

# SAN FRANCISCO WATERFRONT COASTAL FLOOD STUDY, CALIFORNIA

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## APPENDIX A – PLAN FORMULATION

JULY 2026

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USACE TULSA DISTRICT | THE PORT OF SAN FRANCISCO



**US Army Corps  
of Engineers** 



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## Acronyms and Abbreviations

| Acronym | Definition                                    |
|---------|-----------------------------------------------|
| AAC     | Average Annual Cost                           |
| AEP     | Annual Exceedance Probability                 |
| ASA(CW) | Assistant Secretary of the Army (Civil Works) |
| ASP     | Agency Specific Procedure                     |
| BART    | Bay Area Rapid Transit                        |
| Bay     | San Francisco Bay                             |
| BCR     | Benefit-Cost Ratio                            |
| CCSF    | City and County of San Francisco              |
| CFRM    | Coastal Flood Risk Management                 |
| CSD     | combined sewer discharge                      |
| CSRM    | Coastal Storm Risk Management                 |
| EIS     | Environmental Impact Statement                |
| EQ      | Environmental Quality                         |
| EWN     | Engineering with Nature®                      |
| FEMA    | Federal Emergency Management Agency           |
| FWOP    | Future Without Project                        |
| FWP     | Future With Project                           |
| FY      | Fiscal Year                                   |
| G2CRM   | Generation 2 Coastal Risk Model               |
| GDP     | Gross Domestic Product                        |
| GSI     | Green Stormwater Infrastructure               |
| HTRW    | Hazardous, Toxic, and Radioactive Waste       |

| <b>Acronym</b>      | <b>Definition</b>                                               |
|---------------------|-----------------------------------------------------------------|
| IDC                 | Interest During Construction                                    |
| IFR                 | Integrated Feasibility Report                                   |
| IMPLAN              | Impact Analysis for Planning                                    |
| IWR                 | Institute for Water Resources                                   |
| LOD                 | Line of Defense                                                 |
| LPF                 | Low Post-Flooding                                               |
| LPP                 | Locally Preferred Plan                                          |
| LRV                 | Light Rail Vehicle                                              |
| MAP                 | Monitoring and Adaptation Plan                                  |
| MHHW                | Mean Higher High Water                                          |
| MTCO <sub>2</sub> e | Metric Ton(s) of Carbon Dioxide Equivalent                      |
| Muni                | San Francisco Municipal Railway                                 |
| NAVD88              | North America Vertical Datum of 1988                            |
| NED                 | National Economic Development                                   |
| NEPA                | National Environmental Policy Act                               |
| NFS                 | Non-Federal Sponsor                                             |
| NNBF                | Natural and Nature-Based Feature                                |
| OMRR&R              | Operations, Maintenance, Repair, Rehabilitation and Replacement |
| OSE                 | Other Social Effects                                            |
| P&G                 | Principles and Guidelines                                       |
| PDT                 | Project Delivery Team                                           |
| PED                 | Pre-Construction Engineering and Design                         |
| POA                 | Period of Analysis                                              |

| <b>Acronym</b> | <b>Definition</b>                             |
|----------------|-----------------------------------------------|
| POSF           | Port of San Francisco                         |
| PR&G           | Principles, Requirements, and Guidelines      |
| PV             | Present Value                                 |
| RED            | Regional Economic Development                 |
| ROW            | Right-of-Way                                  |
| RPEC           | Regional Planning and Environmental Center    |
| RSLC           | Relative Sea Level Change                     |
| SFBR           | San Francisco Bay Railroad                    |
| SFMTA          | San Francisco Municipal Transportation Agency |
| SFPUC          | San Francisco Public Utilities Commission     |
| TNBP           | Total Net Benefits Plan                       |
| TSP            | Tentatively Selected Plan                     |
| USACE          | U.S. Army Corps of Engineers                  |
| WRDA           | Water Resources Development Act               |
| WSE            | Water Surface Elevation                       |

## 1.0 Introduction

This Plan Formulation Appendix documents the plan formulation strategy to manage the risk of coastal flooding along the densely populated and economically and culturally diverse portion of the San Francisco Bay (Bay) shoreline of San Francisco, California in a manner that balances the risks to human life and property, while maintaining, enhancing, and restoring ecosystem integrity and coastal biodiversity.

### 1.1 Purpose

The goal of this feasibility study is to identify an economically viable, environmentally acceptable plan that addresses the coastal and combined flood risk management needs of the study area and is acceptable to Federal, state, and local interests.

This appendix documents the evaluations and decisions made to identify a resilience plan for the study area to facilitate cost-effective risk management actions in response to increasing risk. It documents the plan formulation strategy and evaluation of coastal and combined flood risk management features against traditional U.S. Army Corps of Engineers (USACE) formulation criteria and the *Economic and Environmental Principles and Guidelines for Water and Related Land Implementation Studies* (P&G) (WRC 1983) that resulted in the identification of a Tentatively Selected Plan (TSP) presented in the Draft Integrated Feasibility Report and Environmental Impact Statement (IFR/EIS) and appendices. Following public and agency review of the Draft IFR/EIS, the TSP was refined into the Recommended Plan for this Final IFR/EIS.

The selection of a Recommended Plan has been coordinated with the Port of San Francisco (POSF), the Non-Federal Sponsor (NFS), and appropriate City and County of San Francisco (CCSF) agencies.

A waiver of policy is required to recommend a plan other than the National Economic Development (NED) plan as the Recommended Plan. On March 18, 2024, the Assistant Secretary of the Army (Civil Works) ASA(CW) approved an exception to the requirement to recommend the NED plan and allowed USACE to recommend a Total Net Benefits Plan (TNBP).

### 1.2 Background

Section 4 provides more details about the multiple risk mechanisms along the Bay shoreline, and specifically, in the sub-portion of the shoreline that is the study area.

The study area also includes coastal habitat and environmentally and historically significant areas, such as the Embarcadero Historic District, the Union Iron Works Historic District, and numerous other individual and group resources listed on the National Register of Historic Places (NRHP). The goal of the feasibility study is to identify an economically viable, environmentally acceptable plan that addresses the coastal and combined flood risk management needs of the study area and considers multiple area hazards.

The complexity of the area risks, physical system, and affected interests required a collaborative planning approach to thoroughly assess opportunities and impacts from local interests and the public. Since 2018, POSF has shared planning strategy summaries and study updates to both government partners and local interests. Their input was considered in the identification of problems, opportunities, objectives, and constraints.

### **1.3 Project Delivery Team**

Plan formulation was accomplished by an interdisciplinary Project Delivery Team (PDT) that included a combination of USACE staff and NFS staff, with technical support from NFS consultants. The study was led by the USACE Tulsa District and included staff from the USACE Southwestern Division Regional Planning and Environmental Center (RPEC), with economics support from the USACE Philadelphia District, cost engineering support from the USACE Memphis District, real estate support from the USACE Sacramento District, and Engineering with Nature® (EWN) support from the USACE San Francisco District.

USACE team members had prior mega-study experience, including:

- Plan formulation
- Marine structural engineering, hydrology, hydraulics, and coastal engineering
- Generation 2 Coastal Risk Model (G2CRM) flood modeling and economics
- EWN
- Real estate
- Other required disciplines

POSF augmented this expertise with experience in shoreline conditions in the study area, including seismic risks, familiarity with infrastructure systems, experience with modeling storm conditions in the Bay, and knowledge of local values and priorities.

## **2.0 Planning Framework**

The USACE Civil Works planning process follows a standard approach to formulate potential water resource solutions so that Federal projects comply with applicable laws and guidance. The P&G was developed to guide the formulation and evaluation studies of the major Federal water resources development agencies. *ER 1105-2-100 Planning Guidance Notebook* (USACE 2000), *ER 1105-2-103 Policy for Conducting Civil Works Planning Studies* (USACE 2023), and the *Planning Manual Part II: Risk-Informed Planning* describe an iterative planning process for all USACE Civil Works studies to develop and evaluate alternative plans.

### **2.1 Principles and Guidelines Accounts**

The P&G established the following four accounts to facilitate the evaluation and display of the economic benefits and effects of alternative plans:

- NED

- Regional Economic Development (RED)
- Other Social Effects (OSE)
- Environmental Quality (EQ)

Benefits and effects of all four accounts (WRC 1983) were considered during the plan formulation process, and plan selection emphasized the plan that reasonably maximizes net NED benefits. *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, RED, OSE, and EQ accounts (i.e., TNBP). These four benefits categories are summarized as follows:

- **NED Account:** Includes consideration of a measure's potential to achieve the planning objective to reduce storm damage, as well as decrease costs of emergency services, lower flood insurance premiums, and consider project costs. Effects of relative sea level change (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 (IWR 2011) defines RED impacts as regional losses in employment or income under the Future Without Project (FWOP) condition. Based on guidance from this handbook, the RED analysis evaluates the regional economic consequences of coastal flooding and RSLC using Federal Emergency Management Agency (FEMA) benefit to 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:** Displays non-monetary benefits and costs regarding significant ecological, cultural, and aesthetic resources.

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

- Completeness is the extent to which the alternative plans provide and account for the necessary investments or other actions to realize the planning objectives, including actions by other Federal and non-Federal entities.
- Effectiveness is the extent to which the alternative plans contribute to achieving the planning objectives.

- Efficiency is the extent to which an alternative plan is the most cost-effective means of achieving the objectives.
- Acceptability is the extent to which the alternative plans are acceptable in terms of applicable laws, regulations, and public policies.

## **2.2 ASA(CW) and USACE Study Guidance**

*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
- 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, as required by the Clean Water Act under Section 404 (40 CFR Part 230)
- For flood risk management studies, a nonstructural plan that includes modified floodplain management practices, elevation, relocation, buyout or acquisition, dry flood proofing, and wet flood proofing
- A Locally Preferred Plan (LPP), if requested by the NFS and approved by ASA(CW), if the LPP is not one of the other plans

Specific guidance for this study was issued by 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, EQ, 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 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 the Water Resources Development Act (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 floodprone areas, and minimizing adverse impacts and vulnerabilities in any case when a floodplain or floodprone area must be used
- Protecting and restoring the functions of natural systems, and mitigating 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.

### 3.0 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 the National Environmental Policy Act (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, implementation period, economic period of analysis (POA), and 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 A-1**).

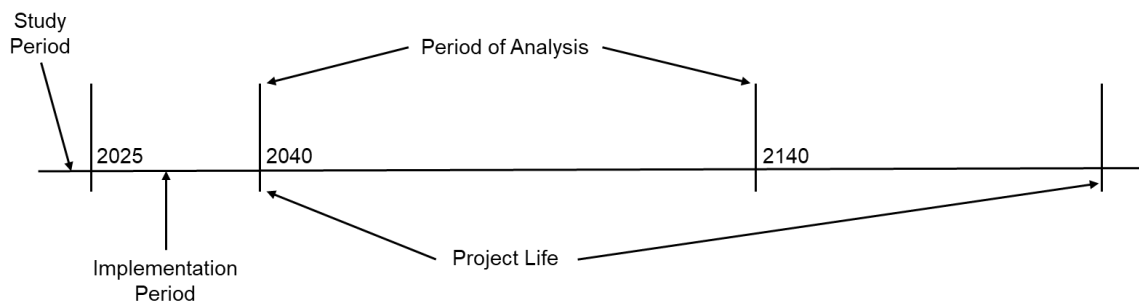


**Figure A-1: Planning Horizon**

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, as conditions may change considerably over that length of time. As directed by the 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 Pre-Construction 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. This phasing is detailed more fully in the alternative descriptions, as appropriate.

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.

## **4.0 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 of underlying soils.
- 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 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.

- 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 NRHP and are more at risk 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 on the waterfront 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 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.
- 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 investments 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's Standards for Treatment of Historic Properties* (NPS 2017)
- Recognize the cultural experiences and traditions of waterfront communities, and incorporate them into the planning and design of alternatives
- Redesign streets and open spaces 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

## **5.0 Planning Objectives and Constraints**

This section describes the planning objectives and constraints for this study.

### **5.1 Federal Objective**

In accordance with ER 1105-2-103, the Federal objective for water resource investments must reflect national priorities, encourage economic development, and protect the environment. In addition, Federal investments in water resources should reasonably maximize all benefits, with appropriate consideration of costs. Public

benefits encompass environmental, economic, and social goals, including monetary and non-monetary effects, and allow for the consideration of quantitative and qualitative metrics.

The Federal objective is to maximize economic, environmental, and social net benefits to the nation; as such, it does not seek to identify specific targets within objectives. The planning process includes formulation of alternative plans to maximize benefits relative to costs.

## **5.2 Planning Objectives**

The overarching goal of this study is to formulate alternatives for coastal and combined flood risk management to determine whether Federal participation in reduction of the damage to assets caused by flooding within the study area is feasible.

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 following study-specific planning objectives for the 100-year 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

## **5.3 USACE Resilience Objective**

The second objective of this study focuses on resilience. In *EP 1100-1-2, USACE Resilience Initiative Roadmap* (USACE 2017), USACE identified four principles of

resilience from the many definitions of resilience that exist. These principles – Prepare, Absorb, Recover, and Adapt – identify the temporal aspects and actions that are necessary to build community resilience capacity.

**Prepare:** The study will define the likely FWOP condition and assess structural and nonstructural actions that may reduce that risk. Communities and agencies can make informed choices to address existing flooding risk. Proactive measures, either through individual action, land use policies, or coordinated action, or some combination of these, can increase preparedness before flood events and make assets within areas prone to future flooding with RSLC more resilient to these hazards.

**Absorb:** This study includes measures that will reduce risk and sustain the function of infrastructure and community resources during and after exposure to coastal flooding.

**Recover:** This study evaluates solutions that not only reduce damages but also reduce the resulting downtime of important community and area resources and critical infrastructure following flooding events, and allow quicker recovery before, during, and after storms.

**Adapt:** This study recognizes adaptation as a main component for risk management under uncertain RSLC timing and identifies compatible structural and nonstructural measures that may be implemented as risk increases. A monitoring plan, with pre-identified technical experts to assess risk and adapt area defenses, will improve the cost-effective response at appropriate points in time.

## 5.4 Federal Environmental Objectives

USACE strives to balance the environmental and development needs of the nation in full compliance with NEPA, and other authorities provided by Congress and the Executive Branch. Public participation is encouraged early in the planning process to help define problems and environmental concerns relative to the study. Therefore, significant environmental resources and values that would likely be impacted, favorably as well as adversely, by an alternative under consideration are identified early in the planning process. All plans are formulated to avoid, to the fullest extent practicable, adverse impacts on significant resources. Significant adverse impacts that cannot be avoided are mitigated, as required by Section 906(d) of the WRDA 1986.

This document is an appendix to the Final IFR/EIS. As with a separate NEPA document, it documents the environmental effects of the Recommended Plan and summarizes compliance with Federal statutes and regulations.

## 5.5 Environmental Operating Principles

Consistent with NEPA, USACE has formalized its commitment to the environment by creating a set of Environmental Operating Principles applicable to all its decision-making and programs. These principles foster unity of purpose regarding environmental issues and help consider environmental conservation, preservation, and restoration during USACE activities. The Final IFR/EIS includes a discussion of the USACE Environmental Operating Principles and how the study addresses them.

## 5.6 Planning Constraints

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. These include NEPA, Section 106 of the National Historic Preservation Act, Clean Water Act, Coastal Zone Management Act, Executive Orders 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

## 6.0 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 event 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 reduce 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 lines of defense. including:
  - The existing shoreline
  - A more bayward alignment
  - An inland alignment requiring partial retreat of buildings and infrastructure over time

- 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 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) 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 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 A-2** illustrates the plan formulation strategy. A detailed summary of the formulation and screening is provided in subsequent sections.

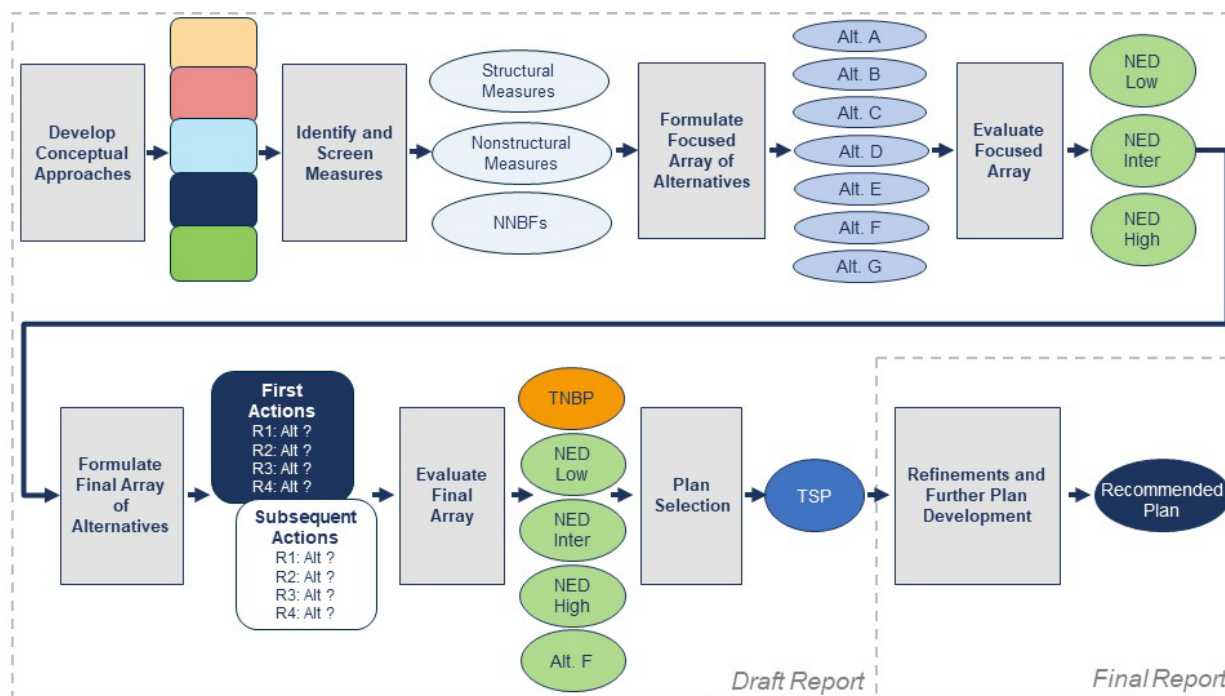


**Figure A-2: Plan Formulation Strategy**

## 7.0 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, shown in **Table A-1**. 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.

**Table A-1: Initial Conceptual Approaches with Screening**

| Approach                             | Description                                                                                                                                                                                                                                                                                                    | Theme                                                                                                           | Benefits                                                                                           | Reason Screened or Retained                                                                                                      |
|--------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| Barrier at Golden Gate Bridge        | Deployable barrier or permanent gate with locks at or near the Golden Gate Bridge.                                                                                                                                                                                                                             | Regional reduction in coastal and combined flood risk.                                                          | Large-scale reduction in coastal storm damages.                                                    | Screened: Extremely costly. Endangered species impacts, water quality, in-Bay fill, and governance issues make plan unacceptable |
| Offshore Wave Attenuator             | Offshore wave attenuator from Aquatic Park to Pier 80, where the project moves to a water's edge, with piers in alignment until the mouth of Islais Creek. There is a barrier at the mouth of Islais Creek, with the alignment resuming at the water's edge (with piers) from Pier 94/96 to Heron's Head Park. | Preserves maritime environment, existing over-water structures, and waterfront uses; least disruptive approach. | Lower cost than offshore wall. Short-term flood risk management. Short-term historic preservation. | Screened: Endangered species impacts, water quality, and in-Bay fill make plan possibly unacceptable. Least cost-effective plan. |
| Offshore Barrier - Entire Study Area | Offshore seawall with gates to support the movement of marine traffic from Aquatic Park to Heron's Head Park.                                                                                                                                                                                                  | Preserves maritime environment, existing over-water structures, and waterfront uses; least disruptive approach. | Minimally disruptive long-term flood risk management with historic preservation.                   | Screened: Endangered species impacts, water quality, and in-Bay fill make plan probably unacceptable.                            |
| Offshore Barrier until Pier 50       | Offshore barrier with gates to support the movement of marine traffic from Aquatic Park to Pier 80, where the                                                                                                                                                                                                  | Preserves maritime environment, existing over-                                                                  | Minimally disruptive long-term flood risk management with                                          | Retained: In-Bay fill and partial water quality issues make plan                                                                 |

## San Francisco Waterfront Coastal Flood Study

| Approach             | Description                                                                                                                                                                                                                                                                                                                                                                                      | Theme                                                                                                                            | Benefits                                                                                                                      | Reason Screened or Retained                                                                                    |
|----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|
|                      | project moves to a water's edge with piers in alignment until the mouth of Islais Creek. There is a barrier at the mouth of Islais Creek, with the alignment resuming at the water's edge (with piers) from Pier 94/96 to Heron's Head Park.                                                                                                                                                     | water structures, and waterfront uses; low disruption approach.                                                                  | historic preservation. Opportunity for restoration south of Islais Creek.                                                     | less desirable, but still possibly acceptable.                                                                 |
| Balanced Alternative | Offshore solution extending from Aquatic Park to Pier 14, where the project moves to a water's edge with piers in alignment, including barriers at the mouths of Mission Creek and Islais Creek, until Heron's Head Park.                                                                                                                                                                        | Preserves the historic core in the northern waterfront with a "return to the Bay" on the southern waterfront.                    | Minimally disruptive long-term flood risk management; historic preservation; environmental restoration.                       | Retained: In-Bay fill and partial water quality issues make plan less desirable but still possibly acceptable. |
| Heritage Plan        | Pier end alignment with a project connecting Aquatic Park to Pier 45. Project continues along pier ends to Pier 14, where the alignment moves to the water's edge with piers. The project resumes its pier end alignment at Pier 24, continuing to Pier 50, where it becomes a water's edge with piers in alignment until Heron's Head Park. There are barriers with gates at both creek mouths. | Maximum historic preservation with opportunities for pier restoration, as opposed to offshore approaches. Pier-centric approach. | Lower cost than offshore plans, with greater pier preservation potential and some seismic benefits to piers.                  | Retained: Appears acceptable, though there are possible view and aesthetics issues.                            |
| New Seawall          | Water's edge with piers in alignment from Aquatic Park to Pier 45, where it becomes a new nearshore seawall extending south to Pier 50. The northern waterfront alignment briefly becomes water's edge with piers to accommodate the Ferry Building. South of Pier 50, the alignment is water's edge with piers to the end of the project at                                                     | New seawall; multi-hazard risk management. Includes assumption of incidental seismic benefits.                                   | Long-term flood risk management that reduces seismic risk and offers more space to allow for natural shoreline opportunities. | Retained: In-Bay fill issue; otherwise, plan appears acceptable.                                               |

## San Francisco Waterfront Coastal Flood Study

| Approach             | Description                                                                                                                                                                                                                                                                                                                 | Theme                                                                                                                 | Benefits                                                                                                                                               | Reason Screened or Retained                                                                               |
|----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------|
|                      | Heron's Head Park. There are barriers at both creek mouths.                                                                                                                                                                                                                                                                 |                                                                                                                       |                                                                                                                                                        |                                                                                                           |
| Depend on the Piers  | Water's edge with piers in alignment from Aquatic Park to Pier 50, where the alignment becomes water's edge without piers until Heron's Head Park. Barriers at both creek mouths.                                                                                                                                           | Piers provide flood risk management, which is a medium-term solution.                                                 | Offers the opportunity for some seismic design requirements for piers and seawall, and medium-term flood risk management.                              | Retained: Plan appears acceptable; possible view and aesthetics issues.                                   |
| Shoreline Defense    | Beach nourishment at Aquatic Park, with a water's edge without piers in alignment throughout the remaining project area. Barriers at both creek mouths. Potential flood proofing of select pier structures and construction of new select piers.                                                                            | This is a no-pier defense solution that reduces flood risk at the shoreline, with additional solutions at some piers. | Offers the opportunity for long-term flood risk management without relying on stability of existing piers. May support construction of some new piers. | Retained: Plan appears to be acceptable, though there are possible access issue to over-water structures. |
| Living with Water    | Alignment along first inland roadway from Aquatic Park to 19th Street, where the project takes advantage of high ground until 23rd Street; at which, point it resumes along the roadway (23rd Street to Cargo Way; Illinois Street from Cargo Way to Jennings; Jennings Street until Evans Street, where the project ends). | Embracing the water.                                                                                                  | This is a potentially lower-cost solution that accepts our risk to rising waters.                                                                      | Retained: Least costly, but the BCR is expected to be > 1.                                                |
| Full Managed Retreat | Retreat to high land.                                                                                                                                                                                                                                                                                                       | Return to the original shoreline.                                                                                     | Significant and long-term reduction in flood risk.                                                                                                     | Screened: Most acceptable plan to regulatory agencies but screened due to very low efficiency.            |

> = greater than  
BCR = benefit to cost ratio

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

In consultation with representatives from City 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.

## **8.0 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 referenced 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

### **8.1 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 address 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 on **Figure A-3**. These approaches can be implemented through alternatives built from measures. Measures are the basic building blocks of a comprehensive approach to addressing coastal and combined flood risk. They are applied based on how they align with short- and long-term goals, current shoreline configuration, existing infrastructure, area of open space (or potential for open space), and conceptual feasibility, among other considerations.

The alternatives produced with these approaches supported comparison of costs and benefits of distinct approaches to reduce flood damage from inundation from Bay waters, including consideration of water levels, wave hazards, and RSLC. **Table A-2** presents a brief set of example measures, as they align with the three approaches.

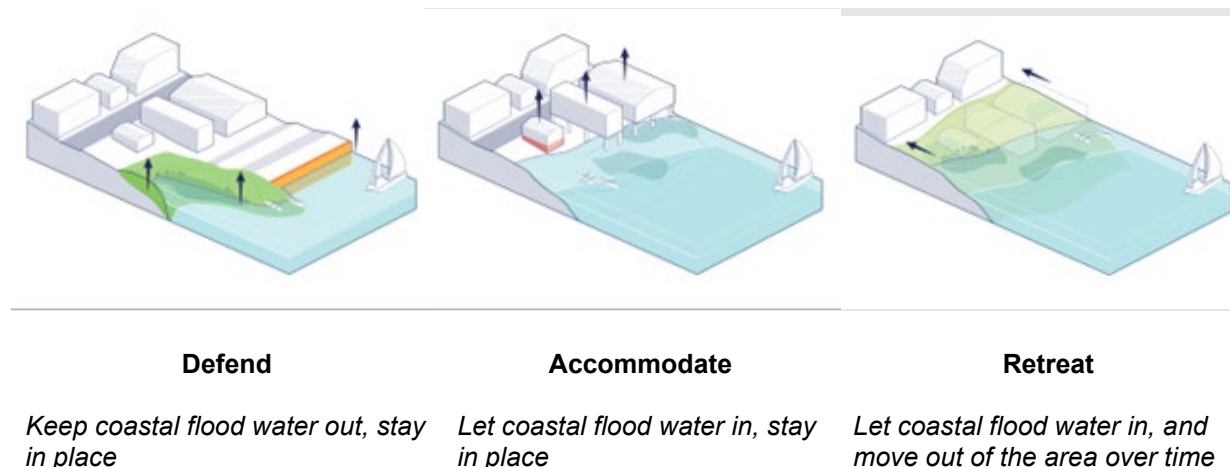


**Figure A-3: Approaches to Reduce Risk**

**Table A-2: Measure Examples for Approaches to Reduce Risk**

| Adaptation Approach | Physical Measure Examples                                                                                             | Policy Measure Examples                                                                                                                         |
|---------------------|-----------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| Defend              | Seawalls, levees, floodwalls, gates                                                                                   | Updated flood hazard maps                                                                                                                       |
| Accommodate         | Floodproofed buildings, relocated sensitive equipment to upper floors, and deployable flood barriers (e.g., sandbags) | Robust warning system and preparedness plans, financial and technical support programs for residents and businesses, and updated building codes |
| Retreat             | Relocated buildings or sensitive infrastructure to lower-risk areas                                                   | Land use and zoning changes and voluntary buyout programs                                                                                       |

## 8.2 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. **Figure A-4** illustrates this concept. 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.

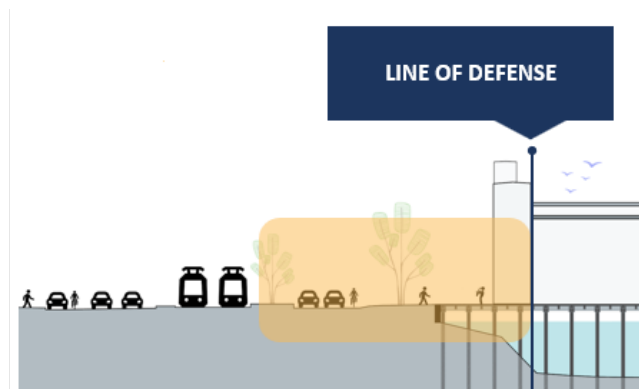


**Figure A-4: Line of Defense**

### 8.2.1 Definition of the Line of Defense and Zones

The LOD defines the boundary between two related forms of flooding: an inland flood zone and a coastal flood zone (**Figure A-5**). Raising the shoreline defends against coastal flooding, but it also has the potential to create or exacerbate inland flooding

behind the LOD. Inland flooding can be addressed with pumping and with flood-resilient buildings and streets.

If coastal flood defenses are at the shoreline, the inland flood zone will be larger. If coastal flood defenses are farther inland, there is a big coastal flood zone, reducing the need for as much pumping behind the LOD. The location of the LOD will help to identify what other physical and policy measures are needed to reduce risk in each zone.

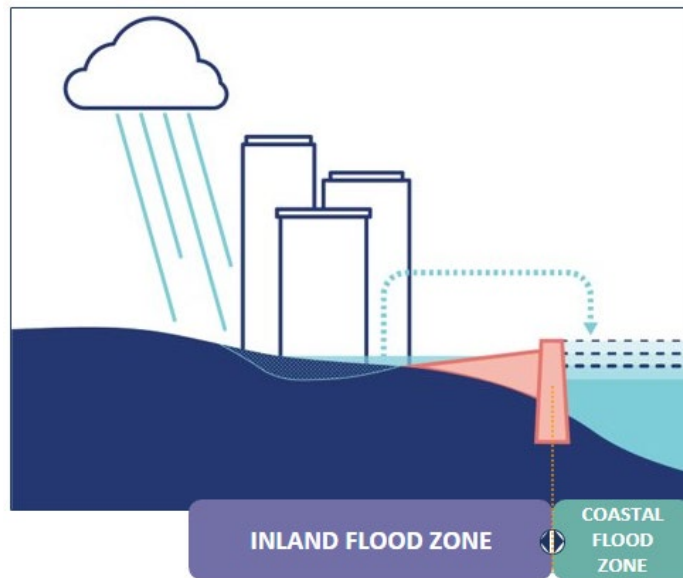


**Figure A-5: Flood Zones**

### **8.2.2 Adaptation Space Considerations for the Line of Defense**

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, 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.

### **8.3 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.

### **8.4 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. 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 occurring 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 in Appendix G will ultimately address how USACE and POSF will manage the risks of RSLC over time through implementation of subsequent Federal actions, in congruence with City 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 life of asset, 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, City, and State to manage the risks over time.

- Recommend approaches for Congressional authorization and future PED strategies that will allow USACE and the Port 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.

## 9.0 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. Specifically, Section 152, as amended, states:

*SEC. 152. TREATMENT OF CERTAIN BENEFITS AND COSTS.*

*(a) IN GENERAL. - In the case of a flood risk management or coastal storm risk management in a region of moderate or high seismic hazard, for the purpose of a benefit-cost analysis for the project, the Secretary shall not include in that analysis any additional design and construction costs resulting from addressing seismic concerns.*

*(b) SAVINGS PROVISION. - Except with respect to the benefit-cost analysis, the additional costs referred to in subsection (a) shall be—*

*(1) included in the total project cost; and*

*(2) subject to cost-share requirements otherwise applicable to the project.*

Because the study area is in an area of high seismic hazard, alternatives were formulated with full consideration of applicable USACE engineering design standards needed to address seismic hazards. 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.

To evaluate NED benefits and costs and calculate benefit to cost ratios (BCRs), the cost basis is assumed to be the scope of work necessary to produce the CFRM 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.

## 10.0 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.

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 displaced by hardened shorelines. The PDT consulted with the USACE National Nonstructural Committee and incorporated lessons learned from current nonstructural policy concerns and recent CFRM studies conducted by the USACE New York, Galveston, and New Orleans Districts.

## 10.1 Structural Measures

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)
- 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.

The structural measures considered in this study are presented in **Table A-3**. Each measure was also screened to determine its applicability in the study area, and the results of the screening are also presented in **Table A-3**.

