DUMBARTON BRIDGE
WEST APPROACH + ADJACENT COMMUNITIES RESILIENCE STUDY TECHNICAL REPORT

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Bay Area Regional Collaborative

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DUMBARTON BRIDGE WEST APPROACH + ADJACENT COMMUNITIES RESILIENCE STUDY

Technical Report • June 2020

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INTRODUCTION

The Dumbarton Bridge, which is part of State Route 84 (SR 84), is a vital link in the Bay Area's transportation network and carries over 81,000 vehicles a day. The western bridge approach area and surrounding communities of Menlo Park and East Palo Alto were previously identified as vulnerable to sea level rise by studies conducted by the Metropolitan Transportation Commission (MTC), the San Francisco Bay Conservation and Development Commission (BCDC), and the County of San Mateo. To address this vulnerability, MTC initiated the Dumbarton Bridge West Approach + Adjacent Communities Resilience Study with support from an SB-1 Adaptation Planning Grant from the California Department of Transportation (Caltrans). The purpose of the project was to develop a phased sea level rise adaptation strategy for the west approach of the bridge and adjacent communities that provides near-term, mid-term, and long-term sea level rise resilience for the critical infrastructure, vulnerable communities, and valuable habitat within the study area. The project was guided by a Project Management Team (PMT) comprising representatives from MTC, Caltrans, City of East Palo Alto, City of Menlo Park, San Francisquito Creek Joint Powers Authority, BCDC, California Coastal Conservancy, and Bay Area Regional Collaborative.

The project area contains a variety of assets and infrastructure that cover a range of transportation, habitat, utilities, and community needs. The existing infrastructure includes: flood protection (including ponds that are part of the South Bay Salt Pond Restoration Project), transportation (including access roads as well as SR 84), infrastructure (including PG&E Ravenswood substation, Menlo Park Fire District training facility, and Facebook Headquarters), and community assets (commercial and residential areas of Menlo Park and East Palo Alto including disadvantaged communities designated as MTC Communities of Concern and the Bay Trail).

There are over 15 prior and on-going studies relevant to sea level rise adaptation efforts in the project area. These were reviewed to identify synergies, common goals, and key findings among the studies to inform and guide the development of project. In particular, alignment and synergies with the SAFER Bay and South Bay Salt Ponds Restoration project were considered throughout.

STAKEHOLDER AND COMMUNITY ENGAGEMENT

The stakeholder and public engagement provided an opportunity for a range of stakeholders and the local community to coordinate with the Project Team on existing projects, to discuss the ways in which the project area is vulnerable to sea level rise and flooding, to understand how this vulnerability affects the community and various assets, and to provide input on the development of adaptation strategies. A Stakeholder Working Group (SWG) formed of 16 organizations including local government, community groups, business organizations, environmental organizations, and state and federal agencies met four times during the project to advise the Project Management Team and consultant team.

There were several parallel climate change engagement efforts being undertaken within the project area at the time of the project, with a focus on Communities of Concern including Nuestra Casa's engagement with BCDC's Adapting to Rising Tides Bay Area project and the Climate Change Community Team being facilitated by Acterra as part of San Mateo County climate change efforts. As a result, and at the recommendation of the City of East Palo Alto (EPA), Nuestra Casa, and Acterra, the community engagement strategy focused on "going to the community" through existing City and community organized events and working closely with the aforementioned community organizations focused on building community capacity for climate resilience. Acterra and Nuestra Casa focus their work on the most vulnerable within the East Palo Alto and Menlo Park area with a focus on reaching community members in a culturally appropriate way and supporting those who speak English as a second language. Both organizations directly advised the project team on community engagement strategy.

REFINED VULNERABILITY ASSESSMENT

A key component of the project was to conduct a refined vulnerability assessment to understand near-, mid-, and long-term flooding and sea level rise vulnerabilities in the project area. Prior assessments of vulnerability in the project area were conducted at a high-level using countywide GIS-based sea level rise inundation maps. More detailed flood hazard modeling and mapping provided a finer scale level of understanding of asset and resource vulnerabilities, by incorporating processes such as storm duration, detention capacity of the ponds, and the physics of overland flow. Specifically, the results from this modeling were used to illustrate how assets first become inundated at lower levels of sea level rise or during extreme tides. In these near-term scenarios, capturing the physics of the flooding processes is very important to develop an accurate depiction of flooding. The modeling results show that the MHHW + 24" scenario is a tipping point for inundation in the project area. Flooding during this scenario impacts only a few assets and is contained to isolated areas near the shoreline. With greater than 24" of sea level rise, flooding becomes widespread across the project area. This indicates that a short-term solution may be adequate to protect up to 24" of sea level rise (or equivalent tide level).

ALTERNATIVES DEVELOPMENT, ANALYSIS, AND EVALUATION

A key objective of the project was to develop alternatives to provide near- and long-term flood protection for the Dumbarton Bridge west approach and adjacent communities, while promoting the ecological and social resilience of the surrounding lands and communities. For the purposes of this project, an "alternative" is defined as a set of complimentary individual "strategies" or "actions" that work together to achieve the project goals for either the near-term or long-term planning horizons. The team developed guiding principles to inform the development of the proposed alternatives including community input, flood protection, ecosystem services and benefits, adaptation pathways and strategy compatibility, public access, and monitoring and adaptive management. The role of ecosystem services and benefits, and the use of green infrastructure, was of particular importance to a number of the stakeholders and community.

In addition to the guiding principles, an alternatives evaluation framework was developed to facilitate a performance assessment of the proposed adaptation strategy alternatives with respect to the project goals. The development of the adaptation alternatives evaluation framework was informed by the guiding principles, MTC's objectives for the study, the review of relevant local studies, the results of the vulnerability assessment, and goals and evaluation criteria from other similar sea level rise adaptation planning projects in the Bay Area and beyond. In addition, local knowledge and expertise of stakeholders and the community informed the development of the adaptation alternatives evaluation framework and its criteria. Criteria were organized around Engineering, Environmental, Feasibility, Social, and Transportation categories.

The development of the adaptation alternatives was conducted in multiple stages. During the first stage of the alternatives development, the project team created an initial list of adaptation strategies. This list was reviewed with the PMT and SWG and additional strategies were identified and added to the list while some were removed. The project team formulated two draft near-term and three draft long-term alternatives that were made up of different combinations of individual strategies. These draft alternatives were further vetted with the PMT and SWG and refined to one near-term and two long-term alternatives. The three final alternatives were then further developed in the Implementation Plans for each alternative.

This project developed alternatives for near-term strategies (Alternative 1) as well as mid- to long-term strategies (Alternative 2 and Alternative 3). Mid- to long-term actions aim to provide flood protection through a high emission, high risk aversion end-of-century sea level rise projection of 83 inches (per OPC 2018) and consider storm surge and wave effects associated with a 100-year coastal storm event.

IMPLEMENTATION PLANS

For each of the three alternatives, a summary of the key elements of each is provided, including strategy narratives, key features, key actions needed to implement the alternative, ecosystem services, plan view schematics and typical sections, cost estimates, and project implementation phasing and timelines. It is noted that implementation of any alternative will require funding and actions across a variety of entities over several decades. No alternative can be implemented by a single agency alone. Phasing details and an implementation timeline is provided for each alternative illustrated through an 'adaptation pathways' type diagram. The Implementation Plan also identifies agencies that could potentially take the lead for implementation and potential stakeholders.

Strategies have been developed to provide flood and sea level rise protection and environmental enhancement. These elements are seen as being of equal importance and both are critical to the success of the project. The alternatives were measured against a set of evaluation criteria crafted with input from the PMT and SWG to ensure that each alternative met the needs of the project. A regulatory overview is provided as well as a summary of the anticipated regulatory laws that may be triggered by the proposed alternatives.

For full legends for each of the graphics below (explaining the numbers), please see Chapter 5.

Alternative 1 – Near-Term: Interim flood protection and restoration preparation

This alternative is a series of strategies that addresses near-term flooding impacts to the project site and the future restoration and/or management of Ponds R1 and R2 by the Don Edwards San Francisco Bay National Wildlife Refuge and South Bay Salt Pond Restoration Project. The flood protection strategies would mitigate against flooding from smaller flood events (equivalent to MHHW +24") and are intended to lessen the frequency and magnitude of flood impacts until a long-term alternative is implemented. The near-term actions facilitate sediment accumulation in Pond R1 and R2 to raise the pond beds in anticipation of either future tidal restoration or ongoing managed pond operations (depending on which action is deemed most appropriate for these ponds based on monitoring and adaptive management in the future).

Alternative 2 – Long Term: Protect in Place

This alternative is a long-term strategy to provide flood protection to critical infrastructure and the community by protecting assets in place up to 83 inches of sea level rise. This alternative would construct a levee along the north and south side of SR 84 and maintain the highway at its present elevation and alignment. The levee would generally follow the proposed SAFER Bay levee alignment presented in the SAFER Bay Feasibility Report.

Starting at the eastern edge of the Facebook Headquarters, the levee would parallel the north edge of SR 84, wrap around the Ravenswood Substation, continue along the north access road to the Bay shoreline, wrap around the Dumbarton Bridge touchdown (or tie into the bridge abutment), and continue along the south access road to the divider berm between the eastern and middle cells of Pond SF2 and continue southward. This alternative aligns the line of defense landward in the southern part of the study area, providing flexibility for future ecological restoration and management decisions.

Alternative 3 – Long Term: Raise the Road (2 options)

This alternative is a long-term strategy to provide flood protection to critical infrastructure and the community by protecting and adapting assets up to 83 inches of sea level rise. Alternative 3 would raise SR 84 within the project area and place it on a causeway (i.e., an elevated bridge-type structure) to protect the highway from sea level rise and flooding, reduce the length of levee required, and allow for hydrologic and ecologic connectivity between the eastern portion of Pond SF2 (to the south of SR 84) and Mosley Tract (to the north of SR 84) and potentially to Ponds R1 and/or R2 in the future. The causeway would extend inland to the SAFER Bay levee segments on the north and south sides of SR 84. This alternative would effectively relocate the touchdown point of the bridge farther inland.

The project included two options for Alternative 3 related to causeway alignment: 1) one which extends past the eastern cell of Pond SF2 and touches down at approximately the eastern edge of the PG&E substation and 2) one which extends past the middle cell of Pond SF2 and touches down prior to University Avenue. The Dumbarton Bridge was constructed in 1981 and has an expected design life of 75 years (approximately 2050 to 2060). It is anticipated that raising the western approach of the bridge on a causeway would occur in the next 20 to 30 years and may coincide with the replacement of the bridge at the end of its functional lifespan. If this is the case, the elevated causeway could be incorporated into the full bridge replacement project instead of it being constructed as an independent project. Critical decision points relating to this alternative include how far to realign the bridge touchdown and whether or not the PG&E Ravenswood Substation can be moved or would be protected in place. While it is more likely that the substation and associated assets would be protected in place due to cost, the project included two options for Alternative 3 to reflect the potential for the substation to be moved.

Landside Strategies

The project area is prone to flooding and ponding of stormwater runoff due to natural factors including low elevation, flat topography, low permeability soils, and a high groundwater table, but also due to an inadequate stormwater system and the proliferation of impermeable surfaces throughout the region. These hazards will be exacerbated by sea level rise, which will increase the risk of stormwater runoff becoming trapped during high tides and will cause the inland groundwater table to rise, limiting infiltration capacity, contributing to saltwater intrusion, and potentially mobilizing contaminants in the soil at toxic sites.

The scope of the project was not intended to solve the stormwater flooding issues in East Palo Alto or Menlo Park; however, some consideration to landside strategies was included given that sea level rise will exacerbate stormwater issues, and any bayside levees proposed in the alternatives described above could cut off the drainage routes for some portions of the project area. Strategies recommended include monitoring of groundwater near contaminated sites to proactively address potential mobilization of contaminants, low impact development and sea level rise-ready stormwater infrastructure requirements for new developments, ensuring upgrades to the stormwater system are designed to accommodate the construction of bayfront levees, and further study of the Ravenswood Pump Station adjacent to SR 84 to understand if it can accommodate higher future Bay water levels and stormwater from all portions of northwestern East Palo Alto.

NEXT STEPS

Several participants of the project management team will continue to discuss how to refine and move these strategies forward. This includes coordinating with other agencies and stakeholders, such as the San Mateo County Flood and Sea Level Rise Resiliency District, to form partnerships for further strategy development, collaborate on related projects and activities, and leverage funding opportunities.

Many of the stakeholder working group members were also interested in being involved or kept abreast of future discussions. Nuestra Casa and Acterra will be valuable partners in keeping community participants involved particularly with those who were engaged in the Parent Academies and Community Climate Change Team.

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1 INTRODUCTION

1. INTRODUCTION

1.1. PROJECT OVERVIEW AND PURPOSE

The Dumbarton Bridge, which is part of State Route 84 (SR 84), is a vital link in the Bay Area's transportation network and carries over 81,000 vehicles a day. The western bridge approach area and surrounding communities of Menlo Park and East Palo Alto were previously identified as vulnerable to sea level rise by studies conducted by the Metropolitan Transportation Commission (MTC), the San Francisco Bay Conservation and Development Commission (BCDC), and the County of San Mateo. To address this vulnerability, MTC initiated the Dumbarton Bridge West Approach + Adjacent Communities Resilience Study in 2018 with support from an SB-1 Adaptation Planning Grant from the California Department of Transportation (Caltrans). The purpose of the project was to develop a phased sea level rise adaptation strategy for the west approach of the bridge and adjacent communities that provides near-term, mid-term, and long-term sea level rise resilience for the critical infrastructure, vulnerable communities (including disadvantaged communities identified by MTC as Communities of Concern within East Palo Alto and Menlo Park, see Section 1.3.2), and valuable habitat within the study area. The project was guided by a Project Management Team (PMT) comprising representatives from MTC, Caltrans, City of East Palo Alto, City of Menlo Park, San Francisquito Creek Joint Powers Authority, BCDC, California Coastal Conservancy, and Bay Area Regional Collaborative.

Key goals and objectives of the study included:

- Build a strong working relationship and trust between the project partners, stakeholders, and public
- Educate stakeholders and community members about the existing and future flood vulnerabilities in the project area
- Develop a consistent vision for the future landscape and potential flood protection strategies in the project area
- Develop a phased approach to near-term and long-term flood protection strategies that integrates stakeholder and public input and is consistent with previously completed planning and design efforts in the project area
- Identify next steps and roles for project partners and stakeholders

1.2. REPORT ORGANIZATION

This report documents the key findings of the study and presents a range of potential alternatives to provide near-term and long-term sea level rise resilience for the Dumbarton Bridge west approach and adjacent communities. The report is organized as follows:

- Chapter 1 – Introduction: Provides an overview of the project scope and purpose, report organization, project area, and summary of prior studies.
- Chapter 2 – Stakeholder and Community Input: Summarizes engagement with the Stakeholder Working Group and community conducted in support of the project.
- Chapter 3 – Refined Vulnerability Assessment: Summarizes key findings of the vulnerability assessment, which included hydrodynamic modeling of near- and mid-term flood vulnerabilities in the project area.
- Chapter 4 – Alternatives Development: Describes the process to develop and evaluate potential project alternatives for near- and long-term planning horizons.

- Chapter 5 – Implementation Plans: Presents a potential implementation plan for near- and long-term alternatives, identifying key regulatory considerations and narratives, schematics, and adaptation pathways for each alternative.
- Chapter 6 – Conclusions and Next Steps: Summarizes the key findings and next steps to advance implementation of adaptation strategies in the project area.

1.3. PROJECT AREA

The Dumbarton Bridge west approach is located along the San Francisco Bay shoreline in southern San Mateo County. The project area encompasses areas of Menlo Park and East Palo Alto immediately surrounding the western touchdown of the Dumbarton Bridge (Figure 1).

1.3.1. Existing Assets

The project area contains a variety of assets that cover a range of transportation, habitat, utilities, and community needs. The existing can be organized into four categories: flood protection, transportation, infrastructure, and community assets.

FLOOD PROTECTION

The Ravenswood complex of ponds, which includes Ponds R1 and R2 lie on the north side of the highway. The outer Ravenswood berm[1], which separates Pond R1 and R2 from Mosley Tract and the Bay serves as the primary bayfront berm providing protection for SR 84, the north access road, and other infrastructure assets in the area. The internal Ravenswood berm, which separates Pond R1 and R2, functions as a divider between Ponds R1 and R2 and as a redundant barrier for the north side in the event the outer Ravenswood berm overtops or breaches. Berms of variable height and condition run along the land side of Pond R2, providing a degree of protection for the north access road, Ravenswood Substation, and SR 84. Along Mosely Tract a recently constructed steel sheet pile and concrete barrier serves a similar purpose, protecting the north access road and SR 84 from bayside flooding entering from the tidal Mosely Tract. The primary Facebook campus (Facebook HQ) is surrounded by a levee that wraps around the bayside of the development.

The Pond SF2 outboard berm, which is located on the south side of SR 84, is intended to provide a barrier for Pond SF2 to enable its operation as a managed pond as part of the South Bay Salt Pond Restoration Project. The Pond SF2 outboard berm also provides a degree of protection for the south access road and SR 84. Tidal flows into Pond SF2 are managed by a tide gate that mutes the tidal elevations in the ponds relative to the full tide range in the Bay, creating more consistent water levels for shorebird habitat within the ponds. The SF2 berm connects to the south access road at the base of the bridge and ties into an older berm/levee system south of Pond SF2. See the Modeling and Refined Vulnerability Assessment memo for more detailed discussion of flood protection assets in the project area.

[1] The term “berm” is used in this report to describe levee-like earthen embankments, primarily constructed of bay mud, for the purposes of separating inland areas or ponds from the Bay to control pond salinity and water levels. These embankments, while not originally constructed for the purposes of flood protection, do provide some degree of protection for landward areas; however, they do not meet contemporary standards for engineered flood protection works. The term “levee” is used in this report to describe engineered earthen embankments constructed specifically for the purposes of flood protection, meeting federal engineering standards for design, construction, and maintenance.

FIGURE 1. PROJECT AREA MAP

TRANSPORTATION

The Dumbarton Bridge touchdown is located approximately 750 ft from the edge of the shoreline. To the west of the touchdown, the roadway is constructed on fill and gradually decreases in elevation to the west. An access road at ground level parallels both sides of the highway, starting on the south side (South access Road) and wrapping under the bridge to continue along the north side of the roadway (North access road) and reconnecting to SR 84 at the Ravenswood substation. This road is intended to provide a turnaround point for drivers, access for repairs and maintenance, and parking for recreational users. Just over a mile from the bridge touchdown, SR 84 intersects with University Avenue, a major transportation corridor that provides access to East Palo Alto, extending through the community and intersecting with US-101 in the southern portion of the city.

INFRASTRUCTURE

To the north of SR 84, the project area includes the PG&E Ravenswood substation, Menlo Park Fire Protection District training facility, and the Facebook Headquarters. Two pump stations, both owned by Caltrans, are located near SR-84. The eastern pump station is located on the bay shore off the north access road and is intended to pump stormwater from SR-84 and the north access road. The western pump station (Ravenswood Pump Station) pumps stormwater that arrives at the station via underground pipe, draining a portion of Menlo Park west of the project area, and a small portion of East Palo Alto. The decommissioned Hetch Hetchy pipeline crosses the Bay and enters the peninsula just north of Ravenswood Preserve. While the old above-ground pipeline is no longer in service, the more recently constructed pipeline passes underneath the Hetch Hetchy facilities and there are various access structures and valve houses that still require flood and sea level rise protection.

COMMUNITY

The communities of East Palo Alto and Menlo Park are located south of SR 84 between the decommissioned railroad and Bay Road. Commercial and residential areas within each city are included in the project area. Within these areas are several community assets such as community centers, churches and schools. This area also contains ecological and recreational assets such as Ravenswood Preserve, the Bay Trail, and Cooley Landing Park, in addition to several neighborhood parks and sports fields.

1.3.2. Existing Communities

The project area includes portions of the City of Menlo Park and the City of East Palo Alto, which are categorized by MTC as ‘high’ Communities of Concern (CoCs[2]). While most of the project area (85%) is within Menlo Park, the majority of the developed areas, and all residential areas within the project area are within East Palo Alto.

The Menlo Park portion of the project area includes a series of commercial office developments south of SR 84. Most offices in this area are occupied by Facebook or various biotech companies. According to the City of Menlo Park, all parcels in this area are planned for redevelopment or improvement (F. Heydari, pers. comm., 2020). North of SR 84, the only commercial development is the Facebook Headquarters. The remaining 15% of the project area is within the City of East Palo Alto. This area consists of both residential and commercial space including the areas of University Village, Ravenswood, and 4 Corners. The residential areas are predominantly single-family homes. The commercial area, concentrated in the Ravenswood area, consists of low density

[2] CoCs are designated at the census tract level based on a framework developed as part of the Plan Bay Area 2040 Equity Analysis. Census tracts are considered CoCs if they have a concentration of both minority and low income households or have a concentration of “disadvantage factors” such as limited English proficiency, severe rent burden, and no vehicle ownership according to the most recent American Community Survey 5-year estimates.

commercial and light industrial mixed with underutilized/vacant parcels. According to the City of East Palo Alto, much of this space is planned for development or improvement (M. Daher, pers. comm., 2019).

The developed portions of Menlo Park and East Palo Alto south of SR 84 are prone to flooding due to natural factors including low elevation, flat topography, low permeability soils, and a high groundwater table, but also due to an inadequate stormwater system and the proliferation of impermeable surfaces throughout the region. Compounding East Palo Alto's high flood risk is the fact that many of the city's residents are at a disadvantage to cope with the impacts. Based on an index developed by the Bay Conservation and Development Commission's Adapting to Rising Tides Program, all census blocks in East Palo northeast of Highway 101 have high or very high social vulnerability to flooding. Compared to the entire Bay Area, census blocks in East Palo Alto are in the 70th percentile or higher for housing cost burden, and some are in the 90th percentile or higher for low income and limited English proficiency (BCDC 2018).

1.3.3. Historical and Existing Habitats

The entire extent of the study area lies within the historical alluvial fan floodplain of San Francisquito Creek. Historically, distributaries at the mouth of San Francisquito Creek spread silt, sand, and gravel broadly across the baylands from south of Bair Island to Palo Alto. This area was characterized by large expanses of marshes, tidal channels, and shallow-water systems adjacent to extensive mudflats. Habitat types included oyster shell beaches, and oyster beds, tidal mudflats, salt and brackish marshes, moist grasslands landward of the tidal marshes, and freshwater marshes (BCDC 2016; Goals Project 2015).

Figure 2 shows the historical and existing habitats in the project area. Considerable tidal marsh habitat has been lost over the past century due to diking and draining of wetlands. The creation of commercial salt production ponds and their subsequent conversion to managed pond habitat has significantly changed the hydrology and habitat mosaic within the project area. The ponds are separated from the Bay by low berms and water flow into and out of the ponds is managed by a tide gate. Today, some of the ponds (such as Ponds R1 and R2) are not connected to the Bay but hold water during wet periods and evaporate during dry periods. Other ponds (such as Pond SF 2) are more similar to lagoons, where there is occasional water exchange with the Bay, and water levels are now carefully controlled to optimize shorebird habitat.

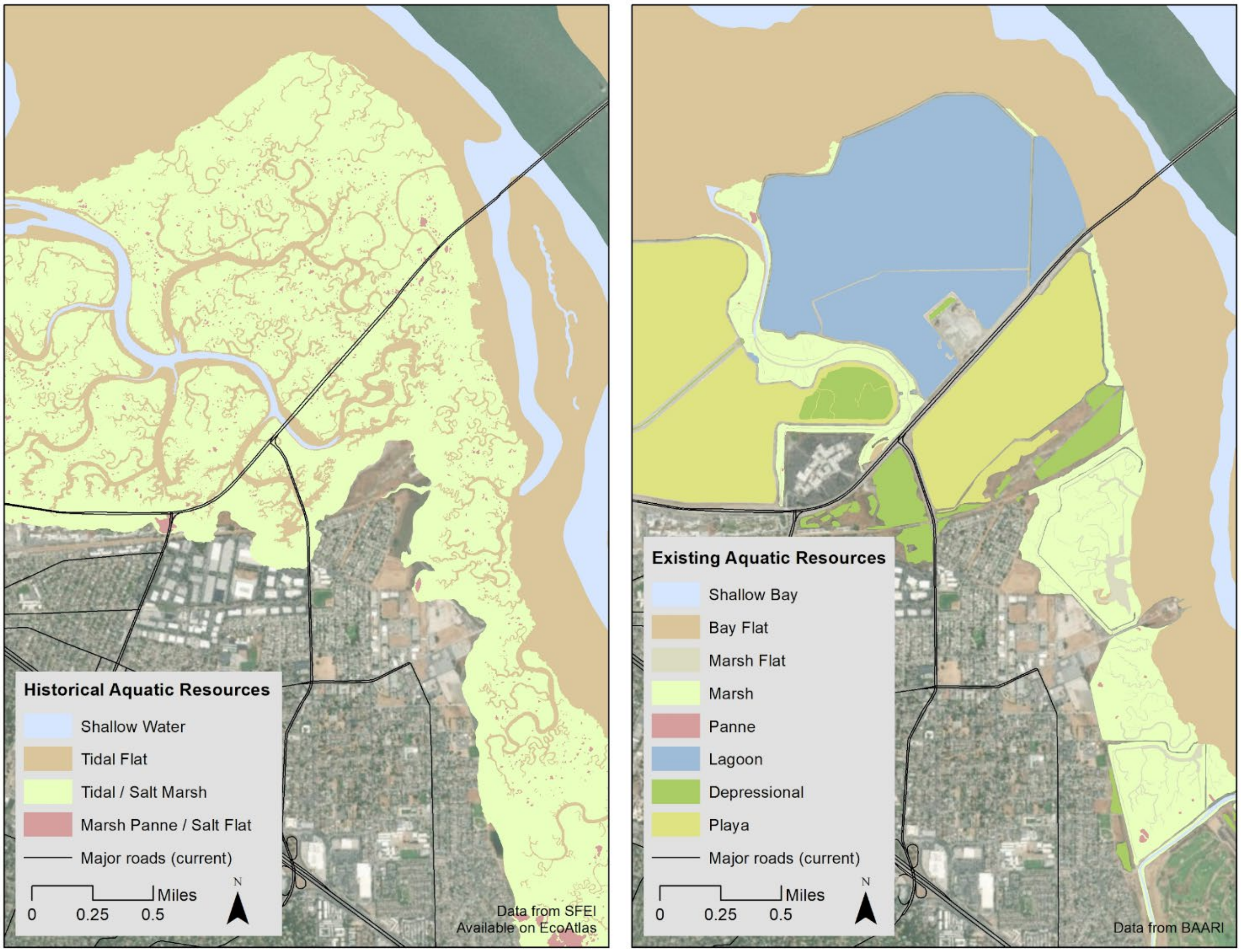

FIGURE 2. HISTORICAL AND EXISTING AQUATIC RESOURCES WITHIN THE PROJECT AREA

Source: Sowers 2004

Today there are significant tidal marshes to the north and south of the project area. To the north, Greco Island is an example of a restored mature salt marsh that was previously managed as a salt pond in the early 1900s (Collins and Grossinger 2004). Bair Island, restored between 2006 and 2015, provides another example of a more recently restored salt marsh. Large remnant tidal marsh patches still exist south of the project area at Ravenswood Open Space Preserve, Laumeister Tract, and Faber Tract. These remnants and restored tidal marshes provide important habitat in the South Bay for endangered species such as the salt marsh harvest mouse and Ridgway's rail and other birds and small mammals. There is little habitat for the endangered Ridgway's rail habitat within the Ravenswood complex and the project area, with the exception of Ravenswood Slough (EDAW et al. 2007). However, the marshes at Greco, Faber, and Laumeister act as major population areas of Ridgway's rail in the South Bay (Olofson Environmental 2018; Goals Project 2015). In addition, extensive mudflats currently exist offshore from the project area. Mudflats are a connection between the tidal marshes and open water and provide a source of sediments for adjacent tidal marshes and foraging areas for migratory birds and fish, and play a role in shoreline protection by dissipating wave energy (van der Wegen et al 2017).

Recommendations from the Baylands Goals Update (Goals Project 2015) include restoring large areas of tidal marsh with estuarine-terrestrial transition zones in former salt ponds to create a continuous band of habitat along the bayfront. Within the Bay region, the project area is one of the few places with significant opportunities for tidal marsh restoration. These restoration efforts are already underway in nearby areas, with approximately 3,200 acres recently restored to tidal marsh habitat at Bair Island, and nearby salt ponds being restored to tidal marshes and ponds managed for wildlife as part of the South Bay Salt Pond Restoration Project. However, the significant urban development in the cities of East Palo Alto and Menlo Park limit the opportunities for creating and restoring the associated estuarine-terrestrial transition zones adjacent to the tidal marshes.

