EDGERLY ISLAND AND INGERSOLL TRACT
FLOOD MANAGEMENT PLAN AND ADAPTATION STUDY

August 30, 2018

Prepared for
Napa River Reclamation District
Napa County Flood Control & Water Conservation District

ESA

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550 Kearny Street
Suite 800
San Francisco, CA 94108
415.896.5900
www.esassoc.com

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EXECUTIVE SUMMARY

ES-1. Introduction

Napa River Reclamation District (NRRD) and Napa County Flood Control and Water Conservation District (NCFCWCD) have collaborated to prepare this Study, which outlines potential flood management approaches to protect Edgerly Island and Ingersoll Tract (EIIT) property and residents from flooding. These approaches, or plans, are detailed in this document for the consideration of the EIIT community.

NRRD and the NCFCWCD established the following objectives for this Study:

- Assess baseline flood hazard for present day conditions and the escalating hazard with settlement and sea-level rise.
- Develop reasonable and feasible flood management plans appropriate to the EIIT setting.
- Assess the plans relative to evaluation criteria of flood risk reduction, environmental impacts, coordination within the community, aesthetics, access, and cost to guide the selection of a plan.
- Integrate recommended improvements into phased management plans for consideration by the EIIT community.

ES-2. Existing Flood Hazard and Management

Edgerly Island and Ingersoll Tract is a residential community with 134 houses (155 parcels) on the west bank of the Napa River, about eleven miles upstream from where the river discharges into San Francisco Bay (Figure 1). The houses and related community infrastructure closely follow the alignment of Milton Road, such that the project area is nearly two miles long and only a few hundred feet wide.

Edgerly Island's houses and community infrastructure are located at elevations around mean sea level. The entire community is located within a Special Flood Hazard Zone established by FEMA. A perimeter comprised of non-FEMA accredited levees and embankments reduces the risk of flooding, but the community remains susceptible to flooding in larger events. On Ingersoll Tract, most houses and infrastructure are built on elevated ground that is just above the range of the daily tides. In addition, the County Code requires that new construction and substantial improvements elevate the lowest floor at least the base flood elevation (BFE) plus one foot of freeboard, and that construction methods and materials reduce the potential for flood damage.

With its proximity to water and low elevations, EIIT has been impacted by substantial flooding about once a decade in the recent past. Floods usually occur in response to a combination of factors, several of which are associated with winter storms. These storm events cause surges in Bay water levels, wind setup, wind waves, and increased river discharge. When these factors add to high tides, the higher water levels have overtopped, seeped through, and breached the levees and floodwalls protecting EIIT.

The soils under EIIT are mostly Bay muds, which are relatively soft soils that compress and settle to lower elevations when weighted with EIIT's levees, buildings, the roadway, and other assets. This settlement has lowered the ground surface across EIIT and will likely continue to reduce the levee heights in the future.

In addition, EIIT will face greater flood hazards with sea-level rise. Three feet of sea-level rise is likely within the next century, which means that flood water levels that now occur only about once a decade would then occur daily with each high tide.

ES-3. Flood Management Plans

To address the existing and growing flood hazards, this Study considered various potential flood management measures and strategies that would be applicable to EITT, and developed and evaluated three flood management plans in detail.

These plans are based on evaluation criteria that articulate this study's overall goal and objectives. After an initial screening of possible flood management measures (Section 3.3), some measures were not consistent with the study's objectives and were therefore dropped from further consideration (Section 3.3.1(a)). The remaining measures were then combined into three flood management plans with increasing levels of flood risk reduction and cost. The plans were evaluated to compare the benefits and tradeoffs of different flood management plans.

In order of lowest flood reduction/lowest cost to highest flood reduction/highest cost, the three proposed flood plans are:

- Plan 1: Flood Preparedness and Planning – This plan acknowledges that NRRD does not have adequate funding and right-of-way easements to mandate flood management measures on private parcels. As such, the plan focuses on community preparedness and planning, with private property owners remaining responsible for protection of their own homes, primarily by floodproofing (Section 3.3.2). The community preparedness would include floodproofing community-owned infrastructure and carrying out flood preparedness and planning studies and practices. These studies and practices include: recommended levee inspection and maintenance, flood response planning, an institutional implementation approach, and the development of potential design standards and implementation guidance for private levee/floodwall upgrades. In addition, if approved by the community, a levee repair fund is proposed for Plan 1 to assist property owners with improving their privately-owned levee sections. A part-time NRRD Levee Coordinator is also proposed to facilitate levee maintenance and improvements, pursue grant opportunities, and facilitate collaboration between the EIIT community and outside entities. Because of its limited scope, this plan would result in the least flood risk reduction, but also has the lowest cost. This plan could be enhanced with additional measures in the future, and as such should be viewed as a starting point for other more extensive protection plans.

- Plan 2: Vinyl Sheet Pile Floodwalls to 12.5 ft NAVD – This plan would improve the stability and reliability of flood barriers around EIIT's perimeter to address the existing flood hazard and partially buffer against increasing flood hazard due to future sea-level rise. The proposed crest elevation of 12.5 ft NAVD has 1.5 ft freeboard above the existing 100-year water level. Improved and new levees would also be constructed on the west side (Section 3.3.1). With the appropriate safety factors, the proposed vinyl sheet pile floodwall would be at or very close to its maximum structural capacity, so raising the crest further to adapt to sea-level rise would be very costly. Elevation and floodproofing of houses and community infrastructure would be the primary mechanism for managing future increases in flood hazard. This approach allows homeowners greater latitude in how they individually adapt to future conditions. The plan assumes that the NRRD is able to secure funding and right-of-way easements from property owners so it can lead implementation of the vinyl sheet pile floodwall. It also assumes that NRRD is able to work with the agencies that own the west side levees to move forward with the proposed improvements on those structures. These proposed barriers would provide a reliable flood management system, but considerably raise the project cost as compared to Plan 1. The plan also includes the same floodproofing, preparedness, and planning measures that are proposed in Plan 1.

- Plan 3: Steel Sheet Pile Floodwalls to 15.5 ft NAVD – This plan proposes improvements to flood barriers around EIIT's perimeter, and uses steel sheet piles that are installed at an initial elevation of 12.5 ft NAVD and can be raised to 15.5 ft NAVD as an adaptation measure to the anticipated three feet of future sea-level rise (Section 3.3.1). A steel sheet pile floodwall along the Napa River levee and the west side would form a continuous barrier around EIIT that would remain higher than the anticipated 100-year flood levels even with three feet of sea-level rise. The plan assumes that the NRRD is able to secure funding and right-of-way easements from property owners so it can lead implementation of the steel sheet pile floodwall. It also again assumes that NRRD is able to work with the agencies that own the west side levees to move forward with the proposed improvements on those structures.. As the most intensive and protective plan considered in detail, it also has the highest cost. The plan also includes the same floodproofing, preparedness, and planning measures that are proposed in Plan 1.

Table ES-1 provides a brief summary of the three potential flood management plans' performance relative to the study's evaluation criteria. All plans would require coordination between members of the EIIT community. All plans also assume continued application of the existing County Code flood management requirements regarding minimum first floor design elevation and floodproofing for construction of new and substantially improved houses and facilities. Therefore, individual homeowners would remain responsible for funding and implementing these existing measures on their own, possibly with community assistance. Grants such as FEMA's Hazard Mitigation program could provide matching funds to lower the direct financial burden to homeowners for these improvements.

For flood hazard reduction, the amount of sea-level rise (SLR) that will cause 10-year flood water levels to exceed the typical levee crest elevation is used as a simple metric. Currently, the 10-year flood event on the Napa River falls just below the typical levee crest and poses a significant risk for levee and floodwall seepage and potential failure. The different amounts of sea-level rise that will increase the 10-year flood event over the levee crest of each plan, as well as the projected decade this amount of sea-level rise will occur, are shown in the table.

Table ES-1 Comparison of flood management plans relative to evaluation criteria

Evaluation Criteria	Plan 1: Flood Preparedness & Planning	Plan 2: Vinyl Sheet Pile Floodwalls to 12.5 ft NAVD	Plan 3: Steel Sheet Pile Floodwalls to 15.5 ft NAVD
Flood Hazard Reduction	At risk to 10-year flood with 1 ft SLR (c. 2040)	At risk to 10-year flood with 2 ft SLR (c. 2090)	At risk to 10-year flood with 5 ft SLR (after 2100)
Environmental Impact	Negligible	Moderate wetland fill for west side levee improvements	Moderate wetland fill for west side levee improvements
Community Coordination	Requires funding	Requires funding and right-of-way easements	Requires funding and right-of-way easements
Aesthetics & Access	No change	Slight increase in east floodwall heights. Raised and new west side levees and floodwalls.	Slight (first stage), then noticeable (second stage, after 2 ft sea-level rise) increase in east floodwall heights. Raised and new west side levees and floodwalls.
Construction & Mitigation Cost	$3,500,000	$38,300,000	$79,300,000
Community Investment per Parcel*	$23,000	$247,000	$512,000

*** These estimated costs, distributed across 155 parcels, should not be viewed as a per parcel owner cost at this time, but rather as the per parcel share of total community investment for each plan. These costs do not consider the source of funding, which may be offset to some degree by grants.**

In the last row of Table ES-1, the estimated community investment per parcel is provided, assuming 155 parcels. Implementing the preferred plan is anticipated to be a collaborative effort with the larger external community, consisting of county, regional, state, and federal agencies and grants, as viable funding sources. By leveraging these community opportunities, a plan's cost need not be funded by individual homeowners alone. In the past, well-organized flood management projects have been able to secure about half of their funding from sources beyond the local community. The plans should also be viewed as an investment to protect its existing assets from the growing flood hazard posed by sea-level rise and settlement of existing infrastructure. Otherwise, more frequent and intense flooding will threaten and escalate the potential damages to the infrastructure (water, sewer, gas, electrical, and road), to public safety, and property. EIIT may be come flooded and uninhabitable more often for short periods, or even permanently.

ES-4. Next Steps

The intent of this study is to provide a feasibility-level engineering assessment to guide EIIT community decision making for strategic flood management planning. Refining and implementing a preferred plan will require additional community education and outreach, planning, engineering, environmental review, and funding. Suggested next steps in support of these efforts include: community discussion and planning to determine interest and desire to fund flood management measures; integration with regional planning; additional engineering data collection and analysis; environmental review and permitting; and pursuit of funding opportunities.

1. INTRODUCTION

Napa River Reclamation District (NRRD) and Napa County Flood Control and Water Conservation District (NCFCWCD) have collaborated to prepare this Study, which outlines flood management approaches to protect Edgerly Island and Ingersoll Tract (EIIT) property and residents from flooding. The approaches, or plans, are detailed in this document for consideration of the EIIT community.

NRRD and the NCFCWCD established the following objectives for this Study:

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1.1 Plan Development Process

This study is being led by staff from the NCFCWCD and a committee from the NRRD Board of Directors and interested homeowners, a group referred to as the Study Advisory Team (SAT). The NCFCWCD and NRRD requested technical assistance from ESA to assist with plan development. ESA received technical support for structural engineering from COWI and for geotechnical engineering from Hultgreen-Tillis Engineers.

Over the course of the study, the SAT met five times with ESA to review historic flooding, select evaluation criteria, consider baseline flood findings, and review management measures and plans. Between SAT meetings, ESA conducted technical assessments including an elevation survey; hydraulic, structural, and geotechnical engineering analyses; development and evaluation of flood management measures and plans; and preparation of study presentations and documentation. The study also included two public meetings, the first to present the existing flood hazard and potential flood management measures, the second to present the three flood management plans described in this report. Public input during and after each public meeting, as well as comments on a draft of this report were then incorporated into the study.

1.2 Report Organization

Section 2 of this report describes the existing flood hazard and management issues which apply to EIIT. While doing so, many of the technical concepts and engineering analyses underlying the study are introduced. Next, Section 3 describes the development and evaluation of three flood management plans, which ramp up in their level of flood hazard reduction and cost. Before describing the plans in detail, the first part of the section outlines the approach used to develop the plans by explaining the evaluation criteria used, as well as the flood management strategies and measures that were considered in the process of creating the plans. Section 4 presents recommendations for next steps towards implementing a flood management plan. Technical details supporting the main report are provided in the appendices.

2. EXISTING FLOOD HAZARD AND MANAGEMENT

Floods are naturally occurring events that are an inherent part of the waterways next to Edgerly Island and Ingersoll Tract (EIIT). Flood hazards threaten the project area when water levels rise above their typical range and threaten normally dry areas. Floods become hazardous to people and property when they inundate an area where development has occurred, impede access, damage property, and endanger human safety. Minor flooding may have little impact, such as shallow ponding or the generation of unwanted debris. Severe flooding can damage and destroy buildings, ruin infrastructure, and cause injury or death.

Edgerly Island and Ingersoll Tract is a residential community with 134 houses (155 parcels) on the west bank of the Napa River, about eleven miles upstream from where the river discharges into San Francisco Bay (Figure 1). The houses and related community infrastructure closely follow the alignment of Milton Road, such that the project area is nearly two miles long and only a few hundred feet wide.

Edgerly Island's houses and community infrastructure are located at elevations around mean sea level. The levee on the east side of Edgerly Island, between the houses and the Napa River, prevents daily high tides on the Napa River from inundating the project area. On Ingersoll Tract, most houses and infrastructure are built on elevated ground that is just above the range of the daily tides. To the west of Edgerly Island, on land owned by the NCFCWCD and California Department of Fish and Wildlife (CDFW), water is diverted and detained by a network of embankments and managed wetlands. These elements limit water levels and flood hazard from the west.

With its proximity to water and low elevations, EIIT has been impacted with substantial flooding about once a decade. Floods usually occur in response to a combination of factors, several of which are associated with winter storms. These storm events cause surges in Bay water levels, wind setup, wind waves, and increased river discharge. When these factors add to high tides, the higher water levels can overtop and seep through the levees and floodwalls protecting EIIT.

The soils under EIIT are mostly Bay muds, which are relatively soft soils that compress and settle to lower elevations when weighted with EIIT's levees, buildings, the roadway, and other assets. This settlement has lowered the ground surface across EIIT and will likely continue to reduce the levee heights in the future.

In addition, EIIT will face greater flood hazards with sea-level rise. Three feet of sea-level rise is likely within the next century, which means that flood water levels that now occur only about once a decade would then occur daily with each high tide.

These existing flood hazards and the flood management measures are described in more detail in the sections below.

2.1 Vertical Datums

To accurately measure and evaluate flooding and its management requires a measuring system for elevation. This enables a consistent basis for answering 'how high?' in regards to water levels, levees, and houses.

A vertical datum is a reference elevation which establishes the starting point or 'zero' for measuring elevation. By selecting and using a standard vertical datum, measurements can be synchronized over large areas. In the past, the National Geodetic Vertical Datum (NGVD) of 1929 was the prevailing datum, including for the EIIT flood study in the 1980s (Bracewell, 1984). In 1988, a new vertical datum was adopted by the National Geodetic Survey, the North American Vertical Datum (NAVD) of 1988. Over the last few decades, many elevation measurements have been converted from the old datum, NGVD, to the new datum, NAVD. Elevation measurements which have changed to NAVD include Napa County's system of survey benchmarks and FEMA's floodplain map updates (FEMA, 2016).

Because of these changes to key regional elevation measurement practice, unless indicated otherwise, all vertical elevations in this report are referred to NAVD.

To convert between NAVD and NGVD datums, the National Geodetic Survey provides an online tool for vertical datum conversion, VERTCON, that provides the offset between the two datums. At the project location, the following conversion applies:

$$\mathrm{EL}_{\mathrm{NAVD}} = \mathrm{EL}_{\mathrm{NGVD}} + 2.33\ \mathrm{ft}$$

Note that converting between datums does not change the absolute elevation of the measured point. Instead, the starting point for the 'ruler' being used to make the measurement has been shifted, resulting in a different numeric value that is specific to the selected datum. For example, the target levee crest elevation from the 1984 study (Bracewell, 1984), 10 ft NGVD, is the same as 12.33 ft NAVD. This shift in elevation measurements is shown schematically in Figure 2.

For higher levels of accuracy suitable for design and long-term monitoring of settlement, VERTCON conversions should be reviewed, and vertical datums should be prepared and confirmed by a certified Professional Land Surveyor.

2.2 Historic Flood Events

The project site has experienced a number of notable historical flood events in recent history. A brief review is provided below and additional photographs can be found in Appendix A. Storm surge and elevated river flows, as well as wind, combined to cause high water levels and flooding in 1973, 1983, 1986, 1998, 2006, and 2017.

High water levels in 1973 stressed the Edgerly Island levees and in spite of extensive emergency sandbagging, still causes a levee breach (Figure 3). As a result, Edgerly Island was inundated for days with several feet of water.

Water levels during January and December 1983 caused the highest observed water levels along much of the Bay shoreline. The January 1983 event was particular hazardous since the highest water level was nearly matched on several successive days' high tide. The flooding from high water levels in 1983 were compounded by levee breaching on Edgerly Island in December 1983.

The highest recorded river flow on the Napa River was in February 1986, due to extremely high rainfall within Napa Valley. The river flow was very fast, dislodging boats and docks at EIIT. Ingersoll Tract was flooded. During the same event, Edgerly Island's levee was not overtopped, in part because of levee improvements that had been recently made. This flooding pattern is not typical of other flooding events, since the ground elevation are similar between the two areas and have experienced similar flooding during other flooding events. This difference may be due to a combination of debris hung up on the upstream side of the Brazos Bridge which may have raised the upstream water surface and rainfall runoff from the areas west of Ingersoll Tract. This runoff could not drain through the culvert under Milton Road because the river was high, so the runoff accumulated and eventually flooded Ingersoll Tract from the west.

Levee breaching was threatened, but did not occur in 1998 when water was observed gushing from the land side of the riverfront levee due to high seepage rates.

High Bay water levels and extensive rainfall and runoff threatened EIIT in February 2017. On the Napa River, water levels crested just below several low points in the levee and floodwalls. Several floodwalls had substantial leaks which required temporary plastic sheeting and sandbagging (Figure 4). Runoff from the lands west of Ingersoll Tract could not drain to the river because water levels in the river were so high. Substantial ponding west of Ingersoll inundated several hundred feet of Milton Road.

2.3 Flood Water Levels and Frequency

The water levels next to EIIT are determined by the Napa River and San Francisco Bay. Most of the time, water levels adjacent to the project area are determined by Bay tides. On average, where the Brazos Railroad Bridge crosses the Napa River, the tides range daily from -0.1 ft NAVD on low tide to 6.6 ft NAVD on high tide. The highest tides of the year, sometimes referred to as 'king tides' usually occur in December or January and are a little more than a foot higher than the average daily high tide.

In the winter, storms cause even higher water levels, known as storm surge. These higher water levels threaten EIIT with flooding. Storm surge affects the entire Bay. This surge is caused by the low atmospheric pressure and regional winds that raise ocean water levels along the Pacific coast, which, in turn, raise water levels in San Francisco Bay by a few feet. In addition to this regional surge in water levels, local factors further raise water levels around EIIT. High flows down the Napa River can bump up water levels at EIIT. When winds blow from the south, they tend to funnel water up the mouth of the Napa River, also increasing water levels. These winds generate waves, which can worsen flooding by overtopping a levee even if the still water level is below the levee crest.

Of key importance to flood management is knowing how high water levels can go and how frequently the extreme high water levels occur. A commonly used frequency for flood management is the 100-year event. Technically defined, the 100-year event is an event that has a 1% probability of being exceeded in any given year. Therefore, there is no guarantee that the 100-year event will only occur once every 100 years. In fact, the chance of the 100-year event occurring during the 30 years of a typical mortgage is 26% or about 1 in 4. The 100-year event is used by FEMA to map its flood hazard zones. The 100-year water level in these zones is referred to as the ‘base flood elevation’ (BFE). The BFE is used by FEMA and Napa County as a benchmark for assessing flood risk and designing flood protection measures.

These extreme water levels can be predicted for EIIT by applying statistical analyses to data observed nearby EIIT. Multi-decade records that were analyzed for this study include Bay water levels at Port Chicago, Napa River flow at Napa, and Napa County Airport wind data. Details of this analysis are provided in Appendix C.

The results of this analysis are shown in Table 1, as well as estimates from two prior studies. When compared in NAVD, the three studies are within a few tenths of a foot of one another. For reference, the estimate from the older EIIT study, Bracewell (1984), is also shown in its original vertical datum, NGVD. Converted to NAVD, the estimated peak water levels during the January 1983 and December 1983 events reported in Bracewell (1984) were 9.6 ft NAVD and 10.5 ft NAVD, respectively. These observed water levels add credence to the 100-year water level estimates. A 1984 report by the U.S. Army Corps of Engineers is another widely used study of extreme Bay water levels. On the Napa River at Mare Island, about nine miles downstream from EIIT, this study estimates the 100-year water level to 9.1 ft NAVD. The difference of approximately two feet between this Bay water level and the water levels upstream at EIIT is likely due to river flow as well as the funneling of wind and waves up the confined Napa River channel.

Table 1 Comparison of 100-year water level estimates for the Napa River adjacent to EIIT

	Bracewell (1984)		FEMA (2016)	Current study (2018)
Still Water Level *(Bay tides & storm surge)*	7.5 ft NGVD	9.8 ft NAVD	10.0 ft NAVD88	9.6 ft NAVD88
Wind, waves *(Local wind, waves, riverine)*	1.3 ft	1.3 ft	1.4 ft	1.6 ft
Total Water Level **100-year Event**	**8.8 ft NGVD**	**11.1 ft NAVD**	**11.4 ft NAVD**	**11.2 ft NAVD**

The applicable FEMA flood hazard mapping for EIIT is the Flood Insurance Rate Map panels 06055C0604F and 06055C0608F, effective August 2, 2016. According to these FIRM panels, all the EIIT properties are located well within a Special Flood Hazard Area mapped as Zone AE (Figure 5). The Zone AE designation means the area is assumed to flood during the 100-year event and the BFE is provided. This zone is not considered a Coastal High Hazard Area, which requires additional protection against damage from larger waves. Along EIIT, the BFE, which is rounded by FEMA to the nearest foot, fluctuates between 10 ft NAVD and 11 ft NAVD. This fluctuation between two BFEs is an artifact of FEMA's mapping methodology. Wave hazards were mapped using a one-dimensional model along a straight coastal transect. This transect cuts across the existing topography such that the model interprets points of high ground as blocking waves and reducing the predicted wave heights for a stretch downwind of the high ground. In reality, waves can develop and propagate continuously along the meanders of the Napa River. Therefore, the BFE at 11 ft NAVD better reflects the project area's flood hazard along the entire Napa River levee and is recommended as the BFE for the entire project area.

The same analysis used for estimating the 100-year water level also provides estimates for the 10-year (10% annual probability of being exceeded) and 1-year (99% annual probability of being exceeded). These values, as well as the average daily high tide ('mean higher high water'), mean sea level, and low tide ('mean lower low water') from NOAA's Brazos Drawbridge station are listed in Table 2. Flood water levels are shown relative to a representative Edgerly Island cross section in Figure 6. For these existing conditions, the 1-year water level is more than a foot below the levee crest, the 10-year event is just at the levee crest, and the 100-year event is about two feet above the levee crest.

Table 2 **Water levels for the Napa River adjacent to EIIT**

Hydraulic condition	Water Level (ft NAVD)
100-year	11.2
10-year	9.2
1-year	7.7
Mean Higher High Water (MHHW)	6.6
Mean Sea Level (MSL)	3.5
Mean Lower Low Water (MLLW)	-0.1

The above analysis is feasible for the Napa River on the east side of the project site because of the unobstructed hydraulic connectivity of the river and the Bay, and the availability of nearby long-term observations. These water levels are also conveyed to the far west side of Edgerly Island via Mud Slough (Figure 1), the main tidal channel to the west of EIIT.

Between Mud Slough, the project area, and the railroad tracks, the west side of Edgerly Island is comprised of former marsh which is now a system of embankments, and managed wetlands. These embankments and managed wetlands, which are owned by NCFCWCD and CDFW (URS, 2008), provide flood hazard reduction for the project area by blocking flood water and storing water that does manage to overtop the embankments. This hazard reduction is supported by observations from EIIT residents, which indicate that project area's west levee and embankment crest elevations are several feet higher than the highest water levels observed in the managed wetlands. However, for the 100-year flood event, particularly if this event was accompanied by waves or embankment breaches, would likely overwhelm the capacity of the western embankments and managed wetlands (Appendix C). For these most severe flood events, the west side of the project area probably faces a similar flood hazard as the east side of the project area.

North of the railroad tracks, there have been elevated water levels as recently as February 2017 that have inundated low parts of Milton Road as it runs through Ingersoll Tract. These elevated water levels are largely due to precipitation and runoff which backs up before draining through a culvert under Milton Road to the Napa River. This ponded drainage occurs when high water levels in the river limit the culvert's discharge capacity through the tide gate which protects the low lying land from inundation during high tides. In February 2017, the water levels on the private parcel reached about 5 ft NAVD and inundated portions of Milton Road (Figure 4).

2.4 Sea-level Rise

Over the last three decades, observations at Port Chicago, the nearest long-term gauging station to EIIT, have demonstrated sea-level rise at a rate of 0.6 ft/century (NOAA, 2018). This historic rate is consistent with the rate from more than a century of observations at the Golden Gate at the mouth of San Francisco Bay.

In addition to these observed sea-level rise trends, the best available science, as reviewed specifically for California (Griggs et al., 2017), predicts that sea-level rise will continue and accelerate throughout this century and into the next century (Figure 7). Because specifics about future greenhouse gas emissions and climate response cannot be fully known in advance, the exact sea-level rise scenario that will occur is not precisely known at this time. However, considering a range of all but the most extreme but most unlikely scenarios, sea-level rise by 2100 is projected to be between one foot to five feet in San Francisco Bay.

Even if sea-level rise stays within the lower end of this range by 2100, several contributing factors all point to increasing future flood hazard:

- Because of the added weight of levees and structures, the soil underneath EIIT is gradually consolidating, causing the ground surface to settle. Long observed at EIIT and discussed in more detail below (Section 2.5.1), settlement causes the levees to decrease in elevation.
- Climate change may also cause increased precipitation and river discharge (Cayan et al., 2016; Dettinger et al., 2016). Since Napa River flows can contribute to flood water levels at EIIT (Herdman et al., 2016), addressing the threat from sea-level rise would also provide adaptation to more frequent and intense river discharge flooding.
- For all scenarios, sea-level rise is projected to continue increasing beyond 2100. So even if higher levels of sea-level rise do not occur by 2100, they will become increasingly likely in the next century.

Given the projections for increasing sea-level rise, as well as the contributing factors above, this study considers sea-level rise as part of existing conditions that will increase flood hazard. While increased precipitation due to climate change could also increase flood hazard, this process is considered a secondary factor and was not considered for this study. Given the dominant role of the Bay in setting the local flood hazard, adapting to sea-level rise will be the primary challenge and doing so will also afford some protection from higher precipitation as well.

California recently adopted new guidance to plan for sea-level rise (OPC, 2018). The guidance recommends considering range of scenarios and includes flexibility for local priorities to inform final decisions. Interpreting this guidance for EIIT, this study considers flood management that minimizes flooding for up to three feet sea-level rise. Flood water levels with one, two, and three feet of sea level rise are shown relative to Edgerly Island levees in Figure 8 and Figure 9. Three feet corresponds to state guidance recommended for typical coastal housing up to 2070 or, if risk tolerance is higher, up to 2100. In addition, this study qualitatively considers adaptive capacity for up to five feet of sea-level rise. Flood water levels with five feet of sea level rise are shown relative to Edgerly Island levees in Figure 9. Five feet of sea-level rise by 2100 is consistent with the state's recommended projection for typical coastal housing.

2.5 Geotechnical Considerations

The soil and levees around EIIT are comprised of Napa River deposits several hundred feet thick and consist mostly of clays, with lenses of peat, silt, sand, and unconsolidated gravel. These deposits are susceptible to several geotechnical processes which can compromise flood management, particularly structures such as levees and certain types of floodwalls.

2.5.1 Settlement

Settlement occurs as the weight of overlying soils and structures squeezes water from the pore space between sediment particles, resulting in consolidation and loss of volume. As a result, the ground surface elevation lowers, which can reduce a levee or floodwall's crest height for protection from flooding. For the predominantly clay soils at EIIT which limit the outflow of pore water, this process is relatively slow and can persist for decades,

By repeatedly surveying the eyebolt benchmarks that were placed in 1984 as targets for the levee/floodwall crest elevation, the rates of settlement over time can be monitored. A summary of the elevations and resulting settlement rates for three eyebolts that have been surveyed three times over 33 years is provided in Table 3. These rates as consistent with the settlement rates estimated in Bracewell (1984). Assuming the most recent settlement rate of 0.01 ft/yr continues, settlement over the next century would be approximately one foot.

Table 3 Levee eyebolt marker elevation changes, 1984-2017

Eyebolt identifier #	Elevation 1984 ft NAVD	Elevation 2009 ft NAVD	Settlement 1984-2009 ft/yr	Elevation 2017 ft NAVD	Settlement 2009-2017 ft/yr
216	12.3	11.14	0.05	11.03	0.01
211	12.3	11.31	0.04	11.23	0.01
217	12.3	10.82	0.06	10.76	0.01
AVERAGE	**12.3**	**11.09**	**0.05**	**11.01**	**0.01**

2.5.2 Seepage

Seepage is a potential failure mode of earthen levees (Figure 10) whereby water percolates through or under a levee. Seepage can never be fully eliminated and low rates of seepage are tolerable. However, higher seepage rates can lead to levee failure via several mechanisms: (1) the landward levee slope becomes saturated and unstable; (2) seepage water flows fast enough to scour soil from the levee; or (3) seepage volume exceed the pumping capacity to remove inflow.

When seepage flows fast enough to scour soil, the resulting ‘sand boil’ may continue to enlarge, and eventually may undermine the levee. Sand boils have been observed on along the Napa River levee on Edgerly Island during flood events, demonstrating the existing of sand lenses within the levee.

When water has accumulated in the NCFCWCD’s dredge spoil site to the west of Milton Road, seepage was observed through the inboard berm, filling the drainage ditch along Milton Road. The ditch has limited conveyance to the stormwater pump station. Although this seepage did not cause levee damage, this occurrence is concerning since this berm has steeper side slopes than recommended, which makes the berm less stable. Slope stability is discussed in the next section.

2.5.3 Slope Stability

Slope stability refers to the levees’ capacity to resist movement. This movement can occur gradually over time or rapidly.

Some long-term residents have noted that portions of the Napa River levee have been slowly slumping towards the river. The portions that appear to be most susceptible to this slumping are found in the southern part of Edgerly Island. This portion of the site is located on an outside bend, where natural riverine processes tends to scour the deepest point of the channel cross-section. Spot depth measurements and the lack of fringing marsh confirm that the channel below the toe of the levee slopes down relatively steeply to the depths of the channel.

Rapid slope failures have not been observed at EIIT to date, but they remain a possible levee failure mechanism. One possible cause of rapid failures are earthquakes, which are discussed in more detail in the next section.

2.5.4 Earthquakes

The project area is located within a zone of high earthquake activity, with active faults found through the surrounding region. In 2014, the South Napa earthquake of magnitude 6.0 had its epicenter just north of EIIT and was strongly felt at EIIT. This event may have caused new seepage paths to develop within the Napa River levee by shifting the position of sand lenses and may have caused cracking in some of the low floodwalls on the Napa River levee crest. These cracks needed to be covered with temporary plastic sheeting to seal the floodwall during the February 2017 flood event (Figure 4).

Future earthquakes could occur on nearby fault systems and damage the levees. Although fault rupture and liquefaction are unlikely, given the project area’s location and cohesive soils, ground shaking could cause minor damage, such as the potential damage from the 2014 earthquake that is discussed above. Ground shaking could also cause rapid slope failure, particularly if the levee is saturated with water and thus less resistant to movement.

2.5.5 Breaches

Seepage, slope stability, earthquakes, and other levee failure modes shown in Figure 10 have caused levee breaches at EIIT in the past and can still occur. Breaching is a particular risk to Edgerly Island, since much of Edgerly Island is at elevations of 3-4 ft NAVD, below typical high tides and well below flood water levels. Most structures on Ingersoll Tract are situated at elevations of 7-8 ft NAVD and less exposed to breaching, except for a stretch of Milton Road and the Milton Road Water Company's pump house at about 5 ft NAVD.

For example, a single breach on just one Edgerly Island parcel could introduce several feet of water across all of the Edgerly Island during just a few hours of peak water levels. Until repaired, a breach would continue to expose the island to inundation with each high tide. Even at full capacity, the storm water pump station would take several days or a week to remove flood waters from the island.

2.6 Community Infrastructure

This study identified several key infrastructure elements which are exposed to flood hazard at EIIT, as shown in Figure 11. A brief description of these elements, with their owners listed in parentheses, is provided below.

- Edgerly Island Fire Station (NRRD): According to ASCE (2014), as an emergency response and recovery facility, this structure could be assigned to Flood Design Class 4, the most stringent class, because it often contains emergency vehicles used for emergency response and recovery. The average elevation of the fire station is 4 ft NAVD. The station is a one-story timber structure with no basement and a small maintenance shed.

- Edgerly Island Drinking Water Pump House (Meyers Water Company): located at approx. 5 ft NAVD, the pump, which draws from deep groundwater, is primarily exposed to damage through flood water intrusion into electro-mechanical components.

- Edgerly Island Stormwater Pump Station (NRRD): the stormwater pump station stands at about 2.6 ft NAVD. It is at risk of being submerged during overtopping flood events. The pump station is a key part of post-flood response, since it is used to remove flood waters from Edgerly Island.

- Wastewater Treatment Plant and Ponds (NRRD): the wastewater treatment plant complex comprises water treatment facilities and supporting buildings. The buildings are located near the Milton Road and railroad track intersection. The two one-story buildings consist of unreinforced concrete masonry units (CMU) with no basements. Their approximate elevation is 7.8 ft to 8.1 ft NAVD. Since these facilities are at higher elevation and on the west side, the schedule for floodproofing would be triggered as sea-level rise approaches two feet.

- Sewage Collection System (NRRD): this system could be damaged by flooding and also could release sewage during a flood event. The system consists of gravity sewer pipes used to deliver sewage to one of fourteen relay pumps. The pumps then convey the sewage to the wastewater treatment plant. The elevation of the sewer relay pumps varies but along Edgerly Island is anywhere from 3-5 ft NAVD, and at Ingersoll ranges from 7-9 ft NAVD.

- Ingersoll Drinking Water Pump House (Milton Road Water Company): Similar to the Edgerly drinking water system, the water pump is exposed to damage via water intrusion into electro-mechanical components.

- Ingersoll Tract Culvert and Tide Gate (Napa County): The culvert conveys drainage under Milton Road, from west of Ingersoll Tract to the Napa River. A tide gate on the culvert's outboard end allows gravity-driven flow to the river, but prevents flow from the river. The NCFCWCD is currently replacing the tide gate. When river water levels remain higher during flood events, water backs up west of Ingersoll Tract and can contribute to flooding of Milton Road.

- Milton Road (Napa County): Milton Road varies from 1.7-3.5 ft NAVD on Edgerly Island, to about 3.5-8 ft NAVD on the Ingersoll Tract. Raising Milton Road with fill is generally not recommended, as it would increase loading on weak bay mud and cause settlement. This settlement would likely cause disruption of the existing water and sewage systems, and may require additional fill in the future.

- Railroad Tracks and Bridge (Northwestern Pacific Railroad Company): these major pieces of infrastructures are not within the purview of this study. The railroad tracks cross Milton Road at an elevation of approximately 12 ft NAVD, providing high ground that separates Ingersoll Tract from the more subsided Edgerly Island.

2.7 Existing Flood Management

The existing earthen embankments surrounding Edgerly Island and on Ingersoll Tract were constructed from Bay mud and sands starting in the early 1900's. Much of this material was dredged from the adjacent Napa River. Over time, the embankments have been incrementally improved by adding fill and, in some areas, supplemental floodwalls. The existing embankments are approximately 10-15 feet thick. The embankments are not known to be compacted to engineering standards and include lenses of sand and silty sand. These lenses have been the likely cause of seepage and sand boils seen during high water levels.

This study considers a 'levee' to be an earthen embankment that has been designed for or demonstrates capacity to block water for sustained periods. An embankment that does not meet this definition is referred to as a 'berm'. Within the project area, the EIIT embankments along the Napa River are considered levees, as is the embankment on the southwest side of Edgerly Island that detains water in CDFW's managed pond. The embankment on the west side of Edgerly

Island and the NCFCWCD dredge spoil area is considered a berm because it is designed to contained dredge spoils, not for flood control.

The levees east of Milton Road, along the Napa River, are on private parcels and are the responsibility of individual property owners. Although reclamation districts can be responsible for levees, *NRRD does not perform or require levee improvement and maintenance functions and has no legal control over the levees owned by private landowners.*

Based on a prior flood management study, Bracewell (1984), NRRD only provides un-enforceable guidance that recommends crest elevations and methods to achieve these elevations with earth fill or floodwalls. In 1984, eyebolt benchmarks were installed at the target crest elevation of 10 ft NGVD. Converted to the updated vertical datum (Section 2.1), this target elevation is 12.3 ft NAVD. Repeated surveys of the eyebolts suggest that settlement has lowered the eyebolts by 1-1.5 ft (Table 3). Currently, the crest of the earthen levee typically ranges from 8-10 ft NAVD. Floodwalls of various types and structural capacity run along the top of the levee and raise the crest elevation to 9.5-12.5 ft NAVD.

On the west side of Edgerly Island, land is owned by the NCFCWCD and the California Department of Fish and Wildlife (CDFW). These agencies maintain embankments just to the west of Milton Road. Although not intended for flood management, these embankments, along with the other embankments and low-lying areas to the west of Milton Road do prevent water originating in Mud Slough from reaching EIIT. These embankments' crest elevations are approximately 8-9 ft NAVD. The CDFW levee, which runs along the southern third of Edgerly Island, is part of a ring levee that creates a shallow pond. Water from this pond is used to improve water quality in other CDFW ponds on the far side of Mud Slough. The NCFCWCD berm separates the dredge spoil area from Milton Road.

On Edgerly Island, stormwater water from rainfall or water that overtops the levees is collected by a drainage ditch that runs along the west side of Milton Road. This ditch conveys water to the NRRD-operated pump station. Up to three pumps within the pump station can be activated to lift water over the levee and into the Napa River.

Since Ingersoll Tract is higher than surrounding areas and does not have a ring levee, water can drain off by gravity. Water that drains west from Ingersoll Tract joins runoff from the watershed to the west and then flows to the river under Milton Road via through a County-operated culvert and tide gate.

As outboard water levels approach the 10-year return event, 9.2 ft NAVD (Table 2), the existing flood management system is ominously strained. For example, in February 2017, water levels are estimated to have reached 9.3 ft NAVD, leaving less than a half foot of freeboard along some of the east Napa River levee/floodwalls, leaking through floodwalls, and overtopping onto parts of Ingersoll Tract to sheet flow across Milton Road.

2.7.1 County Code Building Requirements

In addition to the existing levees and stormwater pump station, which provide flood protection by blocking and removing water, the Napa County Code specifies building requirements for structures' elevation and floodproofing. These requirements limit damages by making structures more resilient when floodwater reaches the structures.

The County Code's floodplain management Section 16.04 governs new construction, and substantial improvement[1] of any structure within a FEMA Special Flood Hazard Area. All of EIIT falls within this FEMA designation. In these areas, the lowest floor must be elevated to at least the base flood elevation (BFE) plus one foot of freeboard. The lowest floor refers to habitable areas and does not include garage, storage, or access areas. This requirement has been adopted for County-wide compliance with FEMA's National Flood Insurance Program. The base flood elevation plus freeboard is also referred to as the design flood elevation (DFE) in this report.

As discussed in Section 2.3, while there are some variations in the BFE along the Napa River, this study recommends applying a uniform BFE of 11 ft NAVD throughout EIIT, thereby yielding a uniform DFE of 12 ft NAVD for all houses' lowest floors.

In addition to this elevation requirement for the lowest floor, the Code requires that construction methods and materials shall be used that reduce the potential for flood damage. This practice is generally referred to as 'floodproofing'. For residences, this must be 'wet' floodproofing, meaning that the lower walls of the structure cannot be used to block water from entering the structure. Instead, walls below the BFE need to have openings that allow water through, so water pressure does not build up and threaten the structure. In addition, utilities such as propane storage tanks, electrical, heating, cooling, and plumbing need to be designed and installed to be above or to be tolerant of inundation. Specifications to meet these requirements are detailed in ASCE (2014).

Since these County Code requirements for elevation and floodproofing are triggered by new or substantial improvement, pre-existing conditions do not need to meet the Code until the improvement trigger occurs and a floodplain development permit is required.

(a) Implications for Sea-level Rise

Sea-level rise will cause the flood water levels to increase, since flood water levels at EIIT are strongly determined by the Bay. Even though many houses on EIIT have elevated lowest floors that currently meet the County Code, as these houses are improved and/or replaced in the 21st

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[1] 'Substantial improvement' is defined in the County Code as any reconstruction, rehabilitation, or additions equal to or greater than half the structure's market value that occurs cumulatively over a ten-year period. If a structure is substantially damaged, such that restoring the structure to its prior condition would cost at least half of the structure's market value, then the repairs are also considered substantial improvement even if not all of the original structure is repaired.

century, they will need to have their lowest floor further elevated as sea-level rise causes the BFE to increase. The need to elevate the lowest floor will be triggered when a homeowner applies for a County floodplain development permit. Although a homeowner could delay applying for a floodplain development permit by not undertaking new construction or making any substantial improvements, delays could probably not be sustained through 2100. Over this time period, the likelihood that a house will be sold to a homeowner who is willing to elevate the house increases. Or, particularly if future flood management is not implemented to address sea-level rise, the frequency and intensity of flooding will increase to the point that houses that are not elevated will incur substantial damages. Substantially damages also trigger a floodplain development permit and therefore, the need to elevate and floodproof.

For a typical EIIT house, the estimated cost to elevate the lowest floor and the rest of the structure above is approximately $67,000. Floodproofing, which would likely be done at the same time as increasing the elevation, is estimated to cost $33,000. The total cost of $100,000 (in 2018 dollars; see Appendix E) is assumed to be borne by each homeowner at some point in the coming five decades as sea-level rise elevates the BFE. This estimate is intended as an average across all houses; actual costs will vary per parcel. From time to time, FEMA offers grants for properties that qualify for structure elevation. To avoid the need for elevating the house multiple times, an increase of three or four feet above the present day BFE is recommended.

3. FLOOD MANAGEMENT PLANS

As documented in the previous section, Edgerly Island and Ingersoll Tract (EIIT) currently face substantial flood hazards and will see increasing flood hazard with sea-level rise. To address these existing and growing hazards, this section describes the development and evaluation of flood management plans to address this hazard.

To guide the development of these plans, a set of evaluation criteria (Section 3.1) were established to articulate this study's overall goal and objectives. With these evaluation criteria in mind, and with an understanding of the project area, flood management strategies were considered as they relate to EIIT (Section 3.2). A broad set of flood management measures were developed for conditions at EIIT (Section 3.3). An initial screening of the measures indicated that some measures were not consistent with the study's objectives and were therefore dropped from further consideration. The remaining measures were then combined into three flood management plans with increasing levels of flood risk reduction and cost (Section 3.4). Finally, Section 3.5 summarizes and interprets the plans' evaluations to compare the benefits and tradeoffs of different flood management plans.

3.1 Evaluation Criteria

To evaluate flood management measures and plans, this study uses criteria to evaluate the degree to which the measures and plans achieve the plan objectives (Section 1). These criteria provide multiple perspectives to assess the measures and plans for completeness, effectiveness, efficiency, and acceptability. The following criteria were used for evaluating and selecting flood management measures and plans.

(a) Time Horizon and Sea-level Rise

Plan implementation and performance is considered from present day to 2100. A key aspect of this time horizon is the associated rate of sea-level rise, since sea-level rise will increase flood hazard. As described in Section 2.4, the assumed rate of sea-level rise by 2100 is three feet . This amount of sea-level rise could occur sooner or later, which would prompt adjustments to the schedule for implementing flood management measures. Sea-level above three feet is likely by 2150, so the plans' performance for five feet is assessed qualitatively.

(b) Flood Hazard Reduction

The fundamental criteria for flood management is the capacity of a measure or plan to reduce flood hazard to assets in the project area. The extent to which measures reduce flood hazard can usually be characterized by one or more of the following:

- Design flood elevation (DFE) of barrier or structure relative to the water level elevations for a range of flood events, including the 100-year event (FEMA and County's 'base flood elevation' or BFE), the 10-year event, and the 1-year event. If the DFE exceeds a flood event's water level, this buffer is known as 'freeboard'. Specific DFE values are provided below.

- Adaptive capacity for a measure to be improved beyond its initial configuration to response to additional sea-level rise. This criterion differentiates between measures that may otherwise be similar, but one can be more readily improved to provide protection for higher flood levels.

- Seepage cut-off – In addition to being overtopped by water, levees and floodwalls can also fail when water seeps through or under their core rapidly enough to erode levee material (Section 2.5.2). Therefore, barriers which cut-off seepage with impermeable layers, such as compacted clay or sheet pile, provide additional flood hazard reduction as compared to a similar barrier which may be susceptible to seepage.

- Engineering specifications – Measures provide greater flood hazard reduction when they are constructed or improved to meet engineering specifications that result in durable and robust conditions. Meeting these specifications means that measures are less likely to be damaged during flood events or deteriorate over time. Measures are evaluated relative to existing engineering standards, such as U.S. Army Corps of Engineers (2000) for levees and ASCE (2014) for structures. In addition, project-specific assessments of soil settlement and structural loading were made by the project team's geotechnical and structural engineers.

For Napa River, analyses of 100-year water levels range from 11.1 ft to 11.4 ft NAVD (Table 1). By convention, FEMA base flood elevation (BFE) is rounded to nearest foot, so on the Napa River, along the east EIIT levees, the BFE is 11 ft NAVD. For this study, 1.5 feet of freeboard is added to the BFE to arrive at the flood barrier DFE of 12.5 ft NAVD for existing conditions. Previously, Bracewell (1984) estimated the 100-year water level to be 8.8 ft NGVD (the prior vertical datum – see Section 2.1), and then recommended 1.0 ft of freeboard, for a DFE of 9.8 ft NGVD. When eyebolts were installed as levee crest elevation targets, the selected elevation was rounded up to 10 ft NGVD, effectively raising the freeboard to 1.2 ft. To account for slight variations in the 100-year water level estimates of a few tenths of a foot (Table 1), and to maintain a DFE at least as high as the previous one from Bracewell (1984), this study recommends 1.5 ft of freeboard for flood barriers. This is still below the minimum 2.0 ft of freeboard required for FEMA accreditation.

This DFE for existing conditions is assumed to pace sea-level rise, resulting in the DFEs listed in Table 4 for future flood barrier crest elevations. As noted in Section 2.7.1, the existing County Code specifies the DFE for the lowest floor of structures to be 1.0 ft above the BFE.

Table 4 Design flood elevations (DFE) for flood barriers on EIIT, including sea-level rise

Sea-level rise Projected year	EIIT DFE
0 ft sea-level rise 2020	12.5 ft NAVD
1 ft sea-level rise 2040	13.5 ft NAVD
2 ft sea-level rise 2060	14.5 ft NAVD
3 ft sea-level rise 2090	15.5 ft NAVD

For some measures, such as flood preparedness planning, the reduction in flood hazard can be harder to quantify, and their flood management contributions are based more on past experience and guidance.

(c) Environmental Impacts

Important criteria when constructing large physical flood barriers are their environmental impacts, which must be described and mitigated through the California Environmental Quality Act (CEQA) and regulatory agency permitting process. For flood management measures, the most consequential impacts are likely to be long-term damage or infill of wetlands. For instances when a measure cannot avoid these impacts, offsetting mitigation would be required by the permitting agencies, at an additional cost to the project. While jurisdictional delineation of wetlands is not in the scope of this study, initial consideration of potential wetlands impacts has been considered and barrier designs seek to minimize impacts.

(d) Community Coordination

Flooding does not stop at parcel boundaries. Flood waters need only overtop, or even breach a levee on just one parcel to cause problems throughout the community. And even if individual houses have floodproofing, when community infrastructure, such as Milton Road or the wastewater treatment plant, becomes inundated, the entire community can be affected.

Because of these shared hazards, many flood management measures need to be coordinated at the community level. For purposes of this study, community coordination refers to the efforts within the EIIT community to manage flood hazards. This coordination offers potential cost benefits, through economies of scale, particularly for measures that require heavy equipment and costly materials. In addition, community coordination is necessary to pursue many grants and to access other government agency funding. These efforts to work with entities outside of EIIT is referred to as ‘community collaboration’.

