SAN FRANCISCO WATERFRONT COASTAL FLOOD STUDY, CA

DRAFT APPENDIX G MONITORING AND ADAPTATION PLAN

JANUARY 2024

USACE TULSA DISTRICT | THE PORT OF SAN FRANCISCO

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Acronyms and Abbreviations

Acronym	Definition
AMT	Adaptation Management Team
CSRM	Coastal Storm Risk Management
EIS	Environmental Impact Statement
HTRW	Hazardous, Toxic, and Radioactive Waste
IFR	Integrated Feasibility Report
IFR/EIS	Integrated Feasibility Report/Environmental Impact Statement
MAP	Monitoring and Adaptation Plan
NAVD	North American Vertical Datum
NFS	Non-Federal Sponsor
PDT	Project Delivery Team
PED	Preconstruction Engineering and Design
POSF	Port of San Francisco
RSLC	Relative Sea level Change
SFWCFS	San Francisco Waterfront Coastal Flood Study
SLC	Sea Level Change
SLR	Sea Level Rise
TNBP	Total Net Benefits Plan
TSP	Tentatively Selected Plan
USACE	U.S. Army Corps of Engineers

1. Introduction

This appendix provides a feasibility-level monitoring and adaptation plan for the San Francisco Waterfront Coastal Flood Study (SFWCFS) Draft Integrated Feasibility Report and Environmental Impact Statement (IFR/EIS), which proposes coastal flood risk management opportunities for the San Francisco waterfront. This draft IFR/EIS will be used to inform decision makers, stakeholders, and the public of the tradeoffs that should be considered in future decisions to maintain coastal flood risk levels and/or reduce coastal storm risk along the San Francisco waterfront.

This draft Monitoring and Adaptation Plan (MAP) describes the goals, governance, and process for successful monitoring, adaptation, and phasing of the Tentatively Selected Plan (TSP). This draft MAP will be refined for the Final IFR/EIS. Additionally, the MAP is structured to be a living document and is expected to be updated throughout the project life (100 years), by the U.S. Army Corps of Engineers (USACE) and the Port of San Francisco (POSF), in coordination with other collaborating agencies.

The level of detail in this plan is based on currently available data and information developed during plan formulation as part of the feasibility study. Uncertainties remain concerning the exact project features, monitoring elements, and adaptive management opportunities because of the dynamics and uncertainties of climate change and relative sea level change. Uncertainties will continue to be identified, evaluated, and addressed in the Final IFR/EIS as well as the preconstruction engineering and design (PED) phase; this plan will be revised during the PED phase to incorporate more detailed monitoring, adaptive management plans, and cost breakdowns.

Sea level change is the main driver of coastal flooding risk in the study area. There is considerable uncertainty about the rate of sea level change. Different rates of sea level change will necessitate implementing coastal flood risk management actions at different times. The MAP provides a basis for determining the scale and timing of adaptation actions to mitigate coastal flooding risks.

1.1 Purpose of the MAP

The purpose of this MAP is to provide a framework that will ensure long-term project success. Project success is determined by monitoring metrics that are tied to project objectives, targets, and thresholds. The goals, activities, and procedures outlined in this draft MAP will be fully defined by the Adaptation Management Team (see Section 3) during the Pre-construction Engineering and Design (PED) phase, prior to project construction. This document identifies and describes the monitoring, adaptation, and phasing activities proposed for the project.

As a living document, this MAP will be updated, added to, and refined as the project progresses over time. It is expected that adjustments to project design, implementation, monitoring, evaluations, and adaptive actions will occur as the Adaptation Management Team learns from the implementation of the project as sea level changes. This version of the MAP includes a general process for monitoring, adaptation, and phasing that is expected to be refined by the Adaptation Management Team over time.

1.2 Adaptive Management

The MAP has been developed based on the principles of adaptive management used for ecosystem restoration projects. Adaptive management is a rigorous approach for deliberately designing and implementing management actions to test hypotheses and maximize learning about critical uncertainties that affect management decisions, while simultaneously striving to meet multiple management objectives. It is an approach to management that involves synthesizing existing knowledge and identifying critical uncertainties, developing hypotheses related to those critical uncertainties, exploring alternative actions to test those hypotheses, making explicit predictions of their outcomes including level of risk involved with implementation, selecting one or more actions to implement, conducting monitoring and research to see if the actual outcomes match those predicted, and then using these results to learn and adjust further management and policy (Walters, 1986; Walters, 2007; Taylor et al., 1997; Murray and Marmorek, 2003; Williams et al., 2009; Smith, 2011). This sequence is summarized in a six-step process (**Figure G-1**), although this is a simplification of a process which in practice does not flow so sequentially through the steps but is more often iterative between certain steps. The adaptive management cycle depicted in **Figure G-1** and the description below is in alignment with the US Department of Interior's technical guide to adaptive management (Williams et al., 2009).