**Table A-3: Screening of Structural Measures**

| Measure                     | Description                                                                                                                                                                                                                                                                                                                                | Carried Forward | Discussion                                                                                                                                                                                                                                                                                      |
|-----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Floodwalls                  | Floodwalls are hard, vertical structures built to prevent floodwaters from reaching at-risk areas. They are typically built parallel to the shoreline. Floodwalls can be made out of a variety of materials and designs. Examples include sheet pile walls and T-walls.                                                                    | Yes             | Floodwalls are appropriate for some locations within the study area, especially where space is constrained.                                                                                                                                                                                     |
| Levees                      | Levees are earthen structures that are wide at the base and tapered toward the top, made of compacted soil. They can have grassy vegetation on top or can be designed to host walking or biking paths. In coastal environments, they must be designed to include erosion protection. Levees are typically built parallel to the shoreline. | Yes             | Levees can represent a lower-cost option than floodwalls, assuming minimal space constraints. Levees are appropriate for some locations within the study area where space constraints allow.                                                                                                    |
| Ringwalls                   | Sometimes considered a nonstructural physical measure, ringwalls are floodwalls or levees constructed to encircle individual structures or small groups of structures. Ringwalls typically surround the entire building or property with a limited number of access points. They are subject to the same design standards as floodwalls.   | Yes             | These are judged as a reasonable asset level protection suited to the dense urban environment with structures built without the anticipation of structure raising, or dry or wet floodproofing.                                                                                                 |
| Seawalls and Bulkhead Walls | For this report, the terms “seawall” and “bulkhead wall” are used interchangeably. Seawalls are hardened structures parallel to the shoreline to protect from coastal hazards on one side and retain earthen fill on the other side.                                                                                                       | Yes             | Seawalls exist along portions of the current waterfront. They are appropriate, especially in areas with maritime activities.                                                                                                                                                                    |
| Breakwaters                 | Breakwaters are structures constructed at a coastal area to manage the effects of tides, currents, waves, and storm surges. These measures can be fixed or floating and constructed of a number of different materials and methods, including sheet piles, rubble mounds, and stone. They are typically built in water near the shoreline. | Tentatively Yes | Breakwaters are commonly used around the Bay for reducing wave energy in marinas or, in some cases, recreational or habitat areas. There are several existing breakwaters throughout the study area. Breakwaters may be appropriate for consideration in this study at a later stage of design. |

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| Measure                       | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Carried Forward | Discussion                                                                                                                                                                                                                                                                           |
|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Tide Gates                    | <p>Tide gates are operable structures that apply to waterways, such as creeks and rivers, that can be closed to reduce flood risk before a storm event or extreme high tides. Tide gates would tie into adjacent shoreline defenses (such as a seawall or floodwall) to prevent outflanking. These structures would be designed to allow boats and other maritime vessels to pass during standard operations.</p> <p>Tide gates are anticipated to require more frequent closure as sea levels rise. Depending on the rate of RSLC, they could eventually remain permanently shut.</p> | Yes             | Tide gates are in use in multiple locations throughout the Bay. Structure age and condition, risk to rising sea levels, maritime and recreational use, and interactions with ecology and protected species factor into local decision-making about barrier construction, and OMRR&R. |
| Deployable Closure Structures | <p>Deployable closure structures are temporary CFRM measures that could be deployed manually or passively. For example, a flip-up barrier is a passive deployable flood barrier. The passive deployment mechanism allows deployment of a flip-up barrier without any involvement from Operations personnel and is operated by physics (i.e., water pressure) and activated when the design conditions are met (i.e., at the onset of submergence of the base).</p>                                                                                                                     | Yes             | Deployable closure structures will be needed as part of a coastal flood defense system in this study area to allow for pedestrian or vehicular access in constrained locations.                                                                                                      |
| Pump Stations                 | <p>Structural measures, such as seawalls, levees, and floodwalls, tend to trap rainfall runoff associated with storms on the landward side.</p> <p>Pump stations can be used to redirect water in low-lying elevations to more appropriate locations. They generally have a sustained operations and maintenance commitment as well as associated costs.</p>                                                                                                                                                                                                                           | Yes             | Large pump stations are considered for use as a component of a water control structure at the creeks. Pump stations will also be needed in combination with other inland drainage infrastructure to assist in outflow of runoff.                                                     |

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| Measure                        | Description                                                                                                                                                                                                                                                                                                                        | Carried Forward | Discussion                                                                                                                                                                                                   |
|--------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Inland Drainage Infrastructure | Structural measures, such as seawalls, levees, and floodwalls, tend to trap rainfall runoff associated with storms on the landward side.<br>Inland drainage infrastructure can include gravity outlets, like culverts installed along the length of the shoreline, as well as conveyance and storage structures.                   | Yes             | Inland drainage infrastructure is appropriate throughout the study area. The specific types and configuration of inland drainage infrastructure will be determined at a future stage of planning and design. |
| Revetments                     | Revetment reduces erosion caused by wave action, storm surge, and currents. Revetment can be incorporated into the design of other structural measures.                                                                                                                                                                            | Yes             | Revetment is commonly used for managing erosion in the Bay.                                                                                                                                                  |
| Bridge Raising or Replacement  | Bridge raising consists of raising an existing highway, railroad, or pedestrian bridge that crosses a water body to reduce the risk of floodwaters or high tides damaging the bridge. Raising also removes an impediment to the ability of the water body to pass flood flows or to accommodate high-water levels caused by tides. | Yes             | There are four bridges within the study area for which bridge raising or replacement could be appropriate.                                                                                                   |
| Wharf Raising or Replacement   | Wharves along the shoreline can be integrated with the seawall to reduce impacts caused by wave action. This measure consists of demolishing the existing wharf and constructing a new wharf at a higher elevation.                                                                                                                | Yes             | Existing wharves along portions of the shoreline serve multiple purposes, including coastal storm risk management.                                                                                           |

**Notes:**

Yes (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.

OMRR&R = operations, maintenance, repair, rehabilitation and replacement

## 10.2 Nonstructural Measures

Nonstructural measures are permanent or contingent measures applied to a structure or its contents, or both, 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.

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; rather, they 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.

The nonstructural measures considered in this study are presented in **Table A-4**. Each measure was also screened to determine its applicability in the study area, and the results of the screening are also presented in **Table A-4**.

**Table A-4: Screening of Nonstructural Measures**

| Measure                      | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Carried Forward | Discussion                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Building Elevation (Raising) | Elevation involves raising the lowest finished floor of a building to a height above the flood level. This nonstructural technique lifts an existing structure to limit floodwaters from reaching living areas.                                                                                                                                                                                                                                                                          | Tentatively Yes | Structures in the study area are a mix of single-story, industrial-type buildings and multi-story, commercial, institutional, and residential buildings. Elevating these types of existing structures was determined as not likely to be cost-effective or feasible without substantial reconstruction of the existing asset. For the purposes of plan formulation, the only buildings considered for elevation were those that could be elevated on raised ground to accommodate construction of other structural features. |
| Relocation                   | Relocation involves moving people or structures out of the floodplain. USACE policy requires mandatory relocation recommendations be that include the potential use of condemnation, if necessary.                                                                                                                                                                                                                                                                                       | Yes             | The urban environment of the study area is heavily built out, such that relocation of structures in San Francisco was judged as not likely to be cost-effective, when compared to other physical nonstructural measures. However, relocation of infrastructure systems is expected to be required to provide critical services, such as wastewater management and transportation.                                                                                                                                            |
| Acquisition (Buyout)         | Acquisition involves purchase and elimination of flood-damageable structures, allowing for inhabitants to relocate to locations away from flood hazards. Lands can then be preserved for open space, recreation, or other uses. USACE policy requires mandatory acquisition recommendations that include the potential use of condemnation, if necessary.                                                                                                                                | Yes             | Through a managed retreat approach, acquisition of assets is expected and used.                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Dry Floodproofing            | Dry floodproofing includes a range of strategies that seal the exterior of a building from flood waters and is often used to protect non-residential structures, water supplies, and sewage systems. For example, a measure could include applying a waterproof veneer to the outside surface of an existing structure. Backflow valves could be installed on sewer lines to prevent back up during flooding and storm events. At building openings, deployable gates and shields can be | Yes             | USACE policy guidance advises against the use of dry floodproofing for residential structures, but this measure can apply to commercial, industrial, or institutional type structures.                                                                                                                                                                                                                                                                                                                                       |

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| Measure                           | Description                                                                                                                                                                                                                                                                                                                                                                                          | Carried Forward | Discussion                                                                                                                                                                                                                                                                                                                                                                                                          |
|-----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                   | activated during flood events to prevent flood damage to the building interior, while allowing continued use at other times.                                                                                                                                                                                                                                                                         |                 |                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Wet Floodproofing                 | Wet floodproofing allows floodwater to enter the structure. At-risk items, such as utilities, appliances, and furnaces, are relocated or waterproofed to higher locations. By allowing floodwater to enter the structure, hydrostatic forces on the inside and outside of the structure can be equalized, reducing the risk of structural damage.                                                    | Yes             | Wet floodproofing is identified for structure types that can accommodate loss of a first floor by transitioning it from living space to storage or parking space. The cost of wet floodproofing will include additional scope to offset the loss of living space and allow for construction of alternate accommodations.                                                                                            |
| Flood Warning Systems             | A flood warning system is a communication pathway that can provide residents with advance warning of flooding and allow them time to make appropriate preparations. While a flood warning system does not prevent flooding and does not reduce damage to property that is left in the path of floodwaters, it can provide an aid in reducing property loss and increasing the safety of individuals. | Tentatively Yes | Warning systems are beneficial in combination with other measures that reduce flood damages but judged to be insufficient alone to achieve the study objective to reduce flood damages.                                                                                                                                                                                                                             |
| Flood Insurance                   | Flood insurance provides financial benefits for property owners who hold policies. Insurance can be used to offset economic losses due to coastal storm damage.                                                                                                                                                                                                                                      | Tentatively Yes | Flood insurance is a policy tool that would aid in recovery that could be used in combination with other measures that reduce flood damages but judged to be insufficient alone to achieve the study objective to reduce flood damages. Additionally, coastal flooding and RSLC will increase the frequency of damaging events such that insurance providers are unlikely to tolerate the high certainty of claims. |
| Floodplain Mapping                | Floodplain mapping consists of using maps to communicate flood risk. Flood maps are typically generated using hydraulic and hydrodynamic models.                                                                                                                                                                                                                                                     | Tentatively Yes | Flood mapping has been completed for the study area but judged to be insufficient alone to achieve the study objective to reduce flood damages.                                                                                                                                                                                                                                                                     |
| Flood Emergency Preparedness Plan | Emergency preparedness plans are guides that include information about how to prepare for emergencies such as a coastal storm.                                                                                                                                                                                                                                                                       | Tentatively Yes | Flood emergency preparedness planning is beneficial in combination with other measures that reduce flood damages but judged to be insufficient alone to achieve the study objective to reduce flood damages.                                                                                                                                                                                                        |

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| Measure                         | Description                                                                                                                                                                                                                                                                                                                                                                                                              | Carried Forward | Discussion                                                                                                                                                                                                                                                                            |
|---------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Land Use Regulations and Zoning | Through proper land use regulation, floodplains can be managed so that their use is compatible with the severity of the flood hazard. Several means of regulation are available, including zoning ordinances, subdivision regulations, and building and housing codes. Their purpose is to reduce losses by controlling the future use of floodplain lands and would not be effective in mitigating the existing hazard. | Tentatively Yes | Both land use regulation and zoning are policy tools that will influence development of new structures within the floodplain in combination with other measures that reduce flood damages but judged to be insufficient alone to achieve the study objective to reduce flood damages. |
| Evacuation Plans                | Evacuation plans are guides that describe when and how residents will evacuate before an emergency.                                                                                                                                                                                                                                                                                                                      | Tentatively Yes | Evacuation planning is beneficial in combination with other measures that reduce flood damages but judged to be insufficient alone to achieve the study objective to reduce flood damages.                                                                                            |
| Risk Communication              | Risk communication is the exchange of information between experts and people who face a hazard such as a coastal storm.                                                                                                                                                                                                                                                                                                  | Tentatively Yes | Risk communication is beneficial in combination with other measures that reduce flood damages but judged to be insufficient alone to achieve the study objective to reduce flood damages.                                                                                             |

Notes:

Yes (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.

### 10.3 Natural and Nature-Based Features and the Engineering with Nature Philosophy

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. EWN is 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*).

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 2021).

Within this document, the term “NNBF” refers to the natural and nature-based feature, measure, or action; and “EWN” refers to the philosophy governing the feature.

NNBFs can be combined across a terrestrial to aquatic transect to provide multiple *integrated* benefits in one location. The performance of these other benefits enhances coastal and combined flood risk management performance.

The NNBFs considered in this study are presented in **Table A-5**. Each measure was also screened to determine its applicability in the study area, and the results of the screening are also presented in **Table A-5**.

**Table A-5: Screening of Natural and Nature-Based Features**

| Measure                          | Definition and Description                                                                                                                                                                                                                       | Carried Forward | Notes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Enhancement of Existing Wetlands | Restoration or enhancement of existing coastal tidal wetlands, including establishment of an inland migration corridor to maintain the wetland area as sea levels rise                                                                           | Yes             | <ul style="list-style-type: none"> <li>Enhanced coastal and combined flood risk management benefits, increasing wave energy dissipation potential of coastal flood defense</li> <li>Likely efficient due to low relative cost for long-term benefits; areas for wetland enhancement along the shoreline are limited, although the number of species benefiting are numerous</li> <li>Acceptable and in line with local priorities and policies</li> </ul>                                                                                                                   |
| Wetland Creation                 | Establishment of a new coastal tidal wetland primarily located along POSF lands in areas of retreat, requiring de-paving and infrastructure removal                                                                                              | Yes             | <ul style="list-style-type: none"> <li>Enhanced coastal and combined flood risk management benefits, increasing wave energy dissipation potential of coastal flood defense, and relocation of at-risk structures out of the coastal floodplain</li> <li>Efficient at reducing long-term flood risk, although de-paving and removal of structures and infrastructure can be costly</li> <li>Acceptable and in line with local priorities and policies; however, relocation and land use changes for areas with active urban use may not have broad public support</li> </ul> |
| Ecotone Levee                    | Gently sloped habitat gradient that connects flood risk management levees to tidal marsh and can provide transition zone habitat, which is important for high-water refuge and habitat connectivity, and attenuate waves to reduce levee erosion | Yes             | <ul style="list-style-type: none"> <li>Enhanced coastal and combined flood risk management benefits, increasing wave energy dissipation potential of coastal flood defense</li> <li>Acceptable and in line with local priorities and policies</li> <li>Limited locations where ecotone levees can be established along the shoreline</li> </ul>                                                                                                                                                                                                                             |

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| Measure                                  | Definition and Description                                                                                                                                                                                                                                                                                                                               | Carried Forward | Notes                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Coarse Beach                             | Coarse sediment (cobble, gravel, larger rock size) beach acting as a submerged breakwater and wave energy dissipation feature that includes both establishment and nourishment of coarse beach, located on the landward side of a sill or submerged dike parallel to the shore; location adjacent to the shore would not create a navigation hazard      | Yes             | <ul style="list-style-type: none"> <li>Enhanced coastal and combined flood risk management benefits, increasing wave energy dissipation potential of coastal flood defense</li> <li>Efficiency depends on technical cost considerations</li> <li>Acceptable and in line with local priorities and policies, particularly for recreation benefits and shoreline access</li> <li>Limited locations where a coarse beach can be established along the shoreline</li> </ul> |
| Living Seawall and Vertical Enhancements | Structural elements either integrated into seawalls or attached to seawalls (as panels) that create relief and varied microhabitat conditions; living seawall elements can include a variety of structural elements that create shallow water habitat, including habitat benches or staircased shorelines, which are often found at the base of seawalls | Yes             | <ul style="list-style-type: none"> <li>Enhances coastal and combined flood risk management benefits by providing additional wave energy dissipation potential</li> <li>Provides habitat value and may provide enhanced endangered species foraging habitat</li> <li>Public engagement by POSF has drawn broad public and agency support for this feature</li> <li>Acceptable and in line with local priorities and policies</li> </ul>                                  |
| Naturalized or Embankment Shoreline      | Naturalized or embankment shorelines can be planted with native vegetation to increase wave energy dissipation potential, reduce erosion risks, and provide tidal habitats and upland refugia                                                                                                                                                            | Yes             | <ul style="list-style-type: none"> <li>Provides similar coastal and combined flood risk management benefits to traditional earthen levees</li> <li>Reduces operations and maintenance needs by reducing erosion potential, particularly during smaller, more frequent storm events; however, may require managing invasive species</li> <li>Provides additional habitat, improved aesthetic, and community co-benefits</li> </ul>                                       |

## San Francisco Waterfront Coastal Flood Study

| Measure                               | Definition and Description                                                                                                                                                                                                                                                           | Carried Forward | Notes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|---------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ecological Armoring                   | Armoring units or materials that either replace traditional riprap (ecological and green riprap), integrate vegetation, or include enhancing features (such as tidepool units and rocky intertidal habitat)                                                                          | Yes             | <ul style="list-style-type: none"> <li>Provides similar coastal and combined flood risk management benefits to traditional gray armoring measures (riprap)</li> <li>Provides additional habitat, improved aesthetic, and community co-benefits</li> </ul>                                                                                                                                                                                                                                                                                                       |
| Creek Enhancements                    | Improvements to the existing creek banks (beyond raising the shoreline elevation to provide coastal and combined flood risk management benefits) can range in scale and include habitat shelves, planted edges, live crib walls, and other measures that increase surface complexity | Yes             | <ul style="list-style-type: none"> <li>Requires NNBF for the success of other flood risk management measures</li> <li>Enhancements would provide erosion control and stabilization for tidal creek banks</li> <li>Creek bank improvements may improve water quality, although these benefits are uncertain</li> <li>Habitat and community benefits depend on the feature selected for implementation</li> </ul>                                                                                                                                                 |
| Green Stormwater Infrastructure (GSI) | Features that address urban stormwater by slowing, capturing, and infiltrating runoff. Includes green streets, tree trenches, bioswales, green roofs, and other features                                                                                                             | Yes             | <ul style="list-style-type: none"> <li>Requires NNBF for the success of other flood risk management measures</li> <li>RSLC and elevated Bay water levels will increase inland stormwater flood risks due to insufficient stormwater drainage capacity</li> <li>Raised shoreline structures associated with the alternatives will disrupt direct inland runoff to the Bay and increase inland stormwater flood risks</li> <li>GSI features that reduce stormwater runoff can provide habitat value, minimize heat islands, and provide other benefits</li> </ul> |
| Mudflat Augmentation                  | Consolidated, fine-grained sediment deposits to enhance elevations for mudflats                                                                                                                                                                                                      | Tentatively Yes | <ul style="list-style-type: none"> <li>Tentatively retained as part of a combination measure and included as a supplemental component of wetland restoration and establishment</li> </ul>                                                                                                                                                                                                                                                                                                                                                                       |

## San Francisco Waterfront Coastal Flood Study

| Measure                             | Definition and Description                                                                                                                                                                                                                                                                                                                                                                                               | Carried Forward | Notes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Pier and Piling Habitat Improvement | Replacing creosote piles, paneling, and texturing of piles (e.g., pile wraps), as well as substrate improvements                                                                                                                                                                                                                                                                                                         | Tentatively Yes | <ul style="list-style-type: none"> <li>May provide wave energy dissipation underneath piers; insufficient information available to assess coastal and combined flood risk management potential</li> <li>Provides similar habitat benefits as the living seawall feature; greater benefits could result if pier and piling habitat improvements are coupled with adjacent living seawall features</li> </ul>                                                                                                                                                                                                                                          |
| Subtidal Habitat Improvements       | Includes: <ul style="list-style-type: none"> <li>Establishment of beds of underwater flowering plants and submerged aquatic vegetation</li> <li>Creation of shellfish and oyster beds along the shallow Bay floor</li> <li>Creation of artificial reef structures constructed from a variety of materials, ranging from rock to oyster shells, from concrete structures to prefabricated modules and products</li> </ul> | Tentatively Yes | <ul style="list-style-type: none"> <li>Not included as an independent measure; where this feature is appropriate along the San Francisco shoreline, it requires other adjacent features for wave attenuation benefits (e.g., oyster reefs paired with eelgrass beds)</li> <li>Tentatively retained as part of a combination measure and included as a supplemental component of wetland restoration and establishment (e.g., constructed oyster reefs can help reduce marsh edge erosion)</li> <li>Could be integrated into embankment or naturalized embankment shoreline designs to provide toe protection along nearshore environments</li> </ul> |

## San Francisco Waterfront Coastal Flood Study

| Measure                             | Definition and Description                                                                                                                                                                                                                       | Carried Forward | Notes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|-------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Living Breakwater (new or enhanced) | Offshore vertical breakwater structure parallel to the shore with a variety of ecosystem-enhancing features                                                                                                                                      | Tentatively Yes | <ul style="list-style-type: none"> <li>Breakwaters and breakwaters improvements were not considered as part of the alternatives, but they can provide coastal and combined flood risk management benefits</li> <li>Ecosystem enhancements could be added to existing breakwaters to provide habitat benefits</li> <li>A new offshore vertical breakwater can support ecosystem-enhancing features while reducing wave energy, reducing the height of the coastal flood defenses</li> <li>A traditional rock breakwater is likely infeasible given the deep water along the San Francisco shoreline</li> <li>This feature was retained for additional study, given potential coastal and combined flood risk management benefits and applicability to the study area</li> </ul> |
| Afforestation and Urban Corridors   | Extensive tree planting, focusing on areas with extensive nonpermeable surfaces and stormwater runoff                                                                                                                                            | Tentatively Yes | <ul style="list-style-type: none"> <li>This feature does not address the primary study objective of addressing coastal and combined flood risk management benefits</li> <li>May provide inland stormwater drainage benefits and reduce inland stormwater flood risk</li> <li>Supports other benefits, including reducing heat islands and improving community wellbeing</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                             |
| Submerged Breakwater                | Offshore structures parallel to the shore; can be constructed of varied materials, from rock, oyster shell, to artificial reef structures; the highest elevation of the structure is intended to be submerged for some or all of the tidal cycle | No              | <ul style="list-style-type: none"> <li>This feature could pose a navigation hazard within the study area</li> <li>The Bay's large tidal range limits the effectiveness of submerged features for reducing wave energy</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

## San Francisco Waterfront Coastal Flood Study

| Measure                                       | Definition and Description                                                                                                                                                                                                                        | Carried Forward | Notes                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-----------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Sandy Beaches (establishment and nourishment) | Fine-sediment (sandy) beach acting as a submerged breakwater and flood protection and includes creation of a sandy beach on the landward side of a sill or submerged dike parallel to the shore                                                   | No              | <ul style="list-style-type: none"> <li>Sandy beaches are not efficient in this highly constrained and diversified shoreline</li> <li>Erosion concerns for sandy sediments</li> <li>Operations and maintenance costs are likely cost-prohibitive, making this feature inefficient at providing coastal and combined flood risk management benefits</li> <li>Sand can be mixed with coarser material to create mixed gravel beaches, which were retained</li> </ul> |
| Polder Creation                               | Low-lying area enclosed by dikes and disconnected from surrounding hydrology                                                                                                                                                                      | No              | <ul style="list-style-type: none"> <li>Insufficient area to create polders along the San Francisco shoreline</li> <li>Existing restoration efforts in the Bay are focused on restoring tidal action to polders to create tidal wetlands; creation of new polders would be in opposition of this restoration goal</li> </ul>                                                                                                                                       |
| Islands                                       | Constructed or restored barrier, deltaic or in-Bay islands                                                                                                                                                                                        | No              | <ul style="list-style-type: none"> <li>Not appropriate for the deep water setting along much of San Francisco's shoreline; additional challenges include: <ul style="list-style-type: none"> <li>Permitting</li> <li>Local acceptability</li> <li>Cost</li> <li>Feasibility</li> </ul> </li> </ul>                                                                                                                                                                |
| Creek Daylighting                             | Restoration of waterways that have been covered, piped, or canalized to a naturalized, aboveground condition; creek daylighting could include restoration of adjacent floodplains with embankments to contain creek flows during high flow events | No              | <ul style="list-style-type: none"> <li>This feature does not address the primary study objective of addressing coastal and combined flood risk management benefits</li> <li>This feature could potentially be part of a GSI plan to address inland stormwater issues</li> <li>This feature may be cost-prohibitive in the densely urbanized watersheds of San Francisco</li> </ul>                                                                                |

## San Francisco Waterfront Coastal Flood Study

| Measure                                      | Definition and Description                                                                                                                  | Carried Forward | Notes                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|----------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Watershed and Creek to Baylands Reconnection | Restoration of Bay hydrological system across the transect using dam removal, upstream creek restoration, and creek mouth delta restoration | No              | <ul style="list-style-type: none"> <li>Similar to creek daylighting, although larger in scale; could require restoration of historic creek mouth and deltas</li> <li>Restoration of this scale in a densely urbanized city would be cost-prohibitive</li> <li>Restoration of this scale would require substantial retreat, including relocation of homes, businesses, and transportation corridors</li> </ul>                            |
| Wharf Enhancements (Light Penetration)       | Penetrations and wells in wharf structures to allow light to penetrate the water columns under the wharf                                    | No              | <ul style="list-style-type: none"> <li>Light-penetrating features provide enhanced photosynthesis opportunities for species; the water in the vicinity of the seawall is relatively clear</li> <li>The Bay water adjacent to San Francisco's seawall is extremely turbid, blocking light penetration of any significant depth below the water surface; this feature is unlikely to provide much benefit within the study area</li> </ul> |

**Notes:**

Yes (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.

## 11.0 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 City 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 (ROW) 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 plantings, 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 A-6:** 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 0.96, 2.9, and 9.08 feet under the Low, Intermediate, and High USACE RSLC projections. 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 A-6: Change in 1% AEP Water Surface Elevation over Time**

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

<sup>a</sup>9414290 Presidio / San Francisco Tide Gauge

<sup>b</sup>Pier 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.

The PDT identified representative scales of RSLC as building blocks of 1.5 feet, 3.5 feet, and 7 feet of RSLC (**Table A-7**). 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.

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). The focused array includes seven alternatives (**Table A-8, Table A-9**), including No Action alternative (Alternative A). Alternative B was scaled for both lower- and higher-risk scenarios and could include managed retreat. Alternatives C through G include structural measures along or near the shoreline in First Actions. Alternatives D, E, F, and G were designed to be adaptive, with Subsequent Actions occurring around 2090.

These Subsequent Actions increased the crest elevation of the structural measure, providing higher-risk management, and, in some cases, changed the alignment. The 2090 alignments were designed to defend the shoreline (Alternatives D and E), manage the water (Alternative F), or partially retreat from high-risk areas (Alternative G). The 2090 date for Subsequent Actions was selected to allow for fair plan comparison during evaluation; the MAP will inform when Subsequent Actions will be needed.

**Table A-7: RSLC Building Blocks for Plan Formulation**

| Building Block                                 |                              | Expected Time Horizon to Maintain Performance Target, per USACE RSLC Scenario <sup>a,b</sup> |               |               |
|------------------------------------------------|------------------------------|----------------------------------------------------------------------------------------------|---------------|---------------|
| Performance Target Considerations <sup>a</sup> | Crest Elevation <sup>c</sup> | 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 |

<sup>a</sup>For 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.

<sup>b</sup>Table 2-6 provides a summary of RSLC over time across each USACE scenario.

<sup>c</sup>Actual 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 A-8: Focused Array of Alternative Plans**

| Alternative Name                             | First Actions                |                                                                             | Subsequent Actions           |                                   |                                   |                                                              |
|----------------------------------------------|------------------------------|-----------------------------------------------------------------------------|------------------------------|-----------------------------------|-----------------------------------|--------------------------------------------------------------|
|                                              | Crest Elevation <sup>a</sup> | Description <sup>b</sup>                                                    | Crest Elevation <sup>a</sup> |                                   |                                   | Description <sup>b</sup>                                     |
|                                              |                              |                                                                             | 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 Low-       | 13.5 feet NAVD88             | Defend at existing shoreline in Reaches 1-4<br>Designed to support building | --                           | 15.5 feet NAVD88                  | 15.5 feet NAVD88                  | Increase crest elevation of defense structure along existing |

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| Alternative Name                                                    | First Actions                |                                                                                                                                                                                                                                            | Subsequent Actions           |     |                  |                                                                                                                                                                                                     |
|---------------------------------------------------------------------|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|-----|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                     | Crest Elevation <sup>a</sup> | Description <sup>b</sup>                                                                                                                                                                                                                   | Crest Elevation <sup>a</sup> |     |                  | Description <sup>b</sup>                                                                                                                                                                            |
|                                                                     |                              |                                                                                                                                                                                                                                            | Low                          | Int | High             |                                                                                                                                                                                                     |
| Moderate Risk                                                       |                              | higher as risk increases                                                                                                                                                                                                                   |                              |     |                  | shoreline in Reaches 1-4                                                                                                                                                                            |
| Alternative E:<br>Defend Existing Shoreline, Scaled for Higher Risk | 15.5 feet NAVD88             | Defend at existing shoreline in Reaches 1-4<br>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:<br>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<br>Water control structures at creeks<br>Defend at existing shoreline in Reach 3 south of Mission Creek<br>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<br>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<br>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<br>Raise new inland defense structure in remaining portions of Reaches 3 and 4 |

<sup>a</sup>Crest 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.

<sup>b</sup>Alternatives 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

**Table A-9: Measures Proposed in the Focused Array of Alternatives and Implementation Year**

| Alternative<br>Implementation Time<br>Step | Bay Fill | Levee | Bridge Raise or Replacement | Bulkhead Wall and Seawall | Deployable Flood Gate | Roadway Impact | Sheet Pile Wall | Tide Gate | T-wall | Vertical Wall and Curb Extension | Wharf | Ecological Armoring* | Ecotone Levee* | Embankment Shoreline* | Naturalized Shoreline* | Marsh Enhancement* | Vertical Shoreline* |
|--------------------------------------------|----------|-------|-----------------------------|---------------------------|-----------------------|----------------|-----------------|-----------|--------|----------------------------------|-------|----------------------|----------------|-----------------------|------------------------|--------------------|---------------------|
| Alternative C 2040                         |          | ●     |                             |                           | ●                     | ●              | ●               |           | ●      | ●                                | ●     | ●                    |                | ●                     | ●                      |                    |                     |
| Alternative D 2040                         |          | ●     |                             |                           | ●                     | ●              | ●               |           | ●      | ●                                | ●     | ●                    |                | ●                     | ●                      | ●                  |                     |
| Alternative D 2090                         |          |       | ●                           | ●                         |                       | ●              |                 |           | ●      | ●                                | ●     | ●                    | ●              | ●                     |                        | ●                  |                     |
| Alternative E 2040                         | ●        | ●     |                             | ●                         | ●                     | ●              |                 |           | ●      | ●                                | ●     | ●                    | ●              | ●                     | ●                      | ●                  | ●                   |
| Alternative E 2090                         | ●        | ●     | ●                           | ●                         |                       | ●              |                 |           | ●      | ●                                | ●     |                      |                | ●                     | ●                      | ●                  |                     |
| Alternative F 2040                         | ●        | ●     |                             | ●                         |                       | ●              |                 | ●         | ●      | ●                                | ●     | ●                    | ●              |                       |                        | ●                  |                     |
| Alternative F 2090                         |          | ●     |                             |                           |                       | ●              |                 |           |        | ●                                | ●     |                      |                |                       |                        | ●                  |                     |
| Alternative G 2040                         |          | ●     | ●                           | ●                         |                       | ●              |                 |           | ●      | ●                                | ●     | ●                    |                | ●                     | ●                      | ●                  |                     |
| Alternative G 2090                         |          | ●     |                             |                           |                       | ●              |                 |           |        | ●                                |       |                      | ●              |                       |                        | ●                  |                     |
| TNBP First Actions                         |          | ●     |                             | ●                         | ●                     | ●              | ●               |           | ●      | ●                                | ●     | ●                    | ●              | ●                     | ●                      |                    |                     |
| TNBP Subsequent<br>Actions                 | ●        | ●     |                             | ●                         |                       | ●              |                 |           | ●      |                                  | ●     | ●                    | ●              | ●                     | ●                      | ●                  |                     |

Note: ● indicates measure is included in the alternative

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 and 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 (USACE 2019):

*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.

Because the calculated future sea level scenarios have been used in the G2CRM modeling, the damage analysis does reflect the precise calculations from the calculators. This allows those damage assessments to be consistent with the evaluations in other coastal flood risk management (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), allows for Subsequent Actions as actual RSLC is observed.

## **11.1 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 (Main Report Section 2.0). 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 3<sup>rd</sup> 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.

## **11.2 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, or 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.

Per PB 2019-03, the structures evaluated for nonstructural treatment were aggregated into groups based first on reaches, then based on timing of exposure to the 1% AEP flood event. Structures within the 1% AEP floodplain by the end of a 25-year period were considered to be a group that would be eligible for physical floodproofing at the beginning of that 25-year period. Throughout the 100-year POA, the floodproofing actions were applied to subsequent groups such that each risk scenario (lower-risk and higher-risk) had 16 groups of structures (4 reaches, 4 time periods). Although the 1% AEP threshold was the criterion used to determine eligibility, because there are only minor differences in water levels between different AEP events, selecting a different threshold would have only a small impact on the number of structures included. As RSLC is the main driver of risk, the scale and phasing of the nonstructural alternative is tied to that.