The anticipated lead entity for community collaboration and coordination is NRRD, with potential support from other agencies. Institutional roles and responsibilities for implementing a flood management plan requires more exploration. To implement and maintain flood measures on the private parcels that line the EIIT east levees, as well as perhaps the agency-owned land along the west side will require right-of-way easements. Community coordination can also occur with reduced involvement by NRRD. For example, NRRD already recommends guidance for the east side levees’ crest elevation. This recommended guidance could be updated and expanded by NRRD, but left to individual homeowners to implement. Similarly, NRRD could facilitate individual measures, such as floodproofing individual house, that are implemented by homeowners.

(e) Aesthetics and Access

Aesthetics and access affect the way in which EIIT homeowners, residents, and visitors experience EIIT and its adjacent open space. Since flood management includes changes to the levee which separate properties from the shoreline, several measures have the potential to affect aesthetic values such as views from houses of the river and access to the homeowners’ boat docks on Napa River.

(f) Cost

While additional flood management can provide definite public benefits, the cost to achieve these benefits is an important consideration, particularly for a small community like EIIT.

For this study, opinion of probable implementation costs (“cost estimate”) were developed for the flood management plans, based on the conceptual-level flood management measures. In addition to construction itself, the cost estimates also include related soft costs for engineering, design, and permitting. To account for uncertainties surrounding these costs, the estimates assumes a 25% contingency. The cost estimates include mitigation for environmental impacts, but do not include right-of-way easements, or floodproofing privately-owned houses. The cost estimates made for this study are rough order of magnitude estimates in 2018 dollars and have an anticipated accuracy range of +50%/-30%. Further design efforts are needed to reduce uncertainties and improve the accuracy of the cost estimate. In addition, potential changes in the County building codes, floodplain management code, and other design specifications may occur by the time the permits are applied for and the flood management measures are implemented. These changes could result in additional costs for permitting and upgrading to bring buildings, docks, and other accessories into compliance if they are temporarily removed, replaced, and/or repaired.

Additional details about the assumptions made to estimate probable costs can be found in Appendix E.

3.2 Flood Management Strategies

To respond to flood management along the shoreline, particularly in areas exposed to growing threat of sea-level rise, the California Coastal Commission (2015) suggests three flood management strategies to address flooding: protect, accommodate, and retreat. These adaptive management strategies were interpreted for EIIT as follows:

- **Protect** – Protection strategies use physical barriers to defend the perimeter of developed neighborhoods in their current location with minimal changes to the neighborhood interior. Protection strategies can be further divided into “hard” engineered barriers, such as levees and floodwalls, and “soft” natural infrastructure such as beaches and wetlands.

  Within the developed project area, the houses and infrastructure along Milton Road, few, if any, “soft” armoring measures can be implemented, particularly given the space constraints of this narrow strip of land, and the proximity of the Napa River on the east side. To the west of the project area, publicly-owned open space, mostly consisting of managed wetlands, may offer “soft” armoring such as fronting levees with gently sloping habitat transition zones. However, consideration of possible soft measures has been deferred pending more detailed long-term planning by the NCFCWCD for the dredge spoil areas and by CFDW for its managed wetlands. Currently, both these agencies only have plans to maintain these areas in their present state.

  Protective barriers considered for the project area’s perimeter therefore consist of earthen levees and floodwalls along the east and west sides of the project area. These physical barriers can be implemented either by initially constructing as high as possible; or in an adaptive manner, by starting at elevations appropriate for existing conditions while providing capacity to make future upgrades in response to sea-level rise. For example, the initial barrier may be a lower sheet pile floodwall that can then be raised in the future with a concrete cap. Or a levee may be initially constructed with its base wider than necessary for its initial elevation, to facilitate future increases in crest elevation.

- **Accommodate** – This strategy does not prevent water from entering the project area; instead, this strategy consists of modifying structures and practices to tolerate inundation with less damage, thereby increasing resilience and speeding recovery. For instance, accommodation includes floodproofing of both houses and community infrastructure to reduce the forces during flooding, to better resist these forces and inundation, and to lift critical components that cannot tolerate wetting above flood levels. In addition, this strategy includes improving a community’s flood preparedness practices, such as maintenance, flood event procedures, and recovery planning.

- **Retreat** – This strategy re-locates or removes assets from the affected area, thereby limiting their exposure. This can be achieved at the planning level by re-zoning or limiting development in floodplains. Acquisition and buy-out programs, transfer-of-development-rights programs, and removal of structures where the right to protection was waived (i.e., via permit condition) are examples of measures designed to encourage managed retreat. Though further consideration of this strategy may be warranted for sea-level rise beyond three feet, this strategy is not consistent with the community’s preference to remain at EIIT.

3.3 Flood Management Measures

This section provides descriptions of flood management measures, tailored for EIIT, which follow from the evaluation criteria and adaptation strategies discussed above and are the components of the plans below. The measures are grouped into three types: flood barriers to physically block inundation, floodproofing to reduce damages to inundated structures, and flood preparedness to coordinate community planning, maintenance, flood event procedures, and recovery.

3.3.1 Flood Barriers

Flood barriers consist of impermeable structures designed to physically block or impede flooding before water reaches assets. For purposes of this study, barriers refer to structures capable of providing significant levels of protection on a EIIT-wide scale. Other types of local floodwalls, such as low ones around a single structure, are considered in the next group of measures, floodproofing. At EIIT, physical flood barriers considered include the following:

- <u>Earthen levees</u> – These barriers consist of compacted sediment, composed primarily of clay and mud. To be considered levees, features that provide reliable flood protection, they need to be comprised of suitable material that is compacted and shaped to resist seepage, hydraulic forces, slope failure, and seismic events. When levees are not constructed to resist seepage, as is the case for portions of the EIIT levees, the levees can be re-constructed or sheet pile flood walls can be embedded with the levees to address this vulnerability. Particularly when suitable materials are available, levees are typically less expensive than other barriers to construct, but they also require greater amounts of space. If levee improvements intrude into existing wetlands, then the impacts of filling wetlands will need to be offset with mitigation. These mitigation costs can be significantly increase the cost of levees. Because existing houses and the Napa River wetlands severely limit available space along the east levee, a larger levee is not recommended for this portion of the EIIT perimeter.

  The weight of levees causes the underlying soil to consolidate and settle, a slow process that can take a decade or so. For this reason, levees are usually constructed in stages, with layers of limited thickness constructed in each stage, and each stage allowed to settle for 10-15 years before the next layer is constructed. When space is available and time allotted for settlement, this staged construction means that levees have adaptive capacity to be incrementally raised to pace sea-level rise.

- <u>Sheet pile floodwalls</u> – Either made from steel or vinyl, these floodwalls are assembled from individual sections that are interlocked as they are driven into the ground. Although typically more expensive than levees, sheet pile floodwalls may be preferable when lack of space precludes levees. Most of the sheet pile is embedded in the ground, to provide both an impervious layer blocking seepage and structural support for the portion above ground. The maximum achievable height of the floodwall above ground depends on the embedded depth and also the floodwall's material. Vinyl sheet pile has less strength than steel sheet pile, so while vinyl sheet pile floodwalls can be up to four feet high, steel sheet pile floodwalls or steel sheet pile floodwalls supporting a concrete cap, can be up to seven feet high. As a result, vinyl sheet pile floodwalls have limited capacity to adapt to sea-level rise. To raise vinyl sheet pile floodwalls as high as seven feet would require significant steel re-enforcement, which would likely cost as much or more than steel sheet pile floodwalls.

Because of the existing east levee is hemmed in by houses on one side and the Napa River on the other side, sheet pile floodwalls are the preferred measure for the east side of the project area. Installing sheet pile floodwalls high enough to protect against three feet of sea-level rise would impact views from houses, which typically have views across the existing levee crest elevation. To avoid impairing views before three feet of sea-level rise has occurred, the proposed steel sheet pile floodwall would be first installed to address existing flood levels and then a concrete cap would be added in the future, once sea-level rise approaches two feet and settlement reduces the elevation of the original wall. Houses would likely be raised as part of floodproofing (see below), thereby offsetting views impaired by higher floodwalls. To further offset impaired views, homeowners could, for an extra cost, choose to replace some or all of the concrete cap with translucent glass panels to preserve views (Figure 12). Access to docks can be maintained with low stairs overtop the floodwall, openings in the flood wall that are sealed during flood events, or both.

Sheet pile floodwalls also have application for the west side. In areas with limited space because of development and wetlands, floodwalls can be used to raise the flood barrier crest elevation while limiting impacts to adjacent land uses. In addition, sheet pile can cut off seepage risk through the west side embankments.

(a) Flood Barriers No Longer Considered for Flood Management Plans

In addition to the recommended flood barriers described above, several other flood barriers approaches were considered as possible measures for EIIT. However, based on these barriers' characteristics relative to the EIIT evaluation criteria, these measures were deemed to be not appropriate for EIIT and are not recommended for the plans. The following sections describe these flood barriers and explain the reasons for excluding them from the flood management plans.

a. Fill Entire Project Area

Filling the entire project area to the DFE would convert the entire project area into a flood barrier, with all the houses and community infrastructure also raised to sit on top the barrier. While this approach would offer excellent flood risk reduction since all assets would be above flood waters, the scale of the effort is considered infeasible due to costs and disruption to the community.

Assuming the site is raised to 15.5 ft NAVD, the DFE for three feet of sea-level rise, the added fill would be approximately 9 ft thick on Ingersoll Tract and 14 ft thick on the more subsided

Edgerly Island. This fill thickness, applied across the project area, would require locating, purchasing, transporting, and placing over one million cubic yards of fill. In addition to this fill, this approach would also include substantial costs for elevating and re-positioning all the houses and community infrastructure to the top of the fill. Assuming typical costs for purchasing and transporting the fill, this measure would likely cost on the order of $150 million. Even if a lower-cost source, such as dredging spoils, was identified, the handling and placement of this much fill would entail construction costs on the order of $75 million, considerably larger than flood barriers just around the project area perimeter.

Placing this much fill would place considerable stress on the underlying soils, and potentially cause slope stability failure. To avoid this type of failure would require placement in layers, with time for settlement between layers, and/or costly geotechnical interventions. The time for settlement can be several years to a decade or more. During this waiting time, it would be difficult to accommodate houses and community infrastructure because the settlement would affect their foundations. And if multiple fill layers are used, the entire set of houses and community infrastructure would need to be elevated multiple times to respond to each new fill layer. This would mean the construction phase would last more than a decade and be disruptive to the community throughout.

b. FEMA-Accredited Barriers

The flood barriers’ design specifications for flood hazard reduction (Section 3.1(b)) could be made more rigorous to meet FEMA-accreditation standards. FEMA standards further reduce flood risk by imposing higher freeboard and geotechnical standards. However, meeting these higher standards would raise costs as compared to the most expensive plan already being considered, Plan 3 (Section 3.4.3). Based on unit costs for constructing a FEMA-accredited levee north of San Jose (USACE, 2015), which is located in similar setting adjacent to managed wetlands, a FEMA-accredited levee for the EIIT could cost approximately $100 million. Since the costs are the most expensive plan would already significantly burden the community, even greater expense to achieve FEMA accreditation is thought to be infeasible.

Steel sheet pile floodwall added to the levee is probably close to meeting FEMA accreditation standards and is one of the approaches considered for the project area. The floodwall’s initial crest elevation would need to be raised to at least 13 ft NAVD since FEMA accreditation requires freeboard of at least two feet, higher than the proposed one foot of freeboard. At some of the more wave-exposed portions of south Edgerly Island, the crest elevation may need to be higher than 13 ft NAVD. The sheet pile would likely meet FEMA seepage requirements. A more detailed geotechnical study would be needed to assess if the levees also meets FEMA slope stability requirements.

With FEMA accreditation, EIIT would no longer be mapped into the Special Flood Hazard Area floodplain, so homeowners would no longer be required to purchase flood insurance if their mortgage is backed by federally-sponsored lender (which is typical for most mortgages). The cost of these insurance premiums could be re-directed towards funding the flood barriers. Also, homeowners would also no longer be required to raise their lowest floors to one foot above the BFE. However, these benefits would be hard to preserve once sea-level rise exceeds two feet. After this much sea-level rise, an improved floodwall crest elevation of 15.5 ft NAVD would no longer provide sufficient freeboard to meet the accreditation standards. Raising the floodwalls much beyond 15.5 ft NAVD would challenging, since the protruding floodwalls would likely require additional structural re-enforcement.

c. Concrete Floodwalls on Levee Crests

Constructing concrete floodwalls along levee crests is not recommended at the project site, as these floodwalls have been shown to be deficient at EIIT in several ways. Because a concrete wall does not extend into the levee itself, it cannot reduce seepage through the levee. In addition, the concrete wall's weight can cause additional settlement; in some places at EIIT, concrete floodwalls have settled almost two feet.

These two deficiencies with regards to seepage and settlement apply to all concrete floodwalls, even if they are adequately designed and built for structural competence. Floodwalls constructed out of concrete masonry units (CMU or 'concrete blocks') are deficient in a third way. Unless adequately designed and constructed with structural re-enforcement and a foundation, these masonry walls have limited capacity to resist the force of flood water pressing on them. In addition, they are more susceptible to cracking and seepage due to settlement or earthquake. Several existing concrete masonry walls at EIIT leaked during flood events.

3.3.2 Floodproofing

Floodproofing refers to modifications to a structure that reduce impacts from flood waters that reach the structure. These measures make structures more resilient to damage and speed recovery. Elevation to one foot above the BFE and floodproofing to design standards is already part of the County Code's floodplain management chapter (Section 2.7.1). Additional guidance and design specifications for floodproofing can be found in FEMA (2012) and ASCE (2014), respectively. For this study's plans, three floodproofing methods are considered: increased elevation, wet floodproofing, and dry floodproofing:

- Increased Elevation: This method raises an entire structure. At its new elevation, the lowest floor for living space (as opposed to parking, access, or storage space) is at or above the DFE. In this study, the likely method for elevation is to raise the building on pile foundations (or equivalent). Elevation can be part of a new structure's original design, or added to an existing structure. Existing structures are elevated by separating the upper portion from the foundation, raising it with hydraulic jacks, and temporarily supporting the structure while a new or extended foundation is constructed. In some cases, raising a house's lowest floor may incur additional costs to meet other aspects of County Code or to address issues with the building's foundation.

- Wet Floodproofing: Wet floodproofing measures are applied to a building and/or its contents to reduce flood damage by allowing floodwaters to safely enter the structure and elevating or protecting water-sensitive components. Water can safely enter a structure by installing wall openings, thereby interior and exterior water levels to equalize. This equalization reduces the force of water on the walls, floors, and other structural supports. For components within a structure, measures may include the use of flood-resistant components, and/or their re-location and modification to limit damage. Wet floodproofing should be applied to both residential and community infrastructure (Section 2.6).

- Dry Floodproofing: Dry floodproofing measures lower the potential for flood damage by reducing the likelihood that floodwaters enter the structure. Examples include waterproof wall membranes, low-elevation perimeter floodwalls, and watertight doors. Dry floodproofing should be only considered in limited instances and only for short-term flooding. Because dry floodproofing relies on the structure itself to withstand water's hydrostatic, impact, buoyancy, and drag forces, a structural engineer should always evaluate the structure's capacity to resist these loads. These loads may cause the failure of a wall system during a flooding event, resulting in significant structural damage. Dry floodproofing is not allowed by County Code for residential structures, but can be used for community structures such as the wastewater treatment plant buildings.

While floodproofing private houses is already the responsibility of individual homeowners, as described in Section 2.7.1, floodproofing community infrastructure would be a community responsibility led by NRRD in coordination with other infrastructure owners. The floodproofing for specific community infrastructure facilities are summarized in Table 5. Additional details regarding best practices for protecting the utilities that serve these infrastructure elements can be found in FEMA (2017).

Table 5 Floodproofing measures for community infrastructure

Infrastructure Element (Owner)	Recommended Floodproofing
Edgerly Island Fire Station (NRRD)	Wet floodproofing for all utilities, to Flood Design Class 4 for emergency services.
Edgerly Island Drinking Water Pump House (Meyers Water Company)	Wet floodproofing of electrical and electro-mechanical components by increasing elevation and/or designing for submergence. Bracing and anchoring for storage tanks.
Edgerly Island Stormwater Pump Station (NRRD)	Wet floodproofing of electrical and electro-mechanical components by increasing elevation and/or designing for submergence.
Wastewater Treatment Plant and Ponds (NRRD)	Higher elevations of buildings and treatment facilities and location on west side indicate that floodproofing could be delayed until sea-level rise approaches two feet. If west levee improvements are included in plan, consider alignment for the improved west levee that protects treatment plant buildings. If buildings remain outboard of levee, wet and/or dry floodproof buildings and utilities. Depending on vulnerability to overtopping and long-term management of NCFCWCD dredge spoil areas, low wall may be needed around holding ponds for two or more feet of sea-level rise
Sewage Pump and System (NRRD)	Coordinate floodproofing of building collection systems and laterals with homeowners. Raise electrical boxes on relay pump stations.
Ingersoll Drinking Water Pump House (Milton Rd. Water Company)	Wet floodproofing of electrical and electro-mechanical components by increasing elevation and designing for submergence. Bracing and anchoring for storage tanks.
Ingersoll Tract Culvert and Tide Gate (Napa County)	Since these structures already tolerate inundation, no floodproofing of the structures themselves is needed. As sea-level rise results in persistent increase in river water levels, drainage of the low-lying lands west of Milton Road will become increasingly poor, and tide gate drainage capacity should be monitored.
Milton Road (Napa County)	Assume levee improvements, including new levee west of roadway on Ingersoll Tract, provides flood protection. As sea-level rise approaches two feet, flood gates or similar barrier augmentation would likely be needed where roadway crosses the railroad tracks.

3.3.3 Flood Preparedness and Planning

Flood preparedness refers to a group of improvement measures that maintain flood management infrastructure, improve response during an emergency, and promote faster recovery after a flood event. In addition, planning measures include assessing implementation needs and process, as well as design standards and implementation guidance. Flood preparedness is relatively low-cost and effective risk reduction measure and can also encourage community coordination. Much of this work can be done without additional right-of-way easements required for other plans. For these reasons, these measures are recommended at the start of all the plans. Flood preparedness and planning consists of the following:

- <u>Flood Management System Inspection and Maintenance</u> – Physical flood management measures, such as EIIT's levees, floodwalls, drainage ditches, and pump station, are vulnerable to deterioration and potential failure through natural processes. For example, levee breaches have occurred at the site and can dramatically worsen flooding (see Section 2.2) and drainage ditches need to be clear of debris to provide adequate conveyance. Levees are subject to potential failure from several factors, including overtopping, scour, seepage, and earthquake damage (Figure 10). Therefore, specifications for the system's measures should be developed, in accordance with the preferred overall flood management plan. The flood management measures should then be inspected to confirm they are meeting these specifications. The inspections should be intermittent during normal conditions and intensive in response to flood and earthquake events. Inspections indicate maintenance needs, as well as deterioration that requires repairs before failure occurs. Because significant portions of the east levee along the Napa River lie on private property, the conditions for inspection and maintenance access should be evaluated (see below). In addition, to fund these efforts, a levee repair fund is proposed to assist property owners with improving their privately-owned levee sections. A part-time NRRD Levee Coordinator is also proposed to facilitate levee maintenance and improvements, pursue grant opportunities, and facilitate collaboration between the EIIT community and outside entities.

- <u>Flood Event Safety Plan</u> – This plan would provide readily available and site-specific operations and procedures to respond to a flood event in a coordinated and effective manner, as well as the preparatory organizing and training which support this plan. Preparedness activities and measures can include monitoring for flood events, communication with the public and operations personnel, training and equipping of emergency response teams, drills and community outreach efforts, levee patrols, and evacuation procedures. To mitigate the impact of a flood event, the plan also includes response protocols for emergency services and emergency contractor support. The plan would also describe recovery steps to return the project area to habitable conditions. Recovery activities are concerned with issues and decisions that should be made after immediate response needs have been addressed. Recovery typically begins after the flood peak has subsided, but some recovery activities may be concurrent with response efforts. This phase may entail permanent repairs to the flood management system, draining floodwaters, debris removal, and support for repairs of damage structures. Flood safety planning should also be formally integrated with community collaborators by inclusion in the Napa County Operational Area Hazard Mitigation Plan (Napa Operational Area Planning Committee, 2013).

- Institutional Implementation Approach – Implementing many of the flood management measures requires community coordination for funding, decision-making, policy enforcement, securing right-of-way easements, and collaborating with partners outside of the EIIT community. This study would clarify and develop the approach for NRRD and the County to implement flood management measures from an institutional perspective, as compared to the engineering perspective that this report focuses on. While NRRD could explore taking the lead for construction of new measures, the County can play a supporting role through its responsibility for floodplain management, coordinating across departments, such as the NCFCWCD and the Planning Division.

- Design Standards and Implementation Guidance – One of the plans proposes that individual homeowners implementing floodwalls on their own. This measure would facilitate this individual implementation by recommending design standards and implementation guidance for measures that meet NRRD objectives.

3.3.4 Residual Risk

Residual risk refers to the remaining potential for flooding and damages after the flood management measures are taken into account. The residual risk is reduced by more extensive and effective flood management measures. However, some nonzero amount of residual flood risk will always remain. Depending on homeowners' level of comfort with the residual risk and requirements from others (e.g. mortgage lenders), homeowners may decide to insure themselves against the residual risk. Self-insurance is one option, but external flood insurance is the most common way of distributing risk. Some fraction of the risk burden is carried by an underwriter (public or private), against a fee, annual premium, or retroactive property title instrument charge to each homeowner. The most common insurance underwriter is the federal government, through FEMA's National Flood Insurance Program. Some private companies also offer flood insurance.

3.4 Flood Management Plans

In response to the physical setting at EIIT, engineering assessments, and discussions with the project advisory team and community, three proposed flood management plans were selected for further consideration. These plans are comprised of different combinations of the flood management measures described above. Compared to the existing flood management at EIIT (Section 2.7), these plans provide increasing levels of flood protection with a corresponding increase in costs. For each plan, this section provides a succinct description of its measures, performance assessment, estimated costs, and timeline.

3.4.1 Plan 1: Flood Preparedness and Planning

(a) Description

Plan 1: Flood Preparedness and Planning, only requires maintaining the existing flood barriers in their current state, with efforts to encourage individual homeowner improvements to the Napa River levee. In anticipation of sea-level rise, homeowners are also encouraged to increase house elevations and wet floodproof to higher elevations than the minimum required by existing County Code. This plan also includes floodproofing for all community infrastructure. The plan does not rely on NRRD procuring right-of-way easement for the east levee, but does propose developing an institution implementation approach to explore an expanded role for the NRRD and County. Flood preparedness plans as well as design standards and implementation guidance for homeowner levee improvements round out the plan. The measures are shown in Figure 13.

- Flood Barriers
  - This plan does not include any community-level efforts to improve or construct flood barriers.
  - Installation of floodwalls and, to the extent feasible, additional earthen fill, along the Napa River may still be implemented by each individual homeowner, preferably in accordance with design guidance provided by NRRD. NRRD should encourage these upgrades via outreach, education, design standards, and implementation guidance, part of the preparedness measures below.
  - If homeowners do not improve the east levee, sea-level rise will cause overtopping events to become more frequent, and this overtopping will expose the levees to potential erosion and breaching. As a privately-owned facility within the floodplain, maintenance and repair of the levee would be the responsibility of the homeowners. The County and NRRD should ensure that each homeowner understands and complies with minimum construction materials and methods specified by the County Code.
- Floodproofing
  - Community infrastructure would be floodproofed, improving these shared assets' resilience to flooding. NRRD will implement floodproofing for community infrastructure it owns, as listed in Section 2.6. NRRD will collaborate with owners of other infrastructure who would be relied upon by the community should do the same. The target elevation for lowest floor elevation and floodproofing will be the current DFE, 12 ft NAVD, plus three feet accommodation for sea-level rise.
  - Increased elevation of houses' lowest floor to the DFE of one foot above the BFE and wet floodproofing is strongly encouraged for all houses that do not meet the existing County Code and required when a homeowner applies for a floodplain development

permit. Particularly with sea-level rise causing flood water levels to increase, this plan's guidance is to further increase elevation beyond the current minimum by three or more feet. Beyond meeting minimum requirements when a floodplain development permit is required, NRRD and the County would be limited to encouragement via education and outreach.

- Flood Preparedness and Planning
  - This plan includes the preparedness measures for maintenance, flood event planning, and institutional implementation approach that are described in Section 3.3.3.
  - Design standards and implementation guidance as described in Section 3.3.3 would encourage homeowners to undertake flood barrier measures on their own, by reducing permitting effort and cost for individuals.
- Residual Risk
  - Since this plan does not include any required flood barrier upgrades, the existing flood risk would increase with sea-level rise. This acceptance and acknowledgement of the increasing risk should be clearly communicated to all homeowners so they can best manage the increasing residual risk on their own.
  - Risk would be externalized through flood insurance with the National Flood Insurance Program (NFIP) or other private insurers. If properties face repetitive losses, they may have to make building improvements or face higher premiums.

(b) Schedule

The proposed schedule for implementing the measures included in this plan is shown in Figure 14. Implementation of some measures are dependent upon an amount of sea-level rise; if the projected time for this sea-level rise trigger shifts from the assumed sea-level rise at the top of the schedule, then the measure's implementation time scenario would shift accordingly. The rationale for specific measures is as follows:

- The flood preparedness measures should all be completed at the start of plan implementation since these measures offer immediate benefits for existing flood risk. The assessment of institutional implementation, design standards, and implementation guidance are also scheduled in the first decade since other measures are supported by these steps. The flood management system inspection and maintenance, as well as the flood event safety planning would be ongoing annual expenses.
- Since no improvement to flood barriers are required, residential elevation and floodproofing should be accelerated relative to the other plans, with a target completion in the next two

decades, by the time sea-level rise reaches one foot and levee overtopping becomes more likely.

- Floodproofing for existing community infrastructure below elevation of 8 ft NAVD should be implemented in the plan's first two decades. For the wastewater treatment plant facilities above 8 ft NAVD, suggested implementation can be deferred to until two feet of sea-level rise is anticipated, approximately 2060.

(c) Costs

The community costs for this plan are estimated to be $3,500,000, as summarized in Table 6 and broken out in more detail in Table 7 for community infrastructure floodproofing and in Table 8 for preparedness and planning measures. For additional cost estimate details, see Appendix E. All of the costs are rough order of magnitude, and have an anticipated accuracy range +50% to -30%. The timing of these expenditures are shown cumulatively on Figure 14.

Because no large-scale barrier upgrades are proposed, mitigation costs are not anticipated to be significant. Some homeowners may decide to install vinyl sheet pile floodwall, which is unlikely to incur significant long-term wetland impacts if the floodwall is embedded in the existing levee.

Table 6 Summary of costs for Plan 1: Flood Preparedness and Planning

Plan Components	Cost
Flood barriers	
West side	n/a
East side	n/a
Floodproofing	
Community infrastructure	$1,190,000
Flood Preparedness and Planning	
Flood management system inspection and maintenance	$1,860,000
Flood event safety plan	$125,000
Institutional implementation approach	$180,000
Design standards and implementation guidance	$150,000
Mitigation	n/a
TOTAL	**$3,500,000**

Table 7. Summary of community infrastructure costs for Plan 1: Flood Preparedness and Planning

Infrastructure Component (Owner)	Cost
Edgerly Island Fire Station (NRRD)	$137,000
Edgerly Island Drinking Water Pump House (Meyers Water Company)	$48,000
Edgerly Island Stormwater Pump Station (NRRD)	$34,000
Wastewater Treatment Plant and Ponds (NRRD)	$897,000
Sewage Pump and System (NRRD)	$21,000
Ingersoll Drinking Water Pump House (Milton Rd. Water Company)	$48,000
TOTAL	**$1,190,000**

Table 8. Summary of flood preparedness and planning costs for Plan 1: Flood Preparedness and Planning

Measure	Estimated Cost*
Flood Management System Inspection and Maintenance	
Levee coordinator *Staff position (part-time) to coordinate community efforts to maintain and improve levees, pursue grant opportunities, and advocate for EIIT community ($25,000/year)*	$600,000
Annual inspection and maintenance *Includes pumps, drainage ditches, and levee & floodwalls ($2,000/year)*	$50,000
Operation plan for stormwater pump system *Includes operational details (automatic and manual), inspection guidelines, and personnel assignments*	$10,000
Levee repair fund *Based on inspections, partner and cost-share with landowners to repair and improve sections of levee and floodwalls ($50,000/year)*	$1,200,000
Flood Event Safety Plan	
Local flood event safety plan *Includes procedures for monitoring, communication, flood fighting, evacuation, and recovery*	$50,000
Annual flood awareness training & preparation event *Hosting and materials ($1,000/year)*	$25,000
Integration with Napa County hazard mitigation plan *Clarify roles with County, improve access for state and federal recovery funding*	$50,000
Institutional Implementation Approach	
Facilitated public outreach meetings	$30,000
Legal and economic services	$100,000
Implementation plan	$50,000
Design Standards and Implementation Guidance	
Design standards and implementation guidelines *Including floodwall design criteria, design templates, guidance for floodwall selection, geotechnical assessments, parcel boundary coordination, public outreach meeting, and coordination with County Planning Department*	$150,000
TOTAL	**$1,360,000**

* All annual costs have been convert to net present value assuming 80-year duration and 4% interest rate and then rounded off

(d) Performance Evaluation

Flood Hazard Reduction: This plan would facilitate some flood hazard reduction through preparedness and floodproofing of houses and community infrastructure. Since improvements to flood barriers would only be recommended, the plan would be challenged to achieve continuous improvements for the entire project area perimeter. This plan would likely achieve some slow progress toward reducing flood risk in the first few decades of implementation. Similar to historic flood management, homeowners are more likely to be pro-active about implementing measures on their property, while other homeowners may be only re-active to flood damages when deciding when and how to implement measures. If the lowest points on the levees are not improved, with only a foot of sea-level rise, the site would be subject to overtopping by the 10-year event and with two feet of sea-level, the 1-year event would threaten to overtop the levees.

Adaptive capacity of this plan relies primarily on increased building elevations, floodproofing, and higher tolerance of residual risk. While this adaptation approach would reduce damages to elevated and floodproofed assets, the community would still face more frequent flooding impacts for garages and other ground-level storage, Milton Road, and greater risk for levee breaching due to overtopping and seepage. Choosing this plan does not preclude adding more measures in the future as additional adaption capacity. However, by not starting on the west levee measures which involve fill placement and the associated period for settlement, this plan may add design challenges for future levee improvements that could be needed in a short timeframe.

Environmental Impacts: Since measures to improve barriers are limited, this plan would have relatively low impact. Design standards and guidance to assist homeowners with implementing individual levee improvements would provide the opportunity for developing consistent impact avoidance and consideration of cumulative impacts.

Community Coordination: This plan requires the least amount of community coordination, and leaves much of the measures that alter structures up to individual homeowners. The initial community-wide infrastructure floodproofing and preparedness measures may help build support for broader coordination.

Aesthetics and Access: Homeowners would be able to make their own decisions about aesthetics and access at the parcel scale. However, as the flooding hazard increases with sea-level rise, flood damages would also increase, likely resulting in more frequent and visible damage and repair efforts.

Costs: The overall community costs associated with this plan are considerably lower than the other two plans, since community-funded improvements to flood barriers are not included.

3.4.2 Plan 2: Vinyl Sheet Pile Floodwalls to 12.5 ft NAVD

(a) Description

Plan 2: Vinyl Sheet Pile Floodwalls to 12.5 ft NAVD, is a combination of flood barriers and floodproofing measures (Figure 15). The plan significantly reduces flood risk from the existing flood hazard with vinyl sheet pile floodwalls and west levee improvements, and provides some buffering for the increasing flood risk due to sea-level rise. However, floodwalls constructed with vinyl sheet pile would be at their maximum height at 12.5 ft NAVD, limiting this plan's adaptive capacity as sea-level rise progresses. Therefore, floodproofing and flood preparedness measures would provide additional hazard reduction and adaptive capacity. This plan assumes that NRRD is able to secure funding and right-of-way easements so it can lead implementation for the floodwalls, levee improvements, and community infrastructure floodproofing.

This plan's measures are as follows:

- Flood Barriers
  - Install vinyl sheet pile floodwalls (or an approved equivalent that meets NRRD design specifications) along the Napa River East Levee. The floodwall's crest elevation shall be at least 12.5 ft NAVD, the present day DFE (Table 4). Additionally, the piles' embedment depth shall meet both structural specifications and eliminate seepage, the sheet pile material shall be able to tolerate structural loads from water levels at its crest, and floodwall segments shall joint impermeably at parcel boundaries. NRRD would construct floodwall segments on community-owned parcels. Although constructing the sheet pile floodwall could be left to individual homeowners and verified by NRRD, coordinated implementation for all parcels provides cost savings due to shared design and permitting, construction efficiencies, and simplified floodwall connectivity at parcel boundaries. Since this plan assumes NRRD secures funding and right-of-way easements for the floodwall, it also assumes implementation would be NRRD-led to reap the cost savings of one large project rather than many individual projects.
  - On the west side, the flood barrier improvements would attain the same 12.5 ft NAVD DFE as the east side. West Levee 1, adjacent to the CDFW managed wetlands, can be enlarged with only earth fill while also avoiding wetland impacts by placing the fill on the east side of the levee. Since the middle reach of the west side appears to be deficient in terms of it slope stability and seepage, this portion, West Levee 2, will be improved. The improvement includes excavating, processing to eliminate layers with high seepage, and replacing to compaction and slope stability standards to the levee's existing elevation of approximately 9 ft NAVD. Then vinyl sheet pile floodwall would be embedded in the levee to reach 12.5 ft NAVD. North of the railroad tracks, a new West Levee 3 will be constructed to elevation of 12.5 ft NAVD, offset just west of Milton Road. West Levee 3

  - will need to be constructed in stages to allow for adequate settlement time, at least 10 years between stages.

  - Connect vinyl sheet pile floodwall and levees at their endpoint to provide continuous protection for the Edgerly Island and Ingersoll Tract perimeters. These junctions may consist of physically embedding sheet pile floodwall in the levees. At other locations with limited space, such as the railroad tracks and the service road leading to the wastewater treatment plant, other methods may be required, such as elevating roadways and flood doors for temporary closure during flood events.

  - Encircling Ingersoll Tract with a levee to the west and floodwalls to the east will keep water out, and also detain precipitation, groundwater, and overtopping. For this plan, which primarily addresses existing flood risk, drainage pathways from within Ingersoll are assumed to be similar to existing conditions and to occur via gravity like the existing drainage via the tide gate under Milton Road. However, as sea level rises and tides shift up, the capacity for gravity drainage will decrease and the need for pumping should be monitored and re-evaluated in the future.

- Floodproofing

  - Community infrastructure would be floodproofed, improving these shared assets' resilience to flooding. NRRD will implement floodproofing for all community infrastructure it owns, as listed in Section 2.6. NRRD will collaborate with owners of other infrastructure who would be relied upon by the community should do the same. The target elevation for lowest floor elevation and floodproofing will be the current DFE, 12 ft NAVD, plus an additional three feet accommodation for sea-level rise.

  - Particularly with sea-level rise causing the BFE to increase, this plan's recommendation is to further increase the design elevation for residential lowest floors and floodproofing beyond the current minimum required by the County Code. As part of its assessment of institutional implementation approach (see 'Preparedness and Planning' below), consider increasing the County Code freeboard requirement for lowest floor from one foot to four feet above BFE. If County Code is not modified to increase the freeboard requirement, NRRD and the County would still encourage this additional freeboard via education and outreach.

- Flood Preparedness and Planning

  - This plan includes the preparedness measures for maintenance, flood event planning, and institutional implementation approach that are described in Section 3.3.3.

  - Since all of the implementation of flood barriers would be community led, design standards and implementation guidance to facilitate individual homeowners' implementation of floodwalls not necessary.

- Residual Risk
  - Since this plan upgrades flood barriers to present-day DFE, implementing this plan in the next one-two decades would initially decrease residual risk. With sea-level rise, residual risk would then start to increase, but at a slower rate than without the flood barrier measures. This acceptance and acknowledgement of the increasing risk should be clearly communicated to all homeowners so they can best manage residual risk on their own, primarily by increased elevation and floodproofing.
  - Risk would be externalized through flood insurance with the National Flood Insurance Program (NFIP) or other private insurers. If properties face repetitive losses, they may have to make building improvements or face higher premiums.

(b) Schedule

The proposed schedule for the implementing these measures is shown in Figure 17. Implementation of some measures are dependent upon a sea-level rise trigger; if the projected time for a trigger shifts from the assumed sea-level rise at the top of the schedule, then the measure's implementation time would shift accordingly. The rationale for specific measures is as follows:

- The flood preparedness measures should all be completed at the start of plan implementation since these measures offer immediate benefits for existing flood risk. The assessment of institutional implementation and programmatic permitting are also scheduled at the start since other measures are supported by these steps. The flood management system inspection and maintenance, as well as the flood event safety planning would be ongoing annual expenses.

- The vinyl sheet pile floodwall should be completed by 2030, so it can provide protection once sea-level rise is projected to reach one foot. Otherwise, with one foot of sea-level rise, the project area will face inundation more frequently than the 10-year event.

- Initiate planning effort for construction of new West Levee 3 as soon as practicable, due to the scale of effort, and the decade waiting period between successive soil placements to allow for settlement.

- Because of increase protection provided by the improved floodwalls and levees, residential floodproofing could be implemented over four decades, in conjunction with the houses' ongoing improvements and replacements.

- Floodproofing for existing community infrastructure below elevation of 8 ft NAVD should be implemented in the plan's first two decades. For the wastewater treatment plant facilities above 8 ft NAVD, suggested implementation can be deferred to until two feet of sea-level rise is anticipated, approximately 2060.

(c) Costs

The community costs for this plan are estimated to be $38,300,000, as summarized in Table 9. For additional cost estimate details, see Appendix E. All of the costs are rough order of magnitude, and have an anticipated accuracy range +50% to -30%. The timing of these expenditures are shown cumulatively on Figure 14.

The potential for significant wetlands impacts was considered at a qualitative level, to inform the measures' design. For example, vinyl sheet pile was selected for a portion of the west levee, WL2, to avoid the need to place new fill in the wetlands along the levee's toe.

Table 9 Summary of costs for Plan 2: Vinyl Sheet Pile Floodwalls to 12.5 ft NAVD

Plan Components	Costs
Flood barriers	
West side	$17,400,000
East side	10,200,000
Floodproofing	
Community infrastructure	$1,190,000
Flood Preparedness and Planning	
Flood management system inspection and maintenance	$1,860,000
Flood event safety plan	$125,000
Institutional implementation approach	$180,000
Design standards and implementation guidance	-
Mitigation	$7,300,000
TOTAL	**$38,300,000**

(d) Performance Assessment

Flood Hazard Reduction: By implementing continuous flood barriers around the perimeter of the project area, this plan would substantially improve the current flood protection for the project area. The proposed crest elevation of 12.5 ft NAVD would improve the current flood protection by providing a foot of freeboard above the current 100-year event. In addition, the floodwalls and targeted levee fill improvements would limit seepage inflows and the potential for seepage to cause levee failure.

These improvements would sustain floodwall and levee crest elevations just above the 100-year flood with up to one foot of sea-level rise, but with decreasing freeboard. As sea-level rise progresses, the adaptive capacity to increase the crest elevation of vinyl sheet pile floodwalls would be limited. The vinyl sheet pile floodwall does not have the required structural strength to be raised without costly structural upgrades. These structural upgrades would be comparable in cost to steel sheet pile in Plan 3. For the west levees, the earthen levees could have additional fill added to adapt to sea-level rise. Overall, the flood barriers' adaptive capacity for sea-level rise in excess of one foot is limited. Therefore, raising and floodproofing houses and community infrastructure to pace sea-level rise would continue as an important long-term measure.

Environmental Impacts: By placing most of the proposed construction either within the existing levee footprint or on uplands, potential environmental impacts for the flood barriers can be minimized. In addition, the vinyl sheet pile can be installed with lighter-duty mechanical equipment, thereby reducing construction-period impacts. To provide a continuous line of protection, a continuous floodwall needs to be built along the entire east side of the project area. This footprint intersects with potentially environmentally sensitive areas (for instance, just south of where the railroad tracks cross Milton Road, which includes tidal marsh wetlands). An option to reduce wetlands impacts might be replacing a stretch of floodwall with increased elevation of Milton Road just south of the railroad tracks. On the west side, north of the railroad tracks, where there currently is not flood barrier, the proposed West Levee 3 would likely include some fill of wetlands. The design of this levee to minimize impacts should be evaluated in the next stage of design in concert with more detailed wetland mapping.

Supplying the earth fill to improve West Levee 1 and to build West Levee 3 would likely require substantial trucking along Milton Road during construction. This trucking would increase traffic along Milton Road, potentially causing congestion and roadway damage.

Community Coordination: This plan assumes that NRRD identifies an approach for funding and right-of-way easements so it can implement the east side floodwalls and a community-led effort can implement barrier improvements on the west side. If the entire project area boundary is not protected, individual parcels with substandard flood protection can threaten the entire community. Construction by individual homeowners to meet required specifications is possible, but would incur higher costs.

Aesthetics and Access: Vinyl and other types of floodwalls to approximately 12 ft NAVD are already in place at multiple houses in the project area. So constructing continuous vinyl sheet pile floodwalls to this height would be similar to current conditions on most parcels. Relative to the levee crest, these floodwalls are approximately waist-high, and at most obscure the lower part of views from most houses and backyards. Access to docks require some modifications, either an opening in the floodwall that can be closed during flood events or a few steps over top the floodwall. While the extent of aesthetic and access changes will depend on the individual house, the existing examples demonstrate that these changes within typical current conditions.

Cost: Because this plan seeks improved flood barriers for the project area's entire perimeter, this plan is approximately ten times more expensive than Plan 1.

3.4.3 Plan 3: Steel Sheet Pile Floodwalls to 15.5 ft NAVD

(a) Plan Description

Plan 3: Steel Sheet Pile Floodwalls to 15.5 ft NAVD, consists of encircling the EIIT perimeter with flood barriers as well as supplemental floodproofing (Figure 18). The plan significantly reduces flood risk from the existing flood hazard with steel sheet pile floodwalls and west levee improvements, and preserves reduced flood hazard for up to three feet of sea-level rise. The steel sheet pile floodwalls on the east side can be initially constructed to a crest elevation of 12.5 ft NAVD, sufficient for the present day flood hazard, but with limited obstruction of views and access to the Napa River. Steel sheet piles have sufficient structural strength such that a concrete cap can be added to the top of the wall as sea-level rise approaches two feet, to bring the long-term crest elevation to 15.5 ft NAVD. Similarly, the west side levee improvements can be initially constructed to 12.5 ft NAVD for the present day flood hazard and then raised to 15.5 ft NAVD to adapt to sea-level rise, or constructed to 15.5 ft NAVD in the first phase if funding is sufficient. Floodproofing and flood preparedness measures would provide additional hazard reduction and adaptive capacity. This plan assumes that NRRD is able to secure funding and right-of-way easements so it can lead implementation for the floodwalls, levee improvements, and community infrastructure floodproofing.

The plan's proposed measures are as follows:

- Flood Barriers
  - Install steel sheet pile floodwalls along East Levee 1 and East Levee 2 in stages. The first stage would have a minimum crest elevation of 12.5 ft NAVD and embedment depth to meet both long-term structural and seepage cutoff requirements. Then, as sea-level rise and settlement decreases the floodwall's relative elevation by approximately two feet, the floodwall would be upgraded with a concrete cap to reach a long-term target elevation of 15.5 ft NAVD. Since steel sheet pile requires heavier construction equipment and larger costs, this measure would almost certainly require implementation by NRRD rather than individual homeowners.
  - On the west side, the flood barrier improvements would be built to the same DFE as the east side, i.e. at least 12.5 ft NAVD initially and could be built in stages to pace sea-level rise to reach 15.5 ft NAVD in the second stage. West Levee 1, adjacent to the CDFW managed wetlands, can be enlarged with only earth fill while also avoiding wetland impacts by placing the fill on the east side of the levee. Since the middle reach of the west side appears to be deficient in terms of it slope stability and seepage, this portion, West Levee 2, will be improved. The improvement includes excavating, processing to eliminate layers with high seepage, and replacing to compaction and slope stability standards to the levee's existing elevation of approximately 9 ft NAVD. Then steel sheet pile floodwall would be embedded in the levee to reach 15.5 ft NAVD. North of the railroad tracks, a new West Levee 3 will be constructed to elevation of 9 ft NAVD, offset

  just west of Milton Road. West Levee 3 will need to be constructed in stages to allow for adequate settlement time, at least 10 years between stages. After settlement and sea-level rise decrease the fill's elevation by approximately two feet, the second phase would be implemented to raise the crest the design elevation of 9 ft NAVD. West Levee 3 would then have steel sheet pile floodwall embedded in its crest to reach the DFE of 15.5 ft NAVD.

  - Connect steel sheet pile floodwall and levees at key junctions to provide full-perimeter protection. These junctions may consist of physically embedding sheet pile floodwall in the levees. At other locations with limited space, such as the railroad tracks and the service road leading to the wastewater treatment plant, other methods may be required, such as elevating roadways and flood doors for temporary closure during flood events.

  - While encircling Ingersoll Tract with a levee to the west and floodwalls to the east will keep water out, this enclosure will also detain precipitation and groundwater. Much like the existing drainage via the tide gate under Milton Road, gravity drainage may be sufficient to drain the Ingersoll interior for the first few decades. However, as sea level rises and tides shift up, the capacity for gravity drainage will decrease. Therefore, the plan includes a new stormwater pump station for Ingersoll Tract as sea-level rise reaches two feet.

- Floodproofing

  - Community infrastructure would be floodproofed, improving these shared assets' resilience to flooding. NRRD will implement floodproofing for all community infrastructure it owns, as listed in Section 2.6. NRRD will collaborate with owners of other infrastructure who would be relied upon by the community should do the same. The target elevation for lowest floor elevation and floodproofing will be the current DFE, 12 ft NAVD, plus three feet accommodation for sea-level rise.

  - Floodproofing of homes and community infrastructure within the flood barriers would not need to be implemented as rapidly, because the flood barriers would provide substantial flood protection. This will allow homeowners wider latitude to schedule increased elevation and floodproofing with other home improvements. However, as homeowners and community structures undergo new construction or substantial improvements, floodproofing will be required by the County Code that is consistent with the BFE at the time of construction and preferable be raised several feet higher so the structure continues to meet the County Code as additional sea-level rise occurs.

- Flood Preparedness and Planning

  - This plan includes the preparedness measures for maintenance, flood event planning, and institutional implementation approach that are described in Section 3.3.3.

  - Since all of the implementation of flood barriers would be community led, design standards and implementation guidance to facilitate individual homeowners' implementation of floodwalls not necessary.

- Residual Risk

  - By achieving the largest risk reduction, this plan corresponds to a low tolerance for risk. Nearly all flood hazard would be intercepted by flood barriers before inundating houses and community infrastructure, leaving low levels of residual risk up through three feet of sea-level rise. However, for sea-level rise greater than three feet, risk would start to increase. This acceptance and acknowledgement of increasing risk in the long-term should be clearly communicated to all homeowners so they can best manage residual risk on their own, primarily by increased elevation and floodproofing.

  - Because this plan does not meet FEMA accreditation standards, the remaining risk would still require externalized through flood insurance with the National Flood Insurance Program (NFIP) if the homeowner's mortgage includes federal or federally related financial assistance (which is common).

(b) Schedule

The proposed timeline for the implementing these measures is shown in Figure 20. Implementation of some measures are dependent upon a sea-level rise trigger; if the projected time for a trigger shifts from the assumed sea-level rise at the top of the schedule, then the measure's implementation time would shift accordingly. The rationale for specific measures is as follows:

- The flood preparedness measures should all be completed at the start of plan implementation since these measures offer immediate benefits for existing flood risk. The assessment of institutional implementation is also scheduled at the start since other measures are supported by these steps.

- The first phase of the steel sheet pile floodwall and west side improvements, to a minimum elevation of 12.5 ft NAVD, should be complete by 2030. The second phase, a concrete cap to extend the floodwall's elevation to a minimum elevation of 15.5 ft NAVD, should be implemented to be completed as sea-level rise approaches two feet above existing conditions, projected to be between 2050-2070.

- Initiate planning effort for construction of new West Levee 3 as soon as practicable, due to the scale of effort, and the decade waiting period between successive soil placements to allow for settlement.

- Because of increase protection provided by the improved floodwalls and levees, residential floodproofing could be implemented over five or more decades, in conjunction with the houses' other improvements and/or replacements.

- Floodproofing for existing community infrastructure below elevation of 8 ft NAVD should be implemented in the plan's first two decades. For the wastewater treatment plant facilities above 8 ft NAVD and a new pump station for Ingersoll, suggested implementation can be deferred to until two feet of sea-level rise is anticipated, approximately 2060.