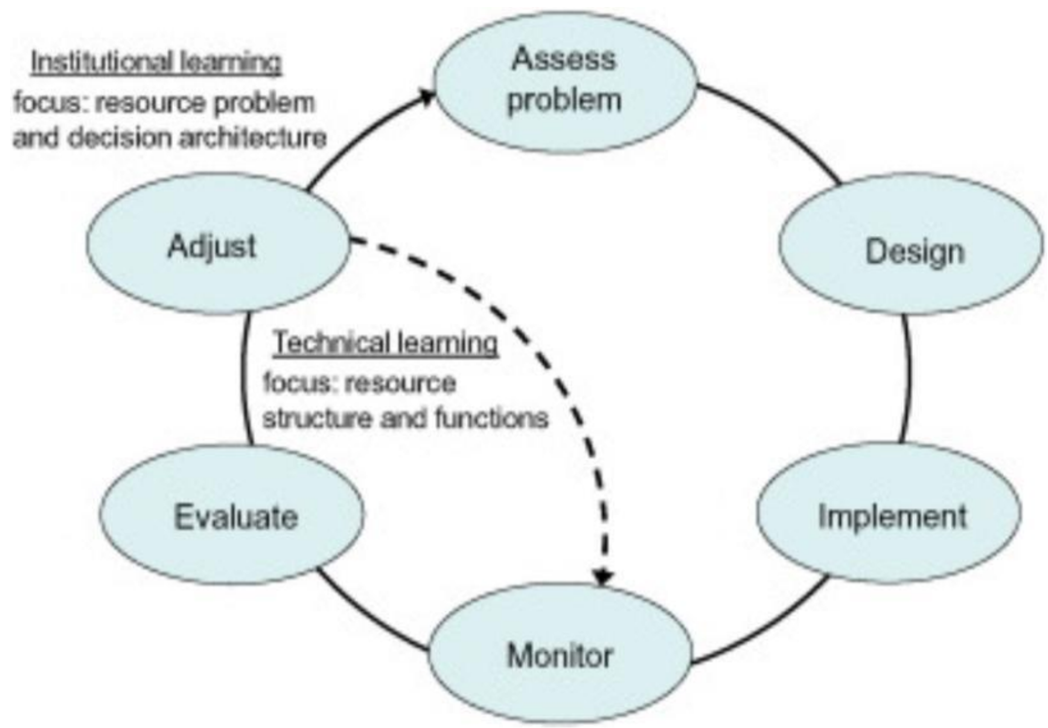


Figure G-1: Adaptive Management Process

2. Plan Formulation

2.1 Project Goals and Objectives

During the plan formulation process, the PDT, with stakeholder input, developed goals and objectives to be achieved by the SFWCFS.

Two broad study goals were identified to develop and implement a resilience strategy to address the multiple risks within the study area. These goals complement the larger resilience efforts proposed by the City of San Francisco in their Resilient SF initiative that will align City agency actions to achieve long-term capability to survive, adapt, and grow within an area with multiple hazards:

- Plan and Prepare: Characterize the multiple study area risks and consequences to inform the range of potential responses and appropriate timing of risk reduction investments to complement and sustain the area’s uses, economic and maritime activity, cultural and historic significance, and residential centers.
- Empower resilience investments: Define an innovative long-term menu of responses to increasing risk that will coordinate or launch cost-effective resilience actions from the City and regional agencies. Align investment with future needs for cost-effective and timely implementation.

A third study goal was subsequently identified to develop a cost-effective method for addressing flooding risk dominated by uncertain timing of RSLC.

The overarching goal of this study is to formulate alternatives for coastal flood risk management to determine if Federal participation in reduction of impacts to people and property caused by coastal flooding within the study area is feasible.

Specific study objectives have been developed to provide a means of determining whether individual management measures can solve the study area’s problems while taking advantage of the opportunities identified and avoiding the constraints. The following study objectives have been developed based on the problems, opportunities, goals, and Federal objectives:

- Reduce risk to human health and safety from coastal hazards and combined flooding in the City of San Francisco
- Reduce costs and risks to national economic development associated with coastal hazards and combined flooding to business, residents, and infrastructure in the City of San Francisco
- Improve the resilience of the local and regional economy to impacts from coastal hazards and combined flooding
- Maximize social benefits and improve resilience of affected communities to impacts from coastal hazards and combined flooding

- Minimize disproportionate impacts to vulnerable communities, including low income and communities of color
- Minimize 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
- Maximize resilience of City transportation infrastructure that is essential to the daily operations and functioning of the city
- Minimize damages from coastal hazards and combined flooding to historic resources and preserve the maritime history of the waterfront
- Maximize ability and flexibility to respond to uncertain rates of relative sea level change
- Leverage public investment in coastal flood risk reduction to reduce earthquake risks
- Maximize environmental benefits, sustainable approaches in project design and construction, and consideration of coastal processes
- Promote and enhance public access to the San Francisco waterfront and San Francisco Bay and minimize disruptions to waterfront access and use
- Preserve, defend, and adapt existing housing, community services and facilities (e.g., libraries, community centers, health centers, homeless shelters, etc.), and cultural and historic resources from rising sea levels and coastal flooding

2.2 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 period of analysis. Adaptations were described in sufficient detail to support estimation of benefits and costs of the alternatives, and scales of adaptation correspond to the target level of performance of each alternative. At this initial stage of plan development, implementation was assumed to occur in a two-step process with the first action occurring in 2040 and second action occurring in 2090. However, the MAP will ultimately be used to model what the forecasted implementation strategy might look like given the associated risks, and to refine implementation dates. This MAP will ultimately address how the USACE and Port will manage the risks of RLSC over time through implementation of subsequent Federal actions, in congruence with City-plans, to outline the need to identify triggers for risk assessment, management, and implementation. The MAP framework includes, but is not limited to:

- Identify thresholds of RSLC that would trigger the need for additional action to avoid increased harm to people or property

- Evaluate the options to address the SLC risk based on those thresholds, considering other factors such as life of asset, other planned projects, and disruption from the construction period
- Describe coordination and involvement of resource agencies, USACE, Port, City, and State to manage the risks over time
- Develop the governance and executive structure that would make project decisions and recommend additional actions to Federal, State, and Local policymakers
- Identify an approach for funding and construction based on thresholds of projected SLR, including appropriate lead times for planning, design, and construction and margin of safety before intervention is needed
- Recommend approaches for Congressional authorization and future PED strategies that will enable USACE and the Port to more efficiently implement Second Actions given the uncertainty regarding future rates of RSLC
- Clarify appropriate scale and alignment of features to be constructed in time to reduce vulnerability to flooding in the study area

2.3 The Tentatively Selected Plan

As described in the Main Report and *Appendix A, Plan Formulation*, the Tentatively Selected Plan (TSP) includes recommended first and second actions to reduce coastal flood risk as shown in Error! Reference source not found. below.

