDT. Consistent with study guidance, the alternative plans were evaluated under three USACE RSLC scenarios. Coastal flood events have relatively little variation in WSE from small to extreme events, thus flood risk is primarily driven by RSLC in combination with coastal storms. The variation of scale and type of actions across alternatives was a strategic approach to assess the difference in performance under the uncertain timing of RSLC. The economic analysis supported assessing the cost-effectiveness of the risks of over- or under-building flood risk management features under each RSLC scenario.

NED benefits were estimated with G2CRM and several important metrics outside of G2CRM, notably operations, maintenance, repair, rehabilitation and replacement (OMRR&R) costs and the relative costs of future changes to the SFMTA transit system and the SFPUC combined sewer system under the FWOP and FWP scenarios.

A detailed description of the implementation of G2CRM including the analytical process, relevant inputs, asset inventory creation, modeling actuation, results for each subsection of the study area and results analysis is provided in *Appendix E: Economic and Social Considerations*.

3.9.1. Costs

Detailed cost estimates for the focused array of alternatives can be found in *Appendix C: Cost Engineering*. A summary of first costs without including seismic design requirements by reach are shown in **Table 3-7** and **Table 3-8** for First Actions and all

actions (First Actions plus Subsequent Actions), respectively. Seismic design requirements costs are not considered when calculating net benefits for this study, in accordance with the requirements of Section 152 of WRDA 2020, as amended.

Table 3-7: Reach-level First Costs, Without Seismic Design Requirements, First Actions

(PV; FY 2023 Price Level; \$1,000s)

Alternative	Reach 1	Reach 2	Reach 3	Reach 4	Total
B Lower Risk	16,196	20,685	319,421	47,679	403,981
B Higher Risk	79,319	109,779	632,903	120,125	942,126
C	165,122	119,631	451,323	725,712	1,461,788
D	130,641	137,271	367,808	736,256	1,371,976
E	3,260,213	4,047,530	4,345,783	4,080,150	15,733,676
F	2,020,388	7,424,087	2,567,612	716,343	12,728,430
G	1,114,543	2,972,348	1,968,653	1,410,364	7,465,908

Table 3-8: Reach-level First Costs, Without Seismic Design Requirements, All Actions

(PV; FY 2023 Price Level; \$1,000s)

Alternative	Reach 1	Reach 2	Reach 3	Reach 4	Total
B Lower Risk	32,985	78,263	409,445	73,383	594,076
B Higher Risk	199,350	601,180	1,443,016	306,609	2,550,155
C	165,122	119,631	451,323	725,712	1,461,788
D	234,273	471,473	620,773	926,551	2,253,070
E	3,386,200	4,298,581	4,595,916	4,229,664	16,510,361
F	2,026,822	7,429,646	2,893,856	1,129,423	13,479,747
G	1,146,254	2,976,378	2,274,144	1,673,908	8,070,684

Though the seismic design requirements costs are not used in benefit-cost calculations in accordance with WRDA 2020, as amended, they are still actual project costs that are incurred. Additionally, the amount of cost that is attributed to seismic design

requirements is not equal across measures; some measures have a larger percentage of their total cost to meet seismic design requirements while others have a lower percentage. For reference, **Table 3-9** and **Table 3-10** show the costs of the focused array of alternatives including seismic design requirements.

Table 3-9: Reach-Level First Costs, Including Seismic Design Requirements, First Actions

(PV; FY 2023 Price Level; \$1,000s)

Alternative	Reach 1	Reach 2	Reach 3	Reach 4	Total
B Lower Risk	16,196	20,685	319,421	47,679	403,981
B Higher Risk	79,319	109,779	632,903	120,125	942,126
C	672,828	2,861,247	1,669,820	6,412,026	11,615,921
D	638,347	2,878,886	1,586,304	6,422,571	11,526,108
E	3,767,919	6,789,145	5,564,278	9,766,466	25,887,808
F	2,580,104	10,375,316	3,229,095	1,632,242	17,816,757
G	1,588,555	5,484,616	2,916,679	2,216,186	12,206,036

Table 3-10: Reach-Level First Costs, Including Seismic Design Requirements, All Actions

(PV; FY 2023 Price Level; \$1,000s)

Alternative	Reach 1	Reach 2	Reach 3	Reach 4	Total
B Lower Risk	32,985	78,263	409,445	73,383	594,076
B Higher Risk	199,350	601,180	1,443,016	306,609	2,250,155
C	672,828	2,861,247	1,669,820	6,412,026	11,615,921
D	741,979	3,213,088	1,839,269	6,612,866	12,407,202
E	3,893,906	7,040,196	5,814,411	9,915,980	26,664,493
F	2,586,538	10,380,875	3,556,750	2,078,358	18,602,521
G	1,620,562	5,486,692	3,402,014	2,553,464	13,062,732

3.9.2. NED Evaluation

The net NED benefits for each plan in each reach under each RSLC curve are shown in **Table 3-11**, **Table 3-12**, and **Table 3-13**.

Table 3-11: NED Evaluation by Alternative, Low RSLC

(PV, FY 2023 Price Level, \$1,000s)

Reach	Damages	NED Benefits, 2040-2089	NED Benefits, 2090-2140	Total NED Benefits	Non-Seismic Cost	Net Benefits	BCR
FWOP							
1	375,852	NA	NA	NA	NA	NA	NA
2	729,221	NA	NA	NA	NA	NA	NA
3	898,963	NA	NA	NA	NA	NA	NA
4	1,606,779	NA	NA	NA	NA	NA	NA
Total	3,610,815	NA	NA	NA	NA	NA	NA
Alternative B							
1	371,323	2,528	2,000	4,528	16,229	-11,701	0.28
2	512,039	125,851	91,331	217,182	20,727	196,455	10.48
3	291,914	411,219	195,830	607,049	320,079	286,970	1.90
4	1,435,775	141,510	29,495	171,005	47,777	123,228	3.58
Total	2,611,051	681,108	318,656	999,764	404,813	594,951	2.47
Alternative C							
1	371,323	2,528	2,000	4,528	205,828	-201,300	0.02
2	512,040	125,850	91,332	217,182	149,123	68,059	1.46
3	307,239	403,161	188,563	591,724	562,584	29,140	1.05
4	1,443,508	136,071	27,200	163,271	904,617	-741,346	0.18
Total	2,634,110	667,610	309,095	976,705	1,822,152	-845,447	0.54
Alternative D							
1	371,323	2,528	2,000	4,528	166,466	-161,938	0.03
2	512,039	125,851	91,331	217,182	174,914	42,268	1.24
3	309,223	402,711	187,028	589,739	468,671	121,068	1.26
4	1,441,398	137,248	28,133	165,381	938,157	-772,776	0.18
Total	2,633,983	668,338	308,492	976,830	1,748,208	-771,378	0.56

San Francisco Waterfront Coastal Flood Study

Reach	Damages	NED Benefits, 2040-2089	NED Benefits, 2090-2140	Total NED Benefits	Non-Seismic Cost	Net Benefits	BCR
Alternative E							
1	2,128	331,581	42,143	373,724	4,495,357	-4,121,633	0.08
2	4,983	556,930	167,308	724,238	5,580,952	-4,856,714	0.13
3	17,328	648,488	233,146	881,634	5,992,200	-5,110,566	0.15
4	14,440	1,483,971	108,368	1,592,339	5,625,931	-4,033,592	0.28
Total	38,879	3,020,970	550,965	3,571,935	21,694,440	-18,122,505	0.16
Alternative F							
1	2,128	331,581	42,143	373,724	2,785,820	-2,412,096	0.13
2	4,983	556,930	167,308	724,238	10,236,731	-9,512,493	0.07
3	115,034	558,014	225,914	783,928	4,847,958	-4,064,030	0.16
4	1,497,785	85,208	23,786	108,994	1,352,541	-1,243,547	0.08
Total	1,619,930	1,531,733	459,151	1,990,884	17,550,645	-15,559,761	0.11
Alternative G							
1	2,128	331,581	42,143	373,724	1,536,792	-1,163,068	0.24
2	4,983	556,930	167,308	724,238	4,098,434	-3,374,196	0.18
3	175,905	527,394	195,663	723,057	2,714,485	-1,991,428	0.27
4	1,548,466	47,118	11,196	58,314	1,944,686	-1,886,372	0.03
Total	1,731,482	1,463,023	416,310	1,879,333	10,294,396	-8,415,063	0.18

BCR = benefit-cost ratio

Table 3-12: NED Evaluation by Alternative, Intermediate RSLC
(PV, FY 2023 Price Level, \$1,000s)

Reach	Damages	NED Benefits, 2040-2089	NED Benefits, 2090 -2140	Total NED Benefits	Non-Seismic Cost	Net Benefits	BCR
FWOP							
1	430,228	NA	NA	NA	NA	NA	NA
2	1,592,498	NA	NA	NA	NA	NA	NA
3	2,116,372	NA	NA	NA	NA	NA	NA
4	1,836,652	NA	NA	NA	NA	NA	NA
Total	5,975,750	NA	NA	NA	NA	NA	NA

San Francisco Waterfront Coastal Flood Study

Reach	Damages	NED Benefits, 2040-2089	NED Benefits, 2090 -2140	Total NED Benefits	Non- Seismic Cost	Net Benefits	BCR
Alternative B							
1	379,122	8,313	42,793	51,106	33,018	18,088	1.55
2	533,137	441,633	617,729	1,059,362	78,306	981,056	13.5 3
3	499,374	968,112	648,886	1,616,998	410,103	1,206,895	3.94
4	1,545,526	205,661	85,465	291,126	73,481	217,645	3.96
Total	2,957,159	1,623,719	1,394,873	3,018,592	594,909	2,423,683	5.07
Alternative C							
1	378,356	8,839	43,032	51,871	205,828	-153,957	0.25
2	520,896	441,632	629,970	1,071,602	149,123	922,479	7.19
3	412,917	935,608	767,848	1,703,456	562,584	1,140,872	3.03
4	1,488,067	208,834	139,750	348,584	904,617	-556,033	0.39
Total	2,800,236	1,594,913	1,580,600	3,175,513	1,822,152	1,353,361	1.74
Alternative D							
1	377,690	9,058	43,480	52,538	270,099	-217,561	0.19
2	513,925	441,644	636,929	1,078,573	509,116	569,457	2.12
3	385,153	934,090	797,129	1,731,219	721,636	1,009,583	2.40
4	1,484,098	212,878	139,675	352,553	1,128,452	-775,899	0.31
Total	2,760,866	1,597,670	1,617,213	3,214,883	2,629,302	585,581	1.22
Alternative E							
1	7,566	338,392	84,270	422,662	4,495,357	-4,072,695	0.09
2	5,422	872,866	714,210	1,587,076	5,580,952	-3,993,876	0.28
3	91,219	1,184,823	840,330	2,025,153	5,992,200	-3,967,047	0.34
4	51,478	1,555,588	229,585	1,785,173	5,625,931	-3,840,758	0.32
Total	155,685	3,951,669	1,868,395	5,820,064	21,694,440	-15,874,376	0.27
Alternative F							
1	7,698	338,331	84,198	422,529	2,785,820	-2,363,291	0.15
2	5,532	872,791	714,175	1,586,966	10,236,731	-8,649,765	0.16
3	154,799	1,114,885	846,689	1,961,574	4,847,958	-2,886,384	0.40
4	1,583,793	147,784	105,075	252,859	1,352,541	-1,099,682	0.19

San Francisco Waterfront Coastal Flood Study

Reach	Damages	NED Benefits, 2040-2089	NED Benefits, 2090 -2140	Total NED Benefits	Non- Seismic Cost	Net Benefits	BCR
Total	1,751,822	2,473,791	1,750,137	4,223,928	17,550,645	-13,326,717	0.24
Alternative G							
1	7,566	338,392	84,270	422,662	1,536,792	-1,114,130	0.28
2	5,532	872,791	714,175	1,586,966	4,098,434	-2,511,468	0.39
3	836,737	994,949	284,687	1,279,636	2,714,485	-1,434,849	0.47
4	1,739,360	82,868	14,423	97,291	1,944,686	-1,847,395	0.05
Total	2,589,195	2,289,000	1,097,555	3,386,555	10,294,396	-6,907,841	0.33

BCR = benefit-cost ratio

Table 3-13: NED Evaluation by Alternative, High RSLC

(PV, FY 2023 Price Level, \$1,000s)

Reach	Damages	NED Benefits, 2040-2089	NED Benefits, 2090 -2140	Total NED Benefits	Non- Seismic Cost	Net Benefits	BCR
FWOP							
1	1,586,714	NA	NA	NA	NA	NA	NA
2	7,834,338	NA	NA	NA	NA	NA	NA
3	9,515,697	NA	NA	NA	NA	NA	NA
4	3,634,010	NA	NA	NA	NA	NA	NA
Total	22,570,759	NA	NA	NA	NA	NA	NA
Alternative B							
1	963,081	320,645	302,988	623,633	199,514	424,119	3.13
2	3,897,001	2,954,739	982,598	3,937,337	601,406	3,335,931	6.55
3	4,309,816	3,742,436	1,463,436	5,205,872	1,444,320	3,761,552	3.60
4	2,652,393	559,020	422,597	981,616	306,857	674,759	3.20
Total	11,822,291	7,576,840	3,171,619	10,748,458	2,552,097	8,196,361	4.21
Alternative C							
1	1,578,225	242,517	(234,028)	8,489	205,828	-197,339	0.04
2	7,491,468	2,823,902	(2,481,032)	342,870	149,123	193,747	2.30
3	8,306,925	3,245,086	(2,036,323)	1,208,763	562,584	646,179	2.15
4	3,479,951	636,362	(482,303)	154,059	904,617	-750,558	0.17

San Francisco Waterfront Coastal Flood Study

Reach	Damages	NED Benefits, 2040-2089	NED Benefits, 2090 -2140	Total NED Benefits	Non-Seismic Cost	Net Benefits	BCR
Total	20,856,569	6,947,867	(5,233,686)	1,714,181	1,822,152	-107,971	0.94
Alternative D							
1	1,584,828	250,491	(248,605)	1,886	270,099	-268,213	0.01
2	6,524,271	2,871,974	(1,561,906)	1,310,068	509,116	800,952	2.57
3	7,476,383	3,330,010	(1,290,705)	2,039,305	721,636	1,317,669	2.83
4	3,086,263	624,576	(76,829)	547,747	1,128,452	-580,705	0.49
Total	18,671,745	7,077,051	(3,178,045)	3,899,006	2,629,302	1,269,704	1.48
Alternative E							
1	434,452	628,632	523,630	1,152,262	4,621,344	-3,469,082	0.25
2	556,059	4,034,467	3,243,812	7,278,279	5,832,004	1,446,275	1.25
3	807,670	5,340,475	3,367,542	8,708,018	6,242,333	2,465,685	1.39
4	355,028	2,302,578	976,403	3,278,982	5,775,445	-2,496,463	0.57
Total	2,153,209	12,306,152	8,111,387	20,417,541	22,471,126	-2,053,585	0.91
Alternative F							
1	143,882	627,631	815,201	1,442,832	2,792,254	-1,349,422	0.52
2	265,043	4,067,968	3,501,327	7,569,295	10,242,290	-2,672,995	0.74
3	891,773	5,342,893	3,281,021	8,623,914	5,174,202	3,449,712	1.67
4	1,983,223	676,750	974,037	1,650,787	1,765,621	-114,834	0.93
Total	3,283,921	10,715,242	8,571,586	19,286,828	18,301,961	984,867	1.05
Alternative G							
1	247,125	628,631	710,958	1,339,589	1,568,503	-228,914	0.85
2	293,399	4,034,266	3,506,673	7,540,940	4,102,464	3,438,476	1.84
3	3,211,672	4,822,057	1,481,959	6,304,016	3,019,975	3,284,041	2.09
4	2,488,744	416,542	728,723	1,145,265	2,208,230	-1,062,965	0.52
Total	6,240,940	9,901,496	6,428,313	16,329,810	10,899,173	5,430,637	1.50

BCR = benefit-cost ratio

There are a number of important takeaways from the results. For the Low and Intermediate curves:

- No structural plans scaled to the higher rate of RSLC (Alternatives E, F, or G) have positive net NED benefits.
- Alternatives C and D are competitive with Alternative B (nonstructural) in Reaches 2 and 3, which have higher-valued assets with current or near-term risk.
- Alternative B is the only solution with positive net NED benefits in Reach 4. Even Alternative B has negative net NED benefits in Reach 1 under the Low curve, which reflects the low existing risk in that reach.

Under the High curve, the structural plans scaled to the higher rate of RSLC are more competitive:

- Every plan except Alternative F has positive net NED benefits in Reaches 2 and 3 under the High curve.
- Structural plans that include Subsequent Actions (Alternatives D, E, F, and G) tend to perform better under the High curve than Alternative C, which has only First Actions.
- Alternative B is competitive in all reaches under the High curve.
- In Reaches 1 and 4, there are structural alternatives that are close to having a BCR of 1, despite the fact that they don't receive more inundation benefits than the smaller alternatives until much later in the study timeframe.

The plans that maximize net NED benefits by reach by RSLC curve are shown in **Table 3-14**. The NED evaluation will likely understate residual risk due to disruption to people and businesses during and after floods (e.g., from a reduction in foot traffic due to streets being flooded) and there will be impacts when high-frequency flooding causes businesses to have to move out of the floodplain, which are not currently calculated under the RED account. Finally, the strict NED evaluation misses the real-world significance that the implementation timeline has on a project of this magnitude in a complex, metropolitan area. Future benefits are discounted heavily in the evaluation, but the lengthy timeline to complete construction means that costs incurred earlier in the evaluation period are not substantially discounted, creating a challenge for justification of large coastal flood studies. The PDT considered this in selection of the Recommended Plan.

Table 3-14: NED Plan by Reach Under Each RSLC Curve

Reach	Low RSLC	Intermediate RSLC	High RSLC
1	No Action	B Int.	B High
2	B Int.	B Int.	G
3	B Int.	B Int.	B High
4	B Int.	B Int.	B High

3.9.3. Insights Gained from NED Evaluation

ER 1103-2-103 Policy for Conducting Civil Works Planning Studies requires that studies should also identify a plan that reasonably maximizes total net benefits including monetized and non-monetized benefits across the NED, EQ, RED, and OSE accounts (i.e., TNBP) consistent with the study purpose. Beyond the four accounts, other decision metrics such as residual risk, long-term exceedance probability, RSLC adaptability, reliability/fragility, and life-safety risk informed the identification of the TSP. This subsection describes the insights gained from the NED analysis to better meet study objectives in a more cost-effective manner (Section 1.9). A more detailed discussion can be found in *Appendix A: Plan Formulation*.

Some insights gained during the initial analysis of the focused array of alternatives are as follows:

- RSLC is the main driver of inundation risk over the study period. The initial engineering suggested that RSLC would be a more significant contributor to the total water surface elevation relative to storm surge and this was confirmed within G2CRM modeling. The interfacing of the storm suite and the economic asset inventory suggests that there is existing risk to the study area from infrequent storm events, but the predominant flood risk comes from RSLC. RSLC may make water levels that occur infrequently today occur monthly or daily in the future.
- Aligning costs and benefits in time helps to maximize net NED benefits. While it may seem efficient to build higher in one phase to have flood risk management measures in place for the future, the analysis demonstrated that building to 15.5 feet or even 19 feet in the initial years is only justified by offsetting risks that occur much later in the study period, if at all. If possible, building to a lower level and then raising the crest elevation when risk increases would be the optimal approach in response to both present and future flood hazards. However, other factors such as constructability, disruption, community and environmental impacts must also be weighed as part of the formulation decision under the comprehensive benefits framework.

- Overtopping of a FWP measure leads to catastrophic damages. Building a measure may shift damages later in time by preventing near- and medium-term damages, but the reduction in hazard means assets don't take protective actions (floodproofing/retreat). Hence, when overtopping occurs, it is in a floodplain with many at-risk assets. Moreover, the water levels are much higher because the coastal defense measure has allowed water to build up behind it; when overtopping occurs, water levels are much higher at the first-floor elevations of the asset. This leads to much higher damages because the benefits accrued before overtopping are "given back" once the measure begins to be overtopped. Preventing overtopping or retreating once the measure is expected to be overtopped will provide more opportunities to maximize net NED benefits.
- The NED OMRR&R benefits, which stem from changes to the existing OMRR&R costs of the extant coastal infrastructure between the FWOP and the FWP, constitute a smaller part of the benefits pool under the High RSLC curve but a larger part of the benefits pool under the Intermediate and Low curves. This is because those benefits differ only marginally by RSLC curve. Note that other "seismic benefits" (outside of the risk to the existing coastal infrastructure) have not been calculated in the NED account to avoid conflict and duplication through the treatment of project costs per WRDA 2020, Section 152, as amended; these benefits are instead qualitatively or semi-quantitatively defined within the OSE account.
- The PDT considered options where smaller-scale measures were built without ground improvements but were provided guidance by USACE that anything that was built in a seismic region would need to achieve USACE seismic codes (meaning plans without ground improvement would not achieve the P&G's Acceptability criterion).
- Measures that may cost effectively reduce risk but are likely to face serious opposition pose a schedule risk. Despite Alternative F having the highest net NED benefits of any measure under the High curve in Reach 3 and being competitive with nonstructural measures in Reach 4, there were concerns about using water management structures across Mission and Islais Creeks. The concerns included that these structures would impact HTRW sites, create water quality concerns, and face opposition from regulatory agencies and the public. There were also concerns about the deployment and reliability of an actively managed flood defense and the issue of the high OMRR&R burden on the NFS.

3.10. Refinement of Net NED Plans Using Insights Gained

To maximize net benefits, costs must be aligned with benefits in time and measures must be of adequate scale to not be overtopped. As such, the PDT considered what kinds of lower-cost, adaptable structures could be built initially. The existing suite of alternatives was formulated to allow evaluation of different risk management

approaches across a range of uncertain future conditions, which allowed for identification of cost-effective solutions for each RSLC curve. They did not, however, fit the bill for aligning the timing of intervention with the arrival of risk.

Alternatives E, F, and G all reduced risk from hazards that did not yet exist, and Alternatives C and D weren't sufficiently adaptable to address a potential High rate of RSLC. Note that for the High RSLC curve, many First Actions were recommended, while for the lower rates of change, fewer (or no) First Actions were recommended.

Because RSLC is uncertain, the rate of change will not be known before having to make a First Action. Therefore, for a First Action to be considered successful in this environment, it needs to perform well at different rates of RSLC. Adaptive actions can be planned for the future, but the First Actions are permanent, such that they cannot be undone if a lower rate of RSLC is realized and the level of flood risk management (and amount of investment) is too high.

As such, the PDT considered whether Alternative D could be adapted around 2090 to the higher height of Alternatives E, F, or G; in essence, moving from a lower-protection plan (13.5 feet) to a higher-protection one (19 feet). Such a plan would allow a lower-cost alternative to be built initially but allow for a suite of adaptations scaled to perform under changing risks in different ways.

Building Alternative D provides an opportunity for a suite of actions that can occur in the future:

- No Subsequent Actions. Building to 13.5 feet is sufficient under the Low RSLC curve.
- Build the Subsequent Actions of Alternative D. This raises the crest elevation to 15.5 feet and is sufficient under the Intermediate RSLC curve. The timing of this move can vary based on the realized rate of change. Under the USACE Intermediate curve, the First Actions are sufficient out to 2130, but a slightly higher rate of change may necessitate sooner action.
- Replace Alternative D with Alternative E or G, built to 19 feet. If observed risk is tracking on the High curve, this move would be necessary by the 2070s to prevent the risk of overtopping of the initial measure. It pushes the higher costs into the future (making it more attractive from a cost-benefit point of view because of the discounting of future costs) but also doesn't incur the cost unless the high rate of change is realized.

Different rates of RSLC will necessitate different Subsequent Actions, meaning the costs are different based on RSLC. This is true for Alternatives D through G (because the planned Subsequent Actions may or may not be necessary) but it is also true for any NED-maximizing plan, as Subsequent Actions are uncertain based on whether they are necessary (depending on RSLC) and when that Subsequent Actions cost is incurred. Removing the Subsequent Actions allows for an analysis that understands RSLC is uncertain and that many different futures exist. Under some rates, a Subsequent Action may be needed sooner, while under other rates, they may be needed later or not at all.

Alternative D is cost-justified under all three RSLC curves for Reaches 2 and 3, though it doesn't perform as well under the High curve because it is overtopped. The structural measures in Reaches 1 and 4 are only justified under the High curve because there are relatively few structures at risk in the near-term in those reaches.

Nonstructural is mostly cost-justified under all three curves, but nonstructural does not perform as well under the High curve later in the POA because assets that were retrofit become permanently or semi-permanently inundated. In most cases, measures that are scaled to the hazard (i.e., that reduce the flood risk without being overbuilt) are justified, and as the flood risk hazard increases, the benefits of potential measures rise faster than the cost of the measures.

What this suggests, then, is that smaller First Actions (Alternative B and Alternative D) are sufficient in the near-term to reduce the flood hazard, but that larger structural measures might need to be brought online to maintain that level of flood risk management under the High RSLC curve. **Table 3-15** shows this framework.

Table 3-15: First and Potential Subsequent Actions, Hybrid Plan

Reach	First Actions	Subsequent Actions Low RSLC	Subsequent Actions Intermediate RSLC	Subsequent Actions High RSLC
1	Alternative B	No Action	Alternative B (Additional nonstructural)	Alternative G (19 feet)
2	Alternative D (13.5 feet)	No Action	Alternative D (15.5 feet)	Alternative G (19 feet)
3	Alternative D (13.5 feet)	No Action	Alternative D (15.5 feet)	Alternative G (19 feet)
4	Alternative B	No Action	Alternative B (Additional nonstructural)	Alternative G (19 feet)

Paying slightly more for Alternative D to provide the adaptability of the measure means that the plan is overbuilt for the Low curve (i.e., there would be higher net NED benefits by just building Alternative C). Nonetheless, having the option to build to 15.5 feet, which is needed under both the Intermediate curve and many of the infinite curves between the Intermediate and High curves, was considered by the PDT to be worth the additional upfront investment, especially because the cost delta between Alternative C and Alternative D is small.

This plan does well in lining up costs and benefits in time because it uses structural measures initially in places with many at-risk assets while nonstructural measures are used where there is less at-risk density and then scales structural measures as risk increases.

Alternative D is preferable to Alternative C because it can be adapted and, when more protection is needed, Alternative G is preferred to Alternative E because it is substantially cheaper. The net NED benefits between Alternatives E and G are close to each other in the southern waterfront, and as such, the comprehensive benefits analysis (which brings in the RED, OSE, and EQ accounts) may suggest a preference for Alternative E, which has less retreat, over Alternative G. Strictly in terms of net NED benefits, though, Alternative G is preferred.

For reference, the Subsequent Actions under the High RSLC curve are all moves to 19 feet in one stage (i.e., the First and Subsequent Actions of Alternative G would be built at once around 2090). This means the costs are approximately the total cost of the sum of the First and Subsequent Actions. In present value (PV), though, the costs are substantially less; instead of the First Actions of Alternative G being built around 2040, they are built around 2090, due to discounting.

This framework relies on monitoring to determine the rate of RSLC and the changing risk. There also need to be “trigger thresholds” that dictate when a Subsequent Action will be undertaken. These thresholds need to respond to the real-world difficulties of construction, including how long it will take to have a project approved, permitted, and built. Additional discussion of these topics can be found in the IFR/EIS and *Appendix G: Monitoring and Adaptation Plan*.

The framework for a “Hybrid Plan” summarized in **Table 3-15** was informed by the NED results from the focused array, but did not yet reflect consideration of RED, OSE, and EQ results. The framework, and the broader lessons learned, informed the decision to include all of the action alternatives (B through G) in the comprehensive benefits analysis at the reach level to develop the TNBP, maximizing net benefits across all benefit categories as required by ER 1105-2-103.

3.11. Final Array of Alternatives

The final array included Alternatives A, B, and G, based on the NED plans resulting from the evaluation of the focused array. The final array also included Alternative F because the PDT considered the combination of competitive NED benefits under the High RSLC curve with the concerns described in Section 3.9.3 warranted additional analysis. The final array included development of the TNBP, which was developed based on the comprehensive benefits analysis across all four P&G accounts as part of final array evaluation.

3.12. Evaluation of the Final Array

Typical feasibility studies identify a NED plan by reasonably maximizing net NED benefits and considering the P&G criteria (completeness, effectiveness, efficiency, and acceptability) and performance differences across RED, OSE, and EQ benefit accounts. ER 1105-2-103 formally requires identification of a plan that reasonably maximizes total net public benefits across all four accounts. In response, the PDT developed a framework for evaluating alternative plans in a comprehensive benefits context.

Important portions of the process and evaluation are presented here, and a summary of the findings is presented in subsequent subsections.

The complexity of the analysis, uncertainty of RSLC timing and scaling, and the compounding complication of factors such as seismic risk, necessitated the development of a framework to guide the analysis. The process to evaluate the final array and develop the TNBP can be described in three steps:

- Step 1: Evaluate the Final Array
- Step 2: Compare the Final Array
- Step 3: Develop the TNBP

For the first step, Evaluate the Final Array, the PDT applied considerable effort to thoroughly define quantifiable metrics to correlate to the specific study objectives to support decision-making in response to this policy. Most of the EQ and OSE benefits are not quantified in dollars, thus the criteria were developed to explore performance differences across plans and to support the developing practice.

The PDT quantitatively and/or qualitatively characterized NED, RED, OSE, and EQ benefits at three RSLC rates, by geographic reach wherever possible. This effort supported the development of reach-level recommendations that would allow selecting the geographic reaches that performed the best for various RSLC scenarios from among the various alternatives in the final array.

This large array of metrics was defined to support evaluation and comparison across alternatives but was reduced to a subset of decision drivers once the quantification was completed. Comparison of the metrics across alternatives illustrated that many did not show meaningful differences and would not influence plan selection; thus, they were deleted to streamline matrix management. Some were informative but did not reflect priority study purposes and were also deleted from the matrix but referenced for descriptive purposes, as appropriate.

For the second step, Compare the Final Array, the PDT used a comprehensive benefits matrix with key decision drivers, described in Section 3.12.2, including summaries of findings for each alternative by reach and RSLC. During this step, the impacts of overinvestment and underinvestment was analyzed by examining the robustness of each alternative under each RSLC scenario, lead times for subsequent adaptation actions, and coastal life safety and seismic performance. This analysis was referred to as a “regret” analysis because overbuilding before risk requires investment and would be inefficient, yet deferring costs until increasing risk is evident may result in insufficient time to adapt.

For the third step, Identify the TNBP, the PDT developed an approach to heat-mapping the results to support identification of the TNBP, by reach as further described in Section 3.12.3 through 3.12.5.

As described in Section 3.8, the alternatives were designed to address the target height of the dominant risk of higher WSEs as RSLCs. This formulation strategy was applied to provide insight about cost-effective performance of plans across time under uncertain risk.

The first comparison of the comprehensive benefits matrix confirmed several relatively intuitive expectations of plan performance and introduced a less obvious insight. NED benefits, which primarily consist of damage avoided, vary as exposure to flood risk is reduced. NED and RED damages are damages avoided and business and regional activities that are disrupted following a flood event.

All metrics vary based on exposure to flood risk, or in other words, metrics vary across alternatives depending on whether assets are located inside or outside of the LOD. Meaningful differences of metrics across alternatives were evident in benefit metrics that are not correlated with the NED benefits, which primarily consist of damage avoided.

Identification of a TNBP required multiple rounds of analysis of plan performance and refinements to identify a plan that best addresses uncertain timing of risk over the POA. The resulting range of multiple scales of actions that can address increasing risk over the POA is a resilience strategy, and the resulting TNBP is a subset of those actions that can be constructed in the near-term and adapted later as suggested by monitoring sea level change and other changing conditions.

The comprehensive benefits matrix measured the four benefit accounts based on exposure to flood hazard and informed the relative performance of plan components and comparison of alternative plans. The factors that led to selecting the TNBP by reach for each RSLC and the timing of investments to produce benefits and accept tradeoffs were life safety, historical district preservation, minimizing construction disruption, concerns with acceptability, and preservation of maritime activity.

3.12.1. Comprehensive Benefits Analysis Approach

NED, RED, OSE, and EQ benefits are discussed comprehensively in *Appendix E: Economic and Social Considerations*. For this study, NED benefits stem from preventing retreat, preventing inundation losses, and protecting the various existing networks in the study area (SFMTA, SFPUC, and the existing coastal defense system). Until recently, the evaluation framework for most studies focused mainly on NED benefits. For this study, RED, OSE, and EQ benefits were evaluated along with NED benefits to produce a comprehensive benefits analysis. This subsection describes how the RED, OSE, and EQ benefits were evaluated.