(c) Costs

The community costs for this plan are estimated to be $79,300,000, as summarized in Table 10. The community infrastructure costs are higher than those summarized in Table 7 because this plan includes a new stormwater pump station for Ingersoll Tract, estimated to cost $343,000. For additional cost estimate details, see Appendix E. All of the costs are rough order of magnitude, and have an anticipated accuracy range +50% to -30%. The timing of these expenditures are shown cumulatively on Figure 20.

The potential for significant wetlands impacts was considered at a qualitative level, to inform the measures' design. For example, sheet pile was selected for a portion of the west levee, WL2, to avoid the need to place new fill in the wetlands along the levee's toe.

Table 10 Summary of Costs for Plan 3: Steel Sheet Pile Floodwalls to 15.5 ft NAVD

Plan Components	Total
Flood barriers	
West side	$37,000,000
East side	$29,600,000
Floodproofing	
Community infrastructure	$1,530,000
Flood Preparedness and Planning	
Flood management system inspection and maintenance	$1,860,000
Flood event safety plan	$125,000
Institutional implementation approach	$180,000
Design standards and implementation guidance	-
Mitigation	9,000,000
TOTAL	**$79,300,000**

(d) Performance Assessment

Flood Hazard Reduction: By implementing continuous, higher flood barriers around the perimeter of the project area, this plan would substantially improve the current flood protection for the project area and include adaptive capacity for up to three feet of sea-level rise. The proposed long-term crest elevation of 15.5 ft NAVD would improve the current flood protection by providing a foot of freeboard above the 100-year event with three feet of sea-level rise. The floodwalls and levees would be built in two stages. The first state would address the current flood hazards and then, as sea-level rise approaches two feet, the second stage would be added to raise the floodwalls and levees to adapt to three feet of sea-level rise. In addition, the floodwalls and levee improvements would limit seepage inflows and the potential for seepage to cause levee failure.

In the scenario that sea-level rise progresses to five feet, additional adaptive capacity to raise the steel sheet pile floodwalls beyond 15.5 ft NAVD would be limited. For the west levees, the sections with only earthen levees, West Levee 1, could have additional fill added to adapt to sea-level rise. Overall, the flood barriers' adaptive capacity for sea-level rise in excess of three feet is limited. Therefore, raising and floodproofing houses and community infrastructure to pace sea-level rise would continue as an important long-term measure.

Environmental Impacts: By placing most of the proposed construction either within the existing levee footprint or on uplands, potential environmental impacts for the flood barriers can be minimized. Although heavy construction equipment and methods associated with installing steel sheet pile may have higher construction-period impacts, mitigation would be the responsibility of NRRD and not individual homeowners. To provide a continuous line of protection, the NRRD will need to build a continuous floodwall extending along the entire east side of the project area. This footprint intersects with potentially environmentally sensitive areas (for instance, just south of where the railroad tracks cross Milton Road, which includes tidal marsh wetlands). An option to reduce wetlands impacts might be replacing a stretch of floodwall with increased elevation of Milton Road just south of the railroad tracks. On the west side, north of the railroad tracks, where there currently is not flood barrier, the proposed West Levee 3 would likely include some fill of wetlands. The design of this levee to minimize impacts should be evaluated in the next stage of design in concert with more detailed wetland mapping.

Supplying the earth fill to build and raise the west levees would likely require substantial trucking along Milton Road during construction. This trucking would increase traffic along Milton Road, potentially causing congestion and roadway damage.

Community Coordination: This plan assumes that NRRD identifies an approach for funding and right-of-way easements so it can implement the east side floodwalls and a community-led effort can implement barrier improvements on the west side. Given the scale of construction methods required for steel sheet pile floodwalls, implementation by individual homeowners is not likely to be feasible.

Aesthetics and Access: Vinyl and other types of floodwalls to approximately 12 ft NAVD are already in place at multiple houses in the project area. So the first stage of constructing continuous steel sheet pile floodwalls to this height would be similar to current conditions on most parcels. Relative to the levee crest, these floodwalls are approximately waist-high, and at most obscure the lower part of views from most houses and backyards. Access to docks require some modifications, either an opening in the floodwall that can be closed during flood events or a few steps over top the floodwall. As sea-level rise approaches two feet, the second stage of adding elevation via a concrete cap, would increase the floodwalls' intrusion into views and dock access. With the assumption of one foot of settlement occurring in the next century, the concrete cap would add four feet of elevation to the initial floodwall crest. The extent of aesthetic and access changes due to the concrete cap will depend on the individual house. Many houses would likely be raised in elevation as part of floodproofing, thereby offsetting views impaired by higher floodwalls. One option to further preserve aesthetic views, at an additional cost to individual homeowners, would be to replace some portion of the concrete cap with glass panels set into a metal frame (Figure 12).

Cost: Because this plan seeks improved flood barriers for the project area's entire perimeter, this plan is approximately twenty times more expensive than Plan 1 and twice as expensive as Plan 2.

3.5 Comparison Between Plans

Table 11 provides a brief summary of the three proposed flood management plans' performance relative to the study's evaluation criteria. All plans also assume continued application of the existing County Code flood management requirements (Section 2.7.1) regarding design flood elevations for houses' lowest floor and floodproofing for houses and other facilities. Individual homeowners would be responsible for funding and implementing these existing measures on their own.

For flood hazard reduction, the amount of sea-level rise that will cause 10-year flood water levels to exceed the typical levee crest elevation is used as a simple metric. Currently, the 10-year flood event on the Napa River falls just below the typical levee crest and poses a significant risk for levee and floodwall seepage. The different amounts of sea-level rise that will lift the 10-year flood event over the levee crest of each plan, as well as the projected decade this amount of sea-level rise will occur, are shown in the table.

Table 11 Comparison of flood management plans relative to evaluation criteria

Evaluation Criteria	Plan 1: Flood Preparedness & Planning	Plan 2: Vinyl Sheet Pile Floodwalls to 12.5 ft NAVD	Plan 3: Steel Sheet Pile Floodwalls to 15.5 ft NAVD
Flood Hazard Reduction	At risk to 10-year flood with 1 ft SLR (c. 2040)	At risk to 10-year flood with 3 ft SLR (c. 2090)	At risk to 10-year flood with 5 ft SLR (after 2100)
Environmental Impact	Negligible	Moderate wetland fill for west side levee improvements	Moderate wetland fill for west side levee improvements
Community Coordination	Requires funding	Requires funding and right-of-way easements	Requires funding and right-of-way easements
Aesthetics & Access	No change	Slight increase in east floodwall heights. Raised and new west side levees and floodwalls.	Slight (first stage), then noticeable (second stage, after 2 ft sea-level rise) increase in east floodwall heights. Raised and new west side levees and floodwalls.
Construction & Mitigation Cost	$3,500,000	$38,300,000	$79,300,000
Community Investment per Parcel*	$23,000	$247,000	$512,000

*** These estimated costs, distributed across 155 parcels, should not be viewed as a per parcel owner cost at this time, but rather as the per parcel share of total community investment for each plan. These costs do not consider the source of funding, which may be offset to some degree by grants.**

A key differentiating aspect of the three plans is their distribution measures to address flood risk. As represented in Figure 21, Plan 1 relies on flood preparedness, planning, and floodproofing, which leaves a relatively large amount of residual flood risk. Plan 2 boosts the use of flood barriers to reduce flood risk and Plan 3 carries this approach further with the greatest reliance on flood barriers to minimize flood risk. The degree to which the plans reduce flood risk is further quantified in Figure 22. In this figure, a representative cross section of the east EIIT levee is shown relative to a range of flood elevations. The flood elevations range from the 1-year to the 100-year return interval and increase with sea-level rise moving down the rows top to bottom in the figure. Baseline conditions, as well as the proposed flood management plans are represented in the figure's columns. For this matrix of flood levels and flood management, this color scale rates the flood risk:

- Green: no flood overtopping for the 100-year event
- Yellow: flood overtopping for the 100-year event but not the 10-year event
- Orange: flood overtopping for the 10-year event but not the 1-year event

  - Red: flooding overtopping for the 1-year event

An assessment the measures' suitability for community coordination are shown in Figure 23. As the plans increase in their level of effort, they will require and benefit from greater community coordination.

In the last row of Table 11, the estimated community investment per parcel is provided, assuming 155 parcels. The term 'community investment' refers to:

- The larger *community*, consisting of county, regional, state, and federal agencies and grants, as viable funding sources. By leveraging these community opportunities, a plan's cost need not be funded by individual homeowners alone. In the past, well-organized flood management projects have been able to secure about half of their funding from sources beyond the local community, i.e. community collaboration. Funding opportunities are discussed in more detail in Section 4.4.

- Similar to the *investments* of maintenance and repair required to keep a car or other assets operational over the long term, EIIT will require investment to protect its existing assets from the growing flood hazard posed by sea-level rise. Otherwise, more frequent and intense flooding will escalate the potential damages, the threat to public safety, and the ability to reside at EIIT. Ultimately, with no plan and escalating sea-level rise, EIIT's assets are likely to experience a loss in value.

A conceptual-level annual damage and cost-benefit analysis model was developed for the three management plans. The analysis estimates the cumulative damages that could be avoided by implementing each plan and considers these avoided damages as economic benefits of each plan. Details of this analysis, which was conducted for earlier, somewhat lower plan cost estimates, can be found in Appendix F. By comparing these beneficial avoided damages to the plans' costs, the benefit-cost ratio can be predicted. A benefit-cost ratio greater than one implies that the plan is likely to result in less total expenditures over the long term than not implementing the plan. Even when accounting for the somewhat higher costs of their latest versions, Plan 1, Plan 2, and Plan 3 all have a benefit-cost ratios above one. Plan 3's benefit-cost ratio is lowest, and just above one. With only about a foot more sea-level rise, all the Plans' benefit-cost ratio increases. This sensitivity to the amount of sea-level rise highlights the Plans' value as an investment to adapt to higher values of sea-level rise.

4. SUGGESTED NEXT STEPS

The intent of this study is to provide a feasibility-level engineering assessment to guide community decision making for strategic flood management. Refining and implementing a flood management plan will require ongoing planning, engineering, environmental review, and funding. Suggested next steps in support of these efforts are provided in the sections below.

4.1 Integration with Regional Planning

Regional planning in and adjacent to EIIT, as well as in the nearby cities, could affect or support implementation of EIIT flood management measures. These integration opportunities include:

- Collaborate with NCFCWCD, CDFW, and other property owner(s) to develop long-term plans for the managed embankments and wetlands west of EIIT, since these areas affect EIIT's flood exposure. Currently, both the NCFCWCD and CDFW intentions only include preserving these areas' current conditions. As current management objectives evolve and sea-level rise poses a greater flood risk, current management practices will also need to adapt to these changes.

- Investigate opportunities to receive dredging spoils in the County's spoil areas, with the new material possibly used for flood management measures.

- Monitor major construction projects in the vicinity of EIIT for projects that need to dispose of earthen fill. Consider accepting clean fill at cost-competitive rates to lower costs for implementing flood improvement measures.

- Coordinate with Napa County Department of Public Works regarding County improvements to Milton Road. Check for overlap in roadway and levee project footprints. Consider improved roadway's capacity to handle truck traffic.

- Update the County hazard mitigation plan with information from this study and any subsequent preparedness planning. An updated plan is a condition for receiving certain types of non-emergency disaster assistance from FEMA, including some of the funding opportunities discussed below.

4.2 Engineering Data and Analyses

Engineering data and analyses are the foundation for describing existing hydraulic and geotechnical conditions, and predicting how these conditions may change in response to sea-level rise and proposed management measures. Possible next steps with regard to engineering data and analyses include:

- Establish robust local vertical benchmarks on and near EIIT that are accurately related to regional benchmarks. These can be used for water level monitoring and to better quantify local settlement rates. Recent surveys in support of USACE tidal datum study may provide a basis for local and regional benchmarks.

- Consider establishing a telemetered water level gage on the Napa River adjacent to EIIT. Data from such a gage could be used to monitor flood hazard in real time, to determine peak water levels that occur during flood events for post-event assessment of flood management performance, and to improve understanding as to how different sources (tides, storm surge, wind, river discharge) affect flood water levels and flood frequency.

- Monitor other regional hydraulic studies, such as forecast modeling by the USGS (Herdman et al., 2016), to glean better understanding of hydraulic conditions and identify potential tools for EIIT-specific analyses.

- Conduct scenario-based flood risk assessments from the areas west of EIIT, which consider sea-level rise, geomorphic change, and levee failure. This assessment would be complementary to coordination with landowners to the west, as suggested above for regional planning integration.

- Collate existing and future geotechnical data, such as coring, cone penetration tests, and soil sample testing collected from EIIT projects, such as house, road, and levee improvements. Implementing the flood barrier measures will require data collection to better characterize the soil conditions underneath and adjacent to the barriers. Data from other projects can supplement and guide the collection of geotechnical data collection for the barriers.

4.3 Environmental Review and Permitting

In the course of developing this study's conceptual flood barrier measures, potential impacts to wetlands were considered when selecting types of measures (i.e. floodwalls instead of levees to reduce footprint) and their alignment. When flood barriers are advanced into the next stage of design, concurrent technical studies in support of environmental review (i.e. assessment in accordance with the California Environmental Quality Act (CEQA) and regulatory agency permitting are recommended. In particular, delineation of jurisdictional wetlands, biological assays for sensitive species, and screening for cultural resource sites should be conducted. These studies can be used to refine measures such that they reduce the severity and magnitude of project impacts.

In addition, initial project design should be discussed with regulatory agency staff for input on potential issues. In addition to potential impacts at the time of construction, regulators, particularly the Bay Conservation and Development Commission (BCDC), will seek to understand the project's performance and adaptive capacity to future sea-level rise.

4.4 Funding

One possible way to offset costs is to seek grant funding opportunities from outside agencies. To improve the chances of acquiring grant funding, projects need to fulfill grants’ objectives, such as FEMA grants that seek to reduce flood damages or multi-objective grants that seek to combine flood protection with restoration (e.g. Bay Area’s Measure AA). Grant assistance programs that could provide funding for components of the EIIT flood management measure are listed in Table 12 below. Funding under these programs is subject to availability of governmental appropriations.

FEMA awards grants each year for communities to undertake mitigation projects to prevent future loss of life and property resulting from hazard impacts, including flooding. Mitigation projects that are eligible for hazard mitigation assistance include, for example, property acquisition, structure elevation, floodproofing, and minor flood control projects, such as the installation or modification of culverts, and stormwater management activities such as creating retention and detention basins. Ineligible projects generally include major flood control projects such as constructing or improving levees and floodwalls. These projects are ineligible because catastrophic failure is a possibility and the potential for loss of life and property is too great. FEMA’s grants are awarded to states that, in turn, provide subgrants to local governments and communities (subapplicant). The applicant selects and prioritizes subapplications developed and submitted to them by subapplicants and submits them to FEMA for funding consideration.

The screening-level economic analysis in Appendix F is conceptual, and while it uses readily available information about EIIT, it also relies on multiple parameters which are selected from the literature as typical values rather than being specific for EIIT. While these initial findings provide an indication of the likely feasibility of the proposed flood management plans, more detailed analysis should be done before basing decisions on this economic analysis. If benefit-cost ratios are confirmed as favorable when analyzed more robustly, this refined economic analysis can be provided as rationale for securing grant funding.

Table 12. Grant Assistance Programs

Mitigation Grant Program	Purpose	Additional Information
Flood Mitigation Assistance (FMA)	Reduce or eliminate claims against the NFIP by reducing long-term risk of flood damage to buildings insurable under NFIP	Cal OES http://www.caloes.ca.gov/cal-oes-divisions/hazard-mitigation/pre-disaster-flood-mitigation FEMA https://www.fema.gov/flood-mitigation-assistance-program
Pre-Disaster Mitigation (PDM)	National competitive program focused on mitigation project and planning activities that address multiple natural hazards	Cal OES http://www.caloes.ca.gov/cal-oes-divisions/hazard-mitigation/pre-disaster-flood-mitigation FEMA https://www.fema.gov/pre-disaster-mitigation-grant-program
Repetitive Flood Claims (RFC)	Reduce flood claims against the NFIP through flood mitigation; properties must be currently NFIP insured and have had at least one NFIP claim	FEMA https://www.fema.gov/media-library-data/20130726-1621-20490-8359/rfc_08_guidance_final_10_30_07.pdf
Severe Repetitive Loss (SRL)	Reduce or eliminate the long-term risk of flood damage to SRL residential structures currently insured under the NFIP	FEMA https://www.fema.gov/pdf/nfip/manual201205/content/20_srl.pdf
Hazard Mitigation Grant Program (HMGP)	Activated after a presidential disaster declaration; provides funds on a sliding scale formula based on a percentage of the total federal assistance for a disaster for long-term mitigation measures to reduce vulnerability to natural hazards	Cal OES http://www.caloes.ca.gov/cal-oes-divisions/recovery/disaster-mitigation-technical-support/404-hazard-mitigation-grant-program FEMA https://www.fema.gov/hazard-mitigation-grant-program
Proposition 1 Climate Ready Grants	Climate Ready Grants are focused on supporting planning, project implementation and multi-agency coordination to advance actions that will increase the resilience of coastal communities and ecosystems	Coastal Conservancy http://scc.ca.gov/climate-change/climate-ready-program/
Measure AA	San Francisco Bay-specific program for restoring habitat, protecting communities from floods, and increasing shoreline public access	San Francisco Bay Restoration Authority http://sfbayrestore.org/sf-bay-restoration-authority-grants.php

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6. LIST OF PREPARERS

ESA staff:

- Matt Brennan, PhD, PE
- Jean Toilliez, PhD, PE
- Bob Battalio, PE
- Jill Sunahara
- Alex Trahan, PE

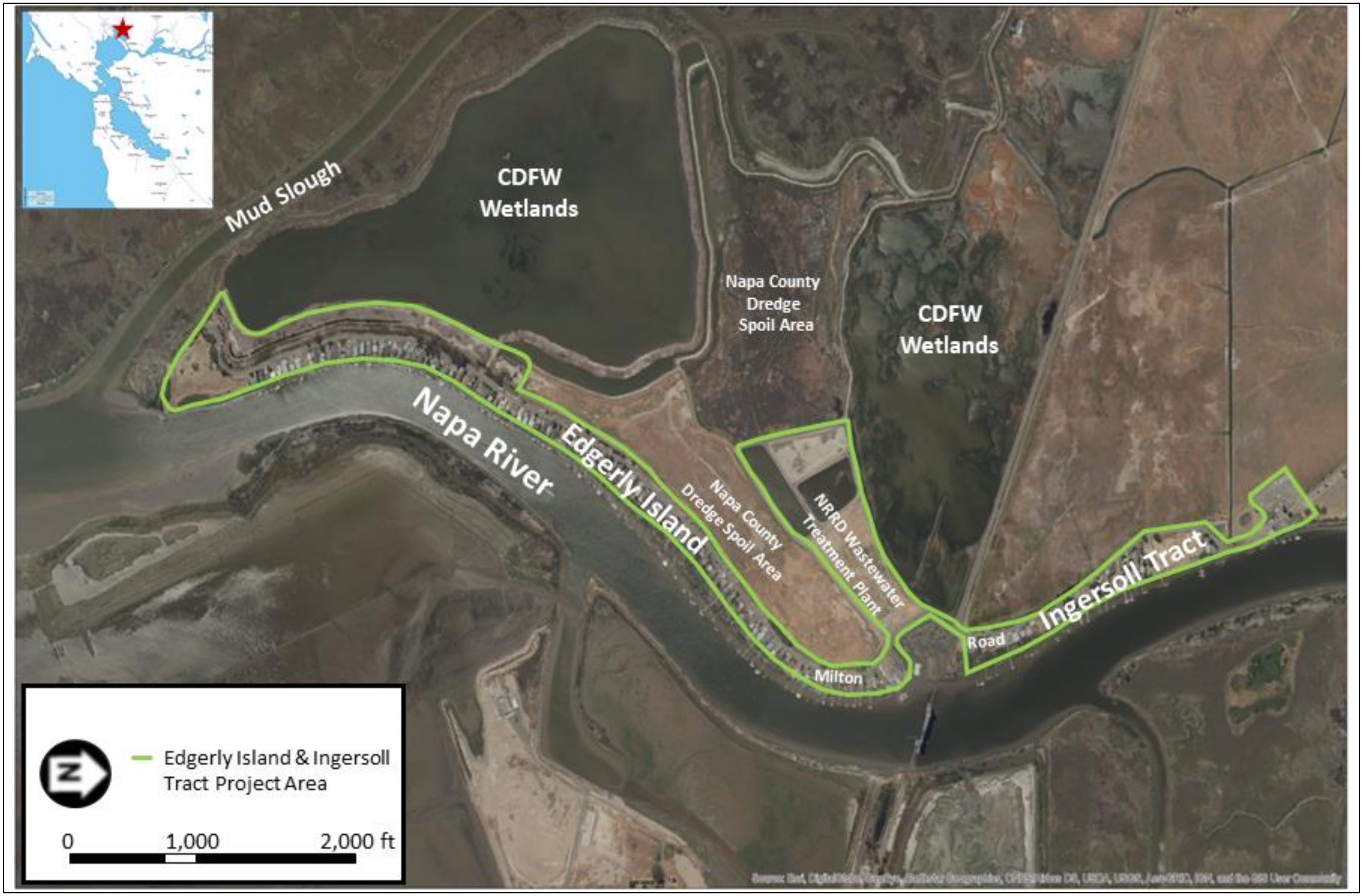
Napa River Reclamation District:

- Jay Gardiner, Chairman, Board of Trustees
- Devra Dallman
- Mark Dallman
- Brian O’Niell
- Cynthia O’Niell

Napa County Flood Control and Water Conservation District:

- Andrew Butler, PE
- Rick Thomasser, PG
- Phil Miller, PE

7. FIGURES



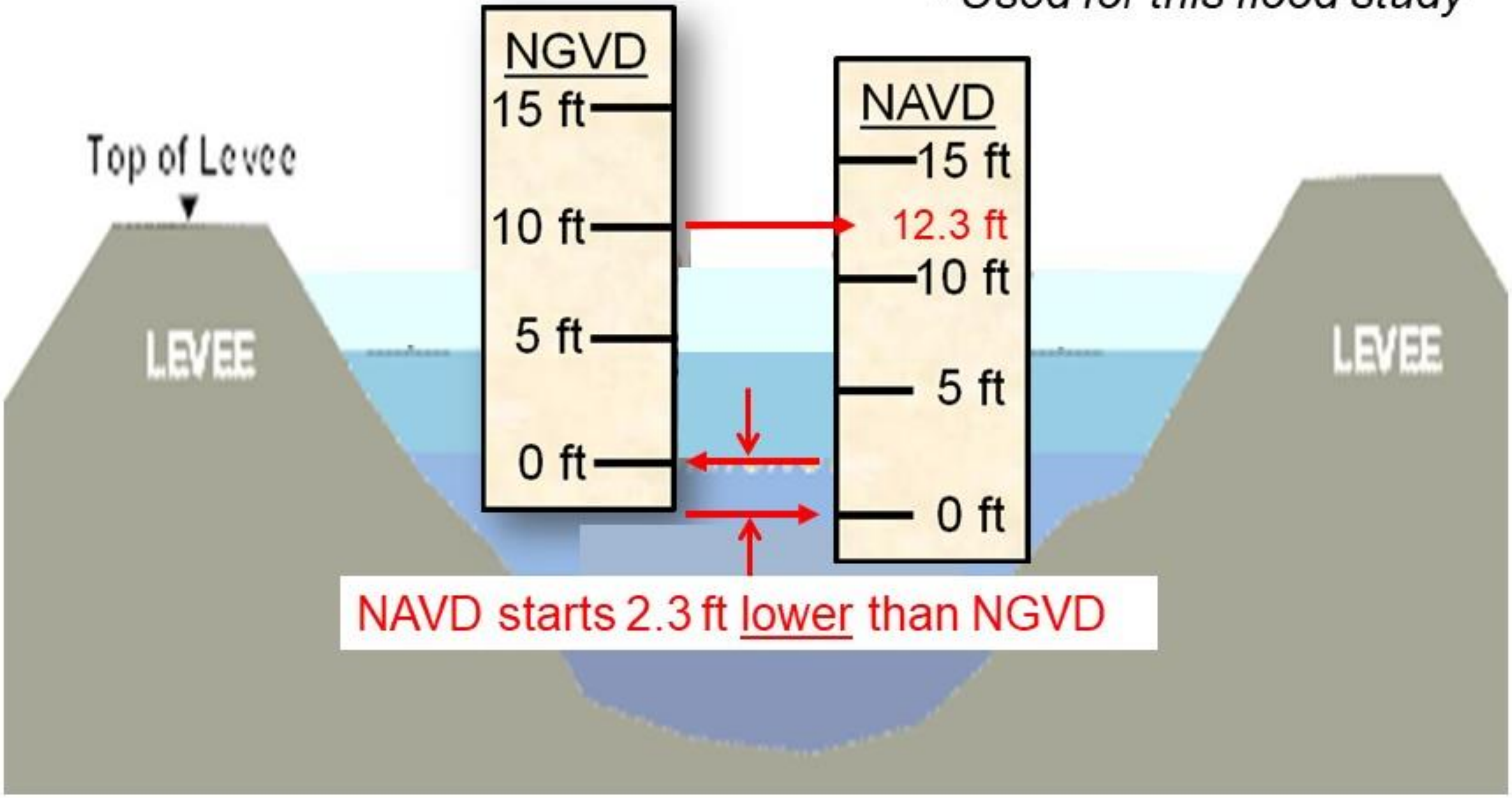
SOURCE: ESRI

Figure 1
Project Area

National Geodetic Vertical Datum of 1929 (NGVD) vs. North American Vertical Datum of 1988 (NAVD)

- *Used in 1984 flood study*

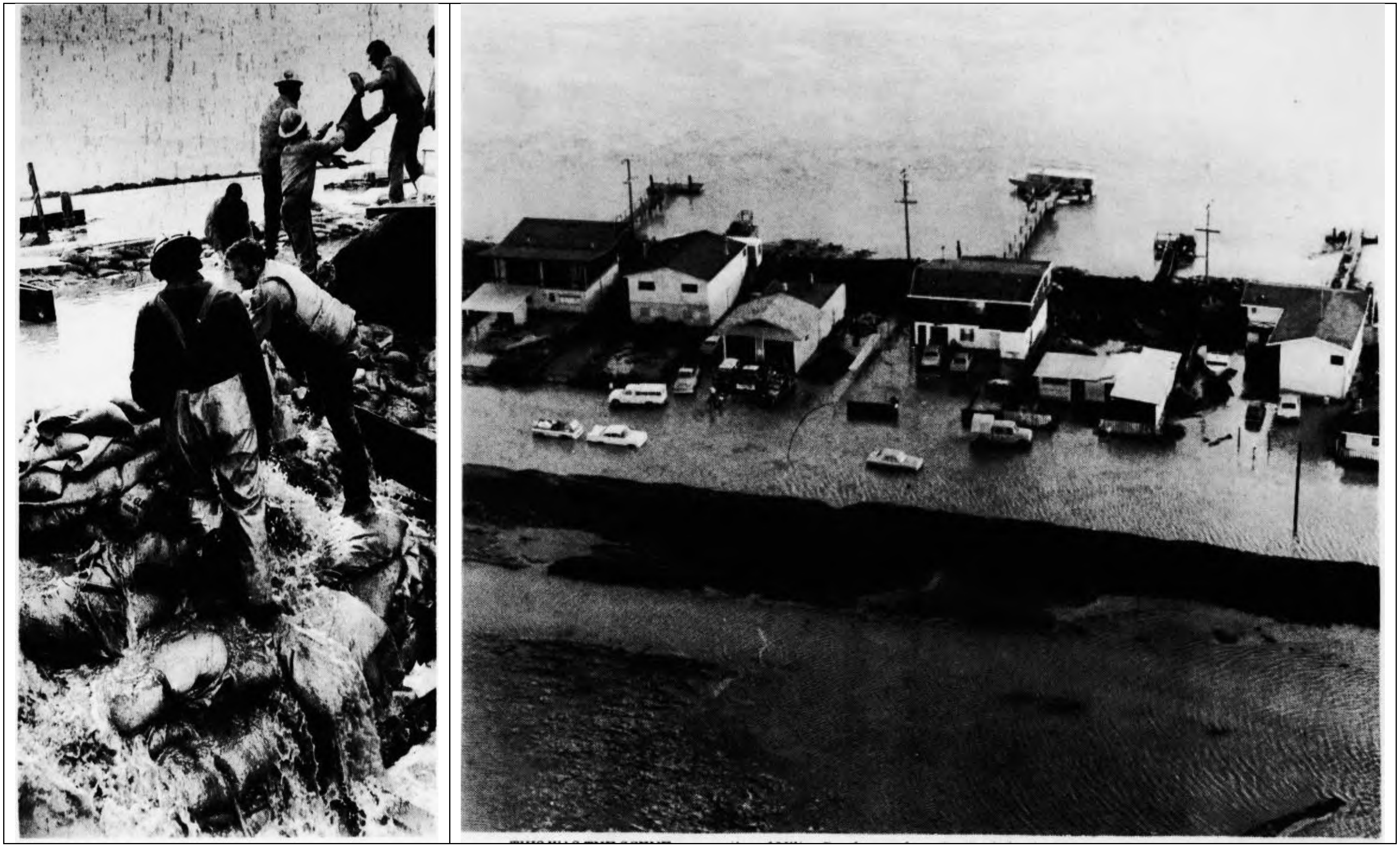
- *Used by FEMA*
- *Used for this flood study*



NAVD starts 2.3 ft lower than NGVD

SOURCE: VERTCON

Figure 2
Vertical Datums



SOURCE: Napa Valley Registert

Edgerly Island & Ingersoll Tract Flood Study .

D160787 **Figure 3**

1973 Flood Event

SOURCE: O'Niell; Dallman

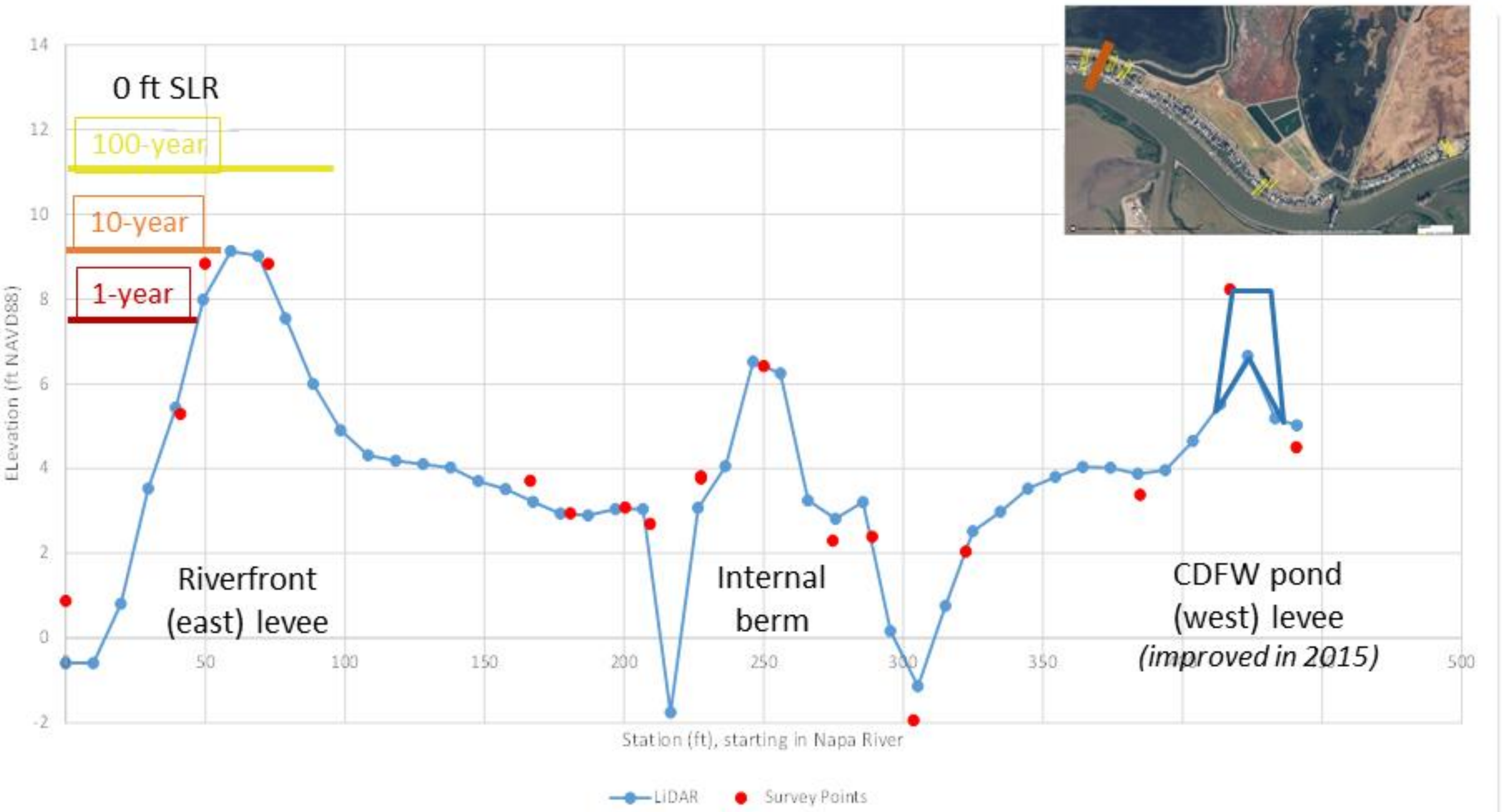
Figure 4
2017 Flood Event

SOURCE:FEMA (2016)

Edgerly Island & Ingersoll Tract Flood Study .

D160787 **Figure 5**

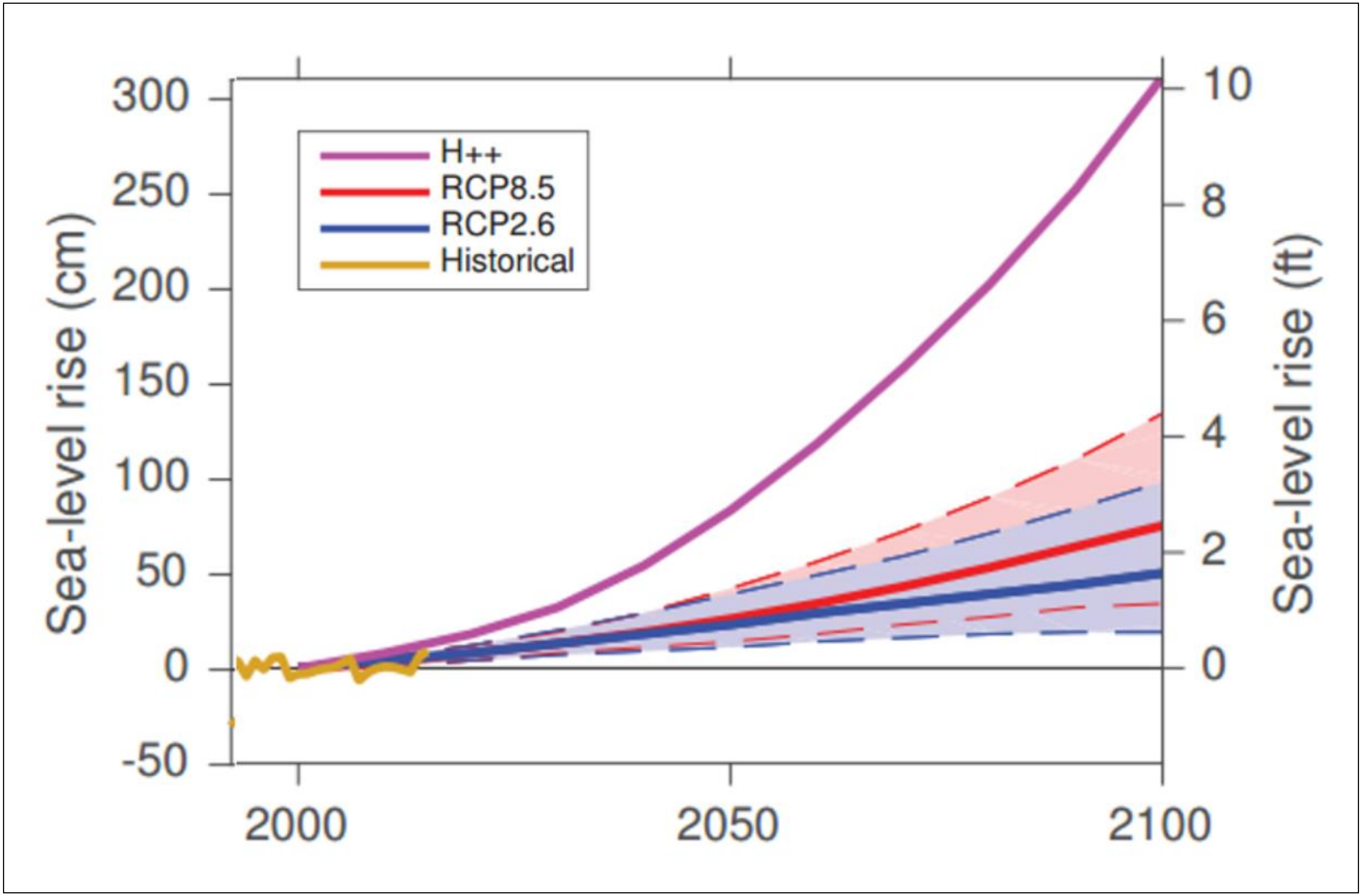
FEMA Special Flood Hazard Areas



SOURCE: LiDAR – NOAA (2010); Survey and water levels- ESA (2017)

Figure 6

Edgerly Island Cross Section &
Flood Water Levels, Existing Conditions

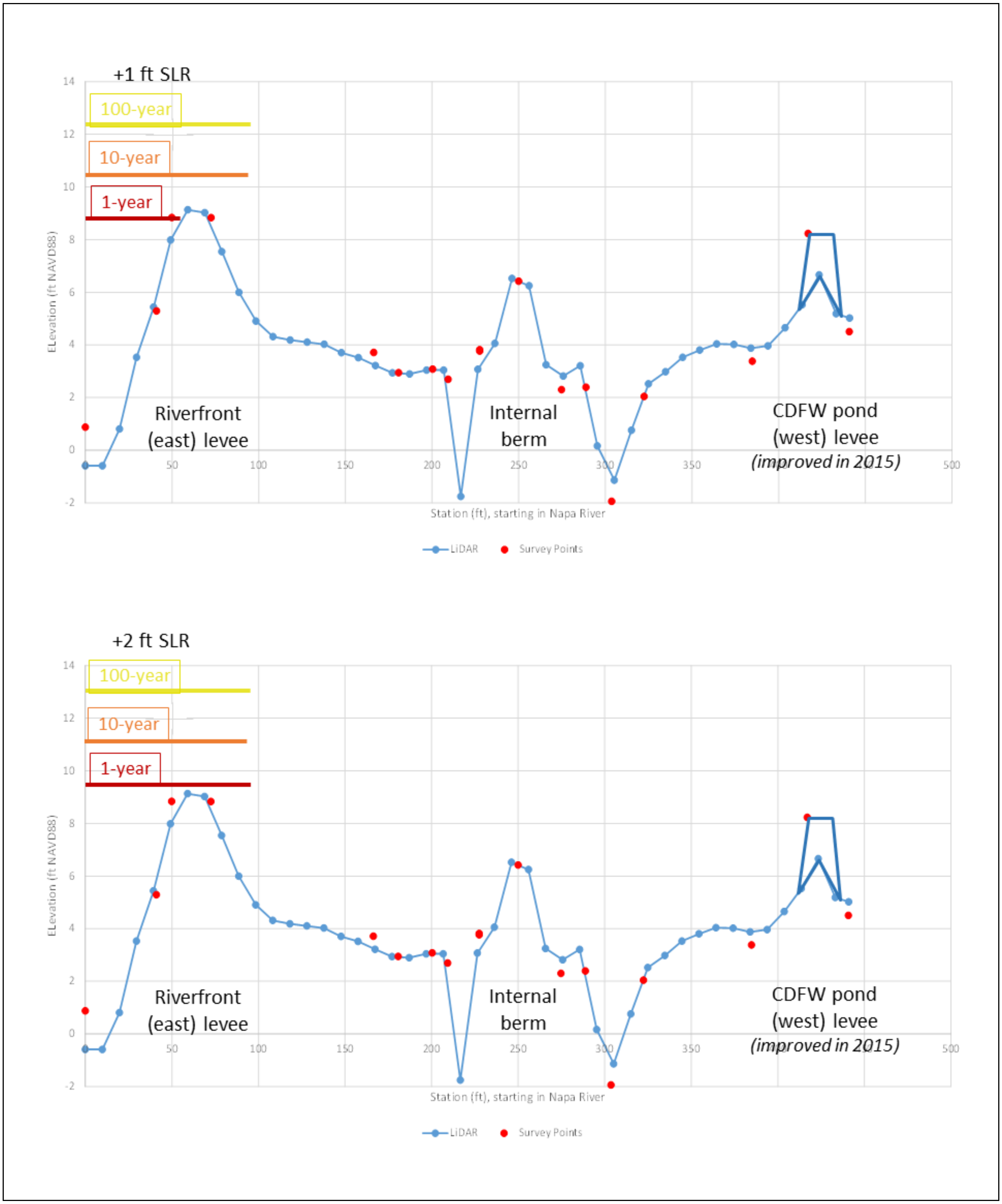


SOURCE: Griggs et al. (2017)

Edgerly Island & Ingersoll Tract Flood Study .