1.4. SUMMARY OF PRIOR STUDIES

The project team carried out a review of relevant documents, reports, and initiatives relevant to sea level rise adaptation efforts in the project area. Prior and ongoing studies were identified in coordination with the Project Management Team and Stakeholder Working Group. The goal of the review was to identify synergies, common goals, and key findings among the studies to inform and guide the development of project objectives. The following reports and/or initiatives were identified and reviewed (in order of date released):

- Bay Area Toll Authority – San Francisco Bay Crossings Study Update (May 2012)
- SAFER BAY – East Palo Alto and Menlo Park Public Draft Feasibility Report (October 2016)
- Adapting to Rising Tides, Bay Area Sea Level Rise Analysis and Mapping Project (September 2017)
- SamTrans – Dumbarton Transportation Corridor Study (November 2017)
- Adapting to Rising Tides (ART) Bay Area – Dumbarton Bridge Focus Area Study (January 2018)
- San Mateo County – Sea Level Rise Vulnerability Assessment “Sea Change SMC” (March 2018)
- Resilient by Design – South Bay Sponge (May 2018)
- Stanford Sustainable Urban Systems – Economic and Social Costs of Sea Level Rise in San Mateo County (June 2018)
- Point Blue Conservation Science – Informing Sea Level Rise Adaptation Planning Through Quantitative Assessment of the Risks and Broader Consequences of Tidal Wetland Loss (December 2018)
- ART Bay Area San Francisquito Local Assessment (January 2019)
- ART Bay Area Belmont-Redwood Local Assessment (February 2019)
- San Mateo County – Climate Ready San Mateo County (Ongoing)
- South Bay Salt Ponds Restoration Project – Phase 1 and 2 (Ongoing)
- Midpeninsula Regional Open Space District – Ravenswood Bay Trail Project (Ongoing)
- SamTrans – Dumbarton Transportation Project (Ongoing)

Please see the separate supporting Prior Studies Review document for a detailed summary of each study reviewed.

The prior sea level rise studies share common goals and overlap to varying degrees with the current study. The previous studies generally either assess existing and future flood vulnerabilities, develop potential physical adaptation strategies, or do both. Vulnerability assessments conducted to date appear to agree on timing and location of inundation and are for the most part using similar exposure assessment methodologies/datasets. The primary differences among the prior studies are in terms of scale, focus, or emphasis on grey vs. green infrastructure.

For example, the ART Dumbarton Bridge Focus Area Study identified traditional flood protection infrastructure to address near-term flood vulnerabilities. These near-term strategies are meant to alleviate flood risk before more long-term projects (SAFER Bay, South Bay Salt Ponds Restoration project, etc.) are implemented. SAFER Bay recommends a mixture of traditional flood protection infrastructure and green infrastructure to provide FEMA accredited flood protection through 36” of sea level rise. South Bay Salt Pond Restoration Project Phase 2 includes plans for transition zones/horizontal levees (currently under construction) but the project is not modifying ponds R1 and R2 in the near-term, and these ponds would have the greatest impact on flood protection for the Dumbarton Bridge approach and surrounding assets.

None of the prior projects or studies have developed a comprehensive vision that integrates flood protection, sea level rise adaptation, habitat restoration, and shoreline and community resilience into a single unified approach for this reach of the Bay shoreline.

While the review of prior efforts did not reveal any major conflicts between studies, the review did reveal the need to ensure coordination of transportation and sea level rise adaptation plans for the project area. The Dumbarton Transportation Corridor Study (DTCS) is a feasibility study that evaluates potential multimodal transportation improvements within the Dumbarton Corridor including potential transit services on the currently unused Rail Bridge and improvements to the Highway Bridge and its approaches. The DTCS recommends a series of approach improvements in the project area, as well as restored service on the Rail Bridge. However, the DTCS does not consider sea level rise.

The ongoing Dumbarton Rail Corridor Project and Menlo Park Transportation Master Plan (in development) are informed by the alternatives recommended in the DTCS (F. Heydari, pers. comm., 2020). As neither of these initiatives are publicly available and there are currently no concrete plans for the rail bridge, this study did not assume any investment/retrofit of the rail bridge; however, alternatives developed as part of this project do not preclude future retrofit of the rail bridge or new work along the existing alignment. Adaptation actions that come out of the Dumbarton Bridge West Approach + Adjacent Communities Resilience Study should continue to coordinate with the Dumbarton Rail Corridor Project to ensure any major transportation investments are also resilient to sea level rise and consistent with this study.

1.5. PLANNING HORIZONS AND SEA LEVEL RISE SCENARIOS

The vulnerability analysis and adaptation alternatives presented in this report reference near-term, mid-term, and long-term planning horizons and sea level rise scenarios. For the purposes of this study, the “near-term” planning horizon (0 to 10 years) refers to actions that aim to lessen the frequency and magnitude of flooding in the near future, while more comprehensive strategies are planned, designed, permitted, and constructed. These actions address existing flood risk today, and only accommodate small amounts of sea level rise (up to 6 inches). The “mid-term” planning horizon generally refers to mid-century time frames (10 to 30 years) and actions that would be implemented in the mid-term would have anticipated lifespans to address sea level rise that may occur through mid-century (up to 24 inches of sea level rise). The “long-term” planning horizon and actions aim to provide flood protection through a high emissions, high risk aversion end-of-century sea level rise projection of 83 inches (OPC 2018) and consider storm surge and wave effects associated with a 100-year coastal storm event.

Implementation of the proposed alternatives would potential be phased over many decades over the 21st century. Therefore, monitoring and adaptability are important considerations in planning future implementation of any adaptation plan. Later sections of this report discuss the concepts of adaptability (Section 4.1.4) and phased implementation (Chapter 0).

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2 STAKEHOLDER AND COMMUNITY INPUT

2. STAKEHOLDER AND COMMUNITY INPUT

2.1. INTRODUCTION

The purpose of the stakeholder and public engagement was to provide an opportunity for a range of stakeholders and the local community, particularly communities of concern, to coordinate with the Project Team on existing projects, to discuss the ways in which the project area is vulnerable to sea level rise and flooding, to understand how this affects the community and various assets, and to provide input on the development of adaptation strategies. Feedback was sought on the evaluation criteria used to assess the strategy alternatives for their ability to meet the diverse needs of the project stakeholders.

2.2. STAKEHOLDER ENGAGEMENT

A Stakeholder Working Group (SWG) to advise the Project Management Team and consultant team was formed of 17 organizations including local government, community groups, business organizations, environmental organizations, state and federal agencies. In addition, the Project Management Team attended each SWG meeting. The SWG was considered particularly important given the number of other projects occurring in the project area as described in Section 1.4 as well as some other community capacity building projects on climate change underway in East Palo Alto described in Section 2.3.

STAKEHOLDER WORKING GROUP MEMBER ORGANIZATIONS

- Acterra
- Citizens Committee to Complete the Refuge
- City of Menlo Park, Public Works
- City of Menlo Park, Belle Haven Community
- City of Palo Alto Regional WQCP
- Committee for Green Foothills
- Facebook
- Midpeninsula Regional Open Space District
- MPC Ready
- Nuestra Casa
- Pacific Gas and Electric (PG&E)
- Ravenswood Shores Business District
- San Francisco Public Utilities Commission (SFPUC)
- San Mateo County
- San Mateo County Transportation Authority
- South Bay Salt Pond Restoration Project
- U.S. Fish & Wildlife Service

The role of the SWG was to:

- Help identify and fill data gaps
- Ensure coordination with other related projects
- Advise on community engagement approach

- Help with sharing information about the project within their agencies/peer groups/communities
- Provide ideas, input and feedback for adaptation strategies
- Help identify potential project opportunities, including partnerships and funding, to move forward shared goals

The SWG met four times during the project timeframe and covered the content outlined in Table 1 at each meeting. Members provided valuable input that directed the Project Team at each phase of the project.

TABLE 1. TIMING AND CONTENT OF STAKEHOLDER WORKING GROUP MEETINGS

Meeting	Date	Content
1	April 11, 2019	Project overview; SWG role; Provided measures of project success; Discussion of data review; Feedback on Community Engagement Plan approach
2	October 7, 2019	Community engagement update and feedback; Review of modelling and vulnerability assessment; Adaptation strategy development process; Review and feedback on draft strategy evaluation criteria
3	December 11, 2019	Community engagement update and feedback; Alternatives Review; Site considerations exercise
4	April 2, 2020	Community engagement update; Updated alternatives review; Ecosystem services update; Recommendations and next steps

FIGURE 3. STAKEHOLDER WORKING GROUP MEETING #3

2.3. COMMUNITY ENGAGEMENT

2.3.1. Engagement Methods and Principles

There were several parallel climate change engagement efforts being undertaken within the project area at the time of the project including Nuestra Casa's engagement with BCDC's Adapting to Rising Tides Bay Area project and the Climate Change Community Team being facilitated by Acterra as part of San Mateo County climate change efforts. The project team was concerned about introducing either meeting fatigue or confusion through hosting additional and separate sea level rise planning meetings with the community. As a result, and at the recommendation of the City of East Palo Alto (EPA), Nuestra Casa, and Acterra, the community engagement strategy focused on "going to the community" through existing City and community organized events and working closely with aforementioned community organizations focused on building community capacity for climate resilience with the most vulnerable. The following principles were established:

- Coordinate closely with city and community-based organization outreach efforts to identify synergies, co-develop the process and avoid duplication.
- Liaise with local community-based leaders to inform the community engagement process and reach deeper within the community, with a focus on reaching communities of concern.
- Prioritize "going to the community" to engage through existing city- and community-sponsored events and compensate participating community members for their expertise and time (through stipends and/or providing dinner where appropriate).
- Build community capacity to understand, discuss and inform sea level rise adaptation strategies.
- Gather community goals, concerns and ideas to inform sea level rise adaptation.

Community Engagement Partners

The project team worked with two non-profit community engagement partners. These organizations were included in the SWG and directly participated in and/or led community engagement activities.

Nuestra Casa is a community-based organization that works to uplift Latino families in East Palo Alto and the mid-peninsula through community education, leadership development, and advocacy. They partner with Latino families to help them navigate the complicated systems that impact their lives and provide guidance to public officials on how to make community engagement processes more welcoming, equitable, and responsive.

Acterra is a 501(c)(3) nonprofit based in Palo Alto that brings people together to create local solutions for a healthy planet and to address climate change. They promote emissions reduction strategies, food sustainability, and resilience and adaptation in the context of empowering underserved communities. Acterra collaborates with community partner organizations as well as local and regional governments to effect change.

2.3.2. Pop-ups at Existing Community Events

Working closely with Acterra and the City of Palo Alto, the Project Team attended four community events to share sea level rise maps and engage on project goals, scenarios and evaluation criteria. At each meeting boards showing projected sea level rise impacts were displayed, with an opportunity for community members to share locations of importance to them and provide feedback on evaluation criteria and ideas for adaptation strategies. The events are summarized in Table 2.

TABLE 2. LIST OF COMMUNITY EVENTS ATTENDED AS PART OF COMMUNITY ENGAGEMENT ACTIVITIES

Date	Event	Location	Approximate Number of People Engaged
April 6, 2019	Woodland Park Spring Celebration	East Palo Alto	15
April 11, 2019	Acterra, GRID, and Habitat for Humanity hosted Solar and Home Repair event	Bellehaven, Menlo Park	15
September 9, 2019	Community Revitalization Fair	East Palo Alto	25
December 14, 2019	Tree Planting run by Canopy, Jack Farrell Park	East Palo Alto	20

FIGURE 4. PROJECT TEAM ATTENDANCE AT EAST PALO ALTO COMMUNITY REVITALIZATION FAIR

2.3.3. Community Capacity Building

Through additional coordination (and funding), the Project Team collaborated with Nuestra Casa and Acterra to host a series of interactive facilitated discussions on sea level rise along with goals, criteria and adaption scenarios for the Dumbarton Bridge project. Capacity building efforts are summarized in the table below and are described in further detail in the following sections.

Date	Event	Approximate Number of People Participating
Nuestra Casa-led Adapting to Rising Tides Community Engagement Meetings and Parent Academy		
March 20, 2019 March 27, 2019	Adapting to Rising Tides Community Engagement Workshops (English and Spanish)	42
December 18, 2019	Environmental Justice: Climate Change Parent Academy Workshop (English and Spanish; Latino, African American and Pacific Islander cohorts)	55 adults, 25 youth
May 26, 2020	Environmental Justice: Climate Change Parent Academy: Follow up sessions on Dumbarton Bridge Alternatives (via zoom under shelter in place conditions, English and Spanish)	30
Acterra-led Climate Change Community Team Meetings		
October 14, 2019	Dumbarton Bridge Project discussed as an agenda item	11
January 30, 2020	Dumbarton Bridge Project-Specific Meeting	14

2.3.3.1. Nuestra Casa-Led Workshop and Parent Academies

The Project Team engaged with Nuestra Casa during two events during the project:

- The Project Team attended the Adapting to Rising Tides Workshops in March 2019 to listen to the discussion regarding sea level rise and share details in English on the Dumbarton Bridge West Approach + Adjacent Communities project (an additional meeting was held the following week in Spanish). In addition, the Project Team coordinated with Nuestra Casa to understand the results of their East Palo Alto Survey and consider how the results might inform the Dumbarton Bridge alternatives and evaluation criteria.

- The Project Team coordinated with Nuestra Casa to support the third session of their Parent Academy. The Parent Academy concept was developed by Nuestra Casa based on a previous capacity building effort to engage parents on local community stewardship and resilience. The Parent Academy was held on Wednesday evenings for three consecutive weeks in December 2019. The Parent Academy offered three parallel sessions each night – each tailored to local cultural identities, including Pacific Islander, African American and Latino/a, and facilitated by a trainer who identified culturally with the group. In addition, the Parent Academy included a youth session and childcare. Finally, Nuestra Casa offered a meal and a lottery to encourage participation. Through this process, participants were able to build their environmental understanding incrementally as a cohort over a multi-week process. A particularly effective approach of the Parent Academy was to inspire participants about their role as parents and the expertise they bring from their cultural background and experiences to improve the environment and prepare for climate resilience. The Project Team coordinated with Nuestra Casa, developed a presentation, coordinated with the facilitators to refine the presentation, developed maps for interactive exercises and attended the sessions to listen and be available as a resource for questions. At the request of the community, Nuestra Casa organized two webinars in May 2020 (one with the Hispanic cohort and one with the Pacific Islander and African American cohorts) to review the final alternatives presented to the Stakeholder Working Group and provide comments for the project team.

2.3.3.2. East Palo Alto Climate Change Community Team

The Project Team engaged with the East Palo Alto Climate Change Community Team (CCCT) (facilitated by Acterra) during two events over the course of the project. The CCCT is composed of city residents, city officials, youth, and leaders from business and faith-based communities and was set up to build capacity in the community in understanding climate change and how it could affect East Palo Alto. It was an ideal group to involve as a community sounding board for the project. For the first meeting, the Project Team attended and participated in one of the CCCT's regularly scheduled meetings to present on the project. For the second meeting, the Project Team led a project-specific meeting to discuss project updates.

- On October 14, 2019, the Project Team attended one of the CCCT's Working Sessions to share sea level rise maps and discuss project goals and evaluation criteria.
- On January 30, 2020 the Project Team hosted a second Working Session to review and discuss potential community benefits from the ranges of strategy alternatives under consideration.

2.3.4. Summary of Key Input

In general, information about sea level rise and how it may impact their community was not a topic that participants previously had much exposure to (apart from members of the CCCT who had spent time focusing on climate change as a topic through a year-long community effort). Community members who interacted with Project Team members at the pop-ups found the inundation maps helpful for visualizing potential impacts from flooding. Many noted that they already experience flooding in in their neighborhoods due to poor street and drainage systems and that they want their kids to feel safe walking to school. Most participants expressed an eagerness to learn more about climate change impacts and especially how to help make their homes, families, and neighborhoods more resilient.

In general, participants shared the following goals:

- Protect homes and neighborhoods from flooding
- Improve streets and drainage, particularly through use of green infrastructure
- Invest in community building, community stewardship, and disaster preparedness
- Incorporate resources, such as information boards, along public access trails to describe sea level rise impacts and how coastal infrastructure is protecting the community

In general, participants showed support for alternatives that included:

- Increasing the height of or further developing the levees
- Planting trees and vegetation and restoring habitat
- Addressing groundwater and stormwater impacts behind the levees
- Protecting and enhancing marshes
- Increasing access to trails, open space and the bay

2.3.5. Lessons Learned and Recommendations

This section summarizes the lessons learned through this process and recommendations for future engagement.

LESSONS LEARNED

- Never assume how much the community knows about general sea level rise and climate change, and how that affects their community
- Engagement was most effective when focusing on two to three big concepts, rather than a lot of technical detail
- More meaningful project feedback was obtained through the organized capacity building project outreach events (Nuestra Casa Parent Academy, Acterra CCCT) than through the pop-up opportunities; however, the latter provided good opportunities to raise awareness about sea level rise and the project in general and reached a diverse audience (both youth and the elderly)
- The community would like more community building and education surrounding climate change, sea level rise, and disaster preparedness to be better prepared for and informed of these potential threats

- Community members appreciated learning about climate change impacts and adaptation in peer groups facilitated by trainers from their culture and being able to connect personal experiences and expertise to identify issues and potential solutions
- Community members would like to continue to be engaged and informed about the project as it develops and compensated for input they provide

RECOMMENDATIONS

- The Acterra CCCT group was well informed and more engagement with them as the project develops would benefit the project and the community
- Focused community capacity building projects with specific partner organizations (e.g. Nuestra Casa, Acterra) should be included in similar long-term climate change projects to ensure broad and deep input from the community stakeholders over time.

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3 REFINED VULNERABILITY ASSESSMENT

3. REFINED VULNERABILITY ASSESSMENT

A key component of the project was to conduct a refined vulnerability assessment to understand near-, mid-, and long-term flooding and sea level rise vulnerabilities in the project area. Prior assessments of vulnerability in the project area were conducted at a high-level using countywide sea level rise inundation maps. As project planning focuses at a project or site level, more detailed flood hazard modeling and mapping can provide a finer scale level of understanding of asset and resource vulnerabilities. This chapter describes the components of the refined vulnerability assessment, including the asset inventory, hydrodynamic modeling, and vulnerability assessment and presents the key findings that informed the development of adaptation strategies to address near-, mid-, and long-term vulnerabilities in the project area.

3.1. ASSET INVENTORY

Key assets were identified throughout the project area and were categorized as either flood protection, transportation, infrastructure, or community assets. The assets were identified based on aerial imagery, site familiarity, and community and stakeholder engagement. A description of the assets and where they fall in the project area is provided in Section 1.3.1 and elevations and heights relative to the daily high tide and the 100-year storm tide are provided in Section 0. Some of the ground elevations of assets within the project area are not far above today's high tide and most lie below the 100-year storm tide elevation. The exposure of these assets to flooding is dependent on not just their elevation, but their location in the study area relative to flood protection features and managed pond areas, which can store floodwaters and buffer inland areas from Bay flooding. A refined vulnerability assessment was conducted using hydrodynamic modeling to obtain a better understanding of the timing, depth, extent, and duration of flooding in the project area and to the key assets (described in next section).

3.2. HYDRODYNAMIC MODELING

3.2.1. Purpose of Modeling

The purpose of the hydrodynamic modeling was to obtain a more realistic representation of the flooding pathways in the project area and the vulnerability of each asset to sea level rise by incorporating processes such as storm duration, detention capacity of the ponds, and the physics of overland flow. Some of the prior studies listed in Section 1.4 developed inundation maps that showed the extent of flooding for specific sea level rise and storm surge scenarios. These maps were developed using GIS methods that projected the Bay water level landward until it intersected with the inland topography, without consideration of these flood processes. As a result, the maps from these studies provide a conservative estimate of flood potential during extreme tide events. By developing a time-dependent simulation in which bay waters propagate in and out based on the fluctuation of the tides, a more accurate representation of the flood characteristics of the project area was obtained.

Specifically, the results from this modeling were used to illustrate how assets first become inundated at lower levels of sea level rise or during extreme tides. In these near-term scenarios, capturing the physics of the flooding processes is very important to develop an accurate depicting of flooding. Once sea level rise increases beyond a threshold level of shoreline overtopping, however, the importance of capturing these flood processes (such as storm duration, detention capacity, and overland flow) is less and the maps produced by the modeling results are similar to those developed from prior studies using GIS methods. Thus, the results from this modeling work were used to enhance the GIS-based maps, especially in the near-term scenarios, when complex flood processes have a larger impact on the resulting flood extent.

3.2.2. Modeling Setup and Methods

The model was developed using MIKE21, a two-dimensional hydrodynamic model that is commonly used to simulate tidal hydraulics in bays and estuaries. The model works by propagating the Bay tidal and flood waters across the project area, which floods and drains as the Bay tide fluctuates. This allows flood duration, detention capacity, and overland flow processes to be captured, obtaining a more accurate representation of the flood characteristics of the project area.

The model requires topographic and bathymetric data to develop a Digital Elevation Model (DEM) that was used to generate the model mesh. The DEM developed for the ART Bay Area Sea Level Rise Analysis and Mapping Project (AECOM 2017) within San Mateo County was used as the basis of the project DEM and was supplemented by a topographic survey performed by AECOM in March 2019. The survey collected elevation data at the project site along areas of interest for the modeling. This included the Pond SF2 berm, south access road berm, pump station pad, concrete barrier and the outer Ravenswood berm (Ponds R1 and R2).

A model mesh was developed to represent the bathymetric and topographic variation in the project area. Care was taken to ensure that features with the potential to control flooding, such as berm crests and low spots, and SR 84 were represented with the correct elevation. The model domain starts at Cooley Landing in East Palo Alto at the southern end of the project area and extends along the shoreline northward to Bedwell Bayfront Park in Menlo Park. It includes Ponds R1, R2, R3 and R4, Facebook HQ, Ravenswood Slough, Mosley Tract, and Pond SF2. Inland it extends to the intersection of University Avenue and Bay Road, including portions of East Palo Alto and Menlo Park. The model domain is shown in Figure 5.

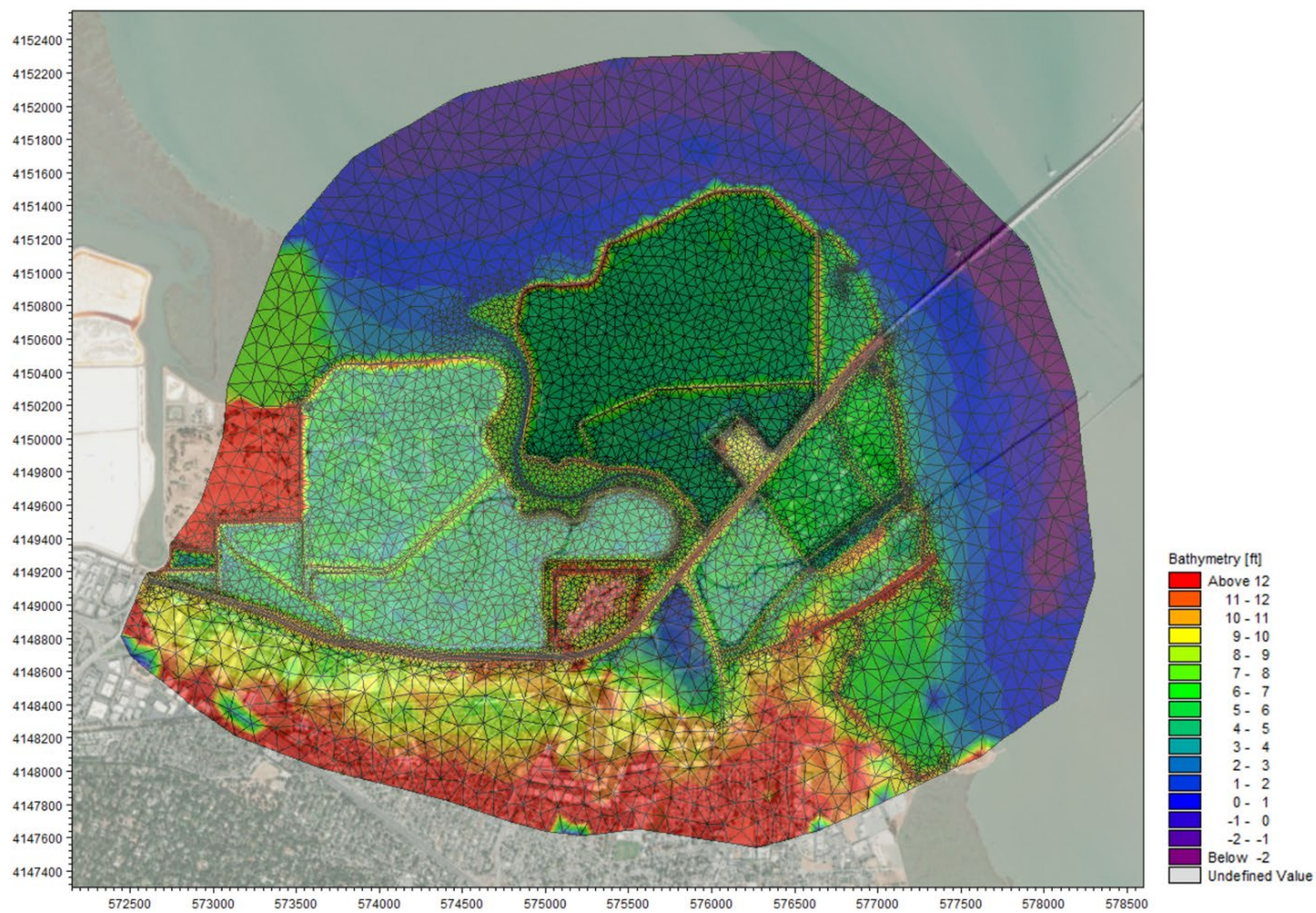

FIGURE 5. MODEL DOMAIN AND MESH WITH SITE TOPOGRAPHY

Five sea level rise and tide scenarios were selected to be modeled based on the prior inundation mapping which identified these scenarios as threshold inundation events resulting in overtopping of flood barriers or causing flooding of critical assets. Following the framework AECOM developed in the ART Bay Area Sea Level Rise Analysis and Mapping Project, these five scenarios can also be used to represent a range of sea level rise and extreme tides combinations. For each model scenario, there is a range of sea level rise and storm surge combinations that are approximately equivalent to the model scenario.

To model these scenarios, a tide boundary conditions was created by adding specific levels of sea level rise ranging from 12" to 66" to a typical 7-day tide time series. This 7-day tide time series was obtained from the DHI hydrodynamic model of San Francisco Bay, completed as part of the Federal Emergency Management Agency (FEMA) coastal flood study (DHI 2013). Within the 7-day time series, the high tides fluctuate around MHHW, with some high tide being greater and some being less than MHHW. The five scenarios and equivalent water level scenarios are listed in Table 3 with the tidal boundary condition used to run the model scenario.

TABLE 3. MODEL SIMULATION AND EQUIVALENT SCENARIOS

MODEL SIMULATION	EQUIVALENT WATER LEVEL SCENARIO	TIDAL BOUNDARY CONDITION
MHHW + 12”	▪ 0” SLR + 1-yr storm surge	7-DAY TYPICAL TIDE + 12”
MHHW + 24” (see Figure 6)	▪ 0” SLR + 5-yr storm surge ▪ 6” SLR + 2-yr storm surge ▪ 12” SLR + 1-yr storm surge	7-day typical tide + 24”
MHHW + 36” (see Figure 7)	▪ 0” SLR + 50-yr storm surge ▪ 6” SLR + 25-yr storm surge ▪ 12” SLR + 5-yr storm surge ▪ 18” SLR + 2-yr storm surge ▪ 24” SLR + 1-yr storm surge	7-day typical tide + 36”
MHHW + 48”	▪ 6” SLR + 100-yr storm surge ▪ 12” SLR + 50-yr storm surge ▪ 18” SLR + 10-yr storm surge ▪ 24” SLR + 5-yr storm surge ▪ 30” SLR + 2-yr storm surge ▪ 36” SLR + 1-yr storm surge	7-day typical tide + 48”
MHHW + 66”	▪ 24” SLR + 100-yr storm surge ▪ 30” SLR + 50-yr storm surge ▪ 36” SLR + 25-yr storm surge ▪ 42” SLR + 5-yr storm surge ▪ 48” SLR + 2-yr storm surge ▪ 52” SLR + 1-yr storm surge	7-day typical tide + 66”

Note: SLR = sea level rise

3.2.3. Modeling Results

The modeling results show the extent of flooding, water surface elevations, and flood depths throughout the study area for each scenario. Inundation maps were developed by extracting the greatest water depth that occurred over the 7-day simulation at each location; this shows the greatest potential extent and damage of flooding for each scenario. The inundation maps for the MHHW+24” and MHHW+36” scenarios are shown in Figure 6 and Figure 7. These full set of inundation maps are provided in the separate supporting Modeling and Refined Vulnerability Assessment Memo, are the basis for the refined vulnerability assessment.