3.12.1.1. Regional Economic Development

Per IWR's *Regional Economic Development Procedures Handbook* (2011-RPT-01) (IWR 2011), RED impacts are defined as the transfers of economic activity within a region or between regions in the FWOP and for each alternative plan. Spending in an area can spur economic activity, leading to increases in employment, income, and output of the regional economy, while chronic or catastrophic flooding can lead to regional losses of employment and income. IWR 2011-RPT 01 defines three types of RED impacts:

- **Direct effects** are the impacts direct Federal expenditure have on industries that directly support the new project. Labor and construction materials are considered the direct components of a project.
- **Indirect effects** represent changes to secondary industries that support the direct industry. For example, rock quarries used in making cement could be considered indirect parts of a project.
- **Induced effects** are changes in consumer spending patterns caused by changes in employment and income within the direct and indirect industries. The additional income earned by workers may be spent in numerous different ways within the region.

Beyond direct, indirect, and induced output loss, RED impacts include employment losses (described as the number of full-time equivalent jobs lost), and transportation and industrial revenue loss for transportation and industrial systems. These benefits were calculated in the FWOP and the FWP across all three USACE RSLC curves. These RED impacts are described in more detail in the RED Report within *Appendix E: Economic and Social Considerations*.

3.12.1.2. Other Social Effects

The OSE analysis comprises five categories: health and safety, economic vitality, social connectedness, community identity, and social vulnerability, in accordance with USACE guidance. The PDT developed a list of drivers to describe the FWOP condition impacts in each of those five categories. Those drivers, along with how they were measured, are summarized in **Table 3-16**.

Table 3-16: Overview of OSE Categories and Metrics

Category	Measures	Measure Type	Description
Health and Safety	Coastal Life-Safety Risk	Qualitative	Qualitative measure of the relative performance of alternatives with respect to life-safety hazard caused by coastal water levels that can potentially expose populated areas to uninhibited flow of water due to overtopping or failure of the coastal flood risk management alternative.
	Seismic Life-Safety Risk and Resilience	Qualitative	Qualitative measure of the effectiveness of the alternative in minimizing earthquake damage and disruption to waterfront disaster response and recovery functions.
	Compromised Disaster Response Assets	Exposure-Based	Semi-quantitative assessment of the count of disaster response assets exposed to a 1% AEP flood event.

San Francisco Waterfront Coastal Flood Study

Category	Measures	Measure Type	Description
Economic Vitality	Maritime Functions	Qualitative	Semi-quantitative assessment of the alternative's impact on deep-draft berthing and backland area to support maritime functions and jobs.
	Job Access	Qualitative	Qualitative measure of the effectiveness of the alternatives in protecting jobs that support low-income communities. New key driver included in FWP for OSE, relies on data from RED analysis.
Social Connectedness	Public Transit Disruption	Qualitative	Qualitative assessment of the potential temporary and permanent disruption caused for SFMTA, the San Francisco waterfront study area's primary public transit system.
	Recreation	Qualitative	Qualitative assessment of the potential temporary and permanent disruption to recreational resources located within the San Francisco waterfront study area due to coastal and combined flooding.
Community Identity	Community and Cultural Assets	Exposure-Based	Semi-quantitative assessment of the count of community and cultural assets exposed to a 1% AEP flood event.
	Historic District Designations	Qualitative	Qualitative evaluation of historic asset loss and district designation impacts, based on improvements to wharf and pier structures for each alternative.
Social Vulnerability and Resiliency	Exposed and Displaced Populations	Exposure-Based	Semi-qualitative assessment of the percent reduction in exposure for socially vulnerable populations. Social vulnerability indices and statistical significance of children, elderly, minority populations, poverty status, disabilities, linguistic isolation, and single parents utilized. Additionally, permanently displaced population is included in the assessment.
	Disproportionate Effects on Underserved Communities	Qualitative and Exposure-Based	Semi-qualitative measure of the alternative's benefits to low-income communities of color considering historical lack of investment, high potential for community displacement, and high environmental contamination.
	Affordable Housing	Exposure-Based	Semi-quantitative assessment of the count of affordable housing sites exposed to 1% AEP and monthly flooding.

These metrics identify how social well-being could change under the alternatives being evaluated by the PDT.

3.12.1.3. Environmental Quality

The EQ metrics were developed in two categories:

- Physical Environment
- Biological Environment

The metrics under the physical environment reflect changes that would result from the implementation of an alternative, including HTRW contaminated sites, carbon sequestration, water quality, and reduced wave runup through EWN. The metrics under biological environment capture impacts to habitats and T&E species. The metrics were not measured in dollars and supported consideration of broader benefits.

While EQ benefits varied across alternative plans, they did not justify any plan over another. EWN measures were shown to contribute EQ streams over time.

3.12.2. Decision Drivers

The USACE evaluation process now includes the documentation of all benefits (comprehensive benefits analysis) as part of the decision-making process and the identification of a TNBP. An important consideration was to identify the metrics that would drive decision-making and comparative analysis.

After the quantification of the RED, OSE, and EQ metrics, the PDT created a “decision drivers” matrix to help in the visualization of the metrics by plan, reach, and RSLC curve. The “decision drivers” matrix included only a subset of the RED and OSE metrics quantified. Working with fewer metrics was assumed to simplify decision-making, but the PDT did not want to cull metrics arbitrarily. Accordingly, the PDT developed over 40 benefit metrics across RED, OSE, and EQ metrics. More information on the development of the decision drivers can be found in *Appendix A: Plan Formulation*.

3.12.3. Comprehensive Benefits Analysis

For each RSLC, a comprehensive benefits matrix (*Appendix A: Plan Formulation, Section 14, and Appendix E: Economic and Social Considerations, Section 9*) was created using the decision drivers to capture the multiple benefits across NED, RED, OSE, and EQ accounts to support evaluation of the alternatives against study objectives at the plan level and at the individual reach level. Within the decision drivers matrix, individual cells within the matrix were shown with a color to show the comparative value for each metric under each alternative under each RSLC curve. The multiple benefits were numerically scored in units appropriate to the metric, and color coded.

3.12.4. Maximizing Total Net Benefits

From the NED analysis, the NED plan is selected simply by subtracting the costs of the alternatives from the NED benefits by alternative to find which plan has the highest net

benefits. Identification of a TNBP is not so straightforward. ER 1105-2-103 requires the identification of “a plan that reasonably maximizes total net benefits across all benefit categories including monetized and non-monetized benefits,” consistent with the study purpose. However, because benefits are monetary and non-monetary while the costs remain monetary, they cannot simply be subtracted from each other to determine the TNBP. Additionally, these metrics must be considered across the various RSLC curves; just as there was a separate NED plan for each RSLC curve, the TNBP is also likely to vary by curve.

One takeaway from the NED analysis is that the benefits that come from preventing inundation damages tend to support plans that prevent those damages. Alternative C and Alternative D can be justified in 2040, while Alternatives E, F, and G can be justified once there is a moderate amount of RSLC. A major takeaway from the decision drivers matrix is that many of the RED and OSE metrics are highly correlated with the NED inundation benefits, because all of the RED and most of the OSE metrics are also based on exposure to flooding.

If there is a strong correlation between NED, RED, and OSE benefits, a few generalizations can be made:

- If a measure has negative net NED benefits but provides relief from flooding, it is possible that the addition of RED and/or OSE benefits would support an assertion that it has positive total net benefits (i.e., RED and/or OSE benefits can “make up” the negative net NED benefits).
- If two plans have equal positive net NED benefits, the one that provides more flood protection will have higher RED and OSE benefits as well, perhaps with the rationale that the higher flood protection plan is the TNBP.
- If a plan has positive net NED benefits, it is even more defensible than it appears in the NED analysis because of the additive RED and OSE benefits.

With respect to the second bullet, consider Alternatives G and E in the southern waterfront under the High RSLC curve. Alternative G has higher net NED benefits than Alternative E, but Alternative G has a large amount of retreat around 2090. This implies Alternative E provides higher flood protection for those areas and that the additional RED and OSE benefits it achieves may “make up” the difference in net NED benefits.

In Reach 4, Alternative G has slightly higher net benefits than Alternative E (a difference of \$100 million). Because Alternative E protects substantially more structures, it can be argued that Alternative E has slightly higher total benefits. In Reach 3, Alternative G has over \$400 million more net NED benefits than Alternative E; is it worth it to sacrifice those net benefits (or, rather, incur the higher cost of Alternative E) to reap the additional RED and OSE benefits? That question is difficult to answer objectively (i.e., the answer will likely depend on one’s values), but it should be kept in mind as the analysis continues.

Another takeaway has to do with nonstructural and structural solutions. Many of the RED and OSE metrics are based on exposure. Structural measures typically transform risk, removing the hazard but potentially leaving communities at-risk to overtopping or

measure failure. Nonstructural, though, prevents the damage from exposure but does not prevent the disruption of flood events within the community. These disruptions are likely to be disproportionately felt by communities that do not have the resources to mitigate these impacts (even if a nonstructural plan has prevented physical damage to assets in the community). As such, RED and OSE benefits may not be correlated with NED benefits for nonstructural plans, meaning a structural plan in Reaches 1 or 4 may outperform the nonstructural First Actions in terms of total net benefits.

While EQ benefits varied across alternative plans, the EQ account did not justify any plan over another. However, EWN measures were shown to contribute EQ streams over time, and the PDT conducted an effort to optimize EWN measures post-TSP (Section 3.15) to inform the Recommended Plan.

3.12.5. Selecting a Total Net Benefits Plan

The previous section suggests potential changes to the strategy that attempts to maximize net NED benefits across RSLC. The leading reasons for this are:

- RED and OSE benefits correlated with flood risk may support Alternative E in the southern waterfront because its alignment is more bayward than Alternative G; as such, it provides more protection for more assets, land, and people.
- Nonstructural alternatives prevent physical damage but do an incomplete job of preventing RED and OSE losses that may stem from disruption. This may support structural instead of nonstructural First Actions in Reaches 1 and 4.
- Residents of at-risk communities in Reach 4 who live and work near Islais Creek, Pier 94-96, and Heron's Head Park may be impacted by flooding in ways that a nonstructural solution does not mitigate. At-risk communities have less resilience to these impacts; this can be thought of as a "multiplier effect" to the disruption impact.
- Replacement of wharves as part of the plan to reduce flood risk will also provide multi-hazard life-safety benefits and extend the life of some culturally significant landmarks. Replacing wharves also presents the opportunity to preserve maritime berths across the waterfront.
- Resiliency concerns in all four reaches may support larger construction earlier in the project timeframe, so that measures are resilient throughout the POA.
- Disaster response assets may not function in areas where nonstructural solutions are chosen. In Reach 4, there are disaster response assets that will face risk around 2040, including assets located by Piers 92 and 94-96 by Islais Creek and Heron's Head Park.
- Major disruptions from construction should be minimized when possible. One way to do this is by building easily adaptable structures or building resilient structures that provide sufficient defense for a long period of time regardless of

RSLC curve. This is particularly important in Reach 2, where the Embarcadero, a major transportation corridor, will be impacted by construction.

Cost-effective plans that achieve each of these goals must be identified. These plans may differ from the plans that maximize net NED benefits. “Cost-effectiveness” means that, for each metric, there is a least-cost plan that achieves a desired level of output. The following set of cost-effective plans by reach efficiently improves the output of at least one non-NED metric:

- **Structural (Alternative D) in Reaches 1 and 4 instead of nonstructural (Alternative B) as a First Action:** This reduces the RED and OSE risks from disruption and provides particular benefits to at-risk communities in Reach 4.
- **Alternative E as a Subsequent Action under the High RSLC curve in Reaches 3 and 4:** This reaps the benefits of not retreating from the waterfront, protecting businesses, people, maritime function, and disaster response assets.
- **Alternative E or G as a First Action in Reaches 1 through 4:** This provides resiliency to the waterfront against all rates of RSLC and provides the most seismic life safety and maritime benefits. This will also mean that a second major construction will be avoided under the High RSLC curve because the larger First Actions can be more easily adapted to a higher crest elevation.

All of these plans are cost-efficient, though cost-efficiency is a necessary, not sufficient, condition for selecting a plan. Note that neither Alternative C nor Alternative F are mentioned above. For Alternative C, this is because of the lack of adaptability, implying it is not a plan that will provide good outcomes under all rates of RSLC. For Alternative F, it is due to concerns regarding environmental impacts and subsequent agency/public opposition, as well as deployment and reliability of an actively managed flood defense.

First, it was determined that Alternative E would be better Subsequent Actions than Alternative G in Reaches 3 and 4 under the High RSLC curve. This decision was made knowing that the net NED benefits between Alternative E Subsequent Actions and Alternative G Subsequent Actions are reasonably close (Alternative G had \$100 million more in net benefits in Reach 3 and \$400 million in Reach 4, though both plans have positive net NED benefits). Alternative E protects 292 assets that Alternative G would retreat from (195 in Reach 3 and 97 in Reach 4), but that also means that thousands of people will be saved from the impact of retreat, and millions of dollars in RED benefits will be saved (190 of the assets in the area that would be retreated from are commercial or industrial); and in Reach 4, at-risk communities won’t have their homes and jobs displaced. The differences in OSE and RED benefits between Alternative E and Alternative G are described in more detail in *Sub-Appendix E.1: RED Report* and *Sub-Appendix E.2: OSE Report*. As such, Alternative E was chosen as the TNBP adaptive action for High RSLC.

When considering whether to “go big” with the First Actions in the name of resiliency in Reaches 3 and 4, the PDT had to evaluate the feasibility of doing multiple adaptive actions. If the First Actions could be a smaller construction and a larger coastal defense system could be brought online in response to the High rate of RSLC, then the costs of

the larger construction are not worth incurring up front. When discussing replacing the wharves for maritime and life-safety benefits (another benefit of “going big” early), it was determined that these benefits were generally small across the reaches (in the life-safety category) or could be deferred to the later time period (for maritime benefits), except for a few localized areas that could be addressed with subreach level plan refinements. As such, incurring the additional cost in 2040 to build a larger plan across the entirety of Reaches 3 and 4 would not maximize total net benefits.

This is not true in Reach 2. In Reach 2, the seismic life-safety risk is considered more severe due to the Embarcadero’s function as a lifeline for the city. Life-safety risk is also expected to be higher in the high-traffic wharves and piers in Reach 2. Finally, the construction disruption is expected to be most impactful in Reach 2 as construction will impact the Embarcadero, likely shutting down lanes of traffic and impacting public transportation. Mitigating this risk by building something comprehensive instead of disrupting the Embarcadero multiple times with construction over the POA is a large benefit. As such, Alternative G is recommended as the First Actions in Reach 2.

The PDT had to decide whether nonstructural or structural was the correct First Actions in Reaches 1 and 4 because nonstructural measures maximized net NED benefits while structural measures presented numerous other sources of benefits in the RED and OSE categories. This difficult decision came down to the number of exposed assets at various flood heights, composition of those assets, number of people exposed, and existing resiliency of the communities. With these factors in mind, it was determined that Alternative B would remain the First Action for Reach 1 while Alternative D would maximize total net benefits in Reach 4.

The results of the TNBP creation are complex because costs and benefits vary across curves and across the 100-year POA. A few takeaways are described as follows:

- Reach 3 is justified based on NED benefits under all three curves. This speaks to the high existing risk of assets within Reach 3 and the comparatively low cost of the First Actions necessary to provide protection.
- Reach 2 has negative net NED benefits under both the Low and Intermediate RSLC curves. This is expected because the NED analysis suggested a smaller initial plan would do better at aligning the costs with the benefits that were measured in time. The RED, OSE, and EQ analysis suggested additional reasons to favor a larger project initially in Reach 2.
- Reach 4 is also negative in terms of net NED benefits under the Low and Intermediate curves. This is also expected because only nonstructural measures were justified in that reach when considering net NED benefits under those curves. As a large part of the NED analysis is done by computing benefits based on structure and content values and lower-income areas have lower-valued assets that take less damage, only considering NED benefits can lead to underinvestment in lower-income areas. The RED and OSE analysis suggested a structural measure in Reach 4 maximized total net benefits.

- Reach 1 continues to be nonstructural measures at first. The scale of the First Actions for the recommended nonstructural plan is the 2065 High 1% AEP event. This leads to overinvestment under the Low and Intermediate RSLC curve but provides additional resilience in the short-term if a higher rate of rise is realized. As nonstructural retrofits are comparatively easy to identify and plan based on risk and exposure, it may make sense to reduce the number of nonstructural measures recommended for 2040 and rely on an implementation plan that is tied to observed RSLC trends.
- The costs and benefits in this analysis are still tied to First Actions (around 2040) and Subsequent Actions (around 2090). Relaxing this assumption—for instance, by making the Subsequent Actions of Alternative D under the Intermediate curve occur in 2130—does a better job of aligning costs and benefits in time. After the First Actions are taken, the decision about when and whether to adapt the measure can be optimized for a variety of criteria. The framework used here is a simplification, and as such, higher net benefits could be had by relaxing and refining this assumption.
- There are infinite potential RSLC curves between the Low and High curves. USACE uses the three curves as a simplification for analysis, but the TNBP performs best looking at a curve somewhere between the Intermediate and High curves (this is close to the California Likely curve, which is one curve used by the State for regulatory and planning purposes). It is important to recognize that this plan has been chosen based on its resiliency across the different curves.

3.12.6. Total Net Benefits Plan

The TNBP was created by comparing performance of the alternative plans for each reach under each RSLC scenario and across the RSLC scenarios to assess the best series of actions to maximize benefits across all four accounts and achieve the study objectives. Adaptability of the plan components over 100 years is the critical study consideration so that a plan can best address risk under the uncertain timing of RSLC.

Although adaptation has been simplified to reflect implementation in 2090 to model the benefits and costs, the MAP (Appendix G) will be further developed to define risk triggers to clarify the appropriate scale, alignment, and timing of the adaptation. This resiliency requirement drives the TNBP to include multiple potential adaptations to address many potential risk scenarios over the study period. The TNBP was formulated as a resilience strategy, to create a continuum of potential plan adaptations to a changing risk scenario.

The TNBP can differ from the NED plan due to:

- Maximizing net benefits across the four accounts
- Holistic approach to multiple hazards along the waterfront, and multiple Federal agency missions

- Emphasis on adaptation planning (selecting alternatives for their overall ability to function with next actions in mind)
- Early impact analysis and feedback from CCSF agencies
- Regulatory risks to permitting, construction, and cost

The TNBP was developed by considering available benefits in a three-step process to assess efficient flood risk management under uncertain timing of risk and to assess tradeoffs of net NED benefits to achieve more benefits across other benefit categories that are consistent with stated study objectives. The three steps that incrementally analyzed available tradeoffs were:

1. Consider what plan features would maximize NED benefits without a specified RSLC scenario.
2. Consider the overall value of higher net benefits for those areas where total net benefits are correlated with NED benefits. For example, consider plan features that provide risk management to the greater study area population and achieve OSE benefits to offset the loss of net NED benefits as the cost of the alternative increases.
3. Consider justification of specific tradeoffs in timing or actions to achieve benefits that are not correlated with NED benefits. For example, consider greater investment earlier in Reach 2 and Reach 4 to avoid disruptions and achieve OSE benefits consistent with study objectives.

Details on the development of the TNBP can be found in *Appendix A: Plan Formulation*. The TNBP is summarized in **Table 3-17**.

Table 3-17: TNBP First and Subsequent Actions

Reach	First Actions	Subsequent Actions Low RSLC	Subsequent Actions Intermediate RSLC	Subsequent Actions High RSLC
1	Alternative B	N/A	Alternative B (Additional NS)	Alternative G 19 feet
2	Alternative G 15.5 feet	N/A	N/A	Alternative G 19 feet
3	Alternative D 13.5 feet	N/A	Alternative D 15.5 feet	Alternative E 19 feet
4	Alternative D 13.5 feet	N/A	Alternative D 15.5 feet	Alternative E 19 feet

The costs of the TNBP under all three RSLC scenarios are provided in **Table 3-18** through **Table 3-20**.

Table 3-18: Cost of First Actions, TNBP

(PV, FY 2023 Price Level; \$1,000s)

Reach	Plan	Total First Cost (Non-Seismic)	Duration (months)	IDC	Subtotal AAC	OMRR&R	Total AAC
1	B High 2040	61,737	3	127	1,822	-	1,822
2	G	2,972,349	180	621,514	105,854	14,862	120,716
3	D	367,809	96	38,426	11,965	1,839	13,804
4	D	736,256	96	76,918	23,951	3,681	27,633

AAC = Average Annual Cost

IDC = Interest During Construction; IDC only included on First Actions.

Table 3-19: Additional Cost of Subsequent Actions, Intermediate RSLC Curve

(PV, FY 2023 Price Level; \$1,000s)

Reach	Plan	Total First Cost (Non-Seismic)	Total AAC
1	B 2065	884	26
2	N/A	-	-
3	D	252,965	7,451
4	D	190,295	5,605

AAC = Average Annual Cost

Table 3-20: Additional Cost of Subsequent Actions, High RSLC Curve

(PV, FY 2023 Price Level; \$1,000s)

Reach	Plan	Total First Cost (Non-Seismic)	Total AAC
1	G	318,793	9,390
2	G	4,030	119
3	E	1,369,510	40,338
4	E	1,200,471	35,359

AAC = Average Annual Cost

3.13. Tentative Plan Selection

The TNBP was identified as the TSP because it was responsive to the study guidance and embodied a resilience strategy that maximizes effectiveness across a broad array of future risk scenarios. This was informed by the comprehensive benefits evaluation (Section 3.12.3) and the effects and consequences analysis documented in Section 4.0. The TSP (**Table 3-21**) was presented in the Draft IFR/EIS, alongside the evaluation results, for public and agency comment.

Table 3-21: TSP First and Subsequent Actions

Reach	First Actions	Subsequent Actions Low RSLC	Subsequent Actions Intermediate RSLC	Subsequent Actions High RSLC
1	Alternative B	No Action	Alternative B (Additional nonstructural)	Alternative G 19 feet
2	Alternative G 15.5 feet	No Action	No Action	Alternative G 19 feet
3	Alternative D 13.5 feet	No Action	Alternative D 15.5 feet	Alternative E 19 feet
4	Alternative D 13.5 feet	No Action	Alternative D 15.5 feet	Alternative E 19 feet

3.14. Independent Measures

The following list of “independent measures” represented a series of measures included in the draft NEPA analysis separately. Each measure was sourced from (or was similar to a measure included in) one or more alternatives. Four of the seven independent measures were eventually incorporated into the Recommended Plan because the PDT determined that they would increase benefits, lower costs, or reduce impacts.

Independent measures incorporated into the Recommended Plan to increase benefits, lower costs, and reduce impacts include:

- **Living Seawalls** (e.g., textured concrete on a vertical seawall) would be designed to reduce wave hazards while supporting nearshore ecology wherever current maritime uses and pier configurations allow. This measure was originally included in Alternative E (First Actions) and is applicable to portions of Reaches 1, 2, and 3. Further details are available in *Appendix I: Engineering with Nature*.
- **Robust Coastal Defense of Ferry Building and Agriculture Building** would be designed to realign the coastal flood defense structure adjacent to the bayside

edge of the Ferry Building and Agriculture Building. The structures could be raised in place with a basement structure or some solid fill underneath. This approach is anticipated to be preferable from an engineering perspective. This is comparable to Alternative E (First Actions).

- **Coarse Beach at Rincon Park** connecting to Pier 14 would be designed to reduce wave hazards, support nearshore ecology, and provide public water access. Some new bay fill is included in this measure so as to address space constraints of the transportation network at this site. This measure is similar to the measure for this location included in Alternative F (First Actions). This independent measure evolved into an engineered rocky intertidal measure in the Recommended Plan. *Appendix I: Engineering with Nature* contains further details.
- **Bay Bridge to South Beach Harbor Raised Shoreline with Rebuilt Wharves** from the Bay Bridge to the mouth of Mission Creek, raise the current shoreline (rather than extending the shoreline into the Bay). This will require redesign of the northbound lanes of the Embarcadero roadway (in collaboration with SFMTA and the Embarcadero Enhancement Project), and the approach is intended to be designed to avoid reconstruction of the light rail track. This is comparable to Alternative G (2040) for this site.

Independent measures that were not incorporated into the Recommended Plan include:

- **McCovey Cove North Curb Extension** raises the shoreline in line with the current shoreline edge on the north side of McCovey Cove (along the ballpark), rather than adding fill and extending the shoreline into the creek. This is comparable to Alternative G (First Actions) for this site.
- **Planted Naturalized or Embankment Shoreline on Mission Bay** south of Pier 50 would be designed to reduce wave hazards, support nearshore ecology, and provide public water access. This measure was originally included in alternative F (First Action).
- **Inland Coastal Flood Defense at Southwest Islais Creek** would include conversion of some industrial lands and public facilities to provide public water access, open space, and ecological benefits. It would also result in more permanent flood risk management due to a small area of gradual retreat along the creek. This is comparable to Alternative G (Subsequent Actions) between the 3rd Street bridge and the inland extent of the channel.

3.15. Refinements Following Draft Report Review

The Draft IFR/EIS was released for public, agency, and stakeholder review in January 2024. As part of the USACE review process, the draft report also underwent agency technical review, USACE policy review, and independent external peer review. Based on the comments received from the review processes, the PDT conducted several

analyses to increase confidence in project benefits, costs, or impacts, and incorporated refinements to the TSP to increase benefits and reduce costs and impacts.

The following review items, organized by technical discipline, led to additional analyses and refinements of the TSP:

- **Engineering – Geotechnical:** The PDT conducted additional desktop research to increase confidence in the type, scale, quantity, location, and geometry of ground improvement necessary to achieve USACE seismic design requirements for structural measures. This analysis resulted in refinements to the extent and volume of ground improvement in the TSP, which subsequently reduced costs of the ground improvement and potentially reduced disturbance for the Recommended Plan (*Appendix B: Engineering*). Further geotechnical analysis will be conducted in the design phase. Note that reductions in the area needed for ground improvement will not necessarily reduce the overall project footprint given other needs as described in *Appendix A: Plan Formulation*.
- **Engineering – Coastal:** The PDT conducted a sensitivity analysis on coastal modeling to increase confidence in the design height of structural measures (*Annex B.1.3: Wave Overtopping Sensitivity*). This did not result in changes to the design assumptions to develop the Recommended Plan. Further analysis will be conducted in the design phase.
- **EWN:** Several public comments expressed a desire for the plan to include more NNBFs. The PDT reviewed the full range of NNBFs across all alternatives and selected the best NNBFs to optimize coastal flood risk reduction and net benefits. This resulted in an optimized suite of NNBFs in the Recommended Plan (*Appendix I: Engineering with Nature*). Opportunities for additional NNBFs will be evaluated in the design phase.
- **Real Estate:** USACE Real Estate prepared a Gross Appraisal for this Final IFR/EIS. The Gross Appraisal is a more detailed evaluation of the costs of real estate than the preliminary real estate estimate prepared for the Draft IFR/EIS. Consequently, the real estate costs for the Recommended Plan have increased significantly from the costs of the TSP (*Appendix F: Real Estate Plan*).

Additionally, the PDT also made targeted refinements to the TSP to further increase cost-effectiveness, reduce impacts, and gain additional benefits. This included the following:

- Addition of two new deployable closure structures to address potential flood pathways
- Minor adjustments to the structural alignment to avoid impacts to infrastructure and historic resources
- Adjustments to wharf raising with the defense structures
- Optimization of NNBFs

- Identification of additional buildings for floodproofing
- Adjustments to the treatment (e.g., move, elevate, or demolish) for select buildings adjacent to coastal defense structures

Other design and value engineering refinements to reduce impacts and costs will be considered during the design phase.

The post-TSP refinements also included incorporation of four of the independent measures that were presented in the Draft IFR/EIS:

- Living Seawalls
- Robust Coastal Defense of Ferry Building and Agriculture Building
- Coarse Beach at Rincon Park connecting to Pier 14 (approach adjusted to an engineered rocky intertidal feature rather than a coarse beach [*Appendix I: Engineering with Nature*])
- Bay Bridge to South Beach Harbor Raised Shoreline with Rebuilt Wharves

Consequently, the Recommended Plan includes these refinements (**Table 3-22**) as a modification to the TSP presented in the Draft IFR/EIS.

Table 3-22: Summary of Refinements

Refinements to First Actions ^a	Reach(es)
Refined extent and volume of ground improvement	2, 3, 4
Added deployable closure structures to address potential flood pathways	2, 3
Minor adjustments to the structural alignment to avoid impacts to infrastructure and historic resources ^b	2, 3
Adjustments to wharf raising with the defense structures ^c	2, 3
Identification of additional buildings for floodproofing	1, 2, 3
Adjustments to the treatment (move, elevate, or demolish) for select buildings adjacent to coastal defense structures	4
Incorporation of living seawalls (e.g., textured concrete on a vertical seawall) in seawall design wherever current maritime uses and pier configurations allow ^d	2, 3
Added engineered rocky intertidal feature ^e	2
Creek enhancements incorporated with structural measures	3, 4
Wetland enhancements to protect existing wetlands	4

^aAll refinements apply to First Actions; Subsequent Actions not substantially altered from TSP to Recommended Plan.

^bIncludes independent measure called *Robust Coastal Defense of Ferry Building and Agriculture Building*

^cIncludes independent measure called *Bay Bridge to South Beach Harbor Raised Shoreline with Rebuilt Wharves*

^dIncludes independent measure called *Living Seawalls*

^ePreviously referred to as the independent measure called *Coarse Beach at Rincon Park connecting to Pier 14*

Section 4.0 Effects and Consequences of Alternative Plans*

This section forms the scientific and analytic basis for the comparison of reasonable alternatives carried forward as required by NEPA and the Fiscal Responsibility Act of 2023. The consequences analysis is based on reasonably foreseeable effects and describes the significance of those effects, granting more focus to those that are considered significant and/or important impacts. These potential impacts apply to the affected environment described in Section 2.0 and include a discussion of cumulative impacts, long-term and short-term adverse and beneficial impacts, identifies any unavoidable adverse impacts, indicates any irreversible and irretrievable commitment of resources, and describes the relationship between short-term uses and long-term productivity. The No Action Alternative, synonymous with FWOP, serves as the baseline against which the alternatives are compared. Unless otherwise stated, desktop available data were overlaid with alternative alignments in conjunction with a review of existing literature to evaluate and disclose the anticipated impacts in sufficient enough detail that meaningful comparisons of environmental consequences between alternatives could be made. This section does not provide an exhaustive description of impacts, rather uses a high-level overview and comparison of the alternatives to discern meaningful contrasts between plans. Technical analyses used to support descriptions in this section can be found in *Appendix D: Environmental and Cultural Resources*.

Appendix D describes the impacts anticipated after avoidance and minimization measures (AMMs) have been incorporated into the designs and construction methodology of each feature. For each resource area, the appendix fully describes the AMMs that have been committed to. Additionally, if unavoidable impacts remain, compensatory mitigation is described in these sections, with the exception for significant ecological habitats, which are described in *Appendix K: Compensatory Mitigation Plan*.

Section 3.0: Plan Formulation and Evaluation, identified five reasonable alternatives that are analyzed in this section:

- No Action – NED Low RSLC Curve
- Alternative B (Nonstructural) – NED Intermediate RSLC Curve
- Alternative F
- Alternative G – NED High Curve
- TNBP

Of note, the Draft IFR/EIS included a separate analysis of independent measures for consideration that have now been screened or fully incorporated into the Recommended Plan, and thus, are not discussed separately in this Final EIS. Additional considerations and justifications for these decisions can be found in Section 3.14. The proposed action would be implemented in incremental steps (*Appendix G: Monitoring and Adaptation Plan*), as such, the consequences of each resource are described for the initial construction action (also referred to as First Actions), as well as Subsequent Actions that incur environmental impacts at a future time step commensurate with a RSLC threat that would warrant additional protection (*Appendix G: Monitoring and Adaptation Plan*). This section describes the impacts assumed to be incurred with First Actions because those are being sought for Congressional authorization at the time of

this report. However, the full extent of consequences for each alternative, to include the First and Subsequent Actions is described in *Appendix D: Environmental and Cultural Resources*. USACE would seek a future Federal decision for the Subsequent Actions; therefore, anything outside of the First Actions in the Recommended Plan would trigger additional or subsequent NEPA to be performed and completed prior to construction.

Sub-Appendix D.1 details mitigation measures by resource that would be implemented to minimize the environmental consequences of alternatives as applicable and/or possible.

This section is organized by describing methodology for evaluating impacts, followed by environmental consequences and impacts common to all action alternatives. Finally, a cumulative impacts analysis is provided in Section 4.6.

Impacts of the No Action Alternative, the FWOP, are described in Section 2.0.

4.1. Methodology for Describing Environmental Consequences

Impacts are described as either *beneficial* or *adverse*. *Beneficial* impacts result in a positive change in the condition of the resource when compared to the No Action Alternative. *Adverse* impacts result in a negative change in the condition of the resource when compared to the No Action Alternative.