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.

The basic assumptions that guide nonstructural actions are:

- Assets within the inundation zone for the 1% AEP coastal event will be dry-floodproofed for inundation depths less than 3 feet.
- Assets within the inundation zone for the monthly coastal event will be acquired, demolished, and abandoned (i.e., retreat).
- Individual assets may be grouped together within flood areas that do not achieve the specified criteria to avoid isolated and stranded assets.

This alternative would only involve actions that reduce human exposure and risk to flooding but does not attempt to change flows. This alternative does not substantially change the area of potential flooding. **Figure A-6** shows the floodproof and retreat

zones across timesteps for the lower-risk scenario, and **Figure A-7** shows the higher-risk scenario.

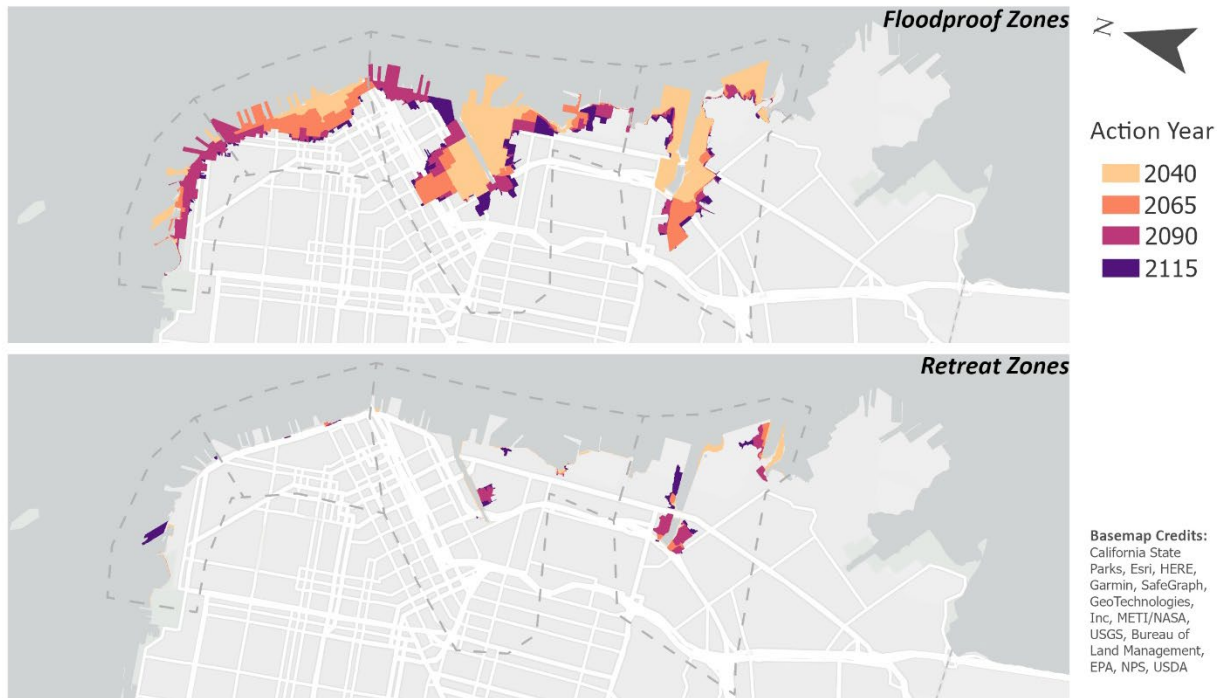
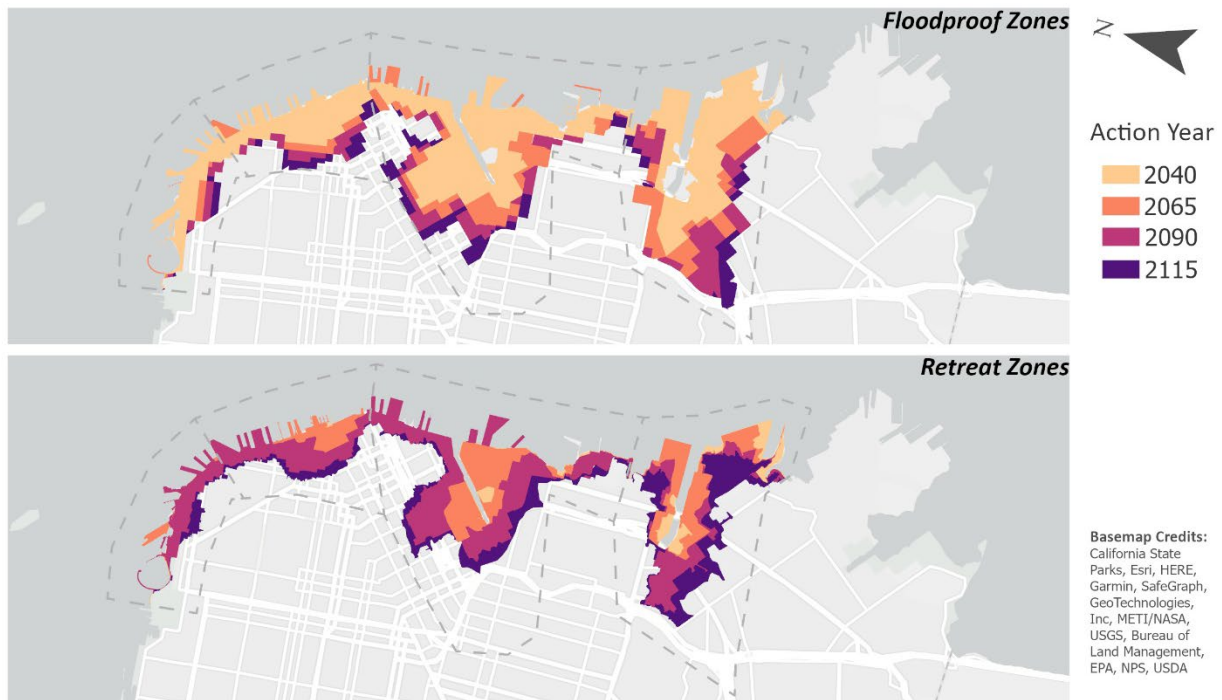


**Figure A-6: Alternative B Floodproof and Retreat by Time Step for Lower-Risk Scenario**



## Figure A-7: Alternative B Floodproof and Retreat by Time Step for Higher Risk Scenario

### 11.2.1 Floodproofing

Alternative B assumes a combination of dry floodproofing, elevation, wet floodproofing, and perimeter ringwalls to reduce risk in the infrequent flood zone. The assumed floodproofing measure was determined based on the frequency of use, structure value, and typical footprint (**Table A-10**).

**Table A-10: Anticipated Floodproofing Measure Based on Structure Type**

| Structure Type                                                                         | Floodproofing Measure          |
|----------------------------------------------------------------------------------------|--------------------------------|
| Industrial                                                                             | Dry floodproofing              |
| Residential, includes residential, single-family residential, multi-family residential | Elevation or wet floodproofing |
| Commercial and Other, includes commercial, institutional, mixed-use, and other         | Perimeter ringwall             |
| Open Space and Vacant                                                                  | None                           |

### 11.2.2 Property Acquisition and Demolition

The proposed acquisition and demolition would serve to eliminate the risk to people and property. Acquisition of these properties would follow the same process of targeting willing sellers and properties in the higher-frequency floodplains first. At this phase, it is uncertain whether the NFS would retain ownership of the land or turn it over to another entity. All acquired properties would have deed restrictions stating that no construction of any structure would be permitted. The ground after demolition would be prepared for regular flooding.

### 11.2.3 Scaling for Lower and Higher Risk

There are different numbers of structures and facilities that would be floodproofed or acquired and demolished, including single-family and multi-family residential homes; institutional, commercial, and industrial buildings; and City services, such as transit corridors and wastewater facilities, depending on the risk. The nonstructural plan was scaled for two levels of risk: a lower risk based on the USACE Intermediate RSLC scenario and a higher risk based on the USACE High RSLC scenario.

Additionally, implementation of the nonstructural plan would be phased. The phased implementation would occur around 2040, 2065, 2090, and 2115. Actions include floodproofing or retreat (acquisition and demolition). **Table A-11** shows the number of structures that would be floodproofed or acquired and demolished by phase for the

lower-risk scenario, and **Table A-12** shows the number of structures that would be floodproofed or acquired and demolished by phase for the higher-risk scenario.

**Table A-11: Number of Structures Floodproofed or Acquired by Time Step for Lower-Risk Scenario**

| Action     | Measures                        | 2040 | 2065 | 2090 | 2115 | Total |
|------------|---------------------------------|------|------|------|------|-------|
| Floodproof | Dry floodproofing               | 254  | 147  | 45   | 37   | 483   |
|            | Elevation and wet floodproofing | 55   | 118  | 27   | 16   | 216   |
|            | Perimeter ringwall              | 204  | 173  | 164  | 80   | 621   |
| Retreat    | Acquisition, demolition         | 16   | 14   | 32   | 21   | 83    |

**Table A-12: Number of Structures Floodproofed or Acquired by Time Step for Higher-Risk Scenario**

| Action     | Measures                        | 2040 | 2065 | 2090 | 2115 | Total |
|------------|---------------------------------|------|------|------|------|-------|
| Floodproof | Dry floodproofing               | 617  | 272  | 289  | 267  | 1,445 |
|            | Elevation and wet floodproofing | 238  | 47   | 193  | 324  | 802   |
|            | Perimeter ringwall              | 567  | 217  | 342  | 262  | 1,388 |
| Retreat    | Acquisition, demolition         | 60   | 460  | 973  | 639  | 2,132 |

Additionally, roadway and trackway routes will be floodproofed or, at times, retreated (lost) due to the frequency of inundation, as shown for the lower-risk scenario (**Table A-13**) and the higher-risk scenario (**Table A-14**).

**Table A-13: Miles of Roadway and Trackway Floodproofed or Retreated for Each Time Step for Lower-Risk Scenario**

| Year            | 2040 | 2065 | 2090 | 2115 |
|-----------------|------|------|------|------|
| <b>Roadway</b>  |      |      |      |      |
| Floodproof      | 23.9 | 15.6 | 14.7 | 6.2  |
| Retreat         | 0.3  | 0.2  | 1.7  | 0.8  |
| <b>Trackway</b> |      |      |      |      |
| Floodproof      | 17.0 | 3.8  | 5.9  | 0.8  |
| Retreat         | 0.0  | 0.1  | 0.6  | 0.8  |

**Table A-14: Miles of Roadway and Trackway Floodproofed or Retreated for Each Time Step for Higher-Risk Scenario**

| Year            | 2040 | 2065 | 2090 | 2115 |
|-----------------|------|------|------|------|
| <b>Roadway</b>  |      |      |      |      |
| Floodproof      | 56.9 | 9.6  | 21.5 | 16.2 |
| Retreat         | 2.5  | 21.7 | 33.7 | 11.5 |
| <b>Trackway</b> |      |      |      |      |
| Floodproof      | 36.2 | 4.8  | 2.2  | 0.4  |
| Retreat         | 0.8  | 12.0 | 12.4 | 5.6  |

### 11.3 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 were incorporated within a more robust plan addressing higher rates of RSLC. The design crest elevation for the measures in around 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 includes 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 ROW, floodwalls within the Embarcadero promenade were identified as the most feasible measure. Additionally, the alternative includes short perimeter ringwalls constructed along the apron of the existing finger piers to provide added protection from coastal storms and waves.

Foundations are constructed to achieve the seismic performance requirements so that 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 features of Alternative C by reach are described in this section. **Figure A-8** shows the alignment of the LOD.

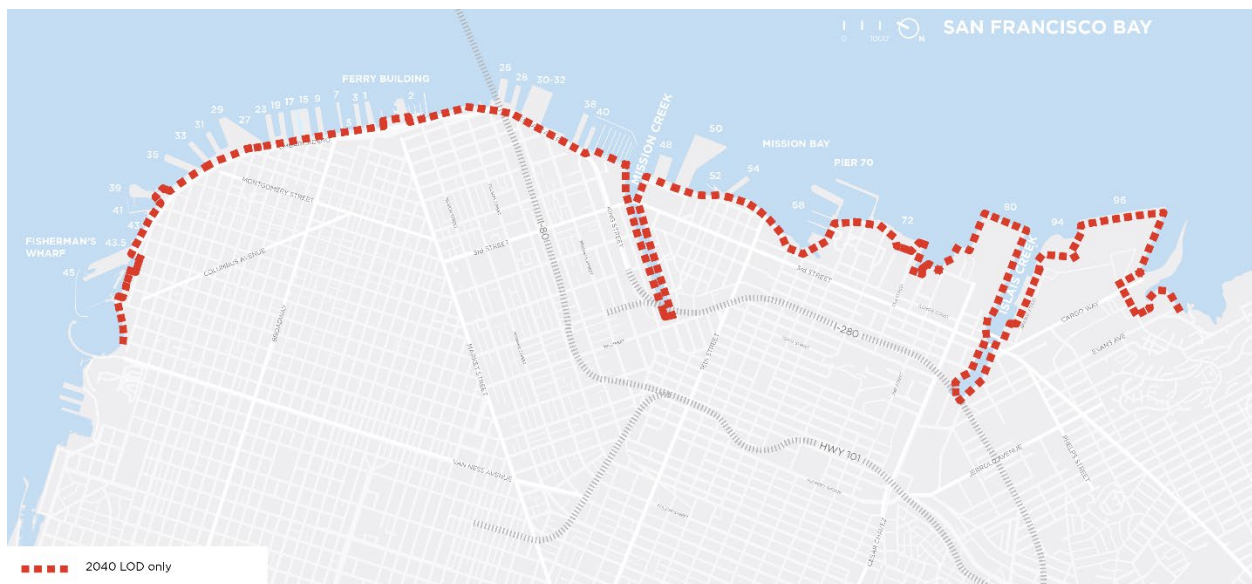


**Figure A-8: Alternative C**

### 11.3.1 Embarcadero (Reaches 1 and 2)

In the Embarcadero geography, Alternative C elevates the shoreline in place with floodwalls and levees, supported by a seismic foundation that extends into the roadway (**Figure A-9**). The actions in these reaches are described as follows:

- Use 1.5- to 4-foot-tall walls and levees within the Embarcadero promenade to add coastal flood protection landward of the existing bulkhead wall.
- Perform ground improvement to meet seismic design requirements of ER1110-2-1806 for the coastal flood defense structures.
- Construct a 2-foot-tall concrete curb around the perimeter of piers, from Pier 47 to Pier 24.
- Install gates and deployable structures at main locations for vehicular and pedestrian access to piers and maritime facilities.
- Rebuild roadways along Little Embarcadero and Taylor Street between Powell and Jefferson streets (adjacent to the Triangle parking lot).
- In Fisherman's Wharf, elevate or floodproof some buildings (less than five), and consider demolition of buildings (less than five) that straddle the coastal flood defense based on factors such as age and condition.
- Build infrastructure to manage stormwater. Coordinate with San Francisco Public Utilities Commission (SFPUC), San Francisco Public Works, and others on changes to the combined sewer system, new pumps, green infrastructure, and other resilient building and street design opportunities and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.



**Figure A-9: Alternative C, Embarcadero (Reaches 1 and 2)**

### 11.3.2 Mission Creek/Mission Bay (Reach 3)

In the Mission Creek/Mission Bay geography, Alternative C defends existing City and community assets in place by elevating the creek and Bay shorelines with levees and floodwalls (**Figure A-10**). 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 actions in Reach 3 are described as follows:

- Use combination of 2.5- to 3.5-foot-tall walls and levees to raise creek and bayside shorelines, providing Bay Trail access atop or adjacent to bayside levees.
- Perform ground improvement to meet seismic design requirements of ER1110-2-1806 for the coastal flood defense structures.
- Construct a 2-foot-tall concrete curb around the perimeter of piers, from Pier 26 to Pier 50.
- Replace the wharf at South Beach Harbor with a new, elevated wharf that ties sloped fill back into existing ground.

- Install deployable closure structures at the northern and southern abutments of 3rd and 4th Street bridges over the creek to defend landward buildings and infrastructure from flood damage in the event of a coastal storm.
- Tie measures into existing and planned high ground at Bayfront, Agua Vista, and Crane Cove Parks, and at the Mission Rock and Pier 70 development areas.
- Incorporate NNBFs into the shoreline along the northern and southern banks of Mission Creek.
- Floodproof some buildings bayside of the coastal flood defense along the Mission Bay shoreline (less than 10) and consider demolition of some buildings bayside of the defenses at Piers 68-70 (less than 5) based on factors, such as age, condition, ground floor elevation, and historic status.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and others on changes to the combined sewer system, new pumps, green infrastructure, and other resilient building and street design opportunities and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.



### Legend

- |                       |                        |                         |
|-----------------------|------------------------|-------------------------|
| Coastal Flood Defense | Inland Adaptation Zone | Coastal Adaptation Zone |
| Tie into High Ground  | Bay Fill               | Planned Development     |

**Figure A-10: Alternative C, Mission Creek/Mission Bay (Reach 3)**

### 11.3.3 Islais Creek/Bayview (Reach 4)

In the Islais Creek/Bayview geography, Alternative C defends the existing shoreline to retain residential and commercial land uses in place, including POSF land uses and maritime facilities (**Figure A-11**). The flood defenses consist of raising the shoreline using levees, floodwalls, concrete curbs, and deployable closure structures, and tying into existing or planned high ground near Potrero Power Station and behind the Pier 94 wetlands (Port backlands). The 3rd Street bridge is currently being redesigned to defend against several feet of RSLC (FWOP condition). The actions in Reach 4 are described as follows:

- Use a combination of 3- to 4.5-foot-tall walls and levees to raise creek shorelines.
- Perform ground improvement to meet seismic design requirements of ER1110-2-1806 for the coastal flood defense structures.
- Install a concrete curb at edge of Pier 80 and levees and walls landward of the Pier94-96 wharf intended to provide protection while maintaining function for maritime uses.
- Raise the Illinois Street Bridge and adjust connecting roads accordingly.
- Incorporate NNBFs into the shoreline along Islais Creek and the Pier 94 wetlands.
- Consider partial or full demolition of some buildings (less than five) that straddle the coastal flood defense.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and others on changes to the combined sewer system, new pumps, green infrastructure, and other resilient building and street design opportunities and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

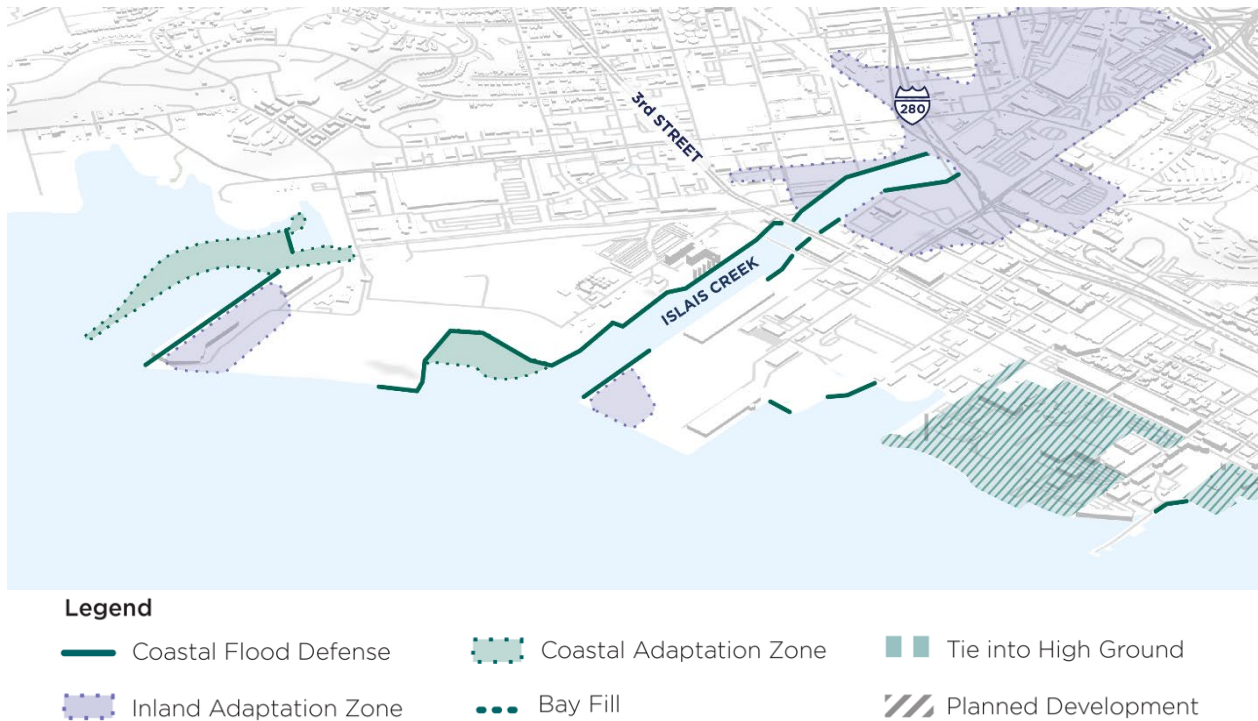


**Figure A-11: Alternative C, Islais Creek/Bayview (Reach 4)**

## 11.4 Alternative D: Defend, Scaled for Low to Moderate Risk

Alternative D is designed to adapt the shoreline to withstand 1.5 feet of RSLC above a 2000 baseline, with the possibility of building higher (up to an additional 2 feet of RSLC) closer to around 2090 if RSLC is projected to increase beyond the first LOD. 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 City 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 located 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 achieve the seismic performance requirements so 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.

#### 11.4.1 Subsequent Adaptations to Alternative D

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 vehicular and rail approaches to accommodate higher water levels while maintaining transportation connections across the creek.

The features of Alternative D by reach for both the First Actions construction and the Subsequent Actions adaptation are described in this section. **Figure A-12** shows the alignment of the LOD.

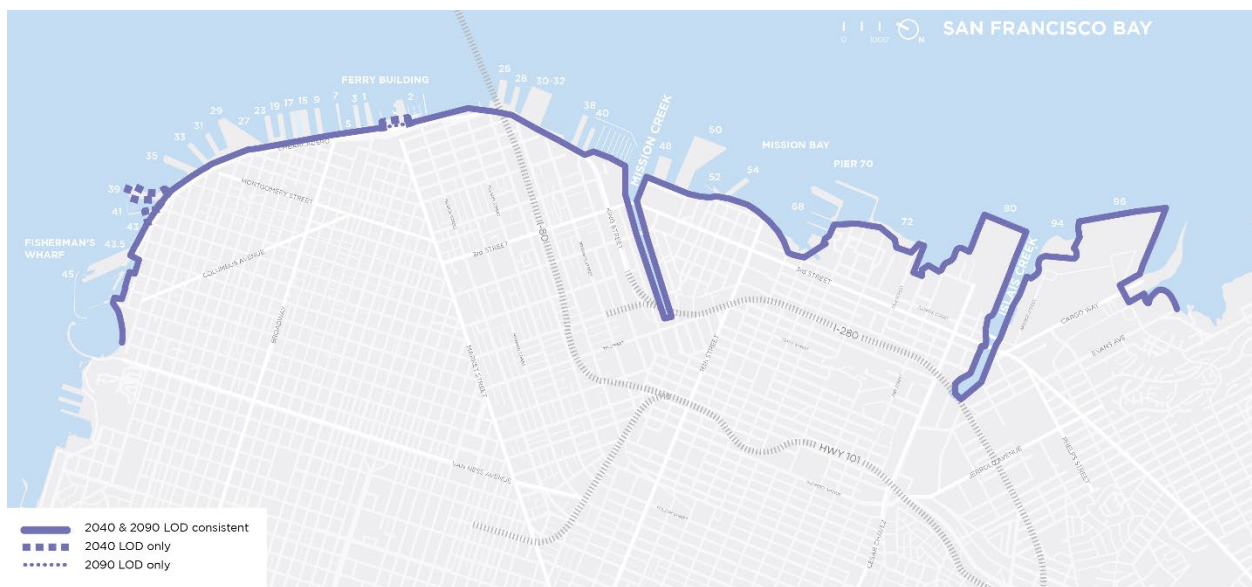


**Figure A-12: Alternative D**

#### 11.4.2 Embarcadero (Reaches 1 and 2)

In the Embarcadero geography, Alternative D elevates the shoreline in place with floodwalls supported by a seismic foundation that extends into the roadway. In the

Subsequent Actions, wharves throughout the waterfront would be rebuilt at higher elevations.

Alternative D would include the following First Actions (**Figure A-13**):

- Use a combination of 2.5- to 4.5-foot-tall walls to raise Embarcadero promenade landward of the existing bulkhead wall and wharves, except at the Ferry Building and Pier 39, where the LOD is a curb at the bayside perimeter of the piers and wharves.
- Build a 1.5- to 4.5-foot-tall wall bayward of the Aquatic Park Trail and Dolphin Club.
- Perform ground improvement to meet seismic design requirements of ER1110-2-1806 for the coastal flood defense structures.
- Construct a 2-foot-tall concrete curb around the perimeter of piers, from Pier 47 to Pier 24.
- Install gates and deployable structures at main locations for vehicular and pedestrian access to piers and maritime facilities.
- Rebuild roadways along Little Embarcadero and Taylor Street between Powell and Jefferson streets (adjacent to the Triangle parking lot).
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and others on changes to the combined sewer system, new pumps, green infrastructure, and other resilient building and street design opportunities and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.



**Figure A-13: Alternative D, Embarcadero (Reaches 1 and 2) First Actions**

Alternative D proposes the following Subsequent Actions (**Figure A-14**):

- Demolish the existing wharves and replace with elevated wharves to address 3.5 feet RSLC. Wharves would meet the top of the stepped levee at landward sides and slope up approximately 2 feet at bayward edges.
- Raise the Ferry Building and historic bulkhead buildings from Pier 24 to Pier 35.
- Where wharves are not reconstructed, add an additional 2 feet to levee crests and floodwalls.
- Build additional infrastructure to manage stormwater and reduce inland flood risk exacerbated by the coastal flood defense structures.

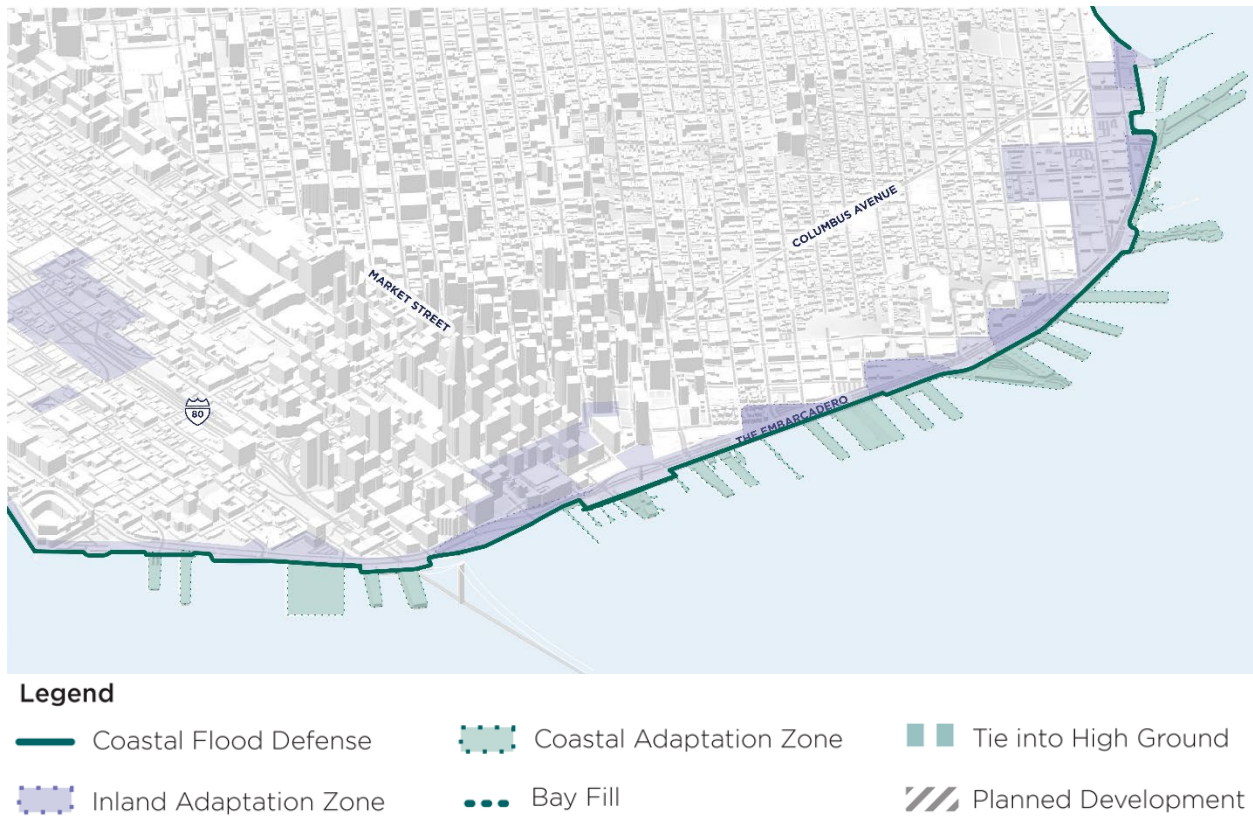


**Figure A-14: Alternative D, Embarcadero (Reaches 1 and 2) Subsequent Actions**

### 11.4.3 Mission Creek/Mission Bay (Reach 3)

In the Mission Creek/Mission Bay geography, Alternative D defends existing City and community assets in place by elevating the creek and Bay shorelines with levees and floodwalls, and, as Subsequent Actions, raised and rebuilt wharves. 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.

Alternative D would include the following First Actions (**Figure A-15**):

- Use a combination of 1.5- to 4.5-foot-tall walls and levees to raise the creek and bayside shorelines, providing Bay Trail access atop or adjacent to bayside levees.
- Perform ground improvement to meet seismic design requirements of ER1110-2-1806 for the coastal flood defense structures.
- Construct a 2-foot-tall concrete curb around the perimeter of piers from Pier 26 to Pier 50.
- Raise and rebuild wharves at South Beach.

- Install deployable closure structures at the northern and southern abutments of 3rd and 4th Street bridges over the creek to defend landward buildings and infrastructure from flood damage in the event of a coastal storm.
- Tie measures into existing and planned high ground at Bayfront, Agua Vista, and Crane Cove Parks, and at the Mission Rock and Pier 70 development areas.
- Incorporate NNBFs at Crane Cove Park and near Pier 68 Shipyard.
- Consider demolition of some buildings bayside of the defenses at Piers 68-70 (less than five) based on factors, such as age, condition, ground floor elevation, and historic status.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and others on changes to the combined sewer system, new pumps, green infrastructure, and other resilient building and street design opportunities and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.



**Figure A-15: Alternative D, Mission Creek/Mission Bay (Reach 3) First Actions**

Alternative D would include the following Subsequent Actions (**Figure A-16**):

- Add an additional 2 feet to levees and walls constructed as part of the 2040 scope.
- Demolish existing wharves from Bay Bridge to South Beach Harbor and replace with elevated wharves to address 3.5 feet RSLC. Wharves would meet the top of the stepped levee at the landward side and slope up approximately 2 feet at the bayward edge.
- Raise the historic bulkhead buildings from Pier 26 to Pier 40.
- Raise 3rd and 4th Street bridges and regrade approaches.
- Maintain, enhance, or expand NNBFs at Crane Cove Park and Pier 68 shipyard.
- Elevate select buildings bayside of the coastal flood defense along the Mission Bay shoreline (less than five) and consider demolition of some buildings north of Crane Cove Park (less than five) based on factors, such as age, condition, and ground floor elevation.
- Build additional infrastructure to manage stormwater and reduce inland flood risk exacerbated by the coastal flood defense structures.



**Legend**

- |                        |                         |                      |
|------------------------|-------------------------|----------------------|
| Coastal Flood Defense  | Coastal Adaptation Zone | Tie into High Ground |
| Inland Adaptation Zone | Bay Fill                | Planned Development  |

**Figure A-16: Alternative D, Mission Creek/Mission Bay (Reach 3) Subsequent Actions**

#### 11.4.4 Islais Creek/Bayview (Reach 4)

In the Islais Creek/Bayview geography, Alternative D 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 levees, floodwalls, concrete curbs, and deployable and closure structures, and tying into existing or planned high ground near Potrero Power Station and behind the Pier 94 wetlands (Port backlands). The 3rd Street bridge is currently being redesigned to defend against several feet of RSLC (FWOP condition).