The modeling shows that for scenarios up to and including MHHW + 24”, the flooding is caused by the overtopping of isolated low-lying areas of the shoreline and results in flooding of a few assets such as the east pump station and the south access road. Specifically, in the MHHW + 24” scenario:

- The south access road berm overtops which leads to flooding of the south access road
- Overtopping of the levee fronting the SFPUC parcel leads to flooding of the SFPUC parcel

- Flooding of the Ravenswood Preserve occurs, and sections of the Bay Trail overtops.

In the MHHW + 36” scenario and above, overtopping occurs over a much longer section of the shoreline and results in widespread flooding of the study area including SR 84, University Ave, East Palo Alto and Menlo Park. The flooding for these scenarios comes from overtopping of the Bayfront levee across Pond SF2 and the SFPUC parcel, and the north and south access road berm. Specifically, in the MHHW + 36” scenario:

- The south access road berm and Pond SF2 bayfront levee overtop and lead to flooding of south access road, Pond SF2, University Ave and Menlo Park.
- The flooding of Ravenswood Preserve and overtopping of Bay Trail lead to flooding of East Palo Alto
- The north access road berm at the end of Ravenswood Slough overtops and leads to flooding of the outer westbound lane of SR 84.

The model also shows that with 48” of sea level rise, flooding originating from the south side of the project area will flow over SR 84 and flood the Ravenswood Substation and north access road. The modeling results are provided in greater detail in the separate supporting Modeling and Refined Vulnerability Assessment Memo.

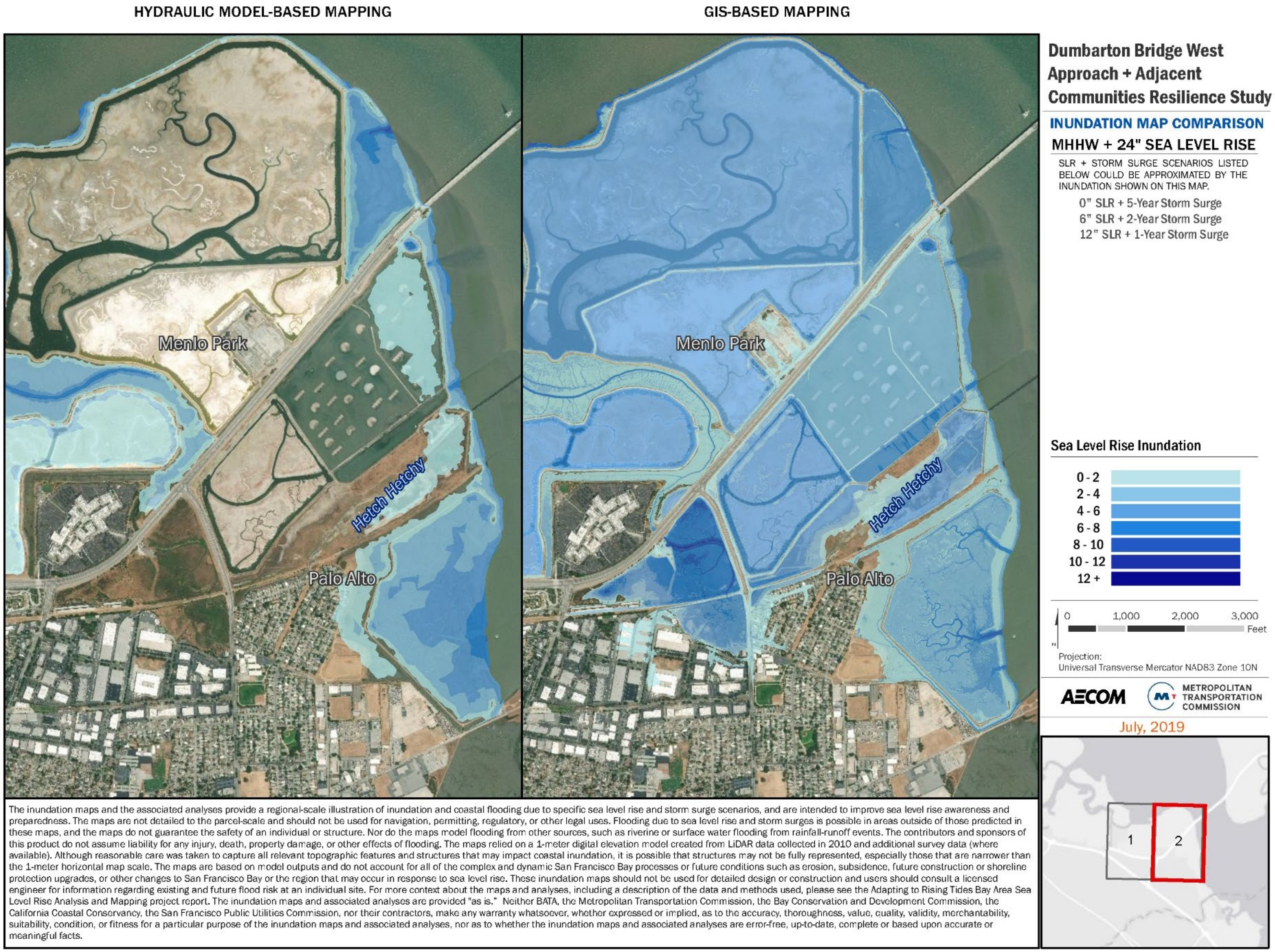

FIGURE 6. SEA LEVEL RISE INUNDATION MAPPING FOR MHHW + 24" SCENARIO

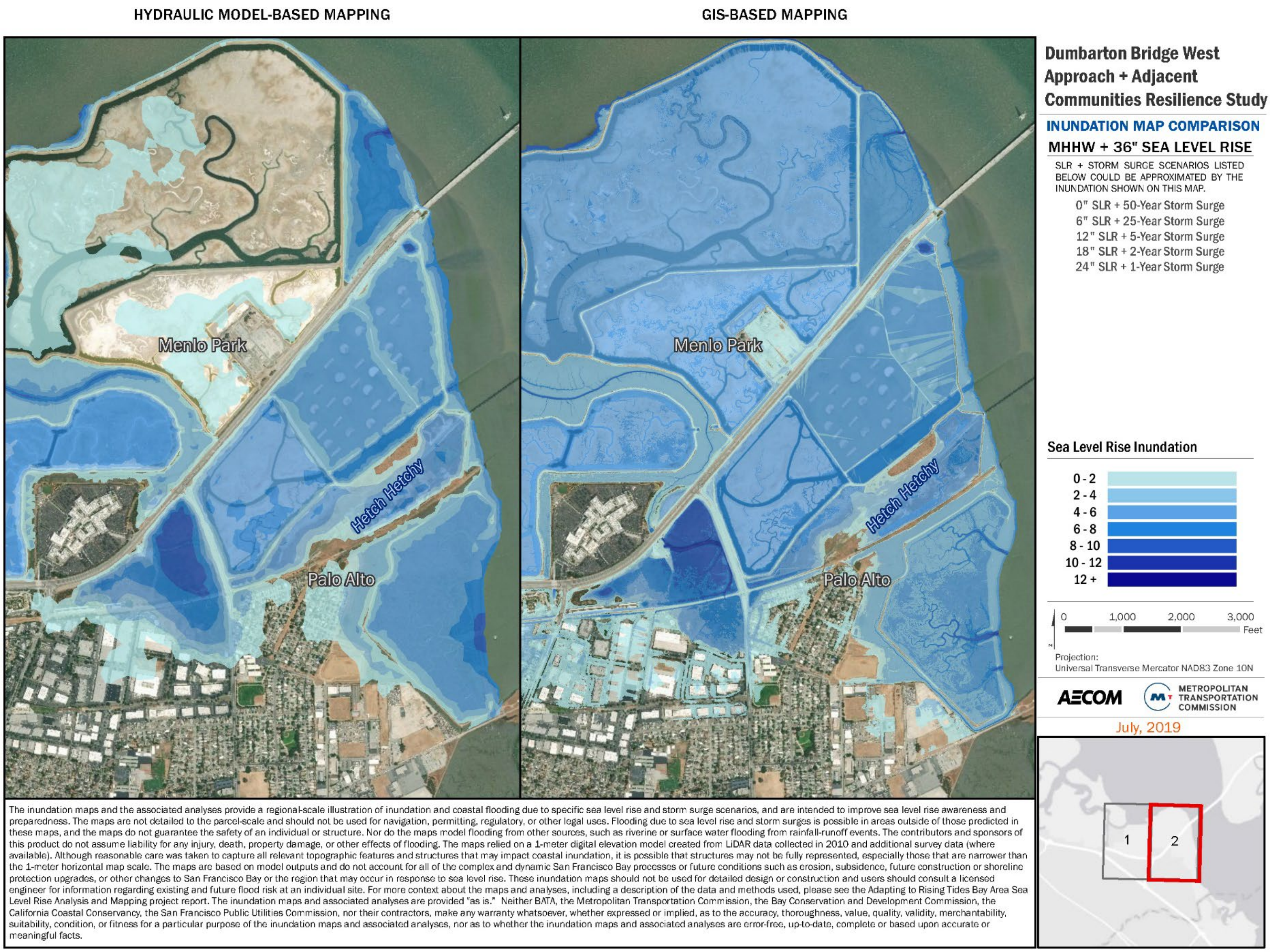

FIGURE 7. SEA LEVEL RISE INUNDATION MAPPING FOR MHHW + 36" SCENARIO

3.3. VULNERABILITY ASSESSMENT

The inundation maps produced by the modeling can be used to estimate the scenario at which each key asset is first flooded. This information is provided in Table 4 where blue cells represent the water levels under which each asset is exposed to inundation. A more detailed account of the mechanism of flooding for each asset is provided in the vulnerability assessment tables in the separate supporting Modeling and Refined Vulnerability Assessment Memo.

TABLE 4. TIMING OF EXPOSURE FOR KEY ASSETS IN THE PROJECT AREA

Asset	Sea Level Rise Exposure	MHHW + 12”	MHHW + 24”	MHHW + 36”	MHHW + 48”
Flood Protection Assets					
Temporary concrete barrier	MHHW + 48”				
Outer Ravenswood pond levee	MHHW + 36”				
Internal Ravenswood pond levee	MHHW + 48”				
North access road berm	MHHW + 48”				
South access road berm	MHHW + 12”				
Pond SF2 levee	MHHW + 36”				
Facebook headquarters levee	MHHW + 48”				
Transportation Assets					
North access road	MHHW + 48'”				
South access road	MHHW + 12”				
SR 84	MHHW + 36”				
University Ave	MHHW + 36”				
Infrastructure Assets					
PG&E substation	MHHW + 48”				
Menlo Park fire protection training center	MHHW + 48”				
East pump station pad	MHHW + 24”				
West pump station pad (Ravenswood Pumping Station)	MHHW + 36”				
Facebook headquarters	MHHW + 48”				
Community Assets					

Asset	Sea Level Rise Exposure	MHHW + 12"	MHHW + 24"	MHHW + 36"	MHHW + 48"
East Palo Alto Residential Area	MHHW + 36"				
East Palo Alto Commercial Area	MHHW + 48"				
Menlo Park Commercial Area	MHHW + 36"				
Bay Trail	MHHW + 24''				
Cooley Landing Park	MHHW + 24''				
Ravenswood Preserve	MHHW + 12"				

3.4. KEY FINDINGS

The model results can also provide information on flooding mechanisms in the project area such as flow pathways, pond detention capacity and threshold inundation events, which can be used to inform the development and implementation of flood protection strategies.

The modeling results shows that the MHHW + 24" scenario is a tipping point for widespread inundation. Flooding during this scenario impacts only a few assets and is contained to isolated areas near the shoreline. With greater than 24" of sea level rise, flooding becomes widespread across the study area. This indicates that a near-term solution may be adequate to protect up to 24" of sea level rise (or equivalent tide level). The short-term solutions would focus on raising the low-lying sections of shoreline such as the south access road berm, and floodproofing the east pump station. Beyond MHHW + 24" large-scale solutions would be required to protect the entire project area. The large-scale solutions would need to be implemented across the project area, as the modeling shows flooding can propagate throughout region. It is likely that the large-scale solution would also be a long-term solution as it will involve substantial improvement to the entire shoreline. If this is the case, other factors such as restoration, recreation, and habitat goals need to be considered in the development of the large-scale solutions.

4 ALTERNATIVES DEVELOPMENT

4. ALTERNATIVES DEVELOPMENT

4.1. GUIDING PRINCIPLES

A key objective of the project was to develop alternatives to provide near- and long-term flood protection for the Dumbarton Bridge west approach and adjacent communities, while promoting the ecological and social resilience of the surrounding lands and communities. For the purposes of this project, an "alternative" is defined as a set of complimentary individual "strategies" or "actions" that work together to achieve the project goals for either the near-term or long-term planning horizons.

There are certain guiding principles that informed the development of the proposed alternatives including community input, flood protection, ecosystem services and benefits, adaptation pathways and strategy compatibility, public access, and monitoring and adaptive management. These guiding principles are described in this section.

4.1.1. Community Input

Community input was elicited through a range of activities as described in Chapter 0 (Stakeholder and Community Engagement). Key input was received on the draft evaluation criteria and the draft alternatives and revisions were made to both in response to the feedback received. The community input received on the evaluation criteria is described in Section 4.2.1 and the input received on the draft alternatives is described in Chapter 5.

4.1.2. Flood Protection

One of the primary goals of the project is flood protection for the transportation, utility infrastructure, and community assets (including homes and businesses of communities of concern) in the project area. Near-term actions attempt to lessen the frequency and magnitude of flooding in the near future while more comprehensive strategies are planned, designed, permitted, and constructed. Mid- to long-term actions aim to provide flood protection through an end-of-century sea level rise projection of 83 inches (OPC 2018) and consider storm surge and wave effects associated with a 100-year coastal storm event.

Where possible, the flood protection strategies reference existing habitat restoration plans (such as SBSP Restoration Project) and aim to incorporate nature-based features such as ecotone slopes and vegetated tidal marsh to create hybrid "green-grey" strategies that provide both flood protection and ecosystem services to create a more resilient shoreline. Gray infrastructure includes conventional physical structures such as levees and seawalls that are designed for coastal protection with minimal concern for the provision of other ecosystem services. Green infrastructure, or nature-based measures, are physical landscape features that mimic characteristics of natural features but are created by human design, engineering and construction in concert with natural processes to provide coastal protection and other ecosystem services (SFEI and SPUR 2019). Working with nature can make shorelines more resilient while providing multiple benefits. Green infrastructure or nature-based solutions may have lower costs and provide more benefits to people, plants, and wildlife than conventional options. Transition zone management and restoration (described in the following section) is an example of green infrastructure strategy that provides flood protection benefits in addition to habitat for special-status species and recreation space for people on trails on top of levees.

4.1.3. Ecosystem Services and Benefits

4.1.3.1. Overview

The benefits that people obtain from wildlife and natural ecosystems are called ecosystem services. Tidal wetlands provide many ecosystem services. For example, fish in the Bay spend at least part of their life cycle in wetland habitats. Floodplains retain and temper flood waters. Tidal marsh plants absorb nutrients and chemicals from the water, and act as natural filtration systems. Wetland plants and soils store large amounts of carbon. Tidal and freshwater wetlands are vital habitat for migratory birds, fish, and mammals, and their loss impacts recreation and biodiversity. While there are several types of ecosystem services (Table 5), the alternatives development for this study focused on environmental benefits in particular. Examples of these types of services are included in the sections below.

TABLE 5. ECOSYSTEM SERVICES, FUNCTIONS, AND BENEFITS

Benefits	Ecosystem Service Category	Services
Environmental	**Supporting baseline services and functions** (fundamental services to allow the earth to sustain life such as photosynthesis, nutrient cycling, the creation of soils, and the water cycle)	Habitat and nursery Biodiversity High tide refugia / transition zone Sediment retention / soil formation Nutrient cycling Primary production
Environmental	**Regulating services** (benefits obtained from the moderation of natural processes, such as flooding)	Carbon sequestration Wave attenuation Water flow and flood regulation (i.e., stormwater retention or infiltration) Groundwater recharge Coastal protection / erosion control / soil stabilization Sediment flow Water filtration / water quality Nutrient removal
Economic	**Provisioning services** (products people use, such as food, derived from ecosystems)	Seafood Other materials / products
Social-Economic	**Cultural services** (non-material benefits to people that affect our cultural, intellectual, and social development)	Recreation (walking, biking, kayaking, hunting, fishing, bird watching) Ecotourism Spiritual and aesthetic benefits

Source: Millennium Ecosystem Assessment (2005), Brander et al. (2006), BCDC ART Bay Area (2020)

4.1.3.2. Incorporation of Ecosystem Services in Alternatives Development

A number of ecosystem services were taken into consideration in the development of the near-term and long-term project alternatives. The following key ecosystem services are summarized in more detail below: coastal protection, habitat, high tide refugia/transition zones, stormwater retention, water filtration/water quality, carbon sequestration, and cultural services.

COASTAL PROTECTION

Coastal protection is the reduction in coastal flooding from storm surges, waves, and sea level rise. Vegetation contributes to vertical accretion of marshes by trapping suspended sediments in the water column, allowing them to accumulate on the marsh surface. This sediment accretion helps maintain the shoreline. Typically, levees and seawalls (hardened or gray infrastructure) are used to provide this protection. It has become widely recognized that marshes, transition zones, oyster reefs and other natural features (nature-based or green infrastructure) can contribute to coastal protection as well and can adapt to sea level rise. For instance, marshes can provide protection by: (1) reducing the height and energy of waves associated with storm surges; (2) spreading out and storing flood waters from both fluvial and Bay events during storms; and (3) reducing erosion by stabilizing shorelines (Shepard et al. 2011).

HABITAT

Habitat protection and restoration is important to support wildlife species of the Bay. Much of the Bay's shoreline habitat has been fragmented and reduced in size due to urban development. To restore a functioning Bay ecosystem, connectivity and patch size are important ecological principles to consider. According to the Baylands Goals Update, one key strategy to improve the resilience of bayland wildlife populations is to increase habitat connectivity. Connectivity means allowing water, sediment and nutrients to move freely within the landscape of marshes, mudflats and adjacent uplands, without restrictions from barriers such as berms, levees, and channels. These flows help support physical and biological processes. Improving connectivity also means establishing habitat ecotones that join different types of habitat in appropriate, adjacent locations. This allows plant and animal species to move and disperse between these habitats, as appropriate, without barriers. The Goals Update recommends that restoration designs prioritize functional connections that allow wildlife movement and dispersal between habitat patches (Goals Project 2015). Populations spread across fragmented patches are less robust to changing environmental conditions than populations in connected patches with more dispersal and gene flow. Larger tidal marsh patches can support larger populations, have fewer detrimental edge-effects (e.g. predation and anthropogenic stress) (EBDA 2015), and more complex tidal channel structures that provide higher-quality habitat for species like the Ridgway's rail (Point Blue 2011). Both alongshore and tidal-marsh terrestrial connections are essential for wildlife movement and resilience in the context of climate change.

HIGH TIDE REFUGIA / TRANSITION ZONES

Estuarine-terrestrial transition zones (transition zones) are located between the marsh and the uplands. They were historically common in the South Bay and are an important component of marsh ecosystems (Nur et al. 2018). Their extent has been diminished by development at the landward edge of the marsh and by the construction of levees for salt ponds (Beller 2013). Historical transition zones were characterized by low-gradient, seasonally flooded fresh and brackish wetlands, wet meadows, and seeps. Within the study area, the historic San Francisquito Creek alluvial fan would have provided extensive transition zone habitat, providing both a topographic and salinity gradient from the uplands to tidal marsh (see San Francisquito Watershed & Alluvial Fan above). Transition zones supported perennial species such as saltgrass (*Distichlis spicata*), creeping wildrye (*Elymus triticoides*), alkali heath (Frankenia salina), and various sedge species (*Carex* spp.) (Baye et al., 2000; Baye

2000; Beller et al. 2013; SFEI and SPUR 2019). These plant species were especially effective at creating dense, clonal root systems that act as stabilizing structures which are resilient to extreme flooding from storm events, and to wave erosion.

The Baylands Goals Update (2015) recognized transition zones as providing critical ecosystem services such as habitat and upland refugia for marsh species, buffering from pollution from terrestrial areas, creeks, and rivers, protect terrestrial areas against erosion, provide areas for sediment and water transport between uplands and marshes and provide wave attenuation during high tide and storm events. The importance of these ecosystem services will grow with climate change, as gently sloping transition zones provide flood protection and accommodation space for marshes to migrate as sea level rises. Transition zones also provide connectivity between different types of habitat, allowing wildlife to move between patches for nesting, refuge from tides, or to forage for food. Transition zone connections facilitate physical processes such as the movement of sediment and water through channels and between habitat types. Most of these connections between the Bay and terrestrial habitats have been disrupted by barriers such as roads, concrete channels, levees, and other infrastructure. Examples of intact transition zones with complete gradients between terrestrial habitat and tidal marsh can still be found in a few places around the Bay such as China Camp in Marin and Coyote Hills in Alameda.

Transition zones within the study area are currently absent or exist adjacent to salt ponds as small fragments of narrow, low-quality fringing levee slopes. With the threat of sea-level rise and the need to create high-tide refuge habitat for endangered species, transition zones are an important consideration in any shoreline adaptation strategy (USFWS 2013). Opportunities exist to create transition zones by placing fill in long shallow slopes (“horizontal levees”) along the back side of tidal marshes (existing or restored) and along the outboard faces of flood risk management levees. New transitional habitat using such slopes is being created near the study area between Bedwell Bayfront Park and Pond R4 as part of a tidal marsh restoration project at Pond R4. Transition zone habitat is also being built between Ponds R3 and R4 as part of the All-American Canal levee upgrade. Creating additional transition zones, where appropriate, along the Dumbarton Bridge west approach will provide alongshore connectivity with transition zones currently under construction and would consistent with recommendations included in the Adaptation Atlas (SFEI and SPUR 2019).

STORMWATER RETENTION

Wetlands can reduce flooding by providing flood water storage capacity. Large and established marshes with tall, dense vegetation can store floodwaters during fluvial events, reducing peak flows during storms. Much of this storage capacity has been lost with urban development on former floodplains.

WATER FILTRATION / WATER QUALITY

San Francisco Bay is a highly urbanized estuary, and runoff from local watersheds contributes pollutants to the Bay. Much of the stormwater runoff travels to the Bay without any form of pollutant removal (SFEI 2019). Salt marshes help maintain water quality in the Bay by filtering out and breaking down contaminants from terrestrial runoff and pollutants. Some marsh plants can even take up nutrients and pollutants in their tissues with the net effect of reducing pollutants that could enter the Bay.

CARBON SEQUESTRATION

Wetlands are important in the global carbon balance and restoring salt marshes can help mitigate the effects of climate change (Crooks et al. 2014). Due to their fast rates of primary productivity and standing biomass, undisturbed marshes serve as important carbon sinks. Salt marsh plants uptake carbon dioxide during photosynthesis, store it in their roots and stems, and then bury it as they decompose, in the form of organic soil.

(Zedler and Kercher 2005) (Burden et al. 2019). As tidal wetlands accrete sediment, the carbon remains within the marsh soil. Tidal marshes are net sinks of carbon, and likely net removers of greenhouse gases in general (Goals Update 2015). Increases in tidal marsh area through restoration are likely to help increase carbon sequestration in the region over time. Managing the existing tidal marshes to ensure persistence will maintain these carbon stores and prevent the future release of sequestered carbon.

CULTURAL SERVICES

Cultural services are provided by areas that are of historical or current importance to local and regional communities, with value for environmental science, education, recreation, and spiritual healing. The shoreline provides public access to the Bay; examples include the Bay Trail and recreational fishing piers. Residents look to the Bay for emotional release and healing through a variety of outdoor activities including walking and cycling. Environmental science and environmental education, birdwatching, kayaking, and various types of recreation are important aspects of the region's culture, and much of this activity occurs on or near shorelines around the Bay (Goals Project 2015).

4.1.4. Adaptation Pathways and Strategy Compatibility

The concept of "adaptation pathways" has gained a lot of interest and traction in the adaptation community over the last few years and to the extent possible these concepts have been incorporated into the development of the alternatives. The adaptation pathways planning approach is a strategy to deal with the substantial uncertainty in future environmental and social conditions and breaks down adaptation into a sequence of manageable steps and decision points over time. Each decision point is triggered by some change (such as exceeding a threshold amount of sea level rise or decommissioning of an infrastructure facility) and has multiple options that can be implemented at that time. The adaptation pathways approach is flexible to changing conditions and community needs and priorities and supports an adaptive management framework.

The alternatives descriptions presented in Chapter 0 provide more information on phasing and linkages between the near-, mid-, and long-term strategies. To the extent possible, near- and mid-term actions lay the foundation for subsequent long-term actions to minimize throw away costs and reduce impacts associated with new construction or implementation of later phases.

4.1.5. Public Access

In some cases, the proposed alternatives may eliminate or alter existing public shoreline access, including trails and parking, although opportunities exist to replace or even improve upon existing public access. Where possible, the proposed alternatives considered ways to address public access, for example, by relocating bayfront trails along more landward and elevated levee alignments[3]. This will provide increased resilience for existing trail segments that may be exposed to more frequent flooding in the future due to sea level rise. The strategy descriptions in Chapter 0 note where public access opportunities exist as identified by the project team. Given the scope of this study and level of evaluation carried out, detailed public access plans have not been developed for each alternative and should be further developed in subsequent stages of design. The community also

[3] Relocating existing public access areas that have land use rights permanently guaranteed for public use in previously issued BCDC Permits will require additional review and approval from BCDC and new recordation of the proposed changes during permitting. For the proposed activities considered here that are in the BCDC 100-foot shoreline band jurisdiction and are outside of their designated water-oriented priority land use area, BCDC's McAteer Petris Act requires that any proposed development provide maximum feasible public access consistent with the proposed project. BCDC could require additional new public access to be included as part of the development actions to meet their requirement in these locations.

recommended that interpretative signage be developed to provide opportunities for educating the community and visitors to the shoreline about the risks of sea level rise, and the role that the landscape around them is playing to reduce vulnerability to sea level rise. This interpretative signage would be appropriate for the Bay Trail and any of the strategy alternatives.

4.1.6. Monitoring and Adaptive Management

Implementation of each of the proposed alternatives would occur over the decades to come. Given the substantial uncertainties that exist with respect to anticipated rates of sea level rise and changing societal and ecological goals, it is impossible to predict exactly when and how the project alternatives would be implemented. In Chapter 0, implementation timing is presented assuming a sea level rise trajectory corresponding to the California Ocean Protection Council's high-risk aversion sea level projections for RCP 8.5 (i.e., a high emissions scenario). Since it is not possible to predict the exact timing of future sea level rise, the actual timing of implementation of each action may occur later than indicated in the phasing diagrams and tables. Monitoring and adaptive management is therefore an important component of any alternative to identify thresholds and triggers to initiate planning for subsequent actions.

In addition, some future ecological enhancement and restoration actions within the project area will be dependent on ongoing monitoring and adaptive management decisions and cannot be prescribed at this time by the current project. For example, the desired future balance between tidal marsh and managed pond areas to achieve future habitat and restoration goals within the south San Francisco Bay depends on continued monitoring and research by the South Bay Salt Pond Restoration project, U.S. Geological Survey researchers, and others. Each alternative identifies a reasonable suite of environmental actions that are generally compatible and complementary with the proposed flood protection and transportation actions; however, the proposed environmental enhancement and restoration actions are flexible and can be modified based on future adaptive management decisions. The proposed alignments of the primary flood protection components of each alternative have generally been delineated to locate the line of defense as landward as possible, allowing for flexibility in the environmental actions that may occur along the Bay shoreline.

4.2. EVALUATION FRAMEWORK

4.2.1. Development of Evaluation Framework

An alternative evaluation framework was developed to facilitate a performance assessment of the proposed adaptation alternatives with respect to project goals. For this project, a set of "strategies" or "actions" formed an "alternative" and the evaluation was conducted at the alternative level, not the individual strategy level. The criteria were drafted in advance of the development of the strategies to inform the team regarding appropriate alternative design. Each alternative was also evaluated based on the selected criteria.

The development of the adaptation alternatives evaluation framework was informed by MTC's objectives for the study as described in the RFP, the review of relevant local studies summarized in Section 1.4, the results of the vulnerability assessment conducted as part of this project, and goals and evaluation criteria from other similar sea level rise adaptation planning projects in the Bay Area and beyond. In addition, local knowledge and expertise of stakeholders and the community was incorporated into the development of the adaptation alternatives evaluation framework and its criteria. The criteria were informed by:

- Input from the Stakeholder Working Group received at the first and second stakeholder meetings

- Values expressed by community members at the Nuestra Casa-led ART Community Engagement Workshops about assets that are important to them in their neighborhoods
- Feedback from the Acterra Climate Change Working Team on the social and environmental criteria
- Feedback from community members who attended various pop-up events

A criterion relating to carbon sequestration was added based on SWG and community input and note taken of a desire for interpretative signage to be provided for any future sea level rise adaptation strategy to educate and inform community members and visitors to the shoreline. A note was also added that the flood protection was for all housing types at community request, including multi-family. There was broad support for the other criteria.