D160787 **Figure 7**

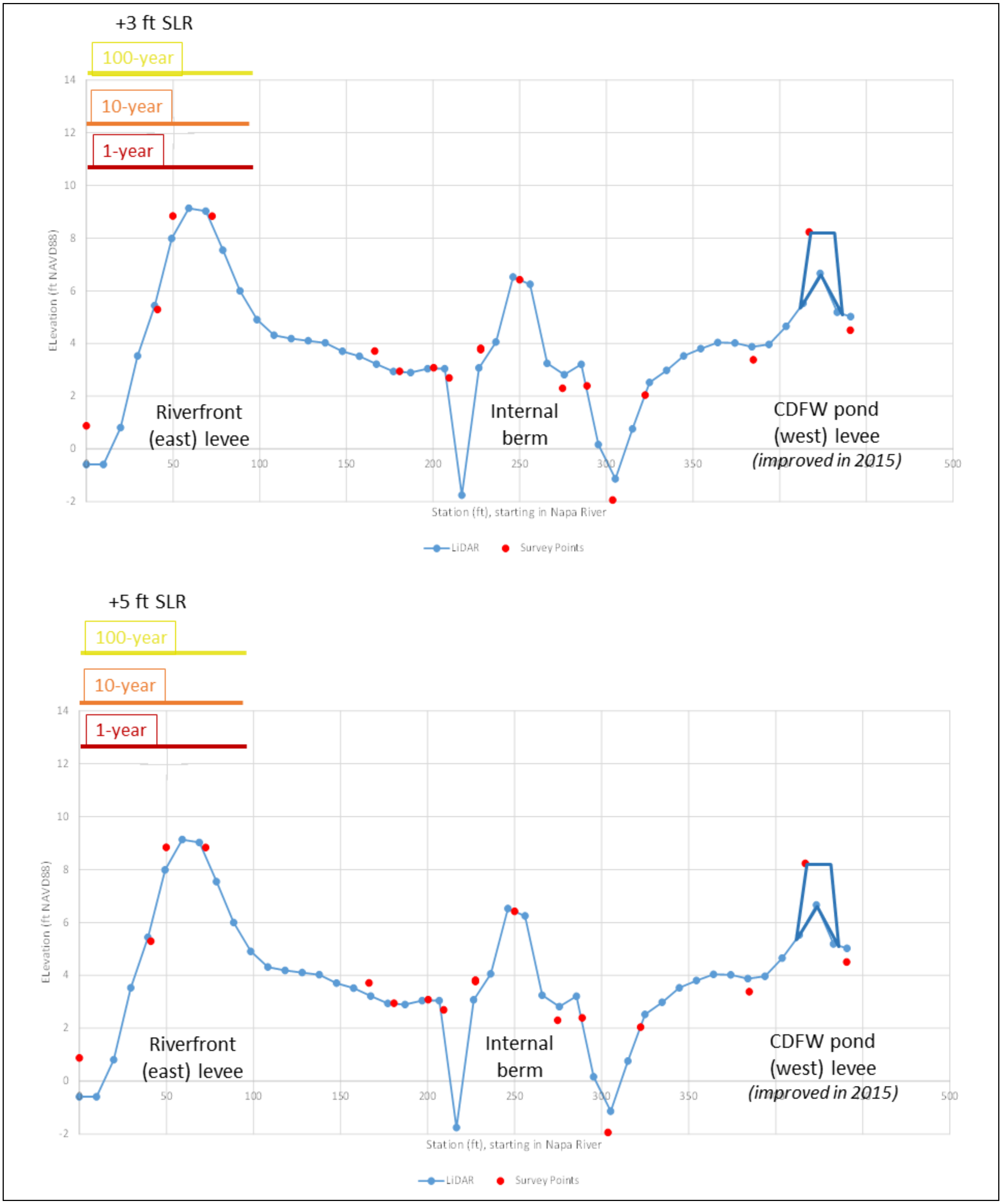
Sea-level Rise Projections



SOURCE:LiDAR – NOAA (2010); Survey and water levels- ESA (2017)

Figure 8

Edgerly Island Cross Section &n Flood Water Levels, +1 ft and +2 ft Sea-Level Rise



SOURCE: LiDAR – NOAA (2010); Survey and water levels- ESA (2017)

Figure 9
Edgerly Island Cross Section &
Flood Water Levels, +3 ft and +5 ft Sea-Level Rise

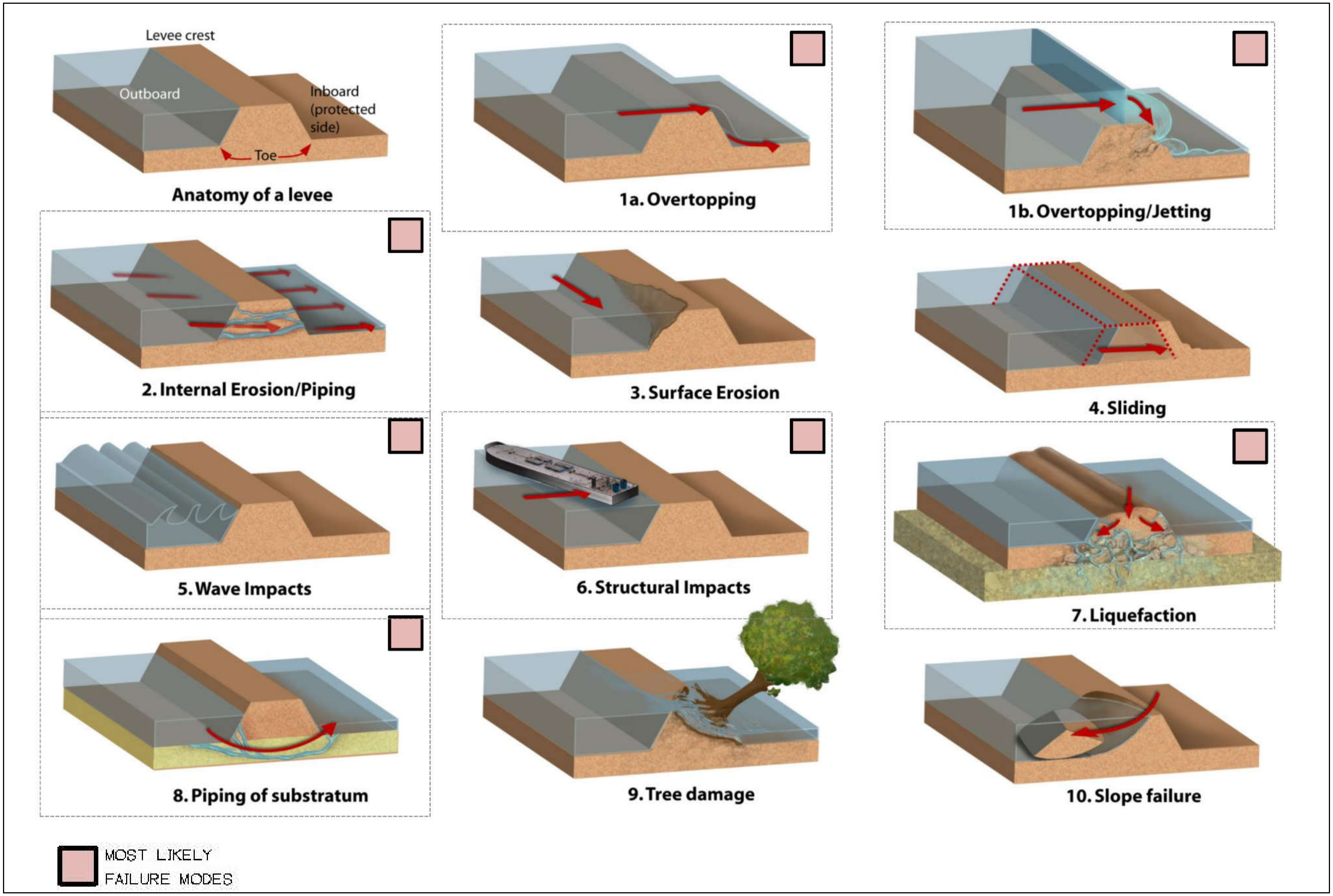
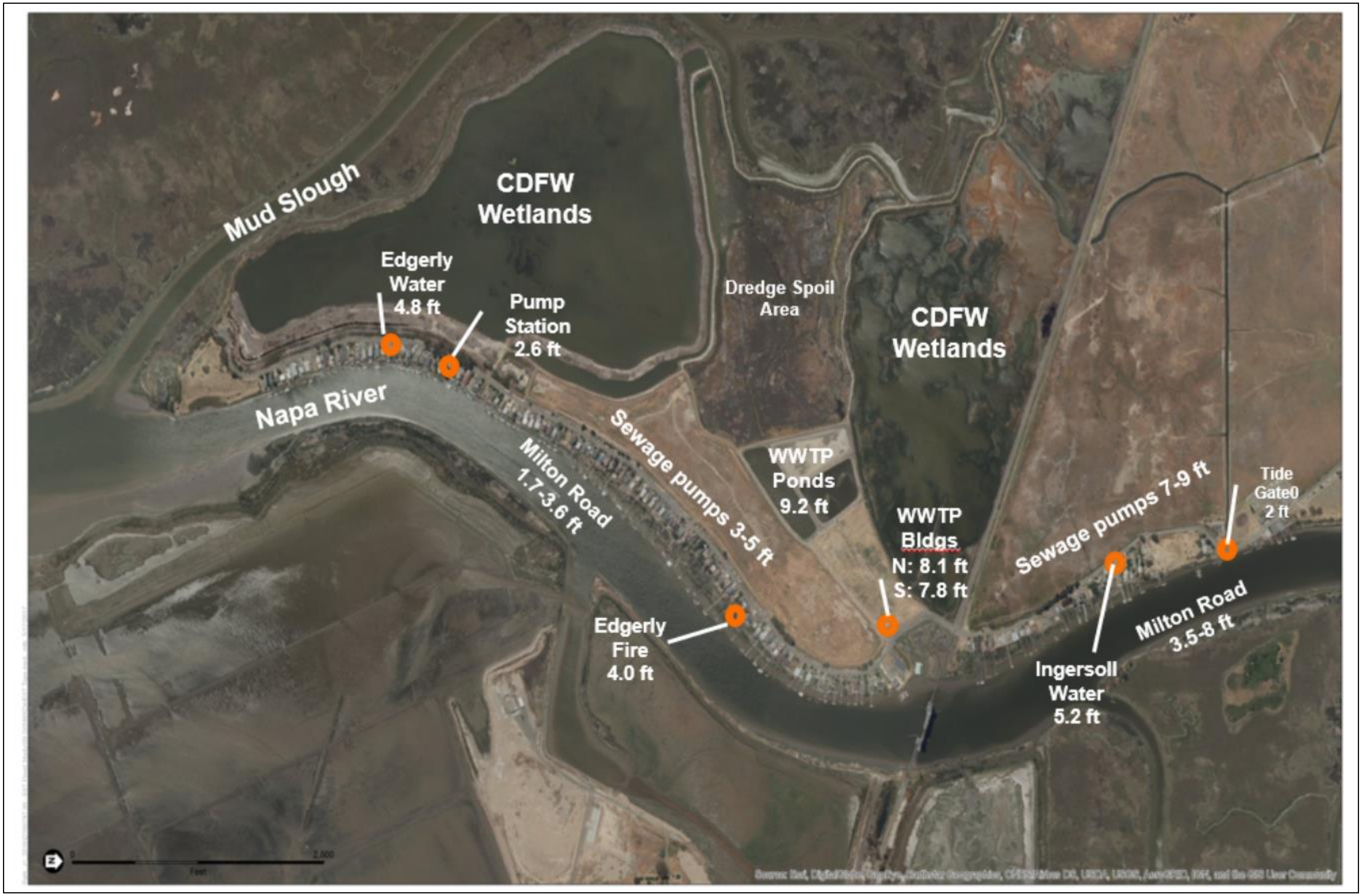


Figure 10
Levee Failure Modes



SOURCE: ESRI

Figure 11
Elevation of Community Infrastructure

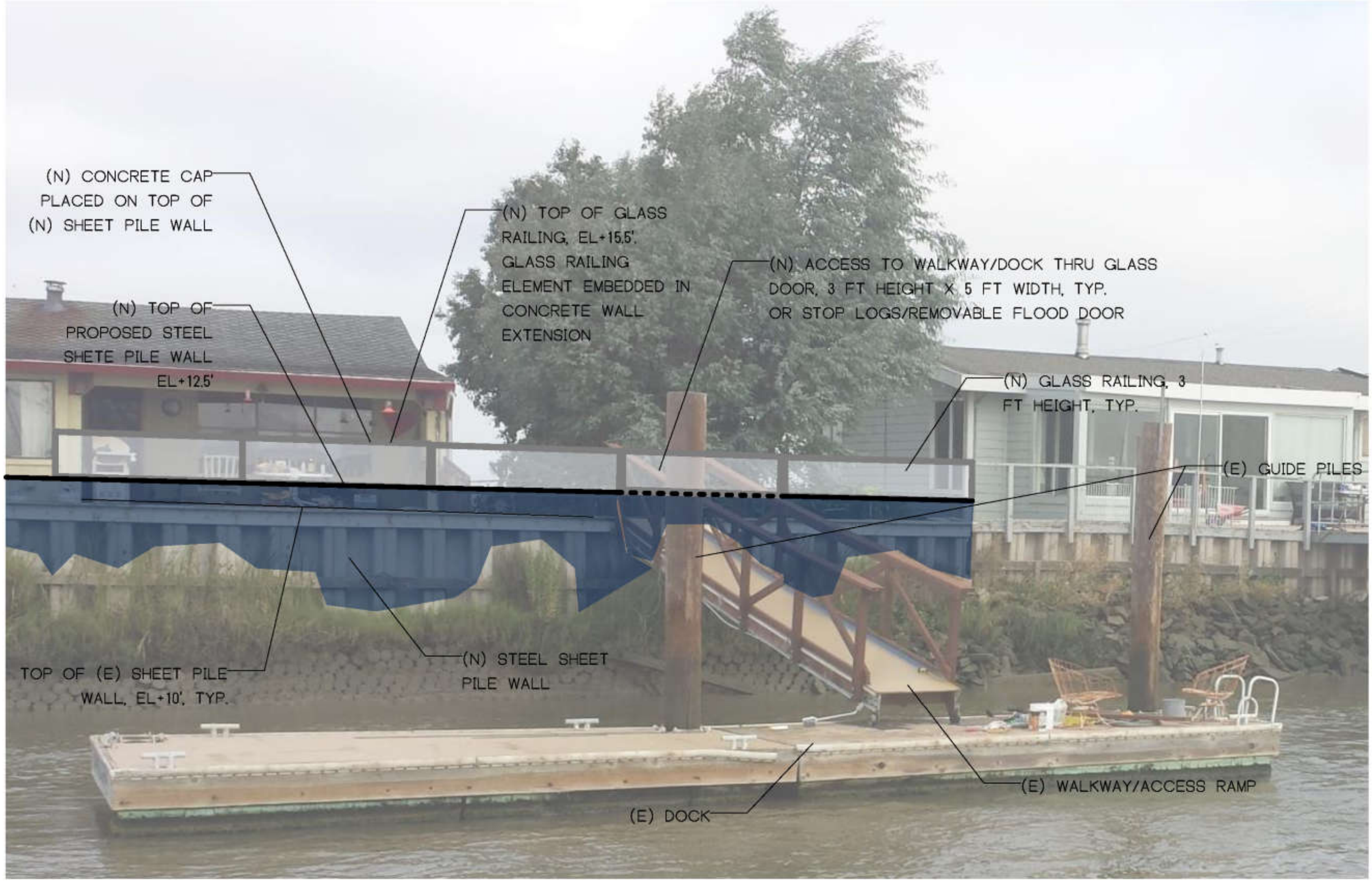
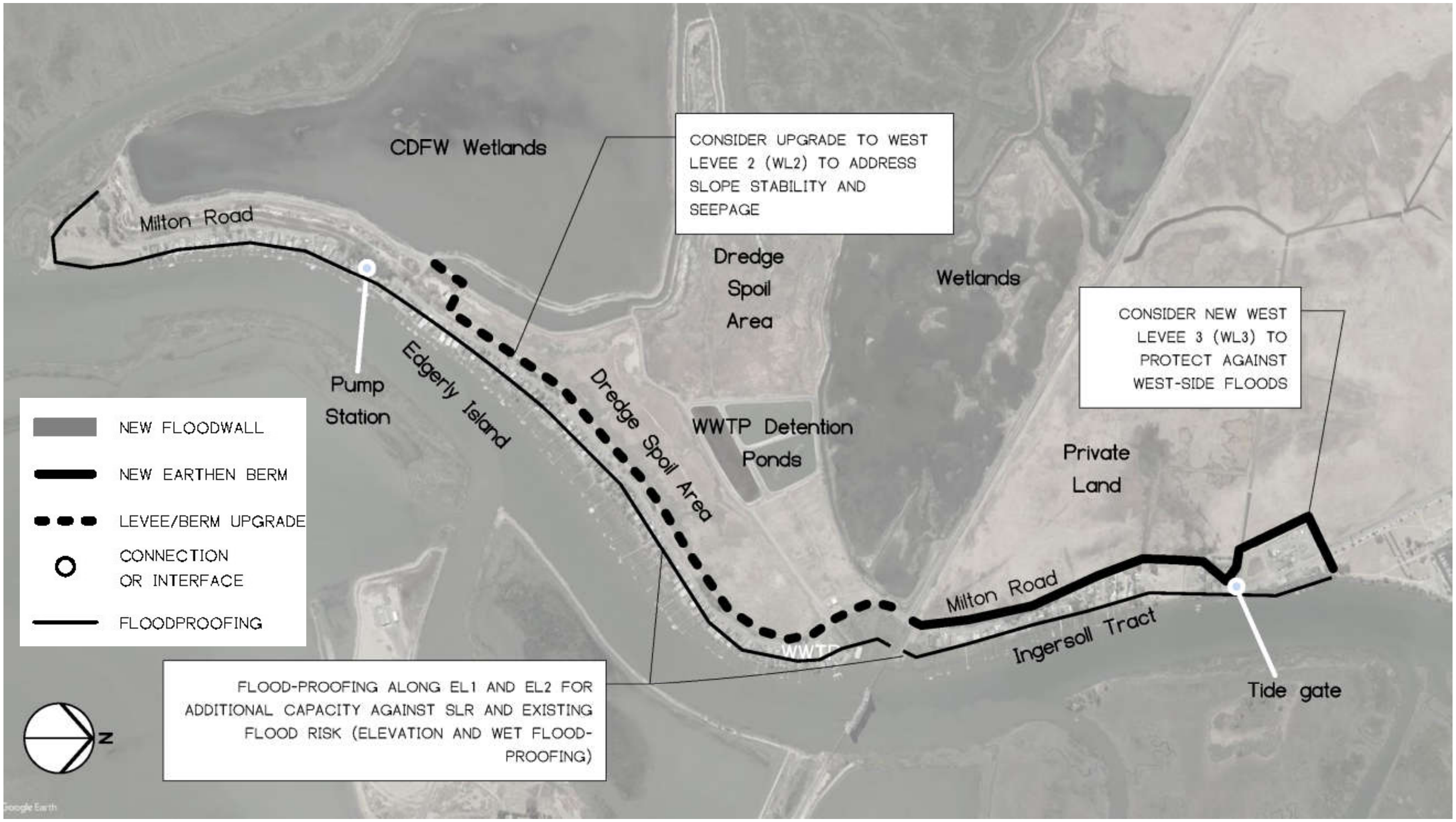


Figure 12

Sheet Pile Wall, Oblique View

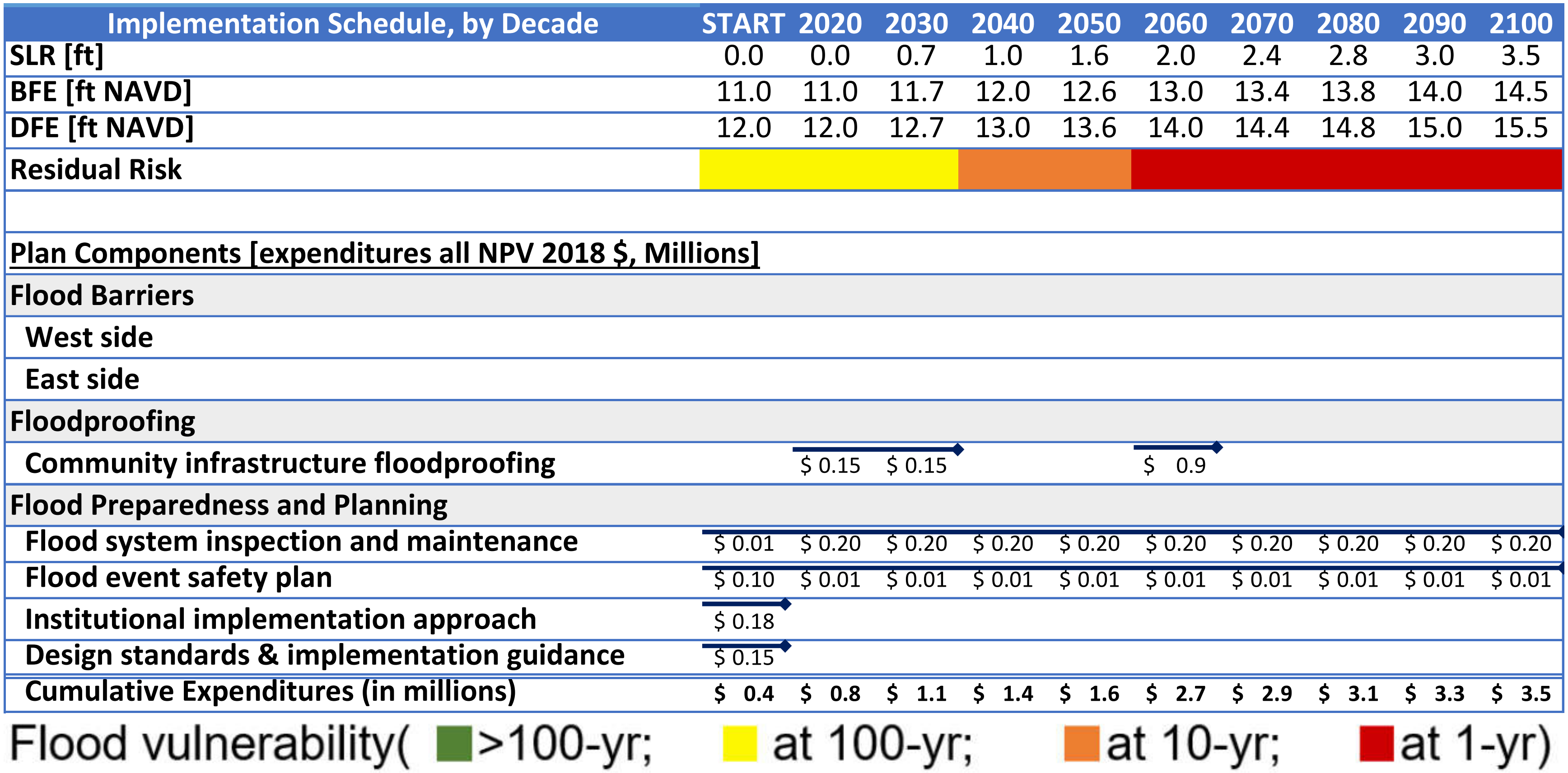


CONSIDER UPGRADE TO WEST LEVEE 2 (WL2) TO ADDRESS SLOPE STABILITY AND SEEPAGE

CONSIDER NEW WEST LEVEE 3 (WL3) TO PROTECT AGAINST WEST-SIDE FLOODS

FLOOD-PROOFING ALONG EL1 AND EL2 FOR ADDITIONAL CAPACITY AGAINST SLR AND EXISTING FLOOD RISK (ELEVATION AND WET FLOOD-PROOFING)

Figure 13
Plan 1: Flood Preparedness and Planning – Map



Implementation Schedule, by Decade	START	2020	2030	2040	2050	2060	2070	2080	2090	2100
SLR [ft]	0.0	0.0	0.7	1.0	1.6	2.0	2.4	2.8	3.0	3.5
BFE [ft NAVD]	11.0	11.0	11.7	12.0	12.6	13.0	13.4	13.8	14.0	14.5
DFE [ft NAVD]	12.0	12.0	12.7	13.0	13.6	14.0	14.4	14.8	15.0	15.5
Residual Risk	🟨	🟨	🟨	🟧	🟧	🟥	🟥	🟥	🟥	🟥
Plan Components [expenditures all NPV 2018 $, Millions]										
Flood Barriers										
West side										
East side										
Floodproofing										
Community infrastructure floodproofing		$ 0.15	$ 0.15			$ 0.9				
Flood Preparedness and Planning										
Flood system inspection and maintenance	$ 0.01	$ 0.20	$ 0.20	$ 0.20	$ 0.20	$ 0.20	$ 0.20	$ 0.20	$ 0.20	$ 0.20
Flood event safety plan	$ 0.10	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01
Institutional implementation approach	$ 0.18									
Design standards & implementation guidance	$ 0.15									
Cumulative Expenditures (in millions)	**$ 0.4**	**$ 0.8**	**$ 1.1**	**$ 1.4**	**$ 1.6**	**$ 2.7**	**$ 2.9**	**$ 3.1**	**$ 3.3**	**$ 3.5**

Flood vulnerability(🟩>100-yr; 🟨 at 100-yr; 🟧at 10-yr; 🟥at 1-yr)

Figure 14

Plan 1 – Flood Preparedness & Planning
Schedule and Cost

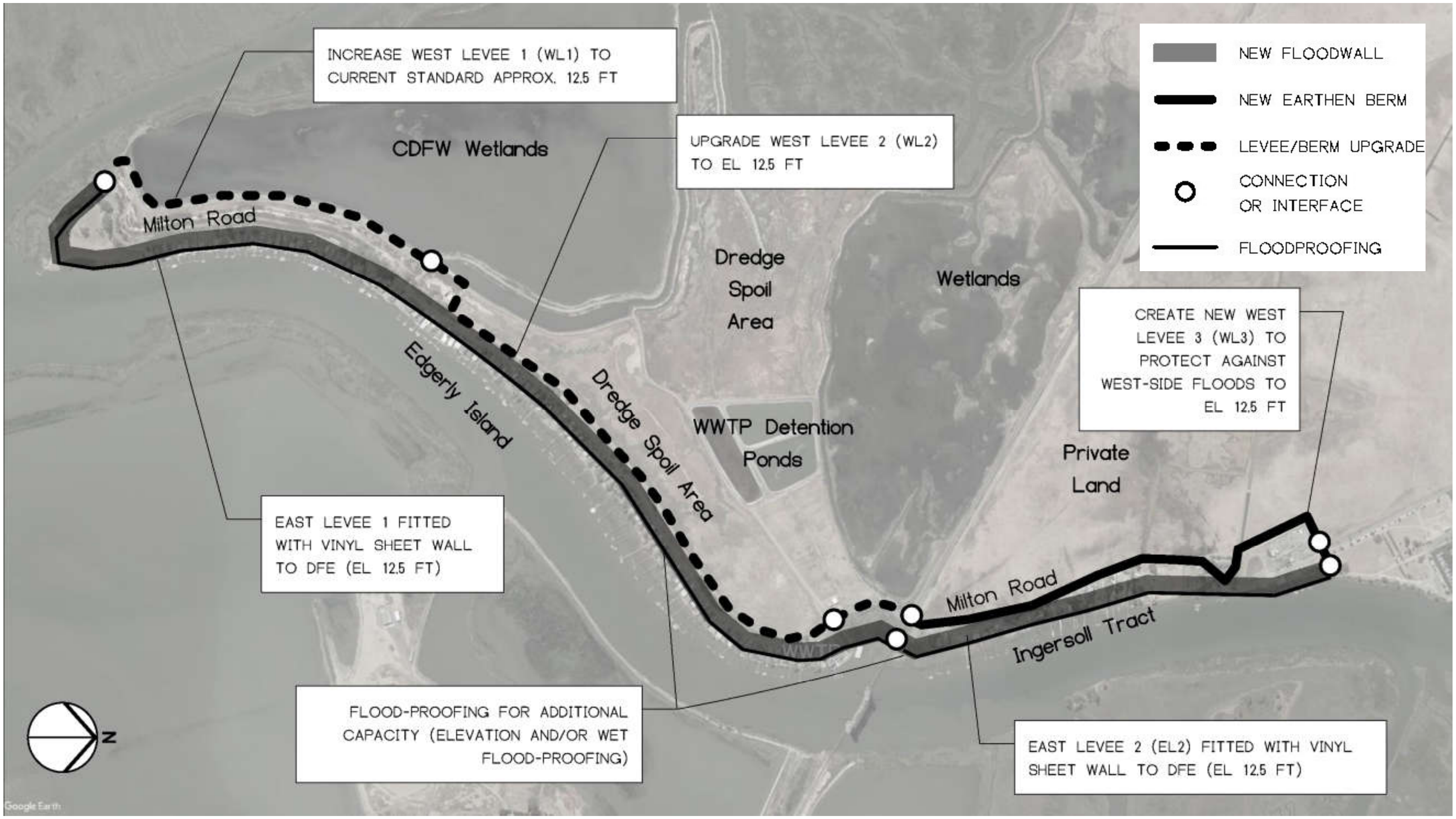
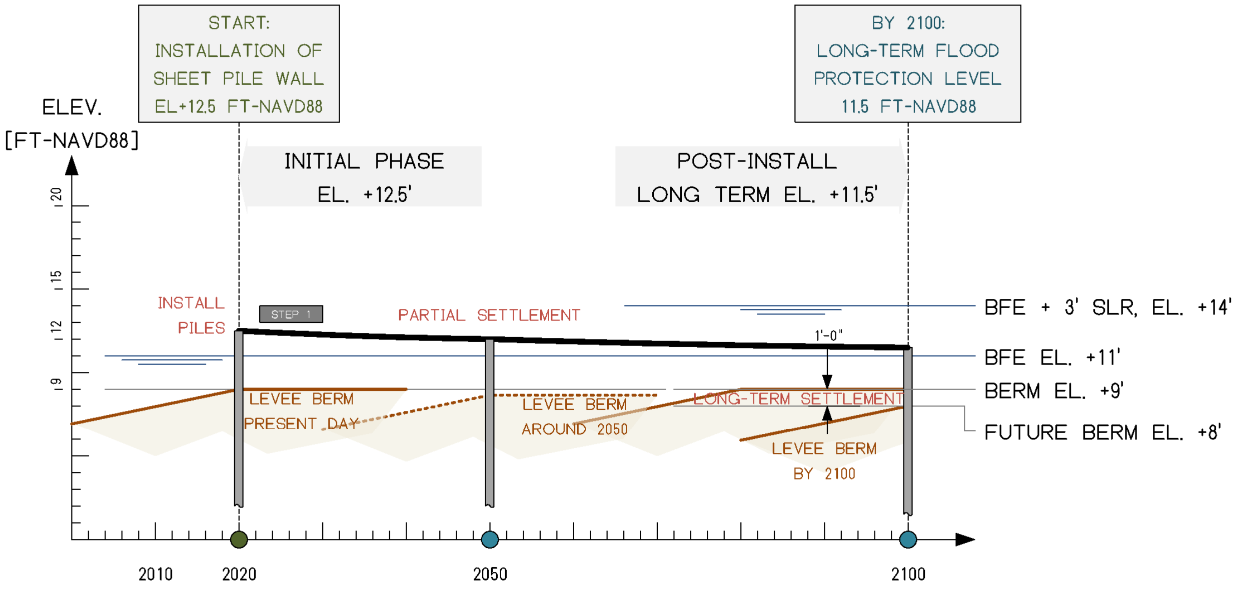


Figure 15

Plan 2: Vinyl Sheet Pile to 12.5 ft NAVD – Map



CONSTRUCTION SEQUENCE

STEP 1. SHEET PILE WALL IS BUILT TO 12.5' TO PROVIDE IMMEDIATE FLOOD PROTECTION.

STEP 2. UNDER THE CONTINUED AND COMBINED EFFECTS OF RISING SEA LEVELS AND LEVEE SETTLEMENT, THE NET LEVEL OF FLOOD PROTECTION DECREASES OVER TIME.

STEP 3. UNDER THE CONTINUED EFFECT OF LEVEE SETTLEMENT, THE LONG TERM ELEVATION REACHES 11'.

Figure 16

Plan 2: Vinyl Sheet Pile to 12.5 ft NAVD – Implementation Sequence

Implementation Schedule, by Decade	START	2020	2030	2040	2050	2060	2070	2080	2090	2100
SLR [ft]	0.0	0.0	0.7	1.0	1.6	2.0	2.4	2.8	3.0	3.5
BFE [ft NAVD]	11.0	11.0	11.7	12.0	12.6	13.0	13.4	13.8	14.0	14.5
DFE [ft NAVD]	12.0	12.0	12.7	13.0	13.6	14.0	14.4	14.8	15.0	15.5
Residual Risk	🟨	🟩	🟩	🟩	🟩	🟨	🟨	🟨	🟧	🟧
Plan Components [expenditures all NPV 2018 $, Millions]										
Flood Barriers										
West side*		$ 18.4		$ 5.4						
East side*		$ 5.5	$ 5.5							
Floodproofing										
Community infrastructure floodproofing		$ 0.15	$ 0.15			$ 0.9				
Flood Preparedness and Planning										
Flood system inspection and maintenance	$ 0.01	$ 0.20	$ 0.20	$ 0.20	$ 0.20	$ 0.20	$ 0.20	$ 0.20	$ 0.20	$ 0.20
Flood event safety plan	$ 0.10	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01
Flood management authority	$ 0.18									
Design standards & implementation guidance										
Cumulative Expenditures (in millions)	**$ 0.3**	**$ 25**	**$ 30**	**$ 36**	**$ 36**	**$ 37**	**$ 38**	**$ 38**	**$ 38**	**$ 38**

*Includes mitigation

Flood vulnerability(🟩 >100-yr; 🟨 at 100-yr; 🟧 at 10-yr; 🟥 at 1-yr)

Figure 17

Plan 2 – Vinyl Sheet Pile to 12.5 ft NAVD
Schedule and Cost

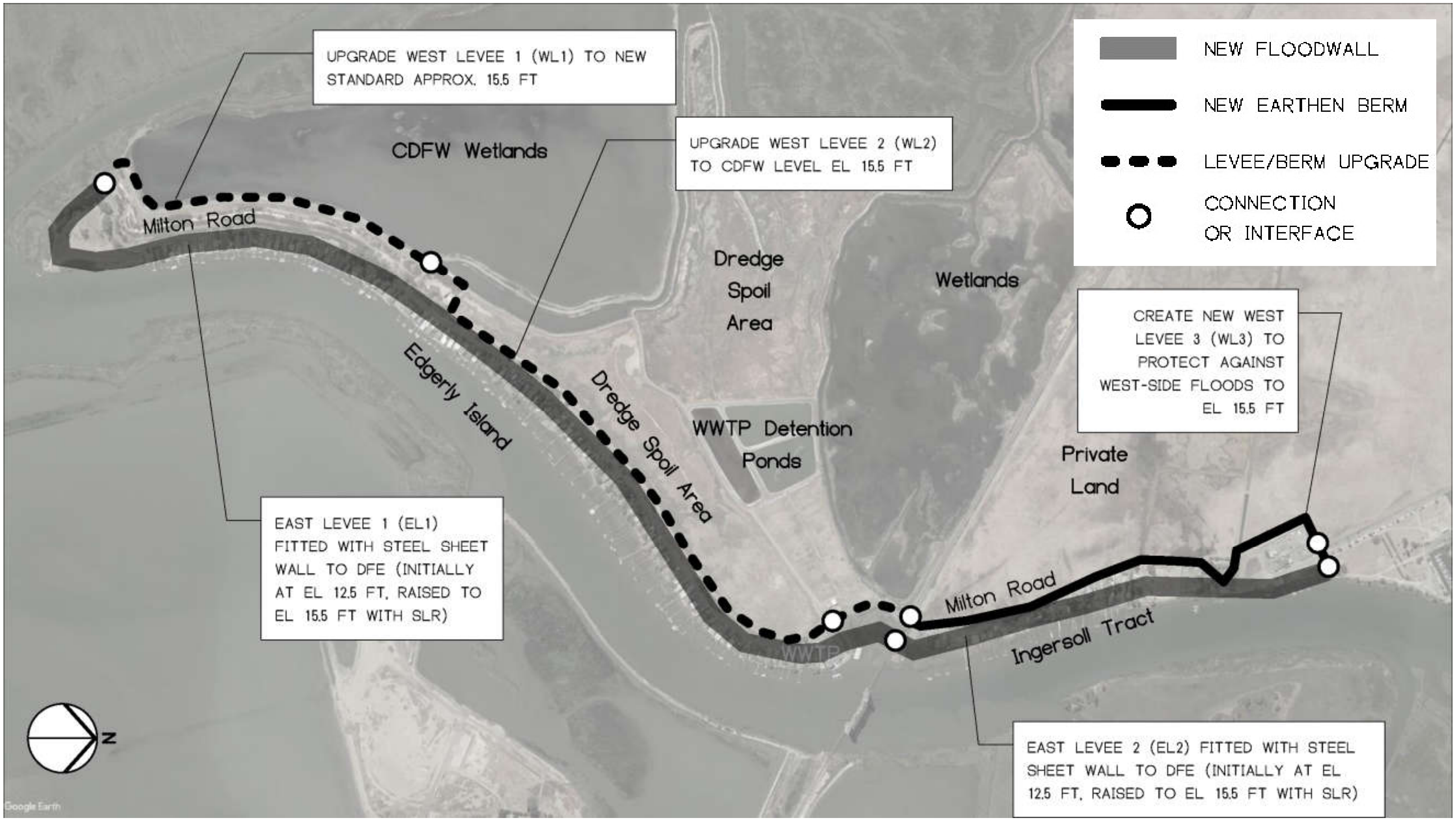
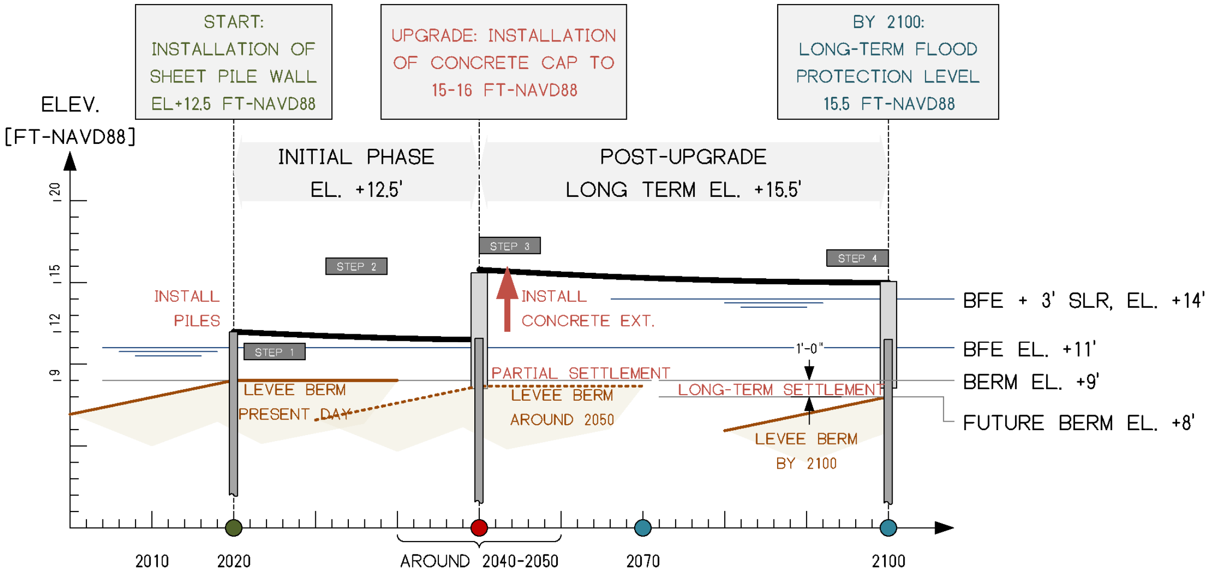


Figure 18

Plan 3: Steel Sheet Pile to 15.5 ft NAVD – Map



ADAPTIVE OR PHASED CONSTRUCTION SEQUENCE

STEP 1. SHEET PILE WALL IS FIRST BUILT TO 12.5' TO PROVIDE IMMEDIATE FLOOD PROTECTION.

STEP 2. UNDER THE CONTINUED AND COMBINED EFFECTS OF RISING SEA LEVELS AND LEVEE SETTLEMENT, THE NET LEVEL OF FLOOD PROTECTION DECREASES OVER TIME. BELOW A CERTAIN THRESHOLD, ACTION IS TRIGGERED TO UPGRADE THE WALL.

STEP 3. A CONCRETE WALL EXTENSION IS INSTALLED ON THE WALL, RESULTING IN A FINISHED CREST ELEVATION OF 15-16' (APPROX.) TO ACCOUNT FOR RESIDUAL LONG-TERM SETTLEMENT.

STEP 4. UNDER THE CONTINUED EFFECT OF LEVEE SETTLEMENT, THE LONG TERM ELEVATION REACHES 15.5'.

Figure 19

Plan 3: Steel Sheet Pile to 15.5 ft NAVD – Implementation Sequence

Implementation Schedule, by Decade	START	2020	2030	2040	2050	2060	2070	2080	2090	2100
SLR [ft]	0.0	0.0	0.7	1.0	1.6	2.0	2.4	2.8	3.0	3.5
BFE [ft NAVD]	11.0	11.0	11.7	12.0	12.6	13.0	13.4	13.8	14.0	14.5
DFE [ft NAVD]	12.0	12.0	12.7	13.0	13.6	14.0	14.4	14.8	15.0	15.5
Residual Risk	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨
Plan Components [expenditures all NPV 2018 $, Millions]										
Flood Barriers										
West side*		$ 31		$ 12.3						
East side*		$ 30			$ 2.2					
Floodproofing										
Community infrastructure floodproofing						$ 1.2				
Flood Preparedness and Planning										
Flood system inspection and maintenance	$ 0.01	$ 0.20	$ 0.20	$ 0.20	$ 0.20	$ 0.20	$ 0.20	$ 0.20	$ 0.20	$ 0.20
Flood event safety plan	$ 0.10	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01
Flood management authority	$ 0.18									
Design standards & implementation guidance										
Cumulative Expenditures (in millions)	**$ 0.3**	**$ 61**	**$ 61**	**$ 74**	**$ 76**	**$ 78**	**$ 78**	**$ 78**	**$ 78**	**$ 79**

*Includes mitigation

Flood vulnerability(🟩>100-yr; 🟨 at 100-yr; 🟧at 10-yr; 🟥at 1-yr)

Figure 20

Plan 3 – Steel Sheet Pile to 15.5 ft NAVD
Schedule and Cost

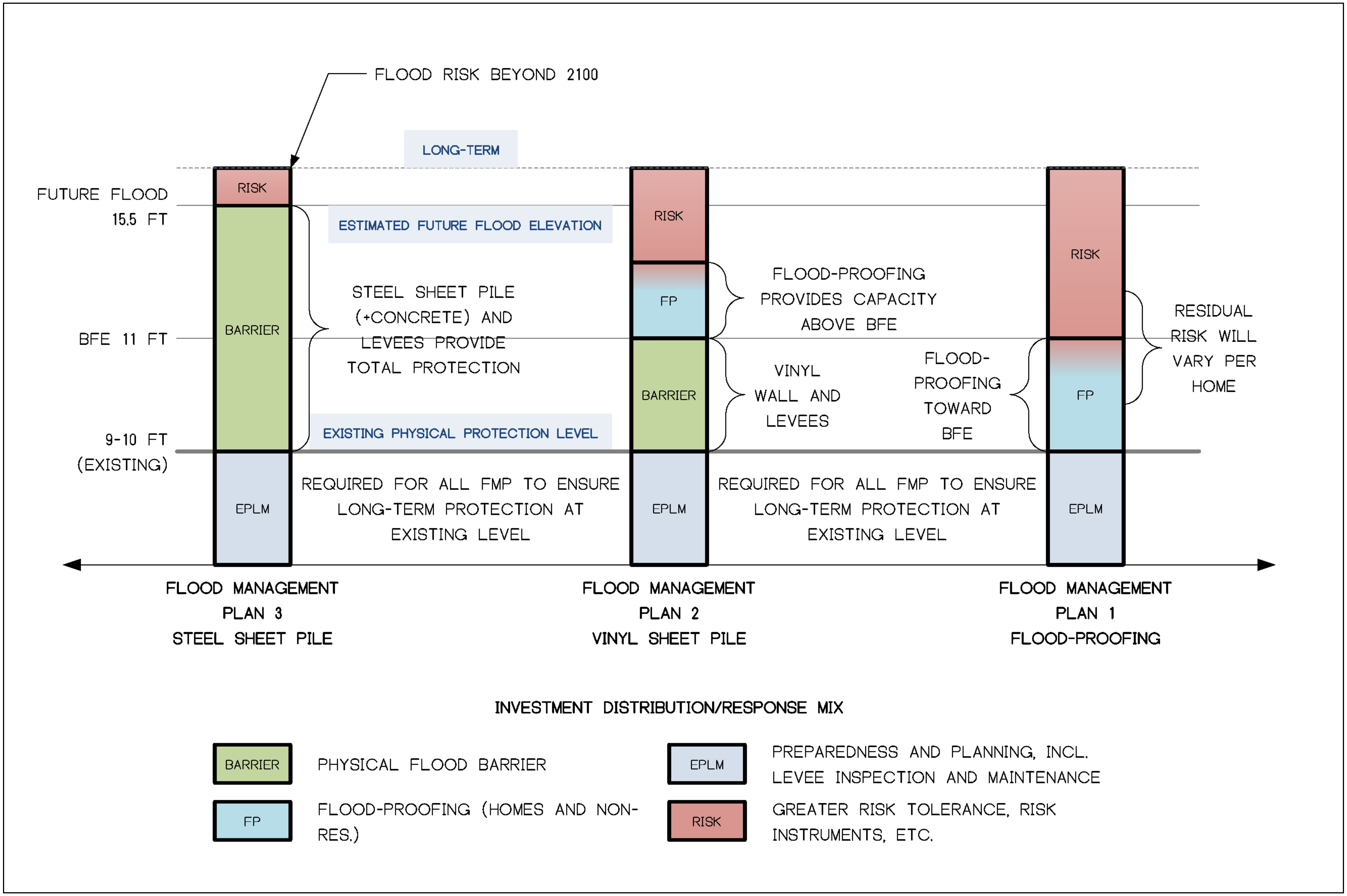


Figure 21

Comparison of Plan Approaches to Flood Risk Reduction

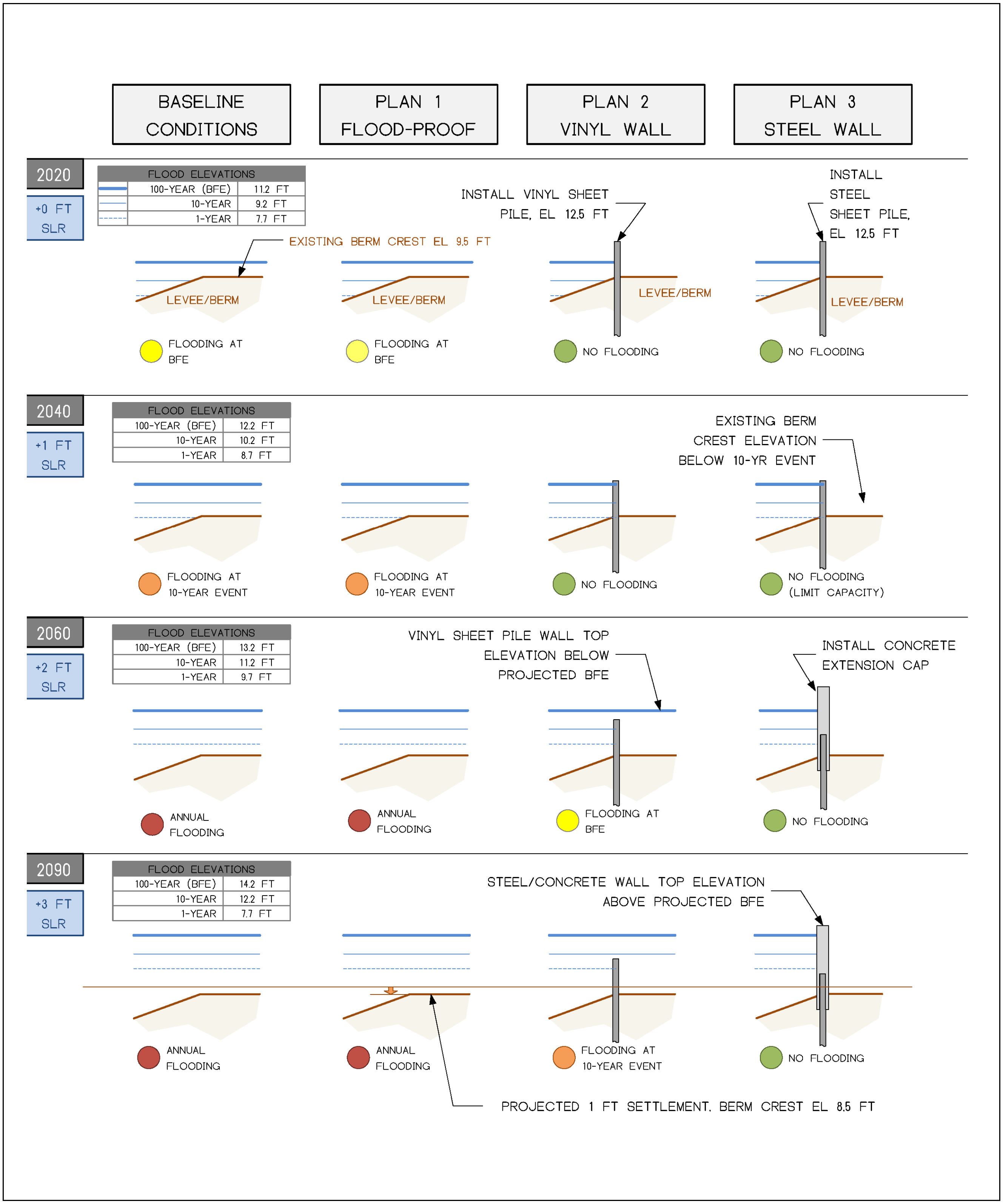
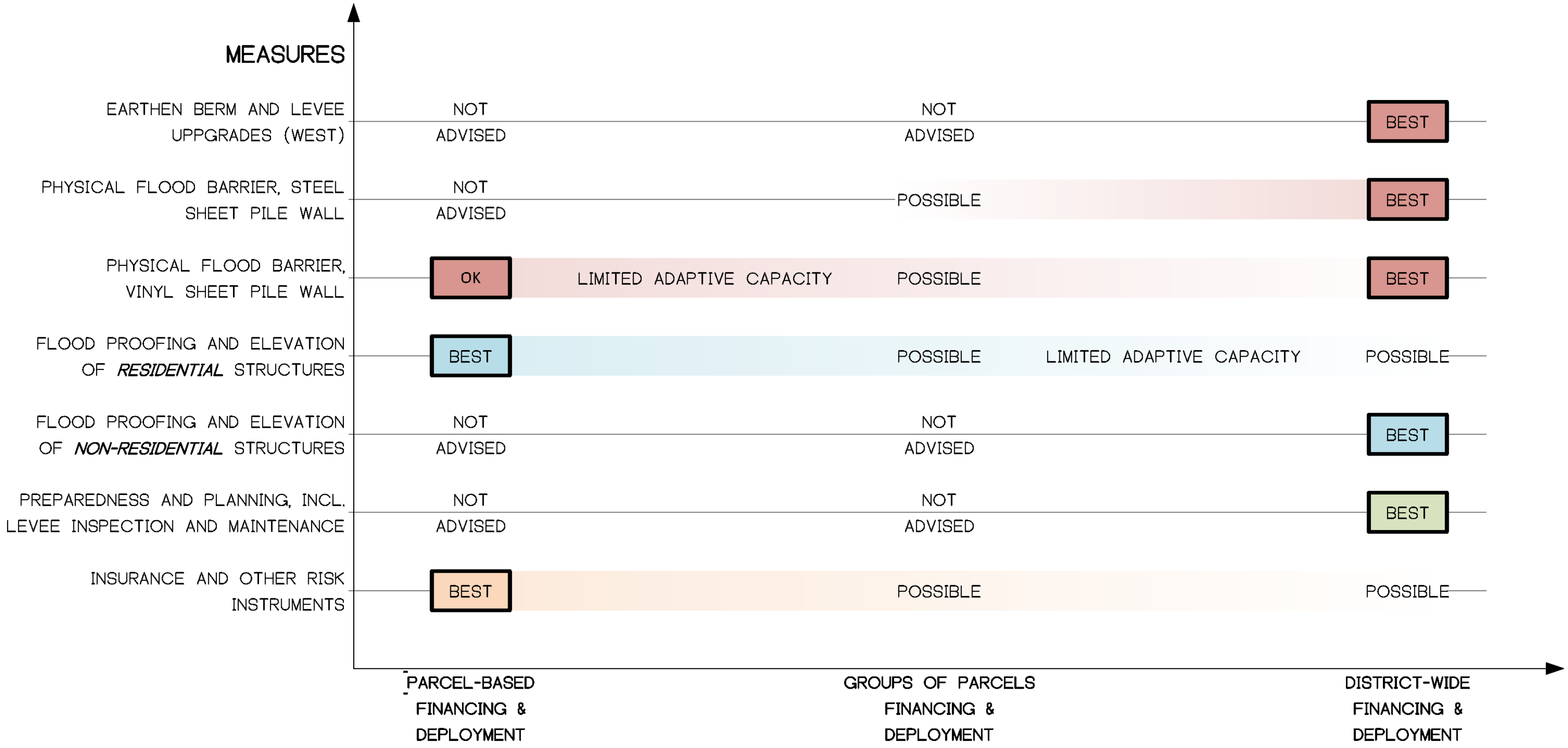


Figure 22

Comparison of Plan Barriers Design Flood Elevations and Flood Event Elevations

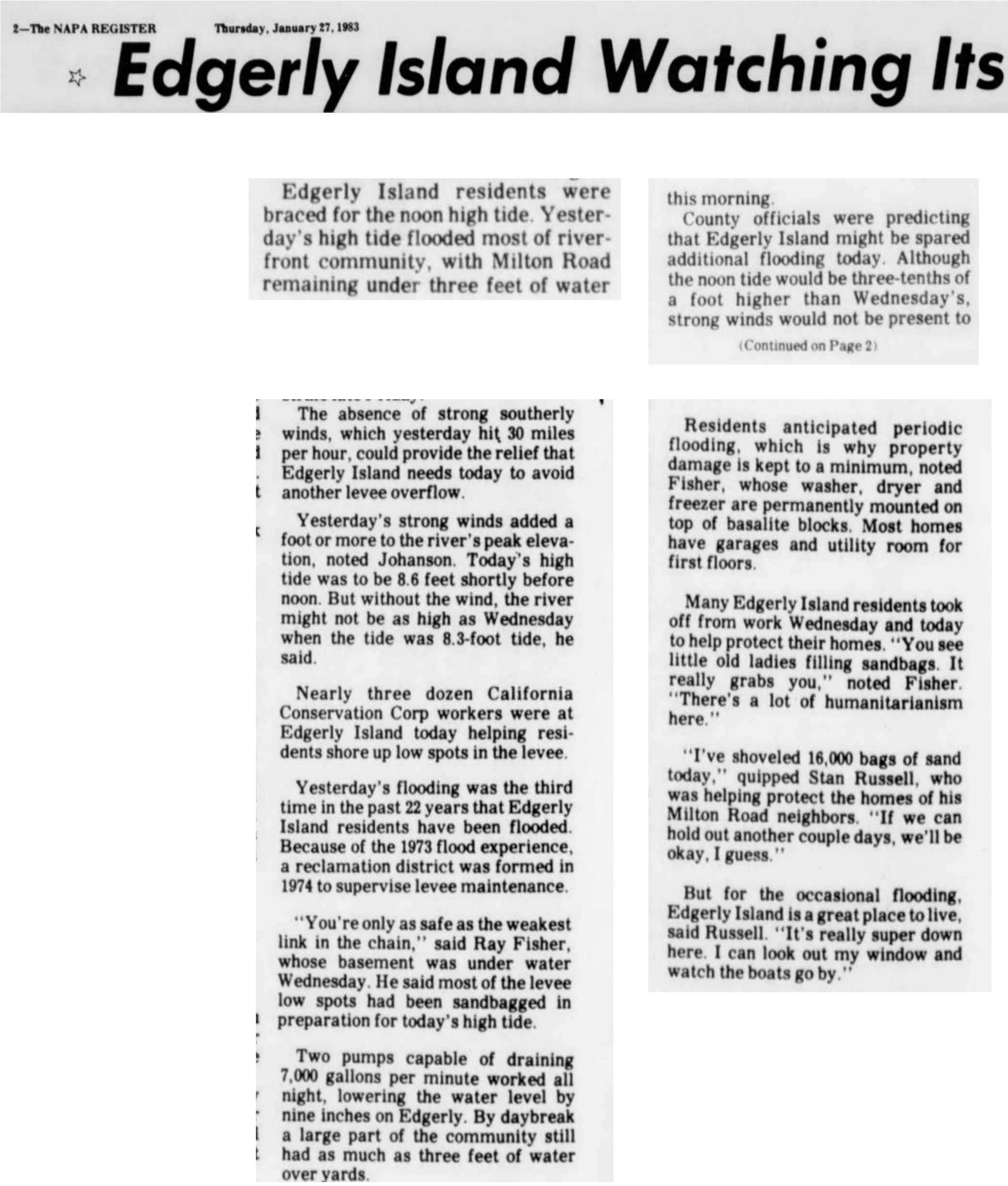


MEASURES	PARCEL-BASED FINANCING & DEPLOYMENT		GROUPS OF PARCELS FINANCING & DEPLOYMENT		DISTRICT-WIDE FINANCING & DEPLOYMENT
EARTHEN BERM AND LEVEE UPPGRADES (WEST)	NOT ADVISED		NOT ADVISED		BEST
PHYSICAL FLOOD BARRIER, STEEL SHEET PILE WALL	NOT ADVISED		POSSIBLE		BEST
PHYSICAL FLOOD BARRIER, VINYL SHEET PILE WALL	OK	LIMITED ADAPTIVE CAPACITY	POSSIBLE		BEST
FLOOD PROOFING AND ELEVATION OF *RESIDENTIAL* STRUCTURES	BEST		POSSIBLE	LIMITED ADAPTIVE CAPACITY	POSSIBLE
FLOOD PROOFING AND ELEVATION OF *NON-RESIDENTIAL* STRUCTURES	NOT ADVISED		NOT ADVISED		BEST
PREPAREDNESS AND PLANNING, INCL. LEVEE INSPECTION AND MAINTENANCE	NOT ADVISED		NOT ADVISED		BEST
INSURANCE AND OTHER RISK INSTRUMENTS	BEST		POSSIBLE		POSSIBLE

Figure 23

Comparison of Community Coordination

APPENDIX A HISTORIC FLOODING



2—The NAPA REGISTER Thursday, January 27, 1983

Edgerly Island Watching Its Levee

Edgerly Island residents were braced for the noon high tide. Yesterday's high tide flooded most of riverfront community, with Milton Road remaining under three feet of water this morning.