All potential impacts, both beneficial and adverse, are described by their characteristics:

- Type (direct, indirect, cumulative)
- Duration (short-term, long-term, permanent)
- Geographic extent (localized or beyond project boundaries)

Note: The terms *consequences*, *impacts*, and *effects* are considered synonymous in this analysis.

4.1.1. Types of Potential Impact

The following definitions of potential impacts were applied to this analysis, consistent with the CEQ regulations in 40 CFR 1508.1(g). These categories are used to describe the nature, timing, and proximity of impacts on the affected resources:

- **Direct impact:** A known or potential impact caused by the proposed action or project that occurs at the time and place of the action.
- **Indirect impact:** A known or potential impact caused or induced by the proposed action or project that occurs later than the action or is removed in distance from it, but is still reasonably expected to occur.
- **Cumulative impact:** A known or potential impact resulting from the incremental effect of the proposed action added to other past, present, or reasonably foreseeable future actions. The timeframe for the cumulative impact analysis is 5 to 10 years after project implementation.

4.1.2. Duration of Potential Impact

The duration of potential impacts is short-term, long-term, or permanent. This indicates the period during which the resource would be impacted. Duration considers the permanence of an impact and is defined as:

- **Short-term impact:** A known or potential impact of limited duration, relative to the proposed action and the environmental resource. For this analysis, short-term impacts may be instantaneous or last from minutes up to 5 years.
- **Long-term impact:** A known or potential impact of extended duration, relative to the proposed action and the environmental resource. For this analysis, long-term impacts are those lasting longer than 5 years.
- **Permanent impact:** A known or potential impact that is likely to remain unchanged indefinitely.

4.1.3. Geographic Extent of Potential Impacts

The geographic extent of potential impacts are:

- **Localized:** Impacts that are site-specific and generally limited to the area within the project boundaries.
- **Beyond proposed boundaries:** Impacts that are unconfined or unrestricted to the project boundaries. These impacts may extend in the immediate vicinity of the project area or throughout the region.

4.1.4. Significance

Finally, impacts are described in relation to their significance. In considering whether the effects of the alternatives are significant, the potential affected environment and degree of the effects of the action are analyzed.

The magnitude or intensity of the proposed action was qualitatively and quantitatively assessed by the degree to which each alternative would impact a resource. The following descriptors are used in this section for consistency in describing impact intensity in relation to significance:

- **No or Negligible Impact:** Impact would cause no discernible change in the environment and does not require mitigation.
- **Less than Significant:** Impact would cause no substantial adverse change in the environment and would not require mitigation. Less than significant determinations also apply to impacts that are determined to be significant based on the significance criteria, but for which mitigation could be implemented to avoid or reduce the environmental effects to less than significant levels.

- **Significant and Unavoidable:** Impact would cause a substantial adverse change in the environment that cannot be avoided or mitigated to a less than significant level if the project is implemented.
- **Too Speculative for Meaningful Consideration:** Impact may have a level of significance that is too uncertain to be reasonably determined and would therefore be considered too speculative for meaningful consideration. Where some degree of evidence points to the reasonable potential for significant impacts, the section may explain that a determination of significance is undetermined, but is still assumed to be “significant.” In other circumstances, after thorough investigation, the determination of significance may still be considered too speculative to be meaningful. This is an impact for which the degree of significance cannot be determined for specific reasons, such as unpredictability of the occurrence or the severity of the impact, lack of methodology to evaluate the impact, or lack of an applicable significance threshold.

4.2. Natural Environment

4.2.1. Aquatic Resources

Adverse impacts to aquatic resources for any action alternative are commensurate with the anticipated level of in-water work. In general, the adverse and beneficial impacts of action alternatives can be summarized by:

- Alternative B would have **minimal to negligible impact** to aquatic resources, attributed to pier removal, noise, and turbidity.
- Alternative F would have the greatest impacts, resulting in **significant adverse impacts** through construction of tide gates, bay fill, and new seawall bayward of the existing structure.
- Alternative G would have **negligible** adverse impact during construction and would have the highest **beneficial impact** to aquatic resources with expansion of habitat through NNBFs.
- The Recommended Plan would have **less than significant adverse impacts with mitigation**, attributed to wharf replacement, installation of sheet-pile walls, and bay fill. Long-term **beneficial impacts** would be expected with improved habitat through NNBFs.

Short-term direct impacts from construction-related activities are anticipated to adversely affect aquatic habitat and wildlife, whether they occur as a resident, migrant, or incidental, within or near the project area. Impacts include habitat removal and/or fragmentation and habitat avoidance due to increased noise, dust generation, vibrations, debris, accidental discharge, and overall lower quality habitat.

Temporary in-water impacts could include increased turbidity during construction activities and resuspension of sediments into the water column during pile driving, placement of concrete blocks, dewatering, and excavation and fill activities. Temporary

and localized impacts to aquatic habitats from vessel anchoring and dewatering activities may occur during active construction. Spills or leaks of fuels, lubricants, and coolant from construction equipment could significantly impact water resources. This could pose temporary risks of exposure of resident aquatic organisms to toxic contaminants and non-edible forage. A site-specific spill prevention control and countermeasure plan) would be developed and implemented to prevent spills and minimize the potential impacts for any inadvertent spills. With implementation of the spill prevention control and countermeasure plan and best management practices (BMPs), impacts from spills or leaks are anticipated to be minor. Water quality is anticipated to return to baseline conditions after construction activities are completed.

Permanent adverse impacts to aquatic fauna include habitat loss through measures such as bulkhead wall construction, wharf replacement, and in-bay fill. Fish are expected to actively avoid most in-water work areas, opting for another appropriate habitat nearby. This avoidance behavior would occur only in those areas where construction is underway. Fish species are expected to return to the area when construction is completed.

Any sessile and/or benthic organisms present on the seabed during bay fill would be smothered and lost. Additionally, bay fill would render affected areas inhabitable and inaccessible to aquatic organisms. The lost habitat would also impact food availability locally for fish, including special status species, which rely on pelagic phytoplankton or benthic organisms for food sources. BMPs would be in place to reduce the likelihood of inadvertent spills of fill material outside of the intended area; however, if spill were to enter the water column, it would result in turbidity that could temporarily affect visual predators and/or suffocate filter feeding invertebrates. The permanent loss of aquatic habitat, and potential loss or injury of marine species because of in-bay fill would be ***significant and unavoidable***.

Losses of slow moving and less mobile species (e.g., aquatic invertebrates and benthic species) are anticipated within the construction footprint due to burial of individuals and/or increased turbidity. Suspension/filter feeding organisms could be impacted due to clogging of gills and feeding mechanisms, which would cause death or reduce growth and reproduction. Visual predators would have a reduced success rate at catching prey due to lower visibility levels. Following construction activities, water quality is expected to return to preconstruction conditions.

In general, most fish, wildlife, and benthic species would become habituated to the work and adapt to the habitat changes; however, species with low tolerance are anticipated to be displaced for the duration of activities. The severity of the impacts is dependent on the final design of features, type of equipment used, and duration of construction activities. Once construction is complete, it is anticipated that construction-related impacts to aquatic organisms would cease. These adverse impacts would be minimized and controlled by implementing the best available practical techniques and BMPs during construction.

Long-term beneficial impacts to aquatic resources are expected with NNBFs such as enhanced or created wetlands, ecological armoring, and vertical shorelines/living seawalls, as they would result in improved habitat conditions and an expansion of

available habitat for aquatic species. Beneficial impacts would be realized with improved diversity, new refuge for aquatic plants and animals, support for increased abundance and foraging opportunities, and new habitat space for colonization. Long-term beneficial impacts could also occur with removal of creosote pilings through improved water quality.

BMPs would be used to minimize impacts to aquatic resources, while compensatory mitigation would help to offset permanent losses to aquatic resources.

Table 4-1 is a summary of the impacts of the action alternatives on aquatic resources.

Table 4-1: Comparison of Measures Impacting Aquatic Resources by Alternatives for First Actions

Alternative	Bay Fill (acres)	Seawall (LF)	Wharf (LF)	NNBF (acres)	Wetland (loss/gain)
No Action	0	0	0	0	Loss
Alternative B	0	0	0	0	Loss
Alternative F	25	13,115	15,800	15	Gain
Alternative G	0	14,600	27,270	40	Gain
Total Net Benefits	9	21,000	10,900	27	Gain

LF = linear feet

4.2.2. Upland Resources

Adverse impacts to upland resources for any action alternative are commensurate with the anticipated level of land work. Amongst action alternatives, noise, light pollution, and physical disturbance are the most likely mechanisms for adverse impacts. In general, the adverse and impacts of action alternatives can be summarized by:

- Alternative B would have **no to less than significant impacts** to upland resources.
- Alternative F would have **no to less than significant impacts**.
- Alternative G would have **less than significant** adverse impact during construction and would have the **significant beneficial impact** with expansion of habitat through NNBFs.
- The Recommended Plan would have **no to less than significant adverse impacts**. Long-term **beneficial impacts** would be expected with improved habitat through NNBFs.

Short-term, localized, adverse effects to wildlife are expected to occur during construction from noise, light pollution, and general physical disturbance of the environment. The level of impact from noise on wildlife depends on decibel levels, durations, the physical characteristics of the environment, and the species threshold to disturbance (Sordello et al. 2020). Overall, impacts from noise would be localized to the general vicinity of the construction zone and limited to the duration of the construction activity. Any wildlife displaced by noise would likely return to remaining habitat once construction is complete. Noise generated from construction activities would be temporary and localized but would be expected to increase the ambient city noise.

Direct injury and/or mortality of birds, small mammals, reptiles, amphibians, and invertebrates may occur during construction through inadvertent destruction of dens, nests, cryptic organisms, or trampling of slower moving or sessile species by heavy equipment or personal vehicles. Mobile species are expected to be capable of avoiding injury or death while crossing haul roads and by avoiding the construction area.

Alternative G maximized the addition of NNBF features as the LOD was retreated inland with RSLC, adding approximately 700+ acres of new green space that transforms the waterfront from mostly urbanized to potential habitat for vegetation and wildlife. The Recommended Plan also incorporates NNBF through ecotone levees, saltmarsh augmentation, and naturalized shorelines. This provides new wildlife corridors and habitat connectivity that is not currently present in the study area. Native grasses would be planted in NNBF features to maximize the survivability and function of the environment, while invasive species would be controlled and managed to reduce establishment or spread. Overall, this would have substantial positive benefits for upland resources.

4.2.3. Special Status Species

The impacts described in Sections 4.2.1 and 4.2.2 would be applicable to marine and terrestrial protected species, respectively, under each action alternative. A biological assessment was prepared to document the impacts of implementing the TSP on ESA-listed species (Sub-Appendix D.5 and Sub-Appendix D.6). Details of construction-related impacts and effects determinations for affected species can be found in the biological assessment. A brief impact assessment was conducted for each action alternative; however, some species were not expected to be impacted by any action alternative because the study area is outside of their known range and/or the area lacks suitable habitat. The USACE determined all action alternatives would have ***no effect*** on the following list of ESA species:

- **Mammals**: Blue whale, Fin whale, Killer whale, North Pacific right whale, Sei whale, Sperm whale
- **Birds**: Western snowy plover
- **Reptiles**: Alameda whipsnake, San Francisco garter snake, Green sea turtle, Leatherback sea turtle, Loggerhead sea turtle, Olive Ridley sea turtle
- **Amphibians**: California red-legged frog

- **Fish**: Delta smelt, Tidewater goby, White abalone
- **Insects**: Monarch butterfly
- **Flowering plants**: Franciscan manzanita, Marin dwarf-flax, Presidio clarkia, Presidio manzanita, San Francisco lessignia, Showy Indian clover, Sonoma sunshine, White-rayed pentachaeta

Adverse impacts to special status species for any action alternative are associated with noise, light pollution, and physical disturbance during construction. In general, the impacts of action alternatives can be summarized by:

- Alternative B would have **less than significant impacts** to terrestrial special status species through mild disturbances during demolition, floodproofing, and relocations.
- Alternative F would have **less than significant adverse impacts with mitigation** with in-water construction activities and installation of tidal gates. Long-term **beneficial impacts** would be expected with addition of NNBFs.
- Alternative G would have **less than significant** adverse impact during construction and would have the highest **significant beneficial impact** with expansion of habitat through NNBFs.
- The Recommended Plan would have **less than significant adverse impacts with mitigation** to aquatic special status species during construction, and **significant and unavoidable** impacts with bay fill upon project completion due to the permanent loss of habitat. For terrestrial species, long-term **beneficial impacts** would be expected with improved habitat through NNBFs, while short-term **adverse impacts** during construction would be **less than significant**.

Terrestrial mammal species (i.e., salt marsh harvest mouse) would experience temporary impacts from vegetation removal, noise, and vibrations during construction site preparation activities. Special status birds that could be present in the study area are predominantly marine or waterfowl that use both aquatic and terrestrial habitat for survival, but there are also small terrestrial species (i.e., bank swallow) that could be adversely impacted during construction. Temporary impacts associated with habitat disturbance, lighting, and noise are expected during construction from activities such as earthwork, use of heavy machinery, pile driving, demolition, placement of fill, installation of stone and concrete, and ground improvements. Turbidity from runoff and dust accumulated in the water column from shore-based construction could temporarily disrupt foraging rates of shore birds, migratory birds, and pelagic species that utilize open water or benthic habitat. It is anticipated that birds would utilize suitable adjacent habitat until construction is complete. Turbidity impacts would be localized and expected to cease when construction is complete.

Protected aquatic species are expected to experience temporary impacts from habitat disturbance with construction of in-water features such as displacement of marine fauna associated with noise, vibration, and physical disturbance. Potential direct impacts during construction include physical contact with construction equipment such as

entanglement and vessel strikes, entrainment, exposure to underwater noise, degraded water quality, and exposure to water or effluent discharges. Sessile and some benthic invertebrates would be lost during removal and replacement of pilings for wharf replacement actions. This would temporarily disrupt prey availability in localized areas for marine protected fish and birds. Other areas would be available for consumption and foraging within and adjacent to the study area, so it is assumed mobile fish and birds would shift elsewhere.

4.3. Physical Environment

4.3.1. Air Quality

Adverse impacts to air quality for any action alternative are commensurate with the anticipated level of construction. Amongst action alternatives, equipment and machinery emissions are the greatest contributors for adverse impacts. In general, the adverse impacts to air quality between action alternatives can be summarized by:

- Alternative B would have **less than significant impact**, with a greater degree of emergency response than other alternatives.
- Alternative F would have **less than significant adverse impacts** to air quality.
- Alternative G would have **less than significant adverse impacts** to air quality. Long-term **beneficial impacts** would be expected with increased sequestration abilities with NNBFs.
- The Recommended Plan would have **less than significant adverse impacts** to air quality. Long-term **beneficial impacts** would be expected with increased sequestration abilities with NNBFs.

Construction activities would result in the generation of dust and emissions from heavy machinery, including the use of emergency generators and maintenance. The specific intensity of air quality impacts through 2040 (First Actions) and from 2070–2130 (Subsequent Actions) would depend on various factors, including the specific location of construction, the duration of construction or modification activities, and the type and number of pieces of equipment used. The intensity and magnitude of criteria pollutants from construction emission sources would be reduced during buildout by State and local regulations. Based on the best available information, the First Actions are below *de minimis*.

4.3.2. Meteorological Conditions

Adverse impacts to meteorological conditions for any action alternative are commensurate with the anticipated level of construction. Amongst action alternatives, equipment and machinery emissions are the greatest contributors for adverse impacts. In general, the impacts of action alternatives can be summarized by:

- Alternative B would have **less than significant adverse impacts**.
- Alternative F would have **less than significant adverse impacts**.

- Alternative G would have **less than significant adverse impacts** during construction and would have **beneficial impacts** with expansion of habitat through NNBFs.
- The Recommended Plan would have **less than significant adverse impacts** to meteorological conditions. Long-term **beneficial impacts** would be expected with increased sequestration abilities with NNBFs.

Construction emissions generated may be offset, to some degree, by a reduced need for emergency action and response. Temporary localized emission increases would be produced from diesel-powered construction equipment working at the various project locations such as operating on- and off-road mobile sources, heavy machinery, non-mobile mechanized equipment, and support vehicles; released CO₂ embedded in steel and concrete during fabrication; and energy consumption (**Table 4-2**).

Table 4-2: Greenhouse Gas Emission Comparison Amongst Action Alternatives

Emissions Estimate (metric tons CO ₂ [MTCO ₂])	Alternative B	Alternative F	Alternative G	Recommended Plan
Annually (MTCO ₂ / year)	24,432	147,610	99,255	80,248
Total (MTCO ₂)	1,222,000	2,952,000	1,985,000	1,604,964

The localized emission increases from the diesel-powered equipment would last only during the project's construction period in each location and then end when the project phase is complete, thus any potential impacts would be temporary in nature and geographically dispersed over the project duration.

There are no apparent negative impacts to carbon sequestration (e.g., loss of wetlands) that would result from implementation of the action alternatives; rather a net gain in carbon sequestration benefits is anticipated with the addition of marsh habitat through NNBF features.

4.3.3. Soils and Minerals

Adverse impacts to soils and mineral resources for any action alternative are commensurate with the anticipated level of dirt-work and land-based construction. In general, the impacts of action alternatives can be summarized by:

- Alternative B would have **negligible impacts** with minor surface work for infrastructure and demolition occurring.
- Alternative F would have **less than significant impacts**.
- Alternative G would have **less than significant impacts** during construction and would have **beneficial impacts** with expansion of habitat through NNBFs.

- The Recommended Plan would have **less than significant** impacts to soils during construction and would have **beneficial impacts** with NNBFs.

Soils would be disturbed as the topsoil and several inches to feet of subsoil would be removed to construct new access roads, flood risk features, and any staging areas. During removal, there is a chance that shallow soil horizons could be mixed, resulting in the blending of soil characteristics and types. This blending would modify physical characteristics of the soil structure, texture, and rock content, potentially leading to a loss of soil productivity and reduced reclamation potential. Compaction from repetitive use or use by heavy equipment would reduce aeration, permeability, and water-holding capacity of soils. An increase in surface runoff could be expected, potentially leading to erosion during construction. After heavy precipitation events, additional soil impacts may occur, such as soil saturation and water erosion. When saturated areas are used, tire ruts develop, increasing the compaction rate and affecting the ability for vegetation to reestablish unless mitigated. Wind erosion would be expected to be a minor contributor to soil erosion except for dust from vehicle traffic traveling on dry access roads during construction. Fill material was assumed to be commercially sourced but has the potential to be beneficial use of dredged material.

The magnitude, extent, and duration of construction-related impacts depend on the erodibility of the soil; proximity of the construction activity to receiving waters; and the construction methodologies, duration, and season.

All action alternatives are anticipated to have **no impact** on mineral resources.

4.3.4. Hydrology and Hydraulics

Adverse impacts to hydrology and hydraulics for any action alternative are commensurate with the anticipated level of permanent in-water features. In general, the impacts of action alternatives can be summarized by:

- Alternative B would have **no impacts** because all construction-related activities are land-based.
- Alternative F would have **less than significant** impacts for most features during construction, but **significant and unavoidable** impacts would be expected with the seawall installation. **Less than significant** impacts are expected overall at the end of construction.
- Alternative G would have **no impact** during construction but could have **less than significant** long-term impacts with changes in scour, sedimentation, and sediment supply.
- The Recommended Plan would have **significant and unavoidable** impacts with the addition of bay fill and construction of the seawall.

Temporary impacts to currents may result during construction of some shore-based measures because this is located at the MHHW line, such as levees, and some NNBFs such as marshes and ecological armoring. Localized, temporary impacts from the in-water measures such as bulkhead walls/seawalls, wharves, and bay fill are also

anticipated to adversely impact currents due to increased velocities at the toe of the structural measures, which may change wave energy in the bay (**Table 4-3**). Wave energies could increase at the hardened structures, which may increase tidal current velocities and lead to temporary indirect impacts from sedimentation or scour. The waterfront is highly urbanized at present; however, some new hardened structures may be introduced to protect against flood risks. Temporary impacts during construction include physical seabed disturbance that increase current velocities such as foundation installation, excavation, and fill activities.

Standard engineering hydrodynamic and wave modeling of tidal currents and wind waves need to be conducted to analyze the proposed projects' impacts associated with altered coastal hydraulics, which would be completed during the design phase.

Table 4-3: In-Water Activity Quantity Estimates for Alternative First Actions

Quantities of In-water Work (acres)	Alternative B	Alternative F	Alternative G	Recommended Plan
Elevate/rebuild wharf	0	3	8	15
Sheet-pile wall with NNBF	0	0	0	0.5
NNBF – Rocky Intertidal Bluff	0	0	0	2
Bay fill	0	25	0	9

4.3.5. Relative Sea Level Change

This study is unique in that it has designed action alternatives predominantly to address the impacts of RSLC; thus, the action alternatives are evaluated considering all three RSLC scenarios for FWP conditions. For the analysis, it was assumed the measures would perform adequately under the RSLC scenario they were designed for. Therefore, it was generally assumed that:

- Alternative B would have **no impact** to or from RSLC because properties would be floodproofed prior to the threats of RLSC being realized.
- Alternative F would have **no impact** to or from RSLC because project features would be designed to protect against RSLC and include an adaptation strategy to increase protection if a greater threat (i.e., higher rate of RSLC) is realized.
- Alternative G would have **no impact** to or from RSLC because project features would be designed to protect against RSLC and include an adaptation strategy to increase protection if a greater threat (i.e., higher rate of RSLC) is realized. Additionally, this alternative moved assets away from the water, reducing risks of flooding from RSLC.

- The Recommended Plan would have **no impact** to or from RSLC because project features would be designed to protect against RSLC and include an adaptation strategy to increase protection if a greater threat (i.e., higher rate of RSLC) is realized.

Sustained flooding with a coastal flood event varies with the approach of each alternative, such that one that defends at the shoreline (Alternative F) should not experience flooding beyond the LOD when construction is completed for the anticipated risk. Whereas an approach that recedes from the shoreline (Alternative G) should experience inland flooding bayward of the LOD as these areas are converted to open space and would likely transition to coastal habitats with increased inundation.

4.3.6. Water Quality

Adverse impacts to aquatic resources for any action alternative are commensurate with the anticipated level of in-water work. In general, the adverse and beneficial impacts of action alternatives can be summarized by:

- Alternative B would have **minimal to negligible impact** to water quality.
- Alternative F would have the greatest impacts, resulting in **significant and unavoidable adverse impacts** through construction of tide gates, bay fill, and new seawall bayward of the existing structure.
- Alternative G would have **less than significant** adverse impacts during construction and would have the highest **beneficial impacts** to aquatic resources with expansion of habitat through NNBFs.
- The Recommended Plan would have **less than significant adverse impacts with mitigation**, attributed to wharf replacement and bay fill. Compensatory mitigation would be used to offset the unavoidable impacts. Long-term **beneficial impacts** would be expected with improved habitat through NNBFs.

Shore-based construction could result in water quality related impacts such as during grading and excavation; demolition of existing structures; construction of access roads; placement of rock revetments along levees; and construction of stormwater conveyance and discharge infrastructure. Localized and temporary impacts to water quality include reduction of water clarity; change in color; and release of organic material with varying quantities of ammonia, nitrogen, and phosphorous, which could stimulate growth of algae and other aquatic plants. The factors responsible include, but are not limited to, increased turbidity, increased suspended sediments, organic enrichment, chemical leaching, reduced DO, and elevated carbon dioxide levels.

Any work along the San Francisco Bay shoreline below the high tide line is considered in-water construction. In-water construction activities would include the use of equipment such as support barges, small support vessels, and vibratory or impact hammers for installation of sheet-pile walls and support piles. In-water construction has the potential to exceed water quality criteria or waste discharge requirements, including water quality standards and effluent limitations.

In-water construction activities would result in disturbance of localized bay sediments, which could contain legacy chemical contamination. Disturbance of these sediments could temporarily increase turbidity and resuspend these contaminants in bay waters. In-water construction activities would involve the use of diesel-fueled construction equipment and potentially require the use of petroleum-based oils and lubricants, as well as application of anti-corrosion coatings (which could be introduced into the bay by accidental spills).

To varying extents, historic creosote wood piles that currently support existing wharf structures would be removed from the bay and discarded. Creosote-treated pilings would be replaced with non-toxic materials such as steel, concrete, or corrosion resistant composite materials, which would result in a long-term improvement in water quality. However, temporary adverse impacts would occur during pile removal through resuspension of sediments and potential debris released during removal efforts. Wood piles would be removed in a manner that minimizes and avoids impacts to water quality of the receiving water.

4.3.7. Groundwater

Adverse impacts to shallow groundwater for any action alternative are commensurate with the anticipated level of excavation and seismic ground improvements. In general, the adverse impacts of action alternatives can be summarized by:

- Alternative B would have **minimal to negligible** impact.
- Alternative F would mostly result in **less than significant** impacts during construction; however, installation of the seawall bayward would have **less than significant impacts with mitigation** through requirements to update groundwater discharge routes and storage.
- Alternative G would have **less than significant** adverse impacts during construction and would have overall **beneficial impacts** to groundwater with conversion of impervious surface to pervious surfaces.
- The Recommended Plan would have **less than significant adverse impacts**, assuming groundwater storage and drainage facilities can be updated. Some **beneficial impacts** would be expected with the incorporation of NNBFs.

The groundwater closest to the surface and most relevant to implementation of the proposed project is shallow groundwater (i.e., water table and shallow aquifer). Potential impacts to shallow groundwater could result from activities associated with construction and operation of the alternatives. Construction-related impacts could occur during excavation, grading, or trenching that could expose soils and shallow groundwater; placement of fill materials into waterways; shore-based dewatering operations; concrete pouring and washout activities; seismic ground improvements; or the storing and use of chemicals, fuels, and lubricants. Constructing coastal flood risk measures along the shoreline would change the three-dimensional characteristics of flow and may require infrastructure or design features to manage inland water. This would be determined during the design phase.

Construction of barriers, grouting, and compaction aimed to lower liquefaction potential (seismic design requirements) would reduce permeability and potentially porosity, which could lead to higher shallow groundwater tables. The level of change would be highly dependent on the specific conditions at the construction site and the mechanisms proposed for improving soils to withstand seismic loading. Conversely, if the groundwater table is already high and requires dewatering, the reduced porosity and permeability could reduce the connectivity of coastal groundwater to San Francisco Bay and allow for more efficient dewatering and less capture of the Bay water. Quantitative modeling would be required to determine the specific impacts of ground improvements on groundwater responses, which would occur during the design phase.

Construction activities would not deplete groundwater resources from the deeper groundwater basins in the study area because, other than temporary and limited dewatering during construction, the proposed project would not require continuous extraction of groundwater for water supply. Thus, construction would have **no impact** on deep groundwater resources.

4.3.8. Geology and Geomorphology

Adverse impacts to geologic resources for any action alternative are commensurate with the anticipated level of excavation, while beneficial impacts are anticipated with seismic ground improvements. In general, the adverse impacts of action alternatives can be summarized by:

- Alternative B would have **no impacts**.
- Alternative F would have **less than significant** impacts during construction and would be expected to have **beneficial impacts** with ground improvements.
- Alternative G would have **less than significant** adverse impacts during construction and would have overall **beneficial impacts** with ground improvements.
- The Recommended Plan would have **less than significant** adverse impacts during construction and **beneficial impacts** with ground improvements.

Excavation actions could expose shallow subsurface geologic layers, which may require drilling through to reach the design depths. Impacts would be localized and no proposed measures would affect regional geology. To raise surface elevation, commercially sourced fill material would be placed on excavated construction sites, which introduces new surface geologic and soil layers. However, the addition of these soils is not expected to induce any seismic related failures or risks.

The use of impact/vibratory hammers are anticipated to have direct, minor, localized, short-term, adverse impacts to geologic structure and soil composition at the surface in the study area. Vibratory hammers or impact hammers would be used to install sheet piles, which generate ground vibrations during operation. The scale and impact of ground vibrations is measurable; however, these are typically used to determine safe operating distances from existing structures rather than impacts to geology (Weng et al. 2020). The vibrations can dislodge soils and geologic layers locally as sheet piles are

driven into the ground, as well as change the interaction of neighboring soils once sheet piles are present.

Ground improvements are intended to reinforce liquefiable soil hazards to reduce the risk of damage from seismic ground shaking and lateral ground motion. The reinforced soils ensure that features, and the foundations, could withstand a strong to violent ground shaking seismic event without the underlying soils experiencing loss of bearing strength, lateral spreading, or seismically induced settlement from liquefaction. As such, the construction of these features is anticipated to have a beneficial impact to geologic resources in the long-term (**Table 4-4**).

Table 4-4: Estimated Ground Improvement Quantities for Alternative First Actions

Ground Improvements (acres)	Alternative B	Alternative F	Alternative G	Recommended Plan
Total	0	44	70	62

4.3.9. Seismic

Construction of CFRM features in the study area would have **no impact** on the risk of fault rupture, landslides, substantial soil erosion or loss of topsoil, expansive soils, or directly or indirectly destroy unique paleontological or geological resources.

4.3.10. Noise and Vibration

Adverse impacts to noise and vibration for any action alternative are commensurate with the anticipated constructed methodologies and durations. In general, the adverse impacts of action alternatives can be summarized by:

- Alternative B would have **less than significant** impacts from noise and vibration.
- Alternative F would result in temporary **significant and unavoidable adverse impacts** predominantly from noise and vibrations during pile driving.
- Alternative G would have **less than significant** adverse impacts during construction from noise and vibration.
- The Recommended Plan would have temporary **significant and unavoidable adverse impacts** predominately from noise and vibrations during pile driving.

Project noise impacts would consist of noise related to construction machinery and construction-related traffic. Construction activities would produce a variety of noise and vibration levels depending on the type of equipment used and distance to sensitive receptors. Impact pile drivers would produce the highest levels of construction noise and vibration and thus would be the type of construction equipment most likely to exceed noise and vibration thresholds. Following completion of construction activities, construction noise and vibration impacts would cease, and ambient noise levels would

return to baseline conditions. Noise levels anticipated from temporary construction activities under the action alternatives are summarized in **Table 4-5**.

Table 4-5: Estimated Construction Equipment Noise Levels for Action Alternatives 100 Feet from the Construction Area

Construction Activity	Alternative B (dBA 1-hour Leq)	Alternative F (dBA 1-hour Leq)	Alternative G (dBA 1-hour Leq)	Recommended Plan (dBA 1-hour Leq)
Demolition	86	86	86	86
Pile Driving	0	111	0	111
Sheet-Pile Wall Installation	0	95	0	95
Levee, Bridge Construction, Relocations, Ground Improvements, Roadway Reconstruction	0	83	83	83

Leq = equivalent sound level

Due to the size of the piles and the force required for driving, structures within 100 feet of pile-driving activity could be exposed to vibration levels higher than the upper range of values shown in Table 2-2 of Annex D.1.2. Heavy equipment types, such as jackhammers or hoe rams, used for demolition would create a perceptible level of vibration, but only in the immediate vicinity of the equipment. Generally, vibration from these types of equipment is not perceptible more than 50 feet from the source.

4.3.11. Cultural Resources

All action alternatives have the potential to impact both known and previously unidentified archaeological resources, above-ground resources, TCP, or unmarked burials:

- Alternative B would have **significant and unavoidable** adverse impacts from inundation and wave energy resulting from sea level rise and has the potential to result in the erosion and loss of archaeological and above-ground resources, consistent with the FWOP. Impacts to aboveground resources would also occur from the installation of floodproofing measures, property acquisition/demolition or relocation, and the loss of properties through abandonment and neglect.
- Alternative F would result in localized, permanent impacts. During construction, both direct physical and visual **significant and unavoidable** adverse impacts would occur. Mitigation could reduce the impacts to less than significant, but this is dependent upon the type, extent, and severity of impacts, some of which are currently too speculative for meaningful consideration.

- Alternative G would have localized, permanent impacts. During construction, both direct physical and visual **significant and unavoidable** adverse impacts would occur. Mitigation could reduce the impacts to less than significant, but this is dependent upon the extent and severity of impacts, some of which are currently too speculative for meaningful consideration.
- The Recommended Plan would have localized, permanent impacts. During construction, both direct physical and visual **significant and unavoidable** adverse impacts would occur. Mitigation could reduce the impacts to less than significant, but this is dependent upon the extent and severity of impacts, some of which are currently too speculative for meaningful consideration.

It is highly likely that when evaluated under Section 106 of the NHPA, impacts on historic properties by all alternatives would be determined adverse effects. The Section 106 regulations define an adverse effect as one that alters, either directly or indirectly, the qualities that make a resource eligible for listing in the NRHP (36 CFR 800.5[a][1]). Consideration must be given to a property's location, design, setting, materials, workmanship, feeling, and association to the extent that such qualities contribute to the integrity and significance of the resource. Adverse effects may be direct and reasonably foreseeable, may be remote in time or distance, or be cumulative (36 CFR 800.5[a][1]). Adverse effects may be avoided, minimized, or mitigated and for purposes of analyses of alternatives, all are considered mitigation.