Table G-1: TSP First and Second Actions

Reach	First Action	Second Action Low RSLC	Second Action Intermediate RSLC	Second Action High RSLC
1	Alternative B	N/A	Alternative B (Additional NS)	Alternative G 19’
2	Alternative G 15.5’	N/A	N/A	Alternative G 19’
3	Alternative D 13.5’	N/A	Alternative D 15.5’	Alternative E 19’
4	Alternative D 13.5’	N/A	Alternative D 15.5’	Alternative E 19’

Proposed First Actions will be refined in response to comments from the public, the Port and City departments, State and Federal agencies and USACE reviewers as the Study progresses. Proposed Second Actions may also be refined.

Note that for the TSP, proposed Second Actions vary depending on the rate of sea level rise. At this stage of the planning process, Second Actions were analyzed assuming implementation in the 2090 timeframe.

It is not the intention of the Project Delivery Team (PDT) to propose at this time the exact adaptive management strategy which will be implemented by future generations or the timing of those subsequent interventions. The MAP will enable USACE and POSF and other collaborating agencies to have more clarity about the process for adaptive management over time.

2.4 Planning and Design of Second Actions

The PDT is not proposing the specific scale or timing of Second Actions. Instead, future generations will have the flexibility to develop those Second Actions consistent with future conditions, values, and fiscal constraints. The MAP will be flexible enough to allow reformulation of plans in the future consistent with the four broad, conceptual, high-level approaches – Defend, Accommodate, Managed Retreat, and Hybrid – that guided plan formulation as described in Appendix A.

This does not mean that future generations will have to start the process over. The PDT will continue to consult with USACE leadership and the Assistant Secretary of the Army – Civil Works regarding approaches to Congressional authorization of this San Francisco Waterfront Coastal Flood Study that could, for instance, allow Congress to authorize funding for planning and design of Second Actions at the same time it authorizes funding for construction of First Actions.

This approach may be a particularly important strategy for areas of the waterfront where one or more RSLC projections suggests the potential need for implementation of Second Actions soon after completion of First Actions. See the discussion regarding *lead time* below.

2.5 Adaptation Strategy

The TSP was informed by a preliminary assessment of the regret of overinvestment and underinvestment and responds to different RSLC scenarios but does not address multi-hazard scenarios as part of its first adaptation actions or include sub-reach level refinements. The PDT will consider these issues as part of continuing plan refinement for the final report.

There are many uncertainties that need to be considered if the final recommended plan is to be an economically efficient, risk informed plan that addresses multiple hazards. These uncertainties include but are not limited to a high level of uncertainty in the rates of RSLC along the San Francisco shoreline and resulting coastal flood damages; the high risk of life loss and injury in the event of an earthquake; the residual life of historic assets along the waterfront that are implicated by the plan that will require replacement in the next 40 years; and affordability of the plan, now and in the future.

The PDT will consider these uncertainties, conduct further Regret and Adaptation Analysis, and review public comment on the draft report to make changes to the TSP and to develop a more refined phasing plan and revisions to the MAP for the final report.

In developing the TSP, the PDT used 2040 and 2090 as planning-level proxies for 1st and 2nd adaptation actions. Using the FWOP and FWP risk and total benefits analysis, the PDT arrived at the TSP with a series of initial actions to address 1.5 ft of sea level change, with a range of second actions to address 3.5 ft of sea level change. Both the initial and second actions were drawn from the existing alternatives.

To address the uncertainties detailed above within the final plan, the PDT proposes to continue applying a Regrets and Adaptation Analysis. An initial regrets analysis was undertaken in developing the TSP and will be refined as the study advances to support decision-making about the cost and scale of first and subsequent adaptation actions.

The analysis completed to date considered the regret of over or under investment in response to different RSLC scenarios based on the Low, Intermediate and High USACE RSLC scenarios (**Figure G-2)**, and the high current seismic risk.

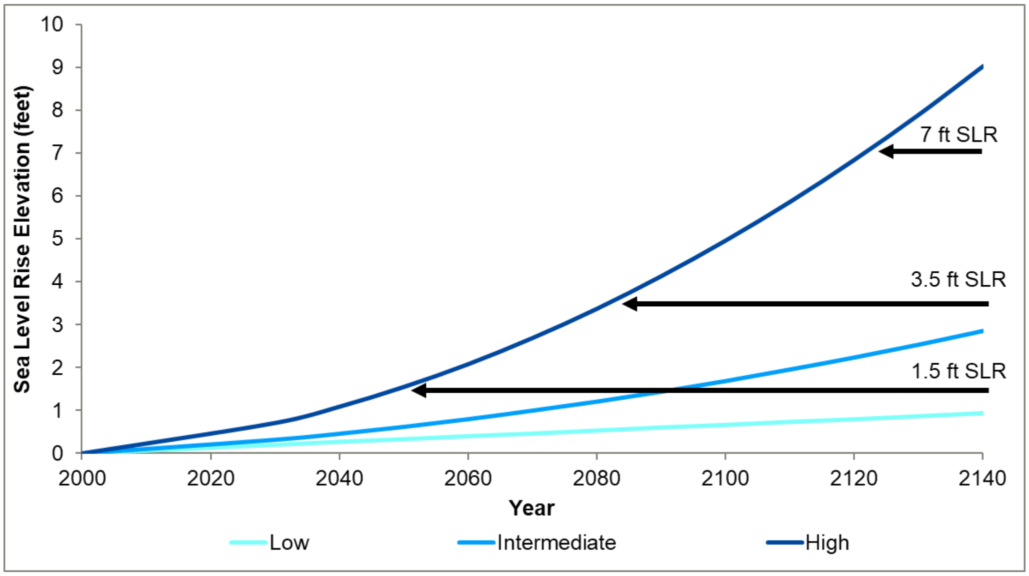


Figure G-2: USACE RSLC Projections

Examples of regret of overinvestment that were considered include:

- Negative net benefits associated with construction of plan features too far in advance of RSLC increasing floods to the design water level;
- Introducing future coastal life safety risk by raising the existing shoreline where retreat from the future floodplain is a viable option

- Inability for the current generation to pay (e.g., insufficient funding in the USACE annual budget or insufficient local capital funding for the coastal flood risk management project local match and/or required HTRW cleanup activities)

Examples of underinvestment that were considered include:

- Substantial monetary and non-monetary damages due to coastal flooding overtopping the shoreline (high residual risk)
- Failure to address seismic life safety risk in vulnerable structures along the shoreline
- Loss of historic resources before planned wharf replacements
- Non-adaptive initial investment
- Inability for a future generation to pay

In the plan refinement phase of the study the PDT will further develop the regrets analysis and undertake an adaptation analysis. The PDT intends to use this Regrets and Adaptation Analysis to shape a final recommendation regarding federal and local investment in a coastal flood risk management system by:

- Examining first and possible second adaptation actions and the scaling (sizing) of these actions
- Considering both phasing and anticipatory (precautionary) actions given the uncertainties
- Developing defined triggers to begin design or construction of subsequent adaptation actions

This additional analysis will allow the PDT to develop a phasing plan with adaptation pathways and defined triggers for subsequent action that can be considered as part of the final recommended plan.

The adaptation analysis will include an examination of the timing of second adaptation actions, the lead time to design and construct those actions, and when design or construction work needs to start given the projected performance of first adaptation actions under the Low, Intermediate, and High USACE RSLC scenarios.

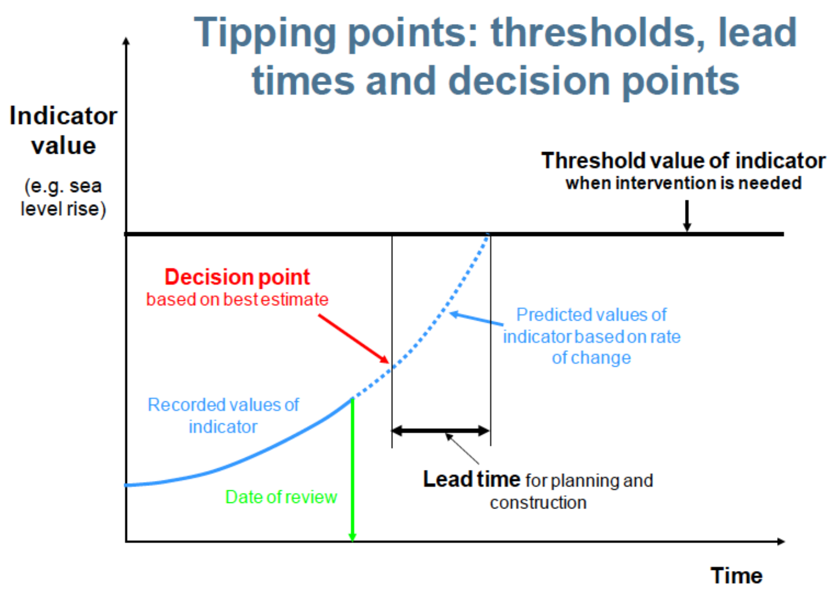
The current state of RSLC science has a level of uncertainty that does not allow the PDT to recommend one RSLC scenario to inform scaling of actions and phasing, which is consistent with Study Guidance. According to the latest Federal interagency analysis (Sweet 2022), the current sea level change trend is slightly above the intermediate RSLC curve. Certainty on the rates of RSLC will improve over time and the PDT expects the Federal government and the State of California will publish new guidance related to RSLC projections with increasing levels of confidence to support decision-making, reinforcing the need for a flexible decision-making framework.

Based on current science, the Low, Intermediate, and High RSLC scenarios do not produce significant differences until between 2040 and 2050 (**Figure G-2**). With improving science and understanding of emissions in the coming decades, it is reasonable to assume that between 2040 and 2050, USACE and the Port will have greater certainty about the actual RSLC trajectory.

When assessing the trigger points to plan for the second and/or subsequent actions, it is important to understand and consider the timescales for planning, design, construction, and acquisition of funding to estimate a “lead time”. **Figure G-3** depicts how to consider lead time in an adaptation framework.

The PDT estimated an initial lead time that suggested if the RSLC tracks the projected high rate of rise, the USACE would need to request, and Congress would need to authorize and appropriate funding, for the design of the subsequent adaptation action(s) before the construction of the first adaptation actions are completed. Furthermore, the recommendation would need to be authorized and funding appropriated before any RSLC monitoring program may signal that the rate of rise is tracking on the high USACE RSLC curve.

This finding suggests considering a range of precautionary (anticipatory) actions in the final recommended plan. This finding also suggests phasing and scaling of first adaptation actions in a manner that allows both the Federal and non-Federal Sponsor sufficient time to program the financial resources needed to execute subsequent adaptation action(s).



(Source: USACE, EP 1100-2-1)

Figure G-3: Impacts of thresholds and tipping points on future decisions

Based on the preliminary lead time analysis, the PDT is developing a recommended approach for the final report that would consider authorizing the first adaptation action and a range of possible subsequent adaptation action(s), subject to a RSLC monitoring. Additionally, the PDT is working to identify other triggers that would afford advanced investment for subsequent adaptation actions, which could reduce lead times by up to seven years. As discussed above, significant additional time savings can be realized if Congress authorizes and appropriates funding for design and entitlement of subsequent adaptation actions scaled to the High RSLC curve.