Note that some of the issues raised by the stakeholder working group, and by community members were not within the scope of the project, but these concerns were consolidated and shared with appropriate agencies (relating to traffic congestion, affordable housing, displacement, undergrounding of utilities and provision of renewable energy).

The vulnerability assessment provided information on the location and timing of flood impacts and showed that flood depth and extent will get increasingly more severe as sea levels increase. To develop strategies that met both short and long-term flood protection goals, alternatives were evaluated on their ability to adapt to higher levels of sea level rise, to provide short and long-term flood protection, and to be incorporated into a larger-scale regional flood protection system.

4.2.2. Evaluation Criteria

4.2.2.1. Ranking System

A qualitative ordinal ranking system was used for evaluation criteria to score the overall performance of each proposed alternative. The goal was to evaluate the trade-offs between the different criteria categories and select alternatives that are the most balanced across the categories rather than calculate a total score per alternative. Table 6 shows how ordinal ranks were used for the evaluation exercise. This ranking system allowed for a qualitative comparison of the alternatives without the need for a total quantitative score.

TABLE 6. ORDINAL RANKING SYSTEM FOR EVALUATION CRITERIA

ORDINAL RANKS	RANK NOTATION	Associated color (for graphical output in evaluation matrix)
Significantly Positive	++	
Positive	+	
Neutral	0	
Negative	-	
Significantly Negative	--	

4.2.2.2. Criteria

Table 6 below shows the evaluation criteria used, along with ordinal ranking logic organized into categories (Engineering, Environmental, Feasibility, Social, and Transportation), presented in alphabetical order.

TABLE 7: PROPOSED ADAPTATION ALTERNATIVES EVALUATION CRITERIA AND ORDINAL RANKING RATIONALE

CRITERIA ID	PROPOSED CRITERIA	ORDINAL RANKING RATIONALE	
	Engineering (N) Criteria		
N1	Construction access and impacts e.g. traffic disruption, environmental impact (feasibility is accounted for in cost)	Construction access & impacts	Rank
		Very Low	++
		Low	+
		Med	0
		High	-
		Very High	--
N2	Ability of alternative to adapt to higher levels of SLR beyond design level (note that this criteria also indirectly addresses SLR lifespan)	Adaptability	Rank
		Greater than additional 24" of SLR (TBD)	++
		Up to additional 24" of SLR (TBD)	+
		Up to additional 12" of SLR	0
		Up to additional 6" of SLR	-
		Not adaptable	--
N3	Ability of alternative to be integrated into large-scale or regional flood protection plans and regional restoration plans (i.e., ability to tie-in to adjacent protective features)	Integration	Rank
		Can integrate into regional flood protection and regional restoration plans	++
		Can integrate into either regional flood protection or regional restoration plans	+
		Not possible to integrate into either	--
N4	Ability of alternative to not preclude other strategies or adaptation pathways	Preclusion	
		Yes	++
		No	--
	Environmental (E) Criteria		
E1	Ability of alternative to align with or make progress towards regional habitat goals	Habitat Goals	Rank
		Highly aligns	++
		Moderate alignment	+
		Not applicable	0
		Does not align	-
		Goes against goals	--
E2	Ability of alternative to protect/enhance/expand/utilize ecosystem value/functions/ services (through nature-based solutions such as wetlands, living levees)	Ecosystem Value	Rank
		Ecosystem enhanced or expanded by alternative	++
		Ecosystem protected/maintained by alternative	+
		No impacts on ecosystem	0
		Ecosystem harmed by alternative	-
		Ecosystem substantially harmed by alternative	--
E3		Sensitive habitat / special species	Rank

CRITERIA ID	PROPOSED CRITERIA	ORDINAL RANKING RATIONALE	
	Ability of alternative to protect/enhance/expand sensitive habitat and special status species	Habitat and species enhanced or expanded by alternative	++
		Habitat and species protected by alternative	+
		No impacts on habitat and species	0
		Habitat and species harmed by alternative	-
		Habitat and species substantially harmed by alternative	--
E4	Ability of alternative to maintain or improve Bay water quality (wetlands, vegetated swales)	<u>Water Quality</u>	<u>Rank</u>
		Water quality greatly improved	++
		Water quality slightly improved	+
		No impacts to water quality	0
		Water quality slightly worsened	-
		Water quality greatly worsened	--
E5	Ability of alternative to provide carbon sequestration benefits	Carbon Sequestration	Rank
		Very High	++
		High	+
		Neutral	0
		Negative (generates some carbon emissions)	-
		Very negative (generates substantial carbon emissions)	--
	Feasibility (F) Criteria		
F1	Capital Cost (excluding engineering and environmental costs)	<u>Capital Cost</u>	
		Very Low (<$10M)	++
		Low ($10-50M)	+
		Medium ($50-500M)	0
		High ($500-1000M)	-
		Very High (>$1000M)	--
F2	Rough order of magnitude annual operating and maintenance cost of alternative	<u>Operational Cost</u>	<u>Rank</u>
		Very Low	++
		Low	+
		Medium	0
		High	-
		Very High	--
F3	Alternative can be accomplished within existing policies, procedures, and regulations	<u>Alternative within Existing Policies</u>	<u>Rank</u>
		Yes	++
		Unknown/ in flux	0
		No	--
F4	Likelihood of alternative obtaining political / community support (as reflected in community input to date)	<u>Political Support</u>	<u>Rank</u>
		Very High	++
		High / positive	+
		Neutral /unknown	0
		Low/Negative	-

CRITERIA ID	PROPOSED CRITERIA	ORDINAL RANKING RATIONALE	
		Very Low/negative	--
	Social (S) Criteria		
S1	Businesses protected	Businesses Protected	Rank
		All protected	++
		Some protected	+
		No change	0
		Some protection reduced or removed	-
		Extensive protection reduced or removed	--
S2	Homes protected (all types)	Homes Protected	Rank
		All protected	++
		Some protected	+
		No change	0
		Some protection reduced or removed	-
		Extensive protection reduced or removed	--
S3	Ability of alternative to prevent mobilization of contaminants from hazardous sites (either groundwater or overland flooding)	Scenario	Rank
		Alternative prevents movement of contaminants from groundwater and inland flooding	++
		Alternative prevents movement of contaminants from either groundwater or inland flooding	+
		Alternative has no impact on movement of contaminants	0
		Alternative facilitates movements of contaminants	--
S4	Ability of alternative to protect/enhance recreational amenities	Scenario	Rank
		Amenities enhanced/created by alternative	++
		Amenities protected by alternative	+
		No impact to amenities	0
		Amenities somewhat reduced by alternative	-
		Amenities substantially reduced by alternative	--
S5	Ability of alternative to improve public access to shoreline	Scenario	Rank
		Shoreline access enhanced/created by alternative	++
		Shoreline access protected by alternative	+
		No impact to shoreline access	0
		Shoreline access somewhat impeded by alternative	-
		Shoreline access substantially impeded by alternative	-
	Transportation (T) Criteria		
T1	Ability of alternative to address flooding of Dumbarton Bridge approach within study area	Yes, completely	++
		Yes, partially	+
		No	--
T2	Ability of alternative to address flooding of adjacent road network within study area	Yes, completely	++
		Yes, partially	+
		No	--

Note: SLR = sea level rise

4.3. DEVELOPMENT OF ALTERNATIVES

The development of the adaptation alternatives was conducted in multiple stages. During the first stage of the alternatives development, the project team developed an initial list of adaptation strategies that could potentially be implemented in the project area. This initial list was reviewed with the PMT and SWG and additional strategies were identified and added to the list while some were removed. The project team formulated two draft near-term and three draft long-term alternatives that were made up of different combinations of individual strategies. These draft alternatives were further vetted with the PMT and SWG and refined to one near-term and two long-term alternatives. The three final alternatives were then further developed in the Implementation Plan (Chapter 0). An overview of the initial strategy and alternatives development is described below.

INITIAL STRATEGY DEVELOPMENT

In the initial strategy development phase, the following information was catalogued for each strategy:

- **Strategy** – short description of the adaptation strategy
- **Asset** – name of asset(s) that would be protected, addressed, or enhanced by the strategy
- **Focus Area** – location of the strategy, either entire study area, north of SR 84, south of SR 84, East Palo Alto, or Menlo Park
- **Timing** – short-term, mid-term, or long-term
- **Strategy Category** – ecology, transportation, stormwater, utilities, flood protection, public access and recreation, and informational

Examples of the range of initial strategies identified are shown in Table 8.

TABLE 8. EXAMPLE STRATEGIES IDENTIFIED DURING INITIAL PHASE OF ALTERNATIVES DEVELOPMENT

Strategy Category	Example Strategies
Flood Protection	Construct new flood protection levees to protect homes, businesses, and infrastructure Raise/retrofit existing flood barriers Raise external and internal pond berms for flood protection and enhanced water flow management
Ecology	Restore managed pond areas to vegetated tidal marsh Remove unnecessary armoring/rubble along berms Coarse beach creation along outboard pond berms for erosion protection Provide additional connectivity of tidal habitats Realign flood protection levees to create habitat and alongshore connectivity Remove embankment fill to create habitat and alongshore connectivity Create upland transition zones adjacent to berms and levees
Transportation	Raise local roads on embankment or causeway Raise bridge approach on causeway for sea level rise adaptation and alongshore habitat connectivity Remove railroad embankment and replace with raised causeway

Strategy Category	Example Strategies
Stormwater	Floodproof stormwater pump stations Retrofit stormwater pumps stations to accommodate higher Bay water levels or increased runoff due to climate change
Utilities	Relocate or retrofit Ravenswood substation and transmission lines to less vulnerable location
Public Access and Recreation	Raise or realign existing trails
Informational	Monitor sedimentation rates in adjacent mudflats and marshes and response of habitats to sea level rise Study feasibility of restoration activities to stabilize eroding marsh edges Study effects of sea level rise on groundwater and mobilization of contaminants

ALTERNATIVES DEVELOPMENT

The initial alternatives development formulated two draft near-term and three draft long-term alternatives from the initial list of potential adaptation strategies.

The near-term alternatives included strategies that are intended to provide near-term flood protection for existing flood vulnerabilities, essentially "buying time" for completion of the longer-range planning, design, permitting, and funding that would be required to implement the more complex and costly long-term alternatives. The near-term flood protection strategies include targeted small-scale berm and shoreline improvements to address existing flood pathways and vulnerabilities identified in Chapter 0. The near-term alternatives also include strategies to facilitate restoration in Ponds R1 and R2, if and when those restoration efforts occur. For example, near-term restoration preparation strategies include enhanced water management to promote natural sedimentation in the ponds to raise bed elevations and construction of an ecotone levee around the Ravenswood substation to allow tidal restoration of either Pond R1 and/or R2.

The long-term alternatives included strategies that are intended to provide long-term flood protection for the transportation, community, and infrastructure assets in the project area. The primary strategies to achieve long-term flood protection are the construction of a system of interconnected flood protection levees with the optional raising of the west approach of the Dumbarton Bridge. The draft long-term alternative to raise the highway considered three potential touchdown points for the west approach of the bridge: (1) at Ravenswood Substation, (2) at University Avenue, and (3) west of University Avenue. The third option was dropped from further development because it was determined to be infeasible from an engineering standpoint due to the complexity of the raised connection with University Avenue. Options 1 and 2 were retained and are presented in more detail in Chapter 0 as Alternative 3 – Raise the Road. The long-term alternatives also incorporate consideration of ecosystem services and co-benefits by removing barriers to the natural flow of water, sediment, wildlife, and public access along the shoreline by enhancing the alongshore connectivity of habitats.

During meetings with the community, the following feedback was provided to the project team on the alternatives. This feedback was considered and incorporated into the final alternatives development and refinement where possible (and other issues noted below for follow-on projects).

- Desire for habitat restoration including the concept of chinampas – floating islands of sediment and sticks that provide habitat, used in South and Central America.
- Desire to understand potential groundwater and stormwater impacts behind the levees and how these would be addressed.
- Support for alternatives that provided environmental stewardship including living levees, trees, vegetation and protecting the marsh.
- Support for alternatives that provide more walkways and trails, recreation areas, and access to the Bay
- Support for raising levees to protect homes and keep the community in place
- Concern over moving the Ravenswood Substation closer to the community. Suggestion to consider that it remain in place or relocate elsewhere away from homes, or enclosing at new location.
- Concern regarding raising SR 84 and mixed support for raising University Avenue, with a desire to understand potential impacts on surrounding streets.
- Concern over the potential disruption that all alternatives will cause during construction.
- Concern over who will pay for the projects. Request for private funding or grant funding.
- Interest in whether the ultimate projects will provide jobs for East Palo Alto residents.

Based on the community input, and further PMT and SWG feedback, the five draft alternatives were refined and consolidated into three final alternatives. For example, major components of the SAFER Bay levee project were incorporated into Alternative 2 – Protect in Place. The three final alternatives (near-term Alternative 1 and two long-term Alternatives 2 & 3) were then developed further as documented in Chapter 0, which includes narrative descriptions, plan view and cross section schematics, cost estimates, adaptation pathways and timeline, and potential project proponents for each alternative.

5 IMPLEMENTATION PLANS

5. IMPLEMENTATION PLANS

5.1. INTRODUCTION

This chapter presents a summary of the key elements of each alternative, including strategy narratives, ecosystem services, plan view schematics and typical sections, cost estimates, and project implementation phasing and timelines. It is noted that implementation of any alternative will require funding and actions across a variety of entities over several decades. No alternative can be implemented by a single agency alone. This section discusses the phasing and implementation timeline for each alternative illustrated through an 'adaptation pathways' type diagram and identifies agencies that could potentially take the lead for implementation. This chapter provides more detail on the sequencing of the various actions that comprise each alternative and identifies near-term, mid-term, and long-term action steps.

Strategies have been developed to provide flood and sea level rise protection and environmental enhancement. These elements are seen as being of equal importance and both are critical to the success of the project. The alternatives that were developed were measured against a set of evaluation criteria crafted with input from the PMT and SWG to ensure that each alternative met the needs of the project (see Section 4.2).

5.2. REGULATORY CONSIDERATIONS

5.2.1. Overview

For each alternative, the individual actions would likely be grouped into separate projects based on common landowner and stakeholder(s). The projects may be sequential or overlapping and could be led by different project proponents and partnering agencies. Each scope of work identified as an individual project would need a local project sponsor to carry it through design, environmental clearance, permits, contract delivery, construction and long-term monitoring, and operations and maintenance.

Depending on the scope of the potential projects, the regulatory process would vary from straightforward and expedited to complex and prolonged. Complex projects would require a greater need for engineering, planning, and mitigation of potential impacts to ensure that all elements are planned and designed appropriately with greater consideration of community input. Without a specifically scoped phase of work championed by a local sponsor identified for each phase or project, it is challenging to put precise timelines on the project delivery process, although approximate timelines are provided below.

Table 9 lists the project attributes that can contribute to the regulatory process and timeline.

TABLE 9. RANGE IN PROJECT ATTRIBUTES CONTRIBUTING TO REGULATORY TIMELINE

Expedited Process (1 to 2 years)	Moderately Complex Process (3 to 5 years)	Complex and Prolonged Process (4 to 8 years)
Individual project with clear and strong project sponsor	Multiple project components with single or multiple project sponsors	Multiple project components with multiple sponsors
Available or existing funding source	Mixed funding sources	Multiple, uncertain, or new funding sources; robust spending oversight
Minimal CEQA and/or NEPA requirements	Moderate CEQA and/or NEPA requirements	Substantial CEQA and/or NEPA requirements
No or minimal environmental impacts	Avoidable or mitigatable environmental impacts	Substantial unavoidable environmental impacts with compensatory mitigation
Minimal state or federal design requirements	Moderate state or federal design requirements	Robust state or federal design requirements
No public or political controversy	Some public or political controversy	High public or political controversy
Single landowner	Multiple landowners	Multiple landowners
Simple engineering design and minimal review	Moderately complex engineering design and review	Complex engineering design and robust review

Figure 8 shows a flowchart that follows the steps and concurrent processes required to deliver a project to completion. This process would be completed for each project to meet the overall goals and objectives of the Dumbarton Bridge West Approach + Adjacent Communities Resilience Study.

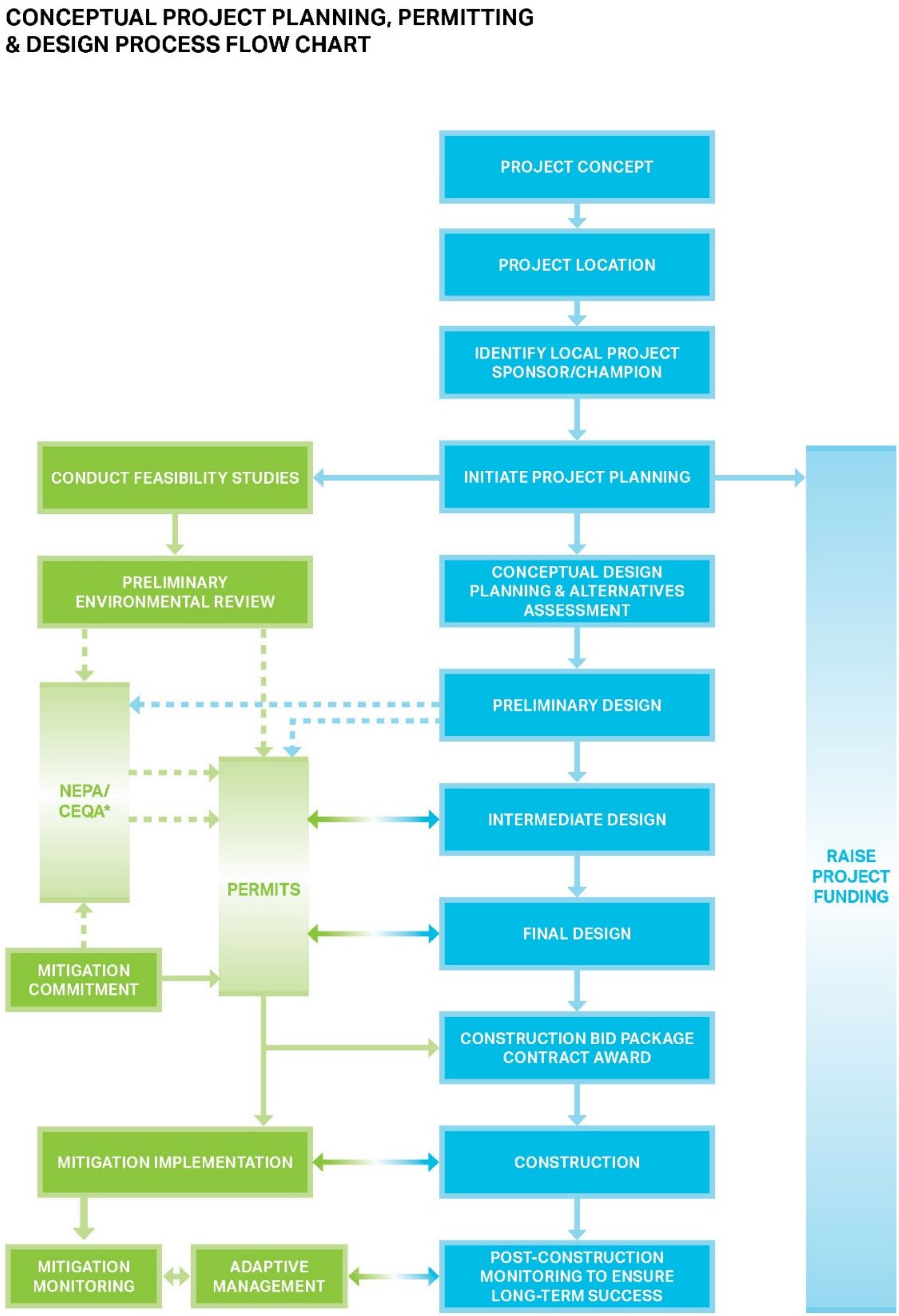

FIGURE 8. STEPS AND CONCURRENT PROCESSES REQUIRED TO COMPLETE A PROJECT

5.2.2. Regulatory Requirements

The proposed alternatives would be subject to state and federal environmental laws, regulations, and policies that protect natural resources. Each project would have its own permitting process depending on the location, jurisdictional areas potentially impacted and level of impact and potential requirements for mitigation. Most of the proposed project elements occur within some portion of the Bay and would overlap multiple jurisdictions, triggering environmental permit requirements. Opportunities for expediting the environmental planning and permitting process may be available to certain components of the various alternatives. For example, the recently formed San Francisco Bay Restoration Regulatory Integration Team (BRIIT) aims to improve the permitting process for multi-benefit habitat restoration projects and associated flood management and public access infrastructure components along the shoreline of the nine Bay Area counties. In addition, the recent BCDC Fill for Habitat Bay Plan amendment may change project proponent perceptions of what type of shoreline activities are permissible in the future, especially related to sea level rise adaptation and implementation of nature-based and grey-green strategies.

A brief summary listing the anticipated regulatory laws that may be triggered by the proposed actions is provided below.

5.2.2.1. Wetlands and Waters

- The federal Clean Water Act of 1972 (CWA) (33 U.S.C. §1251 et seq.). The CWA establishes basic structure and guidance for regulating discharges of pollutants into waters of the US.
- Section 404 of the CWA. CWA Section 404 establishes a program to regulate the discharge of dredged or fill material into waters of the US, including wetlands for review by the US Army Corps of Engineers (USACE).
- Section 401 of the CWA. CWA Section 401 requires that any person applying for a federal permit or license which may result in discharge of pollutants into waters of the US, must obtain a state water quality certification
- Section 10 of the Rivers and Harbors Appropriation Act of 1899 (RHA Section 10) (33 U.S.C 403). RHA Section 10 requires permits for all structures placed in navigable waters of the U.S.
- Porter Cologne Water Quality Control Act (Porter-Cologne Act) (Water Code § 13000 et seq.). The Porter Cologne Act establishes state policy and guidance to regulate and protect the quality of all waters of the state for the use and enjoyment by the people of the states.

5.2.2.2. Coastal Protections

- Coastal Zone Management Act of 1972 (CZMA). The CZMA is the primary federal law enacted to preserve and protect coastal resources. Authority to administer consistency determination under the CZMA in the Bay has been delegated to BCDC.
- BCDC. BCDC retains oversight and planning responsibilities for development and conservation of coastal resources in the Bay. The regulatory authority for BCDC is found in the McAteer-Petris Act and the Suisun Marsh Protection Act. The McAteer-Petris Act directs the Commission to exercise its authority to issue or deny permits for placing fill, extracting material, or changing use of any land, water or structure within the Commission's jurisdiction in conformity with the provisions and policies of both the McAteer-Petris Act and the Bay Plan. BCDC's jurisdiction extends to the mean high tide line in areas that do not contain

tidal marsh and up to five feet above mean sea level in areas of tidal marsh. The 100-foot shoreline band extends inland for 100 feet from the shoreline of the Bay.

5.2.2.3. Protected Species and Habitat

- Migratory Bird Treaty Act of 1918 (MBTA). The MBTA makes it illegal to take, possess, import, export, transport, sell, purchase, barter, or offer for sale purchase, or barter any migratory bird, or the parts, nests, or eggs of such bird except under the terms of a valid federal permit.
- The federal Endangered Species Act of 1973 (ESA) (16 U.S.C. § 1531 et seq.). The ESA provides a regulatory program for the conservation of threatened and endangered plants and animals and the habitats in which they are found. The U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) are the lead agencies responsible for implementing the ESA.
- Magnuson-Stevens Fisheries Conservation and Management Act (MSA). The MSA is the Primary Law governing marine fisheries management and Essential Fish Habitat (EFH) in the U.S. and federal waters. NMFS is responsible for implementing the MSA.
- California Endangered Species Act (CESA). CESA conservers and protects animals at risk of extinction.
- California Fish and Game Code (CFGC) Fully Protected Species. Sections 3511, 4700, 5050 and 5515 of the CFGC designate 37 species of wildlife as "Fully Protected" in California. Fully Protected species may not be taken or possessed at any time and no licenses or permits may be issued for their take except for collecting these species for necessary scientific research and relocation of the bird species for the protection of livestock.
- CDFW 2081(b) Incidental Take Permit (ITP). Section 2081(b) of the CFGC allows CDFW to authorize take of CESA listed species listed as endangered, threatened, candidate, or rare plant species if that take is incidental to otherwise lawful activities and if certain conditions are met.

Each project would have its own permitting process depending on the location, jurisdictional areas potentially impacted, level of impact, and potential requirements for mitigation. Most of the project elements occur within some portion of the Bay and would overlap multiple jurisdictions listed in Table 10, triggering environmental permit requirements for the proposed actions. Opportunities for expediting the environmental planning and permitting process may be available to certain projects included in the scope of this proposed concept.

TABLE 10. POTENTIAL PERMITS REQUIRED BY AGENCY AND JURISDICTION

Permit, Authorization or Agreement	Issuing Agency	Jurisdiction
Clean Water Act Section 404 Permit	U.S. Army Corps of Engineers	Discharge of dredge or fill material to Wetlands and Waters of the U.S.
Section 10 of the Rivers and Harbors Appropriation Act of 1899 Authorization (issued with a 404 permit)	U.S. Army Corps of Engineers	Impacts to Navigable Waters of the U.S.
Clean Water Act Section 401 Water Quality Certification	Regional Water Quality Control Board	Discharge into Waters of the U.S.
Waste Discharge Requirements	Regional Water Quality Control Board	Discharges into Waters of the State
Endangered Species Act Section 7 Consultation resulting in an issued Biological Opinion or Letter of Concurrence	National Marine Fisheries Service and/or US Fish and Wildlife Service	Federally Threatened and Endangered Species and their Critical Habitat
Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation	National Marine Fisheries Service	U.S. Coastal Fisheries
California Fish and Game Code Section 2081 Incidental Take Permit	CA Department of Fish and Wildlife	Take of State Listed Species
California Fish and Game Code Section 1600 Lake or Streambed Alteration Agreement	CA Department of Fish and Wildlife	Alterations to non-tidal lakes and streambeds
San Francisco Bay Conservation and Development Commission Permit	Bay Conservation and Development Commission	The San Francisco Bay, Tidal Wetlands and the 100-foot Shoreline Band
Coastal Zone Management Act Consistency Determination	Bay Conservation and Development Commission	The San Francisco Bay, Tidal Wetlands and the 100-foot Shoreline Band
California State Lands Commission Lease	California State Lands Commission	Public Trust Lands

5.3. COSTING METHODOLOGY

The alternatives cost estimates incorporated costs associated with planning, design, environmental clearance, permitting, and construction of each strategy or action that comprised the alternative. The individual actions were costed from the ground up, meaning the cost for each action was calculated based on the material, labor and equipment required to construct it. Material quantities were estimated from representative cross sections for each action and estimates of labor and equipment were based on construction means and methods. The unit rates for labor, material, and equipment were based on several sources including cost data from Caltrans Cost Indexes, RSMeans (database of US construction costs with location adjustment factors), local projects carried out by AECOM, and prevailing wages. The construction cost of each action was totaled to obtain direct construction costs. Markups were then added to account for contractor mobilization/demobilization, overhead, profit, and insurance. The costs for design contingency, engineering fees, and environmental permitting and clearance were obtained by applying additional markups to the total construction costs.

5.4. ALTERNATIVE 1 – NEAR-TERM: INTERIM FLOOD PROTECTION AND RESTORATION PREPARATION

5.4.1. Description

Alternative 1 is a series of strategies that addresses near-term flooding impacts to the project site and the future restoration and/or management of Ponds R1 and R2 by the Don Edwards San Francisco Bay National Wildlife Refuge and South Bay Salt Pond Restoration Project. The flood protection strategies would mitigate against flooding from smaller flood events (equivalent to MHHW +24") and are intended to lessen the frequency and magnitude of flood impacts until a long-term alternative is implemented. The restoration preparation activities would facilitate accretion of Bay sediment in Pond R1 and R2 to raise bed elevations in anticipation of either future tidal restoration or ongoing managed pond operations (depending on which action is deemed most appropriate for these ponds based on monitoring and adaptive management in the future – see Section 4.1.6).

Alternative 1 is a series of simple and interim actions intended mitigate flooding until a long-term flood protection system is implemented. The permitting and construction time required for all actions is short, about 2 to 3 years for all actions. Due to the existing state of the shoreline, almost all of the actions should be implemented as soon as possible since the majority of the project shoreline is vulnerable to flooding under a 100-yr storm (with no sea level rise). Since these actions are meant to provide temporary protection, they are built to approximate 50 or 100-yr flood level without consideration of sea level rise. The intention of these actions is to provide protection from more frequent and likely events (< 25-yr storm) and not necessarily protect for larger events with sea level rise.