The construction activities for all proposed alternatives (B, F, G, and the Recommended Plan) would result in ground disturbance, vibration, and visual impacts. Any type of ground disturbance or earthmoving has the potential to disturb and adversely impact cultural resources, especially those that were previously unknown. Because cultural resources that would be encountered during construction may be eligible for listing in the NRHP, impacts to these sites may diminish their integrity. Excavation, compaction, or other disturbances may disrupt spatial associations that contain scientifically useful information and alter the potential basis for eligibility, thereby materially altering the resource.

Alterations of the landscape from raising of buildings and wharves, construction of project components, floodproofing, and demolition or relocation of structures may destroy, alter, or introduce new visual elements that cause impacts to resources listed on, or eligible for listing on, the NRHP by altering the integrity of feeling, setting, or association, diminishing the resource's ability to convey its significance. This would be a significant impact.

Potential nonstructural measures such as wet and dry floodproofing, elevation, or relocation of structures could directly impact the structure's eligibility for listing on the NRHP by altering the appearance and characteristics that make the resource eligible. Adverse impacts may be mitigated by developing floodproofing measures consistent with Secretary of the Interior's Standards for Rehabilitation & Guidelines on Flood Adaptation for Rehabilitating Historic Buildings.

For Alternatives B, F, G, and the Recommended Plan, mitigation measures would be necessary. Although cultural resources inventories will be completed in the PED phase,

pursuant to a Section 106 Programmatic Agreement (*Appendix D: Environmental and Cultural Resources*), no inventory can guarantee that all resources would be identified prior to construction. Mitigation measures may lessen, but not completely avoid, significant and unavoidable impacts that are currently too speculative for meaningful consideration.

4.3.12. Hazardous, Toxic, and Radioactive Waste

Amongst action alternatives, demolition and replacement are the greatest contributors for adverse impacts. In general, the adverse impacts to HTRW between action alternatives can be summarized by:

- Alternative B would have **less than significant** impacts to HTRW. Long-term beneficial impacts to HTRW would be expected by lessening the risk of contamination.
- Alternative F would have **less than significant** impacts to HTRW. In the long-term, EWN features (e.g., marsh enhancement and ecological armoring) would be expected to decrease contamination risks in localized areas, offering beneficial impacts.
- Alternative G would have **less than significant** impacts to HTRW due to increase in risk of contamination from sites located in the southern reaches. These impacts can be mitigated or avoided.
- The Recommended Plan would have **less than significant** impacts on HTRW since many sites can be mitigated or avoided. Long-term beneficial impacts are expected from decreased risk of contamination.

Construction activities may result in potential disturbance to HTRW contaminants not identified during the Environmental Site Assessments. Inadvertent discovery of HTRW not previously identified will result in immediate work stoppage, with notification to the Contracting Officer, NFS, and regulating agencies to ensure the site is appropriately addressed by the potentially responsible parties or NFS prior to construction resuming.

4.4. Built Environment

4.4.1. Utilities

Adverse impacts to utilities for any action alternative would be temporary during construction, with no long-term or permanent loss in function. All action alternatives are expected to have **less than significant** impacts to utilities.

Temporary adverse impacts to utilities would occur during shore-based and in-water construction activities. Utilities would likely require modification and/or relocation during construction activities within the construction area. This could result in temporary loss or intermittent availability of some utilities (such as telecommunications and water) during immediate relocation. Temporary services would be provided within the construction area if a utility were to be expected to be compromised for any longer than a few hours. No area of impact would be expected to be without access to sewer, water, or electricity

for any length of time (e.g., more than a few hours) because of construction. After relocation, all utility access would be restored upon construction completion.

In the long-term, **beneficial** impacts to utilities would be recognized with protection from repeated inundation during flood events that could result in damage or loss of the infrastructure.

4.4.2. Transportation

Adverse impacts for the action alternatives can be summarized by:

- Alternative B would have **less than significant** adverse impacts during construction because most transportation would be floodproofed; however, **significant and unavoidable** long-term impacts could be realized with frequently inundated parking spaces in areas of retreat.
- Alternative F would have **significant and unavoidable** adverse impacts during construction to major transit corridors, and long-term **less than significant** impacts with reduced transportation facility capacity and assets.
- Alternative G would have the greatest **significant and unavoidable** adverse impacts during construction to major transit corridors, and long-term **less than significant** impacts with reduced transportation facility capacity and assets.
- The Recommended Plan would have **significant and unavoidable** adverse impacts during construction to major transit corridors, **less than significant** impacts with some reduced capacity, but long-term **beneficial impacts** by reducing damage or loss of transit corridors from coastal flooding.

Temporary adverse impacts during construction would be multi-layered with increased construction traffic, transportation corridor closures or rerouting for construction staging areas, increased congestion, and likelihood for increased commute times. Installation of seismic ground improvements would disrupt vehicle, bike, pedestrian, and transit traffic for the durations of the seismic improvement work in any given location commensurate with the spatial extent being constructed. It would require movement of equipment along areas where ground improvements would occur, restricting transportation and access as work proceeds. Construction detours are expected to be established as roads and lanes are closed, and may include vehicular traffic, relocation of bus or transit stops, and in extreme cases, rerouting of transit rail. Construction detours for rail (in particular along the Embarcadero) would be more disruptive because the rail systems have few redundancies or potential detour routes. Existing travel patterns would be disrupted, which is likely to increase potential congestion on other roadways as traffic (vehicular, transit, bicycles, and pedestrian traffic) is routed around or away from construction areas. A comparison of the extent of transport corridors expected to be impacted during construction for each alternative are summarized in **Table 4-6**.

Permanent impacts would result from transportation system redesign around new levees, walls, some areas of raised elevations, and retreat areas. Certain measures would have permanent impacts on existing transportation facilities and roadways such

as narrowing of roadways to accommodate raising roads and buildings, and transportation system changes such as removing bridges, installing tide gates, and creating levees that would permanently block access to some areas.

Table 4-6: Transportation Corridors Affected from First Actions Construction Activities

Transportation Affected	Alternative B	Alternative F	Alternative G	Recommended Plan
Roadways	4.1 miles floodproofed	3.1 miles	4.5 miles	1.6 miles
Muni Lines	1.2 miles floodproofed	2.3 miles	2.9 miles	1.8 miles
Metropolitan Transportation Commission	1.7 miles floodproofed	3.3 miles	4.0 miles	1.7 miles

4.4.3. Recreation and Access

Adverse impacts for the action alternatives can be summarized by:

- Alternative B would have **less than significant** adverse impacts during construction but could result in a loss to overall recreational area over time.
- Alternative F would have **less than significant** adverse impacts during construction, but long-term **beneficial impacts** by protecting recreational facilities from erosion, damage, or loss.
- Alternative G would have **less than significant** adverse impacts during construction and would provide the highest overall net **beneficial impacts** to the study area with an increase in 700+ acres of recreational space with NNBFs.
- The Recommended Plan would have **less than significant** adverse impacts during construction, but long-term **beneficial impacts** by protecting recreational facilities from erosion, damage, or loss.

Adverse impacts would be temporary and localized to construction sites, where construction-related equipment, activities, and dust could be visible and audible to observers. However, similar recreation opportunities would remain available on adjacent lands and elsewhere in the study area that could be accessed during times of construction. The most recreational impacts would be realized at the waterfront during wharf replacement, seawall construction, and roadway impacts. During this time, the wharves and areas of the waterfront that are undergoing construction may be inaccessible for public safety concerns, depending on the type of construction activity. If required, temporary access would be granted to some of these areas where active

construction was not being undertaken. Once construction is complete, recreationists would have usual access to the waterfront and wharves.

4.4.4. Aesthetics

Adverse impacts to aesthetics for any action alternative are commensurate with the anticipated construction duration. In general, the adverse impacts of action alternatives can be summarized by:

- Alternative B would have **less than significant** impact to aesthetics.
- Alternative F would have **significant and unavoidable adverse impacts** spanning multiple years through construction with **less than significant** long-term impacts.
- Alternative G would have **significant and unavoidable adverse impacts** spanning multiple years through construction with **beneficial impacts** long-term with the addition of several hundred acres of greenspace and habitat.
- The Recommended Plan would have **significant and unavoidable adverse impacts** spanning multiple years through construction with **less than significant** long-term impacts.

The construction activity view would be visually and audibly intrusive to the surrounding viewscape and have **significant and unavoidable** impacts during construction. In general, the adverse impacts would come from the presence of heavy machinery, construction-related debris, temporary fencing used to restrict access, increase in noise from equipment use, etc. This would be visually and audibly disturbing near the construction zones, but also outside of the construction zones from areas that would have the construction within the viewshed. The experience of land use and general user activity would also be disturbed near the construction zone from noise and the visual disturbance of the presence of equipment. Areas may be inaccessible during times of construction for safety purposes that would also disrupt access to visual resources; however, this is anticipated to be temporary.

The study area is urban in character and includes a diverse and intermixed combination of modern and historic buildings and structures, maritime and industrial facilities, vehicular streets, recreational trails, parks and public spaces, and natural areas along its shoreline. The linear stretch of the study area extends through several San Francisco districts and neighborhoods, contributing to its diverse visual character. The study area has and continues to experience physical and visual transformation in the form of redevelopment and infill development. This process of transformation has created a visual environment that includes a wide variety of architectural styles. As a result of this ongoing evolution of the buildings and structures, they do not conform to any strongly discernible overall pattern. Thus, new features from the action alternatives would not drastically change the overall waterfront, rather would contribute to an evolving landscape.

Some features would limit some existing views of visual resources from specific locations, but not to an extent that would be substantially adverse. Abundant views of

scenic and visual resources that are currently available from different vantage points within the study area would remain with new features. Design elements of each feature incorporate the use of materials and architecture that blends with the surrounding landscape and with what was historically present, where appropriate (e.g., historic districts along the Embarcadero), to minimize the long-term visual disturbances.

4.4.5. Port and Marine Facilities

Adverse impacts to port and maritime facilities for the action alternatives can be summarized by:

- Alternative B would have **less than significant** adverse impacts during construction but could result in a significant loss of port and maritime services within San Francisco over time.
- Alternative F would have **less than significant** adverse impacts during construction, but long-term **beneficial impacts** by protecting landside and nearshore access to maritime facilities from future flood and ongoing age-related damage. Gates across Mission and Islais Creek may have adverse impacts to recreational maritime traffic.
- Alternative G would have **less than significant** adverse impacts during construction and would provide the same **beneficial impacts** to maritime facilities in the northern waterfront (Reaches 1 and 2) similar to Alternative F but could result in a **significant loss** of maritime facilities in the southern waterfront (Reaches 3 and 4) over time.
- The Recommended Plan would have **less than significant** adverse impacts during construction, but long-term **beneficial impacts** by protecting port and maritime facilities in Reaches 2, 3 and 4 as part of the First Action. Subsequent Actions in Reach 1 will produce beneficial impacts if constructed in the future.

Adverse impacts would be temporary and localized to construction sites, where construction-related equipment and activities may require maritime operations to be temporarily relocated or modified during portions of construction.

However, similar maritime facilities remain available elsewhere in the study area such that with thorough implementation planning, disruption during construction can be minimized. The most direct maritime impacts would be realized at the waterfront during wharf replacement, seawall construction, and roadway impacts, all of which will affect landside and waterside logistics. During this time, the wharves and areas of the waterfront that are undergoing construction may be inaccessible for public safety concerns, depending on the type of construction activity. If required, temporary access would be granted to some of these areas where active construction allows for it. Once construction is complete, maritime operators would have access to the waterfront facilities as usual.

4.5. Human Environment

4.5.1. Socioeconomics and Community

Adverse impacts for the action alternatives can be summarized by:

- Alternative B would have **less than significant** adverse impacts during construction (floodproofing) but could result in similar displacements as the No Action Alternative with flooding events physically dividing waterfront neighborhoods, inhibiting community function and interaction.
- Alternative F would have **less than significant** adverse impacts during construction and would minimally alter the community structure and connectivity given maintenance of the waterfront attributes.
- Alternative G would have **less than significant** adverse impacts during construction but would substantially alter existing community connectivity and character to support the managed retreat of the shoreline.
- The Recommended Plan would have **less than significant** adverse impacts during construction, and less impacts overall to communities through displacement and economic disruption than Alternatives B, F, or G.

Construction activities have the potential to result in socioeconomic effects related to community and neighborhood interactions and connectivity; to the displacement of residences, commercial and industrial businesses, and community and public facilities; but generally, minimal negative economic effects. For actions that require acquisition and demolition of buildings, there would be a direct displacement effect and for all construction activity there would be temporary interruption related to site access, or road closures, vehicle access, etc. Construction would result in a demand for construction jobs but may relocate or displace other business lines temporarily. However, by preserving businesses with the action alternatives and planning for the incremental removal of some existing land uses, the overall population and tax revenues within the city would likely only experience a slight reduction, if at all, but would shift in location.

4.5.2. Public Health and Safety

All action alternatives are expected to have **less than significant** adverse impacts to public health and safety. No action alternatives would directly impact public facilities or services; however, public facilities could have temporarily interrupted services during construction activities. Increased vehicular congestion along roads, highways, and streets during construction could temporarily impede access of public services; however, detours and alternative access routes would be established to minimize these impacts. Site security (e.g., fencing) would be included around all construction areas to deter the public from accessing active construction sites for safety and health concerns.

Features such as new or relocated driveways, transit corridors, and on-street loading zones would not impede emergency vehicles. No plans are expected to result in

inadequate emergency access. No access would be cut off to emergency service infrastructure (e.g., hospitals and police stations), nor would emergency services be cut off from accessing areas to perform regular or emergency duties. The actual construction should not impose a public health and safety concern because active construction zones would be fenced off to prevent public access. In the long-term, these features would have **beneficial impacts** on public health and safety by reducing the likelihood of damage, loss, or injury from repeated flooding events.

4.5.3. At-Risk Communities

All action alternatives are expected to have **less than significant** adverse impacts to minority and low-income populations, and construction would be dispersed throughout the study area, therefore, would not disproportionately affect communities.

4.6. Cumulative Impacts

NEPA regulations require that cumulative impacts or effects of a proposed action be assessed and disclosed in an EIS or Environmental Assessment. The CEQ regulations define cumulative effects as:

“...effects on the environment that result from the incremental effects of the action [project] when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time” (40 CFR 1508.1(g)(3)).

For purposes of this analysis, cumulative impacts are evaluated if the indirect and direct impacts of the Federal action have substantial temporary adverse or positive impacts to the resource, when considering past, present, and reasonably foreseeable future actions. Potential impacts of the past, present, and reasonably foreseeable future actions include both potential direct effects (caused by the action and occurring at the same time and place as the Recommended Plan), and indirect effects (caused by the action but removed in distance and later in time, and reasonably foreseeable).

The cumulative effects analysis considers the magnitude of the cumulative effect on the resource health, which refers to the overall condition, stability, or vitality of the resource and the trend of that condition. Laws, regulations, policies, or other factors that may change or sustain the resource trend were considered to determine if stress on the resource is likely in the foreseeable future. Cumulative impacts may also occur when the occurrence of disturbances is so close that the effects of one are not dissipated before the next occurs, or when the timings of disturbances are so close that their effects overlap. The general approach provided in CEQ’s Considering Cumulative Effects Under the NEPA was used to conduct the analysis (CEQ 1997).

This cumulative impact analysis was scoped with a temporal boundary approximately 100 years in the past (1920), from the beginning of the study, and approximately 50 years into the future (2190), from construction completion. This POA captures a timeframe when a significant number of environmental laws were enacted in which

resource protection became a priority (past). Additionally, the POA tracks the hydrologic and hydraulic modeling for RSLC threats, as well as future RSLC trajectories.

For a spatial boundary to scope this cumulative impact analysis, projects or actions considered were mostly within the same county and/or in San Francisco Bay.

This study is one of many ongoing efforts to improve coastal and combined flood damages and disaster resilience along the San Francisco waterfront. The San Francisco Waterfront Plan and the Waterfront Resilience Program are led by the POSF and include the study area, as well as areas both north and south of this study boundary.

4.6.1. Past or Present Projects

The past or present projects considered in the cumulative impact analysis include all of those described in Section 1.10 and Section 2.4.6 in addition to those described below.

Pier 48/Seawall Lot 337/Mission Rock Special Use District Project is a 3.6-million-square-foot mixed-use development project that would include retail, commercial, residential, and parking uses as well as 8 acres of parks and open space and historic rehabilitation of Pier 48. The project would include a parking structure with 2,300 spaces, 1.7 million square feet of commercial, 150,000 to 250,000 square feet of retail, and between 650 and 1,500 residential units. Phase 1 of this project currently is under construction.

Pier 70 Mixed-Use District Project is a multi-phase 28-acre mixed-use development including parking spaces, parks, roads, public access, shoreline improvement, and utility infrastructure. Mixed uses include residential (1,712,000 to 903,000 gross square feet), commercial (1.8 million gross square feet), retail and arts spaces (400,000 gross square feet), and research/development space. Phase 1 of this project is currently under construction.

Potrero Power Station Mixed-Use Development Project is a 5.4-million-square-foot mixed-use development that would include hotel, commercial, entertainment, residential, and parking uses as well as 7 acres of open space. The project would include 2,600 residential units, 250 hotel rooms, 1.6 million square feet of commercial (office, research and development, PDR, and retail), 50,000 square feet of community facilities, 25,000 square feet of entertainment/assembly, and 2,700 parking spaces. The buildings would range in height between 65 and 240 feet. Phase 1 of this project is currently under construction.

The Better Market Street Project would revitalize Market Street from Octavia Boulevard to the Embarcadero by optimizing sustainable mobility modes (transit, walking, rolling, and cycling) so that Market Street would be pleasant, reliable, efficient, and safe for all users. The first phase of the project, between Fifth and Eighth streets, began in October 2023.

The Embarcadero Enhancement Program, Central Embarcadero Phase 1 would improve safety, mobility, connectivity, and accessibility for all users of the Embarcadero, which serves as a major transit corridor, tourist destination, marine-oriented commercial

district, and public recreation area. The first phase of the project was completed in 2022.

4.6.2. Reasonable and Foreseeable Actions

TZK Broadway and Teatro ZinZanni Project includes a boutique hotel with approximately 192 rooms with ancillary retail and commercial spaces and a new theater to serve as the permanent home for Teatro ZinZanni and its historic “Spiegeltent”; and an approximately 14,000-square-foot privately financed park at the northern end of the site. Construction has not yet begun.

The POSF’s Waterfront Resilience Program would include developing a series of coordinated projects working to ensure a resilient waterfront in the face of seismic and sea level rise, meteorological change-related hazards, and includes an USACE Flood Study for the entire POSF waterfront and a program to strengthen the 3-mile-long Embarcadero seawall. A project application has not yet been submitted.

The San Francisco Housing Element 2022 Update⁴² would modify the policies of the general plan’s housing element. The goals, policies, and actions are required to plan for the regional housing targets allocated to San Francisco by regional agencies for the 2023–2031 cycle and meet future housing demand in San Francisco. The housing element update includes policies designed to improve housing affordability and advance treating communities equally and would shift an increased share of the city’s future housing growth to transit corridors and low-density residential districts within certain areas of the city. It would not include specific changes to existing land use controls (e.g., zoning) or approve any physical development, but the Environmental Impact Report would evaluate the potential physical environmental impacts that could result from future actions regarding implementation of the policies proposed under the housing element. The Draft Environmental Impact Report was published in 2022, and the plan was adopted in January 2023.

The Mission Bay Ferry Landing project (Phase 2) would provide regional ferry service to and from the Mission Bay neighborhood, as well as the Dogpatch, Potrero Hill, Pier 70, and the Central Waterfront neighborhoods. The Mission Bay Ferry Landing would provide capability to berth two ferry boats simultaneously.

4.6.3. Cumulative Impact Analysis

The measures included in the Recommended Plan would continue the trend of projects designed to make the region more resilient to coastal hazards and changing meteorological conditions, and to protect infrastructure. The majority of measures in the Recommended Plan would have temporary adverse impacts that are anticipated during construction; however, permanent impacts are also expected with limited resources. Temporary impacts would end soon after the construction phase is over and be minimized with the use of BMPs, while permanent impacts would be offset with compensatory mitigation. The cumulative impact analysis is presented by resources grouped into the natural, physical, built, and human environment. Cumulative impacts of past projects and actions are captured in the Existing and FWOP Conditions (Section

2.0) because these would have contributed to the present state of resources in the project area.

4.6.3.1. Natural Environment

Temporary impacts are expected to natural resources as a result of construction activities, present actions, and reasonable and foreseeable actions. Temporary impacts include turbidity, water quality disturbance, physical impacts from construction equipment, and the potential injury or harassment of organisms by construction activities. All of these impacts would be minimized with the use of BMPs and AMMs to the greatest extent practicable. The cumulative impacts could be heightened at any given time if more than one project is occurring within the same area at the same time. The majority of adverse impacts to the natural environment would be realized with in-water construction activities that are planned with this project, the Mission Bay Ferry Landing, and as components of the Waterfront Resilience Program. It is unlikely that all of these projects would have construction activities occurring at the same time, but in the event this occurred, impacts to natural resources would be elevated.

Permanent impacts are also expected to the natural environment from this project and future actions, such as the Mission Bay Ferry Landing with the addition of hardened structures in San Francisco Bay and bay fill. These permanent impacts are not expected to result in net loss because compensatory mitigation would be used to fully account for this impact of construction. However, cumulatively, these projects would result in the permanent modification of bay habitat that is within the direct construction footprint.

There are also beneficial cumulative impacts anticipated as a result of this project and several of the present and reasonably foreseeable actions with the inclusion of EWN features and increase in open space. This project proposes construction of EWN features that would benefit State and Federally protected species, while the Potrero Power Station and Embarcadero Enhancement projects would provide additional recreation and open spaces that could be frequented by local fauna. The increase in naturalized spaces would provide new areas for fauna in an otherwise highly urbanized location.

4.6.3.2. Physical Environment

The SFBAAB is the cumulative study area for air quality, while global atmosphere is the cumulative study area for GHGs. Consequently, there are numerous past, present, and reasonably foreseeable projects within these study areas. Implementation of AMMs would reduce criteria pollutant emissions generated by this project but would not avoid the exposure of sensitive receptors to substantial pollutant concentrations in localized areas. Other projects in the cumulative impacts area may implement comparable mitigation measures, such as using water or dust control chemicals to reduce fugitive dust or complying with relevant air quality regulations. Other cumulative projects may also contribute pollutant concentrations in the same localized areas affected by project construction. Thus, construction of the project would cumulatively contribute to existing

localized air quality impacts in the study area but would not cumulatively contribute to regional air quality impacts.

Construction activities under this project could coincide with construction activities associated with reasonably foreseeable projects, resulting in a combined increase in construction noise. In general, the potential for projects to overlap, resulting in combined or prolonged increases in ambient noise, is more likely when the construction noise of two or more projects overlaps. As such, the cumulative noise from simultaneous construction activity in proximity to one another could result in higher noise levels than would otherwise occur with one project under construction. Construction of multiple projects consecutively could increase the duration of construction noise levels that would be 10 dBA above the ambient noise level or 90 dBA at sensitive receptors. Given that the adaptations constructed under the Recommended Plan would occur along the shoreline in the vicinity of Embarcadero Early Projects and other ongoing construction, this would make a considerable contribution to the significant cumulative construction noise impact. Implementation of AMMs would help to alleviate the level of noise impact if multiple construction projects were underway at the same time and area. Alternatively, construction phases between projects could be coordinated to occur at different times to spatially spread noise disturbance; however, this could result in prolonged noise disturbance for a longer period. It is unlikely that multiple projects generating vibration disturbances would occur at the same time in the same locations, thus it is not expected to contribute to cumulative impacts.

This project is considering seismic hazards for design and construction, and as such, long-term beneficial impacts to geologic resources would be anticipated. It is assumed the reasonable and foreseeable actions would be designing features with seismic loading factored to ensure construction of a stable building or other infrastructure. With that, projects would be expected to be beneficially impacting geologic resources by creating more stable subsurface conditions.

Some cultural resources would be permanently impacted during construction of the Recommended Plan because many are proposed to be elevated to remain in place while being protected from coastal flood hazards. Additionally, many others would be protected with the addition of floodwalls or other coastal flood risk management features in close proximity that would likely change the visible characteristics of many cultural resources. Many of these impacts would be minimized to the greatest extent practicable; however, it is also understood these impacts would remain in perpetuity. This project in combination with the reasonable and foreseeable actions would cumulatively impact cultural resources, either temporarily or permanently, but overall have a goal of protecting the resources with improvements to infrastructure to combat threats of coastal flooding exacerbated by changing meteorological conditions. In this respect, many cultural resources would also have beneficial impacts with the protection from flooding and future damages.

This project is proposed to occur in a historically, heavily industrialized area that has resulted in a relatively extensive distribution of contamination throughout the study area. USACE regulations require sites to be free of contamination prior to construction begins. In this regard, construction would be expected to have a long-term beneficial impact on HTRW by potentially reducing the levels of contamination and thereby risks of

future exposure. For this analysis, it was assumed the reasonable and foreseeable actions would be working with a clean site or would not be disturbing HTRW areas, thus would not contribute to any cumulative adverse impacts associated with contamination.

4.6.3.3. Built Environment

Temporary adverse impacts would occur during construction to infrastructure, both with this project and other current and future proposed projects and actions. Construction impacts are anticipated to cease with construction completion and be minimized with the use of mitigation and BMPs. In the long-term, beneficial impacts would be realized for infrastructure that is being protected from coastal flooding with the addition of coastal flood risk management features. Other projects proposed for the study area would contribute to the benefit of infrastructure such as housing, recreation and access, maritime facilities, and hospitality. It is assumed utilities would be adjusted for this project and others to continue provision of important services, and thereby, often improve the service availability and access. Aesthetics would result in a permanent change to waterfront views, particularly in areas where new infrastructure is proposed or modified. These are assumed to be mostly beneficial because consideration would be given to visual impacts and designs would be modified to minimize those impacts.

Cumulative impacts of other construction projects that could be taking place when construction starts, and cumulative effects to transit or transportation users, would be considered as part of the construction and traffic management plans to be prepared for elements of the project as work progresses to limit overall impacts.

4.6.3.4. Human Environment

The cumulative impacts from this project and the present and reasonably foreseeable actions were assumed to overall improve the human environment by enhancing protection from coastal and combined flooding risks. Temporary impacts during construction would be realized from any of the projects, which would be assumed to be heightened if more than one project was occurring in the same area(s) at the same time. However, generally the plans are designed to enhance the human environment either by improving safety, living standards, recreation, and/or housing and transit availability in the project area.

4.7. Probable, Unavoidable Adverse Environmental Effects

This subsection describes the Recommended Plan's long-term adverse impacts that may be unavoidable and the rationale for proceeding notwithstanding the unavoidable effects.

4.7.1. Air Quality

During construction, there will be unavoidable air quality impacts associated with construction activities, operation of heavy equipment, and transport of personnel and materials into and out of the project area. Operation of heavy equipment would result in the release of exhaust emissions. Additionally, dust could be generated during grading

and excavation activities. Mitigation measures have been incorporated and are fully described in Annex D.1.1 Section 2.3.4. Mitigation would include implementation of BAAQMD's Basic and Enhanced BMPs for Construction, utilizing the highest tier equipment available at the time of construction where practicable, and creating barriers between the construction site and sensitive receptors. As of now, no compensatory mitigation is necessary. However, if modeling indicates emissions are greater than *de minimus* levels once the designs have been refined, compensatory mitigation will need to be considered and would likely include funding an offsite emission reduction project.

4.7.2. Aquatic Resources

Wharf raising/rebuilding and construction of a coarse beach will result in approximately 9.0 acres of bay fill that will require compensatory mitigation in the form of old pile and pier removal from the bay. Loss of fringe wetlands and intertidal habitat is expected during construction of the ecotone levee and marsh enhancements, however, these habitats would be restored as a feature of the design that would enhance the aquatic habitats at these locations over the long-term, resulting in no net loss. Additional mitigation measures have been incorporated to minimize unavoidable impacts and are described in section 4.18.8 of *Appendix D: Environmental and Cultural Resources*.

4.7.3. Noise

During construction, there will likely be unavoidable noise impacts associated with construction activities, operation of heavy equipment, and movement of personnel and material into and out of the project area. Mitigation measures have been incorporated to minimize construction-related noise impacts, such as limiting heavy equipment use to daytime hours not regulated by CCSF to the greatest extent practicable, conducting noise and vibration monitoring, employing common construction BMPs, and complying with all Federal and Federal noise control regulations. Mitigation measures are described in Annex D.1.2 Section 2.3.

4.7.4. Transportation

The project will disrupt traffic patterns, and result in transportation corridor closures, loss of access and parking, detours, and increased construction traffic and congestion near staging and construction areas. These impacts are expected to be temporary but long-term lasting until construction is complete. Permanent unavoidable impacts resulting from changed traffic patterns would be realized with roadway, bike path, sidewalk, and transit redesign, and rerouting in areas of raised elevation or narrowing of roadways to accommodate the levees and floodwalls. Mitigation has been incorporated to minimize the impacts and has been described in Annex D.1.4 Section 2.2.4 and include, but are not limited to, preparing construction traffic management plans to minimize cumulative effects from other projects, maintaining or providing pedestrian and bicycle access to the waterfront to the greatest extent practicable, and providing alternative transit access and stops where necessary.

4.8. Irreversible or Irretrievable Commitments of Resources

NEPA 40 CFR 1502.16(a)(4) requires that the environmental analysis include identification of “any irreversible and irretrievable commitments of resources which would be involved in the proposal should it be implemented.” Irreversible and irretrievable resource commitments are related to the use of nonrenewable resources and the effects that the use of these resources have on future generations. Irreversible effects primarily result from use or destruction of a specific resource (e.g., energy and minerals) that cannot be replaced within a reasonable time frame. If a wetland is filled to build a parking lot, that habitat is irretrievable as long as the parking lot remains. Irretrievable resource commitments involve the loss in value of an affected resource that cannot be restored as a result of the action (e.g., extinction of a threatened or endangered species).

Should the proposed action be implemented, there would be some irreversible or irretrievable commitments of natural and built resources that would be expended in the construction and operation of any action alternative. These resources include:

- Materials used to construct new flood risk management structures and meet seismic design requirements, and modifications to the existing stormwater and transportation systems (e.g. concrete, stone, steel, pavement, etc.)
- Energy in the form of fossil fuels and electricity consumed during operation of heavy equipment, production of construction materials, and transport of equipment, materials, and personnel to and from the project site
- Capital and labor resources required to develop, construct, and operate various components of the flood risk management system

Some components, such as existing structures, pavements, utility lines, or other features requiring removal to construct the new structures, may be recycled upon removal, which would offset some of the material consumed and introduce a minor amount of material that would be available to others. Similarly, any new materials and components placed as part of the new structure may be recycled upon decommissioning, but in the near-term, these materials would not be available to others.

Land and aquatic habitats (e.g. intertidal and subtidal habitats) that would be physically altered by construction would be committed to the new use for the foreseeable future and would represent an irreversible commitment of those areas for the life of the project. Should, however, a greater need arise for the use of the land, or should the proposed project no longer be needed, the land and aquatic habitats could be restored to the original condition or be committed to another use. However, there is no indication that such a need for conversion could develop or would be desirable.

4.9. Relationship Between Short-Term Uses of Environment and the Maintenance and Enhancement of Long-Term Productivity

NEPA also requires that an EIS include a discussion of the relationship between short-term uses of the environment and the maintenance and enhancement of long-term

productivity. This subsection describes how the proposed action would affect the short-term use and the long-term productivity of the environment.

For this analysis, “short-term” refers to the temporary phase of construction of the proposed project while “long-term” refers to the operational life of the proposed project and beyond. The preceding sections in this section evaluate the short- and long-term impacts of implementing each of the alternatives in more detail for each resource.

Construction of any of the alternatives would result in short-term construction-related impacts within the project areas and would include increased air emissions and ambient noise; disturbances to fisheries and wildlife; loss of public access, recreational opportunities and aesthetic value; interruptions and delays in transportation and access in and around the project area; and decreased water quality such as higher turbidity levels and lower DO. These impacts would be temporary and would occur only during construction and are not expected to alter the long-term productivity of the natural or built environment.

Over the long-term, adverse impacts include encroachment/fragmentation of aquatic habitats; changes in hydrologic flows, land use, aesthetic qualities of the iconic landscape, recreation opportunities, public access, and the transportation system; and potential loss or degradation of historic resources or other culturally or socially significant resources. However, most of these adverse impacts can, and have been, avoided or minimized through the design of the structures or incorporation of compensatory mitigation. The alternatives themselves present tradeoffs between the long-term productivity impacts on different resource categories.

The long-term benefits of each alternative include an overall enhancement of the quality of life and reduction in damages caused by coastal and combined flooding, RSLC, and seismic events throughout the 7.5-mile San Francisco waterfront.