The regrets analysis will continue to examine the regret of over-investment and under-investment, with a primary focus on first and second actions in the TSP, to shape a final recommendation for consideration by decision-makers.

As the PDT continues to work on the regret analysis, the intent is to assess the following uncertainties and external factors that may influence an economically efficient adaptation pathway:

- The effect of different RSLC scenarios and the potential for over or under investment
- The spreading of investment over time to make it affordable to this and future generations
- An early action that precludes a preferable future action (such as raising the shoreline now and preventing a future retreat scenario)
- Coastal life safety risk if new CSRM adaptations are holding back the tide on a regular basis, where breach due to earthquake or overtopping might lead to risk to life, and options for reducing this risk through targeted retreat actions
- The opportunity to combine flood and seismic risk reduction that would lead to improved life safety and reduced earthquake damages
- The residual life of the assets along the shoreline and the potential loss of historic resources due to asset deterioration prior to a robust shoreline intervention
- Inability to adapt the first action to accommodate the actual rate of RSLC

3. Governance and Management Structure

As part of the monitoring, adaptation, and phasing process, a team will be established to implement the process. The MAP provides the framework and guidance for an Adaptation Management Team (AMT) to review and assess monitoring results and make recommendations about adaptations and phasing. The AMT is anticipated to be composed of USACE staff, POSF, interested resource agencies, and other stakeholders. The composition of the AMT will be determined for the Final Report.

The AMT focuses on monitoring sea level change and trends within the project area and advise on recommended actions that are consistent with the project goals. The NFS and USACE shall have final determination on all actions and adaptations recommended.

The POSF and USACE are responsible for ensuring that monitoring data and assessments are properly used in the decision-making process. The POSF and USACE are also responsible for project documentation, reporting, and external communication.

It is anticipated that the AMT would meet at least once per year, as scheduled by the POSF and USACE, to assess phasing and determine when adaptations are needed based on the trend of sea level change.

3.1 Team Structure

The AMT will include representatives from USACE and the POSF. The AMT should also include representatives from other agencies, infrastructure operators, and other stakeholders who would serve in an advisory capacity, to assist in evaluation of monitoring data and adaptation planning.

3.2 Communication Structure

A charter defining the AMT's communication structure will be developed during PED. It is expected that the AMT will meet on a periodic basis virtually or at face-to-face meetings. Ad-hoc meetings may be held to facilitate problem solving and reporting.

Communication plans and engagement with stakeholders and the public will also be defined.

3.3 Decision Making and Reporting Process

Decision making is the process of making choices by identifying a decision, gathering information, and assessing alternative resolutions. Using a step-by-step decision-making process can help the AMT make more deliberate, thoughtful decisions by organizing relevant information and defining alternatives. A charter defining the AMT's decision making and reporting process will be developed during PED. Decision makers and reporting pathways will be clearly identified in the charter.

3.4 Management Decisions, Risk and Uncertainty

What makes this project different from other projects is the magnitude of the risk created by uncertainty in the rate of RSLC and the resulting uncertainty in the scale and timing of adaptations necessary to provide flood protection to the San Francisco waterfront. The monitoring, adaptation, and phasing process focuses on operational-scale information that is specific to enabling greater confidence in management decisions, answering questions of greatest importance in making management decisions. This is why the identification of critical uncertainties, and participation of senior managers, is so important in the monitoring, adaptation, and phasing approach: successful and meaningful adaptation requires understanding what it is that managers need to know to increase their confidence in decision-making. It also requires understanding their "decision space" – the range of decisions currently facing managers in the San Francisco waterfront project area, and the degree of flexibility they have in making these decisions. Understanding the "decision space" pertaining to management affecting project goals is important when determining what critical uncertainties and underlying hypotheses will be the focus of learning through adaptive management as well as when designing how to test these hypotheses. It also helps clarify the intended audience for what is learned through the application of adaptive management.

A charter defining the AMT's risk management process will be developed during PED. The AMT will use the Institute for Water Resources Report 92-R-1 "Guidelines for Risk and Uncertainty in Water Resource Planning" as a resource.

Risk is defined as a situation where the decision maker knows all the alternatives available, but each alternative has a number of possible outcomes. Sources of risk and uncertainty that may affect project performance include:

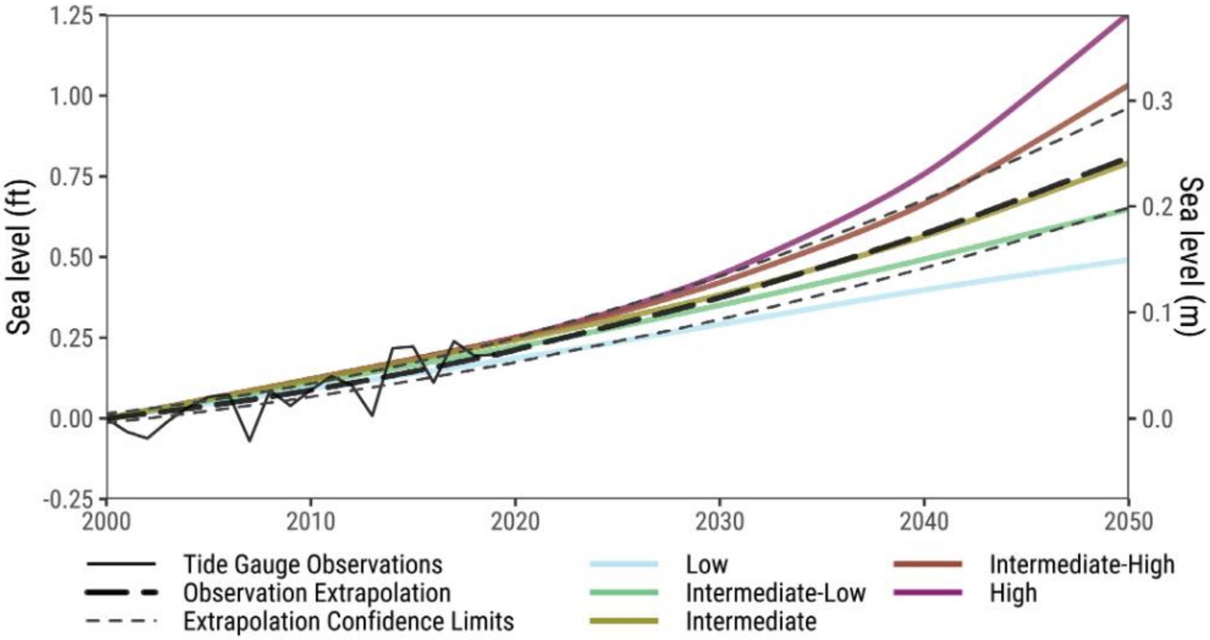
- Climate change
- Relative sea level change
- Disasters such as coastal storms and earthquakes
- Storm frequency
- Funding availability