County officials were predicting that Edgerly Island might be spared additional flooding today. Although the noon tide would be three-tenths of a foot higher than Wednesday's, strong winds would not be present to

(Continued on Page 2)

The absence of strong southerly winds, which yesterday hit 30 miles per hour, could provide the relief that Edgerly Island needs today to avoid another levee overflow.

Yesterday's strong winds added a foot or more to the river's peak elevation, noted Johanson. Today's high tide was to be 8.6 feet shortly before noon. But without the wind, the river might not be as high as Wednesday when the tide was 8.3-foot tide, he said.

Nearly three dozen California Conservation Corp workers were at Edgerly Island today helping residents shore up low spots in the levee.

Yesterday's flooding was the third time in the past 22 years that Edgerly Island residents have been flooded. Because of the 1973 flood experience, a reclamation district was formed in 1974 to supervise levee maintenance.

"You're only as safe as the weakest link in the chain," said Ray Fisher, whose basement was under water Wednesday. He said most of the levee low spots had been sandbagged in preparation for today's high tide.

Two pumps capable of draining 7,000 gallons per minute worked all night, lowering the water level by nine inches on Edgerly. By daybreak a large part of the community still had as much as three feet of water over yards.

Residents anticipated periodic flooding, which is why property damage is kept to a minimum, noted Fisher, whose washer, dryer and freezer are permanently mounted on top of basalite blocks. Most homes have garages and utility room for first floors.

Many Edgerly Island residents took off from work Wednesday and today to help protect their homes. "You see little old ladies filling sandbags. It really grabs you," noted Fisher. "There's a lot of humanitarianism here."

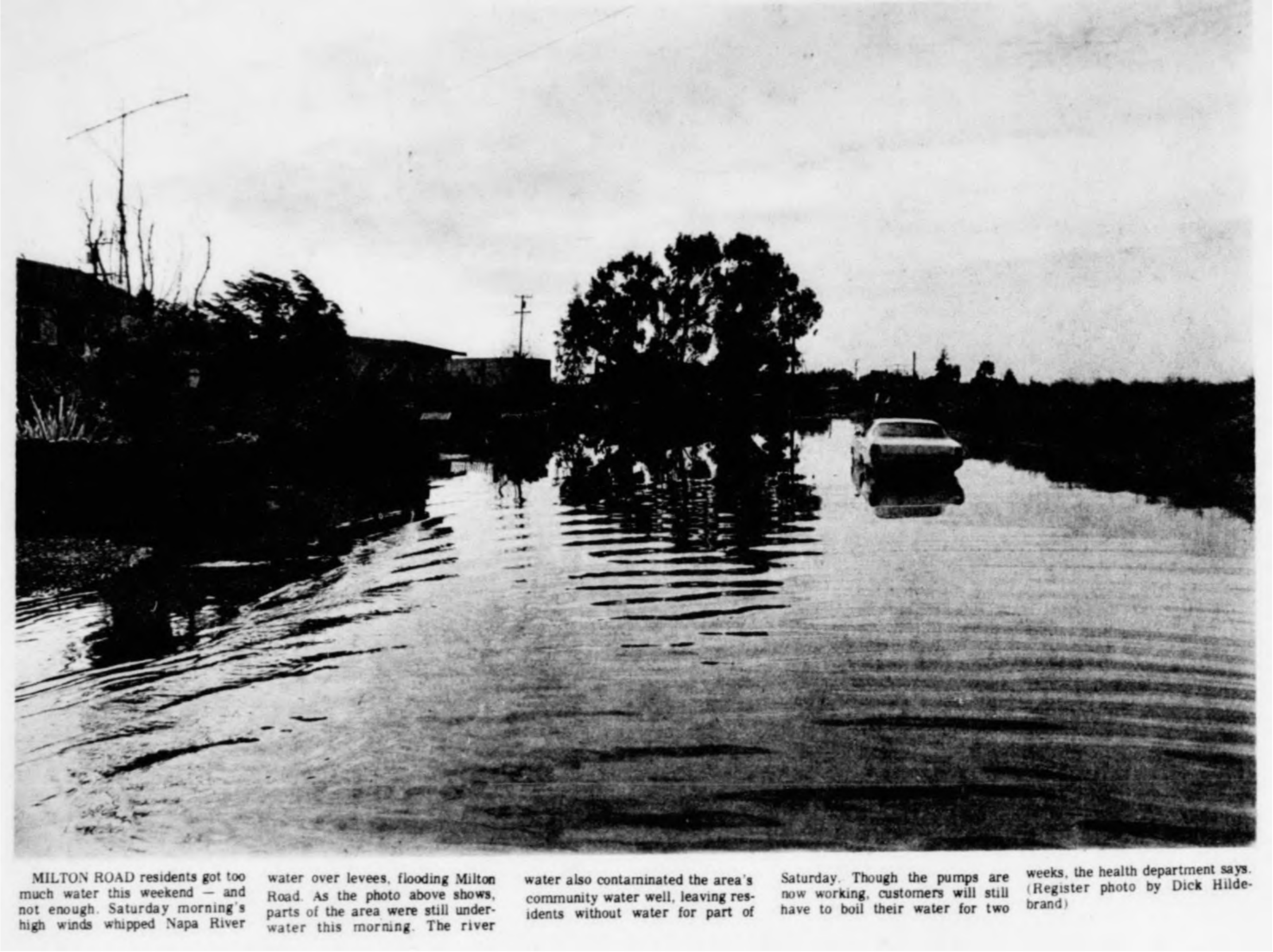
"I've shoveled 16,000 bags of sand today," quipped Stan Russell, who was helping protect the homes of his Milton Road neighbors. "If we can hold out another couple days, we'll be okay, I guess."

But for the occasional flooding, Edgerly Island is a great place to live, said Russell. "It's really super down here. I can look out my window and watch the boats go by."

SOURCE: The Napa Valley Register, January 27, 1983

Figure A.1

Flooding – January 1983



MILTON ROAD residents got too much water this weekend — and not enough. Saturday morning's high winds whipped Napa River water over levees, flooding Milton Road. As the photo above shows, parts of the area were still underwater this morning. The river water also contaminated the area's community water well, leaving residents without water for part of Saturday. Though the pumps are now working, customers will still have to boil their water for two weeks, the health department says. (Register photo by Dick Hildebrand)

SOURCE: The Napa Valley Register, December, 5 1983

Figure A.2
Flooding – December 1983

Gideon Acree, right, helps his father, Dwight Acree, carry some of their family's personal belongings from their Milton Road home on Edgerly Island in south Napa County late Friday after a levy broke, spilling more water into the area.

TODD WHARTON/REGISTER

The brunt of the storm was felt by residents on Milton Lane in the Edgerly Island area of south Napa County, where two to three homes were flooded and two dozen more were threatened when water from the Napa River jumped the levee in one place and broke through it in another. A pair of California Department of Forestry fire crews spent the afternoon sandbagging the levee to stop the leak.

At Edgerly Island, high tide at midday caused water to come over the levee and threaten a series of houses along Milton Road. A boil developed in the levee on the south end of Milton, where there are no houses, Streblow said. Elsewhere, water eroded the back side of the levee, he said.

Water entered a couple of homes, and a couple more residences were surrounded by water.

"What we've done is we've had two fire crews ... working all day to sandbag behind the residences," Streblow said. "The plan is to have a crew back (this) morning to bolster what we've already done."

No homes were evacuated. Some vehicles were moved to higher ground, but residents stayed put. "My feeling is they're sort of used to it," Streblow said. "Living below the levee, they understand it, so we were pretty much assisting them."

SOURCE: The Napa Valley Register, February 7, 1998

Figure A.3
Flooding – February 1998

Fire official says Edgerly Island is in OK condition, but levees are in bad shape

By JAY GOETTING
Register Staff Writer

One of Napa County's most flood prone areas, Edgerly Island, has weathered the current storm pretty well, but in the words of Kevin Joell, the levees there are "at high risk for failure."

Joell is an inspector for the city of Napa's fire department and serves as a volunteer for the county's Edgerly Island Fire Department. "In the grand scheme of things, it looks pretty good," he said.

Joell is also a Milton Road resident, a road where dozens of homes are protected by self-maintained levees. Some of them are not in the greatest of shape, despite the rosy picture painted earlier by some officials.

There was seepage in some areas, especially where property owners' levees are joined. "There are dozens of styles," said Joell. "After Katrina, people got concerned."

Residents met several times after the New Orleans disaster and formulated a response plan. Joell said at Edgerly Island they have the luxury of being able to plan their disasters since much of the worry occurs when the tides are at their highest.

Saturday's tide of over eight feet caused some flooding. A Level One emergency was declared at 9:30 that morning, and by 11 a.m., sheriff's deputies decided the area should be evacuated. California Department of Forestry delta crews came in to assist in sandbagging, forming a human chain to block what Joell said was, "a lot coming through the cracks."

Fifteen homes lost sewer service and are sitting empty until service can be restores, probably some time later today.

He added they don't want to alarm the Milton Road residents needlessly, but they also want to guard against complacency.

At the other end of the greater Napa area and like Edgerly Island, outside the flood control project area, residents around Salvador Creek have had their already-existing problems exacerbated by the excessive water.

Joan Foresman, a Bryce Court resident, said police alerted her at 3 a.m. suggesting she and her neighbors evacuate within two hours. She said it was the first time they have experienced an evacuation, and when they left, "rushing water was over the bank and up to my fence."

Several nearby homes had standing water inside.

Residents near Salvador Creek from Byway East to the Napa River have been pressuring city, county and flood control officials to give them additional help because of erosion, creek blockage and other problems.

Foresman said her neighbor, "has requested help for years and like us, has been basically ignored."

Recently, local officials had promised to pay greater attention to the Salvador Creek problems.

SOURCE: The Napa Valley Register, January 3, 2006

Figure A.4
Flooding – January 2006

Figure A.5

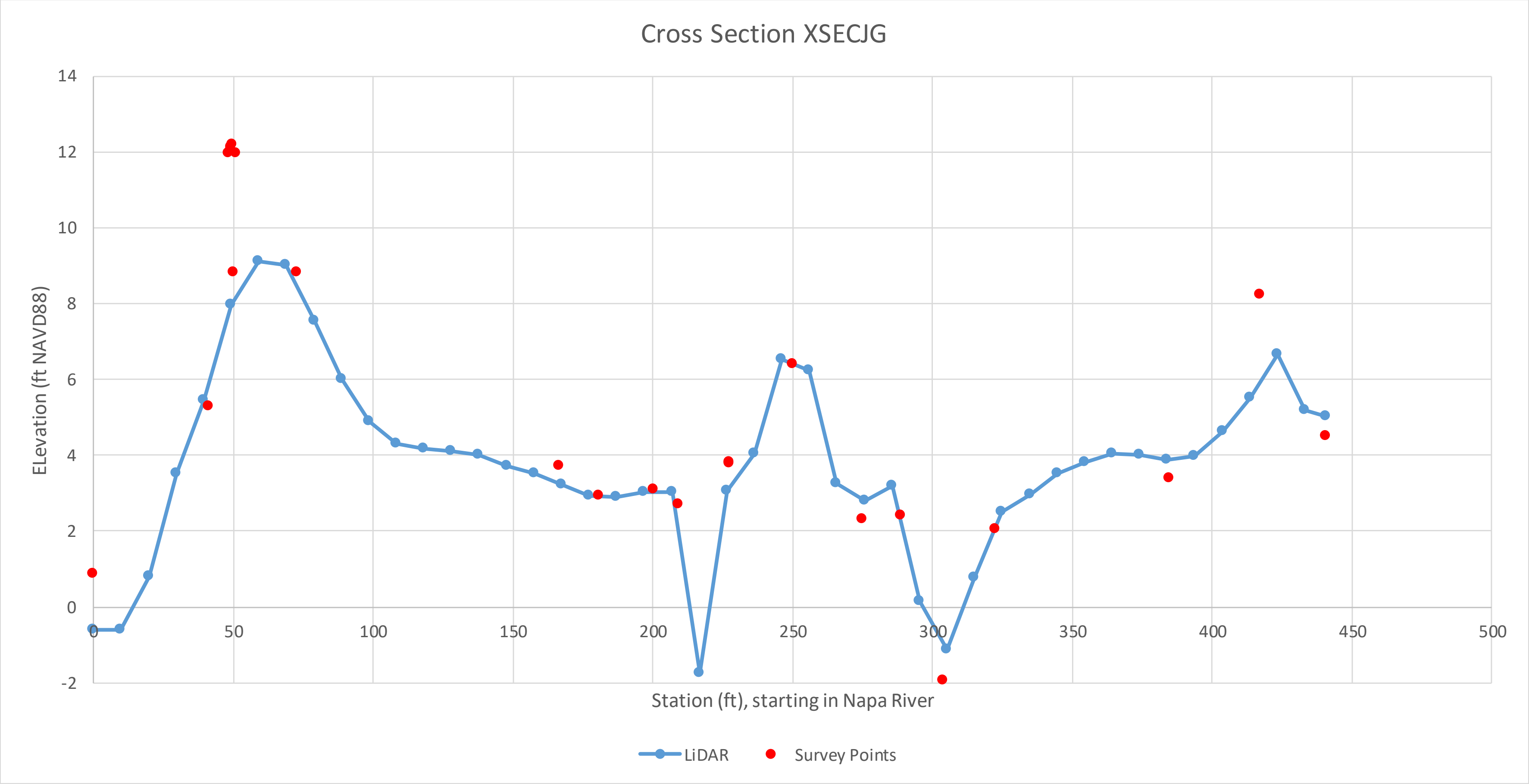
Flooding – February 2017

APPENDIX B ELEVATION SURVEY DATA

SOURCE: ESA (2017)

Edgerly Island & Ingersoll Tract Flood Study . D160787

Figure B.1
Cross Section Locations

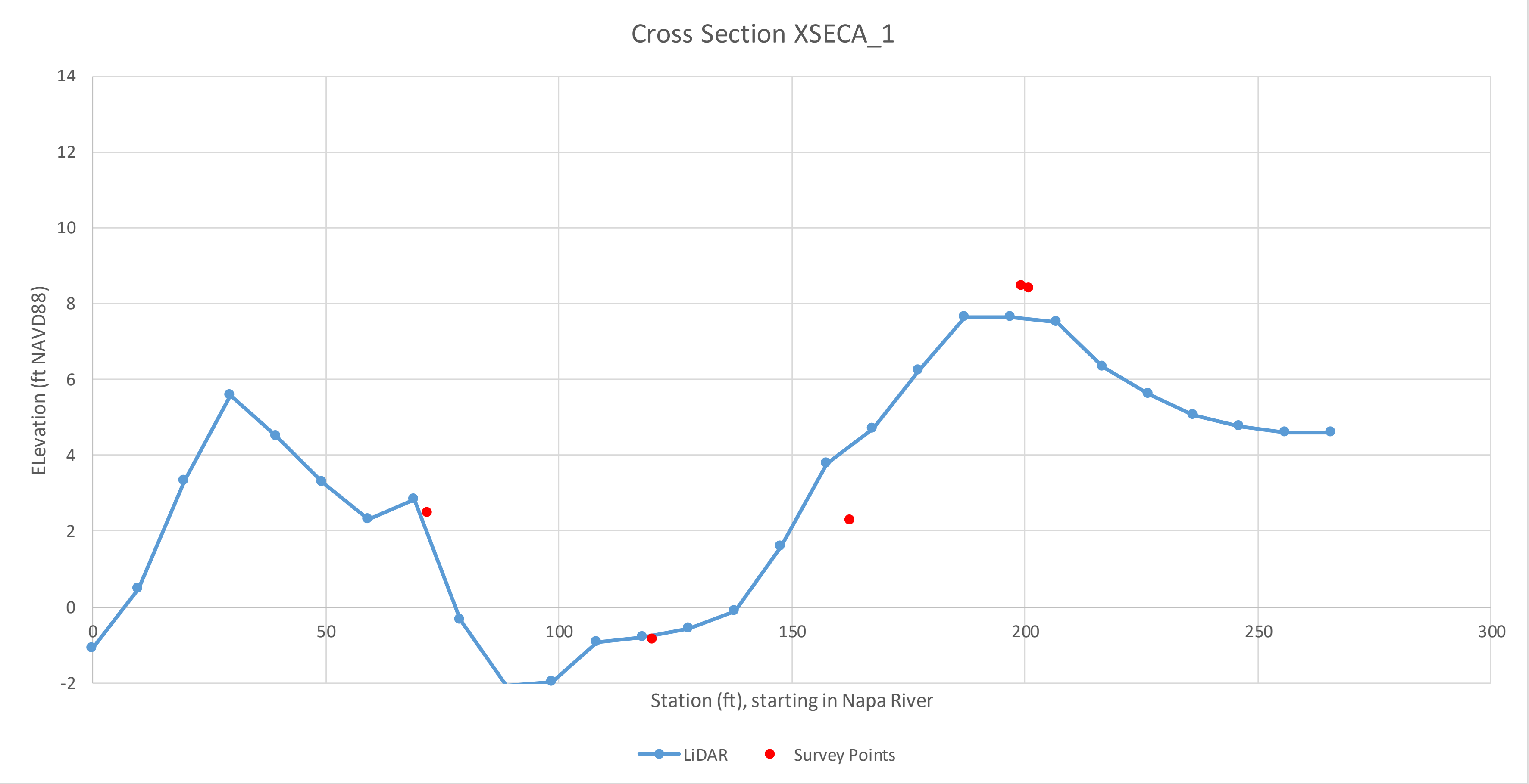


SOURCE: ESA (2017)

Edgerly Island & Ingersoll Tract Flood Study . D160787

Figure B.2

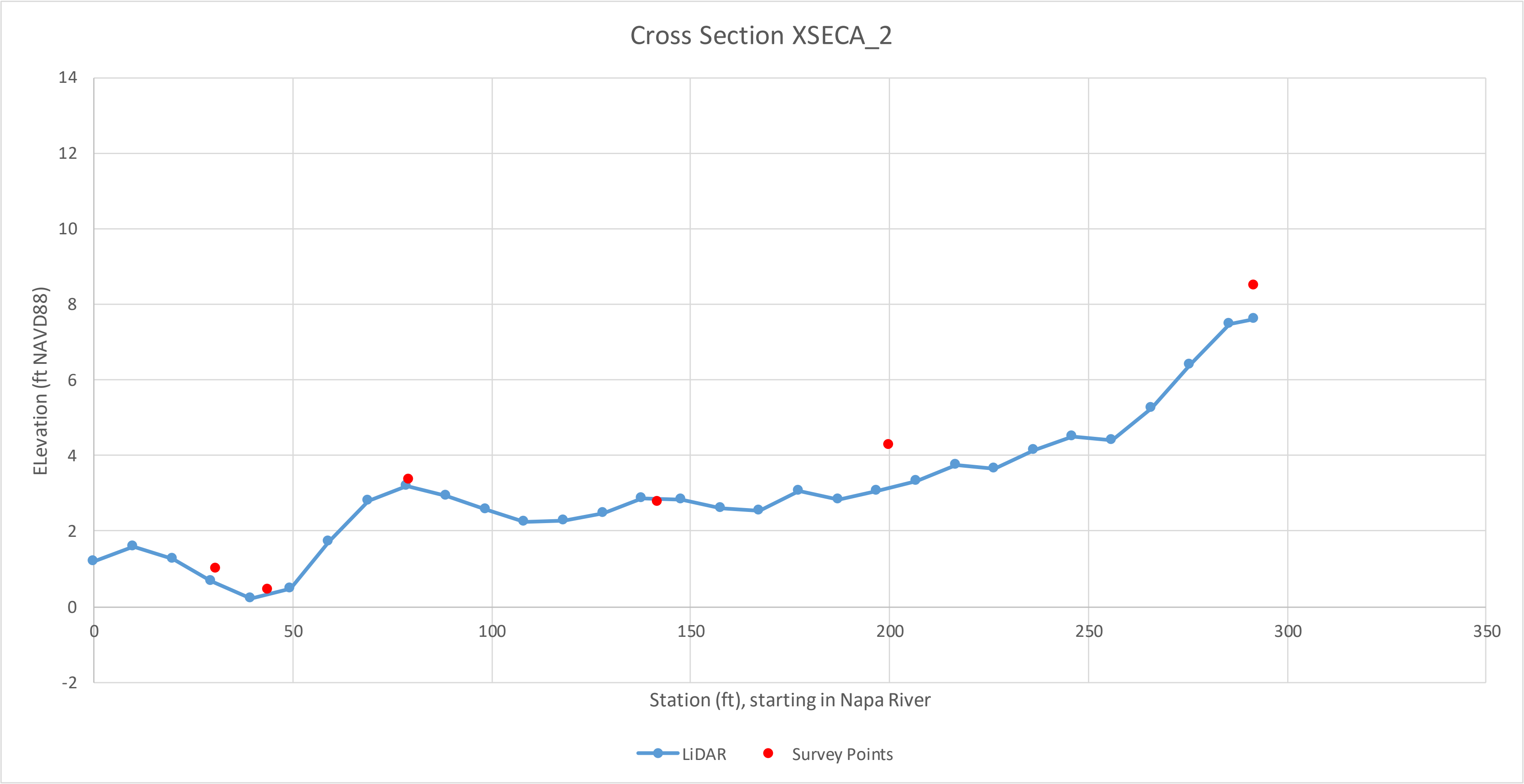
Cross Section JG



SOURCE: ESA (2017)

Edgerly Island & Ingersoll Tract Flood Study . D160787

Figure B.3
Cross Section A_1

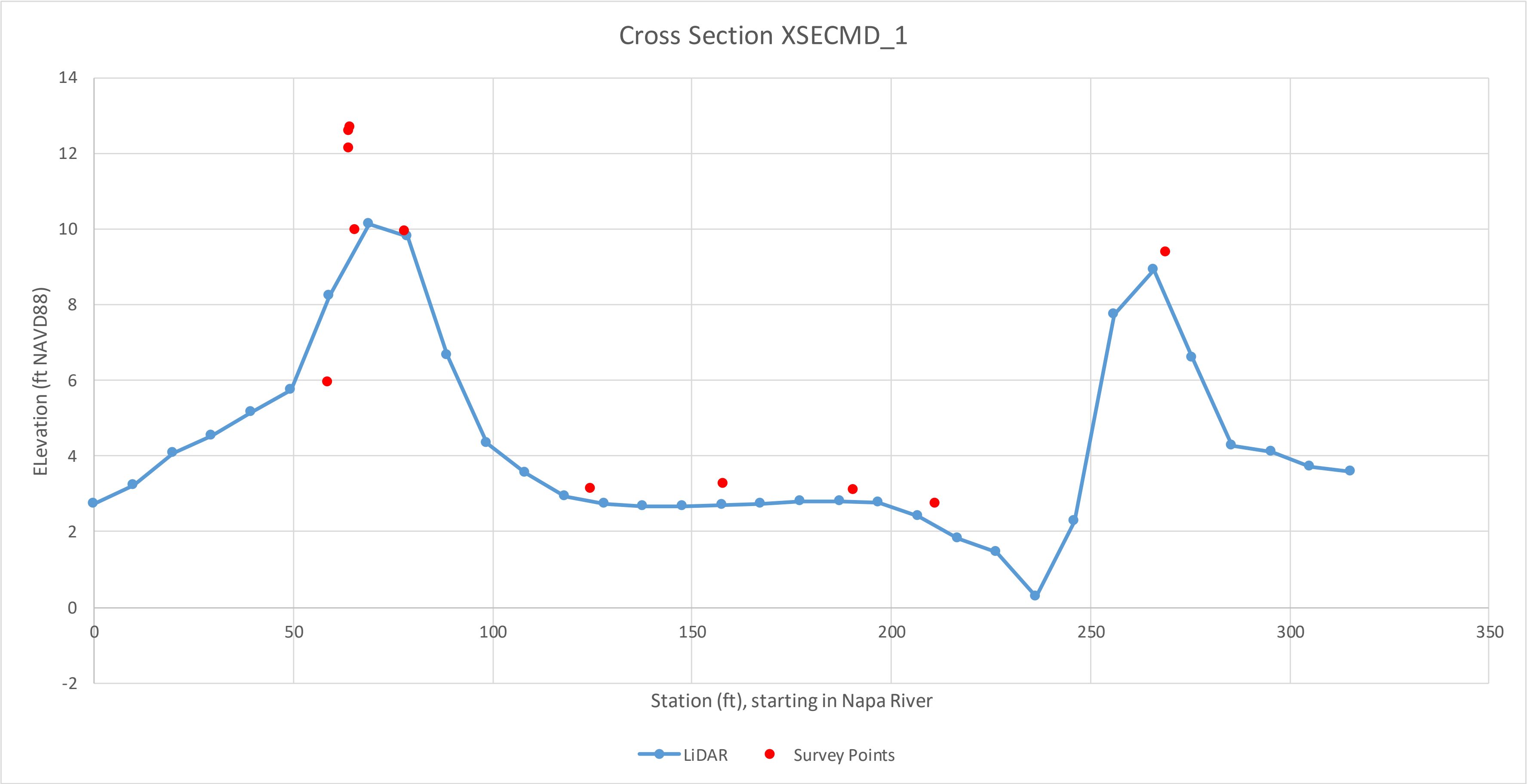


SOURCE: ESA (2017)

Edgerly Island & Ingersoll Tract Flood Study . D160787

Figure B.4

Cross Section A_2

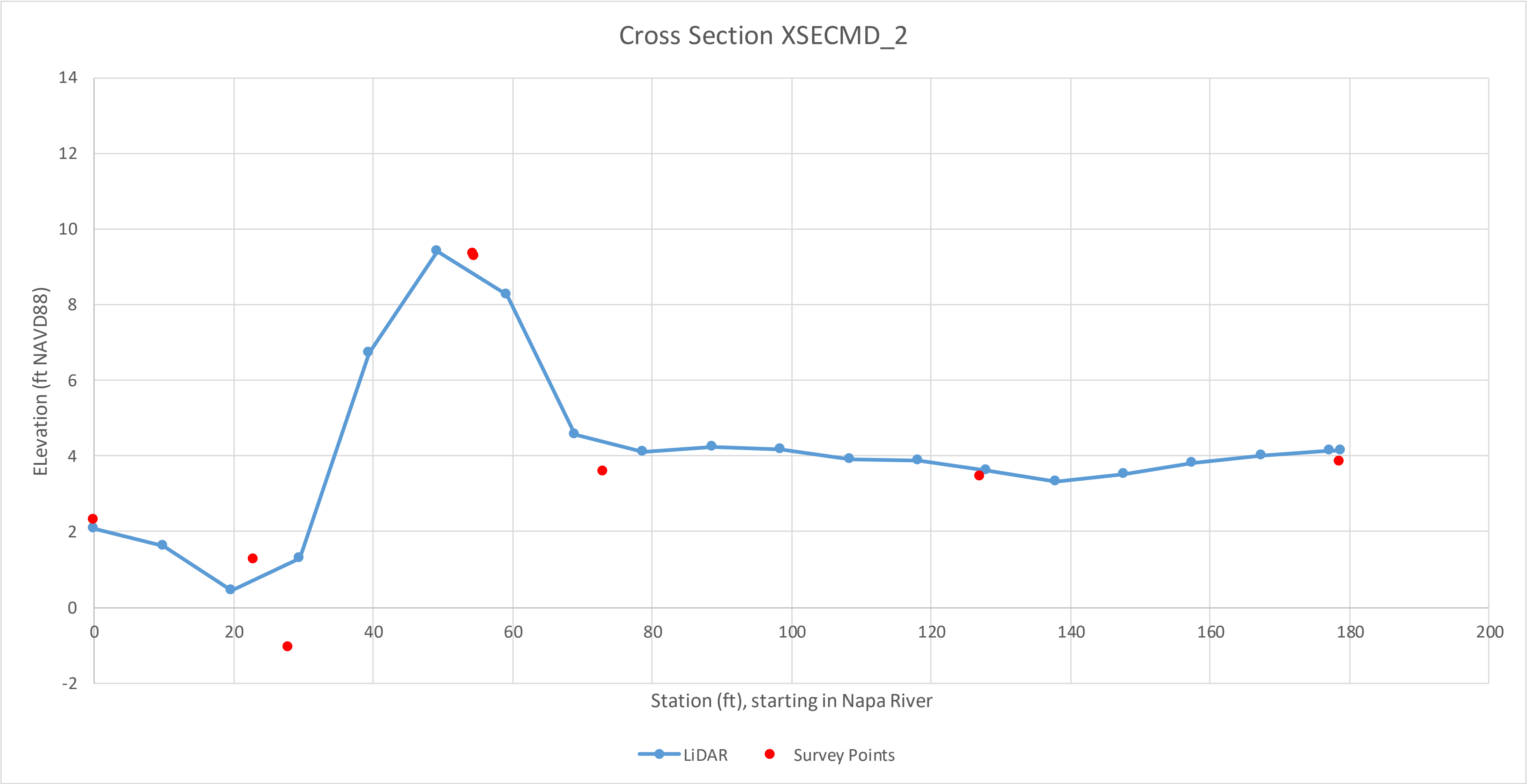


SOURCE: ESA (2017)

Edgerly Island & Ingersoll Tract Flood Study . D160787

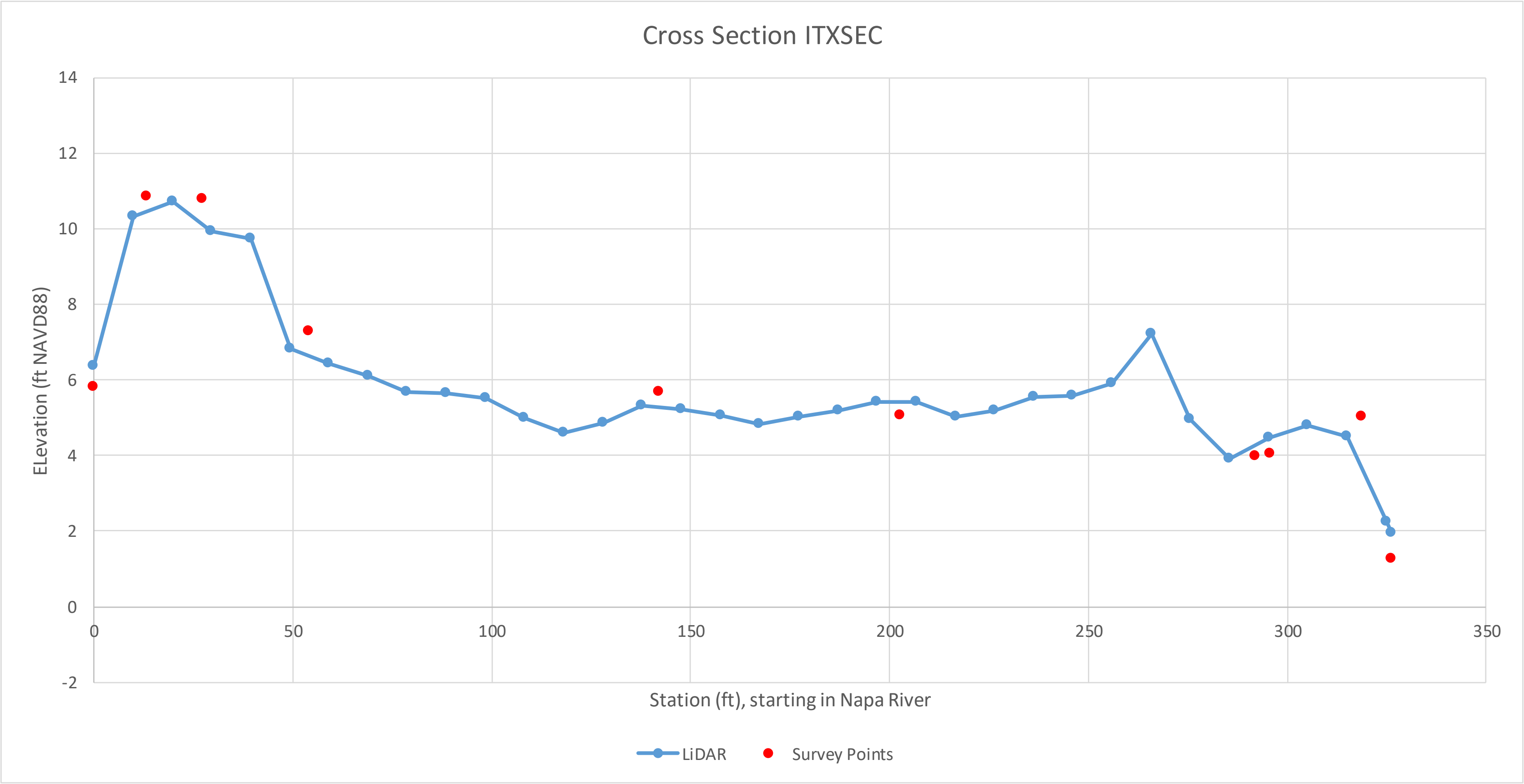
Figure B.5

Cross Section MD_1



SOURCE: ESA (2017)

Figure B.6
Cross Section MD_2

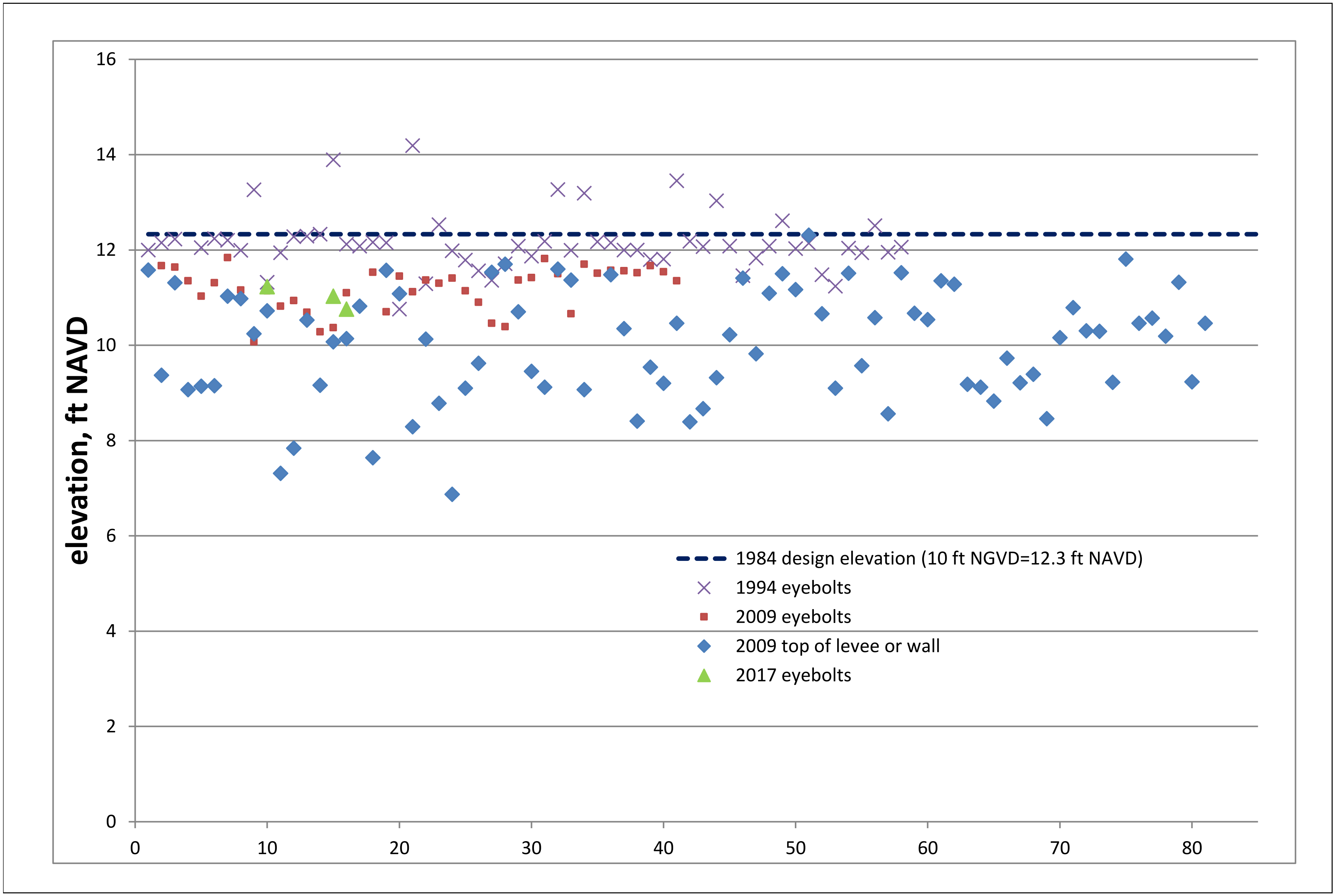


SOURCE: ESA (2017)

Edgerly Island & Ingersoll Tract Flood Study . D160787

Figure B.7

Cross Section IT



SOURCE: NRRD (1994, 2009), ESA (2017)

Figure B.8

Levee Eyebolt & Crest Elevations

APPENDIX C HYDRAULIC ANALYSIS

1.1 Extreme Water Levels

1.1.1 Data Sources

DATA	SOURCE	PERIOD OF RECORD
Still water levels	NOAA Port Chicago #9415144	1979-2017
River discharge	USGS Napa River #11458000	1983-2017
Wind speed and direction	Napa Airport	1983-2017

1.1.2 Components of Total Water Level

Total water levels are a combination of still water levels that occur regionally in the North Bay plus the addition of local effects on the Napa River next to EIIT, including river discharge, wind setup, and wave runup. These components of total water level were predicted as follows:

- The observed water levels at Port Chicago, are assumed to be representative of regional North Bay still water levels. An additional surcharge of 0.4 was added to the Port Chicago water levels to account for the higher tidal datums at EIIT. This surcharge was based on the difference between mean higher high tide in the Carquinez Strait, near the Port Chicago gauge, and the Brazos Bridge adjacent to EIIT (USACE, 1975).
- The river discharge contribution was approximated from the observed discharge by using the discharge-water level relationship from FEMA (2016).
- The wind speed reduced to the degree that the wind direction was off-axis relative to the principle southerly fetch aligned with the Napa River. Then this reduced wind speed was used to predict wind setup and wave heights.
- Wind setup, the tilt of the water surface when wind acts as sustained friction and piles water up on the shoreline, was estimated according to setup equation from USACE (1989).
- Wind waves were predicted using fetch-limited, shallow water methods from USACE (2002), for an assumed southerly fetch of 10,000 ft. Wave runup when the predicted waves arrive and surge up the levee were then predicted using the Direct Integration Method (FEMA, 2005).

These components were calculated hourly from the observations from 1983-2017 to generate time series of each component, except during brief periods when data was not available.

1.1.3 Extreme Value Analysis

From each component's time series, the annual maximum values were extracted and used to fit a Weibull extreme value distribution. The resulting extreme values for the components which contribute to total water level are summarized in Table 1.

Table 1 Extreme values for total water level components

Return interval	Still Water Level (ft NAVD)*	Wind & Riverine Setup (ft)	Wave Runup (ft)
100-year (1% annual exceed. prob.)	9.4	1.3	2.6
10-year (10% annual exceed. prob.)	8.9	0.7	1.6
1-year (99% annual exceed. prob.)	7.8	0.1	0.5

* Based on Port Chicago observations, with addition of 0.5 ft to account for difference between Carquinez Strait and Brazos Bridge.

The extreme values of these components were then combined into several plausible event-based scenarios to represent possible joint occurrences of the components. The components are partially correlated in their occurrence since they are all associated with winter storms (Garrity et al., 2007). The resulting total water levels are shown in Table 2.

Table 2 Extreme values for total water level scenarios

Event scenario	Still Water Level (ft NAVD)*	Wind & Riverine Setup (ft)	Wave Runup (ft)	Total Water Level (ft NAVD)
100-year / 1% annual exceedance probability				
100-year SWL/1-year setup/10-year runup	9.4	0.1	1.6	11.2
10-year SWL/1-year setup/100-year runup	8.9	0.1	2.6	11.7
100-year SWL/10-year setup/1-year runup	9.4	0.7	0.5	10.7
10-year SWL/100-yr setup/1-year runup	8.9	1.3	0.5	10.8
10-year / 10% annual exceedance probability				
10-year SWL/1-year setup/1-year runup	8.9	0.1	0.5	9.6
10-year SWL/5-year setup/no runup	8.9	0.5	0.0	9.4
1-year / 99% annual exceedance probability				
1-year SWL/no setup/no waves (e.g. king tides)	7.8	0.0	0.8	7.8

An alternate approach, which combined all the components to generate a time series of total water level, and then estimated the extreme values from the total water level time series was also evaluated. However, the resulting 100-year extreme value was more than a foot less than those reported from high water mark observations during the January and December 1983 events (Bracewell, 1984). Since the 1983 events are considered the 100-year event of record but could not be re-created by extreme value analysis of the total water level time series, the event-based approach described above was used instead. The total water level approach may fall short of predicting the observed extreme water levels because the data sources are too far apart and not resolved with enough frequency to capture their interactions adjacent to EIIT.

1.2 West Levee Overtopping and Overflow Assessment

The purpose of this rudimentary assessment is to estimate potential inflow volumes and resulting increases in water level that could occur in the managed wetlands on the west side of Edgerly Island for a range of extreme flood scenarios. Mud Slough readily conveys flooding to the west side of Edgerly Island, where the system of embankments and managed wetlands intercepts or partially intercepts this flooding before it reaches the inboard levees that immediately protect the project area. By providing a prediction of water level increase in these managed wetlands, this assessment informs the potential flood hazard to the project area from the west.

1.2.1 Approach

This assessment considered a range of flood scenarios, estimated to range from the 10-year still-water level to scenarios in excess of 100-year conditions. Potential breaching and one foot of sea-level rise were also considered. Because peak water levels are driven by tides, each flood scenario is assumed to last for two hours, approximately the duration of high tide.

The distribution of outboard levee crest elevations and managed wetland storage volumes were derived from 2010 LiDAR data. For a starting elevation in CDFW Pond 8, the water levels are reported as managed at about 4 ft NAVD, consistent with the observed water level on 7/11/17 of 4.5 ft NAVD. Ground surface elevations in the Flood District dredge disposal areas area 2-5 ft NAVD and may include some pre-existing standing water during the wet season. The elevation on the inboard levee/berm between these storage areas and developed Edgerly Island is approximately 8.5 ft NAVD. These elevations suggest that the areas between the west outboard and inboard levees pose an increasing hazard once about 4 ft of water is stored in these areas.

For the flood scenarios' water level and wave conditions, the potential inflow volume from both wave overtopping and still-water overflow was considered, as quantified by the empirical equations from EuroTop (2016).

Accounting for the storage volume of the managed wetlands, the flood inflow volume was converted to a corresponding increase in water levels within the managed wetlands. Note that for the largest events, the predicted water level increase can be significantly higher than the inboard levee crest elevations. In reality, this would cause water would spill over the levee crests, including into developed Edgerly Island and not achieve such high levels. However, the increase in water level is still reported as an indicator of the severity of the flood hazard.

Based on the predicted increase in water levels in the managed wetlands, the flood events were classified as:

- 3 ft or less – Total inflow can probably be stored with minimal risk to inboard levee.
- 4-5 ft – Increased flood hazard from storage areas to developed area of Edgerly Island. Since storage area water levels would be close to the inboard levee crest and of relatively short duration, the overtopping volume into the project area would probably manageable if it did occur.

- >5 ft – Overtopping of inboard levee and into the project area would be significant and likely cause flood damages.

No additional analysis was done for water levels west of Ingersoll Tract. Flooding in this area is likely dominated by a different process, runoff from the local watershed.

This assessment does not consider flood hazard due to seepage. When tide gate failed in the Flood District's outboard levee and caused partial filling of the dredge disposal areas, seepage through the inboard berm into the developed portion of Edgerly Island was observed. This shortcoming has already been addressed in Plan 2 and 3, which call for re-processing of the inboard berm to improve its capacity to resist seepage and remain stable when water levels rise on its western side, as well as for embedded sheet pile.

1.2.2 Results

The potential increase in managed wetland water levels is reported in Table 3 for the NCFCWCD dredge disposal area and in Table 4 for CDFW Pond 8 for existing conditions and one foot of sea-level rise. As indicated by the color-coded last column, the managed wetlands can accommodate increased in water levels for moderate events. However, for the more extreme events, such as 100-year still water levels with waves, the increase in managed wetland water levels could significantly threaten the project area.

Table 3. Increase in NCFCWCD dredge disposal area water level due to wave overtopping and storm surge overflow

Scenario	Water Level (ft)	Wave Height (ft)	Breach	Increase in Storage Area Water Level (ft)
Existing Conditions				
10-yr still water level	9.2	0	No	0.0
10-yr still water level & 1 ft waves	9.2	1	No	1.0
10-yr still water level & 2 ft waves	9.2	2	No	2.1
10-yr still water level & breach	9.2	1	40 ft wide, 3 ft deep*	2.1
100-yr still water level & 1 waves	10	1.4	No	4.5
100-yr still water level & 2 ft waves	10	2	No	7.5

* Breach assumed to be 40 ft at 6 ft NAVD

Table 4. Increase in CDFW Pond 8 water level due to wave overtopping and storm surge overflow

Scenario	Water Level (ft)	Wave Height (ft)	Breach	Increase in Managed Wetland Water Level (ft)
Existing Conditions				
10-yr still water level	9.2	0	No	0.2
10-yr still water level & 1 ft waves	9.2	1	No	1.0
10-yr still water level & 2 ft waves	9.2	2	No	4.6
10-yr still water level & breach	9.2	1	40 ft wide, 3 ft deep[*]	2.2
100-yr still water level & 1 waves	10	1.4	No	5.7
100-yr still water level & 2 ft waves	10	2	No	9.2
+1 ft SLR				
10-yr still water level	10.2	0	No	4.1
10-yr still water level & 1 ft waves	10.2	1	No	5.9
10-yr still water level & 2 ft waves	10.2	2	No	10.4
10-yr still water level & breach	10.2	1	40 ft wide, 3 ft deep[*]	8.8
100-yr still water level & 1 waves	11	1.4	No	15.6
100-yr still water level & 2 ft waves	11	2	No	21

[*] Breach assumed to be 40 ft at 6 ft NAVD

1.3 References

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APPENDIX D: GEOTECHNICAL AND STRUCTURAL ENGINEERING ANALYSES

1.1 General Considerations

1.1.1 Introduction

This Appendix is a summary of the geotechnical and structural analyses that were conducted for flood management measures at Edgerly Island and Ingersoll Tract (EIIT). Not all measures discussed in this Appendix were retained in the flood management plans. The main body of the report provides additional details on the measures' integration in the final plans.