Alternative D would include the following First Actions (**Figure A-17**):

- Use a combination of 2.5- to 5.5-foot-tall walls and levees to raise creek shorelines.
- Construct a concrete curb at the edge of Pier 80 and raise the edge of Pier 94-96 using levees and walls with openings to provide protection while maintaining function for maritime uses.
- Perform ground improvement to meet seismic design requirements of ER1110-2-1806 for the coastal flood defense structures.
- Reconstruct Pier 90 and 92 wharves at higher elevations and incorporate them into LOD.
- Incorporate NNBFs into the shoreline at Warm Water Cove, along Islais Creek, and at the Pier 94 wetlands.
- Install deployable closure structures at the northern and southern abutments of Illinois Street Bridge over the creek to defend landward buildings and infrastructure from flood damage in the event of a coastal storm.
- Consider partial or full demolition of some buildings (less than five) that straddle the coastal flood defense.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and others on changes to the combined sewer system, new pumps, green infrastructure, other resilient building and street design opportunities, and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

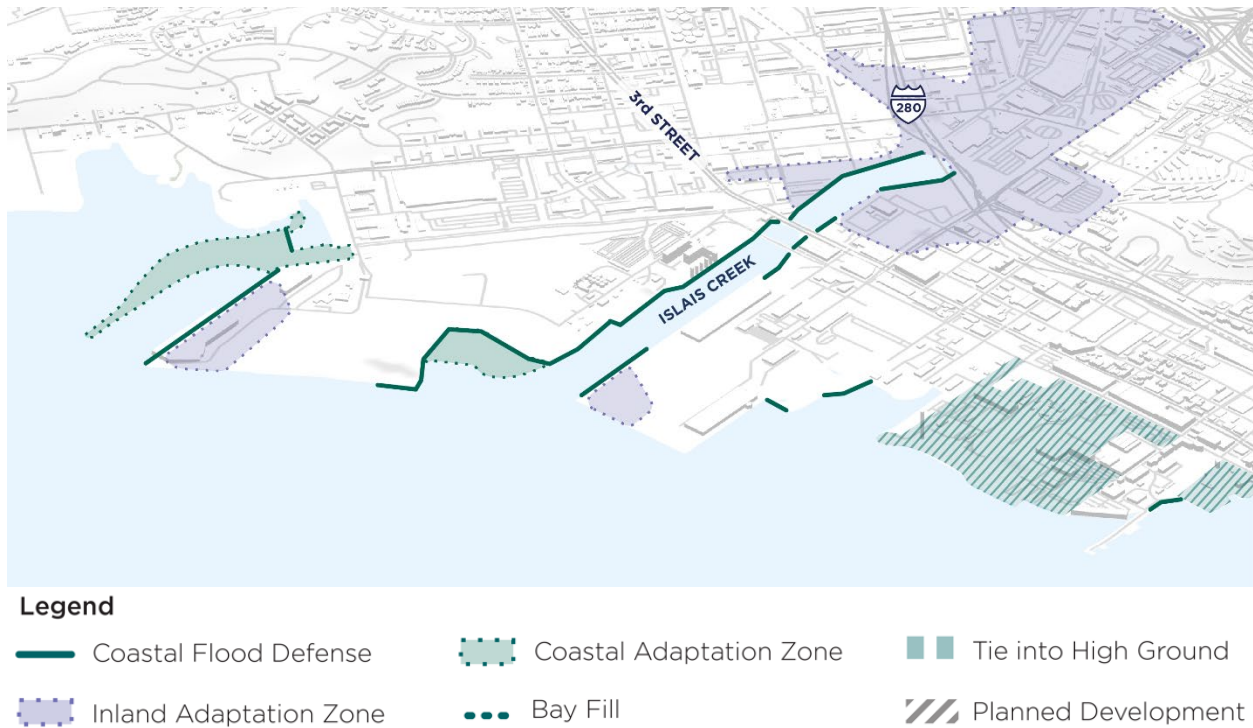


**Figure A-17: Alternative D, Islais Creek/Bayview (Reach 4) First Actions**

Alternative D would include the following Subsequent Actions (**Figure A-18**):

- Add an additional 2 feet to levees and walls constructed as part of the 2040 scope.
- Raise Illinois Street Bridge, and regrade approaches, likely resulting in the loss of freight rail access to Pier 80.
- Maintain, enhance, or expand NNBFs at Warm Water Cove, along Islais Creek, and at the Pier 94 wetlands.
- Consider demolition of some warehouse buildings (less than five) at Warm Water Cove to make room for NNBFs.
- Build additional infrastructure to manage stormwater and reduce inland flood risk exacerbated by the coastal flood defense structures.

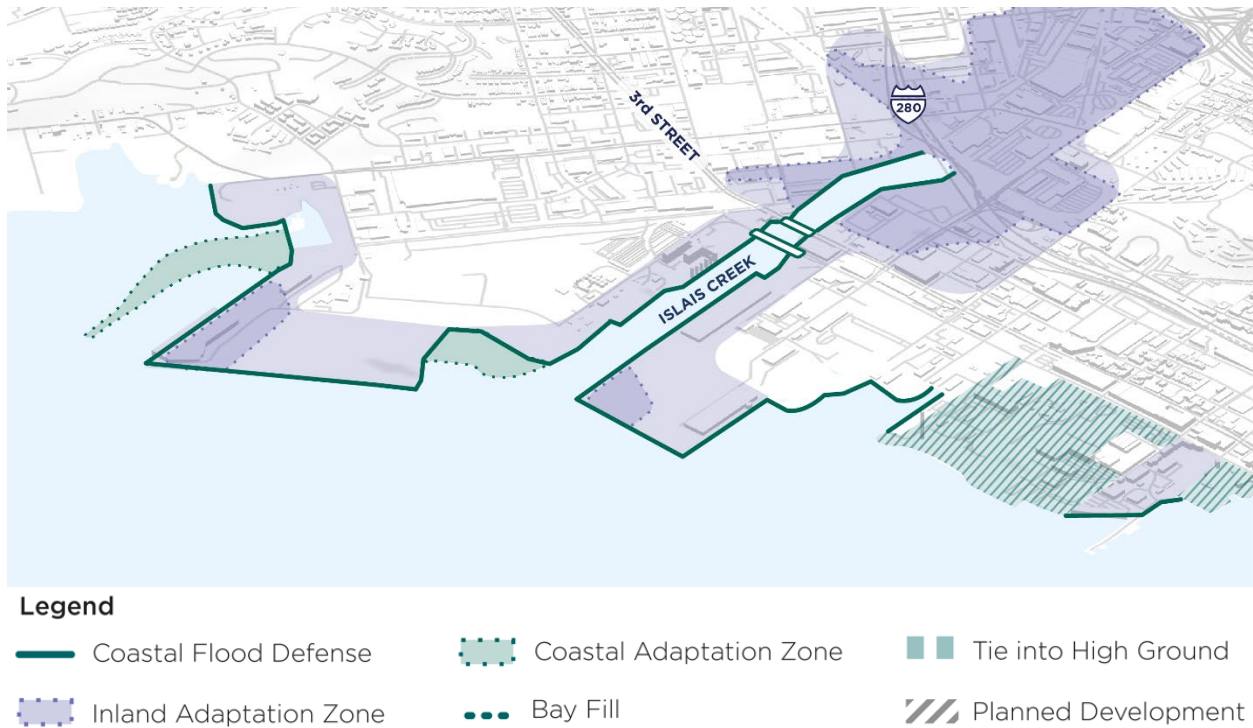


**Figure A-18: Alternative D, Islais Creek/Bayview (Reach 4) Subsequent Actions**

## 11.5 Alternative E: Defend Existing Shoreline, Scaled for Higher Risk

Alternative E is designed to adapt the shoreline to withstand 3.5 feet of RSLC above a 2000 baseline, with the possibility of building higher (up to an additional 3.5 feet of RSLC) closer to around 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 City RSLC guidance. The design crest elevation 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 transportation facilities, emergency services, and other important city features.

Foundations are constructed to achieve the seismic performance requirements so 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.

### 11.5.1 Subsequent Adaptations to Alternative E

The First Actions structures are adaptable to perform under higher water levels as sea levels continue to rise. The Subsequent Actions 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 bridge over Mission Creek and the Illinois Street Bridge over Islais Creek would be raised with regrading of the vehicular and rail approaches to accommodate higher water levels while maintaining transportation connections across the creek.

The features of Alternative E by reach for both the First Actions construction and the Subsequent Actions are described in this section. **Figure A-19** shows the alignment of the LOD.

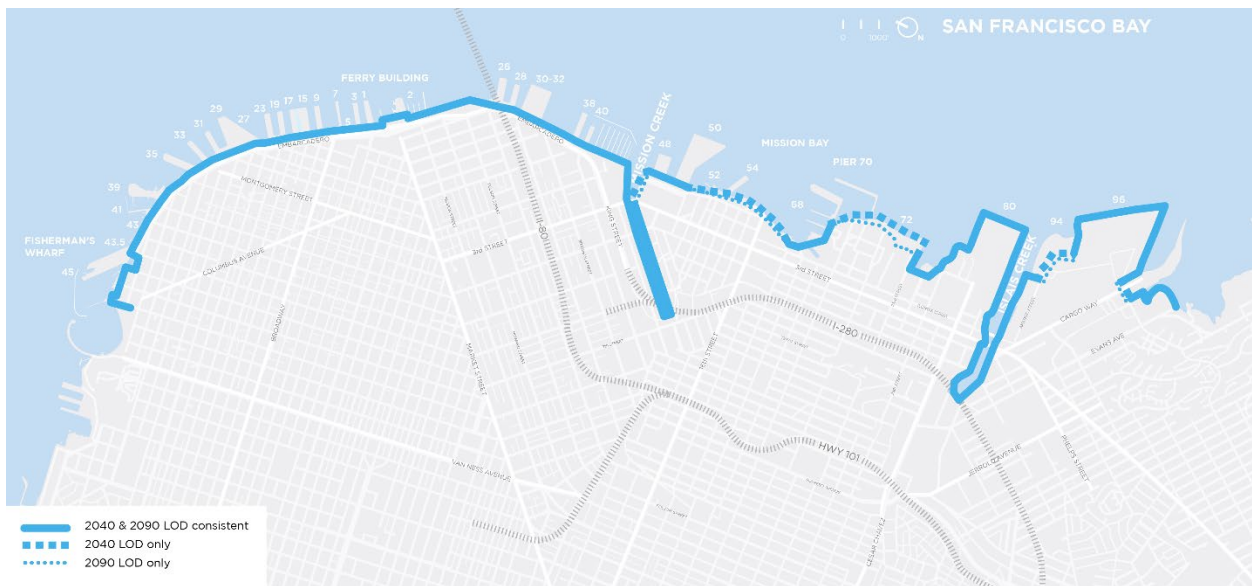


**Figure A-19: Alternative E**

### 11.5.2 Embarcadero (Reaches 1 and 2)

In the Embarcadero geography, Alternative E raises the shoreline using a bayward extension, aligning the new seawall approximately 20 feet bayward of the existing seawall. The extended shoreline includes a new integrated bulkhead wall and wharf. Maintaining a wharf width of approximately 45 feet, the bulkhead buildings and wharf would be shifted bayward, reducing the overall length of the finger piers and historic sheds. To facilitate construction of this extended shoreline, a portion of each existing pier would be demolished during construction and rebuilt.

Alternative E would include the following First Actions (**Figure A-20**):

- Extend the shoreline approximately 20 feet bayward of the existing seawall and elevate by 4 to 6 feet using raised and rebuilt bulkhead walls and wharves, and a levee along Hyde Street, to defend against 3.5 feet of RSLC.
- Perform ground improvement to meet seismic design requirements of ER1110-2-1806 for the coastal flood defense structures.
- Construct a 2-foot-tall concrete curb around the perimeter of piers, from Pier 47 to Pier 24.
- Add a modest amount of new Bay fill along Jefferson Street adjacent to the Inner Harbor between Jones and Taylor streets.
- Reconstruct the northbound lanes and San Francisco Municipal Railway (Muni) light rail trackway along the Embarcadero roadway, including a generous Embarcadero promenade and two-way bike lane for multimodal use and recreation.
- Incorporate NNBFs into the bulkhead wall shoreline with textured vertical surfaces (living seawall) that serve a coastal and combined flood risk management function by influencing wave runup, while also providing ecological functions.
- Elevate buildings (less than 20), including the Ferry Building and bulkhead buildings.
- Consider demolition of some buildings overlapping or adjacent to the construction area north of Jefferson Street and between Taylor and Hyde streets (less than 20) based on factors, such as age, condition, ground floor elevation, and historic status.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and others on changes to the combined sewer system, new pumps, green infrastructure, other resilient building and street design opportunities, and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

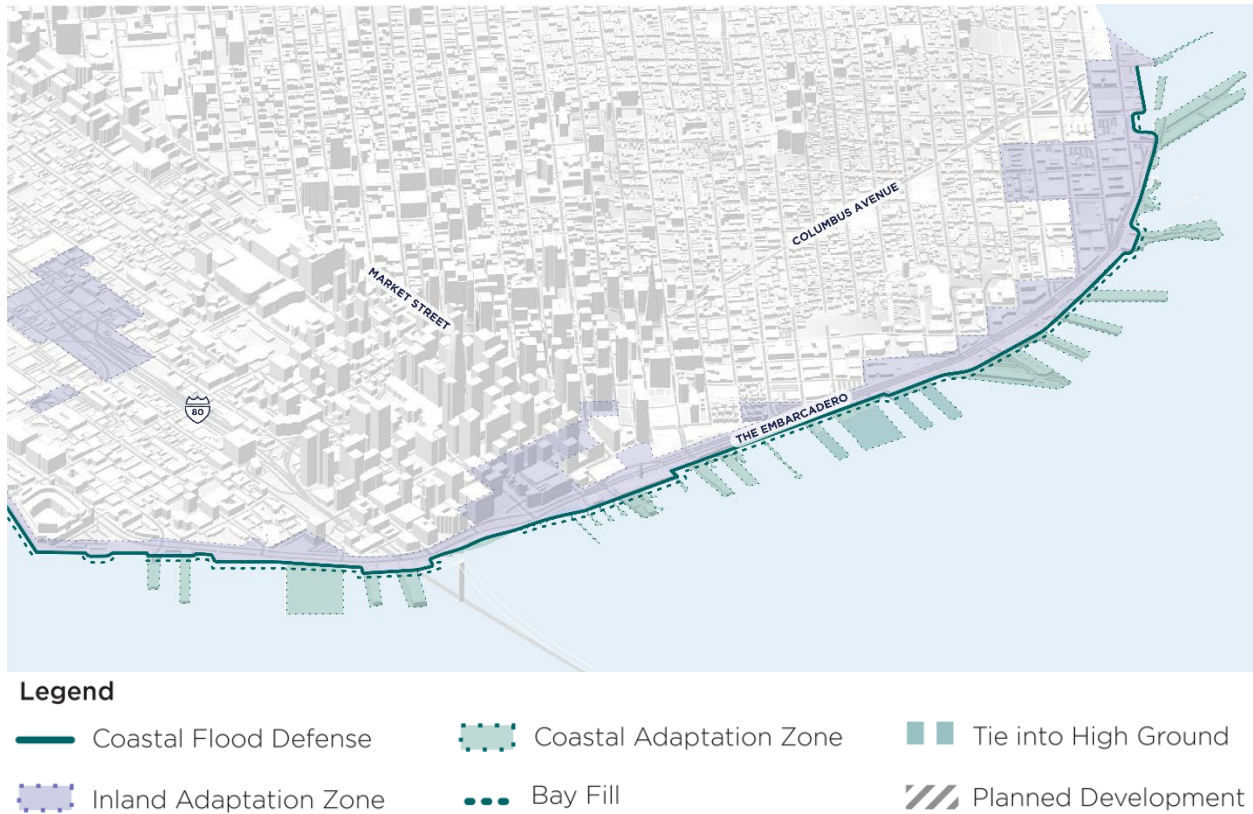


**Figure A-20: Alternative E, Embarcadero (Reaches 1 and 2) First Actions**

Alternative E would include the following Subsequent Actions (**Figure A-21**):

- Raise the shoreline by 3.5 feet by adding additional height to bulkhead walls and levee crests.
- At Rincon Park, extend the shoreline approximately 70 feet into the Bay; and raise the shoreline to defend against 7 feet of RSLC, while minimizing additional impact to the Embarcadero roadway. Includes construction of a new seawall, substantial Bay fill, and ground improvement.
- Raise and rebuild wharves at a higher elevation at the end of their assumed 50-year design life.



**Figure A-21: Alternative E, Embarcadero (Reaches 1 and 2) Subsequent Actions**

### 11.5.3 Mission Creek/Mission Bay (Reach 3)

In the Mission Creek/Mission Bay geography, Alternative E defends existing City and community assets in place by elevating the creek shoreline with a levee, extending parts of the cove and Bay shoreline bayward, installing deployable closure structures, and later raising bridges and tying into existing or planned high ground. This alternative requires some new Bay fill to balance impacts to the roadway along Terry Francois Boulevard while maintaining the necessary amount of space required to achieve the flood defense elevation.

Alternative E would include the following First Actions (**Figure A-22**):

- Elevate the Bay and creek shorelines by 3 to 6 feet using a combination of levees and raised bulkhead walls and wharves to defend against 3.5 feet of RSLC.
- Perform ground improvement to meet seismic design requirements of ER1110-2-1806 for the coastal flood defense structures.
- Construct a 2-foot-tall concrete curb around the perimeter of piers from Pier 26 to Pier 50.

- Install deployable closure structures at the northern and southern abutments of 3rd and 4th Street bridges over the creek to defend landward buildings and infrastructure from flood damage in the event of a coastal storm.
- Modify Terry Francois Boulevard to lose one lane of parking, but retain its current capacity as a roadway.
- Add a modest amount of new Bay fill along the Bay edge at Terry Francois Boulevard and the northern bank of Mission Creek at McCovey Cove.
- Tie measures into existing high ground and planned development projects at Mission Rock, Bayfront Park, Agua Vista Park, Crane Cove Park, and Pier 70.
- Incorporate NNBFs along South Beach, the banks of Mission Creek, and the Mission Bay shoreline, including features that serve a coastal and combined flood risk management function by influencing wave runup, while also enhancing public access and wildlife habitat.
- Elevate buildings (less than 10) including bulkhead buildings and other buildings adjacent to the coastal flood defense structure.
- Consider demolition of some buildings (less than five), such as the South Beach Harbor building and buildings bayside of the defenses at Piers 68-70, based on factors, such as age, condition, ground floor elevation, and historic status.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and others on changes to the combined sewer system, new pumps, green infrastructure, and other resilient building and street design opportunities and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

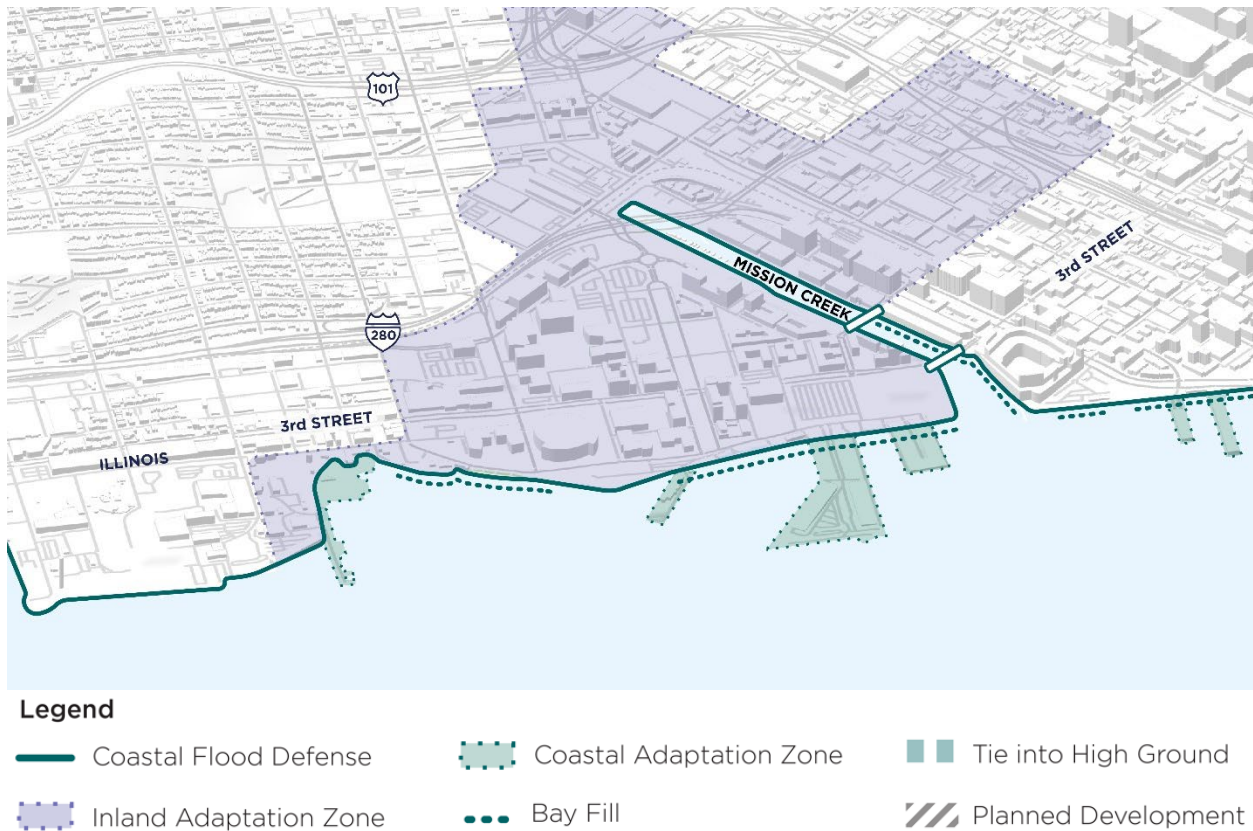


**Figure A-22: Alternative E, Mission Creek/Mission Bay (Reach 3) First Actions**

Alternative E would include the following Subsequent Actions (**Figure A-23**):

- Raise the shoreline by 3.5 feet by extending the landward footprint and height of levees, adding height to bulkhead walls, and reconstructing wharves at a higher elevation at the end of their assumed 50-year design life.
- Raise 3rd and 4th Street bridges, and regrade approaches, which will impact main arterial roadways and intersecting roadways also.

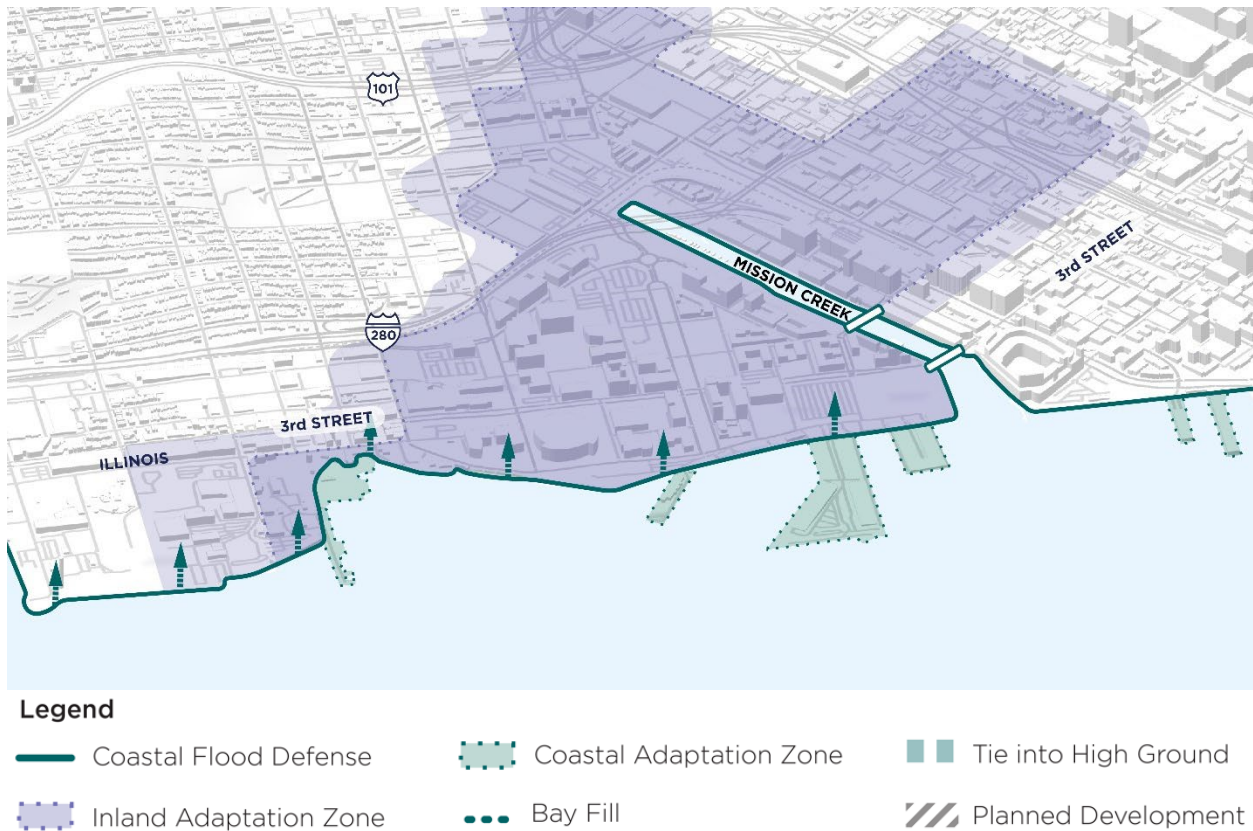


**Figure A-23: Alternative E, Mission Creek/Mission Bay (Reach 3) Subsequent Actions**

#### 11.5.4 Islais Creek/Bayview (Reach 4)

In the Islais Creek/Bayview geography, Alternative E 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 levees and bulkhead walls, raising and rebuilding marginal wharves, using deployable closure structures, and tying into high ground where it exists today south of Pier 70 and behind the Pier 94 wetlands. 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. The 3<sup>rd</sup> Street bridge is currently being redesigned to defend against several feet of RSLC.

Alternative E would include the following First Actions (**Figure A-24**):

- Elevate the Bay and creek shorelines by 4 to 6 feet using a combination of levees, raised bulkhead walls, and wharves to defend against 3.5 feet of RSLC.
- Perform ground improvement to meet seismic design requirements of ER1110-2-1806 for the coastal flood defense structures.

- Install deployable closure structures at the northern and southern abutments of Illinois Street Bridge over the creek to defend landward buildings and infrastructure from flood damage in the event of a coastal storm.
- Incorporate NNBFs into the shoreline along the banks of Islais Creek, Warm Water Cove, and the Pier 94 wetlands with features that serve a coastal and combined flood risk management function by breaking and attenuating waves, while also enhancing public access and wildlife habitat.
- Do not consider additional adaptations for existing habitat areas, including Heron's Head Park, beyond what is already planned under FWOP conditions.
- Consider demolition of some buildings (less than 10) that overlap the coastal flood defense alignment based on factors, such as age, condition, ground floor elevation, and historic status.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and others on changes to the combined sewer system, new pumps, green infrastructure, other resilient building and street design opportunities, and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

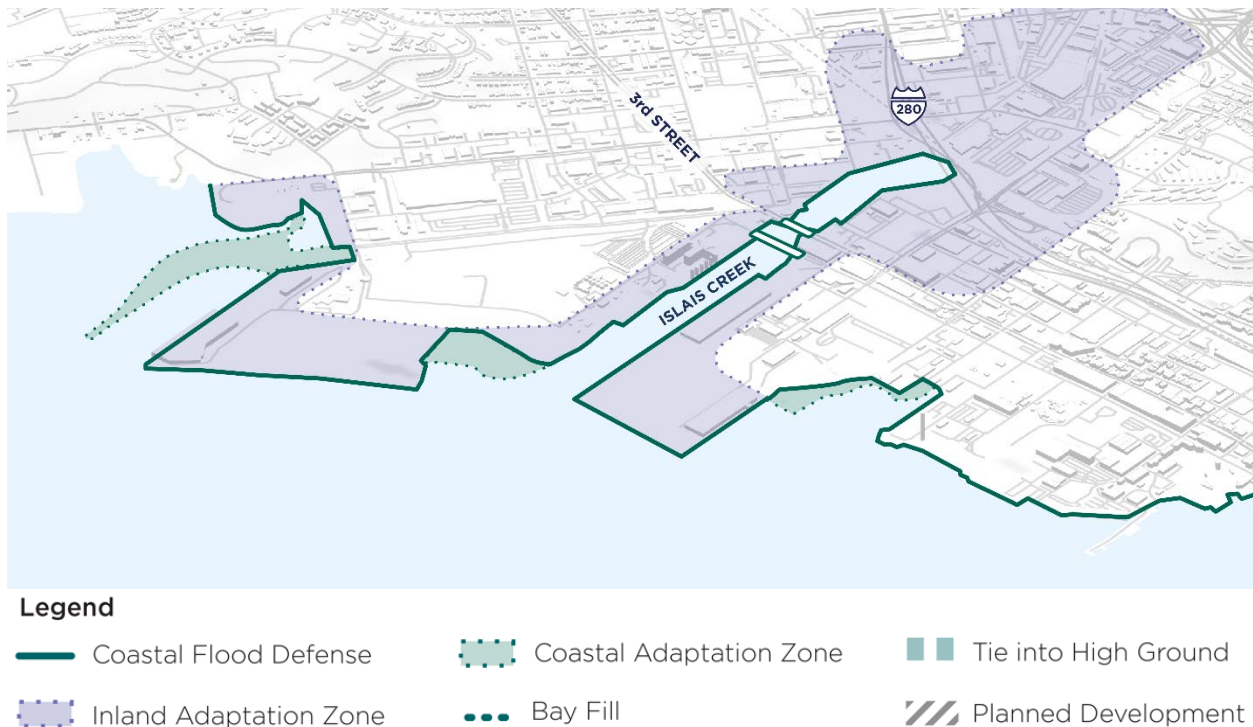


**Figure A-24: Alternative E, Islais Creek/Bayview (Reach 4) First Actions**

Alternative E would include the following Subsequent Actions (**Figure A-25**):

- Raise the shoreline protections by 3.5 feet by extending the landward footprint and height of levees and by reconstructing wharves at a higher elevation at the end of their assumed 50-year design life.
- Raise Illinois Street Bridge, and regrade approaches, likely resulting in the loss of freight rail access to Pier 80.
- Protect existing maritime backlands and deep draft berthing, including buildings and infrastructure that support POSF and City operations and jobs.
- If needed (depending on final design of the 3rd Street bridge), raise the 3rd Street bridge to withstand up to 7 feet of RSLC. *For this analysis, Alternative E assumes that 3rd Street bridge is not raised again within the study period.*

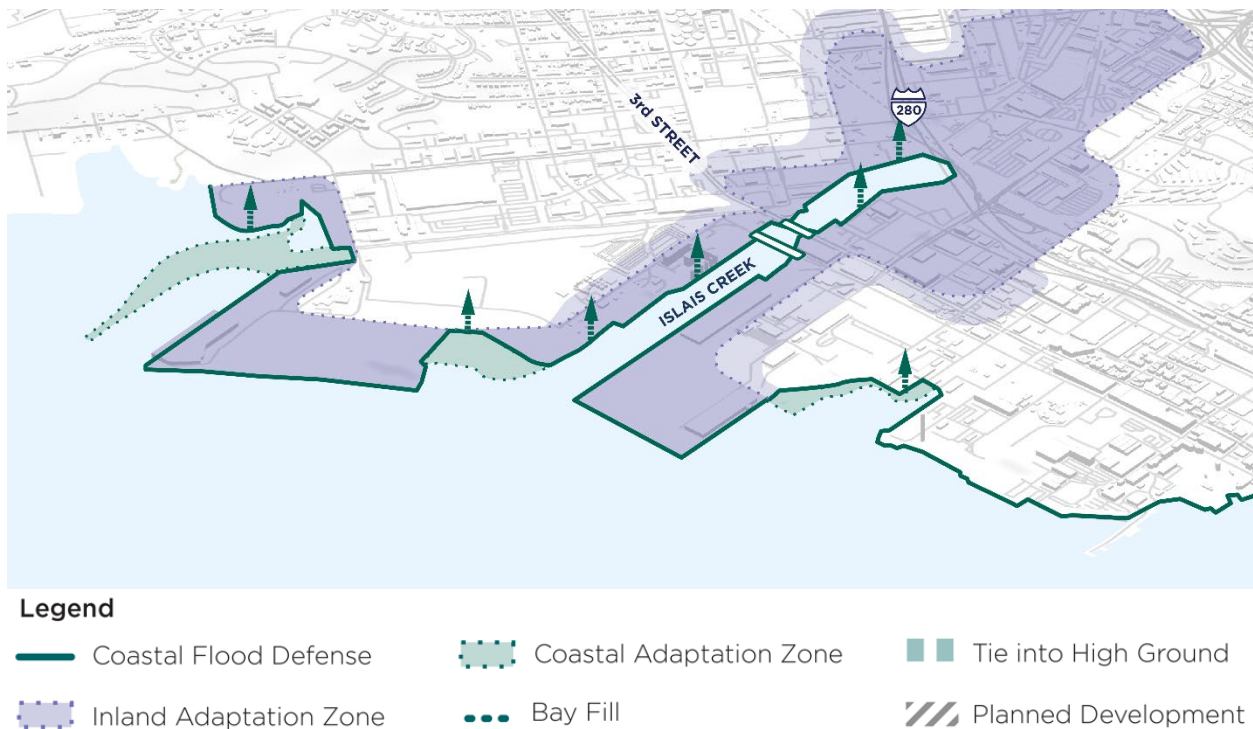


**Figure A-25: Alternative E, Islais Creek/Bayview (Reach 4) Subsequent Actions**

## 11.6 Alternative F: Manage the Water, Scaled for Higher Risk

Alternative F is designed to adapt the shoreline to withstand 3.5 feet of RSLC above a 2000 baseline, with the possibility of building higher (up to an additional 3.5 feet of RSLC) closer to around 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 City RSLC guidance. The design crest elevation for the First Actions 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 achieve the seismic performance requirements so 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.