4. Monitoring

Sea level change is the key driver for the monitoring, adaptation, and phasing process and determining the adaptation strategy. Rather than monitoring individual water level gauges in the study area, the Federal Sea Level Rise and Coastal Flood Hazard Scenarios and Tools Interagency Task Force (Task Force) produces periodic Technical Reports that provide the information needed to support the adaptive management program. These reports (issued about every 5-years) provide global mean sea level rise scenarios that are regionalized for the U.S. coastline. The Task Force, comprised of subject matter experts from eight Federal agencies, including USACE, and academic experts from Rutgers University and Florida International University Institute of Environment relied on these findings to develop regional U.S. based sea level rise projections. The most recent report from the Task Force was published in 2022 (Sweet et al. 2022).

Appendix J: Climate provides more detailed information on climate and sea level change. In addition to sea level rise scenarios, the report includes an "observation-extrapolation" (i.e., an extrapolation of tide gauge data and satellite observations using the methods described in Hamlington et al. (2021) in each region that extends about 30 years into the future). The observation extrapolations were not extended past 2050, as the extrapolations are based on past measurements and do not consider future greenhouse gas emissions, feedback loops, and other factors that will influence future rates of sea level rise.

Figure G-4 presents the observation extrapolation of mean sea level for California and southern Oregon (the Southwest Region in Sweet et al. (2022), which is not exactly aligned with the NCA regions), which highlights that the current trajectory of sea levels along the California coast is aligned with the 2022 Southwest Intermediate scenario.



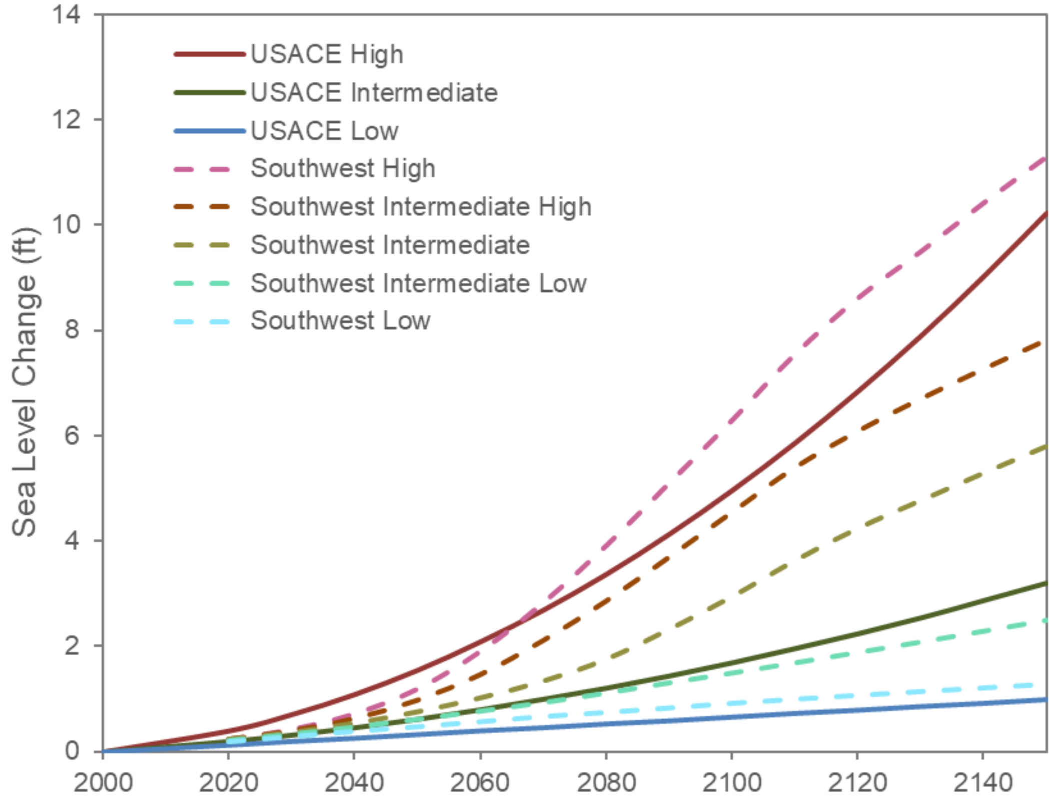
Source: Sweet et al. (2022), Collini et al. (2022)

Average annual water levels from tide gages are overlaid for context. The extrapolation confidence limits represent the 17th and 83rd percentile confidence interval for the observation-based extrapolations.

Figure G-4: Southwest Region (California and Southern Oregon) Sea Level Rise Scenarios and Observation-based Extrapolations

Figure G-5 presents the USACE Low, Intermediate, and High RSLC scenarios used within the SFWCFS relative to the 2022 SLC scenarios for the Southwest region from Sweet et al. (2022). Future updates to the observation extrapolations by the Task Force will be instrumental in assessing the sea level rise trajectory post 2050.