Section 5.0 The Recommended Plan*

This section presents a summary of the Recommended Plan including the components of the plan, cost estimate, and real estate requirements. Implementation of the Recommended Plan is discussed in *Section 6.0: Implementation of the Recommended Plan*. Further technical engineering, environmental, and economic details can be found in the appendices. *Section 7.0: Environmental Compliance* describes how the Recommended Plan complies with relevant environmental laws, regulations, and EOs. The Recommended Plan includes adaptive actions to refine the feature scales and alignments if coastal flood risk increases and could vary in its ultimate implementation, based on the MAP presented in Appendix G.

5.1. Recommended Plan Components

The Recommended Plan manages coastal flood risk through a suite of measures that function as a system, based on rising sea levels, and are implemented over time based on the risk of RSLC. The Recommended Plan was formulated as a complete solution for the entire study area. During PED, the need for interim measures to prevent outflanking of completed sections will be evaluated and implemented, if necessary.

The Recommended Plan consists of two phases of intervention to reduce risk within the study area over a 100-year POA. For analysis, the years 2040 and 2090 were used as approximate First Actions and Subsequent Actions years. The actual timing and implementation of the First Actions will be dependent upon project funding and preconstruction activities, while the timing of Subsequent Actions will be refined in response to monitoring of RSLC and other changing conditions (*Appendix G: Monitoring and Adaptation Plan*). Recommended Plan First Actions are independent of the rate of RSLC. The Subsequent Actions vary in scale by RSLC (Low, Intermediate, or High) to maintain the performance of the system over the full POA based on changing risk conditions. **Figure 5-1** depicts the conceptual framework for the Recommended Plan First Actions and Subsequent Actions.

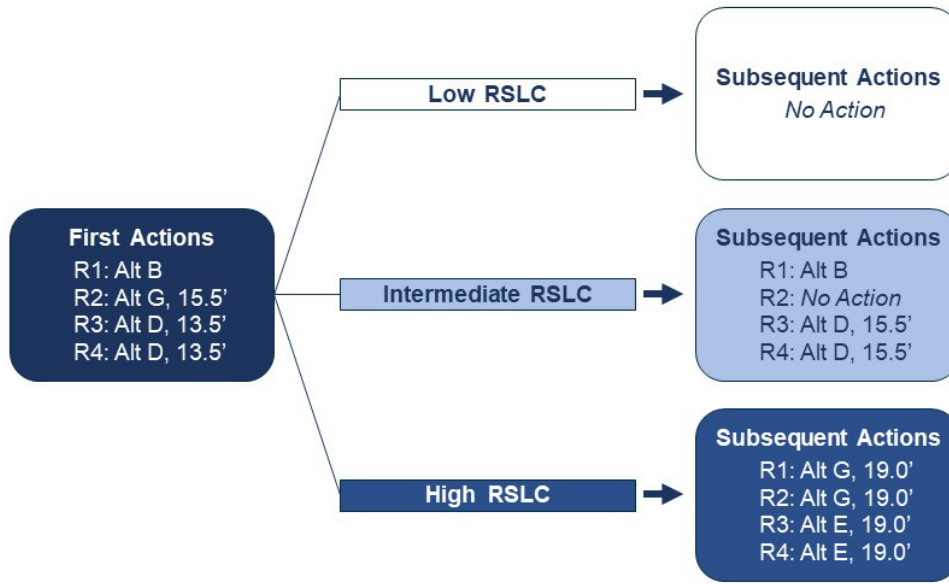


Figure 5-1: Conceptual Framework for Recommended Plan First Actions and Potential Range of Subsequent Actions

The Recommended Plan is a cost-effective, hybridized plan that combines retreat, accommodation, and defend measures, scaled to perform under initial risk and to adapt to risk of a higher rate of RSLC as potential Subsequent Actions. The First Actions (**Figure 5-2**) are proposed to align expenditures with initial risk and Subsequent Actions (**Figure 5-3** and **Figure 5-4**)³ are scaled to add height or adapt measures with the arrival of increased risk in later years to maintain the desired performance level, as determined through monitoring based on the MAP (Appendix G).

The Recommended Plan is summarized in **Table 5-1**. Each reach has First Actions, assumed to be completed in 2040, and a range of Subsequent Actions, assumed to occur in response to future conditions.

³ Note: Under Low RSLC, there are no Subsequent Actions.

Table 5-1: First and Potential Subsequent Actions, Recommended Plan

Reach	First Action		Subsequent Action			
	Crest Elevation ^a	Description ^b	Crest Elevation ^a			Description ^b
			Low	Int	High	
1	--	Floodproofing buildings, phased over time (Alternative B)	--	<i>Only nonstructural action</i>	<i>New defense structure:</i> 19.0 feet NAVD88	<i>Intermediate:</i> Floodproof more buildings, phased over time (Alternative B) <i>High:</i> Defend at existing shoreline (Alternative G)
2	15.5 feet NAVD88	Defend at existing shoreline (Alternative G)	--	--	19.0 feet NAVD88	<i>High:</i> Increase crest elevation of defense structure along existing shoreline (Alternative G)
3	13.5 feet NAVD88	Defend at existing shoreline (Alternative D)	--	15.5 feet NAVD88	19.0 feet NAVD88	Increase crest elevation of defense structure along existing shoreline (<i>Intermediate:</i> Alternative D; <i>High:</i> Alternative E)
4	13.5 feet NAVD88	Defend at existing shoreline (Alternative D)	--	15.5 feet NAVD88	19.0 feet NAVD88	Increase crest elevation of defense structure along existing shoreline (<i>Intermediate:</i> Alternative D; <i>High:</i> Alternative E)

^aCrest elevation columns indicate the assumed structural measure crest elevation for purposes of alternatives evaluation. Actual crest elevation would vary along the waterfront based on local wave conditions, pending further analysis in PED.

^bFirst and Subsequent Actions include a mix of structural measures, nonstructural measures, and NNBFs. The brief description here is intended to highlight key differences by reach. Comprehensive descriptions available in Section 5.

NAVD88 = North American Vertical Datum of 1988

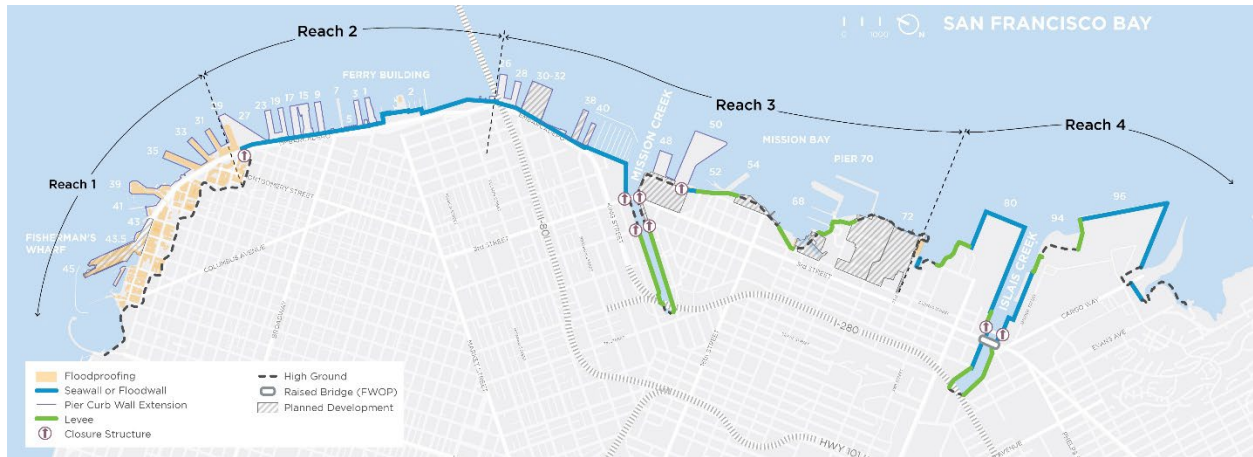


Figure 5-2: Recommended Plan First Actions

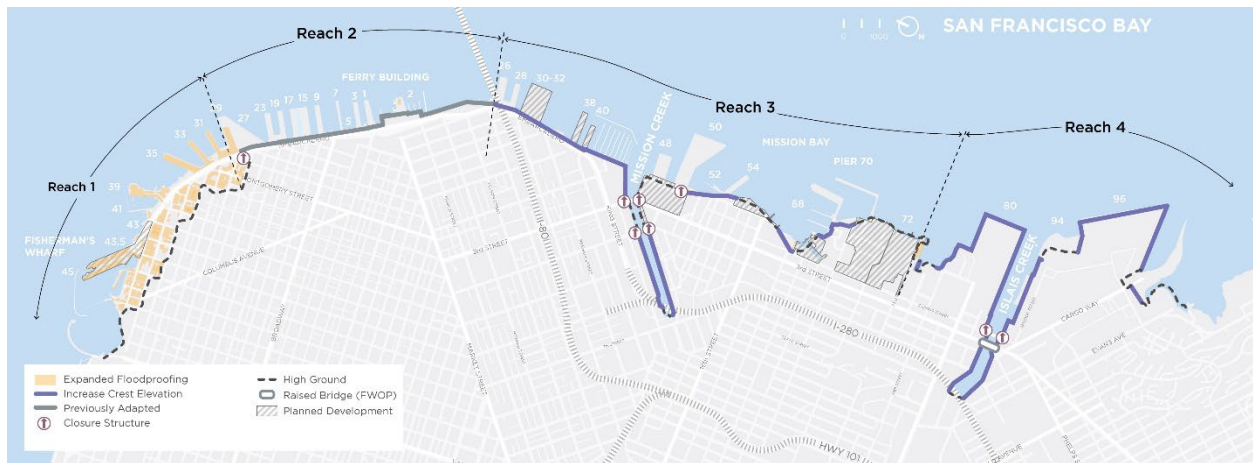


Figure 5-3: Recommended Plan Subsequent Actions (Intermediate RSLC)

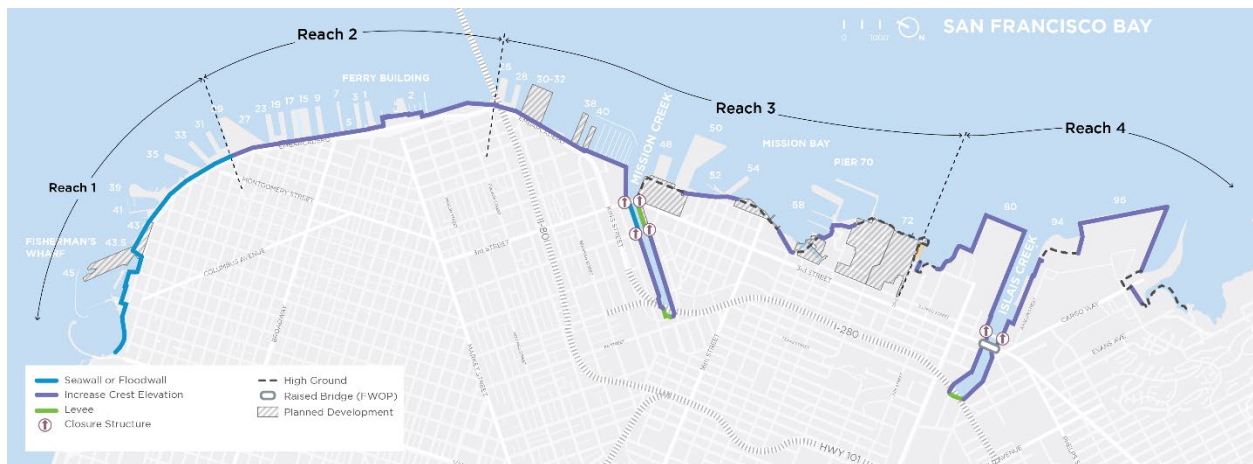


Figure 5-4: Recommended Plan Subsequent Actions (High RSLC)

The features of the Recommended Plan for the First Actions and Subsequent Actions are described by reach in the following subsections. The Recommended Plan does not include any separable recreation features.

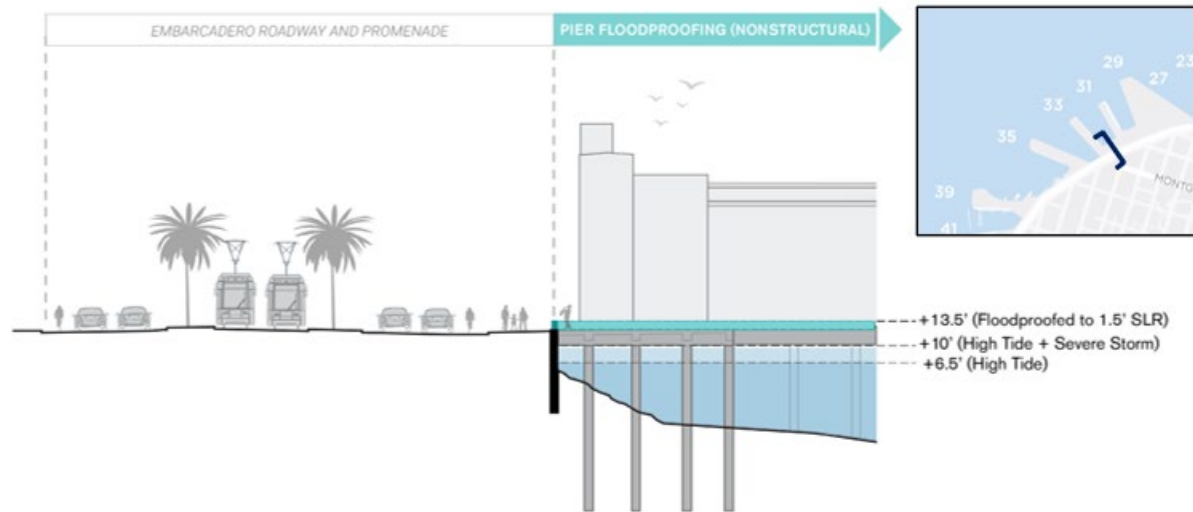
5.1.1. Fisherman's Wharf (Reach 1)

In Fisherman's Wharf, the Recommended Plan initially relies on floodproofing buildings and infrastructure. Piers are floodproofed with concrete curbs around the perimeter to reduce flood risk. Subsequent Actions include additional floodproofing or elevation of the shoreline with seawalls and floodwalls, depending on the rate of RSLC.

5.1.1.1. Reach 1 First Actions

The Recommended Plan in Reach 1 includes the following First Actions (**Figure 5-5**):

- Floodproof at-risk buildings and infrastructure throughout Fisherman's Wharf.
- Construct a 2-foot-tall concrete curb around perimeter of piers from Pier 47 to Pier 29.



Gray and black represent existing conditions; teal represents Recommended Plan First Actions

Figure 5-5: Recommended Plan First Actions: Fisherman's Wharf to Telegraph Hill (Reach 1), Typical Cross Section within Embarcadero Historic District

5.1.1.2. Reach 1 Subsequent Actions

The Recommended Plan includes Subsequent Actions to manage increasing flood risk. The Subsequent Actions vary by RSLC and include:

- Low RSLC: No action.
- Intermediate RSLC: Additional floodproofing.

- High RSLC: Raise the existing shoreline with seawalls, floodwalls, and raised and rebuilt wharves (finish elevation of 19.0 feet NAVD88, adapted according to *Appendix G: Monitoring and Adaptation Plan*). Includes ground improvement. May also include interior drainage infrastructure, NNBFs, and elevating, floodproofing, or removing select buildings and infrastructure.

5.1.2. Embarcadero (Reach 2)

Along the Embarcadero, the Recommended Plan elevates the shoreline in place by raising and reconstructing the bulkhead seawalls and pile-supported wharves north of the Bay Bridge while gradually transitioning down from the new shoreline elevation back to the existing city grade to retain visual and physical access to the waterfront. The plan includes reconstruction of the full Embarcadero roadway right-of-way – surface design of the Embarcadero roadway and promenade will be determined in future project phases. The Ferry Building and bulkhead buildings are raised in place following construction of new pile-supported foundations (wharves). Piers are floodproofed with concrete curbs around the perimeter to reduce flood risk.

5.1.2.1. Reach 2 First Actions

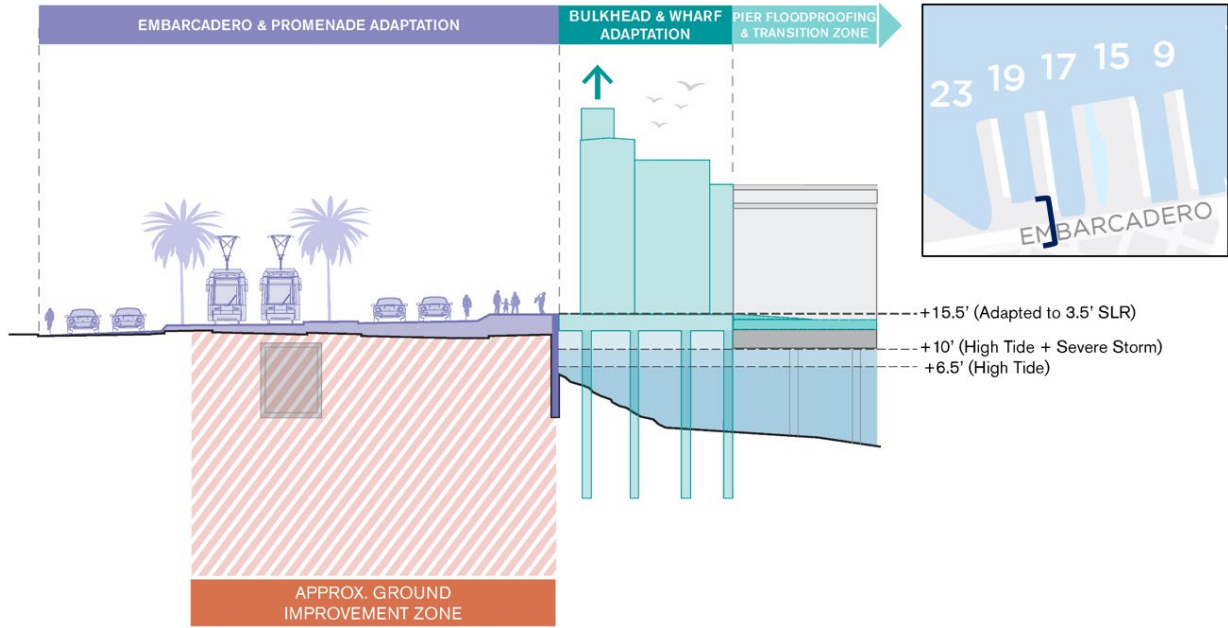
The Recommended Plan in Reach 2 includes the following First Actions (**Figure 5-6 to Figure 5-8**):

- From Pier 27-29 to the Bay Bridge, raise the shoreline along the Embarcadero by 3.5 to 7.5 feet to defend against 3.5 feet of RSLC (2000 baseline, translates to finish elevation of 15.5 feet NAVD88, pending refinement in design) using raised and rebuilt bulkhead seawalls and wharves, approximately aligned with the location of the existing structures, with exceptions described below. Incorporate living seawalls into design where appropriate (*Appendix I: Engineering with Nature*). Provide Embarcadero promenade and Bay Trail access atop and adjacent to the raised ground and wharves.
- At the Ferry Building, align the raised and rebuilt bulkhead seawall with the outer edge of Ferry Building substructure and apron.
- At Rincon Park, adjacent to Pier 14, locate the defense structure approximately 50 feet bayward of the existing wall to minimize impacts to transportation and utility assets while retaining access to the water. An engineered rocky intertidal bluff is incorporated bayside of the defense structure (*Appendix I: Engineering with Nature*). The combination of these measures requires bay fill.
- Perform ground improvement to meet seismic design requirements of ER1110-2-1806 for the coastal flood defense structures.
- Install a closure structure connecting to high ground (15.5 feet NAVD88) at the north end of the coastal flood defense (approximately at Pier 27) to reduce

likelihood of outflanking.⁴ Operational impact to the transportation corridor is expected to be infrequent through at least 2060.

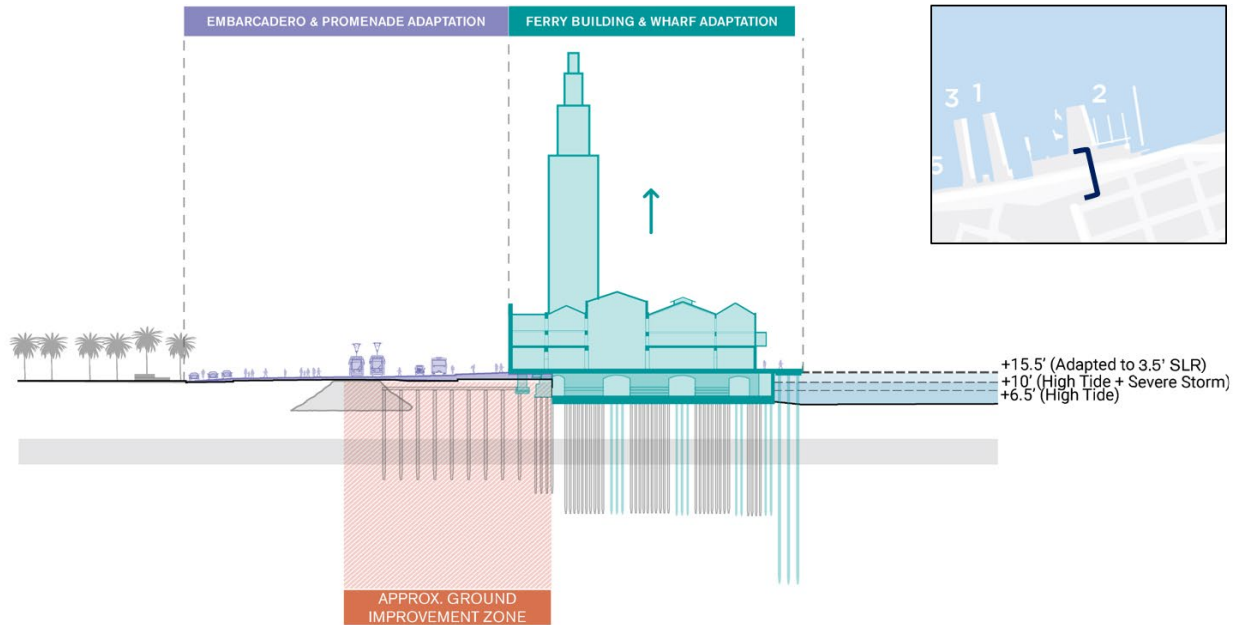
- Replace existing wharves with new ductile concrete wharves with deck elevation to match the top of the new bulkhead seawall. Transition grade from raised wharf and bulkhead building to existing pier elevation. Includes raising the maritime plaza wharf bayside of the Ferry Building to maintain access to regional emergency assets.
- Construct 2-foot-tall concrete curb around perimeter of piers from Pier 27 to Pier 22 ½.
- Reconstruct the full Embarcadero roadway if required from raising the shoreline in place, which could result in a likely reduction of overall roadway width. Design the mobility corridor during PED.
- Elevate buildings on wharves north of the Bay Bridge, including the Ferry Building, Agriculture Building, and bulkhead buildings.
- Floodproof select at-risk buildings bayside of the coastal flood defense (maps used for analysis are in Sub-Appendix B.5).
- Build green/gray infrastructure compatible with existing combined sewer system to manage interior drainage.

⁴ Monitoring of RSLC and other conditions, including potential shoreline projects in Reach 1 that could affect the coastal flood risk profile, will be considered in decision-making. If RSLC trends above the USACE Intermediate curve before the temporary closure structure is installed, USACE and the City and Port of San Francisco may conclude that the USACE High Subsequent Actions for Reach 1 (structural features) are most appropriate to address increasing risk and the temporary closure structure is no longer necessary. The detailed phasing and implementation plan, which will be developed during the design phase, will also influence when and where a temporary closure structure may be built, if it all. The Monitoring and Adaptation process is described in *Appendix G: Monitoring and Adaptation Plan*.



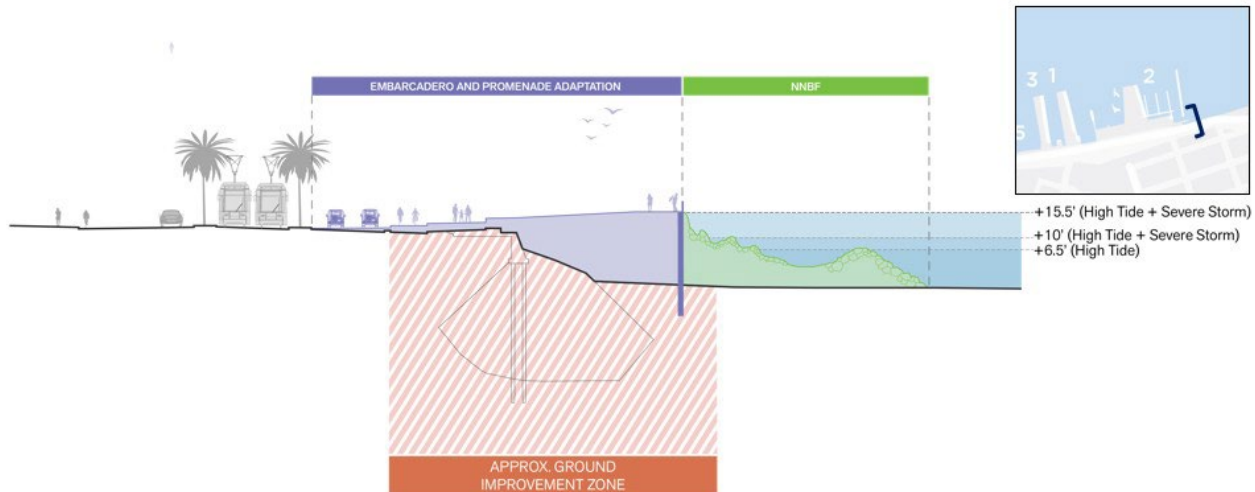
Gray and black represent existing conditions; orange, purple, and teal represent Recommended Plan First Actions. Width of ground improvement zone varies by location and will be refined during design.

Figure 5-6: Recommended Plan First Actions: Telegraph Hill to Bay Bridge (Reach 2), Typical Cross Section within Embarcadero Historic District



Gray and black represent existing conditions; orange, purple, and teal represent Recommended Plan First Actions. Width of ground improvement zone varies by location and will be refined during design.

Figure 5-7: Recommended Plan First Actions: Telegraph Hill to Bay Bridge (Reach 2), Ferry Building



Gray and black represent existing conditions; orange, purple, and green represent Recommended Plan First Actions. Width of ground improvement zone varies by location and will be refined during design.

Figure 5-8: Recommended Plan First Actions: Telegraph Hill to Bay Bridge (Reach 2), Rincon Park

5.1.2.2. Reach 2 Subsequent Actions

In Reach 2, Subsequent Actions may be needed to manage increasing flood risk. The Subsequent Actions vary by RSLC and include:

- Low and Intermediate RSLC: No action.
- High RSLC: Raise the flood defenses (finish elevation of 19.0 feet NAVD88, adapted according to *Appendix G: Monitoring and Adaptation Plan*). May also include interior drainage infrastructure, NNBFs, and elevating, floodproofing, or removing select buildings and infrastructure.

5.1.3. Mission Creek / Mission Bay (Reach 3)

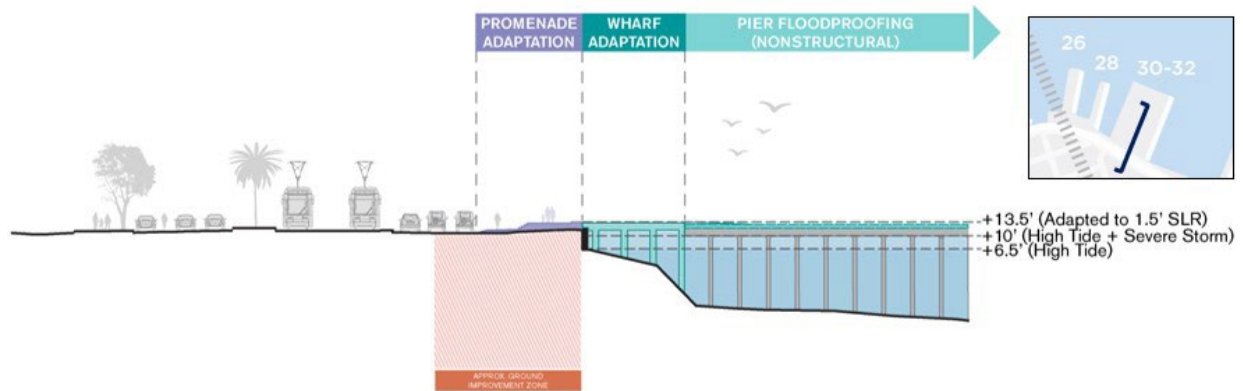
In the Mission Creek / Mission Bay geography, the Recommended Plan defends existing city and community assets in place by elevating the creek and Bay shorelines with raised and rebuilt bulkhead seawalls and wharves, levees, floodwalls, NNBFs, and closure structures. The coastal defense will tie into existing and planned high ground at Bayfront, Agua Vista, and Crane Cove Parks, and at the Mission Rock and Pier 70 development areas. The plan also includes partial reconstruction of the Embarcadero roadway south of the Bay Bridge to manage elevation change in this constrained urban area.

5.1.3.1. Reach 3 First Actions

The Recommended Plan in Reach 3 includes the following First Actions (**Figure 5-9** to **Figure 5-11**):

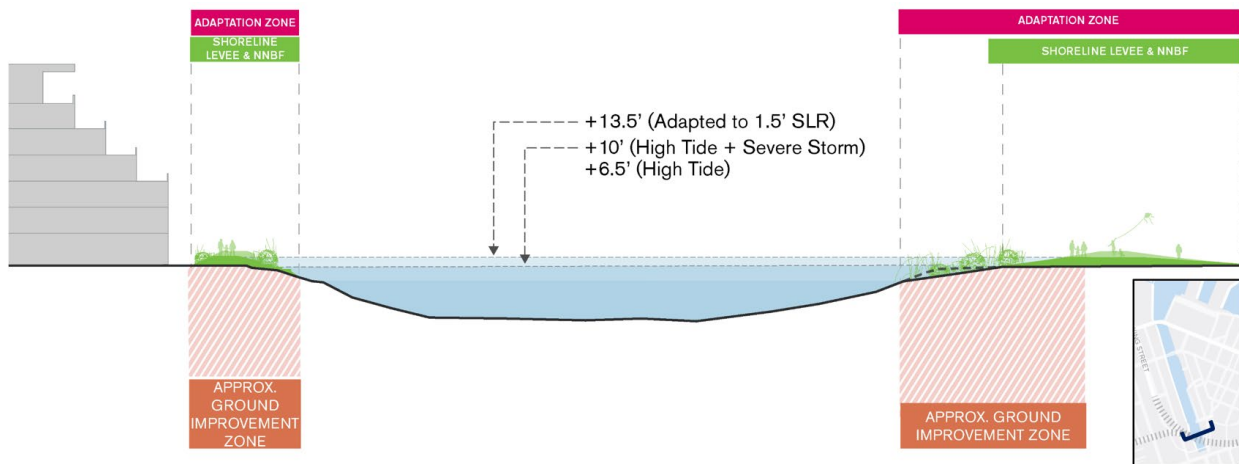
- Raise the Bay and creek shorelines to defend against 1.5 feet of RSLC (2000 baseline, translates to finish elevation of 13.5 feet NAVD88, pending refinement in design) using a combination of 1.5- to 4.5-foot-tall raised and rebuilt bulkhead seawalls and wharves, walls, levees, and NNBFs like creek enhancements and coarse beaches (*Appendix I: Engineering with Nature*). Provide Bay Trail access atop and adjacent to bayside levees, NNBFs, and wharves.
- Perform ground improvement to meet seismic design requirements of ER1110-2-1806 for the coastal flood defense structures.
- Install 2-foot-tall concrete curbs around the perimeters of piers from Pier 24 to Pier 50.
- Install closure structures at the northern and southern abutments of the 3rd and 4th Street bridges over the creek to defend landward buildings and infrastructure from flood damage. Service across bridges will be disrupted for hours to days during high water events. The likelihood of closure is anticipated to be approximately one closure on average every 25-200 years (0.5-4% annual chance) by 2060.⁵
- Tie measures into existing high ground and planned development projects at Bayfront, Agua Vista, and Crane Cove Parks, and at the Mission Rock and Pier 70 development areas. This includes installing a closure structure at Pier 50 to tie into high ground at Mission Rock.
- Floodproof select at-risk buildings bayside of the coastal flood defense (maps used for analysis in Sub-Appendix B.5).
- Build green/gray infrastructure compatible with existing combined sewer system to manage interior drainage.

⁵ Based on USACE Intermediate and High RSLC.