#### **11.6.1 Subsequent Adaptations to Alternative F**

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.

The features of Alternative F by reach for both the First Actions construction and the Subsequent Actions adaptation are described in this section. **Figure A-26** shows the alignment of the LOD.

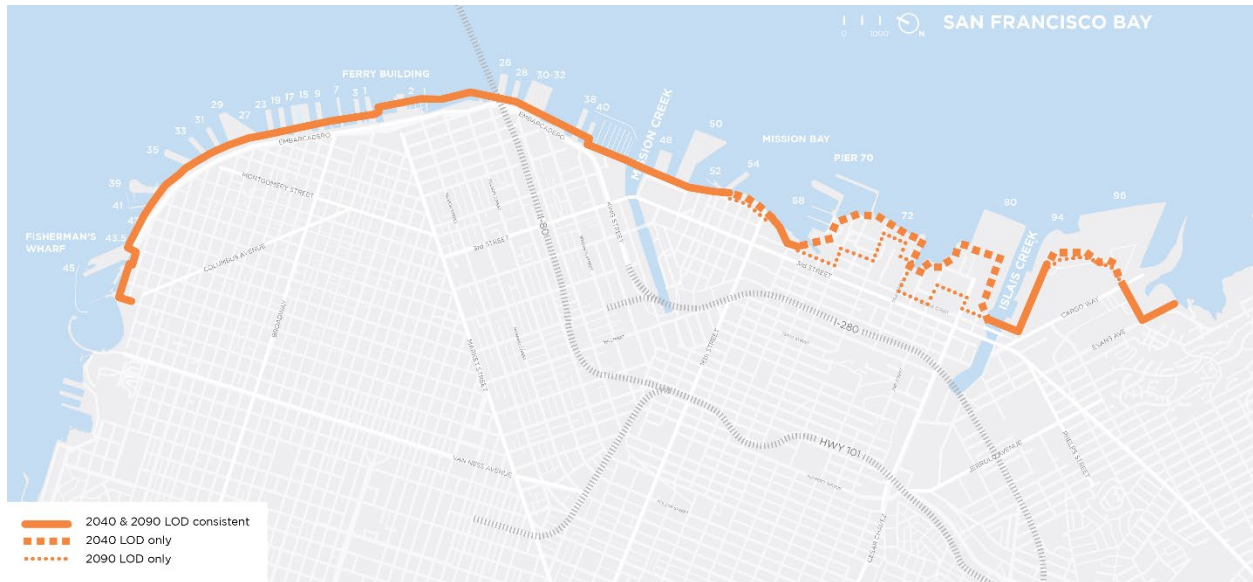


**Figure A-26: Alternative F**

### 11.6.2 Embarcadero (Reaches 1 and 2)

In the Embarcadero geography, Alternative F raises the shoreline with a combination of shoreline extension (beyond the existing wharf zone) and floodwalls. This alternative extends approximately 50 feet into the Bay and uses more fill than the other alternatives as a way to reduce impacts to the Embarcadero roadway.

In Reach 1, only the northbound lanes of the Embarcadero would be reconstructed, requiring less disruption during construction. However, the seismic ground improvement assumed in Reach 2 would require reconstruction of the light rail tracks and northbound lanes of the Embarcadero. When completed, Alternative F would retain the full existing corridor roadway width.

The bulkhead wharves throughout this waterfront would be replaced by a new, robust cantilever or tie-back wall used to retain solid fill. The bulkhead buildings would be reconstructed on top of the new fill, which would transition to the existing or new pile-supported wharves and shed buildings.

Alternative F would include the following First Actions (**Figure A-27**):

- Build a coastal flood defense system that elevates the shoreline by 2.5 to 7 feet to defend against 3.5 feet of RSLC. Extend the shoreline approximately 50 feet bayward along the Embarcadero roadway from Pier 35 to the Bay Bridge.
- Raise the shoreline bayward of the Ferry Building (approximately 300 feet bayward of existing), filling the area between the new offshore cantilever wall and existing bulkhead seawall. The Ferry Building would be kept in the existing location.

- Defend at the shoreline through Fisherman's Wharf by constructing 1.5- to 4.5-foot-tall T-walls along Wharves J9 and J10, Taylor Street, and Pier 45 to Pier 35.
- Construct a new bulkhead wall approximately 40 feet bayward of the existing seawall adjacent to the Inner Harbor along Jefferson Street between Jones and Taylor streets. Fill the space in between the existing and new seawall and raise the shoreline elevation by several feet to minimize transportation and public realm impacts.
- Perform ground improvement to meet seismic design requirements of ER1110-2-1806 for the coastal flood defense structures.
- Construct a 2-foot-tall concrete curb around the perimeter of piers, from Pier 47 to Pier 24.
- Reconstruct northbound lanes of the Embarcadero roadway to meet the promenade in Reach 1. Reconstruct northbound lanes and the railway in Reach 2. Southbound lanes are not impacted.
- Elevate buildings (less than 20), including bulkhead buildings, and maintain their horizontal location relative to the existing Embarcadero promenade and roadway, reconstructing them on top of solid fill, where applicable. Provide a transition from the bulkhead building at a new higher elevation to the pier at the existing lower elevation.
- Floodproof (less than 5), or consider demolition of (less than 10) buildings in Fisherman's Wharf north of Jefferson Street and west of Taylor Street, based on factors, such as age, condition, ground floor elevation, and historic status.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and others on changes to the combined sewer system, new pumps, green infrastructure, other resilient building and street design opportunities, and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

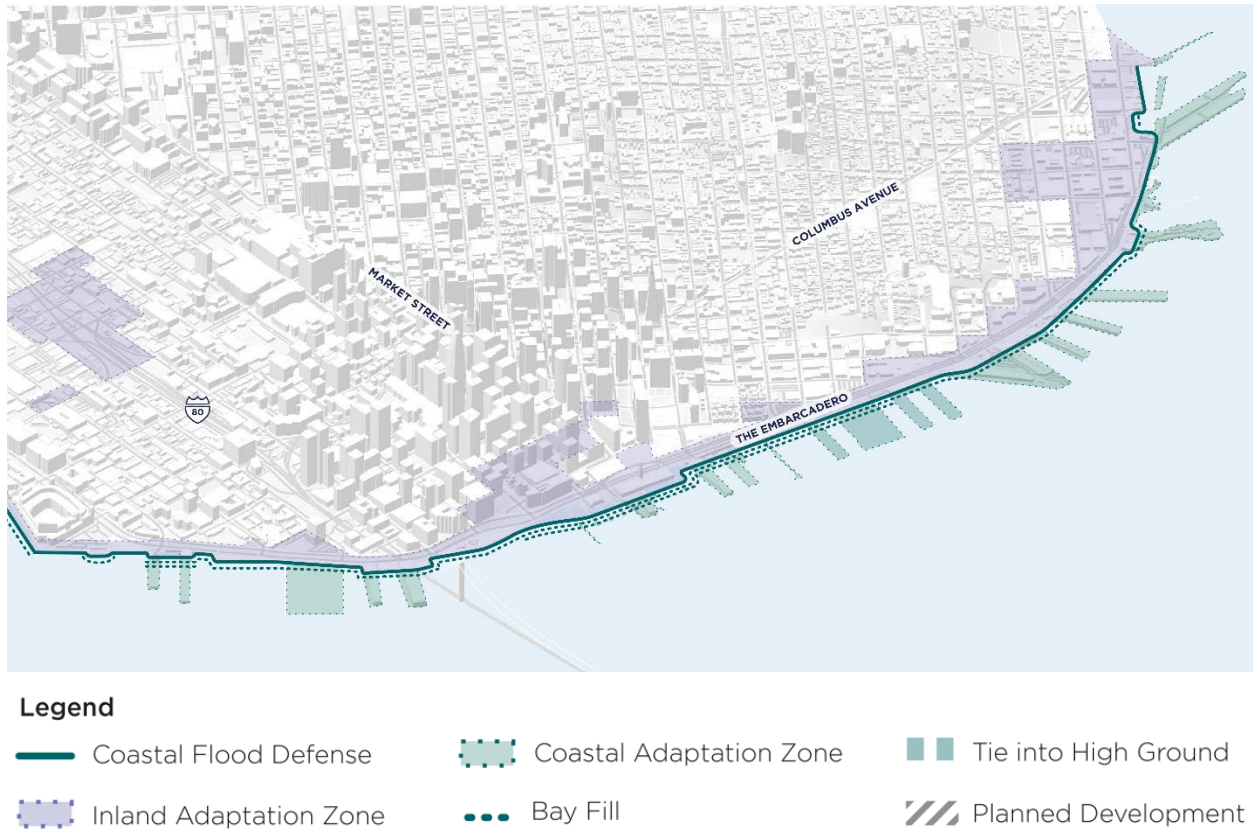


**Figure A-27: Alternative F, Embarcadero (Reaches 1 and 2) First Actions**

Alternative F would include the following Subsequent Actions (**Figure A-28**):

- Raise the shoreline by 3.5 feet to defend against 7 feet of RSLC by adding a 3.5-foot-tall wall on top of measures constructed in around 2040. This includes a vertical wall at the edge of the new shoreline extension between the current wharf and pier interface.
- Due to the height of the extended wall, add 3.5 feet of sloped fill behind the wall in several locations to improve public access along the shoreline edge.
- Consider demolition of additional buildings (less than five) in Fisherman's Wharf along Hyde and Taylor streets, based on factors, such as age, condition, ground floor elevation, and historic status.



**Figure A-28: Alternative F, Embarcadero (Reaches 1 and 2) Subsequent Actions**

### 11.6.3 Mission Creek/Mission Bay (Reach 3)

In the Mission Creek/Mission Bay geography, Alternative F includes construction of a tide gate across McCovey Cove at the mouth of Mission Creek, which reduces the risk of flooding along all of the creek's shoreline and eliminates the need to replace and elevate the two historic bridges solely due to RSLC. (The bridges may have to be rebuilt for other reasons within this time frame, such as age, condition, and seismic risk of the structures.)

At the northern end, the tide gate ties into a raised levee that slopes up to a new bulkhead wharf along the South Beach Harbor shoreline. To the south, the tide gate connects to a series of raised levees that tie into existing and planned high ground at Bayfront, Agua Vista, and Crane Cove Parks, and the Pier 70 development. Structures bayward of the LOD would be floodproofed.

Alternative F would include the following First Actions (**Figure A-29**):

- Elevate the Bay shoreline by 1.5 to 5.5 feet to defend against 3.5 feet of RSLC using a combination of levees, wharves, and a shoreline extension approximately 50 feet bayward along the Embarcadero roadway from the Bay Bridge to Pier 40.

- Perform ground improvement to meet seismic design requirements of ER1110-2-1806 for the coastal flood defense structures.
- Construct a 2-foot-tall concrete curb around the perimeter of piers, from Pier 26 to Pier 50.
- Construct a tide gate across Mission Creek with the crest elevation set to defend against up to 7 feet of RSLC. Design the gate so that it is adaptable to permanent closure around the 2090 time frame, thereby creating a non-tidal freshwater lagoon managed by pumps. Until around 2090, it is expected that during typical Bay conditions (i.e., no high-water events), the creek will remain open and tidal. During high-water or storm events, the tide gate would be closed at low tide to reduce coastal flooding and create storage for precipitation at peak runoff. The bridges and western portion of the creek shoreline do not need to be raised with the tide gate east of 3rd Street defending against high coastal water levels.
- Redesign for a slightly narrower Terry Francois Boulevard (approximately 93 feet) to limit the need for Bay fill to achieve the 15.5-foot crest elevation of the shoreline levee. Incorporate NNBs where appropriate.
- Tie measures into existing high ground and planned development projects at Mission Rock, Bayfront Park, Agua Vista Park, Crane Cove Park, and Pier 70.
- Elevate bulkhead buildings (less than five) and maintain their location relative to the existing Embarcadero promenade and roadway, reconstructing them on top of solid fill, where applicable. Provide transition from the bulkhead building at a new higher elevation to the pier at the existing lower elevation.
- Floodproof (less than 10) or consider demolition of (less than 5) buildings bayside of the coastal flood defense, based on factors, such as age, condition, ground floor elevation, and historic status.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and others on changes to the combined sewer system, new pumps, green infrastructure, other resilient building and street design opportunities, and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

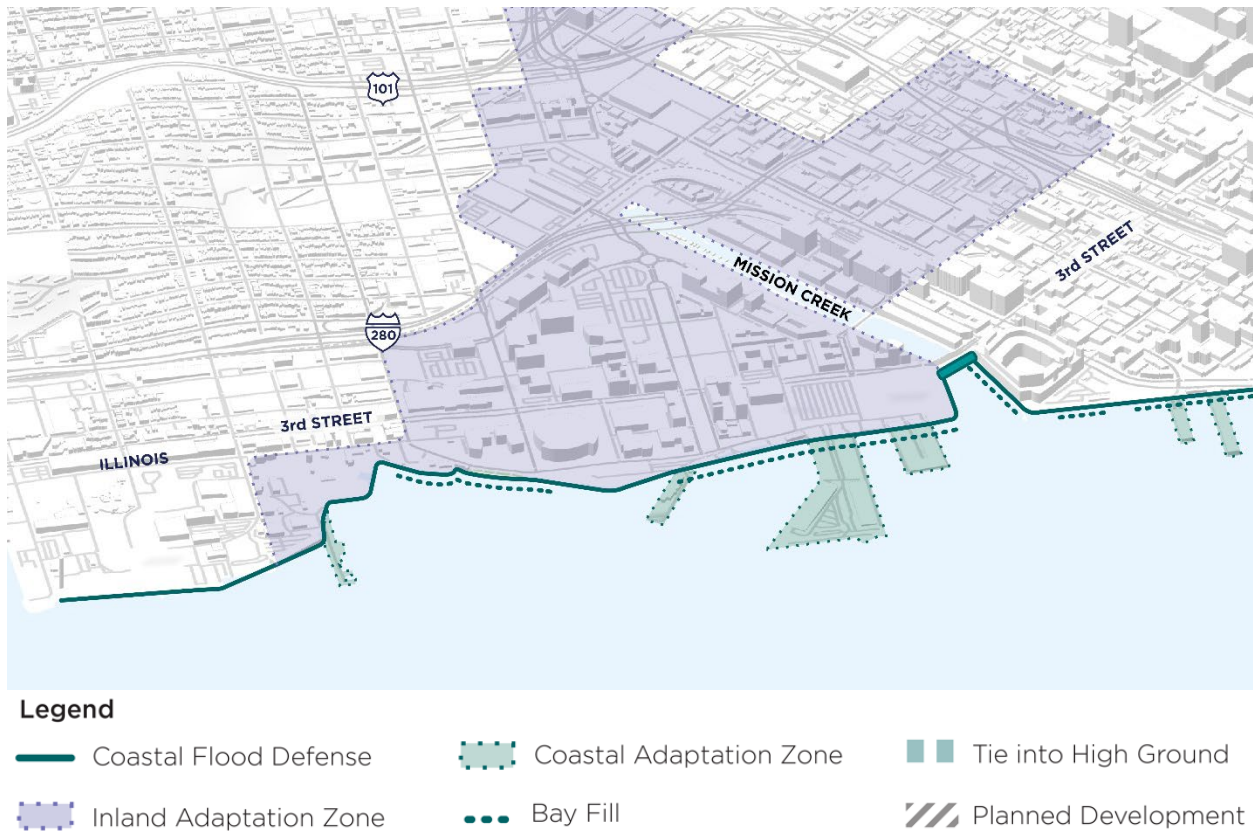


**Figure A-29: Alternative F, Mission Creek/Mission Bay (Reach 3) First Actions**

Alternative F would include the following Subsequent Actions (**Figure A-30**):

- Raise the coastal flood defense an additional 3.5 feet by extending the landward footprint and height of levees and adding additional height to wharves along the Bay to defend against 7 feet of RSLC.
- Convert the tide gate to a permanently closed hydraulic control structure to actively manage water levels in Mission Creek lagoon. The non-tidal, freshwater lagoon will require continual active management to achieve excess storage functionality and flushing for water quality purposes.
- Incorporate NNBFs into the shoreline along Crane Cove Park with features that serve a coastal and combined flood risk management function by breaking and attenuating waves, while also enhancing public access and wildlife habitat.
- Consider demolition of (less than 20) buildings bayside of the coastal flood defense, based on factors, such as age, condition, ground floor elevation, and historic status.
- Build additional infrastructure to manage stormwater and reduce inland flood risk exacerbated by the coastal flood defense structures.

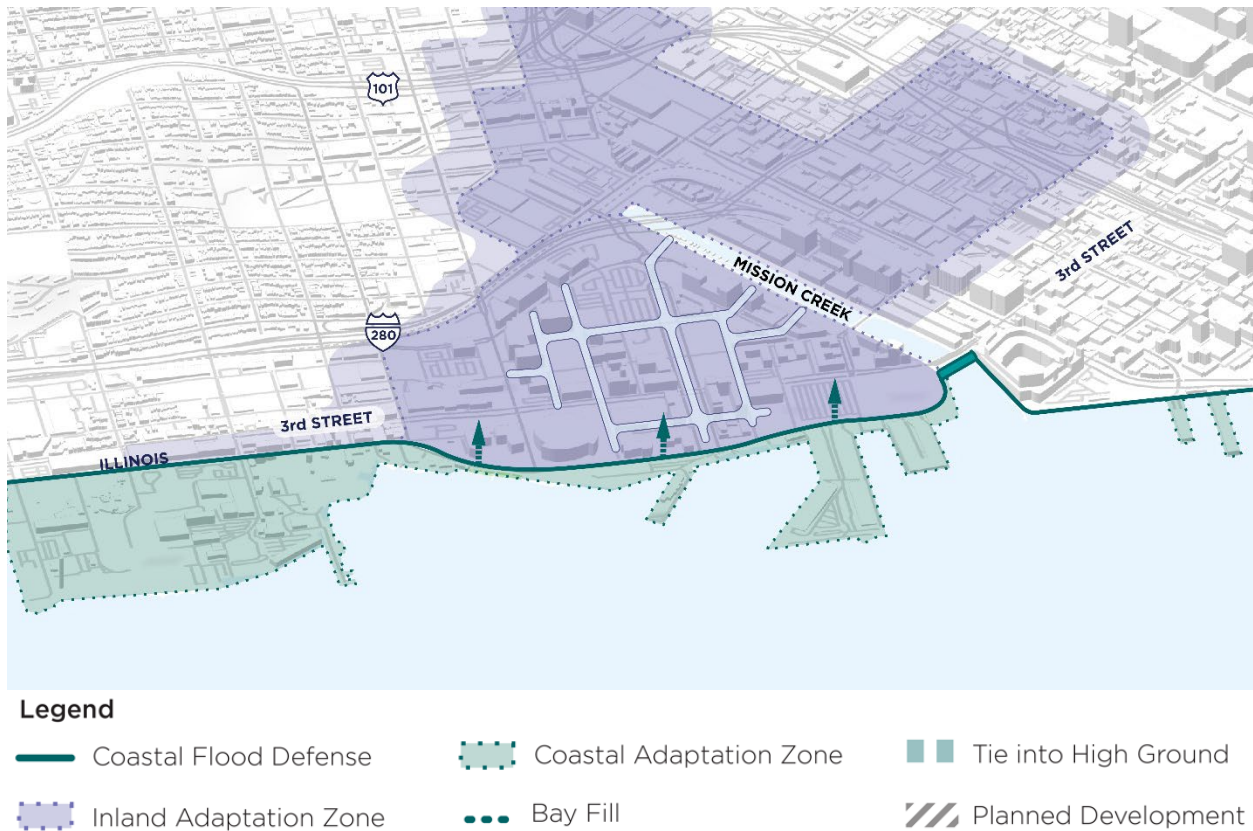


**Figure A-30: Alternative F, Mission Creek/Mission Bay (Reach 3) Subsequent Actions**

#### 11.6.4 Islais Creek/Bayview (Reach 4)

In the Islais Creek/Bayview geography, Alternative F includes the construction of a tide gate in the creek channel east of the 3rd Street and Illinois Street bridges, which reduces the risk of flooding along much of the creek shoreline and eliminates the need to replace and elevate the bridges solely due to RSLC. (The bridges may have to be rebuilt for other reasons within this time frame, such as age, condition, and seismic risk of the structures.) The 3rd Street bridge is currently being redesigned to defend against several feet of RSLC (FWOP condition).

The tide gate forms a central link in the LOD for this geography, other portions of which include levees, a raised roadway (Amador Street), a short segment of floodwall, and existing high ground. Maritime and industrial working lands bayward of this primary LOD will be floodproofed in the 2040 time frame and retreated from around the 2090 time frame.

Alternative F would include the following First Actions (**Figure A-31**):

- Elevate the Bay shoreline by 2.5 to 7.5 feet with levees, walls, and raised roadways to defend against 3.5 feet of RSLC.
- Perform ground improvement to meet seismic design requirements of ER1110-2-1806 for the coastal flood defense structures.
- Construct a tide gate across Islais Creek with the crest elevation set to defend against up to 7 feet of RSLC. Design the gate so that it is adaptable to permanent closure around the 2090 time frame, creating a non-tidal freshwater lagoon managed by pumps. Until around 2090, it is expected that during typical Bay conditions (i.e., no high-water events), the creek will remain open and tidal. During high-water or storm events, the tide gate would be closed at low tide to reduce coastal flooding and create storage for precipitation at peak runoff. The bridges and western portion of the creek shoreline do not need to be raised with tide gate east of Illinois Street defending against high coastal water levels.
- Incorporate NNBFs into the shoreline with features that serve a coastal and combined flood risk management function by breaking and attenuating waves, while also enhancing public access and wildlife habitat.
- Do not consider additional adaptations for existing habitat areas, including Heron's Head Park, beyond what is already planned under FWOP conditions (Main Report Section 2.0).
- Floodproof buildings (less than 15) and equipment among the POSF working lands to protect maritime and industrial operations bayward of the LOD. Buildings and infrastructure would be kept in place, including POSF operations and jobs.
- Build infrastructure to manage stormwater flows impacted by the plan. Coordinate with SFPUC, San Francisco Public Works, and others on changes to the combined sewer system, new pumps, green infrastructure, and other resilient building and street design opportunities and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

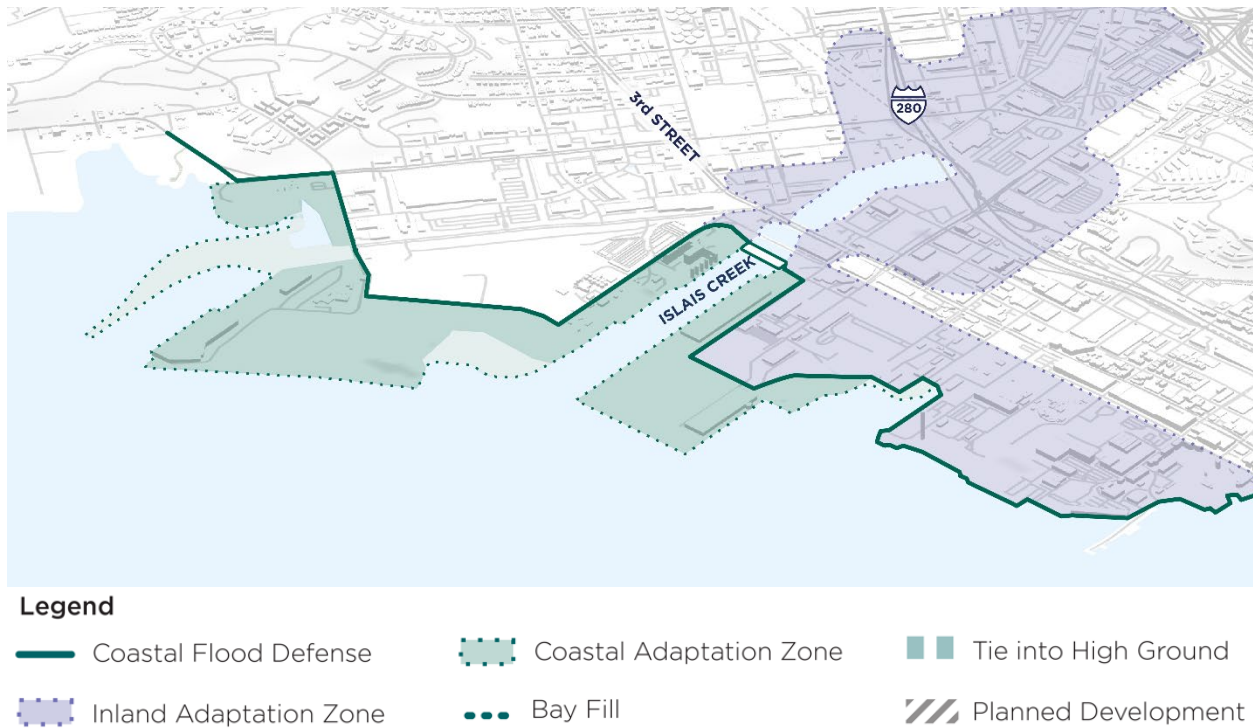


**Figure A-31: Alternative F, Islais Creek/Bayview (Reach 4) First Actions**

Alternative F would include the following Subsequent Actions (**Figure A-32**):

- Convert the tide gate to a permanently closed hydraulic control structure to actively manage water levels in Islais Creek lagoon. The non-tidal, freshwater lagoon will require continual active management to achieve excess storage functionality and flushing for water quality purposes.
- Raise coastal and combined flood risk management structures south of Islais Creek by 3.5 feet by extending the bayward footprint and height of levees and adding additional height to walls to defend against 7 feet of RSLC.
- North of the creek, construct a new levee east of Illinois Street that ties into the water management structure (former tide gate) to the south and high ground to the north between 24<sup>th</sup> and 25<sup>th</sup> streets. This would require removal of existing buildings (less than 15) bayward of Illinois Street.
- Retreat existing POSF maritime and industrial working lands at Piers 80, 90-92, and 94-96, including demolition of buildings (less than 10), de-paving of concrete and asphalt surfaces, as well as restoration and regrading to floodable space. Floodable space may provide recreation and improved habitat in vacated areas.
- Maintain, enhance, or expand NNBFs.
- Build additional infrastructure to manage stormwater and reduce inland flood risk exacerbated by the coastal flood defense structures.

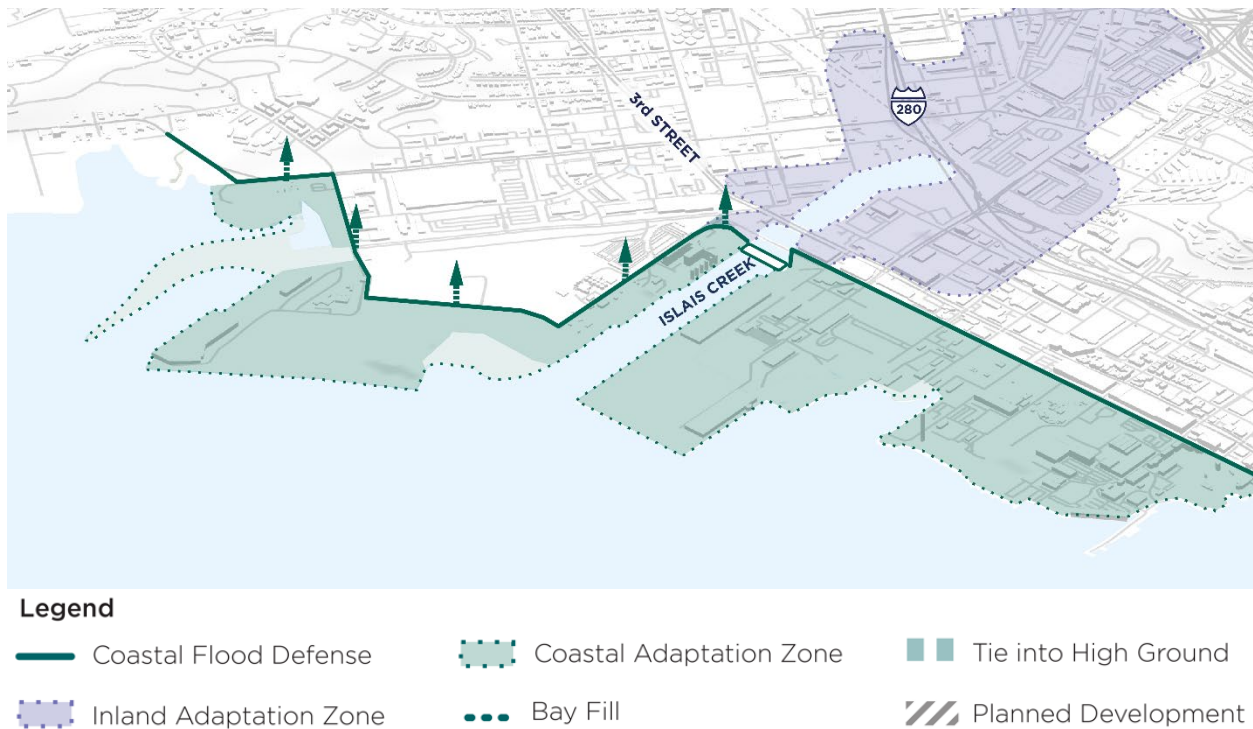


**Figure A-32: Alternative F, Islais Creek/Bayview (Reach 4) Subsequent Actions**

## 11.7 Alternative G: Partial Retreat, Scaled for Higher Risk

Alternative G is designed to adapt the shoreline to withstand 3.5 feet of RSLC above a 2000 baseline, 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 LOD. Alternative G addresses higher rates of RSLC, consistent with the USACE High RSLC curve and is consistent with State of California and City RSLC guidance. The design crest elevation for the First Actions 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 bridge over Mission Creek and the Illinois Street Bridge over Islais Creek would be raised with regrading of the vehicular 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 achieve the seismic performance requirements so 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.

#### **11.7.1 Subsequent Adaptations to Alternative G**

Many of the 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 Actions include increasing the elevation of some of the 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 Actions 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 compared to 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.

The features of Alternative G by reach for both the First Actions construction and the Subsequent Actions adaptation are described in this section. **Figure A-33** shows the alignment of the LOD.

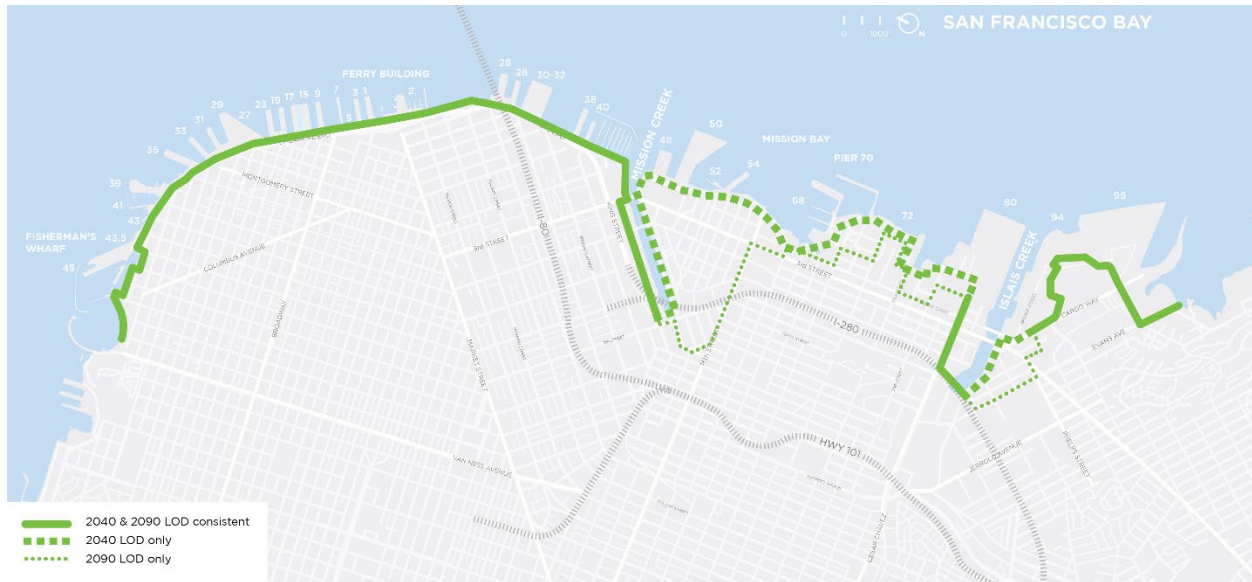


**Figure A-33: Alternative G**

### 11.7.2 Embarcadero (Reaches 1 and 2)

In the Embarcadero geography, Alternative G elevates the shoreline in place and reconfigures the Embarcadero roadway. It would require reconstruction and redesign of the full width of the Embarcadero roadway. Available space for the roadway would be reduced to gradually transition to the new elevation and retain visual and physical access to the waterfront.