Although continued monitoring of sea level rise through tide gauges and satellites is important for tracking future sea level rise trends, relying solely on monitoring coastal water levels at a single tide gauge is insufficient for projecting future trends. The Presidio tide gauge near the San Francisco shoreline has the longest running history of coastal water level measurements in the western hemisphere (e.g., over 120 years of continuous measurements); however, the tide gauge measurements also include numerous other factors which affect measured water levels, including oceanic cycles (e.g., El Niño/La Niña, the Pacific Decadal Oscillation), low-pressure systems, and seasonal changes in winds and currents. These factors can obscure efforts to track the rate of sea level rise. The observation extrapolations presented in Sweet et al. (2022) rely on a network of tide gauges and satellite observations and provide a more robust future projection.



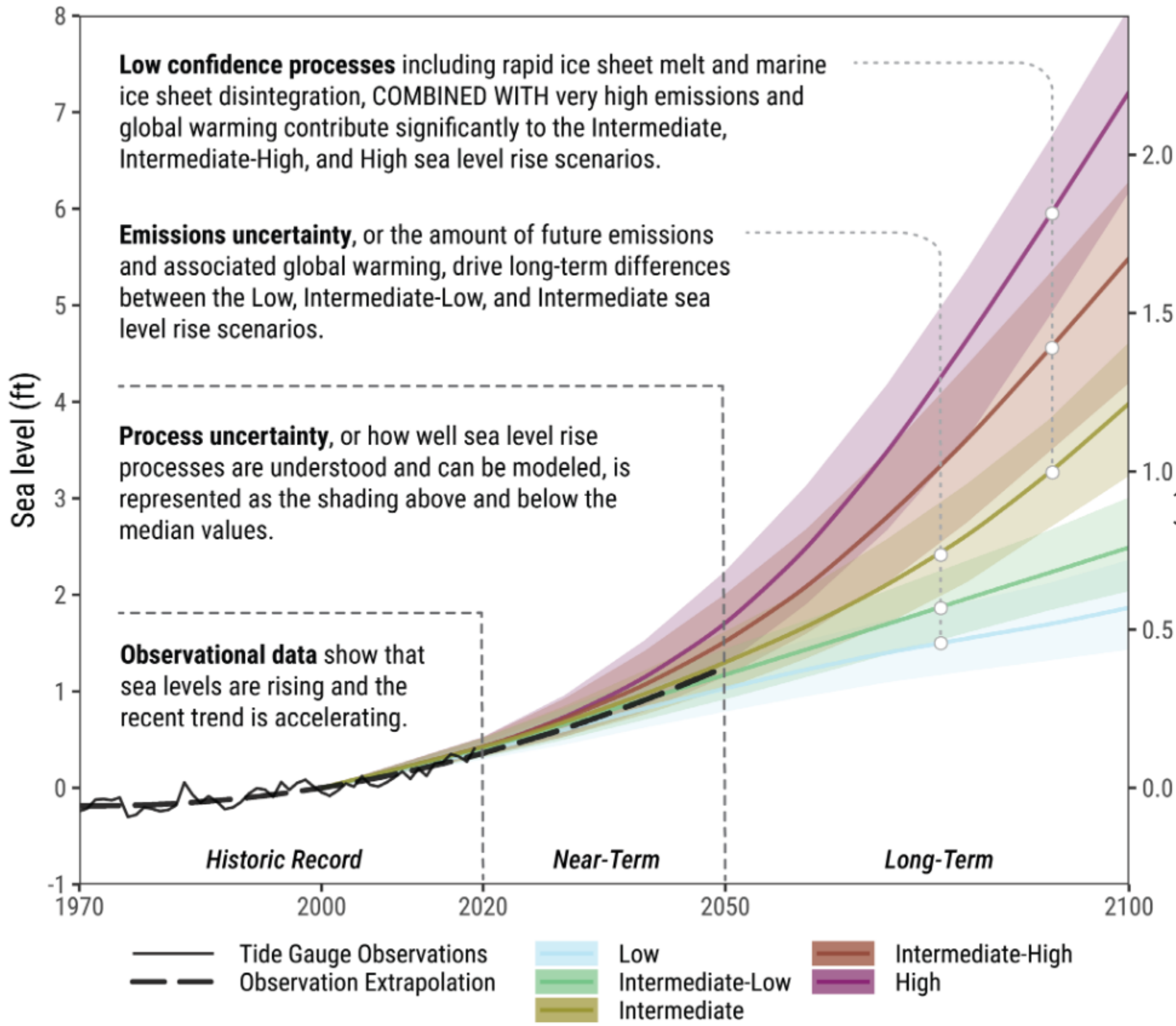
Source: USACE (2020); Sweet et al. (2022)

All projections are baselined to the year 2000 for the purposes of illustration. Inputs for analysis were developed in accordance with USACE requirements, detailed in the Coastal Storms Report within Appendix B.1.

Figure G-5: USACE and the Southwest Region Sea Level Rise Scenarios

After 2050, there are two primary sources of uncertainty related to the future rate of sea level rise (Figure G-6). There is uncertainty in the amount of future greenhouse gas emissions. To date, greenhouse gas emissions have continued to track with the higher emissions scenarios evaluated by the Intergovernmental Panel on Climate Change (IPCC) (IPCC 2023). Tracking both global greenhouse gas emissions and the corresponding amount of global warming may help reduce this uncertainty, but significant global action is required to reverse current trends (IPCC 2023).