5.4.1.1. Key Features

The key features of Alternative 1 (two options) are discussed below. Figure 9 and Figure 11 show plan view schematics and the phasing diagram is shown in Figure 10. The numbers and colors in each figure are corresponding. Figure 12 shows a cross section schematic showing the proposed actions that comprise Alternative 1 – Flood Protection and Restoration Preparation.

FLOOD PROTECTION STRATEGIES

The flood protection strategies include physical strategies such as raising low-lying sections of the existing berm and levee system surrounding the project area. The elevations to which the berms and levees would be raised vary depending on adjacent shoreline elevation, the presence of surrounding ponds that may help retain floodwaters, and planned future levee upgrades. An operational strategy to manage water levels in the SF2 Ponds is also proposed to help limit flooding along the south part of SR 84 in the event of levee overtopping. The individual strategies would be implemented in conjunction with one another to provide comprehensive short-term flood protection for the entire project site.

RESTORATION PREPARATION STRATEGIES

The restoration preparation strategies would facilitate natural sediment deposition into Pond R1 and/or R2 to accelerate future tidal restoration, if and when it occurs. The existing bed elevations in these ponds are approximately 4.5 to 5 ft NAVD88, or about 2 to 2.5 ft below marsh plain elevation. As sea level rises, the ponds will fall farther behind rising tides, making them more difficult or costly to restore or manage in the future. Using two-way water control structures, water would be allowed to flow into Ponds R1 and/or R2 every two weeks on spring tides[4], during which suspended sediment would also be transported into the ponds. Over the subsequent weeks, sediment would settle out of the water column and onto the pond bottom while water would be allowed to slowly drain out to the Bay through an outlet structure[5]. During the next spring tide (approximately two weeks later), the cycle would be repeated. Over time, the bed elevation of the pond would increase through repeated deposition events and help prepare the pond for future tidal marsh restoration and improve the timeline for marsh revegetation in the future. In addition, construction of new water control structures and higher pond bed elevations would allow USFWS to better manage water levels in the ponds seasonally for waterfowl and snowy plover nesting.

5.4.1.2. Key Actions

Key actions to implement this alternative include the following. Action numbers below correspond to the labeling in Figure 9 and Figure 11.

RAISE LOW-LYING SECTIONS IN THE LEVEE AND BERM SYSTEM

- Action 1: Raise the berm along the south access road between the shoreline and the Pond SF2 bayfront levee to 11 ft NAVD88 (approximately equal to today's 100-year storm tide), matching the elevation of adjacent shoreline features
- Action 2: Raise low spots along the berm fronting the SFPUC parcel between the Pond SF2 bayfront levee and railroad berm to 10.5 ft NAVD88 (approximately 0.5 feet below today's 100-year storm tide)
- Action 3: Floodproof the Caltrans pump station located on the north side of the Dumbarton Bridge touchdown to a height approximately 2 feet above the adjacent ground elevation
- Action 4: Raise low spots along the Pond SF2 bayfront levee to 10.5 ft NAVD to lessen the frequency and magnitude of overtopping
- Action 5: Construct a new levee to enable tidal restoration in Ponds R1/R2
  - Option 1 (Figure 9): Construct a new levee at 12 ft NAVD88 (approximately 1 foot above today's 100-year storm tide) with an ecotone slope along the landward edge of Pond R2 and around the

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[4] Spring tides are regularly occurring, predictable astronomical high tides that occur every two weeks at full and new moons

[5] The process of controlled diversion of sediment-laden floodwaters to allow for natural deposition of sediment onto the land surface is called "warping" and was practiced in Europe beginning in the 18th Century and likely much longer on the Nile River in Egypt.

  Ravenswood substation[6] (see Figure 12 for cross section schematic) to enable tidal restoration of Pond R2.
  - Action 5: Option 2 (Figure 11): Construct a new levee at 12 ft NAVD88 (approximately 1 foot above today's 100-year storm tide) with an ecotone slope along the internal berm between Ponds R1 and R2 to enable tidal restoration of Pond R1.
  - Construct new public access trail along the top of the new Pond R1/R2 levee in coordination with USFWS and PG&E (in consideration of potential access constraints related to habitat disturbance and substation security).
- Action 8: Raise the berm along the north edge of SR 84 between the Facebook campus and the western edge of Pond R2 to 12 ft NAVD88. Improve and extend public access trail towards Pond R2.

PREPARE POND R1 AND R2 FOR FUTURE TIDAL RESTORATION AND/OR MANAGED POND OPERATIONS

- Action 6: Replace the intake/outlet structure along the Pond R1 levee at Ravenswood Slough and repair internal berm between Pond R1 and R2 (Option 1)
  - Conduct studies to develop a sedimentation plan for Ponds R1 and R2 to increase accretion rates. This would include the design, location, and operation of the water control structures to maximize accretion rates.
  - Install intake/outlet structure in Pond R2 bayfront levee
  - Operate Pond R1 and R2 water control structures to optimize natural sedimentation in the managed ponds
  - Continue levee maintenance and inspections for erosion along bayfront levees exposed to waves

OPTIMIZE THE DETENTION CAPACITY OF POND SF2

- Action 7: Develop a storm operation plan of the water control structures of Pond SF2 pond to allow maximum detention capacity during storm events in the event of levee overtopping and mitigate flooding of the south access road and SR 84.

[6] Construction of the levee around the Ravenswood substation is a necessary step to restore Pond R2 to tidal marsh and is currently under consideration by the San Francisquito Creek JPA as part of the proposed mitigation for actions that are part of the SAFER Bay project. Due to the in-progress nature of this action, it is included as part of the near-term actions in Alternative 1. SAFER Bay will continue to coordinate with USFWS and the SBSP Restoration Project to evaluate this potential action in Pond R2 moving forward.

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FIGURE 9. PLAN VIEW SCHEMATIC FOR ALTERNATIVE 1 – OPTION 1

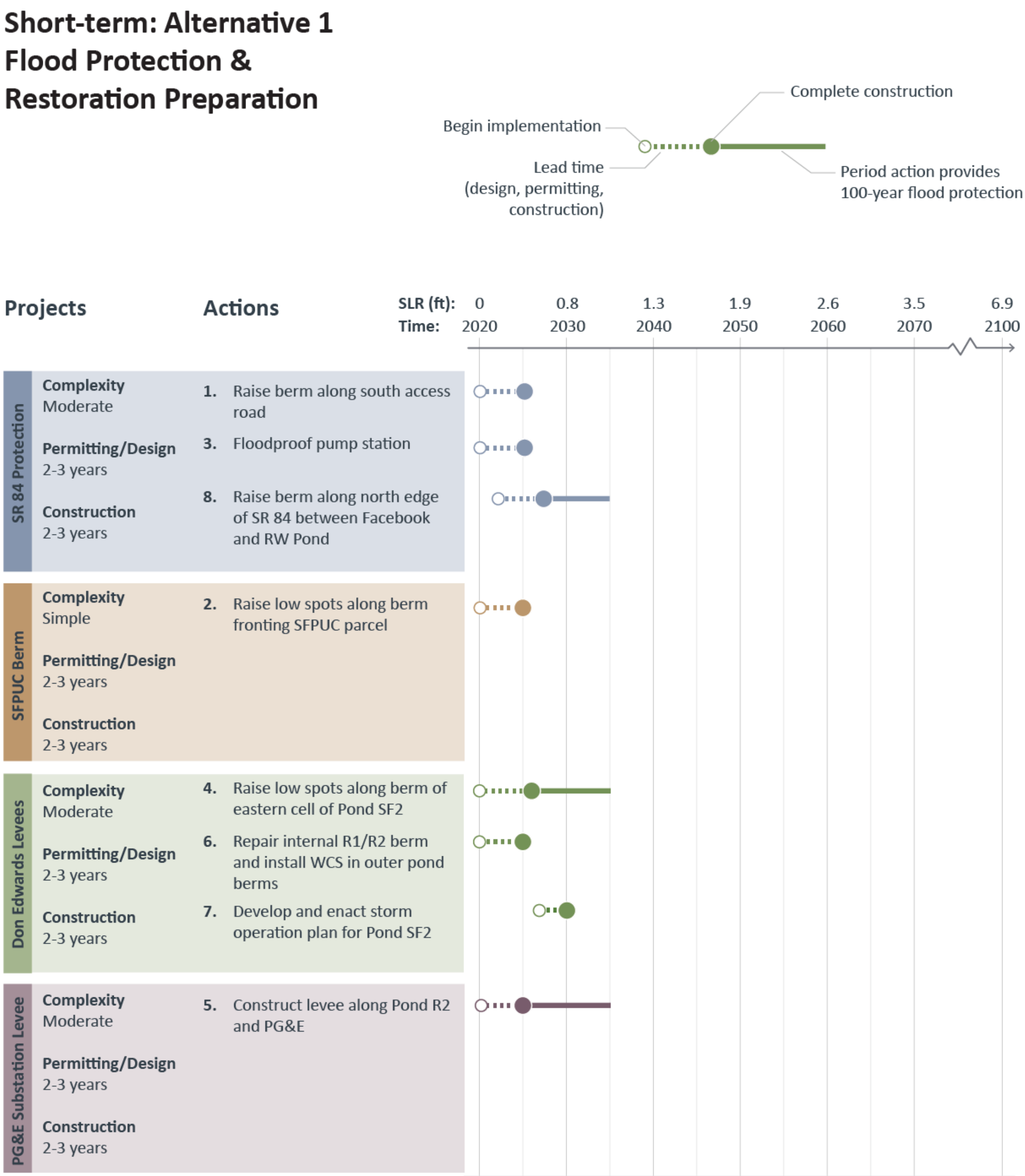

FIGURE 10. PHASING DIAGRAM FOR ALTERNATIVE 1

FIGURE 11. PLAN VIEW SCHEMATIC FOR ALTERNATIVE 1 – OPTION 2

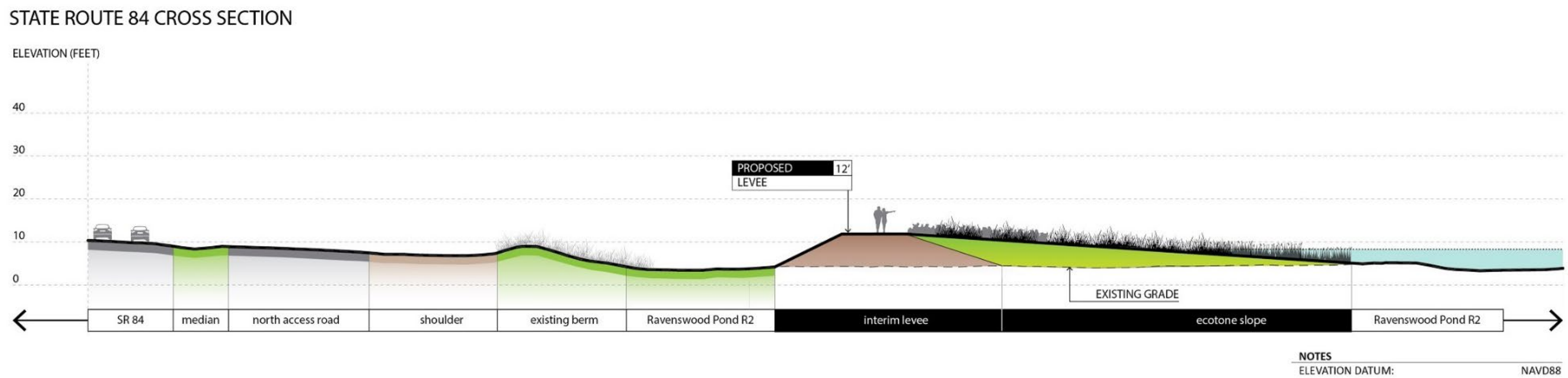

FIGURE 12. CROSS-SECTION SCHEMATIC OF THE LEVEE TO BE BUILT ALONG THE LANDWARD EDGE OF POND R2 ADJACENT TO SR 84 AND AROUND THE PG&E SUBSTATION (OPTION 1)

5.4.1.3. Key Benefits

Implementing the actions in Alternative 1 will have the following benefits to the study area:

- Promotes accretion of sediment in Ponds R1 and R2 to raise pond beds and facilities future tidal restoration and/or management of those ponds by providing an equivalent level of flood protection for landward infrastructure as the existing bayfront berm
- Allows for better management of water levels in Pond R1 and R2 for waterfowl and snowy plover nesting
- Lessens the frequency and magnitude of near-term flooding of SR 84 and the surrounding access roads and infrastructure (such as the Ravenswood Substation)
- Improves public access by raising and extending the path between the public parking at Facebook entrance and Pond R2 levee; additional access opportunities may be created on top of new levee around Ravenswood substation and on divider berm between Pond R1 and R2 (provided security of Ravenswood substation can be maintained and access on divider berm does not disturb bird usage in the ponds)

5.4.1.4. Ecosystem Services

Under this alternative, most ecosystem services will be similar to those provided by existing conditions, including habitat for nesting waterbirds, short-term flood protection, and continued cultural services for people who use the Bay Trail along Pond SF2. At Pond SF2, using both cells of Pond SF2 as floodwater storage would conflict with long-term goals to create tidal marsh in the eastern cell. The timing of the need for flood water storage could affect nesting and roosting waterbirds using islands in Pond SF2. However, keeping these ponds for nesting waterbirds could maintain important habitat for these species in the near-term. Raising the existing berms will also continue to provide some flood protection to SR 84 from storm events.

Alternative 1 maintains existing barriers to habitat movement and decreases opportunities for wildlife and marsh connectivity with other restoration projects and habitats to the north and south of SR 84. The raised berm along the south access road and the raised levee fronting the SFPUC parcel will isolate the fringing tidal marsh habitat that currently exists external to Pond SF2, separating this area from other tidal marshes to both the north and south.

Habitat within Ponds R1 and R2 would largely remain unchanged in the near-term as these ponds continue to be operated as managed ponds until such time as they are restored to tidal marsh. These ponds currently provide flood storage and habitat for nesting bird species. Ponds R1 and R2 are currently managed by the USFWS for seasonal use by dabbling ducks, diving ducks, eared grebes, small shorebirds, medium shorebirds, and for snowy plovers, American avocets, and Forster's terns during nesting season. This management will likely continue until the South Bay Salt Pond Restoration Project restores these ponds to tidal marsh or alternate management decisions are made with regard to maintenance of the ponds. Ponds R1 and R2 will likely provide habitat functions similar to existing conditions as long as the USFWS continues to maintain the external berm, or until sea level rise or storm events overtop or breach the external berm at Pond R1 such that it cannot be repaired. The external berm at Pond R1 currently provided minimal flood protection and during recent winter storms (winter of 2019-2020) as significant segments of the levee eroded. If the external berm at Pond R1 is overtopped or fails, the operational usefulness of the water control structures to seasonally manage the ponds for sedimentation or wildlife may be altered.

5.4.1.5. Other Considerations

Other considerations involved with Alternative 1 include:

- Raising low spots along the existing levee and berm system will provide only an incremental increase in flood protection and some areas will still be vulnerable to flooding during larger events (e.g., > 50-yr storm surge event)
- The elevation to which the berms can be raised is limited by adjacent low-lying areas and sensitive habitat along the shoreline
- Near-term raising of existing low spots along levees and berms may represent a "throw away" cost (albeit a necessary cost) as more comprehensive flood protection actions will still be required in the future. In addition, the effective lifespan of these actions is unknown and dependent on actual rates of sea level rise in the future.
- Cost of managing and maintaining water control structures – especially if they require regular adjustments for sediment management or drawing down for floodwater detention.
- Feasibility of providing public access across and adjacent to bird habitat in managed ponds such as Pond R2 would need to be further evaluated and discussed with USFWS and researchers

5.4.2. Adaptation Pathways and Timeline

The order of implementation for the Alternative 1 key actions was based on prioritization of existing flood vulnerabilities and shoreline elevations, considering existing storm water levels and projected sea level rise. This information is provided in Table 11. This table also provides the approximate duration of permitting and construction for each action based on project complexity. The last column of the table gives the amount of sea level rise that the action will protect against.

TABLE 11. IMPLEMENTATION TIMELINE FOR ALTERNATIVE 1

No.	Action	Implementation Timeline	Required by X" of SLR*	Permitting Lead Time (years)	Construction Lead Time (years)	Provides protection up to X" SLR*
1	Raise berm along south access road	2020 - 2025	0	2 to 3	2 to 3	0
2	Raise low spots along berm fronting SFPUC parcel	2020 - 2025	0	2 to 3	2 to 3	0
3	Floodproof pump station	2020 - 2025	0	2 to 3	2 to 3	0
4	Raise low spots along berm of eastern cell of Pond SF2	2020 - 2025	0	2 to 3	2 to 3	0
5	Construct levee along Pond R2 and PG&E (Option 1) or between Ponds R1 and R2 (Option 2)	2020 - 2025	12	2 to 3	2 to 3	12
6	Repair internal R1/R2 berm and install WCS in outer pond berms	2020 - 2025	n/a	2 to 3	2 to 3	n/a
7	Develop and enact storm operation plan for Pond SF2	2025 - 2030	n/a	2 to 3	n/a	n/a

No.	Action	Implementation Timeline	Required by X" of SLR*	Permitting Lead Time (years)	Construction Lead Time (years)	Provides protection up to X" SLR*
8	Raise berm along north edge of SR 84 between Facebook and RW Pond	2025 - 2030	0	2 to 3	2 to 3	12

*When paired with a 50-year storm event

5.4.3. Action Grouping

The actions in Alternative 1 can be grouped into potential projects for permitting purposes based on location and common stakeholders. Table 12 summarizes these potential projects and lists the actions included for each grouping, which are the same groups shown in the phasing diagram (Figure 10). The table also provides an assessment of the corresponding complexity and estimated general timeline.

TABLE 12. POTENTIAL ACTION GROUPING FOR ALTERNATIVE 1

Potential Project	Project Complexity	Alternative 1 Actions Included	Permitting Lead Time (years)	Construction Lead Time (years)
SR 84 West Approach Protection	Moderately Complex	1, 3, 8	2 to 3	2 to 3
Ravenswood Substation Levee	Moderately Complex	5	2 to 3	2 to 3
Levees and Water Control Structures in Don Edwards National Wildlife Refuge Ponds	Moderately Complex	4, 6, 7	2 to 3	2 to 3
Raise Berm at Hetch Hetchy Facilities	Expedited	2	2 to 3	2 to 3

Note: Action numbering corresponds to labels shown in Figure 9 and Figure 11.

5.4.4. Cost Estimate

A cost estimate was developed for Alternative 1 that estimates high-level conceptual costs for the primary components, including direct costs, mobilization, contractor's fee, engineering fee, design and construction contingency, environmental clearance, and permitting (Table 13).

TABLE 13. COST ESTIMATE FOR ALTERNATIVE 1

	Item	Units	Quantity	Unit Price	Cost	Notes
1	Raise berm along south access road	LF	650	$ 241	$ 157,000	
2	Raise low spots along berm fronting SFPUC parcel	LF	520	$ 32	$ 17,000	Placement of fill along low spots of berm

	Item	Units	Quantity	Unit Price	Cost	Notes
3	Floodproof pump station	L/S	1	$ 200,000	$ 200,000	
4	Raise low spots along berm of eastern cell of Pond SF2	LF	3100	$ 100	$ 310,000	Placement of fill along low spots of berm
5	Construct levee with ecotone slope along Pond R2 and PG&E	LF	5310	$ 4,102	$ 21,782,000	Costs shown for construction of new levee (Option 1)
6	Repair internal R1/R2 berm and install WCS in outer pond berms	LF	5700	$ 369	$ 2,103,000	Includes two 2-way WCS and raising internal berm
7	Develop and enact storm operation plan for Pond SF2	L/S	1	$ 53,000	$ 53,000	
8	Raise berm along north edge of SR 84 between Facebook and Pond R2	LF	2135	$ 406	$ 866,000	
Sub-total					**$ 25,487,000**	
Contractor Mobilization/Demobilization & Overhead				15%	$ 3,823,000	For contractor's move in/out cost and contractor overhead
General Contractor Markup				5%	$ 1,466,000	Contractor profit
General Contractor Bond & Insurance				2%	$ 616,000	Contractor insurance
Sub-total					**$ 31,391,000**	
Design / Estimate Contingency				25%	$ 7,848,000	Scope changes due to existing conditions; unforeseen conditions and change orders during construction
Engineering Fees				10%	$ 3,139,000	Includes preliminary and final design
Environmental Clearance & Permitting				10%	$ 3,139,000	For studies and EIR reviews and oversight; permitting process
Total Cost for Alternative 1					**$ 45,517,000**	

Note: Action numbering corresponds to labels shown in Figure 9 and Figure 11.

5.5. ALTERNATIVE 2 – LONG-TERM: PROTECT IN PLACE

5.5.1. Description

Alternative 2 is a long-term strategy to provide flood protection to critical infrastructure and the community by protecting assets in place, first to 36 inches of sea level rise and then to 83 inches. This alternative would construct a levee along the north and south side of SR 84 and maintain the highway at its present elevation and alignment. The levee would generally follow the proposed SAFER Bay levee alignment (Reach 5) presented in the SAFER Bay Feasibility Report (SFCJPA 2019). Starting at the eastern edge of the Facebook campus, the levee would follow the berm along the north edge of SR 84, wrap around the Ravenswood Substation, continue along the north access road to the Bay shoreline, wrap around the Dumbarton Bridge touchdown (or tie into the bridge abutment), and continue along the south access road to the divider berm between the eastern and middle cells of Pond SF2. While generally "protecting in place", this alternative does align the line of defense landward in the southern part of the study area, providing more flexibility for future ecological restoration and management decisions.

5.5.1.1. Key Features

The key features of Alternative 2 – Protect in Place are discussed below. Figure 13 shows a plan view schematic and the phasing diagram is shown in Figure 14. The numbers and colors in each figure are corresponding. Figure 15 shows a cross section of the flood protection levee across the north access road extending into Pond R2. It shows the proposed levee and ecotone slope along the landward edge of Pond R2. This section builds upon the levee that was initially built in Alternative 1. Figure 16 shows a cross section of the SAFER Bay levee that is proposed along the East Palo Alto shoreline to protection the residential and commercial areas in the southern portion of the study area.

FLOOD PROTECTION LEVEES

Flood protection levees would be constructed along both sides of SR 84 and extend south to Bay Road in East Palo Alto and west to the Facebook Headquarters. The levees would follow the design parameters established by the SAFER Bay project and be built to 18 ft NAVD88 (approximately 7 feet above today's 100-year tide) to withstand a 100-year flood event with 3 feet of sea level rise and appropriate freeboard to obtain FEMA accreditation.

TIDAL RESTORATION

Areas bayward of the flood protection levees would have the opportunity to be restored to tidal marsh, if it is deemed appropriate based on monitoring and adaptive management decisions in the future. Restoration would occur by removing alongshore barriers to connectivity, such as the railroad berm and decommissioned above-ground Hetch Hetchy pipeline, and breaching or removing the redundant bayfront levee. In the interim prior to long-term restoration, these areas (such as managed Pond SF2) could continue to be operated and maintained according to their existing management plans.

5.5.1.2. Key Actions

Key actions to implement this alternative include:

SOUTH OF SR 84

- Action 1: Construct SAFER Bay levee along the East Palo Alto shoreline and across the SFPUC property, connecting to the Pond SF2 levee, to protect landward residential areas and the functional SFPUC infrastructure. Construct a new public access trail on top of the levee and connect to the existing Bay Trail segment to the south of Bay Road. Consider a phased realignment of the Ravenswood Preserve segment of the Bay Trail to the top of the new levee over time as it becomes exposed to more frequent flooding due to sea level rise.

- Actions 2 and 3: Remove alongshore barriers to hydrological connectivity, including the railroad embankment[7] and the decommissioned above-ground Hetch Hetchy pipeline and its supporting infrastructure. The Bay Trail spur that runs along the northern edge of the Ravenswood Preserve could continue to be used for public access until it becomes frequently flooded, at which point it could also be removed.
- Action 4: Restore the SFPUC parcel by lowering or removing the bayfront berm. Grade parcel to intertidal elevations and construct pilot channels and habitat mounds, while preventing inundation of the remediated Sportsmen's Club site immediately south of Pond SF2.
- Action 5: Raise the south access road on a levee starting at the intersection of the roadway with the new Pond SF2 levee and extend to the south side of the bridge abutment.
- Action 6: Construct a flood protection levee along the divider berm between the middle and eastern cells of Pond SF2 and install new water control structures in the levee to manage water levels in the pond. Construct trail on top of new levee to connect to the Bay Trail and replace trail segment along bayfront levee in Pond SF2 that would be lost when eastern cell is restored.
- Action 7: Restore the eastern cell of Pond SF2 by lowering or removing the now redundant SF2 Bayfront levee and its water control structures. Construct pilot channels and grade to intertidal channels if required. Realign existing segment of Bay Trail spur along Pond SF2 shoreline to new levee.

NORTH OF SR 84

- Action 8: Construct levee along the north access road and connect to the north side of the bridge abutment. Near the abutment, a sheet pile wall may be required instead of a levee due to space limitation. The levee or sheet pile wall will be aligned to also protect the Caltrans pump station.
- Action 9: Raise levee along the north edge of SR 84 between Facebook and the western edge of Pond R2. This berm was initially constructed as part of Alternative 1. This action will replace or raise it to meet the design elevation of the SAFER Bay levee. Relocate pedestrian path between Facebook and University Ave to levee top and extend pedestrian path from University Ave to eastern edge of Pond R2.
- Action 10: Raise previously constructed levee along the landward edge of Pond R2 and around the Ravenswood Substation (Alternative 1). This action will raise it to match the design criteria of the SAFER Bay levee.
- Action 11: Raise levee surrounding the Facebook campus to match SAFER Bay levee design criteria.
- Other actions:
    - Retrofit or replace the Ravenswood pump station outfall structure on the north side of SR 84
    - Rehabilitate existing trails and construct new trails on top of new levee segments to provide connected public access across full project area from Facebook to Bay Road.

[7] This embankment runs along the potential Dumbarton Rail Corridor project alignment currently being evaluated by SamTrans and Cross Bay Transit Partners. For the purposes of this resilience study, it was assumed that if a rail project is implemented along the corridor, the portion of the rail line that traverses the study area could be elevated on a raised structure to support the alongshore connectivity goals of the Dumbarton Bridge West Approach + Adjacent Communities Resilience Study.