The wharves throughout the waterfront would be rebuilt at a higher elevation. The Ferry Building and bulkhead buildings throughout this area would be raised to sit on top of the new wharves. Raising the shoreline in place requires reconstruction of the full Embarcadero roadway and results in a reduction of overall roadway width. Design of the mobility corridor and specific use of the available space will be done during the later design phase.

Alternative G would include the following First Actions (**Figure A-34**):

- Construct a new bulkhead seawall landward of the existing wall that allows the shoreline to be raised by 5 to 9.5 feet to defend against 5 feet of RSLC between Pier 35 and the Bay Bridge. This additional elevation, which is greater than under Alternatives E and F, is intended to buy additional time before a future intervention is needed; however, this assumption is expected to be re-evaluated as part of the implementation planning after the Recommended Plan.
- Defend at the shoreline through Fisherman's Wharf by constructing 1.5- to 4.5-foot-tall floodwalls along Wharves J9 and J10, Jefferson Street, Taylor Street, and Pier 45 to Pier 35.

- Perform ground improvement to meet seismic design requirements of ER1110-2-1806 for the coastal flood defense structures.
- Construct a 2-foot-tall concrete curb around the perimeter of piers, from Pier 47 to Pier 24.
- Replace existing wharves with new ductile concrete wharves with deck elevations to match the top of the new bulkhead seawall.
- Elevate buildings (less than 20), including the Ferry Building and bulkhead buildings, at existing locations. Provide a transition from the bulkhead building at a new higher elevation to the pier at the existing lower elevation.
- Floodproof the Dolphin Club and consider demolition of buildings (less than 10) along Hyde Street, Jones Street, and Taylor Street north of Jefferson Street, based on age, condition, ground floor elevation, and historic status.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and others on changes to the combined sewer system, new pumps, green infrastructure, and other resilient building and street design opportunities and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.



**Legend**

- |                        |                         |                      |
|------------------------|-------------------------|----------------------|
| Coastal Flood Defense  | Coastal Adaptation Zone | Tie into High Ground |
| Inland Adaptation Zone | Bay Fill                | Planned Development  |

**Figure A-34: Alternative G, Embarcadero (Reaches 1 and 2) First Actions**

Alternative G would accomplish the following Subsequent Actions (**Figure A-35**):

- Elevate the shoreline to defend against 7 feet of RSLC by adding a 2-foot-high wall on top of the 2040 bulkhead wall between Piers 35 and 24.
- Raise the height of 2040 floodwalls in Fisherman's Wharf by an additional 3.5 feet to defend against 7 feet of RSLC. Consider inclusion of sloped fill behind the T-wall to decrease the exposed vertical height of the wall from the landside and provide a transition from existing city grade to the new shoreline elevation.



**Figure A-35: Alternative G, Embarcadero (Reaches 1 and 2) Subsequent Actions**

### 11.7.3 Mission Creek/Mission Bay (Reach 3)

In the Mission Creek/Mission Bay geography, Alternative G presents a transformative concept for this geography and restores a large portion of the Mission Bay neighborhood to its previous condition as a wetland and open water body. In the near-term, a combination of floodwalls and levees would form a coastal defense along the shoreline of the Bay and creeks. This defense buys time for a managed retreat of the Mission Bay neighborhood that would include land use changes, acquisition of properties, demolition of some structures, and restoration of this space to natural wetland.

At the landward boundary of the retreat area, a combination of floodwalls and levees tie into high ground to form a new coastal LOD that limits the extent of the area for future retreat and defends landward infrastructure from coastal flooding.

This alternative was originally developed with a vision of Mission Bay transforming gradually into a designated floodable district, a bold response to the area's overlapping coastal and inland flood risks alongside seismic risk and subsidence. In this vision, walking and biking paths are elevated, and buildings are floodproofed and accessible by the elevated paths. Creative solutions could be implemented to maintain or improve transportation services, utilities, health facilities, and important cultural assets within the district. Former streets and open areas could be converted to floodable nature-based features. However, due to study limitations and challenges with the viability of this concept, the full scope of this vision is not included in the analysis. Instead, Alternative G assumes a gradual retreat of the Mission Bay neighborhood as part of the Subsequent Actions adaptations.

Alternative G would include the following First Actions (**Figure A-36**):

- From the Bay Bridge to South Beach Harbor, construct a new bulkhead seawall landward of the existing wall that allows the shoreline to be raised by 3 to 6 feet to defend against 5 feet of RSLC. This additional elevation compared to Alternatives E and F is intended to buy additional time before a future intervention is needed; however, this assumption is expected to be re-evaluated as part of the implementation planning after the Recommended Plan.
- Raise the Mission Bay shoreline, southern creek shoreline, and along Berry Street by 2.5 to 5.5 feet using a combination of levees and walls to defend against 3.5 feet of RSLC.
- Perform ground improvement to meet seismic design requirements of ER1110-2-1806 for the coastal flood defense structures.
- Construct a 2-foot-tall concrete curb around the perimeter of piers, from Pier 26 to Pier 50.
- Replace existing wharves with new ductile concrete wharves with a deck elevation to match the top of the new bulkhead seawall.
- Raise 3rd and 4th Street bridges over the creek by 6 feet, and regrade the approaches, creating a sloped embankment that requires modification to the light rail trackway and roadway corridor.
- Tie measures into existing high ground and planned development projects at Mission Rock, Bayfront Park, Agua Vista Park, Crane Cove Park, and Pier 70.
- Incorporate NNBFs into the shoreline along Mission Bay and the banks of Mission Creek that serve a coastal and combined flood risk management function by influencing wave runup, while also enhancing public access and wildlife habitat.

- Elevate bulkhead buildings (less than five) at existing locations. Provide a transition from the bulkhead building at a new higher elevation to the pier at the existing lower elevation.
- Floodproof buildings (less than 15) bayside of the LOD on the northern side of Mission Creek.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and others on changes to the combined sewer system, new pumps, green infrastructure, and other resilient building and street design opportunities and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

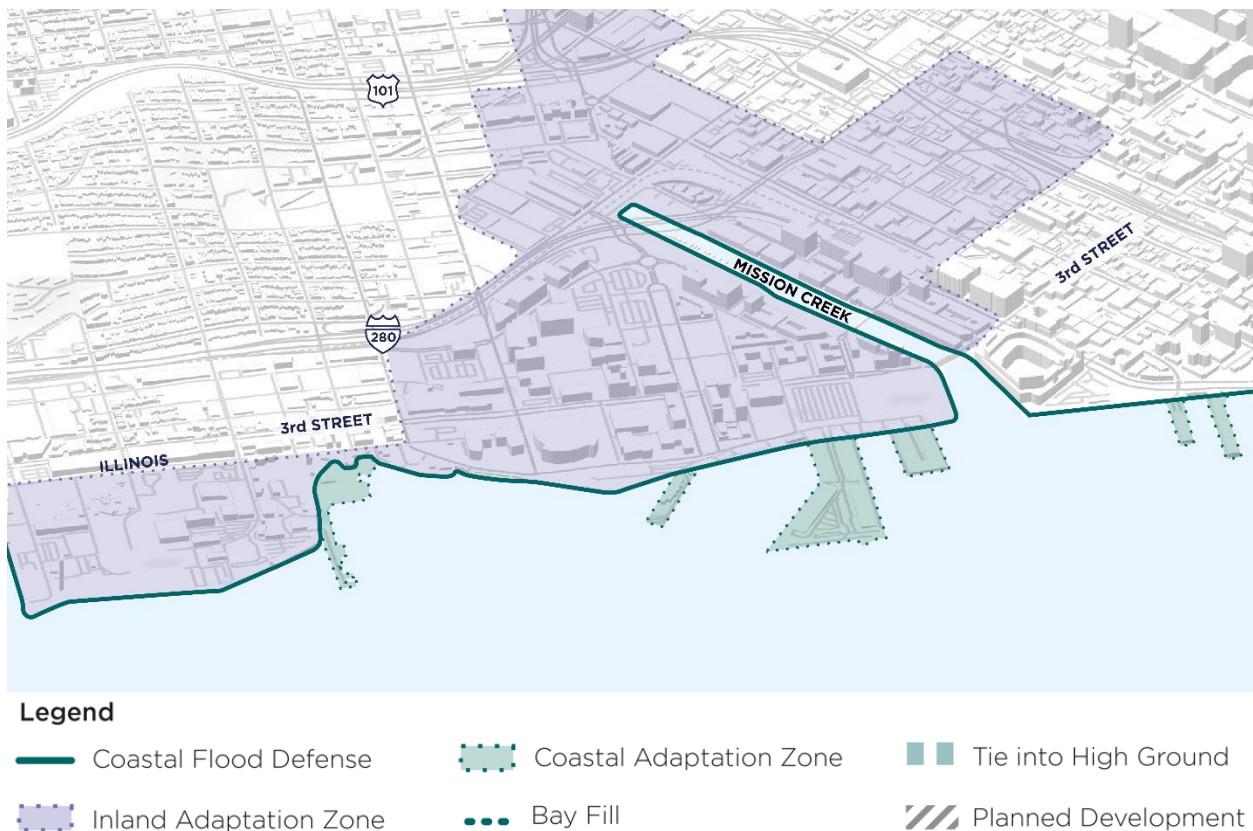


**Figure A-36: Alternative G, Mission Creek/Mission Bay (Reach 3) First Actions**

Alternative G would include the following Subsequent Actions (**Figure A-37**):

- From the Bay Bridge to South Beach Harbor, elevate the shoreline to defend against 7 feet of RSLC by adding a 2-foot-high wall on top of the 2040 bulkhead wall.
- Construct a new levee that raises the ground elevation by 4 to 9 feet along a landward alignment that generally follows King, Berry, 8<sup>th</sup>, and 16<sup>th</sup> streets. The

levee is designed to defend against up to 7 feet of RSLC. Deployable closure structures would be installed in the levee where the LOD crosses the Caltrain ROW.

- Retreat from buildings (more than 25) and infrastructure bayside of the LOD, including demolition and de-paving. This includes severing the light rail connection between the southern waterfront, Muni Metro East rail yard, and the downtown corridor. Additionally, the north-south vehicular arterial of 3<sup>rd</sup> Street would be eliminated between 16<sup>th</sup> and King streets.
- Build additional infrastructure to manage stormwater and reduce inland flood risk exacerbated by the coastal flood defense structures.

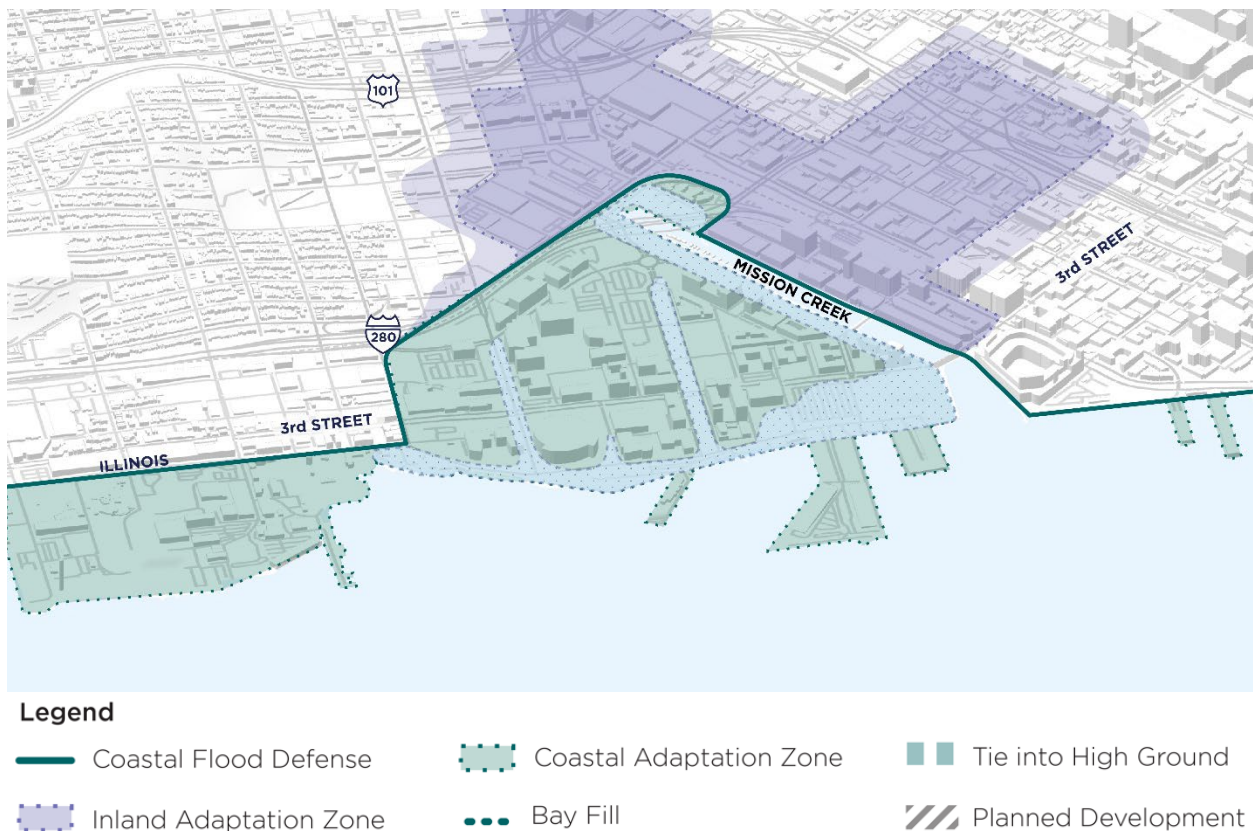


**Figure A-37: Alternative G, Mission Creek/Mission Bay (Reach 3) Subsequent Actions**

#### 11.7.4 Islais Creek/Bayview (Reach 4)

In Islais Creek/Bayview, Alternative G presents a transformative concept and lays groundwork for the potential to eventually restore some of this area to its previous condition as a coastal wetland. Alternative G constructs a series of levees linked to existing high ground. Maritime and industrial working lands bayside of this coastal flood

defense will initially be floodproofed to reduce risk but will eventually become part of a managed retreat. The 3rd Street bridge is currently being redesigned to defend against several feet of RSLC (FWOP condition).

This alternative incorporates several NNBFs to reduce risk, improve the environment, and provide recreational and social benefits. In the long-term, it requires a significant reconfiguration of the transportation network and other city-serving infrastructure. It also requires removal and potential relocation of commercial and industrial land uses. *For this study, these land uses are assumed to be removed. Potential relocation costs and benefits are not included in this alternative.*

Alternative G would include the following First Actions (**Figure A-38**):

- Construct levees that raise the ground by 1.5 to 5.5 feet and tie into high ground to defend against 3.5 feet of RSLC. Use the existing Caltrain embankment as part of the LOD near the head of the creek.
- Perform ground improvement to meet seismic design requirements of ER1110-2-1806 for the coastal flood defense structures.
- Raise Illinois Street Bridge, and regrade approaches, creating embankment causeways from Cesar Chavez Street to Cargo Way. This is expected to result in the loss of freight rail access to Pier 80 and potentially the Intermodal Cargo Transfer Freight Rail Yard.
- Incorporate NNBFs into the shoreline that serve a coastal and combined flood risk management function by influencing wave runup, while also enhancing public access and wildlife habitat.
- Do not consider additional adaptations for existing habitat areas, including Heron's Head Park, beyond what is already planned under FWOP conditions.
- Floodproof buildings (more than 25), equipment, and infrastructure within the POSF maritime and industrial working lands to protect operations at Piers 80, 90-92, and 94-96 from physical flood damages.
- Consider demolition of buildings (less than five) that overlap the LOD along the creek edge based on age, condition, ground floor elevation, and historic status.
- Develop comprehensive land use tools and policies to gradually vacate portions of the adaptation zones. This could include voluntary buyouts; rezoning and land use policy changes; grants, loans, and incentives; and other assistance programs. The cost of these nonstructural actions are not included as part of this alternative.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and others on changes to the combined sewer system, new pumps, green infrastructure, other resilient building and street design opportunities, and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

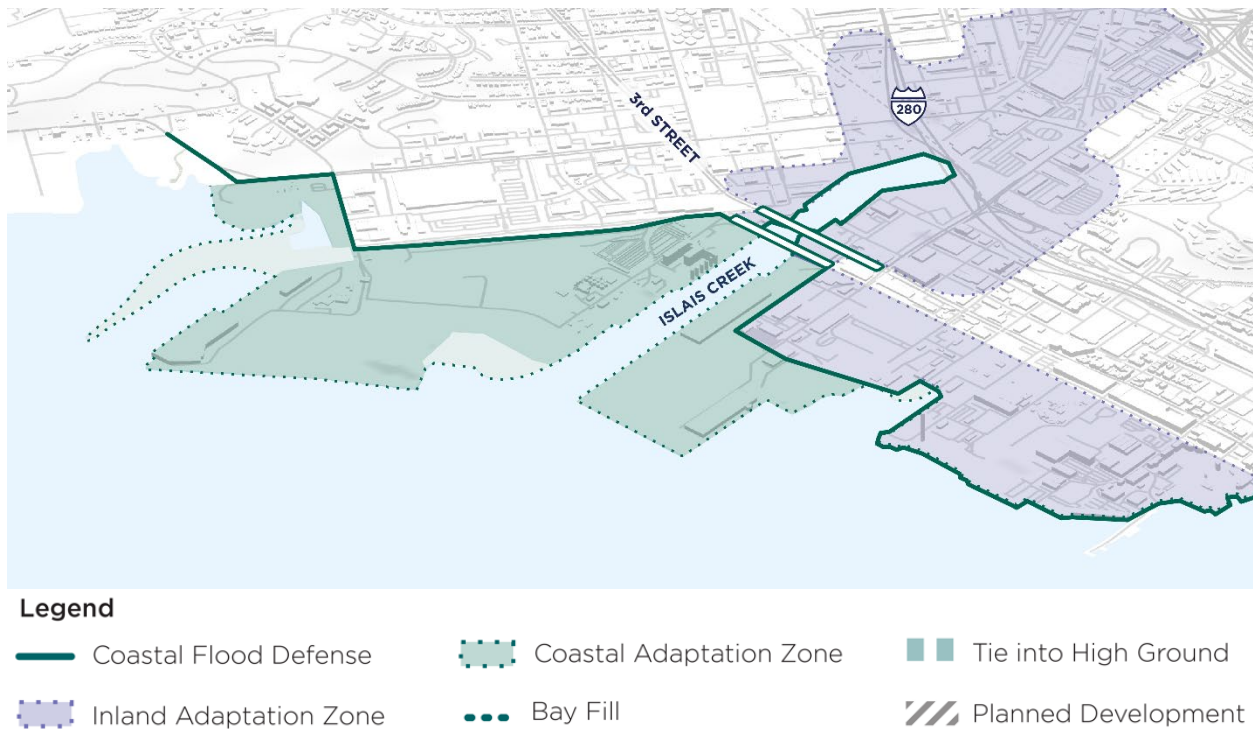


**Figure A-38: Alternative G, Islais Creek/Bayview (Reach 4) First Actions**

Alternative G would include the following Subsequent Actions (**Figure A-39**):

- Along the southern banks of Islais Creek, construct a new levee along Evans Avenue, which results in a retreat between the Caltrain line and 3rd Street. The new levee raises the shoreline by up to 8 feet to defend against up to 7 feet of RSLC.
- Along Islais Creek's northern bank, raise the 2040 levee along Cesar Chavez Street by 3.5 feet, and tie into existing high ground at the Caltrain embankment.
- Along Illinois Street, construct a new levee that elevates the ground up to 4 feet between Cesar Chavez and 24<sup>th</sup> Street.
- Gradually vacate limited areas near the Islais Creek channel over several decades (no residential areas vacated).
- Retreat existing POSF maritime and industrial working lands at Piers 80, 90-92, and 94-96, including de-paving concrete and asphalt surfaces, and restoring and regrading to floodable space. Floodable space may provide recreation and improved habitat in vacated areas.
- Further incorporate NNBFs bayside of the LOD with features that serve a coastal and combined flood risk management function while also enhancing public access and wildlife habitat.

- Acquire and consider demolition of buildings (more than 25) bayside of the LOD based on age, condition, ground floor elevation, and historic status.
- Build additional infrastructure to manage stormwater and reduce inland flood risk exacerbated by the coastal flood defense structures.

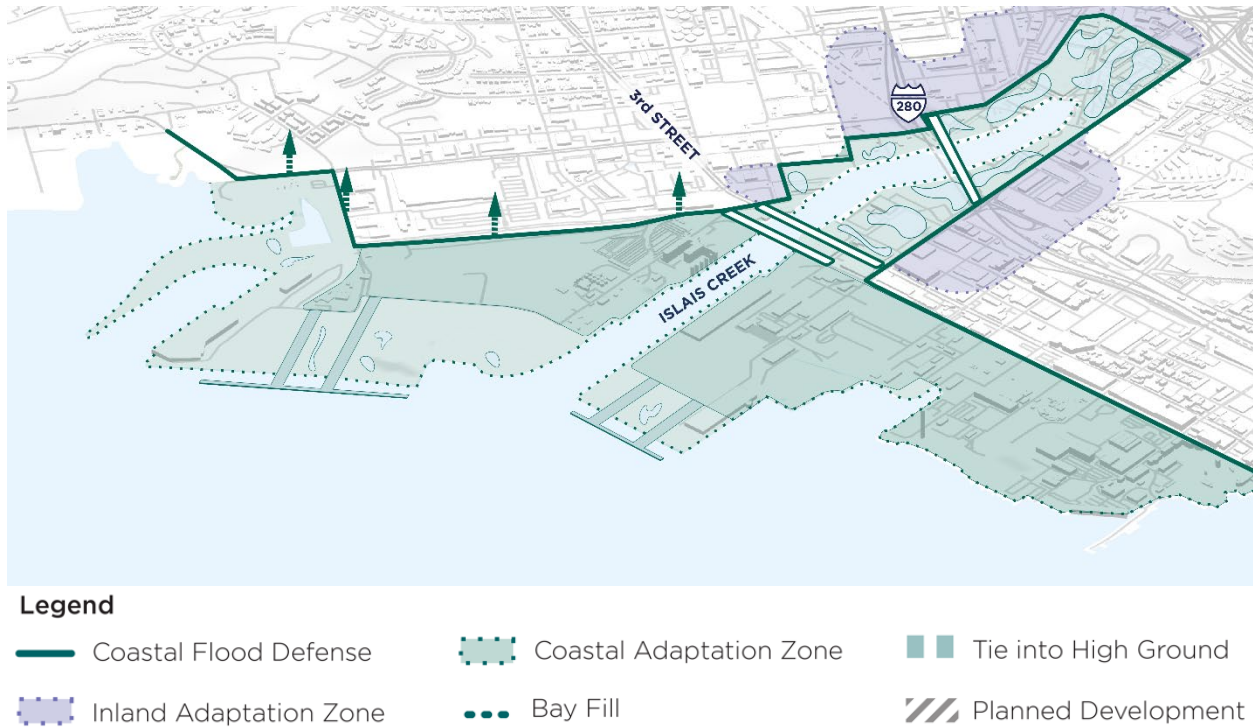


**Figure A-39: Alternative G, Islais Creek/Bayview (Reach 4) Subsequent Actions**

## 12.0 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 difference between the 10% and 1% AEP extreme water level is about 12 inches (*Annex B.1.1: Coastal Extreme Water Levels and High Tide Flooding*).

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 San Francisco

Municipal Transportation Agency (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*.

## 12.1 Costs

The preliminary costs for the plans are shown in **Table A-15** through **Table A-22** by reach. The first four tables show the cost of the First Actions, while the second four tables show the cost of the full reach-level plan (meaning First Actions and Subsequent Actions, where applicable).

Under the High RSLC curve, the assumption is that the higher cost would represent the total, while under the Intermediate and Low RSLC curves, the cost would only include the First Actions. An exception to this is Alternative D, where the Subsequent Actions are needed under the Intermediate RSLC curve.

Note that these costs do not include seismic design requirements costs; in accordance with the provisions of WRDA 2020 Section 152, as amended, the seismic design requirement costs are not considered when calculating net benefits for this study.

The real estate costs were provided by the PDT's Real Estate Team; the derivation of those costs is discussed in *Appendix F: Real Estate Plan*. The estimates on construction duration were provided by the Engineering Team; a discussion of those estimates can be found in *Appendix C: Cost Engineering*. The OMRR&R rates were also estimated by the Engineering Team.

The nonstructural alternatives are assumed to have no OMRR&R (though this may miss expenses associated with storing and deploying equipment, like flood shields, stop logs, and panels that could be part of an asset floodproofing approach or perimeter ring wall), while the structural alternatives used an OMRR&R rate of 0.5% of the capital cost per year. An exception to this is Alternative F in Reaches 3 and 4, where the water management structures were assumed to have a higher OMRR&R rate of 2% per year.

Though the seismic design requirements costs are not used in the benefit calculation due to the WRDA language, they are still real costs that are incurred. Additionally, the amount of cost that is attributed to "seismic" is not equal across measures; some measures have a larger percentage of their total cost considered seismic design requirements, while others have a lower percentage. For example, 86% of the cost of Alternative D is considered seismic, while only 36% of the cost of Alternative G is considered seismic (though the seismic design requirements costs are relatively close in cost between the structural plans). In plan selection, then, the marginal costs including seismic between plans should be considered. For reference, the first costs with seismic design requirements included are provided in **Table A-23** and **Table A-24**. A discussion of these costs is included in *Appendix C: Cost Engineering*.

**Table A-15: Costs, Reach 1, Without Seismic Design Requirements, First Actions**  
(PV; FY 2023 Price Level; \$1,000s)

| Plan            | Total First Cost <sup>a</sup> | Duration (Months) | IDC <sup>a</sup> | Subtotal AAC <sup>a</sup> | OMRR&R <sup>a</sup> | Total AAC <sup>a</sup> |
|-----------------|-------------------------------|-------------------|------------------|---------------------------|---------------------|------------------------|
| B (Lower Risk)  | 16,196                        | 3                 | 33               | 478                       | 0                   | 478                    |
| B (Higher Risk) | 79,319                        | 3                 | 164              | 2,341                     | 0                   | 2,341                  |
| C               | 165,122                       | 72                | 12,676           | 5,237                     | 826                 | 6,063                  |
| D               | 130,641                       | 96                | 13,648           | 4,250                     | 653                 | 4,903                  |
| E               | 3,260,213                     | 180               | 681,706          | 116,106                   | 16,301              | 132,407                |
| F               | 2,020,388                     | 180               | 422,460          | 71,952                    | 10,102              | 82,054                 |
| G               | 1,114,543                     | 180               | 233,049          | 39,692                    | 5,573               | 45,265                 |

AAC = average annual cost; IDC = interest during construction; FY = Fiscal Year; PV = present value

**Table A-16: Costs, Reach 2, Without Seismic Design Requirements, First Actions**  
(PV; FY 2023 Price Level; \$1,000s)

| Plan            | Total First Cost | Duration (Months) | IDC       | Subtotal AAC | OMRR&R | Total AAC |
|-----------------|------------------|-------------------|-----------|--------------|--------|-----------|
| B (Lower Risk)  | 20,685           | 3                 | 43        | 611          | 0      | 611       |
| B (Higher Risk) | 109,779          | 3                 | 226       | 3,240        | 0      | 3,240     |
| C               | 119,631          | 72                | 9,184     | 3,794        | 598    | 4,392     |
| D               | 137,271          | 96                | 14,341    | 4,466        | 686    | 5,152     |
| E               | 4,047,530        | 180               | 846,333   | 144,145      | 20,238 | 164,382   |
| F               | 7,424,087        | 180               | 1,552,367 | 264,394      | 37,120 | 301,514   |
| G               | 2,972,348        | 180               | 621,514   | 105,854      | 14,862 | 120,716   |

**Table A-17: Costs, Reach 3, Without Seismic Design Requirements, First Actions**

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

| Plan            | Total First Cost <sup>a</sup> | Duration (Months) | IDC <sup>a</sup> | Subtotal AAC <sup>a</sup> | OMRR&R <sup>a</sup> | Total AAC <sup>a</sup> |
|-----------------|-------------------------------|-------------------|------------------|---------------------------|---------------------|------------------------|
| B (Lower Risk)  | 319,421                       | 3                 | 658              | 9,428                     | -                   | 9,428                  |
| B (Higher Risk) | 632,903                       | 3                 | 1,305            | 18,680                    | -                   | 18,680                 |
| C               | 451,323                       | 72                | 34,647           | 14,314                    | 2,257               | 16,570                 |
| D               | 367,808                       | 96                | 38,425           | 11,965                    | 1,839               | 13,804                 |
| E               | 4,345,783                     | 180               | 908,697          | 154,766                   | 21,729              | 176,495                |
| F               | 2,567,612                     | 180               | 536,884          | 91,440                    | 51,352              | 142,793                |
| G               | 1,968,653                     | 180               | 411,643          | 70,110                    | 9,843               | 79,953                 |

**Table A-18: Costs, Reach 4, Without Seismic Design Requirements, First Actions**

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

| Plan            | Total First Cost | Duration (Months) | IDC     | Subtotal AAC | OMRR&R | Total AAC |
|-----------------|------------------|-------------------|---------|--------------|--------|-----------|
| B (Lower Risk)  | 47,679           | 3                 | 98      | 1,407        | -      | 1,407     |
| B (Higher Risk) | 120,125          | 3                 | 248     | 3,545        | -      | 3,545     |
| C               | 725,712          | 72                | 55,711  | 23,016       | 3,629  | 26,645    |
| D               | 736,256          | 96                | 76,918  | 23,951       | 3,681  | 27,633    |
| E               | 4,080,150        | 180               | 853,154 | 145,306      | 20,401 | 165,707   |
| F               | 716,343          | 180               | 149,786 | 25,511       | 14,327 | 39,838    |
| G               | 1,410,364        | 180               | 294,905 | 50,227       | 7,052  | 57,279    |

**Table A-19: Costs, Reach 1, Without Seismic Design Requirements, All Actions**

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

| Plan            | Total First Cost | Duration (Months) | IDC     | Subtotal AAC | OMRR&R | Total AAC |
|-----------------|------------------|-------------------|---------|--------------|--------|-----------|
| B (Lower Risk)  | 32,985           | 3                 | 33      | 973          | 0      | 973       |
| B (Higher Risk) | 199,350          | 3                 | 164     | 5,877        | 0      | 5,877     |
| C               | 165,122          | 72                | 12,676  | 5,237        | 826    | 6,063     |
| D               | 234,273          | 96                | 13,648  | 7,302        | 653    | 7,956     |
| E               | 3,386,200        | 180               | 681,706 | 119,817      | 16,301 | 136,118   |
| F               | 2,026,822        | 180               | 422,460 | 72,142       | 10,102 | 82,244    |
| G               | 1,146,254        | 180               | 233,049 | 40,626       | 5,573  | 46,199    |

**Table A-20: Costs, Reach 2, Without Seismic Design Requirements, All Actions**

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

| Plan            | Total First Cost | Duration (Months) | IDC       | Subtotal AAC | OMRR&R | Total AAC |
|-----------------|------------------|-------------------|-----------|--------------|--------|-----------|
| B (Lower Risk)  | 78,263           | 3                 | 43        | 2,306        | 0      | 2,306     |
| B (Higher Risk) | 601,180          | 3                 | 226       | 17,714       | 0      | 17,714    |
| C               | 119,631          | 72                | 9,184     | 3,794        | 598    | 4,392     |
| D               | 471,473          | 96                | 14,341    | 14,309       | 686    | 14,996    |
| E               | 4,298,581        | 180               | 846,333   | 151,539      | 20,238 | 171,777   |
| F               | 7,429,646        | 180               | 1,552,367 | 264,558      | 37,120 | 301,678   |
| G               | 2,976,378        | 180               | 621,514   | 105,973      | 14,862 | 120,835   |

**Table A-21: Costs, Reach 3, Without Seismic Design Requirements, All Actions***(PV; FY 2023 Price Level; \$1,000s)*

| Plan            | Total First Cost | Duration (Months) | IDC     | Subtotal AAC | OMRR&R | Total AAC |
|-----------------|------------------|-------------------|---------|--------------|--------|-----------|
| B (Lower Risk)  | 409,445          | 3                 | 658     | 12,079       | 0      | 12,079    |
| B (Higher Risk) | 1,443,016        | 3                 | 1,305   | 42,541       | 0      | 42,541    |
| C               | 451,323          | 72                | 34,647  | 14,314       | 2,257  | 16,570    |
| D               | 620,773          | 96                | 38,425  | 19,416       | 1,839  | 21,255    |
| E               | 4,595,916        | 180               | 908,697 | 162,134      | 21,729 | 183,863   |
| F               | 2,893,856        | 180               | 536,884 | 101,050      | 51,352 | 152,402   |
| G               | 2,274,144        | 180               | 411,643 | 79,108       | 9,843  | 88,951    |

**Table A-22: Costs, Reach 4, Without Seismic Design Requirements, All Actions***(PV; FY 2023 Price Level; \$1,000s)*

| Plan            | Total First Cost | Duration (Months) | IDC     | Subtotal AAC | OMRR&R | Total AAC |
|-----------------|------------------|-------------------|---------|--------------|--------|-----------|
| B (Lower Risk)  | 73,383           | 3                 | 98      | 2,164        | 0      | 2,164     |
| B (Higher Risk) | 306,609          | 3                 | 248     | 9,038        | 0      | 9,038     |
| C               | 725,712          | 72                | 55,711  | 23,016       | 3,629  | 26,645    |
| D               | 926,551          | 96                | 76,918  | 29,556       | 3,681  | 33,238    |
| E               | 4,229,664        | 180               | 853,154 | 149,710      | 20,401 | 170,111   |
| F               | 1,129,423        | 180               | 149,786 | 37,678       | 14,327 | 52,005    |
| G               | 1,673,908        | 180               | 294,905 | 57,990       | 7,052  | 65,042    |

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**Table A-23: Reach-level First Costs, including Seismic, First Actions**  
(PV; FY 2023 Price Level; \$1,000s)

| Plan            | Reach 1   | Reach 2    | Reach 3   | Reach 4   |
|-----------------|-----------|------------|-----------|-----------|
| B (Lower Risk)  | 16,196    | 20,685     | 319,421   | 47,679    |
| B (Higher Risk) | 79,319    | 109,779    | 632,903   | 120,125   |
| C               | 672,828   | 2,861,247  | 1,669,820 | 6,412,026 |
| D               | 638,347   | 2,878,886  | 1,586,304 | 6,422,571 |
| E               | 3,767,919 | 6,789,145  | 5,564,278 | 9,766,466 |
| F               | 2,580,104 | 10,375,316 | 3,229,095 | 1,632,242 |
| G               | 1,588,555 | 5,484,616  | 2,916,679 | 2,216,186 |

**Table A-24: Reach-level First Costs, including Seismic, Subsequent Actions**  
(PV; FY 2023 Price Level; \$1,000s)

| Plan            | Reach 1   | Reach 2    | Reach 3   | Reach 4   |
|-----------------|-----------|------------|-----------|-----------|
| B (Lower Risk)  | 32,985    | 78,263     | 409,445   | 73,383    |
| B (Higher Risk) | 199,350   | 601,180    | 1,443,016 | 306,609   |
| C               | 672,828   | 2,861,247  | 1,669,820 | 6,412,026 |
| D               | 741,979   | 3,213,088  | 1,839,269 | 6,612,866 |
| E               | 3,893,906 | 7,040,196  | 5,814,411 | 9,915,980 |
| F               | 2,586,538 | 10,380,875 | 3,556,750 | 2,078,358 |
| G               | 1,620,562 | 5,486,692  | 3,402,014 | 2,553,464 |

## 12.2 NED Evaluation

The net NED benefits for each plan in each reach under each RSLC curve are shown in **Table A-25** through **Table A-27**.