1.1.2 Commonly Used Acronyms

This study incorporates a preliminary regulatory review aimed at assessing the overall regulatory burden associated with each of the proposed measures. In doing so, we used acronyms to designate certain agencies or common regulatory processes. For practical purposes, we also listed other commonly used acronyms. These are summarized in the table below.

Table 1 Commonly Used Acronyms.

Acronym	Definition
BA	Biological Assessment
RWQCB	Regional Water Quality Control Board
BCDC	Bay Conservation and Development Commission
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
EIR	Environmental Impact Report
EPA	Environmental Protection Agency
FESA	Federal Endangered Species Act
IS/MND	Initial Study/Mitigated Negative Declaration (part of CEQA process)
ITP	incidental take permit
JD	Jurisdictional Delineation
NAVD	National Vertical Datum of 1988

Acronym	Definition
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
Section 1602	Streambed Alteration Agreement, issued by CDFW
Section 401	Section 401 of the Clean Water Act (lead agency is EPA)
Section 404	Section 404 of the Clean Water Act (lead agency is USACE)
SHPO	State Historic Preservation Officer
SLR	Sea-level rise
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service

1.1.3 Flood Elevation Criteria

The engineering calculations were based on certain flood elevation criteria, which are discussed in greater details in the main body of the report. In summary, the following elevation guided the analyses:

- Plan 2: Vinyl Sheet Pile Floodwall - target elevation of 12.5 ft NAVD
- Plan 3: Steel Sheet Pile Floodwalls - initial target elevation of 12.5 ft NAVD, and long-term target elevation of 15.5 ft NAVD via second phase addition of a concrete cap and incorporating one foot of long-term soil settlement.

1.2 Physical Flood Barriers

1.2.1 Earthen Levees

Earthen levees were identified as an option to upgrade or build a continuous outboard levee on the west side of the project area. The primary reasons driving recommendation for widening or building levees are the presence of existing embankments, which provide a basis for upgrade, and the overall lack of constraints which could otherwise limit levee improvements through fill placement.

(a) Definition

In this report, the term “levee” refers to an embankment whose primary purpose or demonstrated capacity is to furnish flood protection from high water. Embankments which have not demonstrated this capacity are referred to as “berms”.

None of the outboard levee improvements proposed herein would be sufficient to meet FEMA accreditation requirements. Rather, the improvements would consist of providing additional physical protection against flood waters during high water events.

(b) Engineering and Estimating Considerations

Consistent with the scope of work for this study, no quantitative assessment of sub-surface conditions was performed. Rather, to develop conceptual levee configurations, geotechnical and structural parameters were based on reference materials, engineering experience, and data acquired from similar projects, as well as visual evidence gathered during site visits. The thickness, compressibility, strength, and stress history of the soil column should be evaluated further during the design phase of any of the improvements elaborated upon in this report. Offset distances and impacts to utilities should also be assessed further.

For cost estimating purposes, U.S. Army Corps of Engineer (USACE) designated Category II construction method is assumed. Category II construction method is applicable where most or all of the following criteria are met:

- Criterion 1: *There are no severe space limitations and steep-sloped Category I embankments are not required*. This criterion applies. It means that the levee improvements will not need to meet some of the more stringent construction criteria where embankment slopes are much steeper than the proposed 3H:1V slope ratio.

- Criterion 2: *Relatively weak foundations could not support steep-sloped Category I embankments*. This criterion applies. It means that the sub-surface conditions reflect the soil's limited capacity to withstand vertical forces imparted by tall and narrow embankments. Rather, in this case, the levee cross-sectional width will be larger, allowing the total weight of the increased levee to spread over a larger area, therefore reducing the load demand on the existing soil.

- Criterion 3: *Water content of borrow materials or amount of rainfall during construction season is such as not to justify Category I compaction*. This criterion most likely applies: While an assessment of the composition of fill material was not conducted in this study, construction is not anticipated to require additional conditioning or treatment to reduce the water fraction.

- Criterion 4: *Under-seepage conditions are such as to require wider embankment base than is provided by Category I construction*. This criterion may not be directly applicable to the entire project alignment; as under-seepage has not been confirmed based on visual evidence collected at the site. That said, the proposed design incorporates a wide cross-section which will further increase resilience against the risk of through-seepage during flood conditions.

(c) Proposed Measures by Reach

Consistent with the results summarized in the main report, the following improvements and upgrades were discussed for the three West Levee segments, referred to as West Levee 1 through West Levee 3.

West Levee 1

The proposed improvements for this segment include expanding the levee crest elevation and having minimum 3H:1V levee side slope ratio[1]. This is shown in Figure 1. For this segment to achieve its target design elevation for Plan 2, we estimated that a net increase of 4.5 ft of additional vertical capacity will need to be installed on top the existing levee in several lifts, spaced apart by a resting period. Such approach is required to avoid overstressing the ground. This increase of 5.5 ft was calculated as follows:

- 4 ft of extra vertical capacity required to reach the design elevation of 12.5 ft NAVD above the existing crest elevation of 8.5 ft NAVD;
- 1.5 ft overbuild capacity to compensate for the estimated effects of long-term settlement

The placement of fill would proceed in at two lifts, as follows.

- First lift: Place approximately 1.5 ft of fill on the levee, and provide an initial levee crest at 10 ft NAVD;
- Second lift: After adequate consolidation has taken place, place additional to provide the 3 ft of vertical capacity to achieve the design elevation.
- Additional fill would be warranted depending on the long-term elevation desired for the levee crest, e.g. for sea-level rise under Plan 3.

The preferred placement site for the fill is to the east of the crest, on the Milton Road side to avoid potential regulatory hurdles: it is possible that placing fill in the California Department of Fish and Wildlife (CDFW) pond may trigger wetland fill and/or streambed alteration permits. This would need to be confirmed in future project stages during a formal regulatory evaluation assessment.

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[1] The designation 3H:1V refers to the proposed slope ratio for the levees. Physically, it signifies that 3 ft of horizontal extent is needed achieve 1 foot of elevation. A 3H:1V slope ratio corresponds to a slope percent of 33.5% and a slope angle of 18 degree measured from the horizontal.

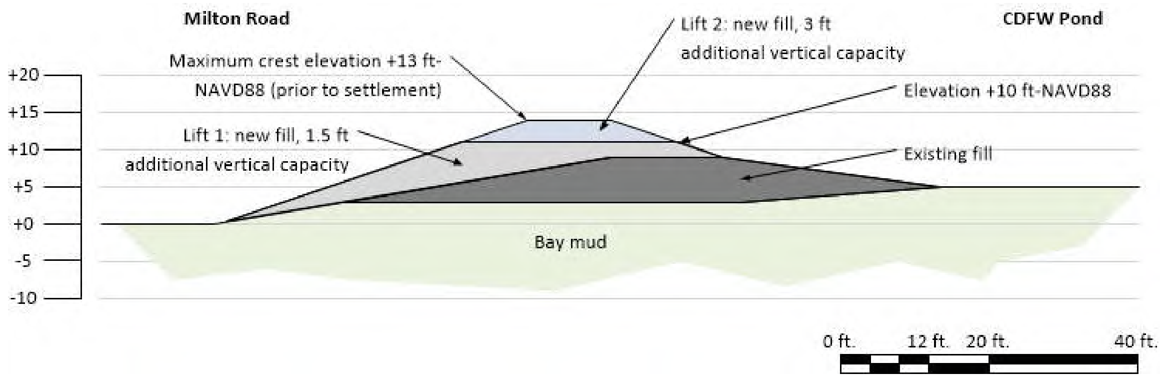

Figure 1 **Schematic of the preliminary configuration of West Levee 1, shown here for a 12.5 ft NAVD crest elevation.**

<u>West Levee 2</u>

A similar approach is proposed for West Levee 2, though additional constraints apply, primarily driven by the presence of jurisdictional wetlands formerly delineated in the County's dredge spoil disposal area. Existing Light Detection and Ranging (LiDAR) data indicates that the existing levee is approximately 15-ft wide with a 2H:1V side slope ratio extending toward Milton Road; and a 3H:1V side slope ratio toward the County's dredge disposal site. The existing elevation of the levee crest is approximately 8.5 ft NAVD. West Levee 2 is a non-engineered berm, comprising on non-compacted fill, for which additional conditioning will be required prior to upgrade, to address the steep slopes and observed seepage.

Two steps were considered for this specific levee segment:

<u>First step:</u> the existing embankment would be excavated, and replaced, using appropriate compaction methods. The goal is to re-process the native fill so as to give it more desirable mechanical properties (e.g. compaction, composition, stability, etc.) and alleviate the risk associated with any slope stability and seepage-prone lenses which may be present along the segment. To achieve the desired side slope of 3:1, the placement of additional material would widen the levee beyond its existing footprint, with potential encroachment into existing wetlands.

- <u>Upgrade path #2</u> would consist of driving sheet piles once the native fill has been re-processed. Rather than using additional fill to provide additional vertical capacity, sheet piles would be driven in the re-processed embankment. The design elevation of the pile tip would be approximately 12.5 ft NAVD via vinyl sheet pile (Plan 2) or 15.5 ft NAVD via steel sheet pile (Plan 3). In absence of significant fill placement, long-term settlement would be minimal, though proper evaluation of long-term settlement in the excavated and replaced embankment is required to provide adequate long-term pile tip elevation.

<u>West Levee 3</u>

The proposed levee would be constructed adjacent just to the west of Milton Road, on what is now private property. Fill placement with an embedded floodwall appears as the preferred option, because the low existing ground surface elevation of approximately 2-3 ft NAVD is too low for a floodwall alone and just fill is likely to have greater wetlands impacts. While a flood wall imbedded within the existing Milton Road embankment could substantially reduce the potential wetlands impact, the road embankment is only at an elevation of only 4-8 ft NAVD. Therefore, a floodwall within the existing embankment, to 12.5 ft or 15.5 ft NAVD would place a wall up to 11 feet high right next to the Milton Road southbound travel lane, which is thought to be a less preferable design for roadway users. Confirmation of the preferred design would be address in later project phases.

LIDAR data indicates that the existing ground surface is approximately 2-3 ft NAVD. The result of conceptual-level settlement analyses indicate that the placement of 11 ft of new fill will cause approximately 4 ft of settlement.

Based on past project experience, new fill placement on Bay mud should be limited to roughly 5 ft-thick lifts to alleviate the risk of excessive loading on the unconsolidated soils. That said, the levee crest portion can be constructed higher to meet the minimum levee crest requirement, with a target elevation of 9.5 ft NAVD. The new fill placement should be offset from the roadway and ditch to avoid impacts to underground utilities. Sheet piles would be installed along the levee's crest to further raise the crest elevation to the design elevation of 12.5 ft NAVD (with vinyl sheet piles) or 15.5 ft NAVD (with steel sheet piles).

A summary of measures is shown in the table below.

Table 2 Summary of earthen berm upgrades along West Levees

Segment	Existing Elevation	Anticipated Upgrade Method
West Levee 1	Approx. EL +8.5 ft NAVD	New fill placement Place additional fill to desired long-term elevation, with allowance for long-term settlement Place in two lifts to allow for sufficient consolidation to take place
West Levee 2	Approx. EL +8.5 ft NAVD	New fill and sheet piles Excavate and replace existing fill Place additional fill as needed Drive sheet piles to provide final vertical capacity
West Levee 3	Approx. EL +2-3 ft NAVD	New levee fill and sheet piles Place in two lifts to allow for sufficient consolidation to take place; limit lift thickness to 5 ft or less, except at levee crest where higher lifts are allowable. Drive sheet piles to provide final vertical capacity

(d) Regulatory Considerations

Regulatory considerations cover both permitting and environmental documentation (e.g. CEQA). A basic regulatory review was conducted to assess the potential costs associated with developing permitting and environmental documentation necessary for the proposed levee upgrades to be implemented. The goal of this regulatory review is to detect any critical flaw associated with the various upgrades discussed earlier.

The level of regulatory involvement varies by segment, as elaborated upon below. This section also documents the various cost assumptions related to the preparation of these permits and documentation. The below itemized list should be considered a risk review of items that must be considered during a later design phase. While not all of the items outlined below will necessarily need to be obtained for the project to be completed, the cost estimate adopted a worst-case stance, and included all of these items in the final estimate. Historically, costs associated with regulatory work in the Bay Area have been significant, and a prudent approach to cost estimating is warranted.

All acronyms are defined in Table 1.

- West Levee 1
    - Impacts to wetlands can be minimized by upgrading the levee from the Milton Road (east) side. Wetland may be impacted on the pond side for nearly the entire length of the new levee; though this would need to be confirmed with CDFW, which has upgraded the existing levee in a manner similar to what is being proposed in this report.
    - If the pond has a tidal connection, a BCDC permit will be needed (as warranted by the 100’ jurisdictional band extending from the High Tide Line[3] at pond), regardless of where fill placement takes place.
    - A CDFW Section 1602 Streambed Alteration Agreement will be required if fill is placed on the pond site.
    - If construction phasing can avoid all wetland impacts, some permits may not be necessary (except for BCDC, if in their jurisdiction).

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[3] According to 33 CFR Part 328, the term "high tide line” means the line of intersection of the land with the water's surface at the maximum height reached by a rising tide. The line encompasses spring high tides and other high tides that occur with periodic frequency but does not include storm surges in which there is a departure from the normal or predicted reach of the tide due to the piling up of water against a coast by strong winds such as those accompanying a hurricane or other intense storm.

- <u>West Levee 2</u>
  - The proposed approach would reduce impact on adjacent wetlands. Not all impacts can be avoided, specifically near the railroad. If construction of the proposed levee can avoid all wetland impacts, some permits may not be necessary (except for BCDC, if in their jurisdiction), see above.
  - BCDC jurisdiction (100’ shoreline band) will be affected at the northern end near the EIIT treatment plant and railroad, thereby requiring a BCDC permit.
  - A Section 1602 Streambed Alteration Agreement only required for levee reaches on banks of ponds/shoreline (primarily at the north and south ends of the levee).
- <u>West Levee 3</u>
  - No wetlands were readily identified in the levee footprint in this study; however, out of caution, our approach incorporated contingency to cover for that eventuality. If it is confirmed that there are no wetlands, permits may not be required for the levee (except for BCDC if in their jurisdiction).
  - Section 1602 Streambed Alteration Agreement would only be necessary for any work performed in the drainage channel.

Cost estimates associated with the above-described regulatory work are as follows.

- CEQA compliance will depend on project complexity and public interest and/or opposition. All three levee segments should be covered in a single document. The cost of an IS/MND is estimated at $75 to $100k; an EIR would carry a much higher level of effort, and our estimates range from $500-950k, depending on the level of complexity and resources agencies’ level of interest in the project.
- Permitting costs will vary, but were estimated as follows:
  - Technical studies necessary for the preparation of permits would include: $40-60k (jurisdictional delineation, biological assessment, cultural, and botanical surveys) – one set of reports that cover the entire project area will be sufficient.
  - Permit applications is estimated between $80 to $120k. It includes: USACE Section 404 and 401, BCDC, CDFW Section 1602, CESA, FESA, NHPA Section 106. We assumed that only one set of applications for the entire project area will be submitted.
  - We carried out an allowance for conducting regulatory agency coordination, a necessary component of any permitting effort, which for a project of this magnitude ranges anywhere from $35k to $60k.

Some assumptions were made in our cost estimates; these are anticipated to evolve as more information becomes available and is gathered during subsequent phases of design. They read as follows.

- Permits are likely only necessary for the first lift associated with construction work; later lifts would not likely require permits.
- Assume one set of permits would be secured for the entire project (all 3 West Levees). Permits will cover 5 years for construction followed by a 5-year potential renewal, which corresponds to the 10-year consolidation cycle recommended for the placement of fill on soft bay muds.
- There is a 10-year limit that applies to permits involving phased construction. Therefore, it is possible that separate permits may be required if additional geotechnical information gathered at the site requires that more than two consecutive lifts, or that they be spaced apart by more than 10 years.
- USACE 404 Individual Permit(s) would allow Phase 1 levee construction over 5 years followed by a 5-year renewal
- FESA Section 7 consultations can be conducted for the entire project, assuming the USACE agrees. Formal consultations will likely be required (it may take 12 months to secure approvals)
- CESA ITP for multiple species covering the entire project (the fee per permit may be $30k depending on the total project cost)
- USACE, CDFW, RWQCB, and BCDC will require compensatory mitigation for wetland losses (temporary and permanent; seasonal and tidal), and USFWS and CDFW may require mitigation for species habitat impacts. This cost estimate does not include costs to identify and establish wetland mitigation sites or to purchase mitigation credits.
- The CEQA document would cover the entire project.
- The CEQA document will have to disclose SLR, adjacent/opposite, up/downstream effects of the new levee and operation/maintenance of the tide gate, culverts, and levee slopes/road.
- We assumed that no cultural/historic resources are present (i.e., the project would only require a simple SHPO consultation process) and no rare/special-status plants are present.
- Construction will require on-site biological monitors and avoid sensitive seasonal periods for protected species, such as migratory birds.

(e) Construction Cost Considerations

Our cost estimate integrates all steps and assumptions described in previous sections regarding the construction of the upgraded or new berms. The cost estimate assumes that fill will be sourced locally, and carries a unit cost of $38 per ton (2,000 lbs), which is corresponds to approximately 30% of the construction costs. Another important cost driver will consist of controlling compaction, and controlling erosion throughout the project implementation. For more details, the reader is invited to consult the cost estimate appendix of this report.

1.2.2 Steel Sheet Pile Floodwall

(a) Overview

For Plan 3, steel sheet pile floodwalls would be installed on the river-facing embankment (East Levee) and West Levee to a design elevation of 15.5 ft NAVD. The sheet piles would also be long enough to provide adequate seepage control along the entire face of the existing levee. As part of a design phase, a thorough verification of sub-surface conditions would be required.

Steel is the preferred material to provide adequate structural capacity and to afford long-term flood protection to adapt to up to three feet of sea-level rise. The steel floodwall could either be built initially to an elevation of 16.5 ft NAVD (with the additional foot to compensate for settlement), or the floodwall could be initially built to an elevation of 12.5 ft NAVD, and then a concrete extension cap could be added in response to future sea-level rise. Before installing the sheet pile floodwall, the existing berm in the reach West Levee 2 is assumed to be upgraded and a new levee is assumed to be built in the reach West Levee 3. The resulting flood barrier ring would provide encompassing perimeter protection of all interior assets against flooding.

(b) Engineering Considerations

The wall would be built sequentially either as a single operation, or as part of a parcel-based approach. We note that while a parcel-based approach is doable, to be successful and to provide a uniform level of flood protection at the site, it would require significant coordination efforts and strict design requirements to ensure that each segment of sheet pile floodwall can be connected on either side of the property. Generally, a parcel-based approach for construction is not recommended. Each wall element will be driven using a press-in method into the existing levee, consisting primarily of uncompressed bay mud. The toe of the wall is located at elevation 9 ft NAVD, which is a representative elevation assessed based on a review of the entire project alignment.

(c) Structural and Geotechnical Considerations

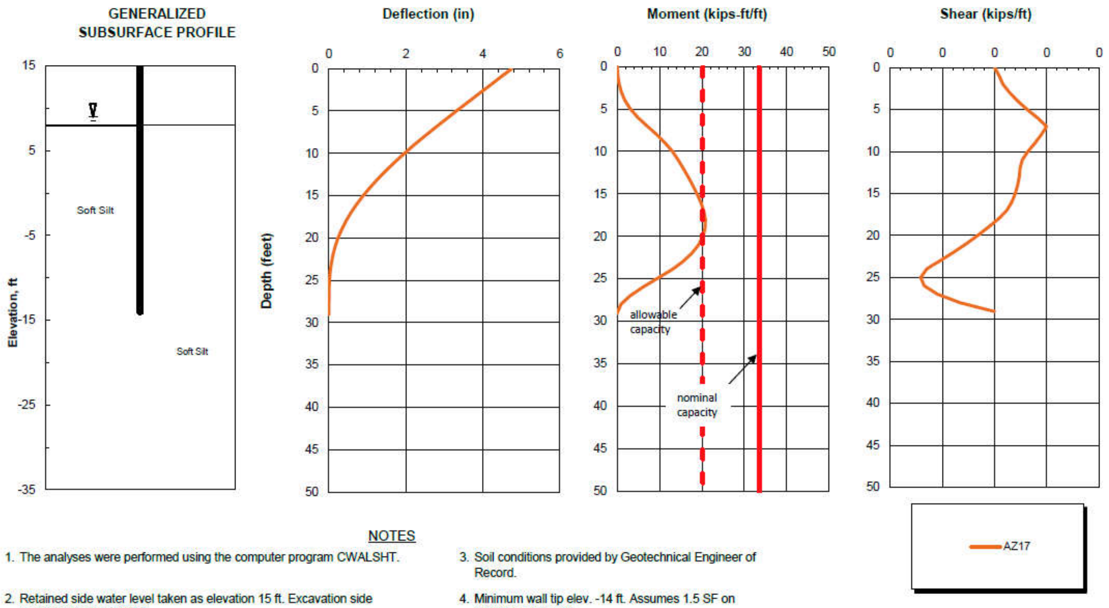
Our long-term settlement evaluation is based on assuming that the most recent fill raising occurred in the 1980’s and 1990’s. Our assessment indicates that most of the primary settlement occurs within the first 5 to 20 years. The settlement occurs at a rate of about 1 foot for the first decade then starts decaying to less than half a foot the next decade and so forth. The analysis also includes an estimate for secondary compression.

Construction of the wall further away from the levee crest is technically achievable but would require placing fill to provide adequate support for the wall. This method may then incur significant settlement of the existing levee, which is generally not recommended.

For the purposes of the sheet pile floodwall design, an allowance of 1 foot for long-term levee crest settlement should be used. That is, the long-term top of the berm crest elevation is 8 ft NAVD, assuming that in 2017 the top crest elevation is 9 ft NAVD. We note that these elevations are representative, and that along the levee, there are significant variations in elevations, with some location exhibiting berm elevation upward of 10 ft NAVD.

For sheet pile analysis, we selected AZ-17-700 steel sheet piles, which were determined to be a suitable pile type for the proposed application. Though we included paint coating in the design of the wall, the calculations incorporated an allowance for loss of structural strength due to corrosion. We modeled the upper 4 ft of fill with an undrained shear strength of 500 pounds per square foot (psf). The lower fill has an undrained shear strength decreasing from 500 psf to 200 psf (or about 500 psf – 50 psf/ft). Bay mud has an undrained shear strength of 200 psf + 9 psf/ft (Su/p'=0.3). We analyzed the embedment depth for a retained height of 7 ft of water. The long-term top of the sheet pile is at 15.5 ft NAVD and the top of the levee crest is at Elevation 8 ft NAVD. The results indicate a minimum embedment depth of 18 ft, which corresponds to a minimum sheet pile length of 25 ft and a minimum sheet pile tip elevation of -10 ft. The results include a factor of safety of 1.5 on the passive resistance.

The existing levee fill may include lenses of sand and silty sand, which are potential paths for through-seepage. To mitigate the risk of through-seepage during flood conditions, the sheet piles should extend at least 5 ft below the bottom of the existing levee fill. At a tip elevation of -10 ft, the sheet piles extend beyond the 5 ft below existing fill minimum. For final design, subsurface exploration should be performed to develop design criteria for the sheet piles and to confirm preliminary conclusions.



NOTES

1. The analyses were performed using the computer program CWALSHT.
2. Retained side water level taken as elevation 15 ft. Excavation side water level taken as 8 ft.
3. Soil conditions provided by Geotechnical Engineer of Record.
4. Minimum wall tip elev. -14 ft. Assumes 1.5 SF on passive resistance.
5. Allowable stress taken as 30 ksi (0.60*fy).
   Passive safety factor of 1.5 assumed for embedment analysis.
   AZ 17-700 Sheet pile (S=32.2 in3/ft).
   Corroded S=0.25*32.2 in3/ft =8.05 in3/ft

3. [illegible]

FIG.

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SHEETPILE WALL
ANALYSIS

November 2017

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FIG.

Figure 2 Summary of steel pile wall calculations.

(d) Notable Features

To inform the cost estimating process, the following features were incorporated in the design:

- Erosion protection at the toe of the existing levee will be provided in the form of rock mattresses installed at the base of the embankment in areas subject to erosion (approximately 2,000 lineal ft of protection are anticipated).

- The wall will be coated down to approximately 3 ft below ground surface elevation to provide extra protection against corrosion (approximately 15 vertical ft total).

For the purpose of this study, the steel sheet pile floodwall is envisioned as a continuous stretch of wall, with adequate connection points providing total protection against floodwaters along the Napa River. The most notable connections points and interferences would include the following:

- Transition section to end of West Levee 1: When a sheet pile wall terminates within a levee, the piling is typically extended a minimum of 5 feet into the full levee section.

- Interface with stormwater pump outlets: When it is necessary for a utility to penetrate a sheet pile wall, a sleeve must be provided to permit relative motion at the crossing. Typically, the utility line is cut and reconnected on either side of the sleeve. The sleeve is then packed with a plastic sealant and covered with a water tight rubber boot. See Figure 12 in the main report for typical utility crossing details.

- Intersection with railroad requiring the installation of flood doors and other devices to prevent floodwaters from entering ring system at that location;
- Tidal gate: we anticipate that this will be integrated in the wall design in a manner similar to the utility crossing shown below. Alternatively, a field-fitted plate may be installed during construction; and
- Final transition section with proposed West Levee 3.

While most of these connection points can be reasonably dealt with using conventional methods, the design of large flood doors at the railroad intersection may carry a significant risk of high design and fabrication costs due to the high level of specificity of the design.

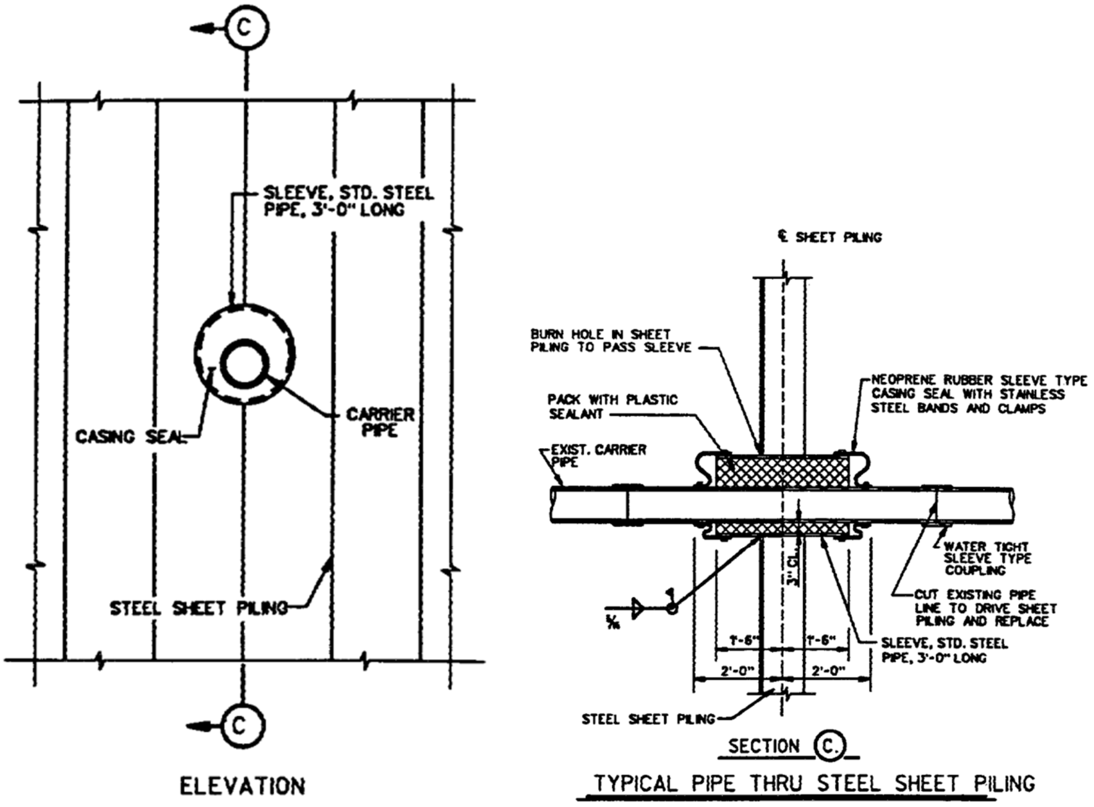


Figure 3 Typical utility crossing. Source: USACE EM 1110-2504.

(e) Concrete Cap Extension

To reduce visual impact on residents, a steel sheet pile floodwall may be installed in two phases. The first phase would require that the wall be installed with a top elevation corresponding to the

DFE, or 12.5 ft NAVD. Later on, as sea-level rises and flood conditions approach the top elevation of the wall, a cast-in-place concrete cap extension may be constructed to extend the crest elevation to at least 15.5 ft NAVD.

Major advantages of this method include the relative flexibility of concrete in incorporating other elements, such as flood doors (access to walkways), glass panels (to reduce visual impacts), and architectural elements (timber, shot-crete, etc.). Specifically, the concrete wall extension can either consist of a plain reinforced concrete wall or can incorporate higher added-value flood proofed structural elements, such as: glass-aluminum railings, glass doors, hinge doors to provide access to docks and gangways. For cost estimating purposes, the anticipated construction date for the wall is 2020, with a design service life of approximately 50 years.

We note that, though not required, the inclusion of such high-value items would increase overall costs significantly.

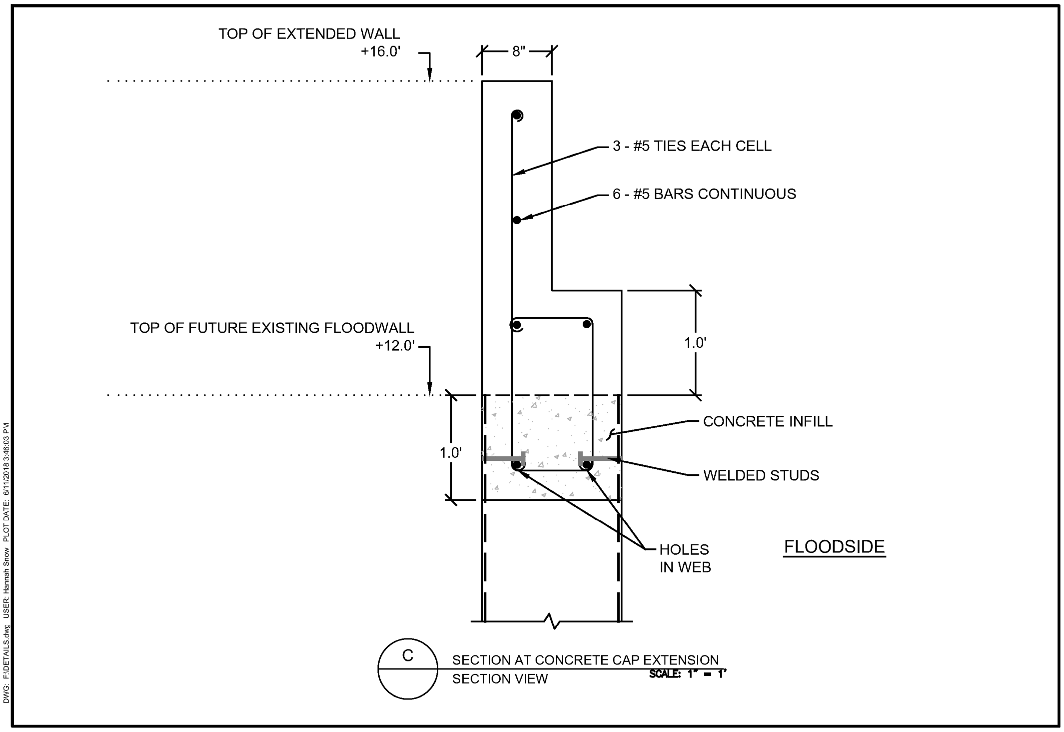


Figure 4 Typical detail: section view of a concrete cap extension constructed on top of steel sheet pile wall. Elevations are approximate and will ultimately depend on actual differential and global settlement rates.

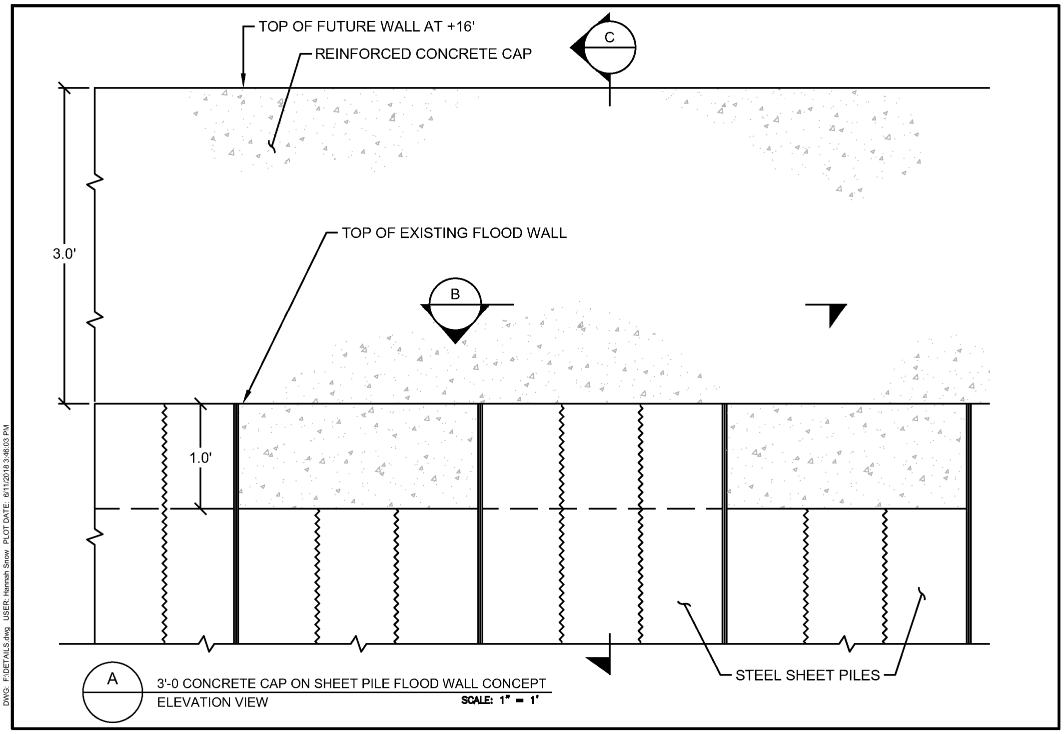


Figure 5 Typical detail: elevation view of a concrete cap extension constructed on top of steel sheet pile wall.

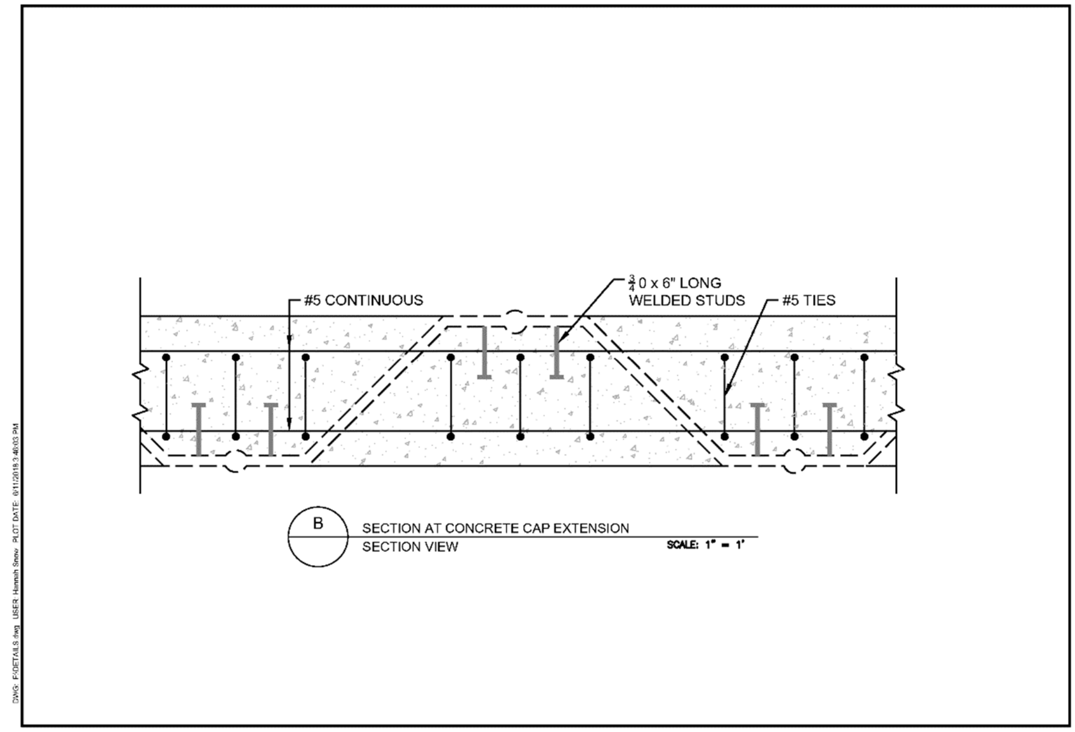


Figure 6 **Typical detail: section view of a concrete cap extension constructed on top of steel sheet pile wall.**

(f) Parcel-by-parcel Approach

This study does not generally recommend that isolated stretches of steel sheet pile wall be installed by homeowners, for the following reasons:

- <u>Small and inefficient operations</u>: significant interference with existing structures (e.g. homes, walkways, docks, etc.) is to be expected with this approach. These inefficiencies can be better dealt with as part of a single operation.

- <u>Flood protection</u>: the efficacy of a single segment of floodwall is limited by that of floodwalls installed on adjacent properties. The installation of steel sheet piles in a parcel-by-parcel basis would require the use of connecting elements consisting of welded steel plates. While technically achievable, such features would necessarily drive costs upward, because they would require that each time a new segment is built, new elements be welded to adjacent segments. A vinyl wall may be slightly superior as it would alleviate the use of heavy construction equipment.

- <u>Permitting</u>: Installing a flood wall of this magnitude will require significant design and permitting efforts, which may be cost prohibitive if borne by a reduced number of homeowners. If a parcel-based approach is reqiured, a vinyl sheet pile floodwall may be preferable from a cost standpoint, though this measure will not afford the same level of long-term protection as the steel wall, and will still require that any new segment be connected to adjacent segments (see above).

(g) Regulatory Considerations

Installation of a steel sheet pile floodwall extending over the entire project alignment represents a significant construction effort that will require the use of heavy construction equipment. This may incur *temporary* or *permanent* impacts on some areas (e.g. where marsh land and wetlands are present). Generally, we estimate the permit requirement for such an undertaking will be significant and will require committed leadership from the lead agency over several years. The project may require to verify CEQA compliance, which will depend on the ultimate project complexity, alignment, resources agencies' level of interest, and general public interest. Permitting work will consist of the following:

- Technical studies associated with jurisdictional delineation (wetlands and other environmentally sensitive areas), biological assessment (endangered species), and cultural resources

- Anticipated permit applications may include: 404, 401, BCDC, 1602, CESA, FESA, 106, and State Lands). State Lands may apply for any portion of the project which will take place below mean lower water. See below for a summary of anticipated permits which will need to be secured for the project. This excludes any public outreach effort and consultation related to the final project alignment.

Table 3 Summary of Permits Anticipated for Steel Sheet Pile Wall.

Permit	Authority/Agency	Rationale
Section 404 Permit	U.S. Army Corps of Engineers	Discharge of dredged or fill material into waters of the United States
Section 401 Permit	U.S. Army Corps of Engineers	Discharge into navigable waters
BCDC Permits	BCDC	Development within 100-ft shoreline band project
Section 1602 Permit	CDFW	Lake and Streambed Alteration Program
CESA	CDFW	California Endangered Species Act (CESA) Permits
FESA	CDFW	Federal Endangered Species Act (FESA) Permits
Section 106	ACHP	National Historic Preservation Act of 1966
CSLC Permit	California State Lands Commission	Operation below ordinary low water mark (placement of erosion mat at base of levee)

Some assumptions were made in our cost estimates; these may evolve based on available information and should not be regarded as final. They read as follows.

- <u>CEQA compliance</u>: the overall costs involved in environmental documentation will depend on project complexity, connecting and ancillary elements, as well as public interest/opposition:

  - IS/MND – $75-100k
  - EIR - $500-950k
- Permitting
  - Technical studies: $25-60k (JD, BA, Cultural)
  - Permit applications: $80-120k (404, 401, BCDC, 1602, CESA, FESA, 106, State Lands)
  - Regulatory agency coordination: $25-60k

Some assumptions were made in our cost estimates; these may evolve based on available information and should not be regarded as final. We note that most of these are consistent with those of the earthen berm. They read as follows:

- USACE 404 Individual Permit that would allow wall construction over a 5-year period. We have assumed that the wall would take approximately 1 season to construct.
- CESA for steelhead and maybe plants (the anticipated fee for this permit may be $30k, and depends on the total project cost)
- USACE, CDFW, RWQCB, and BCDC will require compensatory mitigation for wetland losses (temporary and permanent; seasonal and tidal). This cost estimate does not include costs to identify and establish wetland mitigation sites or to purchase mitigation credits. In our cost estimate, we have assessed that potential risk. These mitigation costs can be significant, as documented in the cost estimate appendix.
- Napa County will serve as the lead agency for CEQA compliance.
- The CEQA document would cover the entire project.
- The CEQA document will have to disclose SLR, adjacent/opposite, up/downstream effects of the new hardened bank (the seawall) and operation/maintenance of the tide gate, pumps, and seawall.
- No cultural/historic resources are anticipated to be present based on the assessment performed in this study.
- Construction will require on-site biological monitors and avoid sensitive seasonal periods for protected species.

(h) Construction Cost Considerations

The bulk of the costs associated with a steel sheet pile floodwall are the price of steel. Recent changes in tariffs for steel may drive costs up significantly (on the order of 25% based on 2018 Q1 trends).

Consequently, there are no major cost implications of installing a steel sheet pile floodwall in one single operation to 16.5 ft-NAVD (i.e. maximum level of protection right away, with an allowance for one foot of settlement), or installing the wall in two phases (build today to 12.5 ft-NAVD, then upgrade flood protection level using a concrete wall extension). To reduce long-term maintenance costs, the estimate includes an allowance to paint the sheet with an epoxy-based coat, and limit corrosion.

On the other hand, there is a significant benefit in installing the steel sheet pile floodwall in one single operation (i.e. district-wide) vs. a parcel-by-parcel basis. Installation of the sheet piles will require the use of heavy equipment and water-based construction activities. Mobilization costs will not scale according to the length of wall to install. Therefore, economies of scale will be significant and every effort should be made to capture these potential cost savings. Based on our assessment, we estimate that the unit cost per linear foot for a stretch of wall would be at least 30% higher if implemented on a group of parcels (on the order of 10-20 parcels); the unit cost increases may be as high as 100% over base unit costs if implemented on a single parcel.

1.2.3 Vinyl Sheet Pile Floodwall

(a) Overview

For Plan 2, vinyl sheet pile floodwalls would be installed on the river-facing embankment (East Levee) and on West Levee 2 and West Levee 3 to a design elevation of 12.5 ft NAVD. While vinyl is not as structurally capable as steel, it offers significant advantages in terms of cost reduction and reduced maintenance needs, since vinyl sheet piles are not subject to corrosion. Segments of vinyl sheet pile floodwalls have already been installed at the project site, though it appears unlikely that the engineering design criteria used for the installation of these segments will meet the engineering criteria considered in this study. The existing vinyl floodwalls are likely not embedded deep enough for this study's proposed tip depth and would therefore not cutoff seepage. In addition, the crest elevation of the existing vinyl floodwalls varies, and may not be 12.5 ft NAVD in all locations.

Unlike the installation of steel sheet pile, which requires the mobilization of heavy construction equipment, vinyl sheet pile may be installed with lighter construction equipment and on a parcel-by-parcel basis. However, a parcel-by-parcel approach would result not benefit from economies of scale, and therefore have higher unit costs of mobilization, labor, material, and equipment. This approach would also require adequate supervision and control so that a continuous barrier may eventually be built over time.

(b) Engineering Considerations

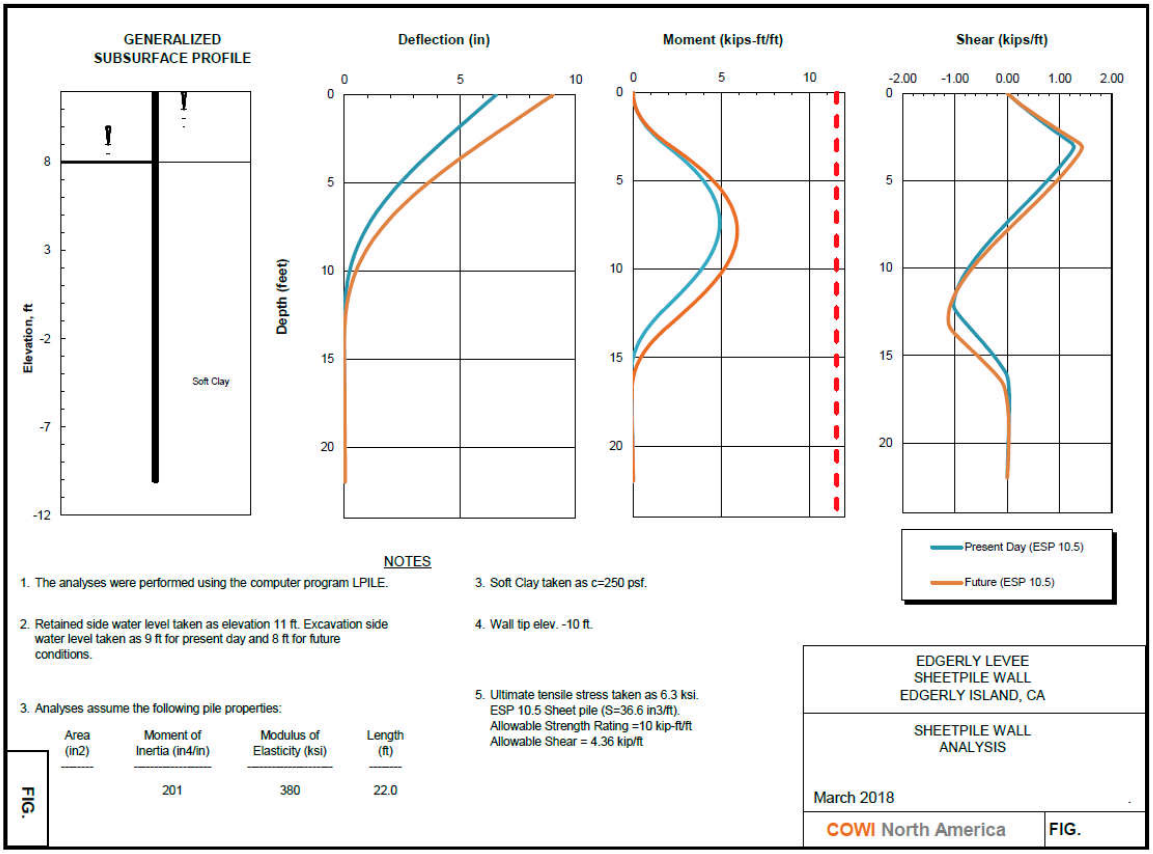
Engineering considerations involved in the design of a vinyl sheet pile wall are identical to those covered in the steel sheet pile wall section. A major difference between steel and vinyl is the structural capacity of a vinyl wall, which is lower than that of steel. In general, our assessment indicates that the recommended vertical capacity of a vinyl sheet pile wall installed in a cantilevered configuration is three feet above the adjacent ground surface elevation. Beyond that, calculations indicate that the hydrostatic forces that would apply during a flooding event would likely exceed the structural capacity of the vinyl sheet pile wall. Also, from a practical standpoint, the magnitude of the deflection of vinyl piles (measured at the tip) would become significant, and would greatly exceed the tip deflection anticipated for steel piles.