FIGURE 13. PLAN VIEW SCHEMATIC FOR ALTERNATIVE 2 – PROTECT IN PLACE

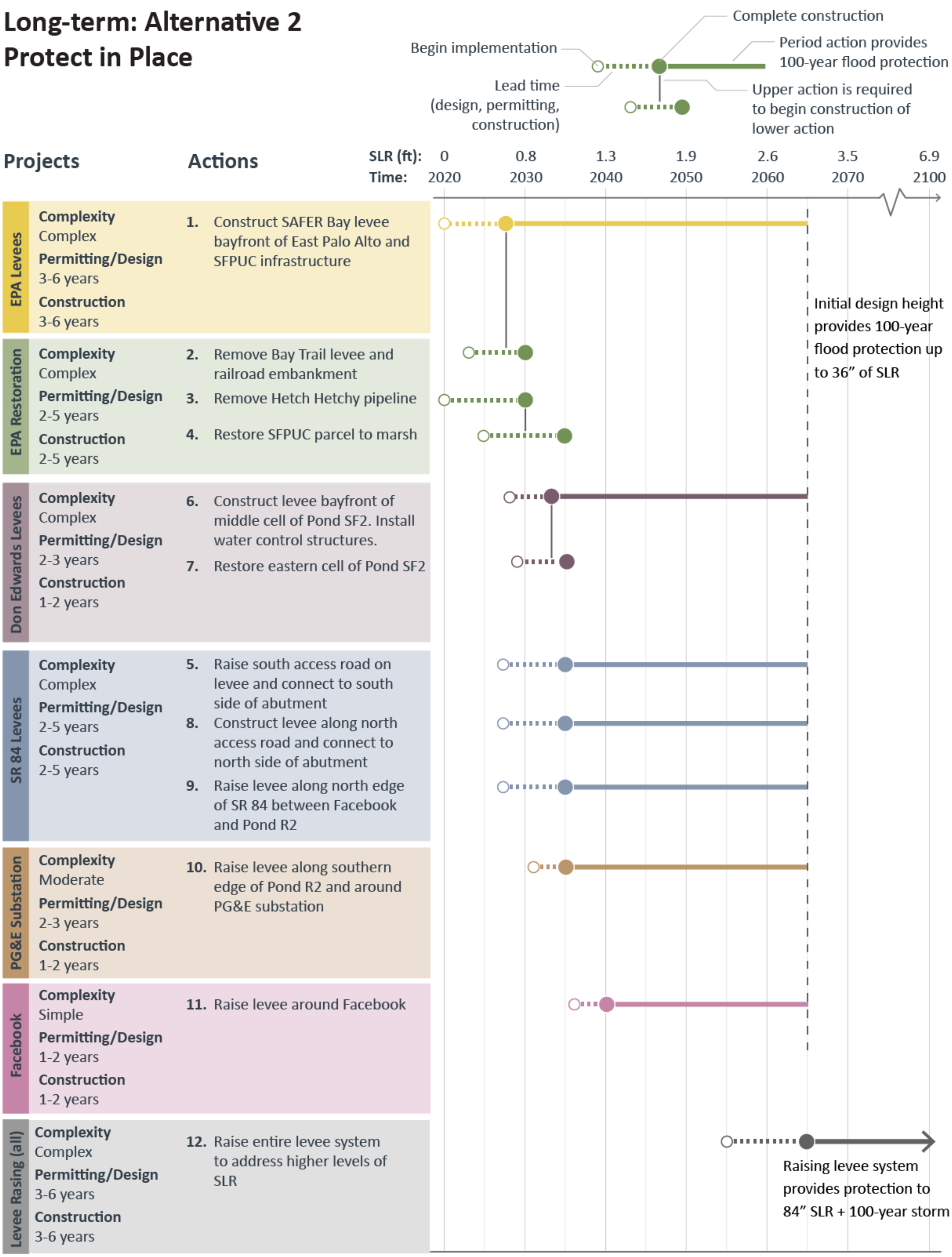

FIGURE 14. PHASING DIAGRAM FOR ALTERNATIVE 2 – PROTECT IN PLACE

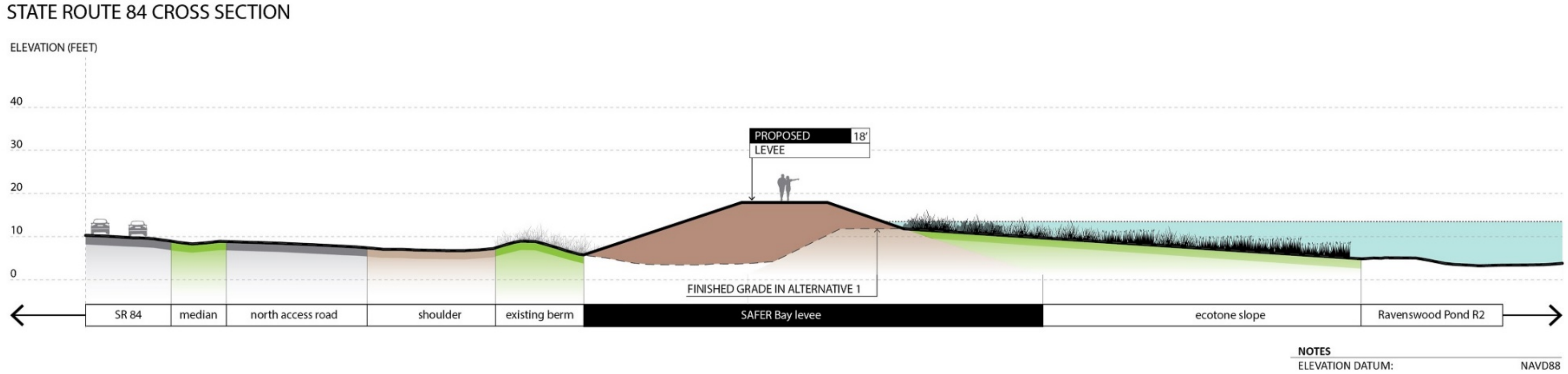

FIGURE 15. CROSS-SECTION OF THE NORTH ACCESS ROAD AND POND R2 FOR ALTERNATIVE 2 – PROTECT IN PLACE

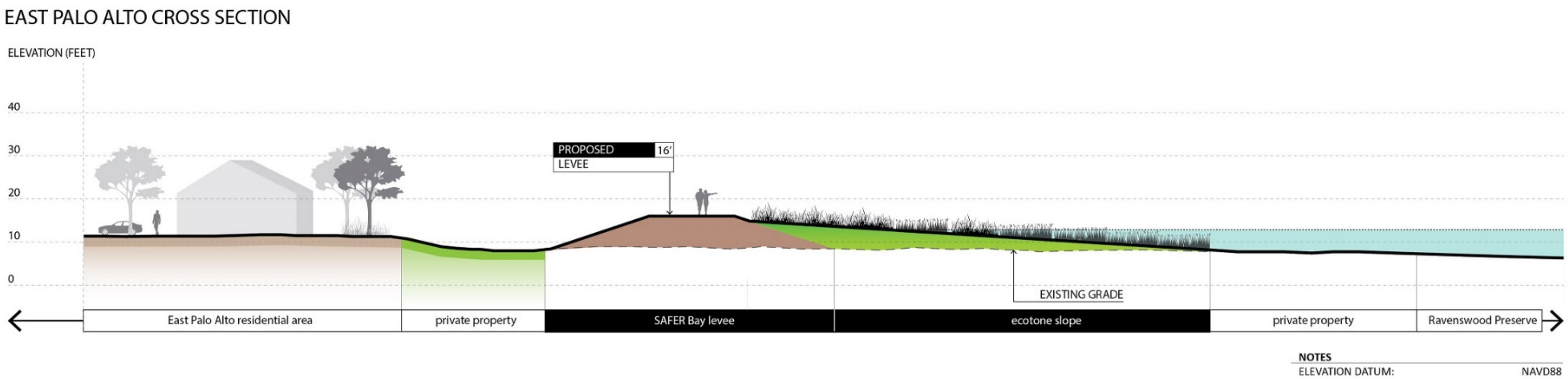

FIGURE 16. CROSS-SECTION OF THE SAFER BAY LEVEE ALONG THE EAST PALO ALTO SHORELINE FOR ALTERNATIVE 2 – PROTECT IN PLACE

5.5.1.3. Key Benefits

Implementing the actions in Alternative 2 will have the following benefits to the project area:

- Provide comprehensive and adaptable flood protection to the study area up to a 100-year storm event with 83 inches of permanent sea level rise (approximately 10 feet above today's high tide)
- Allow for flexibility in near-term management in Pond SF2 to continue to operate as a managed pond until construction of a long-term flood protection solution is required
- Allow for flexibility in long-term restoration and management plans by providing the option for tidal restoration of Ponds R1 and R2, the eastern portion of Pond SF2, and currently diked bayfront areas (such as the SFPUC property)
- Allows for flexibility for long-term operation of managed pond habitat in a portion of Pond SF2
- Reduce or eliminate alongshore barriers to habitat and hydrologic connectivity in the southern portion of the study area
- Opportunity to improve connectivity of the Bay Trail by connecting trail segments from Bay Road northward across the project area to Pond SF2 and the Dumbarton Bridge and provide a more landward and elevated alignment for bayfront segments of Bay Trail that may be exposed to flooding in the future due to sea level rise

5.5.1.4. Ecosystem Services

The SBSP Restoration Project is currently planning to restore full tidal action to Ponds R1 and R2 at some point in the future (EDAW et al. 2007). The construction of flood protection levees around the Facebook campus and the north edge of SR 84 would be consistent with that plan and will provide protection for both Facebook, the Ravenswood Substation, and SR 84 as tidal marshes are restored. These levees would not affect current pond management or long-term tidal marsh establishment at Ponds R1, R2, and between those ponds and the Mosely Tract. In conjunction with tidal marsh restoration at Pond R4 as part of Phase 2 of the SBSP Restoration Project, this would allow for the potential of a large continuous extent of tidal marsh on the north side of SR 84.

South of SR 84, this alternative is consistent with current plans by the SBSP Restoration Project to return the eastern portion of Pond SF2 to tidal marsh outboard of the waterbird habitat in the center cell of the pond and provide a diversity of habitats at Pond SF2 that will benefit salt marsh species, waterbirds, and snowy plovers.

Tidal and brackish marshes with well-developed tidal channel networks and nearby upland areas are used by Ridgway's rails (Point Blue 2011). The Faber-Laumeister Tract south of the project area is an example of a tidal marsh with well-developed tidal channels that harbors a substantial population of Ridgway's rails (Olofson Environmental 2016). The construction of the flood protection levee across the middle of Pond SF2 (as opposed to on the bayfront) and removing alongshore barriers to connectivity by lowering existing berms between Pond SF2 and the Ravenswood Preserve would allow for the connection of Pond SF2 with marshes to the south (Ravenswood Preserve and the Faber-Laumeister Tract).This would allow for species such as Ridgway's rail to travel and establish populations in patches across a wider area. Additional benefits from increased marsh area include flood protection, stormwater retention, habitat connectivity, improvements in water quality through buffering upland runoff before it enters the bay, and increased carbon sequestration over time. The new flood control levee between SR 84 and Ravenswood Preserve will allow cultural opportunities for the public to interact with nature through birdwatching, hiking, and cycling along the trail.

However, the proposed flood protection levee designed to protect the access road and pump station on the north side of SR 84 will essentially cut off the connection between Mosely Tract (a developing tidal marsh) and the proposed restored marsh outboard of Pond SF2, thereby reducing connectivity between Mosely Tract and marshes south of SR 84.

The alternate flood control levee alignment along the bayfront at Pond SF2 would eliminate the connection between Pond SF2 and the marshes to the south but would still allow for the connection the SFPUC property to those southern marshes. This would need to be coordinated with the SBSP Restoration Project to ensure that the levee placement is consistent with long-term planning for Pond SF2.

5.5.1.5. Other Considerations

Other considerations involved with Alternative 2 include:

- SR 84 and low-lying areas behind the levee will require on-going stormwater management and improvements and may experience future issues with stormwater ponding or groundwater flooding
- The Caltrans pump station located north of the bridge abutment may need to be moved inland or protected via a seawall along the Bay shoreline due to space limitations. Functional elements in the pump station may also need to be relocated, raised, or floodproofed[8]
- Feasibility of providing public access across and adjacent to bird habitat in managed ponds such as Ponds SF2 and R2 would need to be further evaluated and discussed with USFWS and researchers
- For regions within 100-ft of the shoreline that are within BCDC's jurisdiction, relocating permitted public access could trigger requirements for additional review by BCDC

5.5.2. Adaptation Pathways and Timeline

The order of implementation for the Alternative 2 key actions was based on prioritization of future flood vulnerabilities, considering storm water levels and projected sea level rise. This information is provided in Table 14. This table also provides the duration of permitting and construction for each action based on project complexity. The last column of the table gives the amount of sea level rise that the action will protect against. Using information about the timing of exposure and flood pathways, the phasing of the individual actions can be estimated. The completion of a specific action is required before it becomes vulnerable to frequent storms (< 50-yr storm), assuming a sea level rise trajectory corresponding to the California Ocean Protection Council's high-risk aversion sea level projections for RCP 8.5 (i.e., a high emissions scenario). By taking the duration of permitting and construction, and working backyard from the completion date, the date of project initiation can be estimated. This method was applied to all actions to develop a phasing diagram (Figure 14) for Alternative 2. The diagram shows the year at which individual actions must begin initiation and construction to prevent exposure to large storm events and sea level rise. Note that the year of completion shown on the diagram does not necessarily indicate that the existing infrastructure is protected up until that time, but rather the point at which the existing infrastructure becomes exposed to large storm events. The year of project initiation was estimated by considering shoreline vulnerability, action prioritization, rate of sea level rise and action interconnectivity.

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[8] A detailed evaluation of the pump station configuration and feasibility of retrofitting or floodproofing was not conducted as part of this study. Additional investigation would inform the details of this strategy.

TABLE 14. IMPLEMENTATION TIMELINE FOR ALTERNATIVE 2

No.	Action	Implementation Timeline	Required by X" of SLR*	Permitting Lead Time (years)	Construction Lead Time (years)	Provides protection until X" SLR*
1	Construct SAFER Bay levee along East Palo Alto shoreline from Bay Road to Pond SF2	2020 - 2030	0	2 to 5	2 to 5	36
2	Remove railroad embankment and remove or lower Bay Trail spur north of Ravenswood Preserve	2025 - 2030	n/a	2 to 5	2 to 5	n/a
3	Remove Hetch Hetchy above-ground pipeline	2020 - 2030	n/a	2 to 5	2 to 5	n/a
4	Restore SFPUC parcel	2025 - 2035	n/a	2 to 5	2 to 5	n/a
5	Raise south access road on levee and connect to south side of bridge abutment	2030 - 2040	0	2 to 5	2 to 5	36
6	Construct levee across interior of Pond SF2. Install new water control structures in levee.	2030 - 2035	n/a	2 to 3	1 to 2	36
7	Restore eastern cell of Pond SF2 to tides	2035 - 2040	n/a	2 to 3	1 to 2	n/a
8	Construct levee along north access road and connect to north side of bridge abutment	2030 - 2040	12	2 to 5	2 to 5	36
9	Raise levee along north edge of SR 84 between Facebook and Pond R2	2030 - 2040	12	2 to 5	2 to 5	36
10	Raise levee along Pond R2 and around Ravenswood Substation (2nd phase of raising)	2035 - 2040	12	1 to 2	1 to 2	36
11	Raise levee around Facebook	2040 - 2050	18	1 to 2	1 to 2	36
12	Raise entire levee system to address higher levels of SLR	2065+	36	3 to 6	3 to 6	83

*When paired with a 50-year storm event

5.5.3. Action Grouping

The actions in Alternative 2 can be grouped into potential projects for permitting purposes based on location and common stakeholders. Table 15 summarizes these potential projects and lists the actions included for each project, which are the same groups shown in the phasing diagram (Figure 14). It also provides the corresponding complexity and estimated general timeline.

TABLE 15. POTENTIAL ACTION GROUPING FOR ALTERNATIVE 2

Potential Project	Project Description	Project Complexity	Alternative 2 Actions Included	Permitting Lead Time (years)	Construction Lead Time (years)
SR 84 Levees	Levees along north and south edge of SR 84	Complex	5, 8, 9	2 to 5	2 to 5
PG&E Substation Levee	Levees along Pond R2 and around PG&E	Moderately Complex	10	1 to 2	1 to 2
Facebook Levees	Levees around the Facebook campus	Expedited	11	1 to 2	1 to 2
Don Edwards Levees	Levees and water control structures in Don Edwards National Wildlife Refuge ponds	Moderately Complex	6, 7	2 to 3	1 to 2
East Palo Alto Levees	Levee along East Palo Alto shoreline to Pond SF2; relocate existing bay trail	Complex	1	2 to 5	2 to 5
East Palo Alto Restoration	Build levee across SFPUC and SamTrans property and connect to SF2 levee; remove existing utilities and restore tidal function	Expedited	2, 3, 4	2 to 5	2 to 5
Levee Raising (2nd phase)	Raise SAFER Bay Levees across all reaches for higher SLR (may be separate projects)	Moderately Complex	1, 5, 6, 8, 9, 10, 11	3 to 6	3 to 6

Note: Action numbering corresponds to labels shown in Figure 13.

5.5.4. Cost Estimate

A cost estimate was developed for Alternative 2 that shows high-level conceptual costs for the primary components, including costs for direct costs, mobilization, contractor's fee, engineering fee, design and construction contingency, environmental clearance and permitting (Table 16).

TABLE 16. COST ESTIMATE FOR ALTERNATIVE 2

	Item	Units	Quantity	Unit Price	Cost	Notes
1	Construct SAFER Bay levee bayfront of East Palo Alto and SFPUC infrastructure	LF	4550	$ 3,428	$ 15,599,000	Includes ecotone slope
2	Removal of Bay Trail levee and railroad embankment	LF	5800	$ 75	$ 438,000	
3	Removal of Hetch Hetchy pipeline	LF	2800	$ 4,923	$ 13,786,000	Removal of both pipes and trestle to just below MLW
4	Restore SFPUC parcel	AC	55	$ 25,753	$ 1,416,000	Lowering of outboard levee, grading to intertidal elevation
5	Raise south access road on levee and connect to south side of abutment	LF	1730	$ 4,917	$ 8,506,000	
6	Construct levee bayfront of middle cell of Pond SF2. Install WCS in new levee.	LF	5430	$ 7,345	$ 39,883,000	Includes ecotone slope on levee and installation of 2 WCS in levee
7	Restoration of eastern cell of Pond SF2	AC	60	$ 42,889	$ 2,573,000	Lowering outboard levee; constructing pilot channels; grading to intertidal elevation
8	Construct levee along north access road and connect to north side of abutment	LF	2130	$ 5,397	$ 11,496,000	Removal of existing concrete barrier; construction of sheet pile wall to tie into abutment; floodproofing of pump station

	Item	Units	Quantity	Unit Price	Cost	Notes
9	Raise levee along north edge of SR 84 between Facebook and Ravenswood Pond	LF	2120	$ 3,393	$ 7,192,000	Includes raising headwall of WCS underneath SR 84
10	Raise levee along Pond R2 and around PG&E (2nd phase of raising)	LF	5310	$ 3,250	$ 17,258,000	Initial levee to 12 ft NAVD88 already built in Alternative 1
11	Raise levee around Facebook	LF	4450	$ 3,575	$ 15,909,000	
12	Raise entire levee system to 22 ft NAVD88	LF	25,600	$ 2,043	$ 52,302,000	Raise levee to 100-year + 83" SLR level of protection
Sub-total					**$ 186,358,000**	
GC / GR & Overhead				15%	$ 27,954,000	For contractor's move in/out cost and contractor overhead
General Contractor Markup				5%	$ 10,716,000	Contractor profit
General Contractor Bond & Insurance				2%	$ 4,501,000	Contractor insurance
Sub-total					**$ 229,528,000**	
Design / Estimate Contingency				25%	$ 57,382,000	Scope changes due to existing conditions; unforeseen conditions and change orders during construction
Engineering Fees				10%	$ 22,953,000	Includes preliminary and final design
Environmental Clearance & Permitting				L/S	$ 12,000,000	For studies and EIR reviews and oversight; permitting process
Total Cost for Alternative 2					**$ 321,863,000**	

Note: Action numbering corresponds to labels shown in Figure 13.

5.6. ALTERNATIVE 3 – LONG-TERM: RAISE THE ROAD (2 OPTIONS)

5.6.1. Description

Alternative 3 is a long-term strategy to provide flood protection to critical infrastructure and the community by protecting assets first to 36 inches of sea level rise and then to 83 inches. Alternative 3 would raise SR 84 within the study area and place it on a causeway (i.e., an elevated bridge-type structure) to protect the highway from sea level rise and flooding, reduce the length of levee required (compared to Alternative 2), and allow for hydrologic and ecologic connectivity between Mosley Tract (to the north of SR 84) and the eastern portion of Pond SF2 (to the south of SR 84). The causeway would extend inland to the SAFER Bay levee segments on the north and south sides of SR 84. This alternative would effectively relocate the touchdown point of the bridge farther inland.

Critical decision points relating to this option include whether or not the PG&E Ravenswood substation can be moved or would be protected in place. Discussions with PG&E have been held, and while it is more likely that the substation and associated assets would be protected in place due to cost (on the order of hundreds of millions of dollars to relocate substation), it is included as an option. In addition, community members expressed concern over the potential relocation of the substation closer to residential communities. This concern could be partially allayed by relocating and enclosing the substation; however, these options would need to be further evaluated.

5.6.1.1. Key Features

Figure 17 and Figure 18 show a plan view schematic and phasing diagram for Alternative 3, Option 1 – Raise the Road. The numbers and colors in each figure are corresponding. Note the interconnectivity between some actions. Figure 19 and Figure 20 show the same schematics and phasing diagrams for Alternative 3, Option 2. Figure 21 shows a profile view of the raised causeway along SR 84. It shows the roadway elevated above the underlying marsh and the flood protection levee joining the causeway at the touchdown structure. Option 1 and 2 vary in SR84 touchdown location.

Conceptual engineering plans showing the realigned and raised highway segments are included in the Highway Raising Plan and Profile Conceptual Drawings supporting study document.

RAISE HIGHWAY ON CAUSEWAY

The causeway would comprise an elevated bridge-type structure supported by piles. The causeway would be built along the same alignment as the existing roadway. In order to maintain use of SR 84 during construction, a temporary causeway would be constructed parallel and south of the existing roadway. It would tie into the existing roadway (two options considered) and allow on-going use of SR 84 during construction[9]. Once the permanent causeway is completed, the temporary causeway could be decommissioned and removed. The permanent causeway would be built such that the lowest structural component of the bridge would be above the 100-year flood event (storm surge and waves) with 7 feet of sea level rise plus freeboard. The temporary causeway would likely be designed to a lesser elevation while still maintaining an appropriate amount of vertical clearance over the underlying levee segments.

[9] Note that the design speed of the temporary causeway would be below the design speed of the existing highway (40 mph vs. 60 mph) given the configuration of the two proposed options. The existing bridge has non-standard shoulders and median widths and the same non-standard design is proposed for the temporary structure to match the existing bridge width. These non-standard design exceptions would require approval from Caltrans.

Two options for causeway alignment are presented: 1) one which extends past the eastern cell of Pond SF2 and touches down at approximately the eastern edge of the PG&E substation and 2) one which extends past the middle cell of Pond SF2 and touches down prior to the University Ave. A third option which extended west of University Ave was initially considered but dropped due to engineering feasibility and cost considerations of having to reconfigure and elevate the intersection of University Ave and SR 84.

The Dumbarton Bridge was constructed in 1981 and has an expected design life of 75 years (approximately 2050 to 2060). It is anticipated that raising the western approach of the bridge on a causeway would occur in the next 20 to 30 years and may coincide with the replacement of the bridge. If this is the case, the elevated causeway could be incorporated into the full bridge replacement project. At minimum, the west approach causeway should be designed such that a new bridge, when constructed can be tied into it. If it were decided to replace the full bridge in the future with a fully standard facility (i.e., standard lanes, shoulders, median, stopping sight distance, etc.) that may influence the design of the elevated causeway, whether or not the causeway construction was coincident with the full bridge replacement, or occurred in advance of the full bridge project.

FLOOD PROTECTION LEVEES

The flood protection levees would be constructed along the north side of SR 84 and extend south to Bay Road in East Palo Alto. At the touchdown point of the causeway, the levees on either side of SR 84 will abut against the touchdown structure, forming a continuous line of protection. The levees would follow the design parameters established by the SAFER Bay levee project and be built initially to 18 ft NAVD88 (approximately 7 feet above today's 100-year storm tide) to withstand a 100-yr flood event with 3 feet of sea level rise and appropriate freeboard to obtain FEMA accreditation. The levee would be designed to allow for future raising to accommodate higher levels of sea level rise (up to 7 feet).

TIDAL RESTORATION

Areas bayward of the flood protection levees would have the opportunity to be restored to tidal marsh, if it is deemed appropriate based on monitoring and adaptive management decisions in the future. Restoration would occur by removing alongshore barriers to connectivity, such as the railroad berm and decommissioned above-ground Hetch Hetchy pipeline, and breaching, or lowering, the existing redundant bayfront levee. Once the existing roadway becomes decommissioned after construction of the causeway, it can be removed which will allow for the hydrological connection between the eastern cell of Pond SF2 and Mosley Tract (and potentially farther north and east to either Pond R1 and/or R2 if and when they are restored). In the interim prior to long-term restoration, these areas (such as managed Pond SF2) can continue to be operated and maintained according to their existing management plans.

5.6.1.2. Key Actions

SOUTH OF SR 84

- Action 1: Construct SAFER Bay levee along the East Palo Alto shoreline and across the SFPUC property, connecting to the Pond SF2 levee, to protect landward residential areas and the SFPUC's Hetch Hetchy infrastructure. Construct a new public access trail on top of the levee and connect to the existing Bay Trail segment to the south of Bay Road. Consider a phased realignment of the Ravenswood Preserve segment of the Bay Trail to the top of the new levee at some point in the future as it becomes exposed to more frequent flooding due to sea level rise.

- Action 2 and 3: Remove alongshore barriers to hydrological connectivity, including the railroad embankment[10] and the decommissioned above-ground Hetch Hetchy pipeline and its supporting infrastructure. The Bay Trail spur that runs along the northern edge of the Ravenswood Preserve could continue to be used for public access until it becomes frequently flooded, at which point it could also be removed.
- Action 4: Restore the SFPUC parcel by breaching or lowering the bayfront berm. Grade parcel to intertidal elevations and construct pilot channels and habitat mounds, while preventing inundation of the remediated Sportsmen's Club site immediately south of Pond SF2.
- Action 6: Construct a flood protection levee across Pond SF2 and construct trail on top of new levee to connect to the Bay Trail and replace trail segment along bayfront levee in Pond SF2 that would be lost when eastern cell is restored.
    - Option 1: The levee would run along the divider berm between the middle and eastern cells of Pond SF2, passing underneath the temporary causeway (when present) and connecting to the PG&E levee along the north edge of SR 84. When the permanent causeway is constructed, the levee would abut against the touchdown structure of the bridge. Install new water control structures in the levee to manage water levels in the middle cell of Pond SF2.
    - Option 2: The levee would run along the divider berm between the middle and western cell of Pond SF2, passing underneath the temporary causeway (when present) and connecting to the levee along the north edge of SR 84. When the permanent causeway is constructed, the levee would abut against the touchdown structure of the bridge. This option will require the divider berm between the middle and eastern cells of Pond SF2 to be raised and new water control structures to be installed in order manage water levels and maintain operation of the middle cell as a managed pond. The more landward alignment of the flood protection levee in Option 2 would provide greater flexibility in the future to restore the middle cell of Pond SF2 to tidal marsh (or it could continue to be operated as managed pond habitat).
- Action 7: Restore the eastern cell of Pond SF2 by breaching or lowering the now redundant SF2 Bayfront levee and its water control structures. Construct pilot channels and grade to intertidal channels if required. Realign existing segment of Bay Trail spur along Pond SF2 shoreline to new levee. Reconstruct parking and public access trailhead on inboard side of new levee.

SR 84

- Action 5: Raise the section of SR 84 that leads up to the bridge on an elevated causeway.
    - Option 1: The raised section of road would extend past the new flood protection levee between the middle and eastern cells of Pond SF2 and touchdown 1300 ft past the levee near the eastern edge of the PG&E Ravenswood substation. The temporary causeway would be constructed to the south of the SR 84 and pass over the eastern and middle cells of Pond SF2.

[10] This embankment runs along the potential Dumbarton Rail Corridor project alignment currently being evaluated by SamTrans and Cross Bay Transit Partners. For the purposes of this resilience study, it was assumed that if a rail project is implemented along the corridor, the portion of the rail line that traverses the study area could be elevated on a raised structure to support the alongshore connectivity goals of the Dumbarton Bridge West Approach + Adjacent Communities Resilience Study.

    - Option 2: The raised section of road would extend past the middle cell of Pond SF2 and touch down 400 ft east of University Ave. The temporary causeway would be constructed to the south of the SR 84 and pass over all cells of Pond SF2 and join SR 84 at the University Ave intersection.

  For both options the tie in points of the temporary causeway would extend past those of the permanent causeway, as more distance is required to conform to the horizontal and vertical curvature requirements for the highway. Once the permanent causeway is constructed, the temporary causeway would be decommissioned and removed. A turnaround road would be constructed landward of the touchdown point (similar to the existing turnaround road) to maintain access to the PG&E substation (if it remains) and/or allow for an exit prior to the bridge. The turnaround road would be located inside the new flood protection levee.
- Action 8: Reconnect the eastern cell of Pond SF2 and Mosley Tract by restoring the area underneath causeway, grading to intertidal elevation and reconnecting the two areas. Remove supporting infrastructure that would no longer be necessary as a result of the causeway, including existing fill, pavement, parking lots, the north and south access roads, stormwater drainage infrastructure (Caltrans stormwater pump station), and Caltrans flood barrier. This infrastructure will be no longer in service when the causeway is constructed and removing it will also provide hydrologic and ecologic connectivity underneath the highway to connect Mosley Tract and the eastern portion of Pond SF2 and habitats to the south. If Ponds R1 and/or R2 are restored in the future, additional connectivity could be created.

NORTH OF SR 84

- Action 9 (Option 2 only): Relocate the PG&E Ravenswood substation and Menlo Park Fire District training facility (new location to be determined, approximately 11-acre footprint required). One potential location for the substation that would be less vulnerable in the long-term could be adjacent to the existing SFPUC Hetch Hetchy facilities south of Pond SF2. This groups several high value assets together in a smaller footprint which is more easily protected; however, it would also move the substation closer to the East Palo Alto residential community. One option could be to enclose the substation (as is done in urban areas) which may be more acceptable to the community. A complete evaluation of the feasibility of relocating the substation, including engineering feasibility, costs, and potential locations), was not conducted as part of this study.
- Action 10 (Option 1) or Action 11 (Option 2): Raise some or all of the previously constructed (Alternative 1) levee along the landward edge of Pond R2. This action will raise it to match the design criteria of the SAFER Bay levee.
    - Option 1: The raising would occur along the entire length of the Pond R2 levee along the north edge of SR 84 and Ravenswood substation.
    - Option 2: The raising would occur along the western segment of levee that runs along the western edge of Pond R2 to the western limit of the PG&E substation. If PG&E remains in the current location, it may choose to self-protect by raising the remainder of the levee around the substation perimeter. Access to the substation could be provided from the turnaround road.
- Action 9 (Option 1) or Action 10 (Option 2): Raise the levee along the north edge of SR 84 between Facebook and the western edge of Pond R2. This berm was initially constructed as part of Alternative 1. This action will replace or raise it to meet the design elevation of the SAFER Bay levee. Relocate the

pedestrian path between Facebook and University Ave to the levee top and extend the pedestrian path from University Ave to the eastern edge of Pond R2.