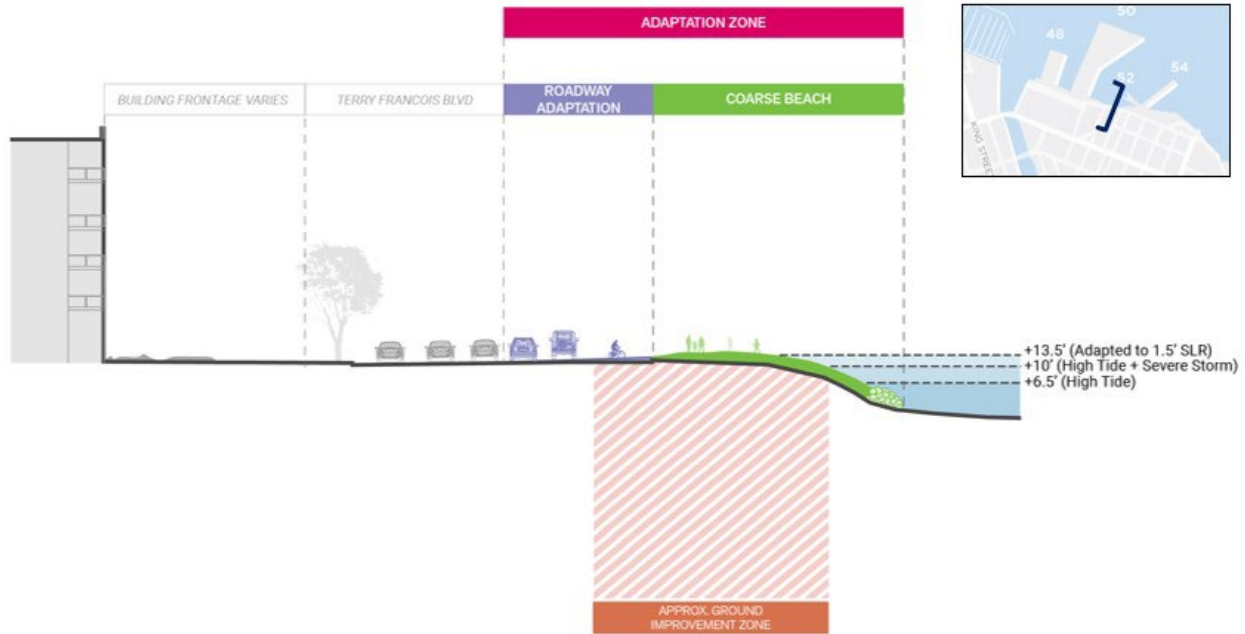
Gray and black represent existing conditions; orange, purple, and teal represent Recommended Plan First Actions. Width of ground improvement zone varies by location and will be refined during design.

Figure 5-9: Recommended Plan First Actions: Bay Bridge to Potrero Point (Reach 3), Pier 30/32



Gray and black represent existing conditions; orange, pink, and green represent Recommended Plan First Actions. Width of ground improvement zone varies by location and will be refined during design.

Figure 5-10: Recommended Plan First Actions: Bay Bridge to Potrero Point (Reach 3), Mission Creek



Gray and black represent existing conditions; orange, pink, purple, and green represent Recommended Plan First Actions. Width of ground improvement zone varies by location and will be refined during design.

Figure 5-11: Recommended Plan First Actions: Bay Bridge to Potrero Point (Reach 3), Terry Francois Boulevard

5.1.3.2. Reach 3 Subsequent Actions

In Reach 3, Subsequent Actions may be needed to manage increasing flood risk. The Subsequent Actions vary by RSLC and include:

- Low RSLC: No action.
- Intermediate and High RSLC: Raise the flood defenses (finish elevation of 15.5 to 19.0 feet NAVD88 for Intermediate and High, respectively, adapted according to *Appendix G: Monitoring and Adaptation Plan*). May also include interior drainage infrastructure, NNBFs, and elevating, floodproofing, or removing select buildings and infrastructure.

5.1.4. Islais Creek / Bayview (Reach 4)

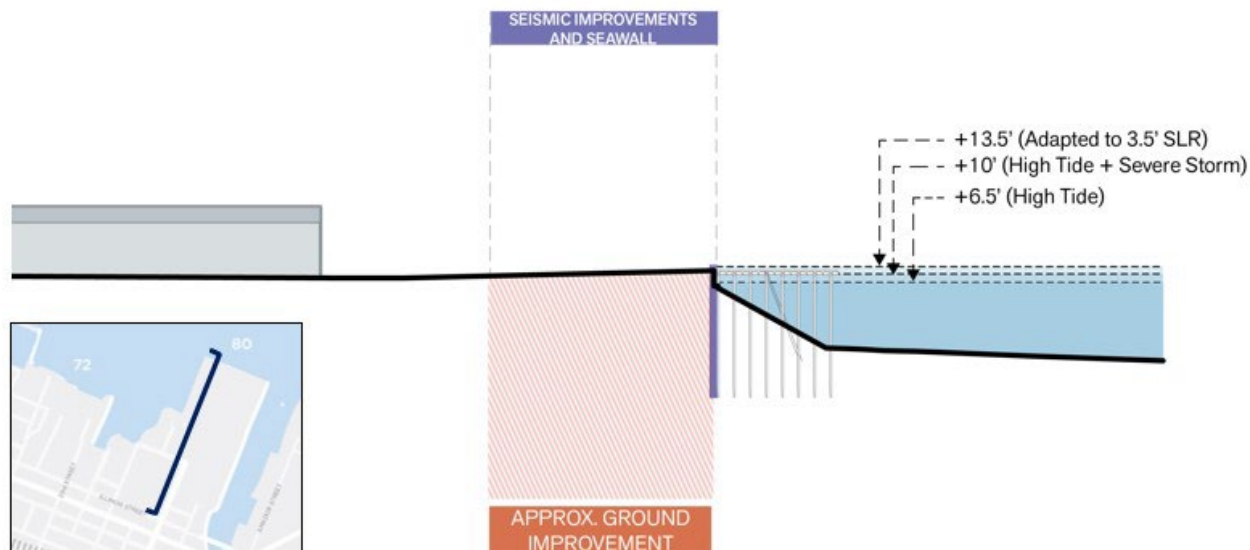
In the Islais Creek / Bayview geography, the Recommended Plan defends the existing shoreline to retain residential and commercial land uses in place, including POSF land uses and maritime facilities. The flood defenses consist of raising the shoreline using bulkhead seawalls, levees, NNBFs, floodwalls, closure structures, and tying into existing or planned high ground near Potrero Power Station and behind the Pier 94 wetlands (Port backlands). This area of the waterfront contains large parcels independent of the combined sewer system, such that the elevated shoreline will require modification to handle stormwater in a safe and effective manner.

5.1.4.1. Reach 4 First Actions

The Recommended Plan in Reach 4 includes the following First Actions (**Figure 5-12 to Figure 5-14**):

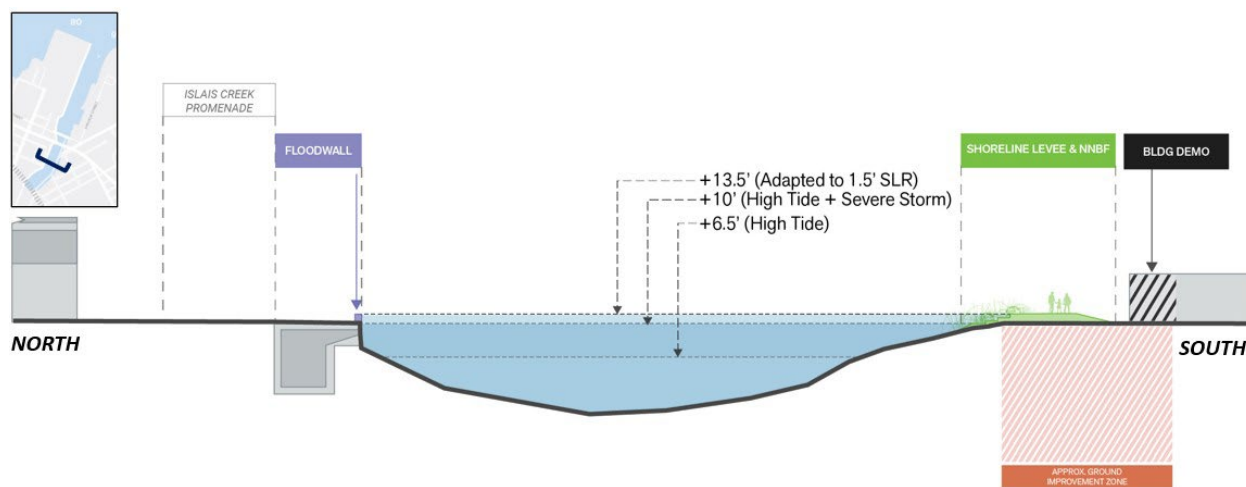
- Raise the Bay and creek shorelines to defend against 1.5 feet of RSLC (2000 baseline, translates to finish elevation of 13.5 feet NAVD88, pending refinement in design), while maintaining functions for maritime and other uses, using a combination of 2.5- to 5.5-foot-tall bulkhead seawalls, levees, closure structures, floodwalls, and NNBFs like coarse beaches, creek enhancements, and wetland protection (*Appendix I: Engineering with Nature*).
- Perform ground improvement to meet seismic design requirements of ER1110-2-1806 for the coastal flood defense structures.
- Install closure structures at the north and south abutments of Illinois Street Bridge to be activated in advance of a coastal storm.
- Rebuild the 3rd Street Bridge at a higher elevation⁶ per the San Francisco Public Works existing project, outside of the SFWCFS (FWOP Condition).
- Tie into high ground at Warm Water Cove, the western end of Islais Creek, Pier 94 wetlands, Heron's Head Park, and the southern boundary of the study area.
- Reconstruct portions of Pier 90 and 92 wharves at 13.5 feet NAVD88 elevation and incorporate them into the coastal defense system.
- Move or remove select buildings (or portions of buildings) that straddle the coastal flood defense structure (maps used for analysis are in Sub-Appendix B.5).
- Build green/gray infrastructure compatible with existing combined sewer system to manage interior drainage.

⁶ Rebuilding of 3rd Street Bridge at higher elevation is external to the SFWCFS project (i.e., it is part of the "Future Without Project" condition).



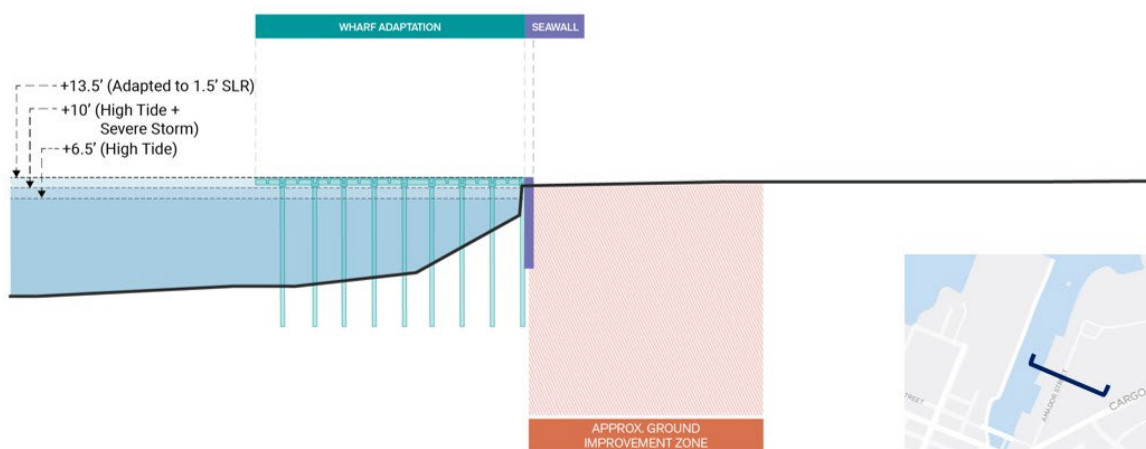
Gray and black represent existing conditions; orange and purple represent Recommended Plan First Actions. Width of ground improvement zone varies by location and will be refined during design.

Figure 5-12: Recommended Plan First Actions: Potrero Point to Heron's Head Park (Reach 4), Pier 80



Gray and black represent existing conditions; orange, purple, and green represent Recommended Plan First Actions. Width of ground improvement zone varies by location and will be refined during design.

Figure 5-13: Recommended Plan First Actions: Potrero Point to Heron's Head Park (Reach 4), Islais Creek



Gray and black represent existing conditions; orange, purple, and teal represent Recommended Plan First Actions. Width of ground improvement zone varies by location and will be refined during design.

Figure 5-14: Recommended Plan First Actions: Potrero Point to Heron's Head Park (Reach 4), Pier 92

5.1.4.2. Reach 4 Subsequent Actions

In Reach 4, Subsequent Actions may be needed to manage increasing flood risk. The Subsequent Actions vary by RSLC and include:

- Low RSLC: No action.
- Intermediate and High RSLC: Raise the flood defenses (finish elevation of 15.5 to 19.0 feet NAVD88 for Intermediate and High, respectively, adapted according to *Appendix G: Monitoring and Adaptation Plan*). May also include interior drainage infrastructure, NNBFs, and elevating, floodproofing, or removing buildings and infrastructure.

5.1.5. First Actions - Physical Quantities and Extents

The physical quantities and extents of the Recommended Plan features are summarized in **Table 5-2**.

Table 5-2: Physical Quantities and Extents of Recommended Plan First Actions

Measure	Total Project ^a		
	Linear Feet	Square Feet	Acres
Floodproofing	--	2,835,000	65
Deployable	--	50,000	1
Elevate Structures	--	750,000	17
Relocate Structures	--	175,000	4

Measure	Total Project ^a		
	Linear Feet	Square Feet	Acres
Remove Structures	--	195,000	4
Curb Wall	51,200	--	--
Elevate Shoreline	11,500	1,030,000	24
Seawall	21,000	--	--
T-wall	1,000	--	--
Elevate/Rebuild Wharf	10,900	660,000	15
Paved Levee	1,800	80,000	2
Planted Levee with EWN Features	11,800	865,000	20
Sheet-Pile Wall with EWN Features	2,900	20,000	0
EWN – Marsh/Coarse Beach Restoration	--	225,000	5
EWN – Rocky Intertidal Bluff	--	85,000	2
Living Seawalls	TBD	--	--
Bay Fill ^b	--	395,000	9
Ground Improvements	38,400	--	--

^aLinear feet values are rounded to the nearest 100 feet, and square feet values are rounded to the nearest 5,000 square feet, and acres are rounded to the nearest whole number. Values denoted as "--" indicate the measurement was not calculated or applicable

^bCommercial fill material was assumed throughout the planning process and in the cost estimates. However, there is an opportunity to consider the beneficial use of dredged material during design and implementation.

5.2. Plan Accomplishments

The Recommended Plan adaptively manages coastal flood risk through a suite of structural and nonstructural measures that function as a system and are implemented over time, based on the risk of rising sea levels along 7.5 miles of the San Francisco waterfront extending from Aquatic Park in the northeast to Heron's Head Park in the south.

5.2.1. Flood Risk Reduction

5.2.1.1. FWOP Flood Damages

FWOP inundation damages were estimated using the G2CRM computer model. Details on the G2CRM model and its use in estimating flood damages for this study can be

found in *Appendix E: Economic and Social Considerations*. Damages were also estimated for floodproofing costs, removal of assets (condemnation) costs, land loss (described as “retreat”), OMRR&R costs, and SFMTA system costs.

The study area is estimated to incur over \$20 billion in PV damage under the USACE High RSLC curve, \$5.4 billion in PV damage under the Intermediate RSLC curve, and \$3.6 billion in PV damage under the USACE Low RSLC curve (**Table 5-3**). Under the USACE High RSLC curve, structure damages are highest in Reaches 2 and 3. These structure damages (which, within G2CRM, include damages to specialized assets such as BART and SFMTA) make up the majority of the FWOP loss under the High RSLC curve. Under the Intermediate and Low RSLC curves, the OMRR&R damages make up a larger percentage of the total losses (48% and 74%, respectively), though those damages are approximately equal across all three RSLC curves. Because of this, FWOP losses under those curves are highest in Reach 4. **Table 5-4**, **Table 5-5**, and **Table 5-6** present FWOP damages in 25-year intervals, helping to describe both near-term and long-term risk.

Table 5-3: FWOP Total Present Value NED Damages by Reach
(FY 2026 Price Levels; 3.25% Discount Rate)

Reach	USACE Low RSLC	USACE Intermediate RSLC	USACE High RSLC
1	\$336,397,000	\$379,148,000	\$1,302,812,000
2	\$592,291,000	\$1,182,576,000	\$6,207,405,000
3	\$867,729,000	\$1,822,247,000	\$8,696,664,000
4	\$1,801,718,000	\$2,057,721,000	\$3,793,564,000
Total	\$3,598,135,000	\$5,441,692,000	\$20,000,445,000

Table 5-4: Total FWOP Damages by 25-Year Period, Low RSLC
(FY 2026 Price Levels)

Reach	2040 to 2064	2065 to 2089	2090 to 2114	2115 to 2139
1	272,639,000	38,493,000	17,322,000	7,942,000
2	366,692,000	120,480,000	65,217,000	39,902,000
3	479,645,000	221,194,000	107,313,000	59,576,000
4	1,218,658,000	425,038,000	108,191,000	49,830,000
Total	2,337,634,000	805,205,000	298,043,000	157,250,000

Table 5-5: Total FWOP Damages by 25-Year Period, Intermediate RSLC
(FY 2026 Price Levels)

Reach	2040 to 2064	2065 to 2089	2090 to 2114	2115 to 2139
1	276,815,000	42,316,000	26,293,000	33,724,000
2	437,761,000	268,843,000	262,452,000	213,521,000
3	700,847,000	494,521,000	382,815,000	244,065,000
4	1,312,774,000	483,723,000	174,110,000	87,113,000
Total	2,728,197,000	1,289,403,000	845,670,000	578,423,000

Table 5-6: Total FWOP Damages by 25-Year Period, High RSLC
(FY 2026 Price Levels)

Reach	2040 to 2064	2065 to 2089	2090 to 2114	2115 to 2139
1	305,549,000	344,181,000	455,691,000	197,390,000
2	1,407,624,000	2,125,211,000	1,863,551,000	811,018,000
3	2,492,478,000	2,936,672,000	2,278,674,000	988,840,000
4	1,719,197,000	1,034,198,000	527,421,000	512,748,000
Total	5,924,848,000	6,440,262,000	5,125,337,000	2,509,996,000

The final results are shown in **Table 5-7** (present value) and **Table 5-8** (average annual value), capturing both the updated costs and the updated benefits.

Table 5-7: Recommended Plan Results, Present Value, FY26 Dollars

Category	FWOP Damages (PV)	Recommended Plan Damages (PV)	Benefits (PV)	Non-Seismic Total Cost (PV)	Net Benefits (PV)	BCR
High Overall	20,000,445,000	2,795,762,000	17,204,683,000	20,713,586,000	(3,508,903,000)	0.83
Int Overall	5,441,692,000	1,644,778,000	3,796,914,000	15,837,291,000	(12,040,377,000)	0.24
Low Overall	3,598,135,000	1,532,347,000	2,065,788,000	15,421,248,000	(13,355,460,000)	0.13
High Reach 1	1,302,812,000	521,802,000	781,010,000	1,549,957,000	(768,947,000)	0.50
High Reach 2	6,207,405,000	286,554,000	5,920,851,000	5,944,248,000	(23,397,000)	1.00
High Reach 3	8,696,664,000	616,430,000	8,080,234,000	5,348,974,000	2,731,260,000	1.51
High Reach 4	3,793,564,000	1,370,976,000	2,422,588,000	7,870,407,000	(5,447,819,000)	0.31
Int Reach 1	379,148,000	339,372,000	39,776,000	835,037,000	(795,261,000)	0.05
Int Reach 2	1,182,576,000	27,812,000	1,154,764,000	5,862,970,000	(4,708,206,000)	0.20
Int Reach 3	1,822,247,000	111,159,000	1,711,088,000	3,182,079,000	(1,470,991,000)	0.54
Int Reach 4	2,057,721,000	1,166,435,000	891,286,000	5,957,205,000	(5,065,919,000)	0.15
Low Reach 1	336,397,000	335,153,000	1,244,000	834,654,000	(833,410,000)	0.00
Low Reach 2	592,291,000	21,465,000	570,826,000	5,862,970,000	(5,292,144,000)	0.10
Low Reach 3	867,729,000	98,650,000	769,079,000	2,949,222,000	(2,180,143,000)	0.26
Low Reach 4	1,801,718,000	1,077,079,000	724,639,000	5,774,402,000	(5,049,763,000)	0.13

Table 5-8: Recommended Plan Results, Average Annual Value, FY26

Category	FWOP Average Annual Damages	Recommended Plan Average Annual Damages	Average Annual Benefits	Average Annual Non-Seismic Total Cost	Average Annual Net Benefits (PV)	BCR
High Overall	677,685,282	94,730,230	582,955,052	701,849,002	(118,893,951)	0.83
Int Overall	184,383,626	55,730,852	128,652,774	536,623,011	(407,970,237)	0.24
Low Overall	121,917,444	51,921,295	69,996,149	522,526,014	(452,529,865)	0.13
High Reach 1	44,143,844	17,680,483	26,463,360	52,517,984	(26,054,624)	0.50
High Reach 2	210,328,671	9,709,455	200,619,215	201,411,988	(792,772)	1.00
High Reach 3	294,673,503	20,886,812	273,786,691	181,242,015	92,544,676	1.51
High Reach 4	128,539,264	46,453,479	82,085,785	266,677,016	(184,591,231)	0.31
Int Reach 1	12,846,865	11,499,115	1,347,751	28,293,985	(26,946,234)	0.05
Int Reach 2	40,069,826	942,368	39,127,458	198,658,004	(159,530,546)	0.20
Int Reach 3	61,744,125	3,766,457	57,977,668	107,820,006	(49,842,339)	0.54
Int Reach 4	69,722,810	39,522,912	30,199,898	201,851,016	(171,651,118)	0.15
Low Reach 1	11,398,311	11,356,160	42,151	28,281,007	(28,238,856)	0.00
Low Reach 2	20,068,898	727,310	19,341,589	198,658,004	(179,316,415)	0.10
Low Reach 3	29,401,704	3,342,608	26,059,096	99,929,994	(73,870,898)	0.26
Low Reach 4	61,048,530	36,495,217	24,553,313	195,657,009	(171,103,696)	0.13

In addition to the analysis of NED damages, the potential regional economic impacts of flooding along the San Francisco waterfront study area were analyzed. The analysis identified how these economic impacts from flooding, also known RED, affect the Bay Area and the larger California economy.

The RED analysis consists of three categories:

- Impacts to critical infrastructure
- Direct economic impacts
- Cascading regional economic impacts

RED impacts to critical infrastructure are calculated in G2CRM and are generally expressed in terms of revenue loss to specific public and private transportation and utility assets. Note that physical damages to transportation and critical infrastructure, losses from transportation disruption, FWOP investment to address RSLC, and various other costs are considered NED. Direct economic impacts include direct economic output losses and direct job impacts. Direct economic output losses are also modeled in G2CRM, while direct job impacts are produced by the Impact Analysis for Planning (IMPLAN) software using the G2CRM direct output losses as a model input. These direct losses occur when a building sustains damage and cannot be occupied during repairs and restoration of flooded components. Cascading regional economic impacts include indirect and induced impacts on economic output and jobs, both estimated with IMPLAN, again using the G2CRM direct output losses as a model input. Indirect effects represent impacts on business-to-business purchases in the supply chain, whereas induced effects stem from changes in household income spending, after removal of taxes, savings, and commuter income.

Table 5-9 summarizes the RED damages for the FWOP condition.

Table 5-9: Summary of RED Damages for FWOP Condition
(FY 2025 Price Levels; 3% Discount Rate)

Type	Present Value		
	USACE Low RSLC	USACE Intermediate RSLC	USACE High RSLC
Revenue Losses for Critical Infrastructure	\$130,000,000	\$220,000,000	\$460,000,000
Direct Output Losses	\$17,000,000	\$140,000,000	\$1,000,000,000
Cascading Regional Output Loss (CA)	\$13,000,000	\$130,000,000	\$970,000,000
TOTAL Losses	\$160,000,000	\$490,000,000	\$2,430,000,000
Job Losses	120	1,100	8,900

5.2.1.2. Recommended Plan Risk Reduction

Table 5-10 shows the Recommended Plan's impact on risk across the various NED risk categories. Conceptually, inundation risk is addressed. Exposure risk is mostly addressed, except for areas bayward of the line of protection and in areas that use nonstructural instead of structural measures.

Table 5-10: How the Recommended Plan Addresses Risk

Risk	FWOP	Recommended Plan
Inundation	Assets experience damage when stillwater elevation is greater than the first floor elevation.	Structural measures, floodproofing, and proactive retreat reduce inundation risk. Residual risk exists at the end of POA from overtopping.
Floodproofing	Reactive floodproofing is an FWOP loss that occurs due to repetitive damage.	Proactive floodproofing is an FWP cost.
Land Loss	Land loss occurs when land enters the 1-month floodplain.	Land bayward of the seawall is lost when it enters the 1-month floodplain. Protected areas don't suffer land loss.
OMRR&R	OMRR&R on existing coastal defense system is considered an FWOP loss.	For parts of coastal defense system that are replaced, FWOP loss becomes an FWP cost.
SFMTA	SFMTA takes preventative action as their flood risk increases, which is assumed as an FWOP loss.	FWP measures offset the need for some, but not all, SFMTA capital costs, representing a benefit.

5.2.2. Economic Benefits

Residual risk for the Recommended Plan by Reach by damage type is shown in **Table 5-11**, **Table 5-12**, and **Table 5-13**.

Table 5-11: Recommended Plan Damages by Damage Type, Low RSLC

(PV, FY 2026 Price Level, \$)

Reach	Inundation	Retreat	OMRR&R	SFMTA	Total	Damage Reduced
1	2,631,000	819,000	331,702,000	-	335,153,000	1,244,000
2	-	-	21,465,000	-	21,465,000	570,826,000
3	-	250,000	98,400,000	-	98,650,000	769,079,000
4	-	14,000	1,077,066,000	-	1,077,079,000	724,639,000
Total	2,631,000	1,083,000	1,528,634,000	-	1,532,348,000	2,065,786,000

Table 5-12: Recommended Plan Damages by Damage Type, Intermediate. RSLC

(PV, FY 2026 Price Level, \$)

Reach	Inundation	Retreat	OMRR&R	SFMTA	Total	Damage Reduced
1	3,098,000	4,571,000	331,702,000	-	339,372,000	39,776,000
2	-	670,000	21,465,000	5,677,000	27,812,000	1,154,764,000
3	-	12,759,000	98,400,000	-	111,159,000	1,711,088,000
4	-	88,334,000	1,077,066,000	1,036,000	1,166,435,000	891,286,000
Total	3,098,000	106,334,000	1,528,634,000	6,713,000	1,644,778,000	3,796,913,000

Table 5-13: Recommended Plan Damages by Damage Type, High RSLC

(PV, FY 2026 Price Level, \$)

Reach	Inundation	Retreat	OMRR&R	SFMTA	Total	Damage Reduced
1	26,019,000	92,698,000	330,418,000	72,667,000	521,802,000	781,010,000
2	79,884,000	85,921,000	21,020,000	99,729,000	286,554,000	5,920,851,000
3	336,130,000	173,384,000	98,285,000	8,631,000	616,430,000	8,080,234,000
4	72,051,000	125,521,000	1,077,066,000	96,339,000	1,370,976,000	2,422,588,000
Total	514,084,000	477,524,000	1,526,788,000	277,366,000	2,795,761,000	17,204,684,000

There is a significant reduction in residual inundation risk in protected areas for the Recommended Plan. Various alternatives showed both residual risk for unprotected areas and residual risk from overtopping events. The Recommended Plan is the most bayward alignment, providing protection to the most assets possible, and uses nonstructural measures to buy down additional risk. There is also minimal risk of overtopping due to the nature of the hazard, though the residual risk seen under the High RSLC is due to non-deterministic overtopping at the end of the study period (2130 on). As the storm surge and wave contribution to the total water level is minimal (approximately 2 feet), a proactive plan to adapt the crest elevation to match the risk will ensure the measures function as expected throughout the study time period.

Impounding water behind a seawall prevents flooding in a study area but may transform risk. The initial risk is very low because even in storm events, the water level behind the wall will be low. A breach of the measure will equalize water on either side of the wall; these water levels will be 0 to 2 feet, but the water velocity will be higher than if there were no wall. This can add to life-safety risk.

5.2.3. Environmental and Social Benefits

Environmental and social benefits were assessed for each RSLC within a comprehensive benefits matrix that included OSE and EQ accounts to support evaluation of the alternatives against study objectives at the plan level and at the individual reach level.

One dominant theme in the Recommended Plan choices of measures that differ from the NED scale within each is the need that the Recommended Plan be effective in reducing risk across multiple possible RSLC scenarios over the POA. The resulting environmental and social benefits informed the Recommended Plan development by clarifying impacts to the community from exposure to coastal and combined flood risk.

5.2.4. Plan Performance with Changing Conditions

The performance of the Recommended Plan is defined as follows: Recommended Plan First and Subsequent Actions will maintain low risk of consequences to people, economy, and the environment in the event of a 1% AEP (or 100-year) coastal flood event throughout the 100-year POA. Detailed design of coastal flood defense structures will include consideration of extreme stillwater levels and total water levels (including wave runoff), account for uncertainty in the magnitude of the 1% AEP event and meet standard USACE design criteria. Residual risk – due to less frequent, higher magnitude coastal flood events – is considered tolerable for the purposes of defining the performance of the Recommended Plan.

Section 5.1 defines three sets of potential Subsequent Actions (associated with Low, Intermediate, and High RSLC), varying by reach. Through the process described in *Appendix G: Monitoring and Adaptation Plan*, which incorporates monitoring of RSLC in addition to other risk factors, one of these three sets of actions will be identified as the most appropriate path forward and further refined based on hazard conditions and technological advancements.

5.3. Monitoring and Adaptation

Adaptive actions are proposed to be implemented at around the 50-year mark after the First Actions are implemented, although the timing could and likely would vary under different RSLC rates. A monitoring system will be utilized to track the rate of relative RSLC in the project area to support analysis and decisions about scale and timing of adaptation. Predefined trigger conditions or elevations will confirm when the adaptive action will be implemented. Appendix G describes a MAP that will define the appropriate personnel, method, and data to monitor the coastal and combined flood risk in the area and processes to initiate Subsequent Actions defined in the resilience strategy. The MAP framework includes, but is not limited to:

- Identify thresholds of RSLC that would trigger the need for additional protection
- Evaluate the level of performance required to address the RSLC risk based on those thresholds, considering other factors such as life of asset, other planned projects, and disruption from the construction period
- Describe coordination and involvement of resource agencies, USACE, POSF, CCSF, and State to manage the risks over time
- Develop the governance and executive structure that could be used to manage uncertainty in a collaborative effort based on trigger points identified for risk assessment and management
- Identify an approach for construction and costs based on thresholds of projected RSLC, including appropriate lead times for planning and construction and margin of safety before intervention is needed
- Recommend approaches for Congressional authorization and future PED strategies that will enable USACE and POSF to more efficiently implement Subsequent Actions given the uncertainty regarding future rates of RSLC
- Clarify appropriate scale and alignment of features to be constructed in time to reduce vulnerability to flooding in the study area

The Recommended Plan also includes NNBFs to optimize coastal flood risk reduction and net benefits. Opportunities for additional NNBFs will be evaluated in the design phase. As these features are implemented, they should be monitored and evaluated for effectiveness and adapted as necessary. Supplemental NEPA and environmental compliance consultations would be completed for the Subsequent Action measures prior to construction.

5.4. Costs

Plan costs were estimated using the Micro-Computer Aided Cost Estimating System, Second Generation (MCACES 2nd Generation, or MII) cost engineering model. The detailed cost estimate is based on a combination of MII's Cost Book, estimator-created site-specific cost items, and local subcontractor and material supplier cost quotes. Cost

contingencies were developed through a standard Cost and Schedule Risk Analysis. Appendices C and F include details of the engineering and real estate cost estimates, respectively.

At FY 2026 price levels, the Recommended Plan has an estimated project first cost of \$17,812,115,000 for the First Actions (**Table 5-14**) and an annualized cost of \$672,477,000 based on 3.25% discount rate (**Table 5-15**). The annualized cost includes planning, engineering and design, construction management, interest during construction, and OMRR&R, including contingencies.

In compliance with Section 152 of WRDA 2020, as amended by Section 8380 of WRDA 2022, the project costs have been allocated into “seismic” and “non-seismic” for the purposes of economic evaluation. The “seismic” cost is equivalent to the total project cost, while the “non-seismic” cost deducts the cost of elements of the plan that would not be required in a low seismic hazard region. For the purposes of this study, the cost of ground improvement required to meet the seismic design requirements of ER1110-2-1806 are allocated as “seismic” costs and constitute approximately 22% of the total project cost. The remaining 78% of the total project cost consists of real estate, Coastal Flood Risk Management (CFRM) features, PED and construction management activities.