**Table A-25: NED Evaluation by Alternative, Low RSLC**  
(PV, FY 2023 Price Level; \$1,000s)

| Reach                | Damages   | NED Benefits,<br>2040-2089 | NED Benefits,<br>2090-2140 | Total NED<br>Benefits | Cost      | Net<br>Benefits | BCR   |
|----------------------|-----------|----------------------------|----------------------------|-----------------------|-----------|-----------------|-------|
| <b>FWOP</b>          |           |                            |                            |                       |           |                 |       |
| 1                    | 375,852   | N/A                        | N/A                        | N/A                   | N/A       | N/A             | N/A   |
| 2                    | 729,221   | N/A                        | N/A                        | N/A                   | N/A       | N/A             | N/A   |
| 3                    | 898,963   | N/A                        | N/A                        | N/A                   | N/A       | N/A             | N/A   |
| 4                    | 1,606,779 | N/A                        | N/A                        | N/A                   | N/A       | N/A             | N/A   |
| Total                | 3,610,815 | N/A                        | N/A                        | N/A                   | N/A       | N/A             | N/A   |
| <b>Alternative B</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  |
| <b>Alternative C</b> |           |                            |                            |                       |           |                 |       |
| 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  |
| <b>Alternative D</b> |           |                            |                            |                       |           |                 |       |
| 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  |

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| Reach                | Damages   | NED Benefits,<br>2040-2089 | NED Benefits,<br>2090-2140 | Total NED<br>Benefits | Cost       | Net<br>Benefits | BCR  |
|----------------------|-----------|----------------------------|----------------------------|-----------------------|------------|-----------------|------|
| <b>Alternative E</b> |           |                            |                            |                       |            |                 |      |
| 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 |
| <b>Alternative F</b> |           |                            |                            |                       |            |                 |      |
| 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 |
| <b>Alternative G</b> |           |                            |                            |                       |            |                 |      |
| 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 |

**Table A-26: NED Evaluation by Alternative, Intermediate RSLC**  
(PV, FY 2023 Price Level; \$1,000s)

| Reach                | Damages   | NED Benefits, 2040-2089 | NED Benefits, 2090-2140 | NED Benefits | Cost      | Net Benefits | BCR   |
|----------------------|-----------|-------------------------|-------------------------|--------------|-----------|--------------|-------|
| <b>FWOP</b>          |           |                         |                         |              |           |              |       |
| 1                    | 430,228   | N/A                     | N/A                     | N/A          | N/A       | N/A          | N/A   |
| 2                    | 1,592,498 | N/A                     | N/A                     | N/A          | N/A       | N/A          | N/A   |
| 3                    | 2,116,372 | N/A                     | N/A                     | N/A          | N/A       | N/A          | N/A   |
| 4                    | 1,836,652 | N/A                     | N/A                     | N/A          | N/A       | N/A          | N/A   |
| Total                | 5,975,750 | N/A                     | N/A                     | N/A          | N/A       | N/A          | N/A   |
| <b>Alternative B</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      | 13.53 |
| 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  |
| <b>Alternative C</b> |           |                         |                         |              |           |              |       |
| 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  |
| <b>Alternative D</b> |           |                         |                         |              |           |              |       |
| 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  |

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| Reach                | Damages   | NED Benefits,<br>2040-2089 | NED Benefits,<br>2090-2140 | NED Benefits | Cost       | Net Benefits | BCR  |
|----------------------|-----------|----------------------------|----------------------------|--------------|------------|--------------|------|
| <b>Alternative E</b> |           |                            |                            |              |            |              |      |
| 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 |
| <b>Alternative F</b> |           |                            |                            |              |            |              |      |
| 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 |
| Total                | 1,751,822 | 2,473,791                  | 1,750,137                  | 4,223,928    | 17,550,645 | -13,326,717  | 0.24 |
| <b>Alternative G</b> |           |                            |                            |              |            |              |      |
| 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 |

**Table A-27: NED Evaluation by Alternative, High RSLC**  
(PV, FY 2023 Price Level; \$1,000s)

| Reach                | Damages    | NED Benefits, 2040-2089 | NED Benefits, 2090-2140 | NED Benefits | Cost      | Net Benefits | BCR  |
|----------------------|------------|-------------------------|-------------------------|--------------|-----------|--------------|------|
| <b>FWOP</b>          |            |                         |                         |              |           |              |      |
| 1                    | 1,586,714  | N/A                     | N/A                     | N/A          | N/A       | N/A          | N/A  |
| 2                    | 7,834,338  | N/A                     | N/A                     | N/A          | N/A       | N/A          | N/A  |
| 3                    | 9,515,697  | N/A                     | N/A                     | N/A          | N/A       | N/A          | N/A  |
| 4                    | 3,634,010  | N/A                     | N/A                     | N/A          | N/A       | N/A          | N/A  |
| Total                | 22,570,759 | N/A                     | N/A                     | N/A          | N/A       | N/A          | N/A  |
| <b>Alternative B</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 |
| <b>Alternative C</b> |            |                         |                         |              |           |              |      |
| 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 |
| Total                | 20,856,569 | 6,947,867               | (5,233,686)             | 1,714,181    | 1,822,152 | -107,971     | 0.94 |
| <b>Alternative D</b> |            |                         |                         |              |           |              |      |
| 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 |

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| Reach                | Damages   | NED Benefits,<br>2040-2089 | NED Benefits,<br>2090-2140 | NED Benefits | Cost       | Net Benefits | BCR  |
|----------------------|-----------|----------------------------|----------------------------|--------------|------------|--------------|------|
| <b>Alternative E</b> |           |                            |                            |              |            |              |      |
| 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 |
| <b>Alternative F</b> |           |                            |                            |              |            |              |      |
| 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 |
| <b>Alternative G</b> |           |                            |                            |              |            |              |      |
| 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 |

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

- None of the 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 more, 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.
- 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 time frame.

The plans that maximize net NED benefits by reach by RSLC curve are shown in **Table A-28**. 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 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 A-28: NED Plan by Reach Under Each RSLC Curve**

| Reach | Low RSLC       | Intermediate RSLC | High RSLC |
|-------|----------------|-------------------|-----------|
| 1     | No Action      | B Intermediate    | B High    |
| 2     | B Intermediate | B Intermediate    | G         |
| 3     | B Intermediate | B Intermediate    | B High    |
| 4     | B Intermediate | B Intermediate    | B High    |

## 12.3 Insights Gained from NED Evaluation

Though the previous section details the determination of the NED plan, *ER 1105-2-103 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 and fragility, and life safety risk informed the identification of the TSP (Section 15.0). This section describes the insights gained from the NED analysis to better meet study objectives in a more cost-effective manner (Section 5.0).

One of the main additional decision metrics is RSLC adaptability. Three NED plans that differ based on the RSLC curve were considered, but because the TSP was determined without knowledge of the future RSLC curve, a plan that performs well under all rates of change must be chosen. Note that plans that perform well under multiple rates of RSLC are unlikely to be the NED plan under any one RSLC curve because a plan that is specifically designed to perform well under a particular RSLC curve will have higher net NED benefits than one that pays for adaptability or overbuilds earlier in the study period to achieve protection against a rate of change not realized.

There is no available methodology for deciding upon an NED plan that considers multiple rates of RSLC change (typically, USACE studies select one RSLC scenario and consider other RSLC scenarios only as a sensitivity test), which is why RSLC is explicitly discussed in this section to support development of a TSP.

There are also opportunities to optimize the existing plans to perform better in terms of NED benefits under the prevailing RSLC scenario. Sub-reach changes to alignments, design, or scaling can reduce costs while maintaining or minimally impacting the benefits. Changes to the implementation date of adaptive measures will change when costs are incurred and better align costs and benefits in time. These optimizations are discussed qualitatively in this section. There also remains the possibility that future optimizations and analyses of the identified TSP may reveal that the selected plan is also the true NED plan in some scenarios.

Other planning considerations were used in this phase of the study to help in plan selection. *ER 1105-2-103 Policy for Conducting Civil Works Studies* mentions four formulation and evaluation criteria: completeness, effectiveness, efficiency, and acceptability:

- Completeness is the extent to which the alternative plans provide and account for all necessary investments or other actions to realize the planning objectives, including actions by other Federal and non-Federal entities.
- Effectiveness is the extent to which the alternative plans contribute to achieving the planning objectives.
- Efficiency is the extent to which an alternative plan is the most cost-effective means of achieving the objectives.

- Acceptability is the extent to which the alternative plans are acceptable in terms of applicable laws, regulations, and public policies.

*ER 1105-2-103, Policy for Conducting Civil Works Planning Studies* 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.

Some of the 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, and community and environmental impacts, must also be weighed as part of the formulation decision under the comprehensive benefits framework.
- Overtopping of an 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 do not take protective actions (floodproofing or 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 in Reach 4, there were concerns about using water management structures across Mission and Islais creeks. The concerns included that these structures would impact hazardous, toxic, and radioactive waste (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.

## **12.4 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 future RSLC is uncertain, the rate of change will not be known before having to make a First Action. Therefore, for First Actions to be considered successful in this environment, they need 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 the 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 or not they are necessary, depending on RSLC, and when that Subsequent Actions cost is incurred. Removing Subsequent Actions allows for an analysis that understands RSLC is uncertain and that many different futures exist. Under some rates, Subsequent Actions 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 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 more structural measures might need to be brought online to maintain that level of flood risk management under the High RSLC curve. **Table A-29** shows this framework.

**Table A-29: First and Potential Subsequent Actions, Hybrid Plan**

| Reach | First Actions             | Subsequent Actions<br>Low RSLC | Subsequent Actions<br>Intermediate RSLC  | Subsequent Actions<br>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 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 optionality 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, as 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; 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 Actions 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 Subsequent Actions 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 A-29** 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.

## 13.0 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 12.3 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 (Section 14.0).

## 14.0 Evaluation of the Final Array

Typical feasibility studies identify an 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 sections.

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 decision drivers, described in this section, including summaries of findings for each alternative by reach and RSLC. During this step, the impacts of overinvestment and underinvestment were 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 this section.

As described earlier in the plan formulation strategy, 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 rise 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.

## 14.1 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 USACE feasibility 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.

The RED, OSE, and EQ benefits are discussed comprehensively as follows:

- RED in *Sub-Appendix E.1: RED Report*
- OSE in *Sub-Appendix E.2: OSE Report*
- EQ in *Appendix D: Environmental and Cultural Resources*

To determine RED and OSE benefit categories, the PDT relied on the Institute of Water Resources materials:

- *Handbook on Applying "Other Social Effects" Factors in Corps of Engineers Water Resources Planning* (09-R-4) (IWR 2009)
- *Regional Economic Development (RED) Procedures Handbook* (2011-RPT-01) (IWR 2011)
- *Other Social Effects: A Primer* (2013-R-02) (IWR 2013)

This section describes how the RED, OSE, and EQ benefits were evaluated.

### 14.1.1 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:

1. **Direct effects** are the impacts direct Federal expenditures have on industries that directly support the new project. Labor and construction materials are considered the direct components of a project.
2. **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.

3. **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.

A summary table showing the takeaways by reach can be found in **Table A-30**, which shows many different types of impacts that affect the RED account. These RED impacts are described in more detail in the Regional Economic Development Report within *Appendix E: Economic and Social Considerations*.

**Table A-30: Economic Profile Takeaways by Reach**

| Profile                      | Reach 1                                                                                                                                                                                       | Reach 2                                                                                                                               | Reach 3                                                                                                                                                                                                                                       | Reach 4                                                                                                                                                                                                                                                                     |
|------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Employment and Income</b> |                                                                                                                                                                                               |                                                                                                                                       |                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                             |
| Demographics                 | <ul style="list-style-type: none"> <li>• High percentage of older workers</li> <li>• Low percentage of high-paying jobs</li> <li>• Higher percentage of Hispanic or Latino workers</li> </ul> | <ul style="list-style-type: none"> <li>• High educational attainment</li> <li>• Higher percentage of high-paying jobs</li> </ul>      | <ul style="list-style-type: none"> <li>• Higher percentage of Hispanic or Latino workers</li> </ul>                                                                                                                                           | <ul style="list-style-type: none"> <li>• High percentage of older workers</li> <li>• Low percentage of high-paying jobs</li> <li>• Higher percentage of Black or African-American workers and Hispanic or Latino workers</li> <li>• Lower educational attainment</li> </ul> |
| Main Employment Sectors      | <ul style="list-style-type: none"> <li>• Retail trade, accommodation, and food services</li> <li>• Professional, scientific, and technical services</li> </ul>                                | <ul style="list-style-type: none"> <li>• Professional, scientific, and technical services</li> <li>• Finance and insurance</li> </ul> | <ul style="list-style-type: none"> <li>• Administration and support</li> <li>• Waste management and remediation</li> <li>• Information</li> <li>• Educational services</li> <li>• Professional, scientific, and technical services</li> </ul> | <ul style="list-style-type: none"> <li>• Construction</li> <li>• Wholesale trade</li> <li>• Transportation and warehousing</li> <li>• Accommodation and food services</li> </ul>                                                                                            |

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| Profile                                  | Reach 1                                                                                                                                                                            | Reach 2                                                                                                                                                                                                             | Reach 3                                                                                                                                                                                                                                                                          | Reach 4                                                                                                                                                                                                                                                                                                                                                               |
|------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Inflow and Outflow, and Commuting Trends | <ul style="list-style-type: none"> <li>Has a net job inflow of 6,100, the lowest of the reaches</li> </ul>                                                                         | <ul style="list-style-type: none"> <li>Largest net inflow of jobs: 220,000</li> <li>Draws a large number of workers from across the Bay Area due to large inflow</li> </ul>                                         | <ul style="list-style-type: none"> <li>Large net inflow of jobs: 110,000</li> <li>Draws a large number of workers from across the Bay Area due to large inflow</li> </ul>                                                                                                        | <ul style="list-style-type: none"> <li>Net job inflow of 14,000</li> <li>Draws a high proportion of its commuters from Equity Priority Communities</li> </ul>                                                                                                                                                                                                         |
| <b>Critical Infrastructure</b>           |                                                                                                                                                                                    |                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                       |
| Transportation                           | <ul style="list-style-type: none"> <li>Muni E and F lines (historic streetcar), cable cars, buses</li> <li>SFMTA Kirkland Division Muni Maintenance Facility</li> </ul>            | <ul style="list-style-type: none"> <li>BART rail lines, Embarcadero and Montgomery Street Stations, and Transbay Tube</li> <li>Muni E and F lines (historic streetcar), KT line (LRV), cable cars, buses</li> </ul> | <ul style="list-style-type: none"> <li>BART rail lines</li> <li>Muni E and F lines (historic streetcar), Muni KT line (LRV), buses</li> <li>Caltrain's San Francisco Station and rail lines</li> </ul>                                                                           | <ul style="list-style-type: none"> <li>BART rail lines</li> <li>Muni KT line (LRV), buses</li> <li>Muni Maintenance Facilities: Muni Metro East, Burke Warehouse, 1399 Marin, and Islais Creek Division</li> <li>Caltrain rail lines</li> <li>SFBR, serving Piers 80, 92, 94, and 96, and the POSF's railyard (the Intermodal Container Transfer Facility)</li> </ul> |
| Utilities                                | <ul style="list-style-type: none"> <li>Wastewater assets include the North Shore Pump Station, the North Point Wet Weather Facility, the Fort Mason Tunnel, and one CSD</li> </ul> | <ul style="list-style-type: none"> <li>Wastewater assets include several buried assets, including the Jackson Transport Storage Box, the North Shore Force Main, and three CSDs</li> </ul>                          | <ul style="list-style-type: none"> <li>Low-pressure assets include Bay Bridge Pump Station</li> <li>Wastewater assets include the North Channel Transport Storage Box, the Channel Pump Station, the Channel Force Main, the smaller Harriet Street and Mariposa pump</li> </ul> | <ul style="list-style-type: none"> <li>Wastewater assets include the Booster Pump Station, the Southeast Lift Station, the Islais Creek Transport Storage Box, and the Southeast Treatment Plant</li> <li>Recology facility on Pier 96</li> </ul>                                                                                                                     |

| Profile | Reach 1 | Reach 2 | Reach 3                       | Reach 4 |
|---------|---------|---------|-------------------------------|---------|
|         |         |         | stations, and<br>several CSDs |         |

BART = Bay Area Rapid Transit  
 LRV = light rail vehicle  
 SFBR = San Francisco Bay Railroad

Building on the data collected in **Table A-30**, the PDT developed categories and metrics to describe the RED impacts to employment, income, and critical infrastructure within and outside of the study area. Those metrics, along with how they were measured, are summarized in **Table A-31**.

**Table A-31: Overview of RED Categories and Measures**

| Category                           | Measure                     | Measure Type | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|------------------------------------|-----------------------------|--------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Benefits from Construction         | Primary Impacts             | \$           | Local capture measures what percentage of Federal spending is captured within the impact area. It is calculated by applying the level-specific (local, state, or national) Local Purchase Coefficients to the expenditures for each industry and aggregating the local capture across all industries.<br><br>As such, the local capture (also called primary impacts) is equal to the monetary direct effect of Federal spending.                                                                                                                                                                                                                                                                                                       |
|                                    | Secondary Impacts           | \$           | Secondary impacts, which include indirect and induced impacts, are multiplier effects on top of the direct impacts. These impacts include payments to industries that support the directly affected industries, while induced effects occur when workers associated with the direct and indirect industries spend their salaries in the impact area, creating additional jobs and income.                                                                                                                                                                                                                                                                                                                                               |
| Impacts to Critical Infrastructure | Transportation Revenue Loss | \$           | Revenue losses affect an agency's ability to continue to provide the same level of service. Revenue loss was established for three primary transportation assets: SFMTA, BART, and the SFBR facility.<br><br>BART: BART is expected to lose ridership and revenue due to system disruption caused by flood damage. Revenue losses are estimated using disruption time estimates until partial and full capacity of the system can be restored. Disruption time estimates were developed using FEMA Hazus data and expert judgment and were confirmed appropriate by BART.<br><br>Muni: SFMTA is expected to lose Muni ridership and revenue due to system disruption caused by flood damage at Embarcadero Station and Central Station. |

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| Category                | Measure                       | Measure Type | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-------------------------|-------------------------------|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                         |                               |              | <p>Revenue losses are estimated using disruption time estimates until partial and full capacity of the system can be restored. Disruption time estimates were developed using FEMA Hazus data and expert judgment and were confirmed appropriate by SFMTA.</p> <p>SFBR. The SFBR facility handles 1,000–3,000 tons of cargo per day. Analysts used the Bureau of Transportation Statistics value of domestic rail per daily ton to estimate lost revenue associated with facility disruption due to flooding.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|                         | Utility Revenue Loss          | \$           | <p>Utility impacts were established for three primary public and private utilities dealing with potable water, the combined sewer system, and waste management.</p> <p>Potable Water: Flood damage expected at the Bay Bridge low pressure water pump station will disrupt potable water service to Treasure Island and Yerba Buena Island. SFPUC may experience revenue losses, as the agency will not collect service fees because of reduction in potable water use. Revenue losses use total daily demand, cost per gallon, and functional downtime to estimate loss.</p> <p>Combined Sewer System: FEMA has established a standard value per person per day of associated GDP that may be lost due to disruption in wastewater treatment service. The Southeast Treatment Plant treats about 80% of the sewage in San Francisco, serving the entire San Francisco Waterfront Coastal Flood Study population during dry weather and much of it during wet weather as well. Outage at the treatment plant should not cause loss of service to the residents and businesses of San Francisco; however, it could result in quantities of wastewater being dumped directly into the Bay, depending on the length of the outage. The proposed approach to estimate economic impacts of loss of utility service is sourced from FEMA benefit to cost analysis methodologies that use functional downtime of utility systems, the service area population, and daily per capita estimates of GDP.</p> <p>Waste Management: Revenue loss for Recology is estimated based on information provided by a Recology representative. Analysts used the annual revenue of the facility and restoration times from FEMA Hazus to estimate how much annual revenue may be lost if the facility were damaged by coastal flooding.</p> |
| Direct Economic Impacts | Direct Economic Output Losses | \$           | Output represents the value of industry production and includes labor income factors (employee compensation and proprietor income), taxes on production and imports, other property income, and intermediate inputs. For                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

| Category                            | Measure                                     | Measure Type | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|-------------------------------------|---------------------------------------------|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                     |                                             |              | industries that do not hold inventory, output equals revenues. For industries that do hold inventory, output equals revenues less the value of goods sold. Direct output losses are modeled in G2CRM.                                                                                                                                                                                                                                                               |
|                                     | Direct Job Losses                           | #            | Jobs represent all full-time, part-time, and temporary employment opportunities available on average within an industry, as calculated with IMPLAN. This metric is not a specific job count but represents a localized average of likely employment statistics based on annual economic activity. IMPLAN job counts are usually larger than many other sources because they account for all full-time, part-time, and seasonal jobs, and other data sources do not. |
| Cascading Regional Economic Impacts | Indirect and Induced Economic Output Losses | \$           | Same description as for Direct Economic Output Losses. Indirect and induced output losses are modeled through IMPLAN using the G2CRM direct output losses as a model input. This metric demonstrates the impacted industries that contribute the most to national GDP.                                                                                                                                                                                              |
|                                     | Indirect and Induced Job Losses             | #            | Same description as for Direct Job Losses. Indirect and induced job losses are modeled through IMPLAN using the G2CRM direct output losses as a model input.                                                                                                                                                                                                                                                                                                        |

GDP = gross domestic product

#### 14.1.2 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 A-32**.

**Table A-32: 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 CSRM alternative. |

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| Category                            | Measures                                | Measure Type   | Description                                                                                                                                                                                                                                                                                                                                                             |
|-------------------------------------|-----------------------------------------|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                     | 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.                                                                                                                                                                                                                                                                  |
| Economic Vitality                   | Maritime Functions                      | Qualitative    | Semi-qualitative 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 driver included in FWP for OSE relies on data from the 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 at-risk 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. |

| Category | Measures                                            | Measure Type                   | Description                                                                                                                                                                                                            |
|----------|-----------------------------------------------------|--------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          | 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.                                                                                                          |

CSRM = coastal storm risk management

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

### 14.1.3 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 Threatened and Endangered Species. The metrics were not measured in dollars and supported consideration of broader benefits.

The EQ benefits did not vary significantly across alternative plans and did not justify any plan over another, although the EWN measures were shown to contribute EQ benefit streams over time.

### 14.1.4 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. Metrics were removed from consideration for a variety of reasons:

- The metric did not change between the FWOP and any of the FWP conditions. This occurred when the damage occurred outside the LODs (meaning, there would be no change from the FWOP to the FWP) or if there were no damages seen in the FWOP or FWP (for instance, maritime losses were considered but were minimal in the FWOP, meaning there would be no significant difference in the FWP).
- The metric was determined to not be important to the NFS or PDT. This was not possible to determine before seeing the FWOP and FWP impacts; but in some cases, the PDT determined that the difference in impacts was not worth justifying a tradeoff of NED benefits or project performance. For example, the RED metrics, while critically important to those who suffer RED losses, were determined to not support robust decision-making, though they were imperative for accurately describing the FWOP and FWP conditions. This can be considered, giving these metrics zero weight.

Accordingly, the PDT developed more than 40 benefit metrics across RED, OSE, and EQ metrics. The final decision drivers are presented in **Table A-33**.

**Table A-33: Decision Drivers**

| Category                      | Items                                   | Metric                   |
|-------------------------------|-----------------------------------------|--------------------------|
| <b><i>NED Account</i></b>     |                                         |                          |
| Benefits                      | FWOP minus residual risk                | Dollars (\$)             |
| Costs                         | Total construction cost                 | \$                       |
| Efficiency                    | BCR                                     | BCR                      |
| Return on Investment          | Net benefits                            | \$                       |
| Residual Damages              | Residual Damages                        | \$                       |
| <b><i>RED Account</i></b>     |                                         |                          |
| Business Economic Disruptions | Reduced business disruption benefits    | \$                       |
| <b><i>OSE Account</i></b>     |                                         |                          |
| Health and Safety             | Coastal life safety risk (overtopping)  | Score and ranking scheme |
|                               | Seismic life safety risk and resilience | Score and ranking scheme |
| Economic Vitality             | Job protection                          | Variance from FWOP       |
|                               | Maritime metrics                        | Score and ranking scheme |

| Category                   | Items                                           | Metric                            |
|----------------------------|-------------------------------------------------|-----------------------------------|
| Social Connectedness       | Public transit mobility                         | Score and ranking scheme          |
| Community Identity         | Community and cultural assets                   | Assets (number)                   |
|                            | Historic asset and district designation         | Score and ranking scheme          |
| Social Risk and Resiliency | At-risk population exposure                     | People (number) and score         |
|                            | Disproportionate effects on at-risk communities | Score and ranking scheme          |
|                            | Permanently displaced population                | People (number)                   |
|                            | Compromised disaster response sites             | Sites (number)                    |
|                            | Affordable housing                              | Affordable housing units (number) |
| <b>EQ Account</b>          |                                                 |                                   |
| Physical Environment       | HTRW contaminated sites                         | % Exposure reduced                |
|                            | Carbon sequestration                            | MTCO <sub>2</sub> e               |
|                            | Water quality                                   | Score and ranking scheme          |
|                            | Wave runup reduction (EWN)                      | Linear feet                       |
| Biological Environment     | NNBF                                            | Acres                             |
|                            | Threatened and endangered species               | Species benefited (number)        |

MTCO<sub>2</sub>e = metric ton(s) of carbon dioxide equivalent

## 14.2 Comprehensive Benefits Analysis

For each RSLC, a comprehensive benefits matrix was created using the decision drivers described in **Table A-33** 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 are 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; this process is discussed in *Sub-Appendix E.1: RED Report* and *Sub-Appendix E.2: OSE Report*.

The colors are used purely to allow for a simplified evaluation of metrics at a glance; robust decision-making requires a deeper understanding of these impacts. The decision

drivers matrices, then, are reductive tools to describe performance across an array of metrics. The colors (green being “good,” red being “less good”) allow the viewer to see where plans differ and allowed the Economics Team to visually show where benefits were correlated and what tradeoffs existed. The Economics Team facilitated conversations with the full PDT using the matrices but brought in complementary information, including the actual magnitudes of effects and when impacts would be expected, to support robust decision-making.

**Table A-34** through **Table A-42** show the matrices used in the analysis. The High and Intermediate RSLC curve decision drivers matrices are shown on the reach level, while the Low RSLC curve’s matrix is shown on the waterfront scale. *Sub-Appendix E.1: RED Report* and *Sub-Appendix E.2: OSE Report* discuss each metric used in the matrices in more detail, including what the FWOP conditions are and how the scoring criteria were generated to assign ordinal rankings to each plan in the array of alternatives.