- Action 11 (Option 1) or Action 12 (Option 2): Raise levee surrounding the Facebook campus to match SAFER Bay levee design criteria.
- Other actions:
    - Retrofit or replace the Ravenswood pump station outfall structure on the north side of SR 84.
    - Rehabilitate existing trails and construct new trails on top of new levee segments to provide connected public access across full project area from Facebook to Bay Road.

FIGURE 17. PLAN VIEW SCHEMATIC FOR ALTERNATIVE 3, OPTION 1 – RAISE THE ROAD

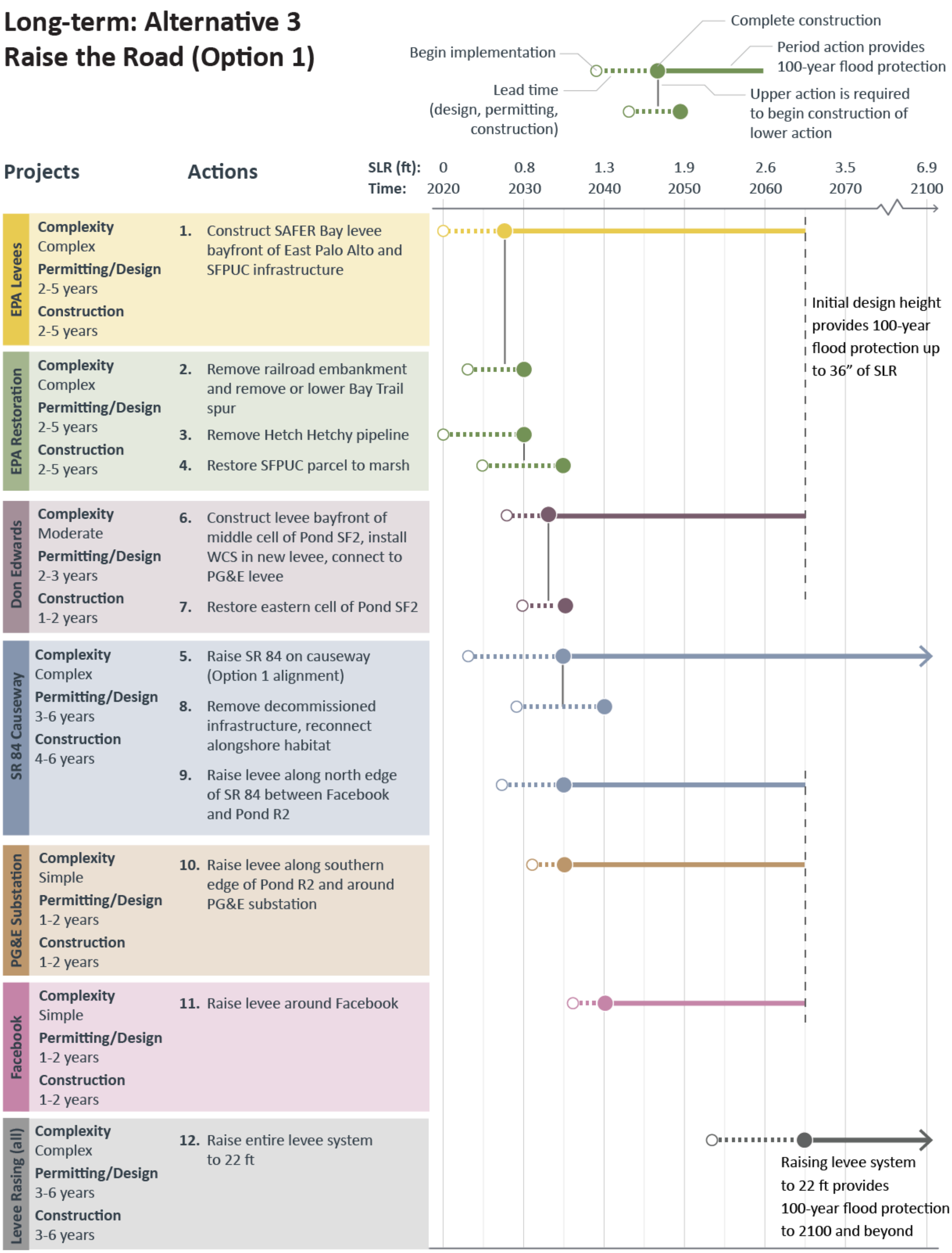

FIGURE 18. PHASING DIAGRAM FOR ALTERNATIVE 3, OPTION 1 – RAISE THE ROAD

FIGURE 19. PLAN VIEW SCHEMATIC FOR ALTERNATIVE 3, OPTION 2– RAISE THE ROAD

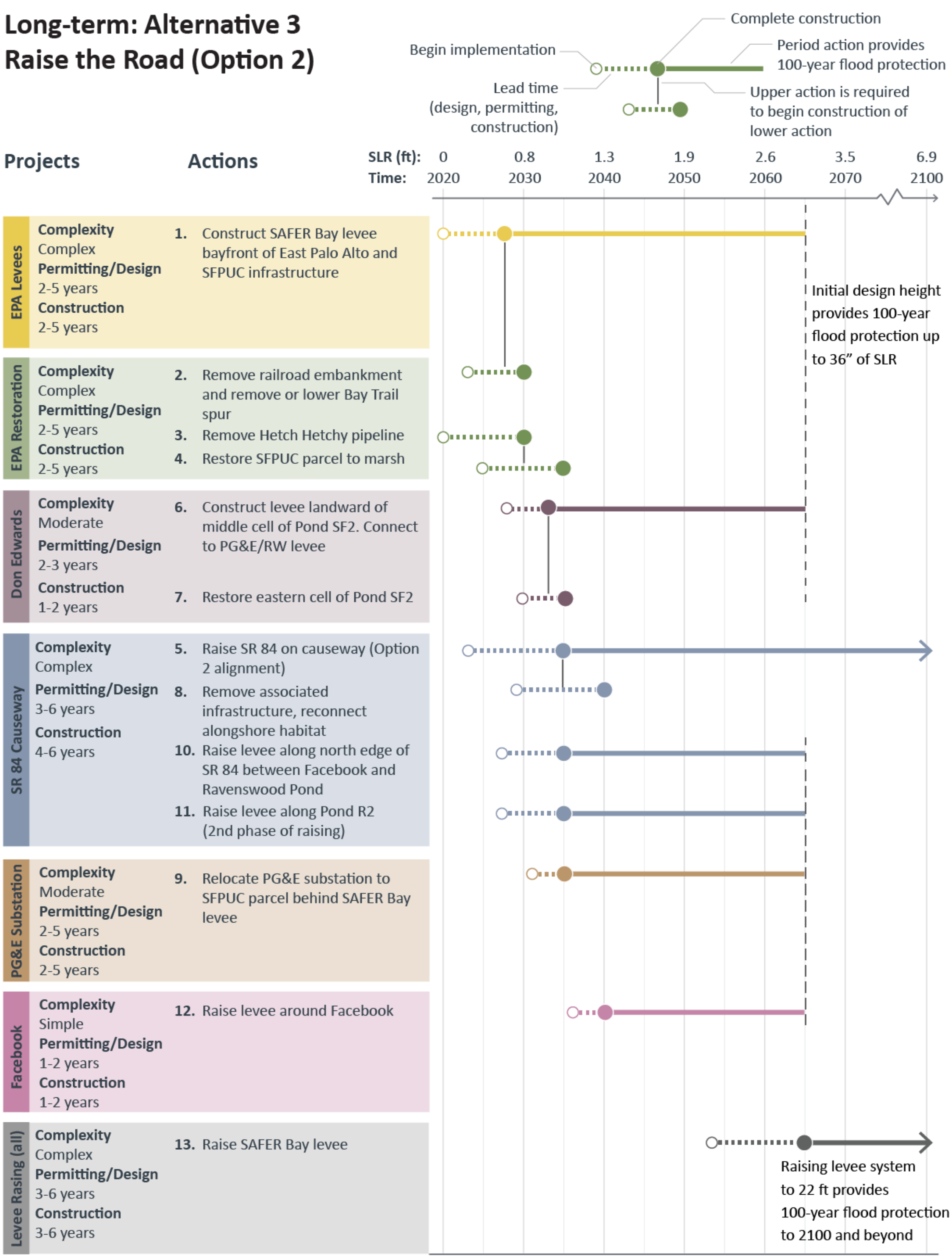

FIGURE 20. PHASING DIAGRAM FOR ALTERNATIVE 3, OPTION 2 – RAISE THE ROAD

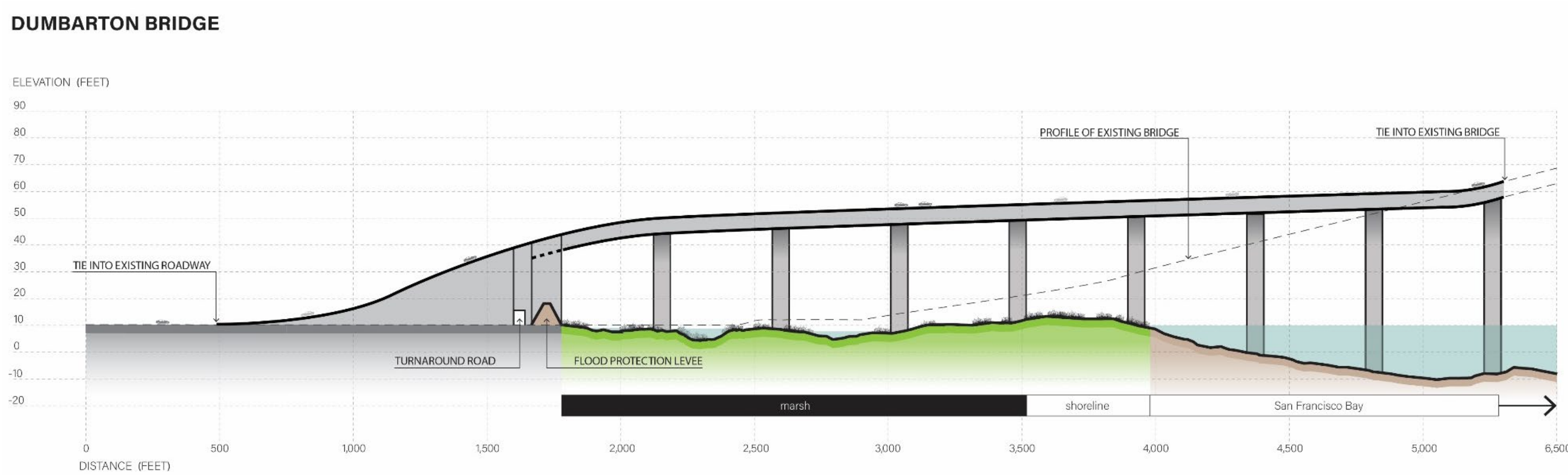

FIGURE 21. PROFILE VIEW OF THE SR 84 CAUSEWAY FOR ALTERNATIVE 3 – RAISE THE ROAD. OPTIONS 1 AND 2 WILL HAVE THE SAME CAUSEWAY PROFILE

5.6.1.3. Key Benefits

Implementing the actions in Alternative 3 would have the following benefits to the project area:

- Provide comprehensive and adaptable flood protection up to a 100-year flood event with 83 inches of sea level rise to the study area, including residential and commercial properties
- Allow for flexibility in near-term management in Pond SF2 to continue to operate as a managed pond until construction of a long-term flood protection solution is required
- Allow for flexibility in long-term restoration and management plans by providing the option for tidal restoration of Ponds R1 and R2, the eastern portion of Pond SF2, and currently diked bayfront areas (such as the SFPUC property)
- Allows for flexibility for long-term operation of managed pond habitat in a portion of Pond SF2, depending on future habitat needs
- Reduces or eliminates alongshore barriers to habitat and hydrologic connectivity in the southern portion of the study area
- Provides opportunity to hydrologically and ecologically connect the eastern cell of Pond SF2 and Mosley Tract
- Opportunity to improve connectivity of the Bay Trail by connecting trail segments from Bay Road northward across the project area to Pond SF2 and the Dumbarton Bridge and provide a more landward and elevated alignment for bayfront segments of Bay Trail that may be exposed to flooding in the future due to sea level rise

5.6.1.4. Ecosystem Services

Both options of Alternative 3 provide the greatest habitat connectivity along the shoreline compared to Alternatives 1 and 2. Alternative 3 provides opportunities to restore large areas of marsh connected to extensive offshore mudflats and increase habitat for endangered species and important bird species. Alternative 3 also provides opportunities to create large transition zones in select areas on the front of the flood protection levees, which would not only provide flood protection but provide a habitat gradient from transition zone to marsh to mudflat to open water.

Alternative 3 connects the areas to the north of SR 84 including the SBSPR Project Ponds R1 and R2 and Mosely Tract and with marshes to the south of SR 84 at Pond SF2, Ravenswood Preserve, and Faber-Laumeister Tracts. In both options of Alternative 3, the removal of fill, pavement, flood barriers, and the decommissioning of the old highway and access roads will not only remove hard physical barriers, but reconnect historical habitats and allow for establishment of a well-connected complex of tidal marshes consistent with recommendations included in the update to the Goals Report (2015).

Similar to Alternative 2, Alternative 3 provides opportunities for species dispersal from nearby marshes. The Faber-Laumeister Tract south of the project area harbors a substantial population of Ridgway's rails that could disperse to areas of increased habitat (Olofson Environmental 2016). Removing alongshore barriers by lowering existing berms between Pond SF2 and the Ravenswood Preserve would allow for the connection of Pond SF2 with these marshes to the south (Ravenswood Preserve and the Faber-Laumeister Tract). This would allow rails to travel and establish populations in patches across a wider area.

Additional benefits from increased marsh area include flood protection from increased marsh area on the bayward side of urban areas, stormwater retention during storms, habitat connectivity, improvements in water quality through buffering upland runoff before it enters the Bay, and increased carbon sequestration as marshes develop over time. The new flood control levee between SR 84 and Ravenswood Preserve will allow cultural opportunities for the public to interact with nature through birdwatching, hiking, and cycling along the trail.

5.6.1.5. Other Considerations

Other considerations involved with Alternative 3 include:

- The segments of SR 84 that are not raised and low-lying areas behind the levee will require on-going stormwater management and improvements and may experience future issues with stormwater ponding or groundwater flooding
- The structural limitations of the existing bridge require the eastern tie in point of the causeway to extend into the bay, which will have environmental impacts and make permitting more difficult
- Option 2 of this alternative may require the relocation of the PG&E substation, which would be costly and may be difficult to identify a suitable location that is feasible and acceptable to the community
- Feasibility of providing public access across and adjacent to bird habitat in managed ponds such as Ponds SF2 and R2 would need to be further evaluated and discussed with USFWS and researchers
- For regions within 100-ft of the shoreline that are within BCDC's jurisdiction, relocating permitted public access could trigger requirements for additional review by BCDC
- The elevated causeway could be incorporated into the full bridge replacement when it reaches the end of its lifespan, creating opportunities for increased efficiencies and reduced cost

5.6.2. Adaptation Pathways and Timeline

The order of implementation for the Alternative 3 key actions was based on prioritization of future flood vulnerabilities, considering storm water levels and projected sea level rise. This information is provided in Table 17 and Table 18 for both options. The tables also provide the duration of permitting and construction for each action based on project complexity. The last column of the table gives the amount of sea level rise that the action will protect against.

Using information about the timing of exposure and flood pathways, the phasing of the individual actions can be estimated. The completion of a specific action is required before it becomes vulnerable to frequent storms (< 50-yr storm), assuming a sea level rise trajectory corresponding to the California Ocean Protection Council's high-risk aversion sea level projections for RCP 8.5 (i.e., a high emissions scenario). By taking the duration of permitting and construction, and working backwards from the completion date, the date of project initiation can be estimated. This method was applied to all actions to develop a phasing diagram (Figure 18 and Figure 20) for Alternative 3. The diagrams show the year at which individual actions must begin initiation and construction to prevent exposure to large storm events and sea level rise. Note that the year of completion shown on the diagrams does not necessarily indicate that the existing infrastructure is protected up until that time, but rather the point at which the existing infrastructure becomes exposed to large storm events. The year of project initiation was determined by considering shoreline vulnerability, action prioritization, rate of sea level rise and action interconnectivity.

TABLE 17. IMPLEMENTATION TIMELINE FOR ALTERNATIVE 3 OPTION 1

No.	Action	Implementation Timeline	Required by X" of SLR*	Permitting Lead Time (years)	Construction Lead Time (years)	Provides protection until X" SLR*
1	Construct SAFER Bay levee bayfront of East Palo Alto and SFPUC infrastructure	2020 - 2025	0	2 to 5	2 to 5	36
2	Remove railroad embankment and remove or lower Bay Trail spur north of Ravenswood Preserve	2020 - 2025	n/a	2 to 5	2 to 5	n/a
3	Remove Hetch Hetchy pipeline	2020 - 2025	n/a	2 to 5	2 to 5	n/a
4	Restore SFPUC parcel	2020 - 2025	n/a	2 to 5	2 to 5	n/a
5	Raise SR 84 on causeway (Option 1)	2035 - 2040	0	3 to 6	4 to 6	84
6	Construct levee bayfront of middle cell of Pond SF2. Install WCS in new levee. Connect to PG&E levee.	2030 - 2040	0	2 to 3	1 to 2	36
7	Restoration of eastern cell of Pond SF2	2030 - 2040	n/a	2 to 3	1 to 2	n/a
8	Remove decommissioned roadway infrastructure (concrete barrier, pump station and SW infrastructure). Reconnect alongshore habitat.	2040-2045	n/a	3 to 6	4 to 6	n/a
9	Raise levee along north edge of SR 84 between Facebook and Ravenswood Pond	2030 - 2040	12	3 to 6	4 to 6	36
10	Raise levee along Pond R2 and around Ravenswood Substation (2nd phase of raising)	2035 - 2040	12	1 to 2	1 to 2	36
11	Raise levee around Facebook	2040 - 2050	18	1 to 2	1 to 2	36
12	Raise SAFER Bay levee (2nd phase)	2065+	36	3 to 6	3 to 6	84

*When paired with a 50-year storm event

TABLE 18. IMPLEMENTATION TIMELINE FOR ALTERNATIVE 3 OPTION 2

No.	Action	Implementation Timeline	Required by X" of SLR*	Permitting Lead Time (years)	Construction Lead Time (years)	Provides protection until X" SLR*
1	Construct SAFER Bay levee bayfront of East Palo Alto and SFPUC infrastructure	2020 - 2025	0	2 to 5	2 to 5	36
2	Remove railroad embankment and remove or lower Bay Trail spur north of Ravenswood Preserve	2020 - 2025	n/a	2 to 5	2 to 5	n/a
3	Remove Hetch Hetchy pipeline	2020 - 2025	n/a	2 to 5	2 to 5	n/a
4	Restore SFPUC parcel	2020 - 2025	n/a	2 to 5	2 to 5	n/a
5	Raise SR 84 on causeway (Opt 2)	2035 - 2040	0	3 to 6	4 to 6	84
6	Construct levee landward of middle cell of Pond SF2. Connect to PG&E/RW levee	2030 - 2040	0	2 to 3	1 to 2	36
7	Restoration of eastern cell of Pond SF2	2030 - 2040	n/a	2 to 3	1 to 2	n/a
8	Remove decommissioned roadway infrastructure (concrete barrier, pump station and SW infrastructure). Reconnect alongshore habitat	2040-2045	n/a	3 to 6	4 to 6	n/a
9	Relocate PG&E Ravenswood substation	2030 - 2040	12	2 to 5	2 to 5	n/a
10	Raise levee along north edge of SR 84 between Facebook and Ravenswood Pond	2035 - 2040	12	3 to 6	4 to 6	36
11	Raise levee along Pond R2 (2nd phase of raising)	2040 - 2050	12	3 to 6	4 to 6	36
12	Raise levee around Facebook	2065+	18	1 to 2	1 to 2	36
13	Raise SAFER Bay levee (2nd phase)	2040-2045	36	3 to 6	3 to 6	84

*When paired with a 50-year storm event

5.6.3. Action Grouping

The actions in Alternative 3 can be grouped into potential projects for permitting purposes based on location and common stakeholders. Table 19 and Table 20 summarize these potential projects and list the actions included for each project, which correspond to the numbering in the phasing diagrams. The tables also provide the corresponding complexity and estimated general timeline.

TABLE 19. POTENTIAL ACTION GROUPING FOR ALTERNATIVE 3 OPTION 1

Potential Project	Project Description	Project Complexity	Alternative 3 Actions Included	Permitting Lead Time (years)	Construction Lead Time (years)
SR 84 Causeway	Replace SR 84 new raised structure	Complex	5, 8, 9	3 to 6	4 to 6
PG&E Substation Levee	Levees along Pond R2 and around PG&E	Moderately Complex	10	1 to 2	1 to 2
Facebook Levees	Levees around the Facebook campus	Simple	11	1 to 2	1 to 2
Don Edwards Levees	Levees and water control structures in Don Edwards National Wildlife Refuge ponds	Moderately Complex	6, 7	2 to 3	1 to 2
East Palo Alto Levees	Levee along East Palo Alto shoreline to Pond SF2; relocate existing bay trail	Complex	1	2 to 5	2 to 5
East Palo Alto Restoration	Build levee across SFPUC and SamTrans property and connect to SF2 levee; remove existing utilities and restore tidal function	Complex	2, 3, 4	2 to 5	2 to 5
Levee Raising (2nd phase)	Raise SAFER Bay Levees across all reaches for higher SLR (may be separate projects)	Moderately Complex	1, 5, 6, 9, 10, 11	3 to 6	3 to 6

Note: Action numbering corresponds to labels shown in Figure 17.

TABLE 20. POTENTIAL PROJECT GROUPING FOR ALTERNATIVE 3 OPTION 2

Potential Project	Project Description	Project Complexity	Alternative 3 Actions Included (Figure 19)	Permitting Lead Time (years)	Construction Lead Time (years)
SR 84 Causeway	Replace SR 84 new raised structure	Complex	5, 8, 10, 11	3 to 6	4 to 6
Relocate PG&E Substation	Relocate PG&E substation (location TBD)	Complex	9	2 to 5	2 to 5
Facebook Levees	Levees around the Facebook campus	Expedited	12	1 to 2	1 to 2
Don Edwards Levees	Levees and water control structures in Don Edwards National Wildlife Refuge ponds	Moderately Complex	6, 7	2 to 3	1 to 2
East Palo Alto Levees	Levee along East Palo Alto shoreline to Pond SF2; relocate existing bay trail	Complex	1	2 to 5	2 to 5
East Palo Alto Restoration	Build levee across SFPUC and SamTrans property and connect to SF2 levee; remove existing utilities and restore tidal function	Moderately Complex	2, 3, 4	2 to 5	2 to 5
Levee Raising (2nd phase)	Raise SAFER Bay Levees across all reaches for higher SLR (may be separate projects)	Moderately Complex	1, 5, 6, 10, 11, 12	3 to 6	3 to 6

Note: Action numbering corresponds to labels shown in Figure 19.

5.6.4. Cost Estimate

A cost estimate was developed for Alternative 3 that shows high-level conceptual costs for the primary components, including costs for direct costs, mobilization, contractor's fee, engineering fee, design and construction contingency, environmental clearance and permitting (Table 21 and Table 22).

Note that this cost estimate is for raising the highway on a causeway and reconnecting it to the existing bridge. It is anticipated that raising the western approach of the bridge on a causeway would occur in the next 20 to 30 years and may coincide with the replacement of the bridge at the end of its functional lifespan. If this is the case, the elevated causeway could be incorporated into the full bridge replacement project creating opportunities for increased cost efficiencies.

TABLE 21. COST ESTIMATE FOR ALTERNATIVE 3 OPTION 1

	Item	Units	Quantity	Unit Price	Cost	Notes
1	Construct SAFER Bay levee bayfront of East Palo Alto and SFPUC infrastructure	LF	4550	$ 3,428	$ 15,599,000	Includes ecotone slope
2	Remove Bay Trail levee and railroad embankment	LF	5800	$ 75	$ 438,000	
3	Remove Hetch Hetchy pipeline	LF	2800	$ 4,923	$ 13,786,000	Removal of both pipes and trestle to just below low tide level
4	Restore SFPUC parcel	AC	55	$ 25,753	$ 1,416,000	Lowering of outboard levee, grading to intertidal elevation
5	Raise SR 84 on causeway	LS	1	$458M	$458,000,000	Construction of temporary and permanent causeway, demolition of temporary causeway, turnaround road.
6	Construct levee bayfront of middle cell of Pond SF2. Install WCS in new levee. Connect to causeway abutment.	LF	5430	$ 7,345	$ 39,883,000	Includes ecotone slope on levee and installation of two water control structures in levee
7	Restoration of eastern cell of Pond SF2	AC	60	$ 42,889	$ 2,573,000	Lowering outboard levee; constructing pilot channels; grading to intertidal elevation
8	Remove decommissioned roadway and associated infrastructure (concrete barrier, pump station and SW infrastructure). Reconnect alongshore habitat.	AC	12	$ 793,685	$ 9,524,000	Includes pilot channels to connect habitats

	Item	Units	Quantity	Unit Price	Cost	Notes
9	Raise levee along north edge of SR 84 between Facebook and Ravenswood Pond	LF	2120	$ 3,393	$ 7,192,000	Includes raising headwall of water control structure underneath SR 84
10	Raise levee along Pond R2 and around PG&E (2nd phase of raising)	LF	5310	$ 3,250	$ 17,258,000	Initial levee to 12 ft NAVD88 already built in Alternative 1
11	Raise levee around Facebook	LF	4450	$ 3,575	$ 15,909,000	
12	Raise entire levee system to 22 ft NAVD88	LF	21,700	$ 2,043	$44,415,000	Raise levee to 100-year + 83” SLR level of protection
Sub-total					**$ 625,994,000**	
GC / GR, & Overhead				15%	$ 93,899,000	
General Contractor Markup				5%	$35,995,000	
General Contractor Bond & Insurance				2%	$15,118,000	
Sub-total					**$771,006,000**	
Design / Estimate Contingency				25%	$ 192,752,000	
Engineering Fees				10%	$ 77,101,000	
Environmental Clearance & Permitting				L/S	$ 17,000,000	
Total Cost for Alternative 3					**$ 1,057,858,000**	

Note: Action numbering corresponds to labels shown in Figure 17.

TABLE 22. COST ESTIMATE FOR ALTERNATIVE 3 OPTION 2

	Item	Units	Quantity	Unit Price	Cost	Notes
1	Construct SAFER Bay levee bayfront of East Palo Alto and SFPUC infrastructure	LF	4550	$ 3,428	$ 15,599,000	Includes ecotone slope
2	Remove Bay Trail levee and railroad embankment	LF	5800	$ 75	$ 438,000	
3	Remove Hetch Hetchy pipeline	LF	2800	$ 4,923	$ 13,786,000	Removal of both pipes and trestle to just below MLW
4	Restore SFPUC parcel	AC	55	$ 25,753	$ 1,416,000	Lowering of outboard levee, grading to intertidal elevation
5	Raise SR 84 on causeway	LS	1	$697M	$697,000,000	Construction of temporary and permanent causeway, demolition of temporary causeway, turnaround road.
6	Construct levee landward of middle cell of Pond SF2. Connect to PG&E/Pond R2 levee.	LF	5430	$ 3,942	$ 21,406,000	Includes ecotone slope on levee and installation of 2 WCS in levee
7	Restoration of eastern cell of Pond SF2	AC	60	$ 321,994	$ 19,317,000	Lowering outboard levee; constructing pilot channels; grading to intertidal elevation
8	Remove decommissioned roadway and associated infrastructure (concrete barrier, pump station and SW infrastructure). Reconnect alongshore habitat.	AC	20	$ 704,132	$ 14,083,000	Includes pilot channels to connect habitats

	Item	Units	Quantity	Unit Price	Cost	Notes
9	Relocate PG&E Ravenswood substation	L/S	1	$ 250M	$ 250,000,000	Includes relocating and enclosing substation. Relocating only could halve cost.
10	Raise levee along north edge of SR 84 between Facebook and Ravenswood Pond	LF	2120	$ 3,393	$ 7,192,000	Includes raising headwall of WCS underneath SR 84
11	Raise levee along Pond R2 (2nd phase of raising)	LF	1200	$ 3,109	$ 3,731,000	Initial levee to 12 ft NAVD already built in Alternative 1
12	Raise levee around Facebook	LF	4450	$ 3,575	$ 15,909,000	
13	Raise entire levee system to 22 ft NAVD88	LF	15,700	$ 1,637	$25,698,000	Raise levee to 100-year + 83" SLR level of protection
Sub-total					**$ 1,069,975,000**	
GC / GR, & Overhead				15%	$ 160,496,000	
General Contractor Markup				5%	$61,524,000	
General Contractor Bond & Insurance				2%	$25,840,000	
Sub-total					**$1,317,835,000**	
Design / Estimate Contingency				25%	$ 329,459,000	
Engineering Fees				10%	$ 131,784,000	
Environmental Clearance & Permitting				L/S	$ 17,000,000	
Total Cost for Alternative 3					**$ 1,796,078,000**	

Note: Action numbering corresponds to labels shown in Figure 19.