Table 5-16 shows the range of costs of the Recommended Plan First and Subsequent Actions for the Low to High RSLC.

Table 5-14: Recommended Plan First Actions Cost Summary
(FY 2026 Price Level)

WBS Code	Item	Cost
02	Relocations	\$1,253,390,000
06	Fish & Wildlife Facilities (Mitigation)	\$67,211,000
10	Breakwaters & Seawalls	\$5,953,057,000
13	Pumping Plant	\$1,388,466,000
18	Cultural Resource Preservation (Mitigation)	\$108,525,000
19	Buildings, Grounds, & Utilities	\$1,938,131,000
19	Buildings, Grounds, & Utilities (Reach 1 2065)	\$157,123,000
01	Lands & Damages ^a	\$3,689,028,000
30	Planning, Engineering and Design	\$2,158,866,000
31	Construction Management	\$1,098,318,000
	Total First Cost	\$17,812,115,000

^aLands and Damages costs are referenced from *Appendix F: Real Estate Plan*

Values rounded

Table 5-15: Recommended Plan - First Actions Annual Costs
(FY 2026 Price Level; 3.25% Discount Rate)

Item	Cost
First Cost	\$17,812,115,000
Interest During Construction	\$1,099,833,000
Annual OMRR&R	\$31,674,000
Average Annual Cost	\$672,477,000

Values rounded

Table 5-16: Recommended Plan - First and Subsequent Actions Cost
(FY 2026 Price Level)

Item	First Actions	Subsequent Actions			Total Cost Range		
		Low RSLC	Intermediate RSLC	High RSLC			
Lands & Damages ^a	\$3,689,028,000	\$0	\$0	\$3,144,700,000	\$3,689,028,000	to	\$6,833,728,000
Relocations	\$1,253,390,000	\$0	\$757,700,000	\$3,102,400,000	\$1,253,390,000	to	\$4,355,790,000
Construction	\$9,612,513,000	\$0	\$814,600,000	\$7,520,200,000	\$9,612,513,000	to	\$17,132,713,000
Planning, Engineering and Design	\$2,158,866,000	\$0	\$166,400,000	\$1,220,700,000	\$2,158,866,000	to	\$3,379,566,000
Construction Management	\$1,098,318,000	\$0	\$88,400,000	\$649,100,000	\$1,098,318,000	to	\$1,747,418,000
Total First Cost	\$17,812,115,000	\$0	\$1,827,100,000	\$15,637,100,000	\$17,812,115,000	to	\$33,449,215,000

^aLands and Damages costs are referenced from the Real Estate Plan (Appendix F). These costs are assumed to be zero under the Intermediate RSLC curve because a) the Reach 1 footprint will be covered with First Actions, b) there are no Reach 2 Subsequent Actions with Intermediate RSLC, and c) Reach 3 and 4 Subsequent Actions require no change to the structure footprint. It is possible that raising the elevation of the protective structure in Reaches 3 and 4 may incur Relocation Assistance Benefits costs that have not been quantified.

Values rounded

In accordance with USACE guidance, the PDT used a comprehensive benefits approach in evaluating alternatives and developing the Recommended Plan. The Recommended Plan maximizes total net benefits across all benefit categories. It has an economic BCR range of 0.13-0.83 with average annual benefits ranging from \$70 million to \$583 million across the range of future sea level conditions as defined in USACE guidance. The Recommended Plan achieves additional benefit streams within the RED, OSE, and EQ accounts. The suite of benefits include reduction in flood risk

damages and disruption, life safety, increasing transportation infrastructure resilience, maintaining economic activity, maritime function, and other community and ecological benefits.

5.5. Project Risk

A Semi-Quantitative Risk Assessment (SQRA) was completed in general accordance with Engineer Circular 1165-2-218 USACE Levee Safety Program (USACE 2021), consisting of a facilitated Potential Failure Mode Analysis, a site visit, and a risk assessment of potential failure modes judged to be risk drivers. The SQRA was performed for the First Actions of the Recommended Plan. This subsection presents major areas of risk and uncertainty known at this time.

Tolerable Risk Guidelines (TRGs) are used for risk-informed decision-making within the USACE Dam and Levee Safety Programs. These guidelines are the criteria USACE uses to determine if the risks associated with dams and levee systems are “tolerable.” The four TRG are as follows:

- TRG 1 (Understanding the Risk): Society is willing to live with the risk associated with the dam or levee to secure the benefits provided by the dam or living and working downstream or in the leveed area.
- TRG 2 (Building Risk Awareness): There is a continuation of recognition and communication of the dam or levee risk.
- TRG 3 (Fulfilling Daily Responsibilities): The risks associated with the dam or levee system are being properly monitored and managed by those responsible for managing the risk.
- TRG 4 (Actions to Reduce Risk): There are no cost-effective, socially acceptable, or environmentally acceptable ways to reduce risks.

The SQRA team formulated recommendations based on these four TRG to manage and reduce risk. Additional details about the hazard, performance, and consequences can be found in the SQRA report.

Prior to the completion of the SQRA on the Recommended Plan, a set of qualitative life-safety metrics were developed to evaluate the expected performance of the FWP alternatives. These metrics include both a score for coastal life-safety as well as earthquake life-safety due to the incidental seismic benefits that construction of the CFRM system will have on existing, seismically vulnerable structures. The details of these qualitative metrics can be found in Sub-Appendix B.2 and Sub-Appendix B.3.

5.5.1. Life-Safety Risk

Life safety is the risk to individuals who may be affected by coastal storms and other events. Individual life risk is influenced by location, exposure, and vulnerability within a leveed area. A total of seventy potential failure modes (PFMs) were identified by the SQRA team for consideration. PFM 1 – Embankment Overtopping Erosion Breach – was fully evaluated by the PDT. The remaining PFMs were not developed in detail

because they are expected to be addressed during the design phase and are not expected to be risk drivers for the system.

If water levels are forecasted to exceed the top of the various flood risk management features due to a combination of high tides and a storm event, the levee embankment is expected to have a higher probability of breach than floodwalls and bulkhead walls. While the vegetated levees that are expected to be low in overall height are likely able to tolerate some amount of overtopping flows without significant damage or full breach, especially given the short nature of peak tide levels, there are infrequent storm events that can result in enough overtopping to fail the embankments. The risk of overtopping increases over the life of the project due to the RSLC from rising high tides and potential settlement of the constructed levee grade. However, the incremental risk related to overtopping breach is expected to be low because the design includes additional height to account for high uncertainty in the future sea level change condition and additional height to account for limiting wave overtopping from potential coincident waves during peak water levels. The frequency of overtopping is expected to be less frequent than 1/1000 at the end of construction (2040). At 2090, the overtopping frequency is expected to be around 1/500. If a breach were to occur, the expected life loss from both the breach and a non-breach condition are expected to be close to zero. This low life loss estimate is driven by limited inundation area due to the rising terrain, the low depths of flooding, and the ability for advanced warning to take protective action.

Non-breach risk occurs when the flood capacity of the system is exceeded. At this point, the system transitions from managing the flood to passing the flood. For levees, the transition occurs at the overtopping stage. This elevation corresponds to the annual probability of non-breach inundation but may not result in life loss. The AEP when life loss begins to occur ($AEP_{N>0}$) is estimated based on available consequence information and judgment. The annual probability of flooding with non-breach life loss was estimated to be 1/500 AEP based on the top of levee (TOL) elevation (AEP_{TOL}), assuming the RSLC is the expected value between the high and low estimate in the year 2090. For low depths of overtopping, the non-breach life loss is still expected to be near zero. Overtopping would be an extreme event that is predicted in advance and the terrain and flood depths would likely allow for protective action to be successful.

5.5.2. Economic Risk

A total of 70 PFMs were identified by the SQRA team for consideration. PFM 1 – Embankment Overtopping Erosion Breach – was fully evaluated by the PDT. The remaining PFMs were not developed in detail because they are expected to be addressed during the design phase and are not expected to be risk drivers for the system.

Similar to the life-safety risk, incremental economic risk is driven by the probability of an overtopping breach of a levee feature. A breach at the 2090 design loading condition is expected to result in up to \$80 million in damages. This estimate is below the expected annual damages of hundreds of millions of dollars that was documented in the planning study, likely because a breach would limit flow to the project area especially over the short duration of peak high storm tide elevations.

The AEP when flood damages begin to occur ($AEP_{\$>0}$) is estimated based on available consequence information and judgment. The annual probability of flooding with non-breach economic cost was estimated to be 1/500 AEP based on the TOL elevation (AEP_{TOL}).

Non-breach damages for limited depths of overtopping are likely limited, similar to breach flows, due to the short duration of peak storm tides. However, for extreme events with multiple feet of overtopping depths, non-breach damages could reach hundreds of millions to billions of dollars of damages to structures and the contents of structures.

G2CRM modeling links the predictive capability of hydraulic and hydrologic modeling with project area infrastructure information, structure and content damage functions, and economic valuations to estimate the total damage under various proposed alternatives while accounting for risk and uncertainty. More information about economic risk and uncertainty can be found in *Appendix E: Economic and Social Considerations*.

G2CRM provides integrated hydrologic engineering and economic risk analysis during the formulation and evaluation of flood damage reduction plans in compliance with policy regulations ER 1105-2-100 *Planning Guidance Notebook*, ER 1105-2-103 *Policy for Conducting Civil Works Planning Studies*, and ER 1105-2-101 *Risk Analysis for Flood Damage Reduction Studies*. Uncertainty in storm inputs, economic variables, and depth-percent damage functions are quantified and incorporated into evaluation of the FWOP condition and the performance of any proposed alternatives.

For SFMTA, based on the flooding sequence established, the cost to replace specific assets damaged by both flowing and standing water are calculated for key water elevations and plotted as stage-damage functions. The methodology to identify asset replacement costs for each agency includes a range to account for uncertainty. These stage-damage functions and the total damageable value of each system are key inputs into the G2CRM flood model.

The replacement cost for the asset entry represents the maximum increased cost of transportation calculated: \$46 million. A plus or minus 40% uncertainty was applied to the \$46 million, giving a range from \$28 million to \$65 million for the minimum and maximum replacement cost estimates.

To develop the custom depth-damage curve for G2CRM use, the results for different water elevations were mapped to depth based on the critical elevation for the BART system, or 10.34 feet NAVD88. An additional plus and minus 15% uncertainty was applied to the mean depth-damage function given the high level of uncertainty around these estimations.

Custom-made depth-percent damage curves were derived for numerous unique physical and nonphysical assets within the study area. In general, they represented the cost to repair or replace specific assets at key water elevations. Both the asset replacement costs, and the damages assigned by the depth-percent damage curves

have high degrees of uncertainty, which are represented in the triangle distributions used within G2CRM.

Another economic uncertainty is how the study area will react to the High rate of RSLC. Estimates about when asset owners will take protective actions for their property and when they will be forced out of the floodplain due to high-frequency flooding could not be empirically modeled due to a lack of data. Instead, multivariate testing was done within G2CRM, showing how different assumptions about the parameters impacted the results. More information on this can be found in *Appendix E: Economic and Social Considerations*.

5.5.3. Residual Risk

The Recommended Plan reduces coastal and combined flood risk across the POA under multiple RSLC scenarios. Residual risk is evident by the damages that are estimated to continue in the FWP condition (Section 5.2.2). Refinements to the Recommended Plan during design or implementation will seek to reduce residual risk and manage life-safety concerns.

5.5.4. Adaptation

The Recommended Plan is the plan that reasonably maximizes total net benefits across all rates of RSLC largely because of the adaptation proposed at 2090 to increase the scale of measures if RSLC is increasing risk in the study area. The potential adaptive actions have been designed to correspond to possible RSLC rates over time, and have been modeled with the assumed implementation time of 2090, although the actual implementation time may vary based on engineering judgment and changing meteorological conditions assessments. A monitoring plan will be in place to guide risk assessment and adaptation of measures based on predetermined risk thresholds. The MAP is described in *Appendix G: Monitoring and Adaptation Plan*, and will be developed further during design.

5.5.5. Implementation Risk

Ground improvements are required along most of the waterfront. Scheduling and sequencing this work will require several pieces of equipment, multiple subcontractors, or both, working in different locations simultaneously. If work from the water is necessary in Reach 2 near the Ferry Building, this becomes more challenging for the contractor and slows production rates compared to working from the ground. When construction is taking place along the Embarcadero, specifically north and south of Rincon Park, coordinating traffic or finding alternate routes around the area will be necessary.

The Recommended Plan was formulated as a complete solution for the entire study area. Implementing the plan will take multiple contracts and many years. During PED, the need for interim measures to prevent outflanking of completed sections will be evaluated and implemented, if necessary.

5.5.6. Construction and Engineering Risk

HTRW concerns exist in the project area and will require additional investigation and testing prior to construction. The SFWCFS will comply with USACE policy and Federal, state, and/or local regulatory requirements for hazardous substances prior to advertisement for construction contracts.

Construction will occur along and adjacent to the Embarcadero roadway. This will cause traffic to be reduced in those areas or completely rerouted, thus congesting other parts of the city further inland. Lack of staging areas will also be a construction risk for the project, specifically from Crane Cove Park to Fisherman's Wharf. All materials will need to be stored in locations outside of these areas and hauled to the worksite or delivered onsite when needed.

Short or long duration storms, particularly in the winter months could potentially cause delays. As seen this past year, ARs can develop and lead to extended periods of rainfall and flooding. This is not a new phenomenon to the region and other construction projects have successfully dealt with this issue but not without delays.

5.6. Lands, Easements, Rights-of-Way, Relocations, and Disposal Areas

The NFS will be responsible for acquiring and furnishing all land, easements, rights-of-way, relocations (i.e., P.L. 91-646 relocations and utility/facility relocations), and disposal areas (LERRDs) for the project areas, as required for the construction, operation, and maintenance of the proposed project. A Real Estate Plan was developed to present the Real Estate requirements for the Recommended Plan. The standard estates were reviewed and were found to be acceptable for the project. Other relevant information on the NFS's ownership of land, existing Federal projects, potential relocations under the Uniform Relocation Assistance and Real Property Acquisition Policies Act (P.L. 91-646, as amended), facility/utility relocations, a schedule for real estate acquisition activities, and other issues as required can be found in *Appendix F: Real Estate Plan*.

Acquisition of parcels was estimated for real estate costs for those areas not owned by the NFS. From the feasibility level of design, much of the area in the footprint would require a levee easement. In estimating Real Estate costs, the land values were utilized for estimating the value to acquire a levee easement. For the few areas that buildings were to be removed, acquisition of the entire parcel was estimated. Should the NFS provide additional documentation of their ownership after review of the Final IFR/EIS, the Real Estate costs will be adjusted to reflect those changes. A list of the estimated number of businesses that would receive Relocation Assistance Benefits has been received and these costs have been included in the Baseline Cost Estimate. Currently, a Real Estate assessment is not included in the Real Estate Plan that would discuss the types of utilities/facilities identified and the impact to the project. This has been captured as a risk in the Risk Register.

Should it be determined that additional lands are required during the design phase, the NFS would be required to purchase these lands using the appropriate standard estate.

Table 5-17 summarizes the real estate requirements for the Recommended Plan.

Table 5-17: Real Estate Requirements for the Recommended Plan

Action	Required Interest	Required Acres	# Parcels		# Owners	
			Private	Public	Private	Public
First Actions	Fee Interest	3.93	4	0	4	0
	Flood Protection Levee Easement	2.77	4	4	4	1
	Temporary Work Easement	0	0	0	0	0
Subsequent Actions	Fee Interest	1.5	1	0	1	0
	Flood Protection Levee Easement	1.12	5	6	1	2
	Temporary Work Easement	3.74	0	3	0	1

5.7. Cost Sharing

Project first cost is the constant dollar cost of the First Actions of the Recommended Plan at current price levels and is the cost used in the authorizing document for a project. The “Total Project Cost” is the constant dollar fully funded cost with escalation to the estimated midpoint of construction (2045). Total Project Cost is the cost estimate used in Project Partnership Agreements (PPAs) for implementation of design and construction of a project. Total Project Cost is the cost estimate provided to the NFS for their use in financial planning as it provides information regarding the overall non-Federal cost-sharing obligation. For this project, the First Cost of the Recommended Plan First Actions was estimated to be \$17,812,115,000, while the Total Project Cost of the Recommended Plan First Actions (Fully Funded) was estimated to be \$32,312,093,000.

In accordance with the cost share provisions in Section 103 of WRDA 1986, as amended (33 U.S.C. 2213), project design and implementation are cost shared 65% Federal and 35% non-Federal, with the NFS responsible for providing all LERRDs. The non-Federal costs include credit for the value of LERRDs. The estimated Federal first cost is \$11,577,875,000, and the estimated non-Federal first cost is \$6,234,240,000. Total LERRDs are estimated to be \$4,942,418,000, which is less than 35% of the Project First Costs as shown in **Table 5-18**. The fully funded Total Project Cost also has a LERRDs value that is less than 35%. The cost share apportionments for the Project First Costs and Total Project Costs are provided in **Table 5-18** and **Table 5-19**, respectively.

Table 5-18: Apportionment of First Actions Costs

(FY 2026 Price Level)

Item	Cost
Total Project Cost (First Costs)	\$17,812,115,000
Federal Share (65%)	\$11,577,875,000
Non-Federal Share (35%)	\$6,234,240,000
<i>Lands and Damages</i>	<i>\$3,689,028,000</i>
<i>Relocations</i>	<i>\$1,253,390,000</i>
<i>Non-Federal Cash Contribution</i>	<i>\$1,291,822,000</i>

Table 5-19: Total Project Cost (Fully Funded Cost) - Apportionment of First Actions

Item	Cost
Total Project Cost (Fully Funded)	\$32,312,093,000
Federal Share (65%)	\$21,002,860,000
Non-Federal Share (35%)	\$11,309,233,000
<i>Lands and Damages</i>	<i>\$6,048,984,000</i>
<i>Relocations</i>	<i>\$2,306,593,000</i>
<i>Non-Federal Cash Contribution</i>	<i>\$2,953,656,000</i>

5.8. Non-Federal Sponsor Responsibilities

A PPA package will be prepared, coordinated, and executed during the PED phase. The PPA serves as the agreement for implementation of the project. As the NFS, POSF must comply with all applicable Federal laws and policies and other requirements, including but not limited to:

- a. Provide 35 percent of construction costs, as further specified below:
 1. Provide, during design, 35 percent of design costs in accordance with the terms of a design agreement entered into prior to commencement of design work for the project
 2. Provide all lands, easements, rights-of-way, and placement areas and perform all relocations determined by the Federal government to be required for the project
 3. Provide, during construction, any additional contribution necessary to make its total contribution equal to at least 35 percent of construction costs

b. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) that might reduce the level of coastal storm risk reduction the project affords, hinder operation and maintenance of the project, or interfere with the project's proper function;

c. Inform affected interests, at least yearly, of the extent of risk reduction afforded by the project; participate in and comply with applicable Federal floodplain management and flood insurance programs; prepare a floodplain management plan for the project to be implemented not later than one year after completion of construction of the project; and publicize floodplain information in the area concerned and provide this information to zoning and other regulatory agencies for their use in adopting regulations, or taking other actions, to prevent unwise future development and to ensure compatibility with the project;

d. Operate, maintain, repair, rehabilitate, and replace the project or functional portion thereof at no cost to the Federal government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal laws and regulations and any specific directions prescribed by the Federal government;

e. Give the Federal government a right to enter, at reasonable times and in a reasonable manner, upon property that the NFS owns or controls for access to the project to inspect the project, and, if necessary, to undertake work necessary to the proper functioning of the project for its authorized purpose;

f. Hold and save the Federal government free from all damages arising from design, construction, operation, maintenance, repair, rehabilitation, and replacement of the project, except for damages due to the fault or negligence of the Federal government or its contractors;

g. Perform, or ensure performance of, any investigations for hazardous, toxic, and radioactive wastes (HTRW) that are determined necessary to identify the existence and extent of any HTRW regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S.C. 9601-9675, and any other applicable law, that may exist in, on, or under real property interests that the Federal government determines to be necessary for construction, operation and maintenance of the project;

h. Agree, as between the Federal government and the NFS, to be solely responsible for the performance and costs of cleanup and response of any HTRW regulated under applicable law that is located in, on, or under real property interests required for construction, operation, and maintenance of the project, including the costs of any studies and investigations necessary to determine an appropriate response to the contamination, without reimbursement or credit by the Federal government;

i. Agree, as between the Federal government and the NFS, that the NFS shall be considered the owner and operator of the project for the purpose of CERCLA liability or other applicable law, and to the maximum extent practicable shall carry out its responsibilities in a manner that will not cause HTRW liability to arise under applicable law; and

j. Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended, (42 U.S.C. 4630 and 4655) and the Uniform Regulations contained in 49 CFR Part 24, in acquiring real property interests necessary for construction, operation, and maintenance of the project including those necessary for relocations, and placement area improvements; and inform all affected persons of applicable benefits, policies, and procedures in connection with said act.

5.9. Operations, Maintenance, Repair, Replacement, and Rehabilitation

OMRR&R includes actions to sustain the completed project and to maintain the stated level of benefits at the completion of construction and into the future. The NFS is responsible for OMRR&R costs and actions. Generally, the NFS is required to repair, rehabilitate, or provide replacement of components to maintain the original project benefits. A detailed OMRR&R manual will be developed during the design phase to outline the expected OMRR&R requirements for each project component. Preliminary OMRR&R estimates are estimated as a percentage of the project cost and are subject to refinement as design proceeds.

The total estimated annual OMRR&R cost is \$31,674,000. OMRR&R requirements would also include but are not limited to, annual exercising of gates and closure structures, grass mowing of levee and floodwall right-of-way, painting of metal surfaces, pump station operations and maintenance, and general maintenance of drainage structures.

5.10. Compensatory Mitigation

Mitigation needs are currently estimated to be fairly low for the Recommended Plan, pending further consultation with the Regulatory Agency Working Group (RAWG) and consulting parties in the Section 106 process. The Recommended Plan proposes 9 acres of bay fill that would require compensatory mitigation for the loss of 9 acres, or 4,500,000 discounted-service-acre-year [DSAY] of subtidal habitat. The compensatory mitigation provides a few strategies to compensate for the loss and includes various combinations of pier removal and pile removal. Pier removal is compensated on a 1 acre of injury for an acre of restoration (1:1) basis while pile removal is compensated on a 1:1.67 basis. The most cost-effective mitigation plan proposes removal of 9.1 acres of abandoned, derelict, or unnecessary piers from the San Francisco waterfront between Aquatic Park and Heron's Head. Currently, proposed available locations provide a total of 5.5 acres (2,749,995 DSAY). Thus, to implement this plan, an additional 3.6 acres (1,799,996 DSAY) of pier removal options along the waterfront or outside the study area would need to be identified to fulfill the offset. This would be true for any of the alternatives evaluated and is identified as an implementation risk in the mitigation plan. Additional information on the mitigation plan can be found in *Appendix K: Compensatory Mitigation Plan*.

For feasibility, the NNBFs in the Recommended Plan were not considered when calculating offset of project impacts. Instead, the mitigation plan was developed to

account for offset that may be required if NNBFs cannot be constructed at the same time as the impact is incurred or, if when constructed, the NNBFs did not fully offset the impacts. During the design phase, the need for compensatory mitigation will need to be reassessed, and, if the NNBFs are included, the compensatory mitigation documented in feasibility may not be required.

AMMs, as well as BMPs, would be used during construction and in the final designs to avoid permanent adverse impacts that would require additional compensatory mitigation. Details about AMMs and BMPs intended to be applied to each resource can be found in *Appendix D: Environmental and Cultural Resources*.

Preliminary analysis suggests the Recommended Plan is measuring below de minimis for the Clean Air Act and would not require compensatory mitigation for air quality. The PDT will continue to work with resource agencies to determine the most applicable models for use and level of mitigation needed to offset impacts.

5.11. USACE Environmental Operating Principles

The USACE Environmental Operating Principles (ER 200-1-5) were developed to ensure USACE missions include integrated sustainable environmental practices, corporate responsibility, and accountability. These Environmental Operating Principles are:

- Foster sustainability as a way of life throughout the organization
- Proactively consider environmental consequences of all USACE activities and act accordingly
- Create mutually supporting economic and environmentally sustainable solutions
- Continue to meet our corporate responsibility and accountability under the law for activities undertaken by USACE, which may impact human and natural environments
- Consider the environment in employing a risk management and systems approach throughout the life cycles of projects and programs
- Leverage scientific, economic, and social knowledge to understand the environmental context and effects of USACE actions in a collaborative manner
- Employ an open, transparent process that respects views of individuals and groups interested in USACE activities

The Recommended Plan meets the USACE Environmental Operating Principles as documented within this Final IFR/EIS through the USACE planning process and NEPA requirements for Federal agencies to assess the reasonably foreseeable environmental effects of Federally funded projects. USACE and POSF have proactively considered the environmental consequences (and benefits) of the alternative plans and will continue to do so during the design phase. Scientific, economic, and social knowledge was leveraged in the preparation of this report, through special expertise of preparers, subject matter experts, public engagement, and resource agency coordination.

Appendix H: Public Involvement contains additional information on stakeholder engagement and public and agency coordination.

5.12. Least Environmentally Damaging Practicable Alternative Plan

In accordance with 40 CFR 230.10(a) and ER 1105-2-103, the alternatives were evaluated to identify the least environmentally damaging practicable alternative (LEDPA). The purpose of the project is to manage multiple risks including flooding and seismic to provide a more resilient coastline that can withstand uncertainties of changing physio-meteorological conditions.

The No Action Alternative and Alternative B were eliminated as the LEDPA because neither met the purpose and need for the action, therefore, would not be practicable per the definition in 40 CFR 230.3(l), or reasonable alternatives. Alternative B increases the residual life-safety risk attributable to allowing floodwaters to enter the study area as protection occurs on a structure-by-structure basis. Additionally, daily use of the waterfront would be disrupted, such as flooding or reduced use of the transportation systems; movement of people and goods; availability of services, tourism, and recreational opportunities; and ability of emergency services to render aid. The remaining action alternatives (F, G, TNBP) would meet the purpose and need of the action, minimize life-safety risks, and build a coastline that would be resilient to changing conditions; however, each had varying degrees of aquatic impact. Of these three alternatives, the TNBP, herein Recommended Plan, was determined to be practicable and reasonable, and the least environmentally damaging, and, therefore, was identified as the LEDPA.

The Recommended Plan has the least impact to aquatic habitats, as compared to Alternative F and G, that defends the waterfront and minimizes life-safety risk. This alternative avoids and minimizes aquatic impacts to the greatest extent possible but could not avoid all impacts where flood protection features required construction in waterways. However, this was minimized by aligning the majority of flood defenses landward of the existing shoreline and maintaining the same footprints of existing structures slated for reconstruction and raising. The Recommended Plan includes approximately 9 acres of unavoidable adverse impacts; however, Alternatives F and G have greater unavoidable impacts. The Recommended Plan incorporates NNBFs, which would improve the quality and increase the quantity of aquatic habitats in the study area long-term. Standard BMPs to reduce impacts to water quality will be implemented to further minimize effects to aquatic resources.

5.13. National Flood Insurance Program Compliance

Communities participating in a CFRM project with USACE are required to participate in FEMA's National Flood Insurance Program (NFIP) and to develop a floodplain management plan. CCSF is a participant in the NFIP. Under this program, which is managed by the FEMA, the Federal government makes flood insurance available at

affordable rates in the city. Homeowners, renters, and businesses in the city are eligible to purchase Federally subsidized flood insurance to protect their properties. It is important to note that flood insurance rates are not set by USACE nor the State of California.

As a condition of participating in the NFIP, CCSF has adopted and enforces a Floodplain Management Ordinance intended to reduce the risk of damage from flooding in the city. The Floodplain Management Ordinance governs construction in flood-prone areas and designates the City Administrator's Office as the city's Floodplain Administrator.

The ordinance requires that, in designated flood hazard areas, new construction of and substantial improvements to buildings must be protected against flood damage. The ordinance also prohibits uses that would increase flood risks and provides for variances for exceptional circumstances, including historic preservation, maritime uses, and extraordinary hardship. The ordinance was first adopted in 2008 and was amended in 2010 and 2020.

To support the NFIP, FEMA publishes FIRMs that are used for flood insurance and floodplain management purposes in participating communities. FIRMs show SFHAs that are defined as areas subject to inundation during a flood having a 1% chance of occurrence in any given year (also referred to as the Base Flood or 100-year flood). FEMA notified CCSF on September 23, 2020, that the FIRM will be "effective" (i.e., formally published and required for use for flood insurance and floodplain management purposes) on March 23, 2021. The final FIRM designates coastal flood hazard zones for portions of the waterfront piers, Mission Bay, Islais Creek, Bayview Hunters Point, Hunters Point Shipyard, Candlestick Point, Treasure Island, San Francisco International Airport, and Ocean Beach, which may have implications for development plans and insurance requirements in those areas.

Broader initiatives are being developed and implemented by key CCSF agencies to take collective action through planning, policy, and guidance, championing a coordinated vision on climate resilience that streamlines CCSF responses and promotes an equitable, safe, and healthy city for generations to come. Beyond the Coastal Flood Study feasibility effort, CCSF produced a 2020 Climate and Hazards Resilience Plan that presents a detailed strategy for how San Francisco will become a safer and more resilient place by mitigating the impacts of seismic and climate hazards to our communities, buildings, and infrastructure, and adapting to what cannot be mitigated.

5.14. Views of the Non-Federal Sponsor

The POSF, as lead agency for CCSF, fully supports the Recommended Plan as outlined in the SFWCFS Final IFR/EIS. The Recommended Plan closely aligns with the POSF's mission to manage the waterfront as the gateway to a world-class city, and advance environmentally and financially sustainable maritime, recreational, and economic opportunities to serve the city, Bay Area region, and California.

In particular, the Recommended Plan advances the POSF's Strategic Plan resilience goal to protect people, San Francisco neighborhoods, and critical infrastructure from

flooding and other hazards. The Recommended Plan will support POSF initiatives and investments, such as improvement of maritime facilities, historic piers rehabilitation, and waterfront parks and open space by investing in a stable and resilient shoreline and protect city infrastructure and assets, public and private lands, and buildings from coastal flooding.

We view the Recommended Plan as a foundational element for CCSF's overall plan to address flooding through the end of the century and beyond. CCSF appreciates the time and effort invested by community members and groups to shape the Recommended Plan during the feasibility study (*Appendix H: Public Involvement*), and we encourage participation in future opportunities to engage the public during the design stage.

CCSF values the opportunity to continue to engage with USACE to complete the feasibility study and continue to advance toward design and construction. We anticipate playing a significant role in waterfront design, facilitated in part by the Memorandum of Understanding (MOU) signed by CCSF and USACE in February 2025. The MOU references WRDA Section 221 and allows for CCSF to advance design and construction prior to the execution of the PPA.

The POSF has provided a letter of support on behalf of CCSF, which is included in *Appendix H: Public Involvement*.

Section 6.0 Implementation of the Recommended Plan

This section presents the initial development of strategies and processes for implementation of the Recommended Plan. These strategies and processes will be more fully developed and coordinated during the design phase of the project.

The Recommended Plan includes nonstructural features. Additional information about the implementation of the nonstructural features can be found in *Appendix L: Nonstructural Implementation Plan*.

The Recommended Plan is a cost-effective response to coastal flood risk that achieves economic, social, and environmental benefits by adaptively implementing the features and scales of the Recommended Plan to provide adaptive flood risk reduction as flood risk arrives. The implementation strategy is the critical guide to achieving timely and cost-effective risk reduction by guiding the decisions to successfully carry the project through design and construction. This project requires an innovative approach to implementation due to (1) the size and complexity of the study area, (2) the uncertainty of the arrival of timing of RSLC as a major coastal and combined flood risk driver, and (3) the resulting two-step adaptation approach of the Recommended Plan (2040 actions or “First Actions,” and 2090 actions or “Subsequent Actions”).

As a multi-billion-dollar project, significant Federal and local resources will be allocated to implement the Recommended Plan components and adaptations that address risk ahead of its arrival. The implementation strategy is flexible but structured to support responsive action under changing conditions. It allows for adjusting implementation based on available funding while addressing areas with highest impact first. The implementation strategy is informed by four components (**Table 6-1**): Phasing Approach, Early Resilience Actions (ERAs), the MAP, and the Authorization Recommendations.