There is also uncertainty in the scientific understanding of the processes that contribute to rapid ice sheet melting and marine ice sheet disintegration as the planet warms; therefore, these aspects of sea level rise are considered “low confidence” processes and are not included in the low and intermediate low sea level projections (Figure G-6). These processes are included in the intermediate, intermediate high, and high emissions scenarios (Figure G-6). Scientific understanding of these processes has improved greatly since IPCC (2007), but there is still much that is unknown. Observations clearly depict ice sheet melting, retreat, and the calving of glaciers into the ocean. Understanding ice sheet dynamics and the critical temperature thresholds that could trigger rapid melt and/or disintegration is a rapidly growing field of study (Kopp et al. 2017; Slangen et al. 2017; Golledge et al. 2019; Jennings and Hambrey 2021; Bochow et al. 2023; Noël et al. 2023).



Source: Collini et al. 2022

The ranges within and between the five scenarios represent different sources of uncertainty. Average annual tide-gauge observations and the observation-based extrapolation are overlaid for context.

Figure G-6: Sea Level Rise Scenarios for the Contiguous United States

The IPCC and the Task Force will continue to monitor all sources of uncertainty. Developing best estimates of future sea level rise will likely require the Task Force's observation-based extrapolations, along with a better understanding of ice sheet dynamics. Improving projections of future greenhouse gas emissions may remain challenging as these are governed by politics and human behavior.

5. Monitoring and Adaptation Process

As described in the previous sections, monitoring and adaptation was specifically identified as a project component to ensure that feature construction and maintenance over time continues to advance the study objectives in an efficient manner. This process recognizes that the variability of physical elements, storm risk, and human responses introduce uncertainty to a situation that is already uncertain due to the complexities of evaluating the system.

5.1 Assessment

Assessment describes the process by which the results of RSLC monitoring and other information will be compared to the project performance measures, which reflect the objectives of the project.

The results of the monitoring program will be assessed periodically through the AMT. Monitoring results will be compared to the desired project outcomes and decision-making triggers as set forth by the project performance measures. This assessment process will measure the progress of the project in relation to the stated project objectives and consider adaptation actions.

USACE will document and report the monitoring results, assessments, and the results of the AMT deliberations to the managers and decision-makers designated for the project. Results of the assessments will be used to inform decision-making.

5.2 Decision-Making

Decisions on the implementation of adaptation actions are informed by the assessment of monitoring results as well as the regrets analysis. The information generated by monitoring will be used by USACE and the POSF in consultation with other AMT members to guide decisions that may be needed to ensure that the project achieves success. Final decisions on implementation actions are made by USACE.

If monitoring determines that a management threshold has been crossed (i.e., a ‘trigger’ has been “activated”) USACE and POSF will determine the subsequent actions to be undertaken.

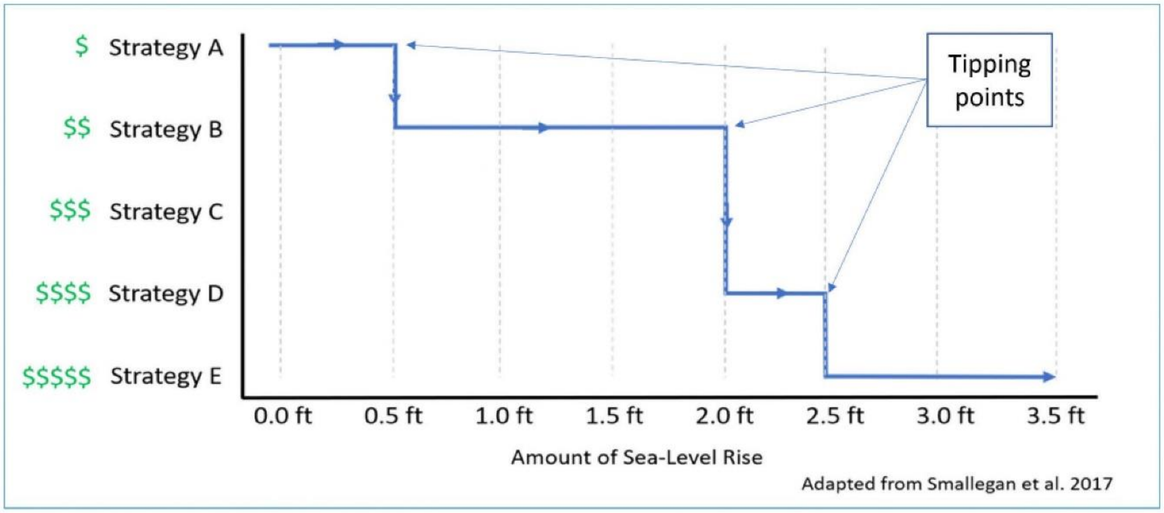
5.3 Adaptation Pathways

The 2022 Task Force report included an application guide (Collini et al. 2022) that was designed to assist decision-makers with applying and integrating the information in the Technical Report. Included in the application guide is a process of using adaptation pathways approach. As defined in the report:

> *“Adaptation pathways identify thresholds, or “tipping points” when an adaptation strategy will no longer be effective (Figure 13). In SLR planning processes, a tipping point can be tied to observed amounts of relative SLR, or any number of other physical, economic, or biological thresholds.*

The various pathways or sequences of actions are also often ordered such that more cost-effective or desired actions are implemented first, whereas more significant or expensive capital projects are deferred to allow time to prepare for more significant and expensive capital projects."

Figure G-7 from the application guide is a conceptualized diagram of an adaptation pathway planning approach that can be used to inform decision-making and the development of adaptations for TSP subsequent actions.



Source: Collini et. al 2022)

Figure G-7: Conceptualized Diagram of Adaptation Pathways Approach

6. Adaptive Management Costs

Costs for the MAP will be refined as the monitoring and coordination efforts are more fully developed for the final report. An annual cost is estimated to be $50,000 for staff time to collect data and coordinate with appropriate study partners or a technical advisory team. MAP activities are contingent on receiving appropriations for design, construction, and operation of the project.

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