5.7. POTENTIAL PROJECT PARTICIPANTS AND STAKEHOLDERS

As discussed in Section 5.2, individual actions that are part of each alternative would likely be grouped into separate projects based on common landowners and stakeholders. Each project could be led by different proponents and partnering agencies. Table 23 presents an initial identification of potential project participants, including land, right of way, and utility owners in the project area and well as potential stakeholder partners that could potentially provide direct support for project planning, coordination, management, or funding.

TABLE 23. LIST OF POTENTIAL PROJECT PARTICIPANTS AND STAKEHOLDERS

Potential Project Participants	Potential Project Stakeholders
California State Lands Commission Caltrans City of East Palo Alto City of Menlo Park Facebook Mid-Peninsula Regional Open Space District Pacific Gas & Electric SamTrans San Francisco Public Utilities Commission San Mateo County U.S. Fish and Wildlife Service	Association of Bay Area Governments (ABAG) Bay Area Toll Authority (BATA) California State Coastal Conservancy California Transportation Commission City/County Association of Governments (C/CAG) East Palo Alto County Water District Menlo Park Municipal Water District Metropolitan Transportation Commission (MTC) Palo Alto Pedestrian and Bicycle Advisory Committee San Francisco Bay Trail San Francisquito Creek Joint Powers Authority San Mateo County Board of Supervisors San Mateo County Flood and Sea Level Rise Resiliency District San Mateo County Mosquito and Vector Control District San Mateo County Planning and Building San Mateo County Transportation Authority South Bay Salt Pond Restoration Project U.S. Geological Survey

5.8. ALTERNATIVES EVALUATION

Table 24 shows how the alternatives performed for each of the selected evaluation criteria. Criteria ratings were applied by project team engineers, ecologists, and cost estimators according to the ordinal ranking logic described in Section 4.2.2. As explained in that section, criteria were chosen based on project objectives, evaluation criteria used for similar sea level rise adaptation planning projects, and stakeholder and community input. This evaluation matrix illustrates the trade-offs between the different alternatives. While it is difficult to compare the near-term and long-term alternatives due to their very different goals and objectives, some general conclusions can be drawn, especially when comparing the two long-term alternatives. Alternative 1 is the cheapest but provides the least protection and co-benefits while Alternative 3 Option 2 performs highly but is also the most expensive and disruptive.

TABLE 24. ALTERNATIVES EVALUATION RESULTS

CRITERIA ID	CRITERIA	Near-Term		Long --Term	
		Alt 1	Alt 2	Alt 3 Option 1	Alt 3 Option 2
	Engineering (N) Criteria				
N1	Construction access and impacts e.g. traffic disruption, environmental impact (feasibility is accounted for in cost)	+	0	-	--
N2	Ability of alternative to adapt to higher levels of SLR beyond design level	--	++	++	++
N3	Ability of alternative to be integrated into large-scale or regional flood protection plans and regional restoration plans (i.e., ability to tie-in to adjacent protective features)	--	++	++	++
N4	Ability of alternative to not preclude other strategies or adaptation pathways	++	--	++	++
	Environmental (E) Criteria				
E1	Ability of alternative to align with or make progress towards regional habitat goals	+	+	+	++
E2	Ability of alternative to protect/enhance/expand/utilize ecosystem value/functions/ services (through nature-based solutions such as wetlands, living levees)	0	+	++	++
E3	Ability of alternative to protect/enhance/expand sensitive habitat and special status species	0	+	++	++
E4	Ability of alternative to maintain or improve Bay water quality (wetlands, vegetated swales)	0	+	+	+
E5	Ability of alternative to provide carbon sequestration benefits	0	+	++	++
	Feasibility (F) Criteria				
F1	Capital Cost	+	0	-	--
F2	Rough order of magnitude annual operating and maintenance cost of alternative	++	-	-	--
F3	Alternative can be accomplished within existing policies, procedures, and regulations	++	++	++	++
F4	Likelihood of alternative obtaining political / community support (as reflected in community input to date)	0	+	0	-
	Social (S) Criteria				
S1	Businesses protected	0	++	++	++
S2	Homes protected (all types)	0	++	++	++

		Near-Term		Long --Term	
CRITERIA ID	CRITERIA	Alt 1	Alt 2	Alt 3 Option 1	Alt 3 Option 2
S3	Ability of alternative to prevent mobilization of contaminants from hazardous sites (either groundwater or overland flooding)	0	+	+	+
S4	Ability of alternative to protect/enhance recreational amenities	0	++	++	++
S5	Ability of alternative to improve public access to shoreline	0	++	++	++
Transportation (T) Criteria					
T1	Ability of alternative to address flooding of Dumbarton Bridge approach within study area	+	++	++	++
T2	Ability of alternative to address flooding of adjacent road network within study area	+	++	++	++

5.9. LAND SIDE STRATEGIES

5.9.1. Project Area Interrelated Flooding Issues

The project area is prone to flooding and ponding of stormwater runoff due to natural factors including low elevation, flat topography, low permeability soils, and a high groundwater table, but also due to an inadequate stormwater system and the proliferation of impermeable surfaces throughout the region. These hazards will be exacerbated by sea level rise, which will increase the risk of stormwater runoff becoming trapped during high tides and will cause the inland groundwater table to rise, limiting infiltration capacity, contributing to saltwater intrusion, and potentially mobilizing contaminants in the soil at toxic sites.

The scope of the Dumbarton Bridge West Approach and Adjacent Communities Resilience Study was not intended to solve the stormwater flooding issues in East Palo Alto or Menlo Park; however, this section was included given that sea level rise will exacerbate stormwater issues, and any bayside levees proposed in the alternatives described above could cut off the drainage routes for some portions of the project area. While the project area does include commercial development within the City of Menlo Park, this section focuses on East Palo Alto because of the prevalence of flood-prone residential areas within the East Palo Alto portion of the Project Area. Furthermore, the City of Menlo Park has recently completed a green infrastructure plan that includes projects to address stormwater flooding in project area. East Palo Alto's green infrastructure plan is currently in development and recommendations made here have the opportunity to inform that process.

During coincident high tide and storm events, storm drains can overflow, resulting in standing water on roadways (City of East Palo Alto 2016). As shown in Figure 22, the City of East Palo is aware of several locations within the project area where stormwater backs up and causes intermittent standing water (K. Fallaha, pers. comm., 2019). It is anticipated that future developments in the area will require additional stormwater infrastructure to address these issues (City of East Palo Alto 2013). As shown in Figure 22, much of the new development in East Palo Alto is proposed within the eastern portion of the city in the immediate vicinity of the shoreline and proposed levee improvements. Street-level green infrastructure improvements are already planned for all streets within the commercial portion of Menlo Park in the project area (City of Menlo Park 2019)

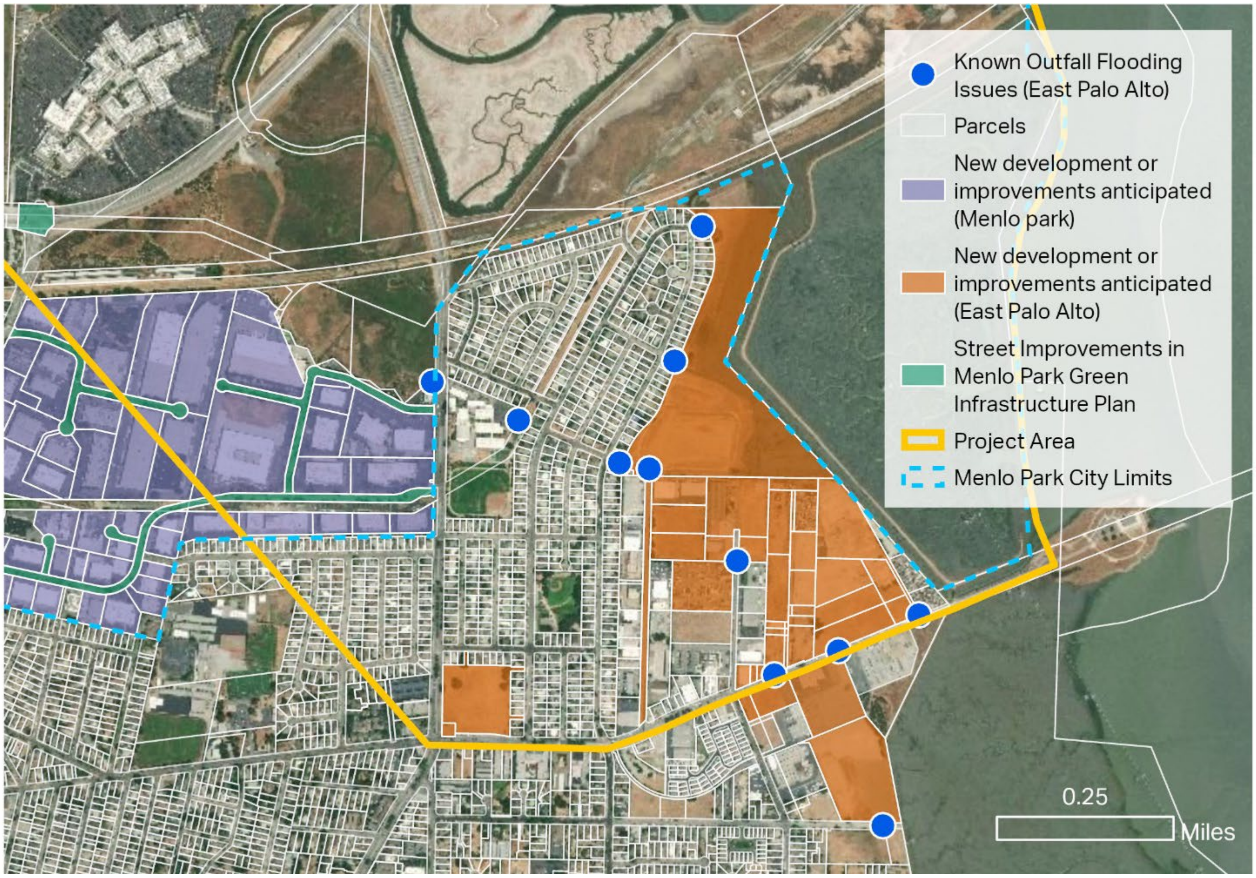

FIGURE 22. ANTICIPATED DEVELOPMENTS OR IMPROVEMENTS IN AND NEAR THE PROJECT AREA

Data Sources: Email Communication with Michelle Daher, Environmental Coordinator, City of East Palo Alto and Fariborz Heydari, Senior Civil Engineer, City of Menlo Park. Graphic developed by AECOM.

5.9.2. Groundwater and Contamination

There are several contaminated sites in East Palo Alto due to a legacy of historical industrial land uses. Legacy contamination has limited development in East Palo Alto's underutilized industrial areas. Contaminants include hydrocarbons, pesticides, and solvents (SWRCB 2016). Concentrated in the Ravenswood area, many of the contaminated sites are now in various stages of cleanup and others have deed restrictions in place that prohibit sensitive uses such as residential homes (Ravenwood Specific Plan). However, the community is concerned that the clean-up plans and remediation statuses of each contaminated site do not consider the threat of a rising groundwater table. Common remediation techniques such as capping may not prevent rising groundwater or saltwater intrusion from mobilizing the contaminants from underneath and spreading them into neighboring areas.

5.9.3. East Palo Alto's Current Stormwater System

While natural factors certainly contribute to East Palo Alto's flooding issues, the city's stormwater infrastructure is currently inadequate and is one of the contributing causes of both flooding and intermittent standing water (City of East Palo Alto 2013 and 2014). The system itself is a traditional gravity-fed system of gutters, storm drains, and pipes that convey stormwater and discharge it to one of two pump stations or directly to the Bay. Most streets in the residential areas of East Palo Alto have curbs and shallow gutters, which limits the system's ability to attenuate peak flows before street runoff enters catch basins (City of East Palo Alto 2014).

Figure 23 depicts drainage routes and outfalls by drainage neighborhood. Within the project area, a small portion of East Palo Alto (Willow-Ravenswood), as well as a large portion of Menlo Park (Menlo Park B), drains via pipe infrastructure to the Ravenswood Pump Station, which is owned and operated by Caltrans and located south of Highway 84 across from the Facebook Headquarters. The eastern half of the University Village neighborhood (University-Tulane) drains into an open space on the western side of University Avenue. This open space, and the area south of it (Adams Drive and Menlo Park A) drain northwards, under the railroad tracks into a Caltrans wetland mitigation site and then under Highway 84 through a culvert adjacent to the Ravenswood Pump Station and into the Ravenswood Slough. Finally, the majority of the Ravenswood Business District (Purdue Avenue – Fordham Street and Bay Road) drains via gravity to the wetlands between East Palo Alto and the Bay Trail. These outfalls have known standing water issues already.

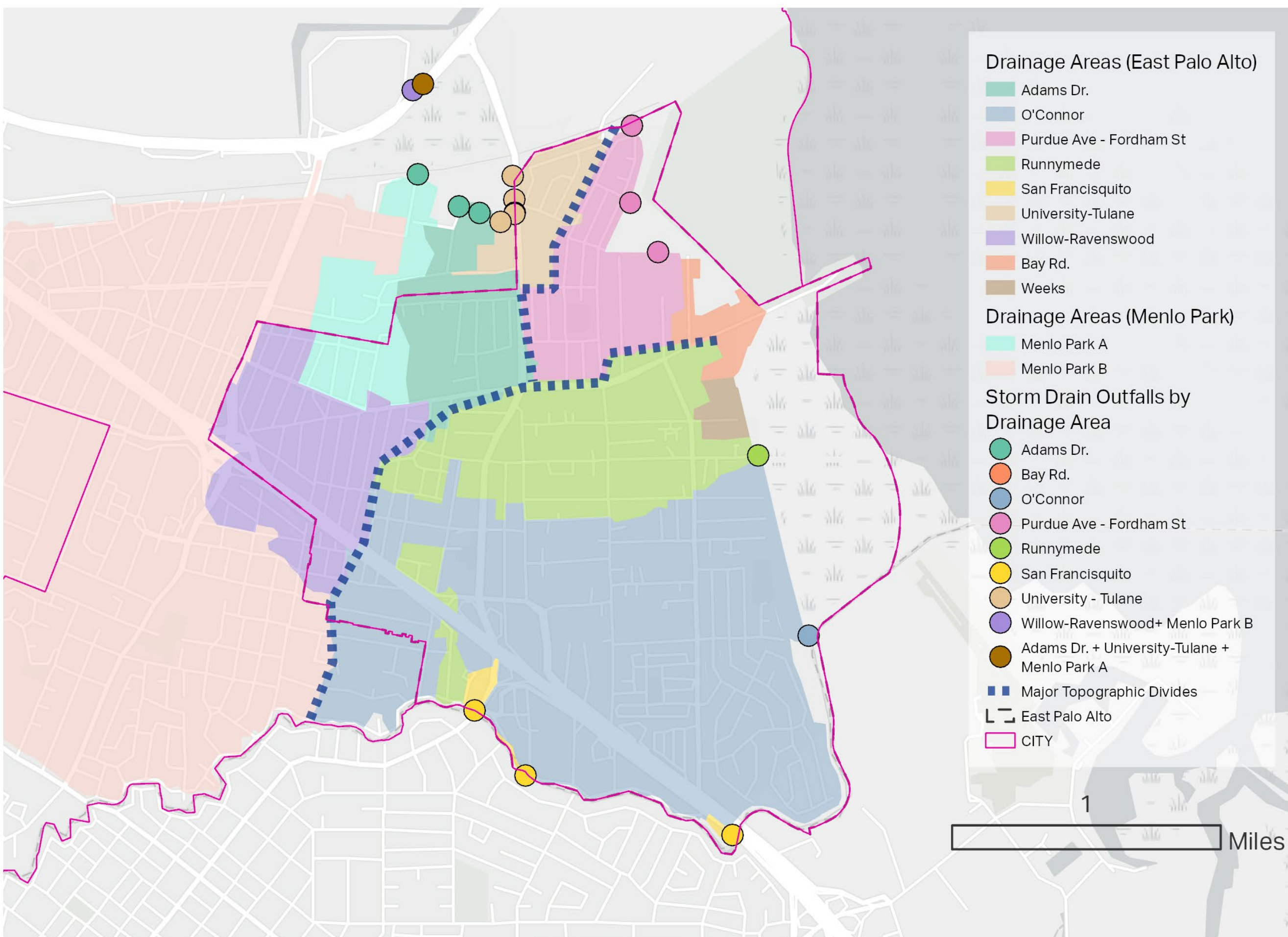

FIGURE 23. PROJECT AREA STORMWATER INFRASTRUCTURE AND DRAINAGE ROUTES

Data Sources: Storm Drain Master Plan (2014) and aerial imagery/elevations from Google Earth. Graphic developed by AECOM.

5.9.4. Potential Strategies

This section provides a series of potential landside strategies (including many recommended from existing City of East Palo Alto and/or City of Menlo Park documents) that could address increased stormwater/groundwater flooding and associated risks due to sea level rise. It should be noted that no site visits, geotechnical analysis, or engineering evaluations were conducted to inform this section and these recommendations represent initial ideas for further evaluation. Therefore, strategies should be viewed as high-level concepts only and each would need to be verified with a full feasibility study in order to be considered further.

PREEMPTIVELY ADDRESS GROUNDWATER THREAT

- The City of East Palo Alto could install groundwater monitoring wells near sites that are on the San Francisco Bay Water Quality Control Board list of known groundwater threats in order to detect if groundwater is rising in the vicinity of contaminants.
- If the groundwater depth reaches an agreed-upon threshold, take preemptive action to avoid groundwater contamination. The best course of action for each contaminated site would depend on site-specific factors, but two options that could be considered are 1) excavating and transporting contaminated soils away from the site and 2) a combined approach of slurry walls with groundwater pumps (and potential treatment) to prevent contaminant mobilization.

REQUIRE LOW IMPACT DEVELOPMENT AND SEA LEVEL RISE-READY STORMWATER INFRASTRUCTURE

- Continue to mandate stringent green infrastructure and stormwater retention requirements for new projects where feasible and consider fast tracking the approval of projects that exceed existing requirements.

BALANCE URBAN FORESTRY AND GREEN INFRASTRUCTURE PRIORITIES THROUGH INNOVATIVE DESIGN

- For the City of East Palo Alto, implement projects from the forthcoming Green Infrastructure and Urban Forest Plan where the projects reduce flood risk, balancing needs for tree canopy, street-level green infrastructure, and limitations of the narrow streets and sidewalks.
- For the City of Menlo Park, implement plans for street-level green infrastructure in the project area as described in the City's Green Infrastructure Plan.

ENSURE COMMUNITY IS PREPARED FOR FLOOD EVENTS

- Develop a flood warning system for the project area (similar to that developed by the SFCJPA for San Francisquito Creek) with targeted outreach to the most vulnerable residents in the most flood prone areas of East Palo Alto and Menlo Park to make sure that they will be reached by flood warnings.
- Participate in the national StormReady program, as recommended by the County of San Mateo's Local Hazard Mitigation, which uses a grassroots approach to help communities develop plans to handle extreme weather.

PREPARE STORMWATER SYSTEM TO ACCOMMODATE SEA LEVEL RISE INFRASTRUCTURE

- All alternatives considered by this project and by the SFCJPA Bay Feasibility Study include a levee along the north side of Highway 84 in the vicinity of Ravenswood Slough, which would likely require some modifications to the Ravenswood Pump Station outfall (SFCJPA 2016). It is recommended that the pumping capacity of the Ravenswood Pump Station be studied to understand if it can accommodate higher future Bay water levels and stormwater from all portions of northwestern East Palo Alto. A series of small retention ponds south of the railroad embankment outside the Caltrans wetland mitigation area could reduce peak flows and therefore reduce the degree to which the Ravenswood Pump Station capacity needs to be increased.

- The northeast portion of University Village, Ravenswood, and the parcels between Weeks Street and Bay Road all drain east into the Ravenswood Preserve or nearby marshes. The City of East Palo Alto has already acknowledged that a new pump station will be necessary to drain this area due to outfall flooding issues (M. Daher, pers. comm., 2019). It is recommended that this pump station and any additional stormwater infrastructure connected to it be designed to accommodate the construction of a bayfront levee. As shown in Figure 24, the new pump station could be located near the end of Fordham Street at the northeastern tip of East Palo Alto, just south of the Hetch Hetchy facilities.
- Ensure that the Ravenswood Bay Trail Project, currently under construction (including a boardwalk across the marsh at the northern tip of East Palo Alto) and connecting the Bay Trail in the Ravenswood Preserve to the SFPUC access road, is not impacted by a new pump station or levee. Interpretive signage planned for the boardwalk could include information about the neighborhood's stormwater management system and how it interacts with the sea level rise adaptation infrastructure.

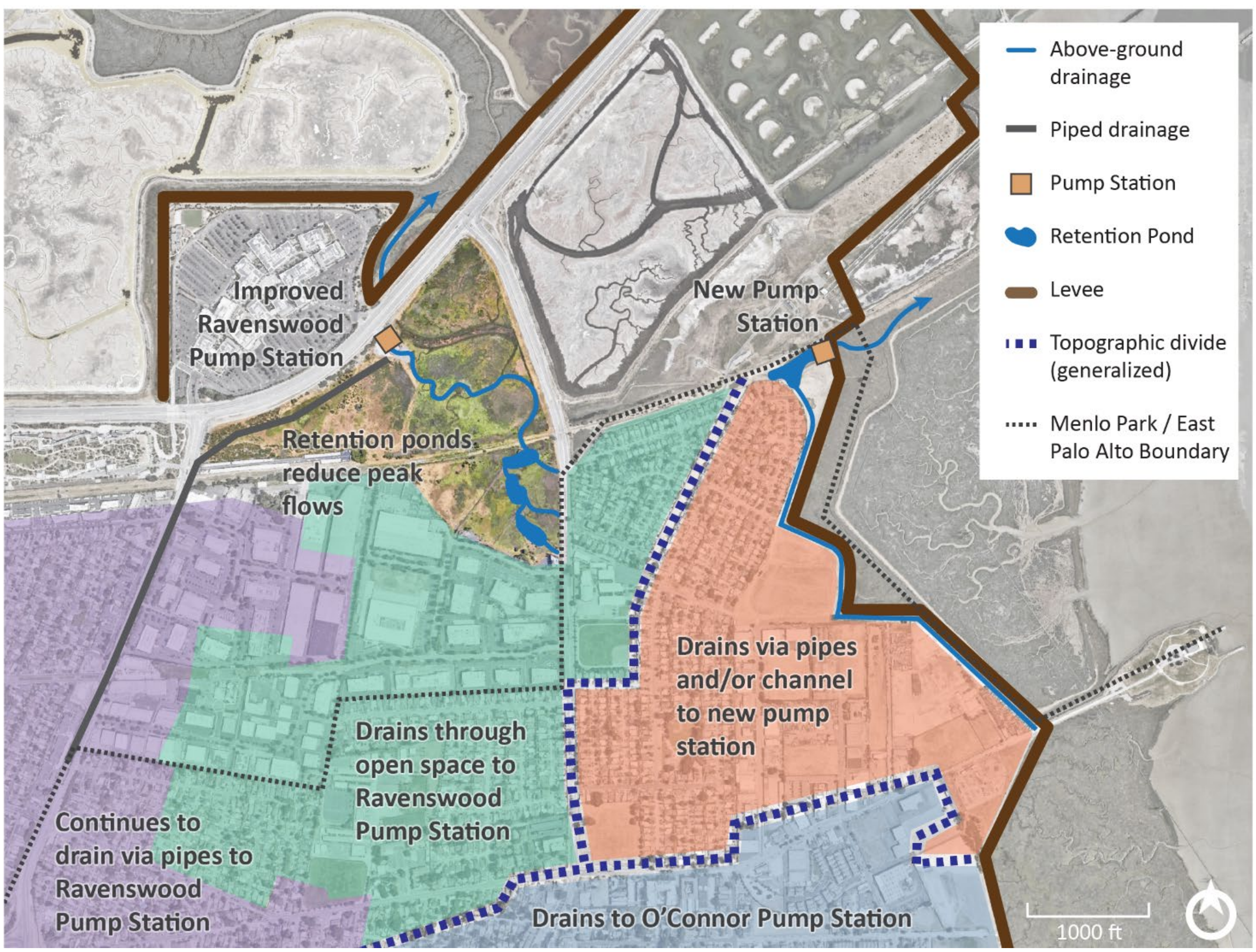

FIGURE 24. CONCEPTUAL STORMWATER INFRASTRUCTURE RECOMMENDATIONS

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6 CONCLUSIONS AND NEXT STEPS

6. CONCLUSIONS AND NEXT STEPS

The purpose of the Dumbarton Bridge West Approach + Adjacent Communities Resilience Project was to develop a phased sea level rise adaptation strategy for the west approach of the bridge and adjacent communities that provides near-term, mid-term, and long-term sea level rise resilience for the critical infrastructure, vulnerable communities, and valuable habitat within the study area. The project identified one near-term and two long-term alternatives that could provide that resilience. While it is not within the scope of this project to finalize what long-term sea level rise adaptation strategy should move ahead to protect the Dumbarton Bridge west approach and its adjacent communities, the near-term Alternative 1, could be progressed in order to address the immediate flooding issues and enable proposed tidal marsh restorations on the north side of the highway. Further stakeholder conversations, community consultation, and specific technical studies will be needed in order to confirm which of the long-term alternatives may be most appropriate and effective, as well as collaboration with adjacent projects to ensure consistency.

Current unknowns relate in particular to the funding and implementation of the South Bay Salt Pond Restoration Project, the implementation of the SAFER Bay Project, the development of the Dumbarton Rail Corridor Project and East Palo Alto developments to name just a few. The raising of the western approach of the bridge on a causeway may coincide with the replacement of the bridge (potentially needed within 20-30 years). If this is the case, the elevated causeway could be incorporated into the full bridge replacement project and the cost would not seem so prohibitive.

Several participants of the Project Management Team will continue to discuss how to refine and move these adaptation alternatives forward. This includes coordinating with other agencies and stakeholders, such as the San Mateo County Flood and Sea Level Rise Resiliency District, to form partnerships for further strategy development, collaborate on related projects and activities, and leverage funding opportunities.

The community pop-up events and capacity building efforts with the local community showed the need for continued education regarding the risks faced due to sea level rise caused by climate change as well as a deep interest and commitment to environmental stewardship of the Baylands. Many of the Stakeholder Working Group members were also interested in being involved or kept abreast of future discussions. Nuestra Casa and Acterra will be valuable partners in keeping community participants involved particularly with those who were engaged in the Parent Academies and Community Climate Change Team.

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SUPPORTING STUDY DOCUMENTS

SUPPORTING STUDY DOCUMENTS

REVIEW OF PRIOR STUDIES, EXISTING DATA, AND GOALS

The Prior Studies, Existing Data, and Goals Review summarizes relevant documents, reports, and initiatives relevant to sea level rise adaptation efforts in the Dumbarton Bridge West Approach study area. The goal of the review was to identify synergies and common goals among the studies to inform and guide the development of project objectives.

MODELING AND REFINED VULNERABILITY ASSESSMENT MEMO

The Modeling and Refined Vulnerability Assessment Memo summarizes the methods and findings of the hydrodynamic modeling, refined flooding analysis, and vulnerability assessment conducted in support of the study.

STORMWATER ISSUES AND POTENTIAL ADAPTATION STRATEGIES MEMO

The Stormwater Issues and Potential Adaptation Strategies Memo summarizes the findings of a review conducted in support of the study to identify existing stormwater flooding issues in the study area, examine how sea level rise may impact stormwater flood risk, describe current and planned actions to address stormwater flooding, and provide high level recommendations for additional adaptation actions that could be integrated into the adaptation alternatives.

HIGHWAY RAISING PLAN, PROFILE, AND SECTION CONCEPTUAL DRAWINGS

The Highway Raising Plan, Profile, and Section Conceptual Drawings include engineering schematics depicting the highway raising component of Alternative 3 (including Options 1 and 2). The schematics are provided for both the temporary re-alignment and the permanent alignment of the raised highway.

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DUMBARTON BRIDGE
WEST APPROACH + ADJACENT COMMUNITIES RESILIENCE STUDY TECHNICAL REPORT

JUNE 2020

Caltrans

METROPOLITAN TRANSPORTATION COMMISSION

Bay Area Regional Collaborative

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City of Menlo Park

Coastal Conservancy STATE of CALIFORNIA

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