ESA was provided with design documents related to the installation of a vinyl sheet pile wall at one of the Edgerly Island parcels. In this design, the typical cross-section includes a timber bracing and support system that most likely increased the maximum vertical capacity of the vinyl floodwall to be greater than three feet. While such a configuration may be achievable on some parcels, it is unlikely to apply to all parcels at EIIT. For that reason, the proposed configuration relied on a cantilevered configuration without bracing to assess minimum structural requirements and to estimate costs of installation.

The recommended length of the vinyl sheet piles matches that of the steel sheet piles: this is a minimum requirement to adequately intercept seepage-prone sand lenses within the levee.

The results of the engineering calculations show that adequately sized vinyl sheet piles can provide adequate capacity against existing flood conditions: we selected ESP 10.5 vinyl sheets from Everlast Seawalls as representative specifications for this study. Calculations also indicate that for a cantilevered wall extending about 4 ft from the ground surface, the magnitude of tip deflection is significant (6-9 inches at the tip of the pile), as shown in the figures attached with this report. While the deflection can be mitigated through the use of external bracing, such additions would necessarily increase construction and design costs. We note that while tip deflection is significant, the maximum moment acting on the pile is not a concern.

The results of this analysis also strongly indicate that, unlike the steel sheet pile wall case, further upgrades of the vinyl sheet pile wall to provide additional vertical capacity are not likely to be practicable and/or cost-effective. To be successful, a vertical wall extension, such as a concrete cap extension, would need to be able to safely transfer any additional loads to the existing wall. In the case of the steel sheet pile, this is possible, because there is sufficient capacity in the sheet piles to withstand hydrostatic loads for water levels exceeding the top elevation of the extended sheet pile wall. For the vinyl sheet pile, such capacity does not exist. Therefore, to provide additional vertical capacity, additional load-bearing or bracing elements, such as soldier piles, would need to be installed, so that the increase in hydrostatic load is adequately transferred. While such upgrades are plausible, they would incur significant costs, which are anticipated to exceed the costs associated with a steel sheet pile solution.



NOTES

1. The analyses were performed using the computer program LPILE.

2. Retained side water level taken as elevation 11 ft. Excavation side water level taken as 9 ft for present day and 8 ft for future conditions.

3. Analyses assume the following pile properties:

Area (in2)	Moment of Inertia (in4/in)	Modulus of Elasticity (ksi)	Length (ft)
	201	380	22.0

3. Soft Clay taken as c=250 psf.

4. Wall tip elev. -10 ft.

5. Ultimate tensile stress taken as 6.3 ksi.
ESP 10.5 Sheet pile (S=36.6 in3/ft).
Allowable Strength Rating =10 kip-ft/ft
Allowable Shear = 4.36 kip/ft

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SHEETPILE WALL
EDGERLY ISLAND, CA

SHEETPILE WALL
ANALYSIS

March 2018

COWI North America

FIG.

Figure 7 **Engineering calculations, summary output for vinyl sheet pile wall, typical berm cross-section, existing and future flood conditions.**

(c) Notable Features

Generally, the same connection points and interferences applicable to the steel sheet pile wall will apply for the vinyl sheet pile wall. Transition sections can be handled the same way as for the steel sheet pile case. Intersections with the utilities may require the use of steel sheet piles, which provide greater fabrication and custom-fitting possibilities than vinyl. Intersection with the tidal gate openings can be handled in a similar fashion.

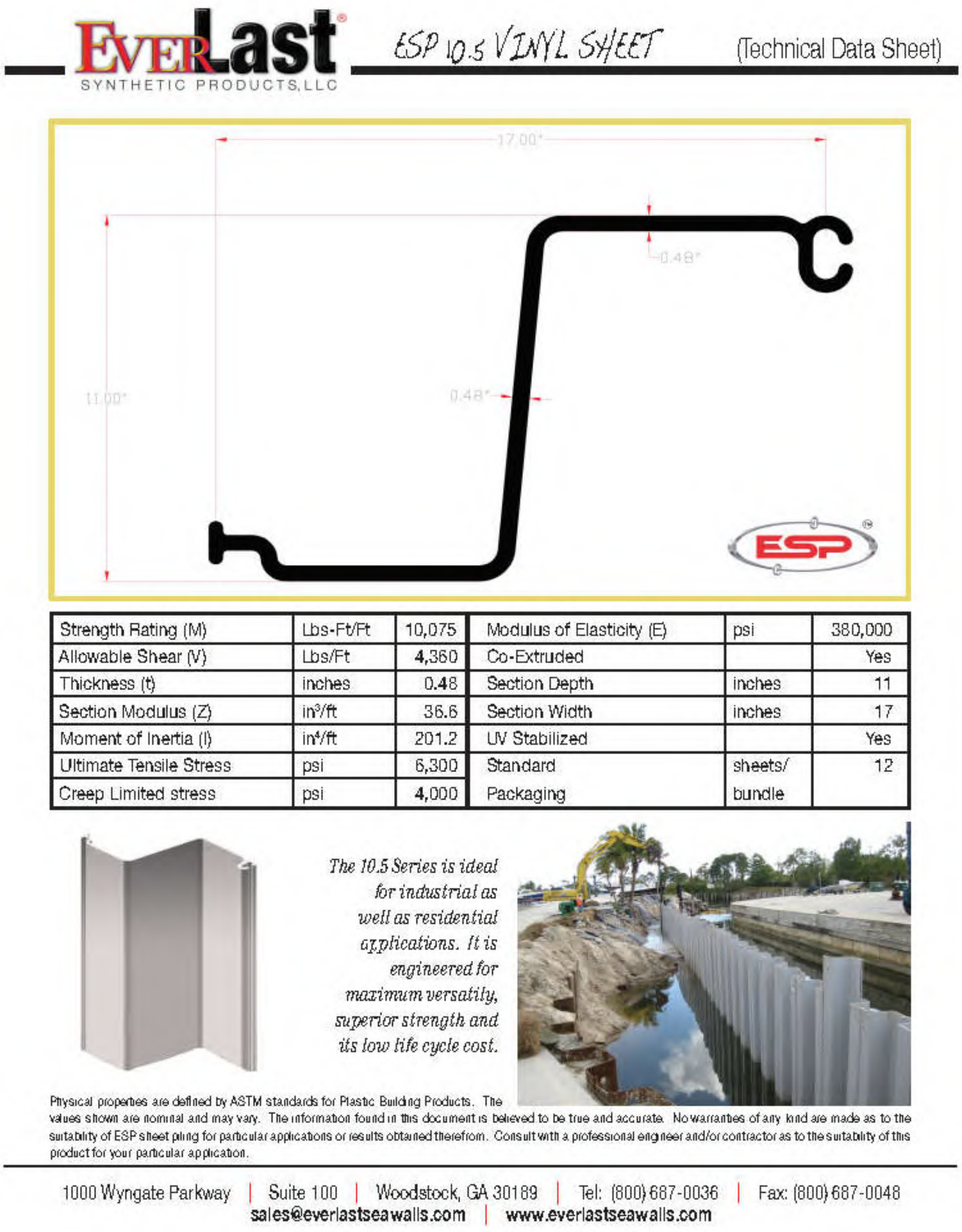
(d) Regulatory Considerations

In general, all of the regulatory considerations listed for the steel sheet pile wall apply in the vinyl wall. The main difference would be in the way the construction of the wall would take place. For a single operation (i.e. the entire wall is built as a single project), the process would be identical. However, unlike the steel sheet pile wall, the lighter vinyl sheet piles open up greater opportunities to accommodate a parcel-by-parcel approach for construction and wetland impact avoidance.

However, if built on a parcel-by-parcel approach, to facilitate construction by an individual or a group of individual homeowners, development of design standards and implementation guidance is recommended. These standards and guidance would simplify the design process for each homeowner and facilitate the overall objective of a consistent and continuous floodwall.

(e) Construction Cost Considerations

Vinyl sheet piles offer significant cost advantages over steel piles, primarily due to reduced costs of material (vinyl is less expensive than steel); costs of labor and installation (vinyl sheet piles require smaller equipment for installation); and maintenance (vinyl piles do not require maintenance and do not corrode). Our cost estimate assumes that the vinyl sheet pile wall would be built in one operation; construction of the vinyl sheet pile on a parcel-by-parcel basis would likely result in higher costs.



EverLast® SYNTHETIC PRODUCTS, LLC

ESP 10.5 VINYL SHEET (Technical Data Sheet)

Strength Rating (M)	Lbs-Ft/Ft	10,075	Modulus of Elasticity (E)	psi	380,000
Allowable Shear (V)	Lbs/Ft	4,360	Co-Extruded		Yes
Thickness (t)	inches	0.48	Section Depth	inches	11
Section Modulus (Z)	in^3/ft	36.6	Section Width	inches	17
Moment of Inertia (I)	in^4/ft	201.2	UV Stabilized		Yes
Ultimate Tensile Stress	psi	6,300	Standard	sheets/	12
Creep Limited stress	psi	4,000	Packaging	bundle	

The 10.5 Series is ideal for industrial as well as residential applications. It is engineered for maximum versatily, superior strength and its low life cycle cost.

Physical properties are defined by ASTM standards for Plastic Building Products. The values shown are nominal and may vary. The information found in this document is believed to be true and accurate. No warranties of any kind are made as to the suitability of ESP sheet piling for particular applications or results obtained therefrom. Consult with a professional engineer and/or contractor as to the suitability of this product for your particular application.

1000 Wyngate Parkway | Suite 100 | Woodstock, GA 30189 | Tel: (800) 687-0036 | Fax: (800) 687-0048
sales@everlastseawalls.com | www.everlastseawalls.com

Figure 8 Technical data sheet for ESP 10.5. Source: Everlast Seawalls.

1.2.4 Other Considerations

The following considerations apply for the earthen levees, steel, and vinyl sheet pile floodwall options.

(a) Obstructions

In this planning phase, a site inspection was conducted to identify obstructions which may interfere with proposed alignments or which may necessitate special construction procedures. For design, these site inspections should be supplemented by information obtained from local agencies to locate underground utilities such as sewers, water lines, power lines, and telephone lines. Undiscovered obstructions will likely result in construction delays and additional costs for removal or relocation of the obstruction.

At the project site, identified obstructions consisted of the following:

- Utilities (pumping station outfalls): the installation of a sheet pile wall would necessarily require the addition of interfacing elements. In this case, the existing Edgerly Island stormwater pump station outfalls may be integrated in the wall through the combination of neoprene and flap gates.

- The potential presence of rock riprap or other type of ad-hoc armoring material on the project site would require removal of the material prior to installing any sheet piles. Survey work would need to be completed in the design phase to quantify the extent of removal operations.

- Railroad tracks and railroad bridge will require that connections be installed along the proposed wall alignment. For example, at the interface with the railroad, large flood doors equipped with rubber seal may be required.

- Existing walls which have been installed by homeowners, and which may prevent direct installation of the proposed sheet piles (regardless of material employed), may need to be removed.

- Docks and walkways are a major obstruction and will require temporary removal or displacement during construction activities. The presence of these structures will need to be accommodated during construction. The approach considered in this project envisions a sequence of operations where each dock would be dismantled to allow for the sheet pile wall to be installed, and repositioned following the installation.

- The sewer line as-built drawings were reviewed and no potential obstructions with the proposed sheet-pile wall alignment were identified. This will need to be confirmed in any subsequent phase of the design effort.

(b) Incorporation of existing vinyl flood walls

The existing vinyl piles which may have been installed by some homeowners do not have enough strength to be reused as part of a structural component of the new wall. Depending on the construction approach retained for the new steel sheet pile wall, they could stay or be removed. In general, the approach considered here would envision installing the new wall on the riverside of the existing sheets and filling the space between with gravel (assuming permitting will allow). If removal is required, this may be achieved at a reasonable cost and would leverage marine-based equipment already mobilized on the fluvial side. Typical removal equipment would include a vibratory hammer to clamp on to the piles and extract them.

(c) Impacts on residential areas

Construction of a sheet pile wall, whether it employs vinyl or steel sheet piles, will incur permanent visual impact on its immediate vicinity. The alignment proposed in this study would require no permanent relocation of residences or businesses, which would entail additional lead times for implementation.

The proposed sheet pile wall will be constructed as flood protection along the waterfront. As a result, operations between the sheet pile wall and the waterfront will be negatively affected during periods of high water and, in addition, depending on the final elevation retained for the wall (i.e. 12.5 ft vs. 16 ft, depending on the phasing of the project), gates or openings through the wall will have to be provided for access.

Temporary impacts of construction can be mitigated to some extent by careful choice of construction strategies and by placing restrictions on construction operations. Two construction approaches were considered in this study: water-based construction activities requiring the use of driving equipment on barges, and a "press-in" methods. In general, a press-in method is superior for this project, given access restrictions. Another advantage of the press-in method is that it alleviates the need to use an impact or vibratory hammer, and is therefore quieter. We note that this press-in method forms the basis of assumptions for the cost estimate developed herein. An illustration of the press-in process is shown in Figure 98.

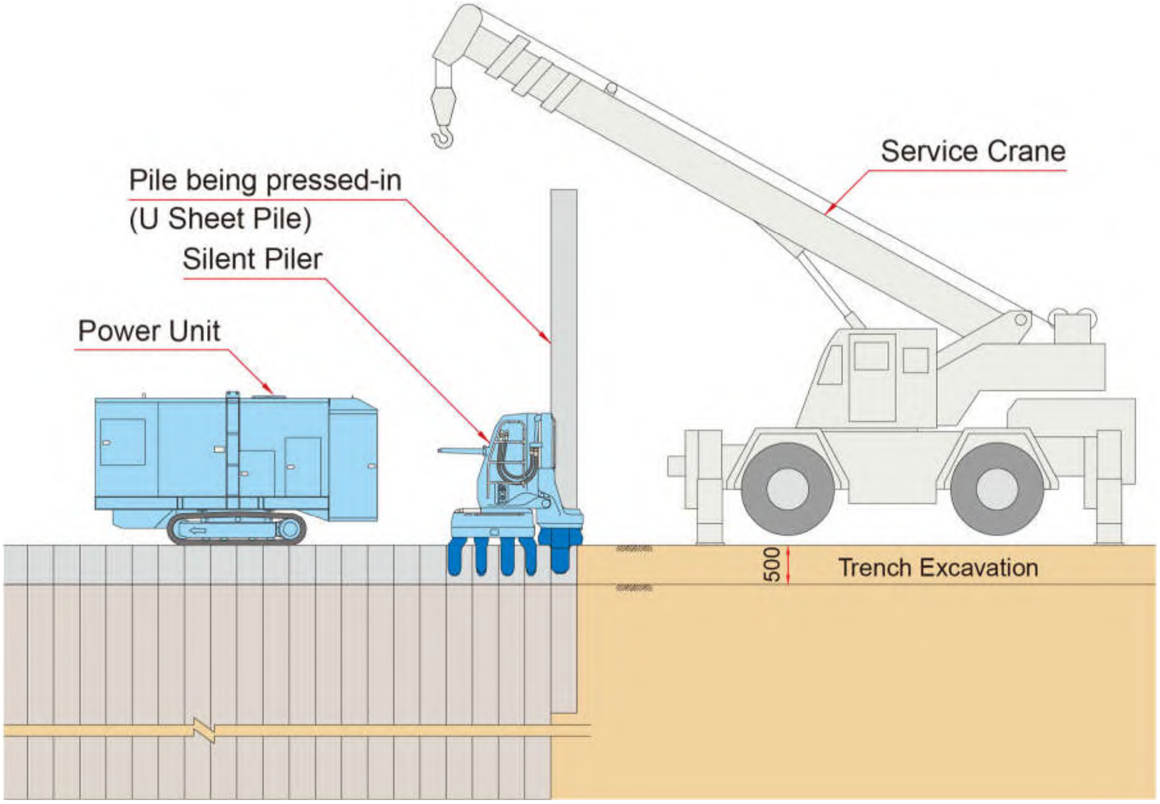


Figure 9 **Illustration of the Giken press-in method proposed for the installation of the steel sheet pile wall. The service crane would be most likely placed on a barge, given access restrictions at the site.**

(d) Right-of-ways

A property map or boundary easement map were not prepared as part of this study. Every effort should be made to maintain the alignment of permanent construction within a dedicated right-of-way. Procurement of new rights-of-way should begin in the feasibility stage of floodwall design and should be coordinated with realty specialists and local interests. For design and construction, temporary arrangements for construction purposes should be determined and delineated in the contract documents. When possible, rights-of-way should be marked with permanent monuments.

(e) Design life and maintenance

This feasibility study assumed that all flood barriers have a service design life of 50 years from construction date. While a finite design life is necessary to assess long-term cost-benefits, actual service life can be greater than the design life if adequate maintenance, repair, and upgrades are properly conducted.

Structures such as the earthen embankments and sheet pile walls discussed herein should be inspected periodically to ensure structural integrity and to identify maintenance needs. Methods of inspection usually include visual inspection, magnetic particle inspection, ultrasonic inspection, radiography, and in some cases nondestructive testing. Typically sheet pile structures are visually inspected, relying heavily on the inspector's experience and knowledge. Ultrasonic measurements have been used to determine the remaining thickness of steel sheet piling.

1.3 Floodproofing

1.3.1 Introduction

Consistent with FEMA nomenclature, retrofitting to floodproof structures may consist of one or more of the following methods:

- Elevation of structure: the foundation of the existing structure is placed on fill or foundation elements such as solid perimeter walls, piers, posts, columns, or pilings;

- Relocation consists of relocating the existing structure outside the identified floodplain;

- Dry floodproofing consists of strengthening of existing foundations, floors, and walls to withstand flood forces while making the structure watertight;

- Wet floodproofing consists of making utilities, structural components, and contents flood- and water-resistant during periods of flooding within the structure; and

Elevation and relocation are considered "structural modifications"; dry and wet floodproofing are considered "non-structural modifications". Finally, with the exception of small-scale perimeter walls, large floodwalls and levees are considered separately, in the section above.

As long as the method selected for retrofitting fits within the property outline and complies with the County building code, and as long as the retrofitting effort does not trigger the substantial improvement clause, the retrofitting of houses is not anticipated to require environmental compliance permits.

(a) Substantial Improvements and Retrofitting

Floodproofing retrofits are required when a homeowner undertakes "substantial improvements". According to NFIP definition, substantial improvements refers to any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the "start of construction" of the improvement. This term includes structures which have incurred "substantial damage," regardless of the actual repair work performed. The term does not, however, include either:

- Any project for improvement of a structure to correct existing violations of state or local health, sanitary, or safety code specifications which have been identified by the local code enforcement official and which are the minimum necessary to assure safe living conditions or

- Any alterations of a "historic structure," provided that the alteration will not preclude the structure's continued designation as a "historic structure."

Similarly, Napa County Code has put in place restrictions for what it refers to as substantially improved buildings. According to *Section 16.04.450 - Substantial improvement*, the term “substantial improvement” refers to the following:

- “Substantial improvement means any reconstruction, rehabilitation, addition or other new development of a structure or facility, the cumulative cost of which over a ten-year period equals or exceeds fifty percent of the market value of the structure before the "start of construction" of the improvement. This term includes structures which have incurred "substantial damage," regardless of the actual repair work performed.”

Floodplain management requirements for new construction apply to substantial improvements. That is, any *new* home or structure built within the Edgerly Island and Ingersoll Tract footprint will necessary be subject to floodproofing restrictions highlighted in this section. References to these potential restrictions and their impacts on the viability of floodproofing measures are made throughout the text.

(b) Applicability of Structural Modifications

To minimize flood hazards, structures at risk of flooding may be raised in elevation (subject to restrictions). This alternative includes working with private property owners to relocate structures and infrastructure at elevations that could be affected by inundation. Depending on the type of structure and infrastructure, there are several treatment options for structural modification to increase elevation. Starting with the most preferable from a cost perspective, these treatments include:

- Moving the entire structure to a higher elevation (“**Relocation**”): in general, this measure is not discussed in this study, as it is the intent of homeowners to remain within EIIT and EIIT does not include elevations above the BFE.

- Raising on fill (“**Elevation**”): this solution is generally not recommended, as it would significant amount of settlement. It is therefore not considered further in this section.

- Raising on piles (shallow footing foundations) (“**Elevation**”): recommended for the project site as a measure that meets code requirements, avoids significant settlement, and can achieve significant flood risk reduction. It is discussed in greater level of detail in the next section.

These results are summarized in Table 45 below.

Table 4 Applicability of Structural Modifications.

Method	Relocation	Elevation (Fill)	Elevation (Piling)
Applicability	Not desirable	Not recommended on soft bay muds	Preferred

(c) Napa County Requirements for Non-Structural Methods

Napa County code contains specific sections addressing the use of floodproofing. These sections may limit the applicability of floodproofing, and are highlighted below.

a. *Non-Residential Structures*

The project features a limited number of non-residential assets where floodproofing could be implemented. According to County Code (*Section 16.04.730 - Nonresidential construction*), new nonresidential construction and substantial improvement of any commercial, industrial or other nonresidential structure within a special flood hazard area shall meet the following requirements:

- Either have the lowest floor, including basement elevated to or above a level equal to the base flood elevation plus one foot of freeboard (12 ft NAVD at the project site);
- **Or** meet all of the following criteria:
    - 1. Be dry floodproofed so that the structure is watertight with walls substantially impermeable to the passage of water below a level equal to the base flood elevation, plus one foot of freeboard, utilizing practices and principles described in technical bulletins TB 1-93, TB 3-93, and TB 7-93;
    - 2. Have structural components capable of resisting hydrostatic and hydrodynamic loads and effects of buoyancy;
    - 3. The floodplain administrator shall be provided the level of floodproofing certified by a registered professional engineer or architect on FEMA form 81-65 that the standards of this subsection are satisfied prior to issuance of a certificate of occupancy.

It should be noted that there are no restrictions applicable to wet floodproofing that apply to existing, non-residential structures subject to improvements considered non-substantial, per Napa county code. This provides additional flexibility in terms of selecting among various floodproofing methods for some non-residential structures.

b. *Residential Structures*

Section 16.04.740 - Enclosed areas below the lowest floor: This section applies to new and substantially improved residential buildings.

- A. All new construction and substantial improvements, with fully enclosed areas below the lowest floor (excluding basements) that are usable solely for parking of vehicles, building access or storage, and which are subject to flooding, shall be designed to automatically equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of floodwaters (wet-floodproofing).

- B. Designs for meeting this requirement must either be certified by a registered professional engineer or architect, or meet or exceed the following minimum criteria:

  - 1. Either a minimum of two openings having a total net area of not less than one square inch for every square foot of enclosed area subject to flooding shall be provided. The bottom of all openings shall be no higher than one foot above grade. Openings may be equipped with screens, louvers, valves or other coverings or devices, provided that they permit the automatic entry and exit of floodwaters; or

  - 2. Nonresidential structures may meet the floodproofing requirements of Section 16.04.730 of [the] code.

A schematic illustration of a compliant floodproofed home is shown in Figure 8Figure 65.

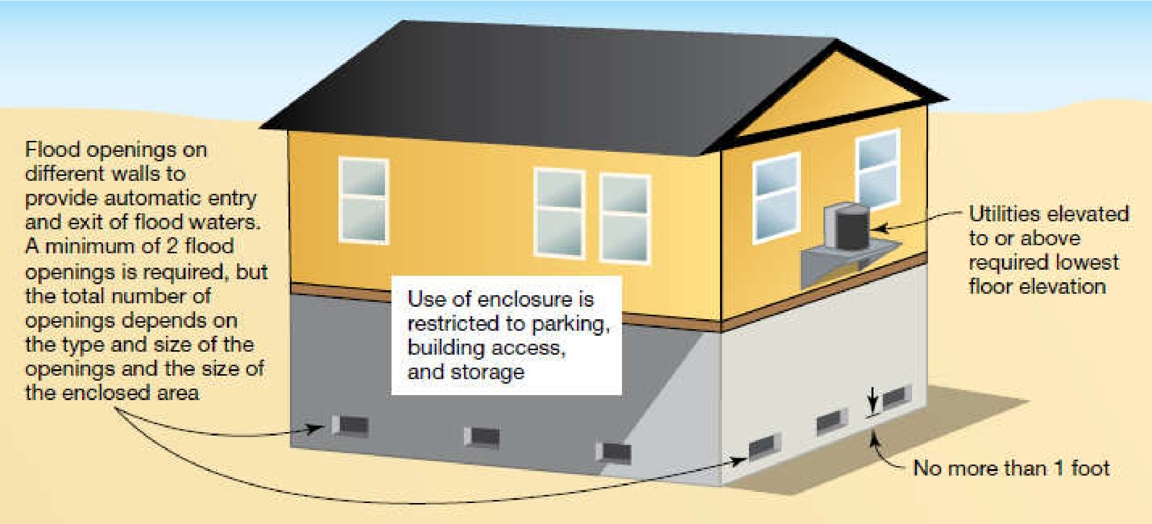


Figure 10 Example of residential floodproofing. Source: FEMA

1.3.2 Elevation on Piling

Pilings refers to any method employing columns, piers, posts and piles, such that these elements support the building at its new elevation (Figure 117). There are limits to how high a house can be supported. Pilings can be used for elevation increases up to approximately to 5 ft, which is anticipated to meet the minimum lift needed to reach the minimum desired elevation contour (e.g. BFE + 1 ft freeboard, or higher if desired). Pilings have the advantage of achieving high cost-effectiveness for each additional unit of vertical capacity. A major limiting factor concerns seismic requirements, which may limit the height of a proposed piling system. Material for pilings may be wood, concrete, or metal, or a combination thereof. The design should also include adequate scour protection around the home, to prevent erosion during flood events, and provide adequate load resisting capacity to the columns or piles.

Shallow foundations may be considered where the presence of non-erodible rock limits pile-driving. This is unlikely to be the case within the project area where the soil column is primarily composed of soft bay muds. Pile-less foundations may include spread footing, and mat and raft foundations (see ASCE 24, Chapter 4).

Due to the complexity of code requirements, any structural floodproofing measure should be carefully evaluated on a case-by-case basis and designed by a licensed structural engineer.

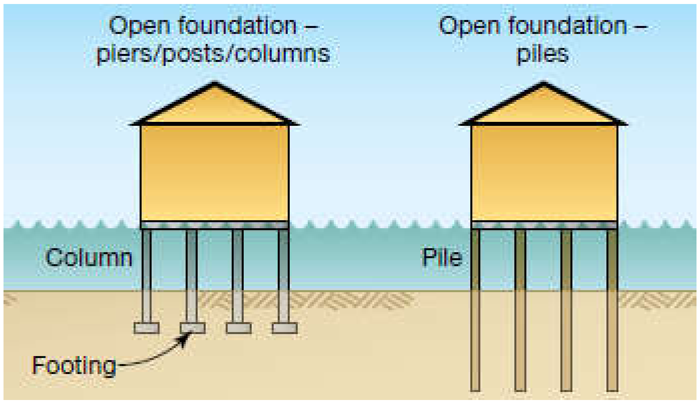


Figure 11 Foundation types for increasing elevation, per ASCE 24 and IRC. Source: FEMA

(a) Cost Considerations

Engineering constraints informing costs of structural modification include physical space, topography, vegetation, geologic substrate, and stability of the existing structure. Seismic loads will increase with the total elevation of the upgraded structure. In some cases, the costs of upgrading a residential property may prove prohibitive and justify the construction of a new home. These factors, as well as property owner preference, need to be evaluated in detail for each structure to develop more precise cost estimates. In this study, only a rough-order-of-magnitude cost estimate was developed, as it is not possible to evaluate each residential property individually.

In some cases, buildings have already been raised on fill or pilings, and in some cases a combination of both; raising these structures may require replacement of the existing foundation of pilings to be structurally sound. In some cases, existing buildings are in poor condition and would not be structurally able to withstand substantial modification. Structures built out of masonry units drive costs significantly upward, and may prove prohibitive entirely.

(b) Anticipated Effects of Structural Modifications

Raising homes would only prevent flood damage to individual houses. It would not alleviate flooding of and damage to community infrastructure such as roadways, pump stations, sewage, water system, etc. Raising houses also has a limited reach in that it would not protect against indirect effects of flooding such as loss in value, and loss of enjoyment of the site.

Regardless of the scale of implementation, impacts of structural modifications will necessarily include any of the following: displacement of occupants during construction, changed aesthetic character and value, decorative element removal, reconnection to utilities, etc., re-grading of vegetated areas; design modification of existing docks and walkways, if so equipped.

1.3.3 Wet Floodproofing

(a) Definition

Wet floodproofing is accomplished through the use of flood damage-resistant materials and techniques that minimize damage to a structure during periods where the lower portion of the structure is inundated by floodwater. Wet floodproofing can be implemented for both residential and non-residential structures.

(b) Methods

Wet floodproofing measures vary for each structure but generally involve the following:

- Using flood damage-resistant materials that may be exposed to floodwaters throughout the building. This can help both reduce damage and facilitate cleanup to allow buildings to restore service as quickly as possible. Interior building elements such as wall finishes, floors, ceilings, roofs, and building envelope openings can suffer significant damage from inundation by floodwaters, which can lead to failure or unsanitary conditions (rot, mildew, etc.).

- Raising utilities and important contents to or above the flood protection level (relocation). Protecting vulnerable equipment and contents by placing them above the DFE is a simple, inexpensive, and effective way to reduce flood damage.

- Installing flood openings or other methods to equalize the hydrostatic pressure exerted by floodwaters (flood louvers) will reduce the exposure of structural elements in a building by cancelling out any hydrostatic load.

- Installing and configuring electrical and mechanical systems to minimize disruptions and facilitate repairs (sealed conduits, waterproof electrical wiring, floodproof HVAC conduits, etc.) following a flood event. While protecting all electrical and mechanical utilities and systems is not possible, a mix of relocation, elevation (i.e. placing equipment on pads) and retrofitting may be employed to reduce post-event damage. Often however, wet floodproofing strategies will need to be supplemented by selective hardening to be successful: hardening in this case consists of building flood-proofed vaults within a wet-floodproofed building to protect assets that would not otherwise be practicably moved or made floodproof, such as control panels, switchboards, etc.

- Installing pumps to gradually remove floodwater from basement areas after the flood (sump pumps).

Wet floodproofing is restricted according to Section 2.7, 4.6 and 6.3 of ASCE 24 for residential buildings. In particular, wet floodproofing is generally restricted to flood design Class 1 structures, enclosures used solely for parking of vehicles (e.g. parking garage), building access, or storage, and structures that are functionally dependent on close proximity to water (e.g. docking facilities).

1.3.4 Dry Floodproofing

(a) Definition

Dry floodproofing is accomplished through the use of flood damage-resistant materials and techniques that render the dry floodproofed portions of a structure substantially impermeable to the passage of floodwater below the design flood elevation. This method is not recommended in areas subject to substantial flood risk. Most notably, dry floodproofing relies on the existing structural capacity of a structure to withstand hydrostatic and hydrodynamic flood loads: not all buildings may be capable of withstanding such loads without undergoing significant upgrade and repair, which may conflict with the substantially improved clause.

As defined in IBC/ASCE and NFIP, dry floodproofing measures are only applicable for non-residential buildings where it has been determined that the existing walls of the structure can withstand the hydrostatic loads that would be exerted against them for a particular design height. In cases where existing walls may not withstand the loads, reconstruction or strengthening would be required.

(b) Methods

Methods used to achieve dry floodproofed conditions include the use of floodproofed doors and openings, backflow preventer and valve-equipped HVAC ducts and utilities openings, and other closure technologies. In general, dry floodproofing techniques are effective for relative flood depths up to 3 ft. This is an important limitation and will impact what techniques can be used for select non-residential assets.

According to FEMA guidelines, dry floodproofing measures include both permanent and temporary systems and are as follows:

- Continuous impermeable walls. Sealing the building’s exterior walls using technologies that include impermeable waterproof membranes and potentially strengthening those walls.

- Flood resistance in interior core areas. Critical core components and areas can be made flood resistant when dry floodproofing the entire building footprint is not needed or possible. This measure consists of making interior rooms containing critical equipment watertight. Wall penetrations would be sealed and floodproof doors would be installed to provide access. Hardening can be accomplished by sealing the existing walls or reconstruction with reinforced walls where required; examples include the use of fabric-reinforced polymer applied on a wall to increase capacity against hydrostatic loads. All penetrations into the rooms would also be sealed or plugged, as explained below.

- Sealants for openings. Protection of the building depends on sealing openings, such as doors, windows, and utility penetrations, and sealing walls and slabs, which are rarely designed to be watertight or resist flood loads.

- Flood shields for openings in exterior walls. Watertight structural systems that close the openings in a building's exterior walls to the entry of water can prevent flooding in the building interior.

- Backflow valves can prevent floodwater flow into the building because of blockages in the sewage system.

- Internal drainage systems. Primary method of removing water that may seep through small fissures and pathways in the protection system. These systems may be supplemented by ad hoc mechanical systems such as sump pumps.

APPENDIX E COST ESTIMATES

1.1 Purpose

This appendix describes details and assumptions about the cost estimates for the measures presented in the flood management plans. The opinion of probable project costs (“cost estimates”) in this appendix are considered a rough order of magnitude estimates and have an anticipated accuracy range of +50%/-30%. This level of accuracy is consistent with the purpose of the study, to evaluate and compare between flood management plans. Additional planning, design, and environmental compliance are needed to revise measures’ description and to improve the accuracy of these cost estimates.

1.2 Disclaimer

In providing opinions of probable implementation costs, ESA has no control over the actual costs at the time of implementation. The actual cost of implementation may be impacted by external economic factors and market forces such as the availability of construction equipment and crews, fuel costs, fluctuation of supply costs, and availability of mitigation credits.

ESA makes no warranty, expressed or implied, as to the accuracy of such opinions as compared to bids or actual costs. When one or more measures are selected for further consideration or implementation, the estimate should be updated in concert with the preparation of more detailed plans and/or designs, as well as in consideration of requirements which may arise as part of the environmental compliance process.

1.3 Summary of Opinion of Probable Costs

A summary of the opinion of probable costs according to each flood management plan is provided in the main body of the report and also replicated below in Table 1. As compared to the more detailed costs estimate information in later sections, these cost estimates are rounded to three significant figures.

Table 1. Summary of Opinion of Probable Costs for EIIT Flood Management Plans

Plan Components	Plan 1: Flood Prep & Plan	Plan 2: Vinyl Floodwalls to 12.5 ft	Plan 3: Steel Floodwalls to 15.5 ft
Flood barriers			
West side	n/a	$17,400,000	$37,000,000
East side	n/a	$10,200,000	$29,600,000
Floodproofing			
Community infrastructure	$1,190,000	$1,190,000	$1,530,000
Flood Preparedness and Planning			
Flood management system inspection and maintenance	$1,860,000	$1,860,000	$1,860,000
Flood event safety plan	$125,000	$125,000	$125,000
Institutional implementation approach	$180,000	$180,000	$180,000
Design standards and implementation guidance	$150,000	-	-
Mitigation Costs	n/a	$ 7,300,000	$ 9,000,000
Total	**$3,500,000**	**$38,300,000**	**$79,300,000**
Community Investment per Parcel*	**$23,000**	**$247,000**	**$512,000**

* These estimated costs, distributed across 155 parcels, should not be viewed as a per parcel cost at this time, but rather as the per parcel share of total community investment for each plan. These costs do not consider the source of funding, which may be offset to some degree by grants.

1.4 Assumptions

1.4.1 Construction Costs

We used a combination of historical, courtesy quotes, and published unit costs (e.g. RSMeans Online Database 2018) to estimate construction costs. All unit costs include labor, equipment, and material, with a basic overhead and profit. The costs presented in this estimates are valid for 2018.

The timing of bidding is an important factor affecting costs. CalTrans guidelines suggest that “the time of the year that the project is advertised and constructed affects the unit cost for items of work. Contractors are usually more readily available for work early in the spring and will therefore bid conservatively at that time. Later in the spring and during the summer, many contractors have ongoing projects that keep them busy; therefore, they tend to bid higher or not at all.”

Other market forces may also significantly affect unit costs of raw materials and fuel. The cost of steel may undergo significant swings in response to proposed import tariffs, e.g. for steel imported from Asia.

All costs presented in this estimate are adjusted to reflect costs applicable in the San Francisco Bay area. When applicable, location adjustments were applied to reflect departures in labor and equipment unit costs from national trends. Location adjustment factors are provided by RSMeans.

The ease of accessibility to the work will affect the cost to do the work. For this project, hauling will require additional considerations: Milton Road’s suitability for heavy truck traffic, as well as staging locations for trucks and loading/unloading operations. Water-based construction could mitigate road traffic impacts but may increase mobilization and demobilization costs. In some instances, operations will require the building of a haul route to the construction site.

The presence of endangered species, and restricted windows prescribed by regulatory agencies may either (1) compress construction schedule which may require more personnel and/or equipment, or (2) delay construction which would instead proceed in phases. Either way, both scenarios would drive costs up.

Smaller quantities of work usually carry a significantly higher unit cost compared to larger volumes. That is because mobilization, drayage, overhead and other costs are distributed over a smaller base. Additionally, production rates can be negatively affected by smaller volumes, which in turn increases unit costs. Cost estimates prepared for this study assume that flood barriers (i.e. steel and vinyl sheet pile floodwalls, levee improvements) are implemented as single projects that benefit from economies of scale. Cost savings from economy of scale are particularly applicable for the construction of the steel sheet pile floodwall for the following reasons: mobilization of heavy and specialized construction equipment is costly and is optimized when distributed over a large volume of work; higher volume of steel may also drive unit costs lower; finally, a single operation would necessarily streamline construction and design.

1.4.2 Right-of-Way Easements

Costs associated with lease, full and partial acquisition, and/or easements were not incorporated in the estimate. The involvement of federal funds in the project may affect the way in which appraisals are conducted and could result in higher compensatory costs.

1.4.3 Engineering and Permitting Costs

‘Soft’ costs related to engineering analysis and design, development of contract documents, regulatory compliance, contract administration, and support were developed for the cost estimate based the magnitude of the construction cost estimate and anticipated complexity of these efforts.

1.4.4 Operations and Maintenance

Maintenance costs were incorporated for the steel sheet pile floodwall. The assumed design life of steel sheet pile is 50 years from the date of construction. Maintenance would consist of a basic work crew to clean and inspect the floodwall every 10 years.

No operations and maintenance costs were included for the other measures and would presumably be included as part of a system-wide operations and maintenance allotment proposed as part of all the plans.

1.4.5 Discount Rate

The interest rate used in discounted cash flow analysis to determine the present value of future cash flows is 4%.

1.4.6 Contingency

The cost estimates include a 25% contingency to allow for uncertainties such as the following: revised project descriptions; anticipated multiple phases for earthwork and excavation, which will require the placement of erosion control measures in the interim; design details; and unanticipated fluctuations in costs of materials and labor.

1.5 Flood Management Measures

1.5.1 Earthen Levees

The cost estimate assumes that the unit cost to acquire and deliver fill is $38 per ton and the handling unit cost for placement and compaction is $27 per cubic yard. Soil compaction tests, consistent with Category II levee construction, were also incorporated in the estimate.

A significant portion of the work will require erosion control for exposed earth during storage and grading. The estimate assumes construction of a haul road during the entire project duration and includes an allowance for traffic control.

No testing of the foundation materials was performed as part of this feasibility study. For design, classification and index tests (water content, Atterberg limits, grain size) should be performed on most or all samples and shear tests should be performed on selected representative undisturbed samples. Consolidation tests should also be performed for design. The strength parameters are not intrinsic material properties but rather are parameters that depend on the applied stresses, the degree of consolidation under those stresses, and the drainage conditions during shear. Consequently, their values must be based on laboratory tests that appropriately model these conditions as expected in the field. These costs were incorporated in the permitting and design costs.

If major levee improvement work is required, such as seepage-lenses mitigation, slope stabilization, soil improvement, etc. costs could increase substantially. This high-impact cost risk was not included in the cost estimate, except to address apparent deficiencies in the existing berm in segment West Levee 2 and to construct a new levee in segment West Levee 3.

1.5.2 Vinyl Sheet Pile Wall

Unit costs of material for the vinyl sheet pile floodwall were obtained through a courtesy quote in early 2018 from Everlast Seawall Products (ESP) for their product ‘ESP 8.5’. The quote assumes all piles are shipped at once to the site, thereby leveraging economies of scale. The estimate assumes that the piles are approximately 22.5 ft tall, to reach a depth of -10 ft NAVD (to intersect any seepage-prone soil layers) and with a crest elevation of 12.5 ft NAVD. Consistent with a previous design detail proposed at the project site, the cost estimate includes a timber brace along the top of the wall. The vinyl sheet pile wall does not include provisions for flood doors. At some interfaces, such as the stormwater discharge outfalls, short segments of steel sheet piles may be required.

1.5.3 Steel Sheet Pile Floodwall

(a) Installation and Staging

The estimate assumes the use of a Giken Ltd. press-in machine for the installation of the steel sheet pile floodwall (Figure 1) to a depth of -10 ft NAVD, with supporting equipment on barges. In general, a press-in method is superior for this project, given access restrictions. Another advantage of the press-in method is that it produces less noise than an impact or vibratory hammer. The unit cost associated with driving the sheet pile is approximately $1,500 per wall segment. The unit costs are predicated on one continuous operation, covering at least 10,000 LF of floodwall. A major assumption is that temporary storage and stockpiling facilities are provided at no cost. We have assumed that the steel sheet piles will be coated using a layer of epoxy-based resin to prevent corrosion. This is a more cost-effective than galvanization, which was determined to be cost-prohibitive when applied over the entire floodwall.

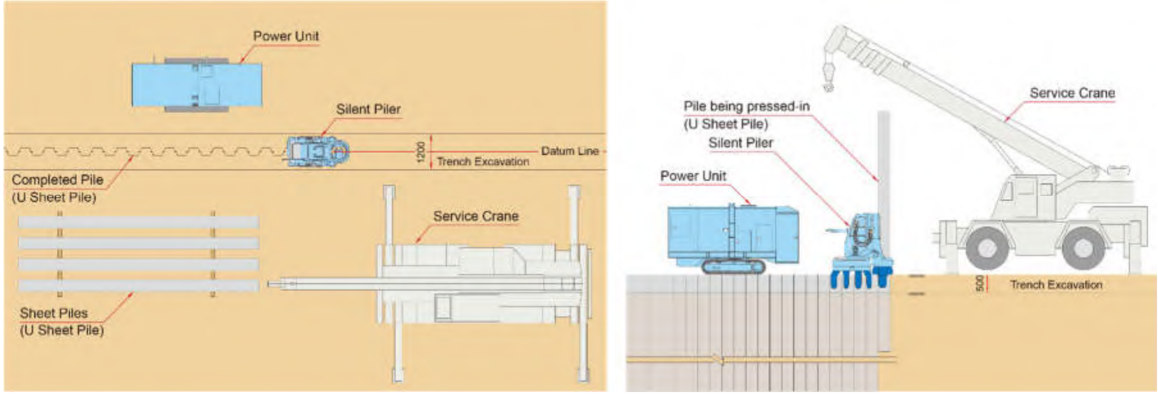


Figure 1 Illustration of the Giken Ltd proprietary press-in method. Courtesy of Giken Ltd.

(b) Unit Prices of Steel

The cost estimate incorporates a unit cost for steel of $2,200 per ton. This cost was prevailing at the time the estimate was prepared. Possible increases in this unit cost may occur due to recent tariff proposals. To assess the possible impact of costs of steel on the overall estimate for the sheet pile, a sensitivity analysis approach is recommended. For example, if the unit cost of steel were to increase by 20%, the construction cost, excluding soft costs, would increase by approximately 2%.

(c) Armor Layer

Along the Napa River levee, there are signs of sediment accretion in the northern portion of the project site, while erosion may be occurring in the south portion of Edgerly Island (Figure 2). Homeowners have anecdotally confirmed placement of material to counteract erosion. Erosion along the toe of the levee reduces stability toward the water side. If not properly managed, continued erosion may precipitate a rotational failure of the sheet pile wall. This suggests that proper design considerations are needed to provide long-term stability at the toe of the sheet pile wall. To manage erosion and loss of stability at the abovementioned locations, the conceptual design includes an allowance for an armored layer consisting of rock (“riprap”) placed along 2,000 LF of the levee.

It is anticipated that up to three sublayers of material may be required for this design, to be confirmed during the design phase. The rock size of the primary sublayer will ultimately depend on the maximum current velocity and local water depth, which was not available for this analysis. Further geotechnical analysis is warranted to reduce the risk of a mud wave to develop at the toe of the levee, or to alleviate the risk of the armor layer sinking into the embankment. The use of a reinforced geo-grid or equivalent may reduce those risks, to some extent. For the purposes of cost estimating, we have assessed typical sublayers based on CalTrans design guidelines. The details are as follows:

- Primary armor sublayer: a standard CalTrans ¼ ton gradation would allow safe protection for current velocity of up to 6 knots assuming that the flow impinges on the bank protection, and that the slope is 1:4. Minimum thickness 3.3 ft.

- Secondary sublayer: none per CalTrans guidelines.

- Base sublayer: Backing No. 2, minimum thickness 1.25 ft.

- Fabric: Rock slope protection Class 8 geotextile.

Based on representative cross-section dimensions, the typical dimensions of the armored layer would be approximately 25 ft wide, with an estimated total thickness of 4.5 ft. These quantities were incorporated in the cost estimate.

Per CalTrans guidelines, two different methods of placement for rock slope protection are allowed: Placement under Method A requires considerable care, judgment, and precision and is recommended primarily where large rock is required and for steeper slopes. However, for this application, we anticipate using Method B, Random Placement. This enables more material to be dumped from a barge. To compensate for a partial loss and assure stability and a reasonably secure protection, the thickness of the armor layer was increased by 25 percent.

Figure 2 **Satellite imagery showing, with arrows, possible locations of (left) erosion and (right) accretion.**

(d) Phasing

The phased approach for the construction of the steel sheet pile wall consists of first driving piles to a depth of -10 ft NAVD and with a crest elevation of 12.5 ft NAVD to address the present-day flood risk, followed by a concrete wall extension to 15.5 ft NAVD to adapt to future sea-level rise and accounting for a foot of settlement. The extension would also include the installation of flood doors ($2,420 per door) to maintain dock access, per FCI courtesy quote. The net present value of the two-phase approach is similar with a one-time approach that constructs a floodwall to 15.5 ft NAVD at the outset. For this reason, and to defer the aesthetic impacts of the higher floodwall, the two-phase approach is preferred.

(e) Obstructions

In this planning phase, a site inspection was conducted to identify obstructions which may interfere with proposed alignments or which may necessitate special construction procedures. For design, these site inspections should be supplemented with information obtained from local agencies to locate underground utilities such as sewers, water lines, power lines, and telephone lines. Undiscovered obstructions may result in construction delays and additional costs for removal or relocation of the obstruction. Further verification is warranted on the field to reduce uncertainty around these items. At the project site, identified obstructions consisted of the following:

- Utilities (stormwater pumping station outfalls): these can be accommodated using a sleeve design (low impact risk item, <5% of proposed costs)

- Potential presence of rock riprap or other type of armoring material at the southernmost end of the project site, with removal of rock required prior to driving sheet pile. Riprap may be reused as part of the proposed armor layer (low impact risk item, <5% of proposed costs)

- Railroad and railroad bridge: a floodwall element may need to be added, which may consist of flood doors located on either side of the railroad or across the rails, which could drive costs up. This is a medium-impact cost risk item, <10% of proposed costs.

- Existing walls: installation of a steel sheet pile could be impacted by the presence of existing vinyl walls. Site-specific removal of existing vinyl walls which may interfere with the construction sequence is not explicitly incorporated in the cost estimate: this is a medium-impact cost risk item, <10% of proposed costs.

- Docks and walkways are a major obstruction and will require temporary removal or displacement during construction activities. The approach considered in this project envisions a sequence of operations where each dock would be dismantled to allow construction equipment access, and then each dock repositioned after installation. This item was explicitly included in the cost estimate.

1.5.4 Floodproofing Community Infrastructure

Cost for floodproofing community infrastructure were assessed based on anticipated operations to be performed at each site. The level of effort envisioned for some of the sites may vary depending on existing conditions. Dry floodproofing is generally not recommended except possibly for dry floodproofing a vault room within the fire station. A list of costs and assumption for each identified item follows. Construction cost estimates were increased by 12% for design and permitting and by 25% for contingencies.