The principles guiding the implementation strategy support the planning goals identified during for this study. The implementation strategy guiding principles are to:

- Address risk at the right time and prioritize immediate flood vulnerability
- Achieve cost-effective risk reduction measures
- Apply innovative approaches to address complex challenges
- Incorporate fair treatment of communities in decision-making
- Leverage interagency participation and cost sharing in proactive resiliency investments
- Use a systems approach to flood risk

Table 6-1: Implementation Strategy Overview

Implementation Strategy Component	Role in Implementation Strategy
Phasing Approach	The Phasing Approach is a decision framework to enable prioritized, incremental construction of First Actions for cost-effective risk reduction when construction of the entire array of First Actions at once (consistent with the engineering recommendation) is not possible due to limitations such as funding or access. It establishes a process for developing a hierarchy of construction, based on coastal flood risk, fair treatment of all communities, and additional phasing criteria. It provides an approach to support construction decision-making in the design phase, while remaining flexible to respond to uncertainty in funding streams and other changing conditions. The PDT designed the Phasing Approach to achieve cost-effective risk reduction for First Actions .
ERAs	The candidate ERAs propose predefined increments of the Recommended Plan that meet the guiding principles and will facilitate its construction under constrained implementation conditions. ERA identification was informed by the Phasing Approach, with an emphasis on the areas with highest risk and consideration of implementation complexity (e.g., where projects could be delivered relatively quickly, or where projects could become critical path).
MAP	The MAP is a defined process to monitor risk and support decision-making for successful implementation of Subsequent Actions, thereby delivering the benefits of the Recommended Plan through input from a technical team. It includes the creation of an Adaptation Management Team, a monitoring program, and a reporting and decision-making process. The PDT designed the MAP to achieve cost-effective risk reduction for Subsequent Actions , which may prove to be a crucial component of providing equitable protection throughout the study area. Depending on the rate of RSLC, components of the monitoring program could influence the timing or design of First Actions.
Authorization Recommendations	The Authorization Recommendations were developed to support implementation of the two phases of the Recommended Plan to ensure timely consideration and progression of risk reduction measures. It includes <i>approval</i> of the entire Recommended Plan (First and Subsequent Actions); <i>authorization</i> for design and construction of all First Actions including possible ERAs; <i>authorization</i> of the monitoring program; and <i>authorization</i> of the reporting and decision-making processes to initiate Subsequent Actions in the Recommended Plan. Reporting requirements include confirmation and documentation that the Subsequent Actions are consistent with the performance requirements established for the Recommended Plan. The Authorization Recommendations support cost-effective risk reduction through the end of the POA by advancing First Actions and reducing barriers to implementing Subsequent Actions.

The implementation strategy establishes adaptive action processes and decision points to facilitate continued refinement of Recommended Plan features and construction timing, consistent with the formulation process documented in this Final IFR/EIS. It also establishes a monitoring program to track and assess risk conditions, with the potential to facilitate cross-agency participation in resilience planning. It is impractical to prescribe specific conditions or agency priorities for project implementation 30 to 40 years into the

future. Consequently, the implementation strategy defines the overarching strategies, priorities, and processes to make and defend future adaptation decisions and refinements that ensure that Subsequent Actions achieve the risk reduction function and comprehensive benefit performance anticipated in the Recommended Plan. Additional information about the implementation strategy can be found in *Appendix G: Monitoring and Adaptation Plan*.

6.1. Phasing Approach

The Phasing Approach creates a decision framework to enable prioritized, incremental construction of the First Actions of the Recommended Plan. It supports decision-making under scenarios where local or Federal funding for design and construction is received in increments rather than a funding stream to construct all First Actions at once. The Phasing Approach also affords flexibility under circumstances that may support phased construction to increase cost-effectiveness or reduce disruption by aligning construction with other investments in the project area. The ultimate order of phases and sequencing of specific actions will be developed in the design phase. The Phasing Approach includes four steps to be completed during the design phase:

- Step 1) **define geographic subreaches** to be phased over time
- Step 2) **establish criteria and ratings** for each subreach for each criterion
- Step 3) **prioritize geographies** using the completed phasing criteria to identify the preferred order of subreaches for construction
- Step 4) facilitate a **decision-making** process to confirm the Phasing Plan and advance into detailed construction sequencing

The approach is intended to be iterative (e.g., the order and boundaries of subreaches can be adjusted as conditions change).

6.2. Early Resilience Actions

The ERAs, or early actionable elements, are segments of the Recommended Plan that meet the guiding principles and will facilitate its construction under constrained implementation conditions. These segments may be initiated first, reducing near-term risk and delivering other early benefits. While the Phasing Approach establishes criteria to successfully carry out the project through design and construction, ERAs support expedited risk reduction when implementation is constrained in any way (e.g., funding and acquisitions). One or more ERAs may be comparable to the first few actionable elements of the Phasing Approach. ERAs also reflect the PDT's recognition of the need to identify areas that can move quickly to design and construction to address near-term flood risk to critical infrastructure and facilities and provide early opportunities to pilot innovative approaches to address complex challenges.

The PDT considered areas with higher near-term flood hazards (**Figure 6-1**) alongside the other phasing criteria, and the Implementation Strategy guiding principles. The PDT

also considered three potential programmatic motivations to advance a portion of the Recommended Plan as an ERA:

- (1) the candidate ERA presents an opportunity to reduce risk quickly (e.g., high-risk area, short lead time, less disruptive, less complex)
- (2) the candidate ERA may become critical path to deliver the First Actions of the Recommended Plan
- (3) the candidate ERA presents an opportunity to strategically leverage other public and private resources (thus greater efficiency) through coordination with capital or development projects

The PDT identified three candidate ERAs to be further refined and confirmed during PED (**Figure 6-2**). Cost estimates reflect project first cost as shown in *Appendix C: Cost Engineering, Attachment C-1*. From north to south, these include:

- **Rincon Park / Embarcadero Shoreline (approximately Pier 14 to Pier 22 ½)** (\$1.4 billion): ERA may include a raised and rebuilt bulkhead seawall, ground improvement, NNBFs, elevating buildings, interior drainage infrastructure, and concrete curbs around pier perimeters. The PDT prioritized this area as a candidate ERA primarily because:
 - Low-lying area with near-term coastal flood risk
 - Critical local and regional assets at risk (e.g., BART and Muni tunnels)
 - Lower construction disruption (minimal impacts to roadway)
 - Opportunity to pilot engineering and construction approaches in an area with complex subsurface conditions
- **Portion(s) of Mission Bay and Creek** (\$1.2 billion): ERA may include levees, floodwalls, ground improvement, closure structures, NNBFs, floodproofing buildings, and interior drainage infrastructure. The PDT prioritized this area as a candidate ERA primarily due to:
 - Low-lying areas with near-term coastal flood risk
 - Critical assets at risk (e.g., wastewater infrastructure, transportation facilities)
 - Construction in the portion of Mission Bay just south of Pier 50 is separable from other First Actions and has relatively low systems complexity
 - Construction in some areas along the creek may be associated with long lead time (e.g., due to HTRW or real estate considerations), pending further investigation in PED or beyond; potential for this area to become critical path for completing construction of entire First Actions
- **Portion(s) of Islais Creek** (\$2.5 billion): ERA may include levees, floodwalls, raised and reconstructed portion of wharves; ground improvement; closure structures; NNBFs; removal of select buildings that straddle the coastal

defenses; interior drainage infrastructure. The PDT prioritized this area as a candidate ERA primarily because:

- Low-lying areas with near-term coastal flood risk
- Critical assets at risk (e.g., wastewater infrastructure, transportation facilities)
- Construction in some areas along the creek may be associated with long lead time (e.g., due to HTRW or real estate considerations), pending further investigation in PED or beyond; the potential for this area to become the critical path for completing construction of the entire First Actions

These potential ERAs are subject to change through ongoing discussion and potentially public input. Any ERAs selected in PED remain subject to all requirements related to environmental compliance and permitting processes as well as any necessary agreements between USACE and POSF.



Figure 6-1: Areas with Higher Near-Term Flood Hazard

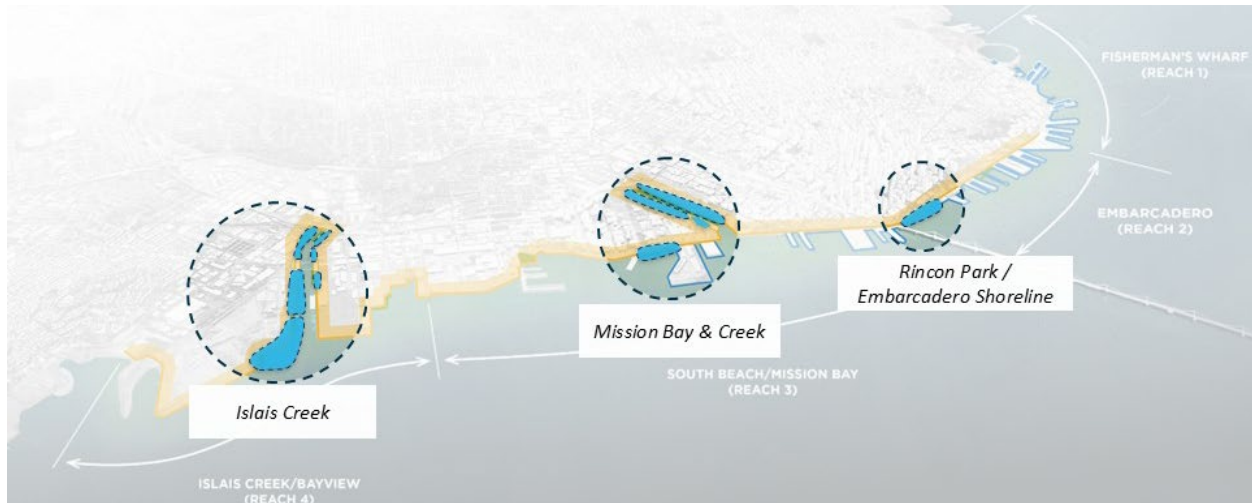


Figure 6-2: Candidate ERAs

6.3. Monitoring and Adaptation Plan

The MAP establishes a process to monitor risk and support decision-making for successful implementation of Subsequent Actions, delivering the benefits of the Recommended Plan over time. It includes the creation of an Adaptation Management Team (AMT), a monitoring program with associated metrics and decision thresholds, assessment and reporting guidance, and a decision-making framework. The MAP is primarily designed to support decision-making for Subsequent Actions. However, the monitoring program may inform design and implementation of First Actions, especially if RSLC is trending high. The estimated cost to implement the MAP is referred to as "Adaptive Management & Monitoring" in *Attachment C-1: Recommended Plan First Actions*.

6.3.1. MAP Process Overview

The MAP process begins in the design phase and culminates with construction of Subsequent Actions. In line with the adaptive risk reduction approach described in EP 1100-2-1 (USACE 2019a), the process is designed to complete construction of Subsequent Actions before the arrival of the risk threshold defined by performance criteria described in Section 6.3.3.

The process begins with the AMT monitoring the study area to determine when the combination of physical and social conditions warrant action, acting like a trigger point in the overall process. Given the complexity of the study area and the broad suite of metrics informing this trigger point, the PDT referred to this moment as the Adaptation Confirmation Threshold (ACT): the instance in which the AMT confirms that multi-metric conditions indicate the need to initiate design for adaptations in order to maintain the desired level of performance of the Recommended Plan (Section 6.3.3). The AMT presents the justification for the ACT in a report to USACE and POSF leadership, and

leadership decides whether they agree that it is time to act or hold for additional information or changing conditions (**Figure 6-3**).

Once USACE and POSF leadership agree that combined conditions reach the ACT, leadership directs a multidisciplinary PDT to develop a Project Adaptation Report (PAR). The PAR is a new reporting vehicle designed to document updates to the Subsequent Actions based on changed conditions and to validate how the refined Subsequent Actions deliver the desired performance of the Recommended Plan. Once the PAR is complete and approved, it will be sent to Congress for authorization. The project can then advance to design and construction (**Figure 6-4**).



Figure 6-3: MAP Process (1 of 2): Monitoring and the ACT

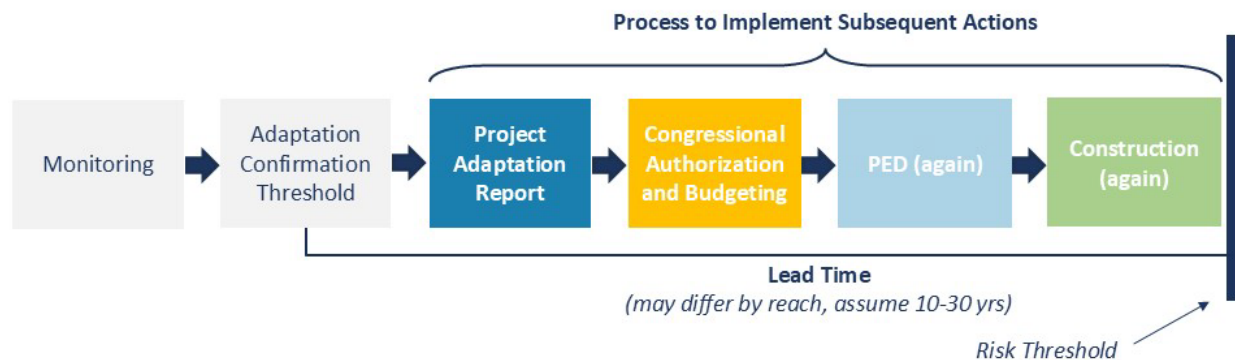


Figure 6-4: MAP Process (2 of 2): Process to Implement Subsequent Actions

6.3.2. Adaptation Management Team

The AMT will be a multidisciplinary, technical body responsible for monitoring, synthesizing results, and reporting to USACE and POSF leadership. The AMT will be chartered at the start of the design phase and led by USACE and POSF. USACE and POSF may invite other agencies to serve on the AMT.

The AMT will coordinate monitoring, assist in the evaluation of monitoring data and adaptation planning, and provide technical expertise and recommendations to USACE and POSF. USACE and POSF leadership have final determination on all actions and adaptations recommended by the AMT. USACE and POSF staff are responsible for ensuring that monitoring data and assessments are properly used in the decision-making process. They are also responsible for project documentation, reporting, and external communication.

The AMT communication structure will be included in the AMT charter that will be developed. It is envisioned that the AMT would meet at least once per year to coordinate monitoring, assess interim results, and discuss potential adjustments to the MAP. The AMT will produce a synthesis report no less than every 5 years for USACE and POSF leadership review.

6.3.3. Monitoring Program

The monitoring program includes monitoring objectives, a monitoring period, a suite of monitoring metrics and associated risk equation to determine when to act, and reporting requirements. Additional details on the monitoring program, including estimated costs, can be found in *Appendix G: Monitoring and Adaptation Plan*.

6.3.4. MAP Costs

The project first cost includes the costs of the MAP at a total cost of \$75,746,000. This estimated cost to implement the MAP is referred to as "Adaptive Management & Monitoring" in *Attachment C-1: Recommended Plan First Actions*. It was estimated as 0.7% of the construction first cost and included in the Planning, Engineering and Design Account. This estimate is sufficient to fund participation on the AMT, development of PARs, monitoring, development of synthesis reports, and monitoring of natural and nature-based features.

6.4. Design and Construction Sequencing

At the completion of this feasibility study, and upon approval by the Chief of Engineers, the Recommended Plan would be provided to Congress for authorization and funding. If authorized and funded by Congress, subsequent phases of the project would include design, construction, and operations and maintenance. The design phase would begin with the signing of a design agreement and the initiation of PED for the first construction contract.

Completion of design and construction of the Recommended Plan, specifically the pace of construction, is highly dependent on Congressional approval and funding. Assuming an ample funding stream, the First Actions of the Recommended Plan could be designed and then constructed over a period of about 32 years. Different increments of the project may be completed as funding allows during this timeframe. Phased implementation will consider the priorities of the NFS, communities benefitted by the project, resource agencies, and efficiencies in the construction and/or contracting process. Furthermore, construction sequencing will also be dependent on completion of

supplemental environmental studies, in accordance with the NEPA approach described more fully in Section 1.0. Ultimately, implementation activities will be optimized to consider the size and frequency of funding infusions, environmental clearance of individual components including the requirements of CEQA, and beneficial sequencing.

Congress has approved two mechanisms for NFSs to participate in study, design, and construction of projects. Section 204 of WRDA 1986, as amended, authorizes a non-Federal interest to carry out a Federally authorized water resources development project, with potential credit or reimbursement, subject to certain requirements. Section 221 of the Flood Control Act of 1970, as amended, is a comprehensive authority that addresses the affording of credit for the value of in-kind contributions related to study, design or construction provided by a NFS toward its required cost share if those in-kind contributions are determined to be integral to a study or project.

Section 7.0 Environmental Compliance*

This Final IFR/EIS has been prepared to satisfy the requirements of all applicable environmental laws and regulations, where possible, and has been prepared using NEPA (P.L. 91-190, as amended through P.L. 118-5) and the USACE's regulation Environmental Quality: Procedures for Implementing NEPA, 33 CFR Part 230. This EIS was prepared prior to rescission of the CEQ's NEPA regulations and USACE's Civil Works guidance for implementing NEPA. As such, the procedures and guidelines used in developing this document followed those preceding regulations. In implementing the Recommended Plan, any compliance that could not be completed during the feasibility phase will be secured during the design phase and USACE would continue to follow the provisions of all applicable laws, regulations, and policies related to the proposed actions.

Based on agency feedback, demonstration of full compliance of the First Actions during feasibility was achieved for the following laws and EOs: NEPA, Fish and Wildlife Coordination Act, ESA, CWA Section 404, NHPA, EO 11988 (Floodplain Management), and EO 11990 (Protection of Wetlands). Full compliance was not achievable at feasibility for CWA Section 401, CZMA and Marine Mammal Protection Act (MMPA). However, San Francisco Bay Conservation and Development Commission (BCDC) and the San Francisco Waterboard provided letters of confirmation to reaching a determination during PED for CZMA and CWA Section 401, respectively.

The following data gaps have been identified by the agencies as being needed to secure full compliance in PED:

- Field verification of bay habitats to confirm the assumptions made and data used during feasibility is an accurate reflection of site-specific conditions to correctly quantify and mitigate impacts (CWA-401, CZMA, MMPA).
- Bay-wide modeling is needed to better understand how engineered structures like seawalls affect hydrodynamics in the bay. The modeling will need to assess changes in tidal amplitude and how that affects erosion and the magnitude and spatial distribution of peak water levels and inundation around the bay (CZMA).
- Water quality and chemistry modeling, including interior drainage and outflow paths, demonstrating the recommended plan would not contribute to temporary or permanent degradation of biological habitats (CWA-401, CZMA).
- Impervious surface modeling based on measure specific design details such as surface area and material used (CWA-401).
- Air quality modeling to quantify criteria pollutant and greenhouse gas emission based on site-specific details for construction timing, duration, equipment used, modes of transport, etc. (Clean Air Act).

- Determination of final detailed footprint, designs, and construction methods that will inform short- and long-term impacts, including:
- Duration, timing, and methodology of all construction actions but of particular interest in water work, pile driving actions, and temporary relocation of structures (CWA-401, CZMA, MMPA);
- Source of construction material (e.g. dredged material or commercial) (CWA-401, CZMA);
- Extent and methodology of completing ground improvements for seismic related issues (CWA-401, CZMA, MMPA);
- Confirmation of assumptions regarding pier retention or abandonment (CWA-401, CZMA); and
- Location of public access points including configuration of transportation, bike lanes, and walk paths (CZMA).

7.1. Compliance Status

Compliance with the following laws, regulations, and EOs (**Table 7-1** and **Table 7-2**), as applicable, is required for environmental acceptability of the project alternatives, which includes but is not limited to those shown. The tables are applicable to the First Action measures described within this report; therefore, supplemental NEPA and environmental compliance would be completed for the Subsequent Action measures prior to construction. First Action measures would be evaluated against the NEPA analysis and compliance during design to determine if supplemental documentation is warranted prior to construction.

Table 7-1: Regulatory Compliance Status

Title of Law	U.S. Code	Compliance Status
Abandoned Shipwreck Act of 1987	43 U.S.C. 2101	Compliant. Sub-Appendix D-3
American Indian Religious Freedom Act of 1978	Public Law No. 95-341, 42 U.S.C. 1996	Compliant. Sub-Appendix D-3
Anadromous Fish Conservation Act of 1974	16 U.S.C. 757 a et seq.	Not Applicable
Archaeological and Historic Preservation Act of 1974	Public Law 93-291 and 16 U.S.C.469-469c	Compliant. Sub-Appendix D-3
Archaeological Resources Protection Act of 1979	16 U.S.C. 470aa–470mm	Not Applicable
Bald and Golden Eagle Protection Act of 1962, as amended	16 U.S.C. 668	Compliant. Sub-Appendix D.1, Section 6.11

Title of Law	U.S. Code	Compliance Status
Clean Air Act of 1972, as amended	42 U.S.C. 7401 et seq.	Compliant. Sub-Appendix D.1 Section 6.3. Conceptual General Conformity Determination included in Sub-Appendix D.2 and air quality evaluation and calculations are included in Annex D.1.1.
Clean Water Act of 1972, as amended	33 U.S.C. 1251 et seq.	Sub-Appendix D.1, Section 6.2 Section 401 -- Delayed until PED. Coordination with the Water Board occurred throughout development of the EIS. The Water Board has provided a confirmation letter for the project committing to coordinating during PED to attain a Water Quality Certification (WQC) prior to construction (Annex D.4.2). The Water Quality Certification will be received during PED. Section 404 – Final 404(b)(1) included in Annex D.4.1
Coastal Barrier Resources Act of 1982	Public Law 114-314	Not Applicable
Coastal Zone Management Act of 1972, as amended	16 U.S.C. 1451 et seq.	Delayed until PED. Sub-Appendix D.1 Section 6.10. Coordination with the BCDC has occurred throughout development of the EIS. A Consistency Determination was developed to describe consistency with the San Francisco Bay Plan based on feasibility level design (Annex D.5.1). BCDC provided a letter of support for the study to continue coordination in PED on September 24, 2025 (Annex D.5.2). The Consistency Determination will be received during PED.
Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980	42 U.S.C. 9601	In Progress. ESA Phase I and II have not yet been conducted. If there is any cleanup or treatment required for hazardous substances of CERCLA sites, the NFS will be fully responsible for completing this prior to work beginning. Annex D.1.6.
Endangered Species Act of 1973	16 U.S.C. 1531	Compliant. Sub-Appendix D.6 provides biological assessments (BA) for USFWS and NMFS managed species (Annex D.6.1 and Annex D.6.2), respectively. A concurrence letter was received from USFWS on September 24, 2025 (Annex D.6.3). A Condensed Biological Opinion was received from NMFS July 8, 2026 (Annex D.6.4).

San Francisco Waterfront Coastal Flood Study

Title of Law	U.S. Code	Compliance Status
Fish and Wildlife Coordination Act of 1958, as amended	16 U.S.C. 661	Compliant. Sub-Appendix D.1 Section 6.7. A Coordination Act Report is included in Sub-Appendix D.7.
Land and Water Conservation Act	16 U.S.C. 460	Not Applicable
Magnuson-Stevens Fishery Conservation and Management Act – Essential Fish Habitat Amendment	16 U.S.C. 1801	Compliant. Sub-Appendix D.1 Section 6.9. A concurrent ESA/EFH assessment is included in Sub-Appendix D.6.2. Consultation was initiated on January 13, 2026. Concurrence was received July 8, 2026.
Marine Mammal Protection Act of 1972, as amended	16 U.S.C. 1361	Delayed until PED. Sub-Appendix D.1 Section 6.8. A memorandum from HQUSACE was received delaying compliance until PED (Sub-Appendix D.8).
Marine Protection, Research, and Sanctuaries Act of 1972	33 U.S.C. 1401	Not Applicable
Migratory Bird Treaty Act of 1918, as amended	16 U.S.C. 703	Compliant, Sub-Appendix D.1 Section 6.6
National Environmental Policy Act of 1969, as amended	42 U.S.C. 4321 et seq.	Compliant. Notice of Intent published July 27, 2023; 60-day comment period for EIS occurred. Sub-Appendix D.1 Section 6.1. Final EIS available for 30-days.
National Historic Preservation Act of 1966, as amended	54 U.S.C. Section 300101	Compliant. Sub-Appendix D.1 Section 6.4 and Sub-Appendix D.3.
Native American Graves Protection and Repatriation Act of 1990	25 U.S.C. 3001	Compliant. Sub-Appendix D.3
Resource Conservation and Recovery Act (RCRA) of 1976	42 U.S.C. 6901 et seq.	In Progress. Environmental Site Assessments (ESA) Phase I and II have not yet been conducted. If there is a cleanup or treatment required for hazardous waste of RCRA sites, the NFS will be fully responsible for completing this prior to work beginning. Annex D.1.6.
Rivers and Harbors Act of 1899	33 U.S.C. 401 et seq.	Compliant. Sub-Appendix D.1 Section 6.12
Hazardous Wildlife Attractants on or Near Airports	FAA AC 150/5200-33C and the Memorandum of Agreement with FAA	Compliant. Sub-Appendix D.1 Section 6.13

Table 7-2: Executive Order Compliance Status

Title of Executive Order	Executive Order Number	Compliance Status
Floodplain Management	11988	Compliant, Sub-Appendix D.1 Section 6.14
Invasive Species	13112	Compliant, Sub-Appendix D.1 section 6.16
Marine Protected Areas (MPAs)	13158	Compliant. No measures proposed in Golden Gate National Recreation Area. No other MPAs are present in or near the study area.
Protection and Enhancement of the Cultural Environment	11593	Compliant. All measures have avoided or minimized impacts to cultural resources and will be mitigated where necessary to compensate for unavoidable adverse impacts. See Sub-Appendix D.1 Section 4.18 and Sub-Appendix D.3
Protection of Wetlands	11990	Compliant, Sub-Appendix D.1 Section 4.14 and 6.15
Protection of Children from Environmental Health and Safety Risks	13045	Compliant, Sub-Appendix D.1 Section 6.17
Responsibilities of Federal Agencies to Protect Migratory Birds	13186	Compliant, Sub-Appendix D.1 Section 6.6

7.2. Compensatory Mitigation Plan

A compensatory mitigation plan (Appendix K) has been included to show unavoidable impacts from bay fill.

Section 8.0 Public Coordination and Views

Coordination with stakeholders has been a critical component of the SFWCFS. Since 2018, USACE and POSF have held numerous workshops and meetings with Cooperating/Participating Agencies and other Federal, state, and local stakeholders to share information on the study scope, purpose, and formulation of alternatives, as well as to exchange ideas and information on natural and marine resources within the study area. Additional information can be found in *Appendix H: Public Involvement*.

8.1. Scoping

The study began in 2018 under the USACE San Francisco District, South Pacific Division and was transferred to the Tulsa District out of the Southwestern Division in 2021. The USACE San Francisco District and POSF issued a Notice of Early Scoping in the Federal Register August 20, 2020. At that time, it was unclear if significant effects would be realized and the need for an EIS was not formally announced.

Virtual public scoping meetings were held on September 16 and 17, 2020, coinciding with the Notice of Early Scoping. During early scoping, several significant environmental and social issues were raised including, but not limited to, minimizing bay fill; effects of high rates of RSLC on any alternative considered; disruptions to businesses, transportation corridors and walk paths; ensuring all communities are treated fairly; impacts to water quality, contaminated sites, and historic resources; and the potential cost and time to implement any of the strategies. In general, there was wide support for the use of nature-based measures in lieu of gray infrastructure, preserving and increasing public access to the waterfront, and incorporating adaptation components to address uncertainties in RSLC.

8.2. Agency Coordination

The PDT has been coordinating with Federal, state, and local governmental agencies throughout the plan formulation process to identify potential concerns, ways to avoid, minimize, and mitigate for adverse impacts, and where NNBFs or other beneficial features could be incorporated into the planning and designs.

USACE and POSF established a RAWG, with participation by other Federal, state, and local agencies. The RAWG serves as a forum, to strive for common objectives and goals, to develop ways to address risks that are adaptive, accountable, and transparent, and to provide for early identification of permitting and policy issues. The RAWG includes POSF, USACE, BCDC, California Department of Fish and Wildlife, EPA, NPS, NMFS, RWQCB, SHPO, State Lands Office, and USFWS. USACE asked Federal and Federal agencies to participate as Cooperating or Participating Agencies in the preparation of the EIS.

Additionally, an EWN Working Group (EWNWG) was set up by the USACE to identify where and which NNBFs should be considered within the study area and help describe how NNBFs contribute to regional habitat goals and project benefits. The EWNWG included 15 individuals from Federal, state, and local agencies, universities, non-

governmental organizations, and private industry who have been identified as experts in the field of EWN and ecological restoration.

NEPA regulations and processes define three types of formal roles for agencies. A Lead Agency is the Federal agency preparing or having taken primary responsibility for preparing a NEPA document. A Cooperating Agency is any Federal agency other than a lead agency which has jurisdiction by law or special expertise with respect to any environmental impact involved in a proposal (or a reasonable alternative) for legislation or other major Federal action significantly affecting the quality of the human environment. A Participating Agency is a Federal or state agency that has an interest in the proposal. Cooperating and Participating Agencies must provide comments within their special expertise or jurisdiction and use the NEPA process to address any environmental issues of concern to its agency. A total of 12 invitations (5 Federal agencies, 7 state agencies) were sent. Two formal acceptance letters were received from Cooperating agencies and two declines were received from state agencies (California State Historic Preservation Office and Bay Area Quality Management District). Any agency who did not formally respond are assumed to have accepted the invitation to be a Cooperating or participating agency. The following is a list of formal agency roles for this study:

- **Lead Agency:** USACE
- **Cooperating Agencies:** U.S. Environmental Protection Agency Region 9 (Formally Accepted), Federal Emergency Management Agency Region IX (Planning and Implementation Branch), National Marine Fisheries Service (Formally Accepted), National Park Service, US Fish and Wildlife Service
- **Participating Agency:** California Department of Fish and Wildlife, California Regional Water Quality Control Board, California State Lands Commission, San Francisco Bay Conservation and Development Commission, and San Francisco Planning Department

8.3. Tribal Consultation

Although there are no Federally recognized Tribes within San Francisco County, California, USACE worked with POSF, CCSF, and the USACE San Francisco District's Tribal Liaison and utilized the database of the State of California's Native American Heritage Commission to identify Native American Tribes with an interest in the project area. The USACE has initiated consultation with the Amah Mutsun Tribal Band of Mission San Juan Bautista, Amah Mutsun Tribal Band, Association of Ramaytush Ohlone, Costanoan-Rumsen Carmel Tribe, Indian Canyon Mutsun Band of Costanoan, Muwekma Ohlone Indian Tribe of the San Francisco Bay Area, The Ohlone Indian Tribe, Rumšen Am:a Tur:ataj Ohlone, and the Wuksache Indian Tribe/Eshom Valley Band. USACE continues to coordinate with these groups with regard to NEPA and NHPA compliance.

8.4. Public Comments Received

A Notice of Intent to prepare an IFR and EIS for the SFWCFS was published in the Federal Register on July 27, 2023. A Notice of Availability for the Draft IFR/EIS was published in the Federal Register on January 26, 2024. The public and agencies were invited to participate in public meetings and submit comments during the comment period which ended March 29, 2024.

Four in-person public meetings were held in San Francisco during the comment period from February 26 – 29, 2024. A total of 154 comments were received during the review period. Public feedback was reviewed and considered in preparation of this Final IFR/EIS. A record of comments received is included in *Appendix H: Public Involvement*, along with the response to those comments. Key themes included: sea level rise, groundwater, and hydrology; infrastructure, flood protection, and relation to other studies; coordination and planning; nature-based solutions/EWN; hazardous materials and contamination; historic resources; socioeconomics and environmental justice; recreation and inclusion of recreational space; transportation, access, and public health; and study area and authority.

Section 9.0 Findings

I find that the San Francisco waterfront is at risk of flooding during coastal storms, extreme tides, and due to future relative sea level change. Flooding along the waterfront would cause extensive damage to public infrastructure and private property, potential loss of life, deterioration of public health and safety, degradation of the natural environment, and adverse changes to the social and economic character of the waterfront communities. These risks and their consequences are expected to increase over time as water levels rise in the bay. Additionally, the study area is in a high seismic hazard region and flood risk measures should be designed in accordance with USACE seismic criteria.

In accordance with the NEPA, a diligent effort was made to coordinate and collaborate with resource agencies, local industry, and community and environmental interests in formulating alternatives and developing the Recommended Plan. Environmental resources concerns were addressed through the study process to ensure that adverse impacts were avoided to the maximum extent practicable. To ensure the Recommended Plan complies with all applicable laws and policies and is acceptable to the public, the draft IFR-EIS had undergone public, policy, and technical review. The study team has addressed any outstanding issues raised during the review and confirmed the analysis in this final IFR-EIS.

USACE policy precludes advancing the Recommended Plan for Congressional authorization until it or separable elements of the plan achieve 35% design maturity and the cost estimate is validated. Moving forward, the NFS may undertake additional design, updated cost estimates, and other implementation actions for elements of the Recommended Plan with oversight from USACE where possible and advance those for consideration by the Chief of Engineers to support a future recommendation for Congressional authorization.

23 JULY 2026

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San Francisco Waterfront Coastal Flood Study

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San Francisco Waterfront Coastal Flood Study

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San Francisco Waterfront Coastal Flood Study

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