**Table A-34: Waterfront-Wide, Low RSLC Curve, Comprehensive Benefits Matrix**

| Category                            | Items                                           | Alt B | Alt C | Alt D | Alt E | Alt F | Alt G |
|-------------------------------------|-------------------------------------------------|-------|-------|-------|-------|-------|-------|
| <b>RED Account</b>                  |                                                 |       |       |       |       |       |       |
| Business Economic Disruptions       | Reduced business disruption benefits            |       |       |       |       |       |       |
| <b>OSE Account</b>                  |                                                 |       |       |       |       |       |       |
| Health and Safety                   | Coastal life safety risk (overtopping)          |       |       |       |       |       |       |
|                                     | Seismic life safety risk and resilience         |       |       |       |       |       |       |
|                                     | Compromised disaster response sites             |       |       |       |       |       |       |
| Economic Vitality                   | Job access                                      |       |       |       |       |       |       |
|                                     | Maritime                                        |       |       |       |       |       |       |
| Social Connectation                 | Public transit mobility                         |       |       |       |       |       |       |
| Community Identity                  | Community and cultural assets                   |       |       |       |       |       |       |
| Social Vulnerability and Resiliency | Vulnerable population exposure                  |       |       |       |       |       |       |
|                                     | Disproportionate effects on at-risk communities |       |       |       |       |       |       |
|                                     | Permanently displaced population                |       |       |       |       |       |       |
|                                     | Affordable housing exposed                      |       |       |       |       |       |       |
| <b>EQ Account</b>                   |                                                 |       |       |       |       |       |       |
| Physical Environment                | HTRW contaminated sites                         |       |       |       |       |       |       |
|                                     | Carbon sequestration                            |       |       |       |       |       |       |
|                                     | Water quality                                   |       |       |       |       |       |       |
|                                     | EWN to reduce wave runup                        |       |       |       |       |       |       |
| Biological Environment              | Habitat (NNBF)                                  |       |       |       |       |       |       |
|                                     | Threatened and endangered species               |       |       |       |       |       |       |

**Table A-35: Reach 1, Intermediate RSLC Curve, Comprehensive Benefits Matrix**

| Category                            | Items                                           | Alt B | Alt C | Alt D | Alt E | Alt F | Alt G |
|-------------------------------------|-------------------------------------------------|-------|-------|-------|-------|-------|-------|
| <b>RED Account</b>                  |                                                 |       |       |       |       |       |       |
| Business Economic Disruptions       | Reduced business disruption benefits            |       |       |       |       |       |       |
| <b>OSE Account</b>                  |                                                 |       |       |       |       |       |       |
| Health and Safety                   | Coastal life safety risk (overtopping)          |       |       |       |       |       |       |
|                                     | Seismic life safety risk and resilience         |       |       |       |       |       |       |
|                                     | Compromised disaster response sites             |       |       |       |       |       |       |
| Economic Vitality                   | Job access                                      |       |       |       |       |       |       |
|                                     | Maritime metrics                                |       |       |       |       |       |       |
| Social Connection                   | Public transit mobility                         |       |       |       |       |       |       |
| Community Identity                  | Community and cultural assets                   |       |       |       |       |       |       |
| Social Vulnerability and Resiliency | Vulnerable population exposure                  |       |       |       |       |       |       |
|                                     | Disproportionate effects on at-risk communities |       |       |       |       |       |       |
|                                     | Permanently displaced population                |       |       |       |       |       |       |
|                                     | Affordable housing                              |       |       |       |       |       |       |
| <b>EQ Account</b>                   |                                                 |       |       |       |       |       |       |
| Physical Environment                | HTRW contaminated sites                         |       |       |       |       |       |       |
|                                     | Carbon sequestration                            |       |       |       |       |       |       |
|                                     | Water quality                                   |       |       |       |       |       |       |
|                                     | EWN to reduce wave runup                        |       |       |       |       |       |       |
| Biological Environment              | Habitat (NNBF)                                  |       |       |       |       |       |       |
|                                     | Threatened and endangered species               |       |       |       |       |       |       |

**Table A-36: Reach 2, Intermediate RSLC Curve, Comprehensive Benefits Matrix**

| Category                            | Items                                           | Alt B | Alt C | Alt D | Alt E | Alt F | Alt G |
|-------------------------------------|-------------------------------------------------|-------|-------|-------|-------|-------|-------|
| RED Account                         |                                                 |       |       |       |       |       |       |
| Business Economic Disruptions       | Reduced business disruption benefits            |       |       |       |       |       |       |
| OSE Account                         |                                                 |       |       |       |       |       |       |
| Health and Safety                   | Coastal life safety risk (overtopping)          |       |       |       |       |       |       |
|                                     | Seismic life safety risk and resilience         |       |       |       |       |       |       |
|                                     | Compromised disaster response sites             |       |       |       |       |       |       |
| Economic Vitality                   | Job access                                      |       |       |       |       |       |       |
|                                     | Maritime metrics                                |       |       |       |       |       |       |
| Social Connection                   | Public transit mobility                         |       |       |       |       |       |       |
| Community Identity                  | Community and cultural assets                   |       |       |       |       |       |       |
| Social Vulnerability and Resiliency | Vulnerable population exposure                  |       |       |       |       |       |       |
|                                     | Disproportionate effects on at-risk communities |       |       |       |       |       |       |
|                                     | Permanently displaced population                |       |       |       |       |       |       |
|                                     | Affordable housing                              |       |       |       |       |       |       |
| EQ Account                          |                                                 |       |       |       |       |       |       |
| Physical Environment                | HTRW contaminated sites                         |       |       |       |       |       |       |
|                                     | Carbon sequestration                            |       |       |       |       |       |       |
|                                     | Water quality                                   |       |       |       |       |       |       |
|                                     | EWN to reduce wave runup                        |       |       |       |       |       |       |
| Biological Environment              | Habitat (NNBF)                                  |       |       |       |       |       |       |
|                                     | Threatened and endangered species               |       |       |       |       |       |       |

**Table A-37: Reach 3, Intermediate RSLC Curve, Comprehensive Benefits Matrix**

| Category                            | Items                                           | Alt B | Alt C | Alt D | Alt E | Alt F | Alt G |
|-------------------------------------|-------------------------------------------------|-------|-------|-------|-------|-------|-------|
| <b>RED Account</b>                  |                                                 |       |       |       |       |       |       |
| Business Economic Disruptions       | Reduced business disruption benefits            |       |       |       |       |       |       |
| <b>OSE Account</b>                  |                                                 |       |       |       |       |       |       |
| Health and Safety                   | Coastal life safety risk (overtopping)          |       |       |       |       |       |       |
|                                     | Seismic life safety risk and resilience         |       |       |       |       |       |       |
|                                     | Compromised disaster response sites             |       |       |       |       |       |       |
| Economic Vitality                   | Job access                                      |       |       |       |       |       |       |
|                                     | Maritime metrics                                |       |       |       |       |       |       |
| Social Connection                   | Public transit mobility                         |       |       |       |       |       |       |
| Community Identity                  | Community and cultural assets                   |       |       |       |       |       |       |
| Social Vulnerability and Resiliency | Vulnerable population exposure                  |       |       |       |       |       |       |
|                                     | Disproportionate effects on at-risk communities |       |       |       |       |       |       |
|                                     | Permanently displaced population                |       |       |       |       |       |       |
|                                     | Affordable housing                              |       |       |       |       |       |       |
| <b>EQ Account</b>                   |                                                 |       |       |       |       |       |       |
| Physical Environment                | HTRW contaminated sites                         |       |       |       |       |       |       |
|                                     | Carbon sequestration                            |       |       |       |       |       |       |
|                                     | Water quality                                   |       |       |       |       |       |       |
|                                     | EWN to reduce wave runup                        |       |       |       |       |       |       |
| Biological Environment              | Habitat (NNBF)                                  |       |       |       |       |       |       |
|                                     | Threatened and endangered species               |       |       |       |       |       |       |

**Table A-38: Reach 4, Intermediate RSLC Curve, Comprehensive Benefits Matrix**

| Category                            | Items                                           | Alt B | Alt C | Alt D | Alt E | Alt F | Alt G |
|-------------------------------------|-------------------------------------------------|-------|-------|-------|-------|-------|-------|
| <b>RED Account</b>                  |                                                 |       |       |       |       |       |       |
| Business Economic Disruptions       | Reduced business disruption benefits            |       |       |       |       |       |       |
| <b>OSE Account</b>                  |                                                 |       |       |       |       |       |       |
| Health and Safety                   | Coastal life safety risk (overtopping)          |       |       |       |       |       |       |
|                                     | Seismic life safety risk and resilience         |       |       |       |       |       |       |
|                                     | Compromised disaster response sites             |       |       |       |       |       |       |
| Economic Vitality                   | Job access                                      |       |       |       |       |       |       |
|                                     | Maritime metrics                                |       |       |       |       |       |       |
| Social Connection                   | Public transit mobility                         |       |       |       |       |       |       |
| Community Identity                  | Community and cultural assets                   |       |       |       |       |       |       |
| Social Vulnerability and Resiliency | Vulnerable population exposure                  |       |       |       |       |       |       |
|                                     | Disproportionate effects on at-risk communities |       |       |       |       |       |       |
|                                     | Permanently displaced population                |       |       |       |       |       |       |
|                                     | Affordable housing                              |       |       |       |       |       |       |
| <b>EQ Account</b>                   |                                                 |       |       |       |       |       |       |
| Physical Environment                | HTRW contaminated sites                         |       |       |       |       |       |       |
|                                     | Carbon sequestration                            |       |       |       |       |       |       |
|                                     | Water quality                                   |       |       |       |       |       |       |
|                                     | EWN to reduce wave runoff                       |       |       |       |       |       |       |
| Biological Environment              | Habitat (NNBF)                                  |       |       |       |       |       |       |
|                                     | Threatened and endangered species               |       |       |       |       |       |       |

**Table A-39: Reach 1, High RSLC, Comprehensive Benefits Matrix**

| Category                            | Items                                           | Alt B | Alt C | Alt D | Alt E | Alt F | Alt G |
|-------------------------------------|-------------------------------------------------|-------|-------|-------|-------|-------|-------|
| <b>RED Account</b>                  |                                                 |       |       |       |       |       |       |
| Business Economic Disruptions       | Reduced business disruption benefits            |       |       |       |       |       |       |
| <b>OSE Account</b>                  |                                                 |       |       |       |       |       |       |
| Health and Safety                   | Coastal life safety risk                        |       |       |       |       |       |       |
|                                     | Seismic life safety risk and resilience         |       |       |       |       |       |       |
|                                     | Compromised disaster response assets            |       |       |       |       |       |       |
| Economic Vitality                   | Job access                                      |       |       |       |       |       |       |
|                                     | Maritime                                        |       |       |       |       |       |       |
| Social Connection                   | Public transit mobility                         |       |       |       |       |       |       |
| Community Identity                  | Community and cultural assets                   |       |       |       |       |       |       |
|                                     | Historic asset and district designation         |       |       |       |       |       |       |
| Social Vulnerability and Resiliency | Vulnerable population exposure                  |       |       |       |       |       |       |
|                                     | Disproportionate effects on at-risk communities |       |       |       |       |       |       |
|                                     | Permanently displaced population                |       |       |       |       |       |       |
|                                     | Affordable housing exposed                      |       |       |       |       |       |       |
| <b>EQ Account</b>                   |                                                 |       |       |       |       |       |       |
| Physical Environment                | HTRW contaminated sites                         |       |       |       |       |       |       |
|                                     | Carbon sequestration                            |       |       |       |       |       |       |
|                                     | Water quality                                   |       |       |       |       |       |       |
|                                     | EWN to reduce wave runup                        |       |       |       |       |       |       |
| Biological Environment              | Habitat (NNBF)                                  |       |       |       |       |       |       |
|                                     | Threatened and endangered species               |       |       |       |       |       |       |

**Table A-40: Reach 2, High RSLC Curve, Comprehensive Benefits Matrix**

| Category                            | Items                                           | Alt B | Alt C | Alt D | Alt E | Alt F | Alt G |
|-------------------------------------|-------------------------------------------------|-------|-------|-------|-------|-------|-------|
| <b>RED Account</b>                  |                                                 |       |       |       |       |       |       |
| Business Economic Disruptions       | Reduced business disruption benefits            |       |       |       |       |       |       |
| <b>OSE Account</b>                  |                                                 |       |       |       |       |       |       |
| Health and Safety                   | Coastal life safety risk                        |       |       |       |       |       |       |
|                                     | Seismic life safety risk and resilience         |       |       |       |       |       |       |
|                                     | Compromised disaster response assets            |       |       |       |       |       |       |
| Economic Vitality                   | Job access                                      |       |       |       |       |       |       |
|                                     | Maritime                                        |       |       |       |       |       |       |
| Social Connection                   | Public transit mobility                         |       |       |       |       |       |       |
| Community Identity                  | Community and cultural assets                   |       |       |       |       |       |       |
| Social Vulnerability and Resiliency | Vulnerable population exposure                  |       |       |       |       |       |       |
|                                     | Disproportionate effects on at-risk communities |       |       |       |       |       |       |
|                                     | Permanently displaced population                |       |       |       |       |       |       |
|                                     | Affordable housing exposed                      |       |       |       |       |       |       |
| <b>EQ Account</b>                   |                                                 |       |       |       |       |       |       |
| Physical Environment                | HTRW contaminated sites                         |       |       |       |       |       |       |
|                                     | Carbon sequestration                            |       |       |       |       |       |       |
|                                     | Water quality                                   |       |       |       |       |       |       |
|                                     | EWN to reduce wave runup                        |       |       |       |       |       |       |
| Biological Environment              | Habitat (NNBF)                                  |       |       |       |       |       |       |
|                                     | Threatened and endangered species               |       |       |       |       |       |       |

**Table A-41: Reach 3, High RSLC Curve, Comprehensive Benefits Matrix**

| Category                            | Items                                           | Alt B | Alt C | Alt D | Alt E | Alt F | Alt G |
|-------------------------------------|-------------------------------------------------|-------|-------|-------|-------|-------|-------|
| <b>RED Account</b>                  |                                                 |       |       |       |       |       |       |
| Business Economic Disruptions       | Reduced business disruption benefits            |       |       |       |       |       |       |
| <b>OSE Account</b>                  |                                                 |       |       |       |       |       |       |
| Health and Safety                   | Coastal life safety risk                        |       |       |       |       |       |       |
|                                     | Seismic life safety risk and resilience         |       |       |       |       |       |       |
|                                     | Compromised disaster response assets            |       |       |       |       |       |       |
| Economic Vitality                   | Job access                                      |       |       |       |       |       |       |
|                                     | Maritime                                        |       |       |       |       |       |       |
| Social Connection                   | Public transit mobility                         |       |       |       |       |       |       |
| Community Identity                  | Community and cultural assets                   |       |       |       |       |       |       |
| Social Vulnerability and Resiliency | Vulnerable population exposure                  |       |       |       |       |       |       |
|                                     | Disproportionate effects on at-risk communities |       |       |       |       |       |       |
|                                     | Permanently displaced population                |       |       |       |       |       |       |
|                                     | Affordable housing exposed                      |       |       |       |       |       |       |
| <b>EQ Account</b>                   |                                                 |       |       |       |       |       |       |
| Physical Environment                | HTRW contaminated sites                         |       |       |       |       |       |       |
|                                     | Carbon sequestration                            |       |       |       |       |       |       |
|                                     | Water quality                                   |       |       |       |       |       |       |
|                                     | EWN to reduce wave runup                        |       |       |       |       |       |       |
| Biological Environment              | Habitat (NNBF)                                  |       |       |       |       |       |       |
|                                     | Threatened and endangered species               |       |       |       |       |       |       |

**Table A-42: Reach 4, High RSLC Curve, Comprehensive Benefits Matrix**

| Category                      | Items                                           | Alt B | Alt C | Alt D | Alt E | Alt F | Alt G |
|-------------------------------|-------------------------------------------------|-------|-------|-------|-------|-------|-------|
| <b>RED Account</b>            |                                                 |       |       |       |       |       |       |
| Business Economic Disruptions | Reduced business disruption benefits            |       |       |       |       |       |       |
| <b>OSE Account</b>            |                                                 |       |       |       |       |       |       |
| Health and Safety             | Coastal life safety risk                        |       |       |       |       |       |       |
|                               | Seismic life safety risk and resilience         |       |       |       |       |       |       |
|                               | Compromised disaster response assets            |       |       |       |       |       |       |
| Economic Vitality             | Job access                                      |       |       |       |       |       |       |
|                               | Maritime                                        |       |       |       |       |       |       |
| Social Connection             | Public transit mobility                         |       |       |       |       |       |       |
| Community Identity            | Community and cultural assets                   |       |       |       |       |       |       |
| Social Risk and Resiliency    | At-risk population exposure                     |       |       |       |       |       |       |
|                               | Disproportionate effects on at-risk communities |       |       |       |       |       |       |
|                               | Permanently displaced population                |       |       |       |       |       |       |
|                               | Affordable housing exposed                      |       |       |       |       |       |       |
| <b>EQ Account</b>             |                                                 |       |       |       |       |       |       |
| Physical Environment          | HTRW contaminated sites                         |       |       |       |       |       |       |
|                               | Carbon sequestration                            |       |       |       |       |       |       |
|                               | Water quality                                   |       |       |       |       |       |       |
|                               | EWN to reduce wave runup                        |       |       |       |       |       |       |
| Biological Environment        | Habitat (NNBF)                                  |       |       |       |       |       |       |
|                               | Threatened and endangered species               |       |       |       |       |       |       |

### 14.2.1 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, but 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 (Section 12.0) 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 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.

Beyond the metrics that were correlated with NED benefits are metrics not correlated with the NED benefits. The uncorrelated other benefit categories may justify actions beyond the current actions determined in **Table A-28** that were revised through the correlation analysis (i.e., moving from Alternative G to Alternative E in Reaches 3 and 4), including using structural measures instead of nonstructural measures or building to a higher crest elevation earlier in the POA.

Some of the metrics that are not correlated with flood risk are as follows:

- **Seismic, including Life Safety:** A small portion of seismic benefits of the existing coastal defense system can be found in the NED discussion of the OMRR&R in *Appendix E: Economic and Social Considerations*, but there are seismic impacts to life safety on the wharves and piers and in the waterfront areas. In the FWP, the reduction of these impacts is tied to whether the at-risk wharf structures are replaced, especially along the Embarcadero. Projects that replace seismically at-risk, aging waterfront structures with new, code-compliant structures will inherently reduce the life safety risk of waterfront assets. Additionally, the inclusion of substantial ground improvement in areas at risk for lateral spreading and liquefaction will reduce subsurface seismic hazards, thereby influencing the seismic performance of nearby structures. Alternatives B, C, and D do not replace these wharves (Alternative D does in Subsequent Actions), while Alternatives E through G replace them in First Actions. Whether or not the wharves are replaced will impact life safety and resilience.
- **Resiliency:** A relevant factor for this study is that the adaptations to measures require time to come online. It is a concern that if a higher rate of RSLC is realized, a new measure will take time to be authorized, designed, and constructed such that the residual risk during that period will result in high levels of damages. One way to provide resiliency is to overbuild in the present so that when a higher risk is realized, another action would not need to be taken that might be slow to be constructed. Adaptation strategies (e.g., the Subsequent Actions of Alternatives D through G) build in the potential for quick increases in

crest elevation, but the strategies that do not build on initially constructed risk management structures but build new works instead may be slower. A larger question here is about what will be authorized by Congress. If only the First Actions are authorized, then the Subsequent Actions will take longer to come online because of the need for them to be authorized by Congress again. A discussion of this is provided in the Main Report.

- **Socioeconomics:** Impacts to at-risk communities, in some cases, will track with inundation. In Reach 4, however, where Alternative B is expected to reduce much of the risk of inundation, there is an argument to be made for investment in a structural solution earlier. Flood risk has multiple economic impacts on the community and its residents, and those impacts are amplified in at-risk communities where income and wealth provide less resiliency than communities with higher-income residents. Employment is often tied to community and long-term cultivation of opportunities, rather than professional training that can easily be relocated. Access to employment can be transit-dependent and impacts to transit can cause proportionally large income losses in at-risk communities. One of the largest factors that contribute to generational wealth is homeownership and the appreciation of the family home over time. Risk to floods hampers appreciation and requires continued repair and investment for those fortunate enough to be homeowners. While BCRs may more easily justify investment in higher-value communities, a more nuanced evaluation of the benefits of reducing risk in at-risk communities can justify longer LODs or additional or higher-scaled measures in applicable areas.
- **Concerns with Disruptions:** Constructing structural measures across the San Francisco waterfront is a large-scale undertaking that will have many impacts. Disruptions to transit, both public and private, are expected, which will hamper the ability of people to move about the city. These negative impacts have not been quantified, but there is an argument for constructing a larger measure in high-traffic areas to not have to repeatedly disrupt the study area. In a case like Reach 2, this would mean constructing Alternative G (15.5 feet) immediately instead of Alternative D (13.5 feet). This loss of optionality and earlier cost is traded off with the opportunity to only disrupt the functioning of the city once.
- **Compromised Disaster Response Assets:** In areas where nonstructural actions are recommended, disaster response assets—staging areas, boat launches, mobile hospitals, fire truck connections, and other disaster-related sites—may no longer be accessible during storm events. This may compromise the CCSF's ability to respond to disasters by making it challenging for emergency personnel, supplies, and equipment to reach affected areas. This is one of the types of assets where reducing physical damage through nonstructural means may not be sufficient. Instead, protecting disaster response assets with physical solutions will allow them to function properly and provide value to the waterfront and the city. Considering these assets will support the determination that an

alternative achieves an overall study objective related to post-disaster capacity and resilience.

- **Historic Districts, including community identity and culturally significant landmarks:** Areas along the northern waterfront are cultural and historic assets with significance to the community and region, including several assets on the NRHP. These places drive the regional economy as tourist attractions. Alternatives that preserve or sustain the function and existence of these landmarks contribute benefits and may not be correlated with dollar-denominated benefits that accrue due to reduced flood damages in the study area.
- **Concerns with Water Management Structures:** As discussed in Section 12.0, Alternative F was screened in Reaches 3 and 4 due to acceptability concerns with the water management structures across Islais and Mission creeks. Though those alternatives do a good job of reducing flooding in those areas, the multifaceted concerns about the alternative were such that it was not carried forward south of the Embarcadero.
- **Maritime Berthing:** The maritime functions main driver comprises a metric measuring the exposure of deep draft berthing and backland area, two critical components of an operable maritime port. Several maritime business lines rely on these components of maritime infrastructure so that the maritime industry remains viable. The study area is home to all major POSF operations within the city; therefore, it is important to evaluate each alternative. The PDT evaluated the impacts on these areas, and like with the disaster response assets, these are impacts that cannot be reduced with nonstructural measures.

#### 14.2.2 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 time frame, 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 in 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, and 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 both Alternative C and Alternative F are not 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 how feasible doing multiple adaptive actions was. If the First Actions could be a smaller construction, but 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 sub-reach 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 Actions 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 curves 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; 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.

### 14.3 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 City 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.

The TNBP is summarized in **Table A-43**.

**Table A-43: TNBP 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        |

The costs of the TNBP under all three RSLC scenarios are provided in **Table A-44** through **Table A-46**.

**Table A-44: Cost of First Actions, TNBP**  
(PV, FY 2023 Price Level; \$1,000s)

| Reach | Plan        | Total First Cost | 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    |

**Table A-45: Additional Cost of Subsequent Actions, Intermediate RSLC Curve**  
(PV, FY 2023 Price Level; \$1,000s)

| Reach | Plan   | Total First Cost | Total AAC |
|-------|--------|------------------|-----------|
| 1     | B 2065 | 884              | 26        |
| 2     | -      | -                | -         |
| 3     | D      | 252,965          | 7,451     |
| 4     | D      | 190,295          | 5,605     |

**Table A-46: Additional Cost of Subsequent Actions, High RSLC Curve**  
(PV, FY 2023 Price Level; \$1,000s)

| Reach | Plan | Total First Cost | 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    |

The benefits from the TNBP, especially as they differ from the plans that maximize net NED benefits (described in **Table A-28**), are described in this section and in *Sub-Appendix E.1: RED Report and Sub-Appendix E.2: OSE Report*. The costs and benefits of this plan are provided in **Table A-47** by reach for each of the RSLC curves. Highlighted lines represent scenarios with positive net NED benefits; therefore, that the BCR is greater than 1.

**Table A-47: Costs and Benefits for the TNBP by Reach**  
(PV, FY 2023 Price Level; \$1,000s)

| By Reach | Curve | NED Benefits | Costs     | Net NED Benefits | BCR  |
|----------|-------|--------------|-----------|------------------|------|
| 1        | Low   | 4,528        | 61,864    | -57,336          | 0.07 |
|          | Int   | 51,106       | 62,748    | -11,642          | 0.81 |
|          | High  | 1,341,527    | 380,657   | 960,870          | 3.52 |
| 2        | Low   | 724,238      | 4,098,435 | -3,374,197       | 0.18 |
|          | Int   | 1,570,802    | 4,098,435 | -2,527,633       | 0.38 |
|          | High  | 7,556,338    | 4,102,465 | 3,453,873        | 1.84 |

| By Reach | Curve        | NED Benefits | Costs     | Net NED Benefits | BCR  |
|----------|--------------|--------------|-----------|------------------|------|
| 3        | Low          | 589,739      | 468,672   | 121,067          | 1.26 |
|          | Intermediate | 1,728,206    | 721,637   | 1,006,569        | 2.39 |
|          | High         | 8,709,775    | 1,838,182 | 6,871,593        | 4.74 |
| 4        | Low          | 165,381      | 938,157   | -772,776         | 0.18 |
|          | Intermediate | 350,764      | 1,128,452 | -777,688         | 0.31 |
|          | High         | 3,278,982    | 2,138,628 | 1,140,354        | 1.53 |

Highlighted lines represent scenarios with positive net NED benefits with a BCR greater than 1.

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

- Reach 3 is justified based on NED benefits under all three curves. This speaks to the high existing vulnerability 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 the 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 all the Low and Intermediate curves. This is also expected, considering only nonstructural was 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 and exacerbation of existing inequalities. The RED and OSE analysis suggested a structural measure in Reach 4 maximized total net benefits.
- Reach 1 continues to be nonstructural 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 curves 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 amount of nonstructural recommended for around 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; as such, higher net benefits could be had by relaxing and refining this assumption.
- There are infinite potential RSLC curves between the Low and the 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.

#### 14.4 Contributions to Planning Objectives and Avoidance of Constraints

Alternative plans were judged upon whether they make significant contributions to the planning objectives and sufficiently avoid the constraints. The planning objectives for this study are presented in Section 5.2, and Section 5.6 presents the constraints. For each RSLC, a matrix was created to evaluate how alternatives contribute to the planning objectives and avoid the constraints. Within each matrix, individual cells were scored to show the comparative value for each metric for each alternative under each RSLC curve. The contributions to the planning objectives and the avoidance of constraints were evaluated using the following scoring system:

- High – Alternative performs well in comparison to other alternatives.
- Medium – Alternative performs moderately in comparison to other alternatives.
- Low – Alternative performs poorly in comparison to other alternatives.

**Table A-48** shows the contributions to planning objectives and avoidance of constraints matrix using the USACE Low RSLC scenario. **Table A-49** shows the contributions to planning objectives and avoidance of constraints matrix using the USACE Intermediate RSLC scenario; and **Table A-50** shows the contributions to planning objectives and avoidance of constraints matrix using the USACE High RSLC scenario.

**Table A-48: Waterfront-Wide, Low RSLC Curve, Contributions to Planning Objectives, and Avoidance of Constraints**

| Objectives and Constraints                             | Alt B      | Alt C  | Alt D  | Alt E | Alt F | Alt G  |
|--------------------------------------------------------|------------|--------|--------|-------|-------|--------|
| <b>Planning Objectives</b>                             |            |        |        |       |       |        |
| Reduce Human Health and Safety Risk                    | Low        | Medium | High   | High  | High  | High   |
| Reduce Economic Cost and Risks                         | High       | High   | High   | Low   | Low   | Low    |
| Increase Community Resilience Opportunities            | Medium     | High   | High   | High  | High  | Medium |
| Reduce Maritime Facilities and Functions Disruptions   | Medium     | Medium | Medium | High  | High  | High   |
| Manage Risk to Historic Resources                      | Low        | Medium | High   | High  | High  | Medium |
| Increase Ability and Flexibility to Respond to RSLC    | High       | Low    | Medium | High  | High  | High   |
| <b>Constraints</b>                                     |            |        |        |       |       |        |
| Avoid Actions that Violate Port Trust Responsibilities | High       | High   | High   | High  | High  | High   |
| Minimize Disruption to Permitted Public Access         | High       | High   | High   | High  | High  | High   |
| Maintain Bay Ecological Functions                      | High       | High   | High   | High  | High  | High   |
| Avoid Removing Vital Community Infrastructure          | High       | High   | High   | High  | High  | High   |
| Avoid Major Loss of Housing                            | High (LPF) | High   | High   | High  | High  | High   |

Alt = alternative

LPF = low post-flooding, i.e., the alternative performs poorly (Low) with respect to this constraint after exposure to multiple flood events.

**Table A-49: Waterfront-Wide, Intermediate RSLC Curve, Contributions to Planning Objectives, and Avoidance of Constraints**

| Objectives and Constraints                             | Alt B      | Alt C  | Alt D  | Alt E | Alt F  | Alt G      |
|--------------------------------------------------------|------------|--------|--------|-------|--------|------------|
| <b>Planning Objectives</b>                             |            |        |        |       |        |            |
| Reduce Human Health and Safety Risk                    | Low        | Medium | High   | High  | Medium | Medium     |
| Reduce Economic Cost and Risks                         | High       | High   | Medium | Low   | Low    | Medium     |
| Increase Community Resilience Opportunities            | Low        | High   | High   | High  | High   | Low        |
| Reduce Maritime Facilities and Functions Disruptions   | Low        | Medium | Medium | High  | High   | High       |
| Manage Risk to Historic Resources                      | Low        | Medium | High   | High  | High   | Low        |
| Increase Ability and Flexibility to Respond to RSLC    | High       | Low    | Medium | High  | High   | High       |
| <b>Constraints</b>                                     |            |        |        |       |        |            |
| Avoid Actions that Violate Port Trust Responsibilities | High       | High   | High   | High  | High   | High       |
| Minimize Disruption to Permitted Public Access         | High       | High   | High   | High  | High   | High       |
| Maintain Bay Ecological Functions                      | High       | High   | High   | High  | High   | High       |
| Avoid Removing Vital Community Infrastructure          | High       | High   | High   | High  | High   | High       |
| Avoid Major Loss of Housing                            | High (LPF) | High   | High   | High  | High   | High (LPF) |

Alt = alternative

LPF = low post-flooding, i.e., the alternative performs poorly (Low) with respect to this constraint after exposure to multiple flood events.

**Table A-50: Waterfront-Wide, High RSLC, Contributions to Planning Objectives, and Avoidance of Constraints**

| Objectives and Constraints                             | Alt B      | Alt C      | Alt D      | Alt E | Alt F  | Alt G      |
|--------------------------------------------------------|------------|------------|------------|-------|--------|------------|
| <b>Planning Objectives</b>                             |            |            |            |       |        |            |
| Reduce Human Health and Safety Risk                    | Low        | Medium     | Medium     | High  | High   | High       |
| Reduce Economic Cost and Risks                         | High       | Medium     | Medium     | Low   | Low    | High       |
| Increase Community Resilience Opportunities            | Low        | Low        | Low        | High  | High   | Medium     |
| Reduce Maritime Facilities and Functions Disruptions   | Low        | Low        | Low        | High  | Medium | Medium     |
| Manage Risk to Historic Resources                      | Low        | Low        | Medium     | High  | High   | High       |
| Increase Ability and Flexibility to Respond to RSLC    | High       | Low        | Medium     | High  | High   | High       |
| <b>Constraints</b>                                     |            |            |            |       |        |            |
| Avoid Actions that Violate Port Trust Responsibilities | High       | High       | High       | High  | High   | High       |
| Minimize Disruption to Permitted Public Access         | High (LPF) | High (LPF) | High (LPF) | High  | High   | High       |
| Maintain Bay Ecological Functions                      | High       | High       | High       | High  | Medium | High       |
| Avoid Removing Vital Community Infrastructure          | High (LPF) | High (LPF) | High       | High  | High   | High       |
| Avoid Major Loss of Housing                            | High (LPF) | High (LPF) | High (LPF) | High  | High   | High (LPF) |

Alt = alternative

LPF = low post-flooding, i.e., the alternative performs poorly (Low) with respect to this constraint after exposure to multiple flood events.

## 14.5 Contributions to P&G Formulation and Evaluation Criteria

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

For each RSLC, a matrix was created to evaluate how alternatives contribute to the P&G criteria. Within each matrix, individual cells were scored to show the comparative value for each metric under each alternative for each RSLC curve. The contributions to the P&G criteria were evaluated using the following scoring system:

- High – Alternative performs well in comparison to other alternatives.
- Medium – Alternative performs moderately in comparison to other alternatives.
- Low – Alternative performs poorly in comparison to other alternatives.

**Table A-51** shows the contributions to the P&G formulation and evaluation criteria using the USACE Low RSLC scenario. **Table A-52** shows the contributions to the P&G formulation and evaluation criteria using the USACE Intermediate RSLC scenario; and **Table A-53** shows the contributions to the P&G formulation and evaluation criteria using the USACE High RSLC scenario. The contributions to the P&G formulation and evaluation criteria were evaluated.

**Table A-51: Waterfront-Wide, Low RSLC Curve, Evaluation of Alternatives Against Four P&G Formulation and Evaluation Criteria**

| Criteria      | Alternative B | Alternative C | Alternative D | Alternative E | Alternative F       | Alternative G |
|---------------|---------------|---------------|---------------|---------------|---------------------|---------------|
| Completeness  | High          | High          | High          | High          | High                | High          |
| Effectiveness | Medium        | Medium        | Medium        | High          | High                | High          |
| Efficiency    | High          | High          | High          | Low           | Low                 | Low           |
| Acceptability | High          | High          | High          | High          | Medium <sup>a</sup> | High          |

<sup>a</sup>Acceptability concerns of Alternative F are related to water management structures (*Appendix E: Economic and Social Considerations*).

**Table A-52: Waterfront-Wide, Intermediate RSLC Curve, Evaluation of Alternatives Against Four P&G Formulation and Evaluation Criteria**

| Criteria      | Alternative B | Alternative C | Alternative D | Alternative E | Alternative F       | Alternative G |
|---------------|---------------|---------------|---------------|---------------|---------------------|---------------|
| Completeness  | High          | High          | High          | High          | High                | High          |
| Effectiveness | Medium        | Medium        | Medium        | High          | High                | Medium        |
| Efficiency    | High          | High          | High          | Low           | Low                 | Medium        |
| Acceptability | High          | High          | High          | High          | Medium <sup>a</sup> | High          |

<sup>a</sup>Acceptability concerns of Alternative F are related to water management structures (*Appendix E: Economic and Social Considerations*).

**Table A-53: Waterfront-Wide, High RSLC, Evaluation of Alternatives Against Four P&G Formulation and Evaluation Criteria**

| Criteria      | Alternative B | Alternative C | Alternative D | Alternative E | Alternative F       | Alternative G |
|---------------|---------------|---------------|---------------|---------------|---------------------|---------------|
| Completeness  | High          | High          | High          | High          | High                | High          |
| Effectiveness | Medium        | Medium        | Medium        | High          | High                | High          |
| Efficiency    | High          | Medium        | Medium        | Medium        | Medium              | High          |
| Acceptability | High          | High          | High          | High          | Medium <sup>a</sup> | High          |

<sup>a</sup>Acceptability concerns of Alternative F are related to water management structures (*Appendix E: Economic and Social Considerations*).

## 15.0 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) and the effects and consequences analysis documented in Section 4.0. The TSP (**Table A-54**) was presented in the draft IFR/EIS, along with the evaluation results, for public and agency comment.

**Table A-54: TSP First and Potential Subsequent Actions**

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

## 16.0 Independent Measures

The following list of independent measures represent a series of measures included in the 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 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 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 LRV track. This is comparable to Alternative G (around 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 northern 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 Actions).
- **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.

## 17.0 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 improvements 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 compared to 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 in 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 as a modification to the TSP presented in the Draft IFR/EIS.

## 18.0 References

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