The retro-fitting of the fire station carries a significant amount of uncertainty, and therefore, may result in increased costs. This study did not include extensive assessment of existing conditions and applicable building code for the building, which would be required prior to designing a retro-fitting approach. It is possible that the existing structure does not meet basic requirements for dry flood-proofing: for instance, foundations may be too weak to support possible hydrodynamic loads on the structure. Additional restrictions may also apply on flood-proofing techniques which may render this approach moot, such as ASCE design guidance for Flood Design Class 4 buildings. Potential structural deficiencies (Figure 3) may include:

- Weak foundation and connections to the structure may not provide adequate capacity against buoyancy loads

- Carport foundations and pile support may not withstand hydrostatic loads and scour

- Structural capacity of garage doors may not withstand hydrostatic loads before levels equalize

- Structural capacity of existing walls may not withstand hydrostatic loads before levels equalize

As a result, more extensive and expensive upgrades may be required, but these costs are not included in this cost analysis.

Figure 3 Summary of potential structural deficiencies at the existing fire station.

The bulk of the costs for the wastewater treatment plant improvements are incurred by a perimeter wall to protect the discharge ponds. Additional allowances are made for the plant's two buildings and raising the electrical components of the pump stations along Milton Road.

1.5.5 Residential Floodproofing

Costs associated with residential floodproofing include foundation raising (elevation) and wet floodproofing. Costs are estimated for a typical 2,000 two-story house, with uninhabited garage/storage space on the lower floor and livable space only on the second floor. No mitigation costs were included since residences are assumed to maintain the same existing footprint. The components of residential floodproofing are assumed as follows:

- Foundation raising and placement on blocks was provided as a courtesy quote in November 2017 by Rogers Moving company. This excludes foundation work.

- Foundation work consisting of installing ten shallow piers, likely made of reinforced concrete. This work excludes any building reinforcement which may be required as a result of elevating the foundation.

- Because of the variability between houses, the contingency was increased from 25% to 50% for this portion of the cost estimate, to incorporate complexities inherent to the elevation process, including utilities connection, rewiring, reinforcement, etc. In some instances, significant departures from this initial estimate may occur.

- Wet floodproofing includes basic operations anticipated during a retrofitting effort, including:

- Electrical floodproofing, e.g. retrofitting of boxes and panels, conduit proofing, re-wiring, etc.: 80 hours of skilled electrician labor.

- Relocation of furnace and other large units and appliances: 80 hours of skilled labor, including reconnection

- Utilities floodproofing (primarily sewage), including installation of backflow preventers, etc.: 80 hours of skilled plumbing labor.

- Louvers and vents and other openings in floodable areas: 40 hours of skilled labor.

- A flat $5,000 allowance for materials and specialty items

- No permitting costs

- 25% contingency to account for variations in design and need for site-specific upgrades

As per the main report, the costs of residential floodproofing assumed to be borne by each homeowner at some point in the coming decades in response sea-level rise. Additional details for the cost estimate are provided below in Table 2 and Table 3.

Table 2. Cost Estimate for Residential Foundation Raising

LINE ITEM	QTY	UNIT OF MEASURE	UNIT PRICE	TOTAL PRICE
Raise home	1	LS	$ 15,000	$ 15,000
Install foundation	1	LS	$ 16,667	$ 16,667
Total Price				**$ 31,667**
Other costs				
1. Design				$ 10,000
2. Permitting				$ 10,000
3. Contingency			50%	$ 15,833
Total Project Costs				**$ 67,500**

Table 3. Cost Estimate for Residential Wet Floodproofing

LINE ITEM	QTY	UNIT OF MEASURE	UNIT PRICE	TOTAL PRICE
Electrical flood-proofing	80	HRS	$ 86.00	$ 6,880
Relocation of furnace and other large units	80	HRS	$ 78.34	$ 6,267
Utilities flood-proofing (backflow preventers)	80	HRS	$ 85.81	$ 6,864
Openings in floodable areas	40	HRS	$ 78.34	$ 3,134
Total				**$ 23,145**
Other costs				
1. Costs of materials				$ 5,000
2. Permitting				$ -
3. Contingency			25%	$ 5,786
Total Project Costs				**$ 33,931**

1.6 Flood Management Plan Construction Cost Estimates

1.6.1 Plan 1: Flood Preparedness and Planning

All of the cost estimate information developed for this study's Plan 1 are reported in the main report.

1.6.2 Plan 2: Vinyl Sheet Pile Floodwalls to 12.5 ft NAVD

The breakdown of construction cost estimates for Plan 2 is provided in Table 4 for the east levee reaches and in Table 5 for the west levee reaches. Costs for the community infrastructure and flood preparedness and planning measures are the same as Plan 1.

Table 4. Cost Estimate for Plan 2 – East Levee Reaches

LINE ITEM	QTY	UNIT OF N	UNIT PRICE	TOTAL PRICE
Mobilization and demobilization	1	EA	$ 100,000	$ 100,000
Remove docks and walkways	125	EA	$ 510	$ 63,750
Furnish lumber for brace template	12500	LF	$ 35	$ 437,500
Furnish vinyl sheet piles	264000	SF	$ 10	$ 2,640,000
Install brace template	12500	LF	$ 25	$ 312,500
Install vinyl sheet piles	4166	PR	$ 620	$ 2,582,920
Install sheet cap	12500	LF	$ 7	$ 87,500
Re-install docks and walkways	125	EA	$ 1,020	$ 127,500
Construction Costs				**$ 6,351,670**
Other costs				
1. Design and permitting				$ 2,120,000
2. Contingency			25%	$ 1,587,918
3. Maintenance				$ -
4. Environmental monitoring			2%	$ 127,033
Total Project Costs				**$ 10,186,621**

Table 5. Cost Estimate for Plan 2 – West Levee Reaches

LINE ITEM	QTY	UNIT OF MEASURE	UNIT PRICE	TOTAL PRICE
Mobilization and demobilization	1	EA	$ 100,000	$ 100,000
Purchase fill, WL1 & WL3				
Phase 1 fill	29600	TNS	$ 38	$ 1,124,800
Phase 2 fill	68900	TNS	$ 38	$ 2,618,200
Remove existing trees	30	EA	$ 1,125	$ 33,750
Place and compact fill, WL1 & WL3				
WL1 Phase 1	7600	CY	$ 27	$ 205,200
WL1 Phase 2	15200	CY	$ 27	$ 410,400
WL3 Phase 1	21200	CY	$ 27	$ 572,400
WL3 Phase 2	51900	CY	$ 27	$ 1,401,300
WL2 Exacavate, process, and replace exisiting fill	32900	CY	$ 15	$ 493,500
Install vinly sheet pile wall along WL2	4700	LF	$ 512	$ 2,406,400
Build haul roads	5800	LF	$ 74	$ 429,200
Erosion control	18	MO	$ 69,540	$ 1,251,720
Compaction tests	1	LS	$ 198,900	$ 198,900
Traffic control	18	MO	$ 37,700	$ 678,600
Construction Costs				**$ 11,924,370**
Other costs				
1. Design and permitting				$ 2,290,000
2. Contingency			25%	$ 2,981,093
3. Maintenance				$ -
4. Environmental monitoring			2%	$ 238,487
Total Project Costs				**$ 17,433,950**

1.6.3 Plan 3: Steel Sheet Pile Floodwalls to 15.5 ft NAVD

The breakdown of construction cost estimates for Plan 2 is provided in Table 6 for the east levee reaches and in Table 7 for the west levee reaches. Costs for the community infrastructure and flood preparedness and planning measures are the same as Plan 1.

Table 6. Cost Estimate for Plan 3 – East Levee Reaches

a) Phase 1 – Steel sheet pile floodwalls to 12.5 ft NAVD

LINE ITEM	QTY	UNIT OF MEASU	UNIT PRICE	TOTAL PRICE
Mobilization and demobilization	1	EA	$ 200,000	$ 200,000
Remove docks and walkways	125	EA	$ 510	$ 63,750
Furnish sheet piles (AZ17) [see calcs]	5000	TNS	$ 2,200	$ 11,000,000
Coat sheets	180000	SF	$ 8	$ 1,440,000
Install sheets	3000	PR	$ 1,470	$ 4,410,000
Cut sheet pile and install cap	12000	LF	$ 39	$ 468,000
Reinstall docks and walkways	125	EA	$ 1,020	$ 127,500
Armor layer	1	LS	$ 1,541,667	$ 1,541,667
Construction Costs				**$ 19,250,917**
Other costs				
1.Design and permitting				$ 2,570,000
2. Contingency			25%	$ 4,812,729
3. Maintenance				$ 716,402
4. Environmental monitoring			2%	$ 385,018
Total Project Costs				**$ 27,735,066**

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b) Phase 2 – Concrete cap to 15.5 ft NAVD

LINE ITEM	QTY	UNIT OF MEASU	UNIT PRICE	TOTAL PRICE
Mob and demob marine equipment	1	EA	$ 48,000	$ 48,000
Burn sheet holes	21000	EA	$ 5	$ 105,000
Install studs	10500	EA	$ 27	$ 283,500
Furnish and install rebars	333760	LBS	$ 2	$ 667,520
Furnish and install forms	98070	SF	$ 5	$ 490,350
Furnish and install concrete	1043	CY	$ 285	$ 297,255
Strip forms	98070	SF	$ 1	$ 98,070
Sack and patch wall area	98070	SF	$ 2	$ 196,140
Remove docks and walkways	67	EA	$ 510	$ 34,170
Reinstall docks and walkways	67	EA	$ 1,020	$ 68,340
Furnish and install basic flood doors	134	EA	$ 2,428	$ 325,352
Construction Costs				**$ 2,613,697**
Other costs				
1.Design and permitting				$ -
2. Contingency			25%	$ 653,424
3. Maintenance				$ -
4. Environmental monitoring			0%	$ -
Total Project Costs (at time of Phase 2)				**$ 3,267,121.25**
Escalation after 15 years				$ 5,090,068
De-escalation using interest rate				$ 1,844,875
Total Project Costs, NPV				**$ 1,844,875**

Table 7. Cost Estimate for Plan 3 – West Levee Reaches

LINE ITEM	QTY	UNIT OF MEASURE	UNIT PRICE	TOTAL PRICE
Mobilization and demobilization	1	EA	$ 100,000	$ 100,000
Purchase fill*				
Phase 1 fill	24400	TNS	$ 38	$ 927,200
Phase 2 fill	57100	TNS	$ 38	$ 2,169,800
Remove existing trees	30	EA	$ 1,125	$ 33,750
Place and compact fill				
WL1 Phase 1	5700	CY	$ 27	$ 153,900
WL1 Phase 2	11400	CY	$ 27	$ 307,800
WL3 Phase 1	18133	CY	$ 27	$ 489,591
WL3 Phase 2	44325	CY	$ 27	$ 1,196,775
WL2 Exacavate and replace	32900	CY	$ 15	$ 493,500
Install steel sheet pile wall along WL1	3200	LF	$ 1,597	$ 5,111,467
Install steel sheet pile wall along WL2	4700	LF	$ 1,597	$ 7,507,467
Install steel sheet pile wall along WL3	3300	LF	$ 1,597	$ 5,271,200
Build haul roads	5800	LF	$ 74	$ 429,200
Erosion control	18	MO	$ 69,540	$ 1,251,720
Compaction tests	1	LS	$ 198,900	$ 198,900
Traffic control	24	MO	$ 37,700	$ 904,800
Construction Costs				**$ 26,547,069**
Other costs				
1. Design and permitting				$ 2,590,000
2. Contingency			25%	$ 6,636,767
3. Maintenance				$ 668,642
4. Environmental monitoring			2%	$ 530,941
Total Project Costs				**$ 36,973,420**

1.7 Mitigation Costs

Construction activities will incur temporary and permanent impacts on adjacent lands. Particularly, we note that the sheet pile wall option (either steel or vinyl) will intersect with areas that are likely to be designated as environmentally sensitive (e.g. jurisdictional wetlands or riparian habitat). Consequently, the placement of fill at these locations may trigger the need to mitigate for these losses. Mitigation costs were assessed on a basis of 1(impacted):3(mitigated).

1.7.1 Mitigation Credit Unit Costs

Mitigation can be implemented in two ways: the project sponsor may restore wetlands or negotiate a mitigation pathway with the regulators: this opens the way for opportunistic mitigation. Otherwise, the project sponsor may decide to purchase mitigation credit from a range of applicable banks. Mitigation credit unit costs were estimated from courtesy quotes and published values, as follows:

- Burdell Ranch wetland mitigation bank, with a unit cost of $99,830 per 1/10 acre (equivalent cost of $1M per acre) quoted on January 8, 2018 (project within bank service area);

- North Suisun mitigation bank, maxed out by with available vernal pool credit for $125,000 per acre quoted on January, 8 2018 (out of bank service area);

- San Francisco Bay Wetland Mitigation Bank quoted at $300,000 per acre (out of bank service area)

For purposes of an order of magnitude estimate of mitigation costs, we selected the unit cost from the San Francisco Bay Wetland Mitigation Bank as a regional reference unit cost for an initial cost estimate. Final estimates are subject to accuracy of quantity take-off of impacted wetlands, which will take place during later phases of the design. Assuming a mitigation ratio of 3 (mitigated):1(impacted), i.e. for each acre of wetland impacted, 3 acres of mitigation are required, the unit cost for mitigation is $20.66 per square foot.

Actual mitigation areas may vary significantly as a result of agencies' policies, preferences, and priorities in force at time of design. Future banks may open which may afford further mitigation credit purchasing opportunities. Alternatively, if the EIIT flood management measures play a role in facilitating restoration of adjacent parcels, the flood management measures could obtain mitigation credit from this restoration.

1.7.2 Potential Impacts and Costs

To assess potential impacts, recent aerial maps and available wetlands delineations were used to identify possible areas which may need wetland loss mitigation. For Plan 2, which has a lower design crest elevation, lower construction intensity needed for vinyl sheet pile, and greater flood risk tolerance (i.e. does not factor in SLR), the mitigation assessment assumed that it more likely that design decisions can be made to avoid wetlands impacts. Additional detail about the Plan 2 mitigation costs are shown in Table 8. For Plan 3, which has a higher crest elevation, larger construction intensity for steel sheet pile, and less willingness to compromise on flood protection (i.e. include capacity for 3 ft sea-level rise), the mitigation assessment assumed that it more likely to incur wetland impacts. Additional detail about the Plan 3 mitigation costs are shown in Table 9.

Table 8. Cost Estimate for Mitigation, Plan 2: Vinyl Sheet Pile Floodwall to 12.5 ft NAVD

Flood Barrier Measures		Qty	Units	Unit cost	Cost
East Levee 1: New vinyl sheet pile into existing levee to 12.5 ft					
Potential impacts:	Immediately south of RR track (840 LF, 30 ft wide)	25200	SF	$ 20.66	$ 520,659
East Levee 2: New vinyl sheet pile into existing levee to 12.5 ft					
Potential impacts:	First segment north of RR bridge, houses along wetlands (810 LF, 15 ft wide)	12150	SF	$ 20.66	$ 251,032
	Second segment north of RR bridge, houses along wetlands (370 LF, 15 ft wide)	5550	SF	$ 20.66	$ 114,669
West Levee 1: Add fill to raise levee from 8.5 ft to 12.5 ft					
Potential impacts:	(none - Assume fill on east side of levee not in wetlands)				-
West Levee 2: Re-process existing fill & widen to decrease side slope, new sheet pile flood wall to 12.5 ft					
Potential impacts:	Fill in wetlands after re-processing (4950 LF, 15 ft wide)	74250	SF	$ 20.66	$ 1,534,085
West Levee 3: New levee to 12.5 ft					
Potential impacts:	Wetlands fill for levee footprint (3300 LF, 72 ft wide)	237600	SF	$ 20.66	$ 4,909,071
Total Costs					**$7,329,516**

Table 9. Cost Estimate for Mitigation, Plan 3: Steel Sheet Pile Floodwall to 15.5 ft NAVD

Flood Barrier Measures		Qty	Units	Unit cost	Cost
EL1: New steel sheet pile into existing levee to 15.5 ft					
Potential impacts:	Immediately south of RR track (840 LF, 30 ft wide)	25200	SF	$ 20.66	$ 520,659
	1/4 total length impacted by construction (2110 LF, 30 ft wide)	63300	SF	20.66107438	1307846.008
EL2: New steel sheet pile into existing levee to 15.5 ft					
Potential impacts:	First segment north of RR bridge, houses along wetlands (810 LF, 30 ft wide)	24300	SF	$ 20.66	$ 502,064
	Second segment north of RR bridge, houses along wetlands (370 LF, 30 ft wide)	11100	SF	$ 20.66	$ 229,338
WL1: Add steel sheet pile to 15.5 ft					
Potential impacts:	(none - Assume fill on east side of levee not in wetlands)				-
WL2: Re-process existing fill & widen to decrease side slope, new sheet pile flood wall to 15.5 ft					
Potential impacts:	Fill in wetlands after re-processing (4950 LF, 30 ft wide)	148500	SF	$ 20.66	$ 3,068,170
WL3: New levee to 9 ft, with steel sheet pile to 15.5 ft					
Potential impacts:	Wetlands fill for levee footprint (3300 LF, 50 ft wide)	165000	SF	$ 20.66	$ 3,409,077
Total Costs					**$9,037,154**

APPENDIX F: CONCEPTUAL ECONOMIC ASSESSMENT

This appendix summarizes the key assumptions and results of a conceptual-level Estimated Annual Damage and Cost-Benefit Analysis assessment model developed for the Edgerly Island and Ingersoll Tract. This analysis was performed to assess the relative performance of each Flood Management Plan (FMP or Plan), at the community level against a variety of sea-level scenarios.

1.1 Intent

The intent of this rudimentary economic assessment is to illustrate a known basic principle in benefit-cost analysis, which states that, generally, flood management measures aimed at reducing the risk of more frequent, less damaging events carries a higher benefit-cost ratio than those aimed at reducing the risk of infrequent, damaging events. As such, this economic assessment is primarily aimed at capturing orders of magnitude costs and benefits to illustrate this principle. Therefore, emphasis should not necessarily be placed on actual figures, but rather, on conclusions and trends, which are mostly insensitive to small changes in construction cost, or flood protection levels.

1.2 Model Presentation and Limitations

While this tool and methodology are useful in supporting flood mitigation decision-making at the project site, the methodology presented is intended to provide a rough-order-of-magnitude cost estimate of the estimated annual damage only for select flood management plans.

Specifically, the damage model used herein relies on simplifying assumptions that do not take into account important flooding parameters, which are likely to impact flood damage. Some of the limitations of the model are as follows:

- Flood depth and duration: the model calculates flood depth as the difference between the flood elevation and the first floor elevation when the flood level exceeds the flood protection level. This uniform “bathtub” approximation does not take into account time-based and hydrodynamic effects which may reduce the effective flood depth, and therefore damage, around a particular structure.

- The model relies on simplifying assumption of hydraulic connectivity throughout the entire project. For each flood management plan evaluated herein, the model also assumes a uniform level of protection along the entire project alignment. Local variations in levee crest elevations and flood storage in the managed areas west of EIIT would be best captured in a geo-spatial model, which is beyond this scope of work.

- The model does not incorporate levee failure modes. In this case, the model assumes that the levee is well maintained and will act as an overtopping weir during flooding events. A levee failure, which may include slope failure, overtopping and scour, seepage, etc. is a catastrophic event whose contributions to damages, both direct and indirect, would largely exceed those incurred in the scenarios explored herein.
- The model is limited to assessing damages to residential structures, as they form the large majority of high-value assets within the project limits. Direct damages incurred to other structures, such as roads, pump stations, etc., were not incorporated, because the cost of replacement of these assets is low compared to the cost of replacement of residential assets. Moreover, while direct costs associated with the loss of non-residential assets were not included, indirect costs were included in the economic assessment. Indirect costs are related to loss of enjoyment, loss of economic activity, and loss of access to the site.

Undertaking such effort using this tool is therefore not a substitute for undertaking a detailed assessment before commissioning any particular component of the flood management plans presented in the main body of the report.

1.3 Approach

We used DWR's Flood Rapid Assessment Model (F-RAM) (DWR 2008) as a basis for assessing estimated annual damages at the project site. The F-RAM model follows an approach to benefit-cost analysis that is consistent with standard FEMA guidelines.

Unlike the F-RAM model, the model developed herein incorporates a time-based component in the form of relative sea-level rise to estimate damage and benefits of a given project over time.

1.4 Estimated Annual Damage

The core methodology used in this economic assessment is presented below.

1.4.1 Damage-Probability Curve

In estimating the cost of flood damages, a damage -probability curve is developed. The curve plots damages (in dollars) against their annual exceedance probability (AEP). For example, the large damages resulting from a major flood event are associated with a low probability (e.g., probability of 0.01 for a flood with an average return period of 100 years), and the relatively smaller damages from a minor flood are associated with a higher probability (e.g., probability of 0.1 for a 10- year average return period event). This is repeated over a large number of AEP to form the damage probability curve.

1.4.2 Calculating the EAD

The area under the curve represents the weighted average of damage $D(p)$ incurred by flood events associated with an AEP p. In other words:

$$\mathrm{EAD} = \int_0^1 D(p)\mathrm{d}p$$

This area can be estimated by integrating the loss-probability curve. The EAD is the average loss due to flooding that could be expected to occur in any given year.

The efficacy of a Plan is given by its ability to truncate most of the damage which occurs during smaller, more frequent flooding events. Mathematically, an effective Plan reduces the interval of integration:

$$\mathrm{EAD}_{\mathrm{Plan}} = \int_0^1 \Phi(p - p^*) \cdot D(p)\mathrm{d}p = \int_{p^*}^1 D(p)\mathrm{d}p$$

1.4.3 Estimated Annual Benefits

A corollary to the EAD is the Estimated Annual Benefits (EAB), which captures the amount of financial benefits that a project brings annually. It is calculated as follows:

$$\mathrm{EAB}_{\text{With Project}} = \mathrm{EAD}_{\text{Baseline}} - \mathrm{EAD}_{\text{With project}}$$

To calculate Net Present Value (NPV), EAB are compiled in a single cash flow, which is then discounted using an appropriate discount rate.

1.5 Summary of Model Results

Key results are presented below, along with references to figures, located at the end of this memo.

- The magnitude of the EAD is directly proportional to the level of flood protection afforded by each of the Flood Management Plans assessed herein (see Figure 785 and Figure 896): the steel sheet pile wall is able to eliminate most of the damage except for extremely rare events, resulting in a very projected EAD (corollary, a very large annual benefit), even over time as SLR continues.

- The results of the model show that the EAD of each Plan increases significantly over time, except that of Plan 3, which remains zero for all practical purposes. This is because Plan 3 features a very high level of physical protection which prevents floodwaters from coming in contact with homes.

- Whether future SLR trajectories will follow a “high” or a “low” emissions scenario affects future EAD, and directly, EAB, (see Figure 10118). In particular, for FMP 2, after SLR reaches a value of approximately 3 ft, the EAB begin to dip: that is because both the frequency and magnitude of flooding events keep increasing. On the other hand, the EAB of Plan 3 continues to increase proportional to the amount of damage averted by the steel sheet pile wall.

- The Net Present Value captures the cumulative benefits of a given Plan assuming a 50-year period. The results of the model show that the highest NPV, assuming a construction date of 2020, is achieved for Plan 2 (vinyl sheet pile wall). This conclusion applies regardless of the SLR trajectory selected, "low" or "high". See Figure **11**129.
- The Benefit-Cost-Ratio (BCR) illustrates the return on investment (ROI) of each Plan. Given the cost estimates devised for each Plan, the highest BCR is achieved by Plan 1; the second highest is Plan 2 (vinyl sheet pile wall). See Figure **11**129.

1.6 Model Assumptions

1.6.1 Discount Rate

Per discussion with representatives from Napa County Flood Control and Water Conservation District, the model uses a 4% discount rate for all NPV calculations.

1.6.2 Typical Cross-section

The model focuses on estimating direct and indirect damages caused by the flooding of waterfront properties. The model relies on estimating flood depth during flood events based on a simplified approach, as shown in Figure 2. The model simply assumes zero flood depth if the flood level is below an existing flood protection system elevation; otherwise the flood depth is calculated by measuring the difference between the flood elevation, and the basement elevation. Damage is then computed using an applicable flood-depth/damage curve, published by FEMA.

1.6.3 Education and Outreach

(a) Concept

We used benefits-cost guidance provided in DWR (2008) to inform our rough order of magnitude benefit-costs analysis. Specifically, the study discusses the ratios of actual to potential damages based on warning time, and level of flood experience of the community. This is motivated by the fact that actual damages tend to be lower than potential damages, which are upper bounds.

Put simply, more experienced communities who are given more warning time will be more likely to relocate valuables away from flood waters, will be more likely to use sandbags or other methods to reduce the impact on their homes, etc. As a result of this greater awareness, direct damages can be reduced.

(b) Implementation

For the purpose of our assessment, we incorporated these concepts by assuming that the value of an outreach and education program would translate in (1) heightened overall preparedness at the community level and (2) improved early warning systems. Ratios between actual and potential damages were proposed in the DWR study, and they were incorporated some of these findings in our benefit-cost assessment as follows.

For the base case, we assumed that the residents of the Edgerly Island and Ingersoll Tract are generally experienced, and as a result, have developed a measurable culture of preparedness. For this reason, our model incorporates a 20% reduction in direct damages for the base case (i.e. no adaptation plan). Plans 1 to 3 add a formal education and outreach component which translates into an additional 20% reduction in direct damages through improved awareness and preparedness. We note that for 24-hour and longer warning time, DWR data suggests a reduction in actual damage of 60% over potential damage: this is illustrated in Figure 3. This value was not used in our assessment.

1.6.4 Flood Management Plans

Consistent with the Flood Management Plans (Plan) elaborated in details in the main report, we assessed four management scenarios, as explained below:

- Plan 3 assumes a constant protection elevation of 16.5 ft-NAVD88 (excluding long-term settlement, which is incorporated in the RSLR calculation, and will results in a net protection elevation of 15.5 ft-NAVD88), and offers a 40% reduction in direct flood damages to residential structures through resident education and outreach;

- Plan 2 assumes a constant protection elevation of 12.5 ft-NAVD88, excluding long-term settlement, and offers a 40% reduction in direct flood damages to residential structures through resident education and outreach;

- Plan 1 assumes a constant protection elevation of 10.5 ft-NAVD88 afforded primarily by a well-maintained Napa River levee, and offers a 40% reduction in direct flood damages to residential structures through resident education and outreach; we note that the direct damage reduction could be increased significantly if homeowners were to raise their home above BFE. This potential is not captured in the results presented herein.

- Baseline Conditions Scenario assumes that no flood protection improvements are built at the site; however, the model incorporates some reduction in direct flood damage, primarily due to increased level of awareness among residents, which offers a reduction in direct flood damage of 20%.

For more information and literature review surrounding the topic of resident education and outreach, and reduction in direct flood damages, consult the DWR report on the F-RAM model. These parameters are summarized in Table 1.

Table 1 Summary of Plan flood mitigation parameters

Parameter	Plan 3	Plan 2	Plan 1	Baseline
Flood Protection Elevation	16.5	12.5	10	10
Outreach Benefit Damage Reduction	40%	40%	40%	20%

1.6.5 Construction Costs

Assumptions regarding construction cost estimates are based on an initial version of each Plan, similar to the Plans described in more detail in the main body of the report and in Appendix E. Construction costs used to assess the benefit-cost ratio of each Plan are:

- Plan 1: $2,830,000
- Plan 2: $26,400,000
- Plan 3: $53,400,000

In this economic assessment, costs attributable to individual homeowners such as elevation were not included in the economic assessment.

1.6.6 Relative Sea Level Rise Trajectories

To perform the integration at decadal intervals in this appendix, this economic assessment sums sea-level rise and settlement into a single trajectory, which is termed 'relative sea-level rise' (RSLR). Both sea-level rise and settlement were considered in the main report (e.g. Plan 3's floodwalls were designed to accommodate three feet of sea-level rise and one foot of settlement), but a combined trajectory was not needed elsewhere in the report. RSLR is project-specific and is a combination of sea-level rise and settlement: sea-level rise increases total water levels; settlement affects the level of flood protection afforded by decreasing a structure's elevation over the long-term. RSLR affects the financial performance of any project, because when it is larger, it incurs larger damages and therefore increases the monetary benefits of Plan offering higher levels of protection.

The values used in this EAD assessment are shown in Table 2, with relative sea-level rise values used in the EAD model highlighted in orange.

Table 2 Probabilistic RSLR Projections (in feet), from base year 2000, for high emissions scenario in San Francisco.

YEAR	SLR MEDIAN RANGE (50%)	SLR LIKELY RANGE (66%)	SETTLEMENT [FT]	RLSR MEDIAN RANGE (50%)	RLSR LIKELY RANGE (66%)
2000	0	0	0	0	0
2030	0.4	0.5	0.45	0.85	0.95
2040	0.6	0.8	0.6	1.2	1.4
2050	0.9	1.1	0.75	1.65	1.85
2060	1.1	1.5	0.9	2	2.4
2070	1.4	1.9	0.98	2.38	2.88
2080	1.7	2.4	1	2.7	3.4
2090	2.1	2.9	1	3.1	3.9
2100	2.5	3.4	1	3.5	4.4

1.6.7 Flood Events

We used the flood events devised in the main body of the report to estimate damage. These flood events are representative of existing, present-day conditions (year 2017). Long-term effect of relative sea-level rise are added separately to these flood events, as explained later in the text. For practical purposes, the flood elevations were tied to a continuous distribution allowing to relate any AEP with a particular flood event. In this case, the probability distribution function is a Gumbel Distribution with location parameter of 7.90 and a scale parameter of 0.7. The below flood event elevations incorporate still water elevations and wave effects, consistent with FEMA approach.

Table 3 Flood events for year 2017.

ANNUAL EXCEEDANCE PROBABILITY [-]	ELEVATION [FT-NAVD88]	AVERAGE RETURN PERIOD [YEAR]
0.002	12.3	500
0.01	11.17	100
0.02	10.5	50
0.1	9.15	10
0.99	7.65	1

1.6.8 First-Floor Elevation

First-Floor Elevation (FFE) is the sum of the local levee berm elevation and foundation elevation, which is assumed constant at 1 foot above the berm elevation for all residential structures. That is, the finished first floor is located 1 foot above the existing levee crest. In the model, the representative value for the FFE is the median, which reads 10.5 ft-NAVD88. A LiDAR model served as the basis to assess relevant levee berm elevation along the entire project alignment.

1.6.9 Property Value Assessment

Residential properties form the vast majority of assets at the site. Public infrastructure is only a small fraction of the total value at risk. For simplicity, we assessed the market value estimate of properties using public sources including Zillow.com. The methodology used by Zillow relies on approximating a home price index based on locally adjusted parameters. Instead of actual sale prices on every home, the index is created from estimated sale prices on every home. Estimated sale prices (Zestimates) are computed based on proprietary statistical and machine learning models. The models observe recent sale transactions and learn the relative contribution of various home attributes in predicting the sale price. These home attributes include physical facts about the home and land, prior sale transactions, tax assessment information and geographic location. Based on the patterns learned, these models can then estimate sale prices on homes that have not yet sold. Note that such method tends to provide a market-based estimate for each property. According to this methodology, the aggregate value of all properties is $70M.

(a) Tax Records

We also used County assessor information to assess property values. We used a limited subset of representative values to compare with the market-based estimates provided by Zillow.com. Assessed values and market-based values may differ significantly. Proposition 13 replaced the practice of annually reassessing property at market value with a system based on cost at acquisition. Prior to Proposition 13, if homes in a neighborhood sold for higher prices, neighboring properties might have been reassessed based on the newly increased area values. Under Prop. 13, the property is assessed for tax purposes only when it changes ownership. As long as the property is not sold, future increases in assessed value are limited to an annual inflation factor of no more than 2%. Based on the data provided by the County assessor, we inferred representative statistics. According to this measure, the aggregate value of all properties is $40M.

(b) Summary of Property Values

We compiled property values using readily available public records. Key representative statistics for both methods are summarized in Table 415 below. In general, market-based values are significantly above those assessed by the County Tax Assessor, primarily as a direct consequence of Proposition 13, and market forces driving property values upward in the region.

Table 4　Summary of Property Values at the Project Site.

STATISTICS	County Assessor Value	Zillow (Proprietary) Market Value
Min	$ 82,375	$ 233,000
25%	$ 207,989	$ 458,000
Average	$ 344,170	$ 534,847
Median	$ 303,514	$ 492,000
75%	$ 408,895	$ 579,500
Max	$ 795,725	$ 870,000

1.6.10 Depth-Damage Functions

(a) Direct Costs

The model uses two types of depth-damage curves to estimate direct costs in dollars:

- Structure depth-damage curve: to assess damage value in dollars, multiply by the replacement cost of the structure.

- Content depth-damaged curve: Content damage was modeled with the dependent variable being content damage as a percentage of structure value. The new functions calculate content damage as a percent of structure value rather than content value. The content depth-damage functions do not require the intermediate step of calculating content values using content-to-structure value ratio. To assess damage, the depth-damage is multiplied by the replacement cost of the structure.

Damage functions are tabulated below in Table 54.

Table 5 Damage function, structure-depth and content-depth damage, for One Story, With Basement. Source: USACE (2003)

DEPTH	MEAN OF STRUCTURE DAMAGE	STANDARD DEVIATION OF STRUCTURE DAMAGE	MEAN OF CONTENT DAMAGE	STANDARD DEVIATION OF CONTENT DAMAGE
-8	0%	0	0.0%	0.00
-7	0.7%	1.34	0.8%	1.16
-6	0.8%	1.06	2.1%	0.92
-5	2.4%	0.94	3.7%	0.81
-4	5.2%	0.91	5.7%	0.78
-3	9.0%	0.88	8.0%	0.76
-2	13.8%	0.85	10.5%	0.74
-1	19.4%	0.83	13.2%	0.72
0	25.5%	0.85	16.0%	0.74
1	32.0%	0.96	18.9%	0.83
2	38.7%	1.14	21.8%	0.98
3	45.5%	1.37	24.7%	1.17
4	52.2%	1.63	27.4%	1.39
5	58.6%	1.89	30.0%	1.60
6	64.5%	2.14	32.4%	1.81
7	69.8%	2.35	34.5%	1.99
8	74.2%	2.52	36.3%	2.13
9	77.7%	2.66	37.7%	2.25
10	80.1%	2.77	38.6%	2.35
11	81.1%	2.88	39.1%	2.45
12	81.1%	2.88	39.1%	2.45
13	81.1%	2.88	39.1%	2.45
14	81.1%	2.88	39.1%	2.45
15	81.1%	2.88	39.1%	2.45
16	81.1%	2.88	39.1%	2.45

Estimates for the replacement value of residential buildings were then combined with depth-damage curves for structural damage and contents damage to assess flood damages to buildings.

(b) Replacement Costs

Zillow provides market-based valuation data, which differs from the actual costs of replacing the structure ("replacement costs"). To assess these costs, we used a pair of model homes to assess the replacement cost of all residences at the project site using a simplified approach.

- The high-end model home is 1700 SF, 6 corner frame house, one story, forced air central ducted heating and cooling, with developed basement (800 SF), patio (200 SF), built in 1990, quality class 2 (semi-luxury). The estimated market value is $700,000, based on Zillow.com; the estimated replacement cost is $630,000, based on Craftsman Building Cost Calculator. For this house the replacement-to-market ratio is approximately 90%.

- The low-end model home is 1100 SF, 4 corner frame house, one story, no central heating, no developed basement, a patio (200 SF), built in 1980, quality class 3 (best standard). The estimated market value is $465,000, based on Zillow.com; the estimated replacement cost is $300,000, based on Craftsman Building Cost Calculator. For this house the replacement-to-market ratio is approximately 65%.

In light of the assessed market valuations, we used a mean value of 75% as the replacement-to-market ratio for all residential structures located within the project site.

(c) Clean-up Costs

Direct costs for cleanup expenses, unpaid hours for cleanup and repair, emergency damage prevention actions, and other indirect flood-related costs are not included in these damage functions.

From the DWR FRAM development report, we assumed that clean-up costs are estimated at $4,000 per building for all residential structures, and at 30 percent of direct structural damages for commercial and industrial buildings.

1.6.11 Indirect Costs

Indirect damages include the emergency responses to floods, as well as the disruption to normal social activities which occur subsequent to the direct damage of residential assets. At the project site, these indirect costs include:

- Emergency response including food and accommodation;
- Health impacts;
- Disruption of community infrastructure services.

Consistent with the DWR approach, we estimated that the indirect costs associated with each flood event is as follows:

TYPE OF DAMAGE	PERCENT OF DIRECT DAMAGE
Residential	25%

1.6.12 Other Unquantified Damages

Certain other estimates of damage are beyond the scope of this analysis:

- Loss of business to commercial and industrial enterprises;
- Costs of flooding damage to community infrastructure (gas, electricity, water, sewerage, telecommunications and postal services);
- Potential for loss of life;
- Costs imposed on public services, such as education and health services.

At present, information to quantify these damages was lacking. If more detailed economic assessments are performed, these damages can be quantified and included. Overall, including these damages would not significantly change the implications of the economic assessment, the relative benefit-cost ratios of the plans.

1.7 References

California Department of Water Resources (DWR). 2008. Flood Rapid Assessment Model (F-RAM) Development.

1.8 Figures

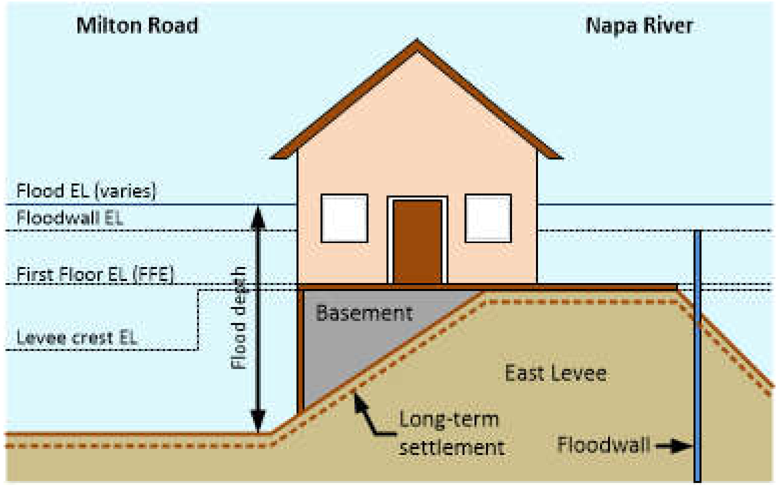

Figure 1 Conceptual cross-section and variable definitions.

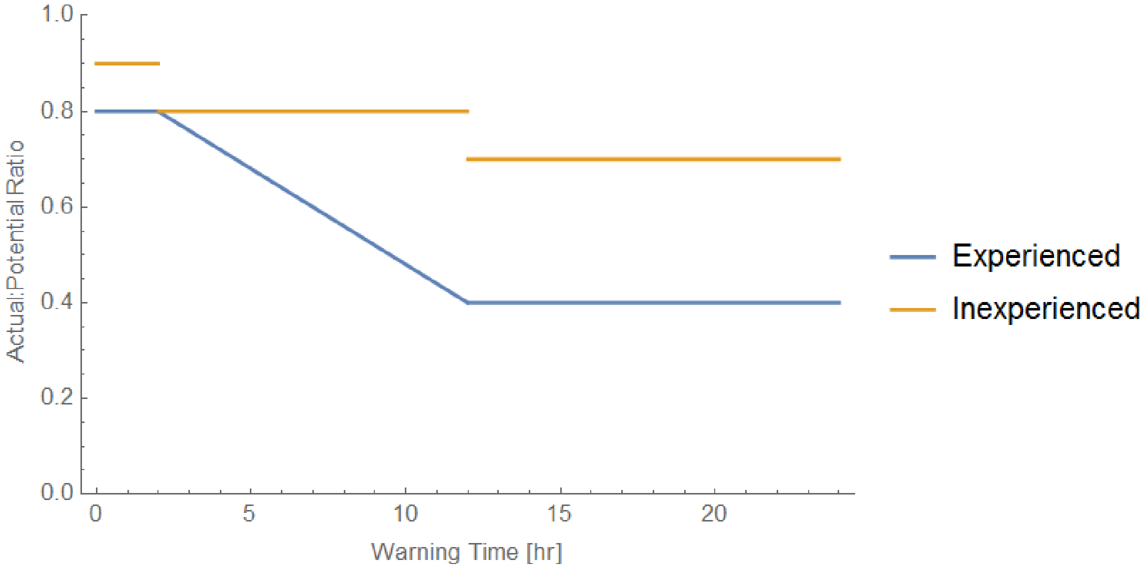

Figure 2 Actual to potential damage as a function of warning time and level of community flood preparedness and experience. Adapted from DWR study.

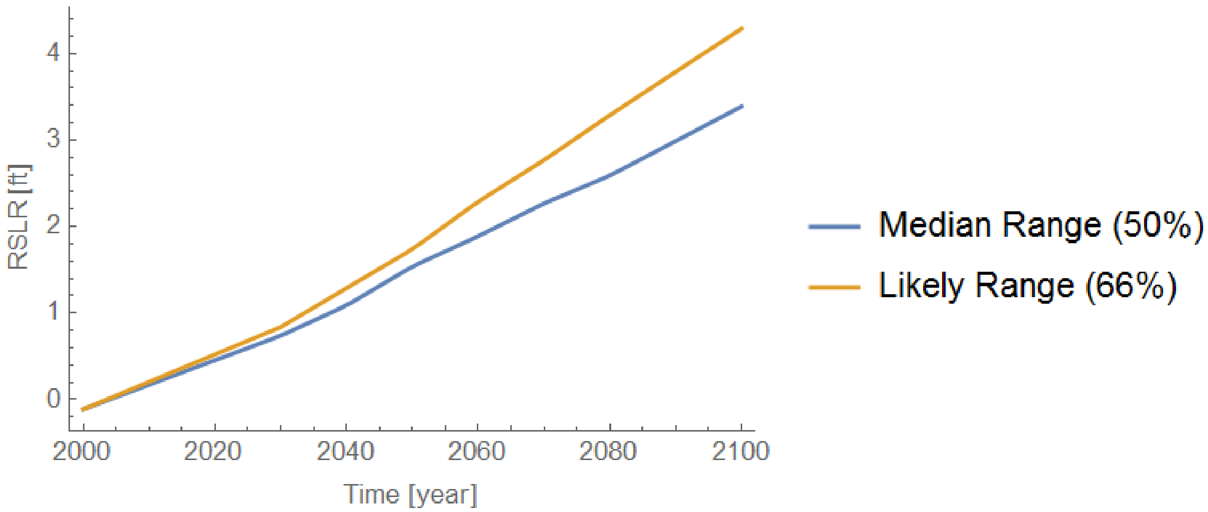

Figure 3 SLR trajectories retained for calculating EADs and EABs for the three flood management plans. Source: OPC/State of California (2018).

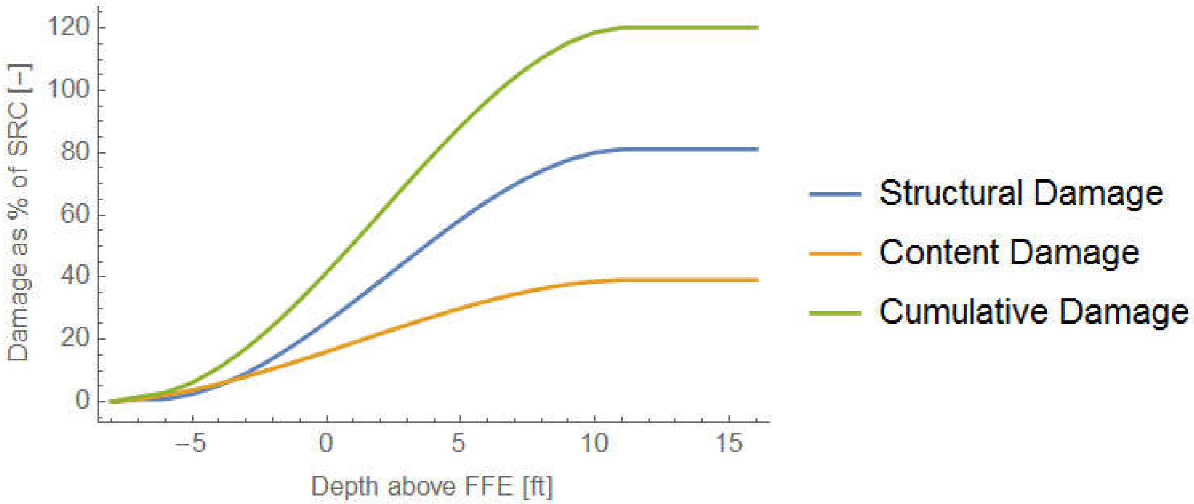

Figure 4 Generic damage curves. Source: USACE, 2003.

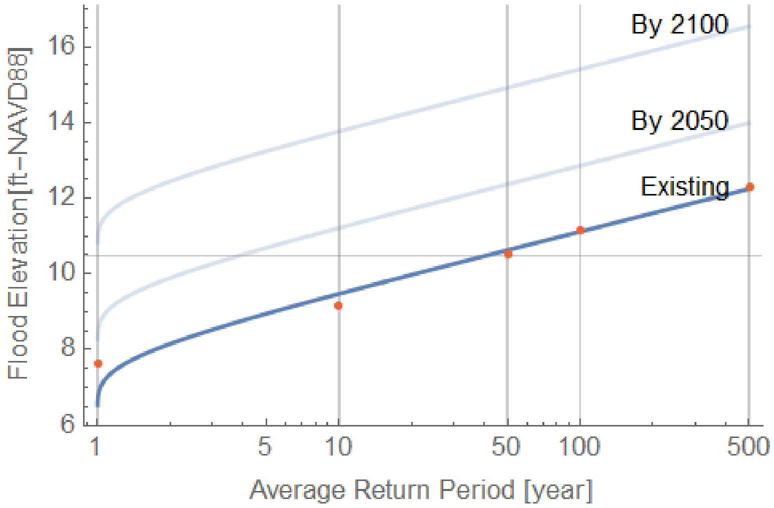

Figure 5 Fitted distribution (blue lines) for the flood events used in the model. Projections are derived by linearly adding SLR to the flood elevations. Shown here for the "high" emissions SLR trajectory.

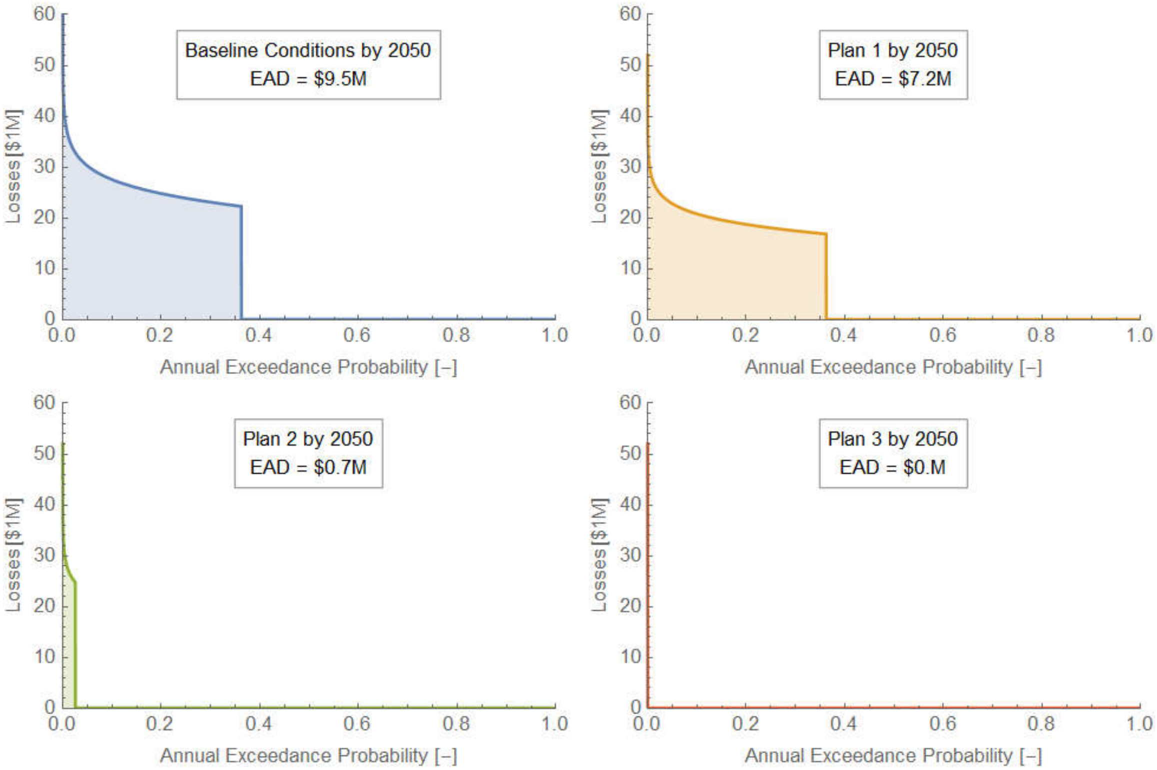

Figure 6 Example of EAD calculation for the 3 Plans and baseline conditions by year 2050, assuming a "high" emissions SLR trajectory.

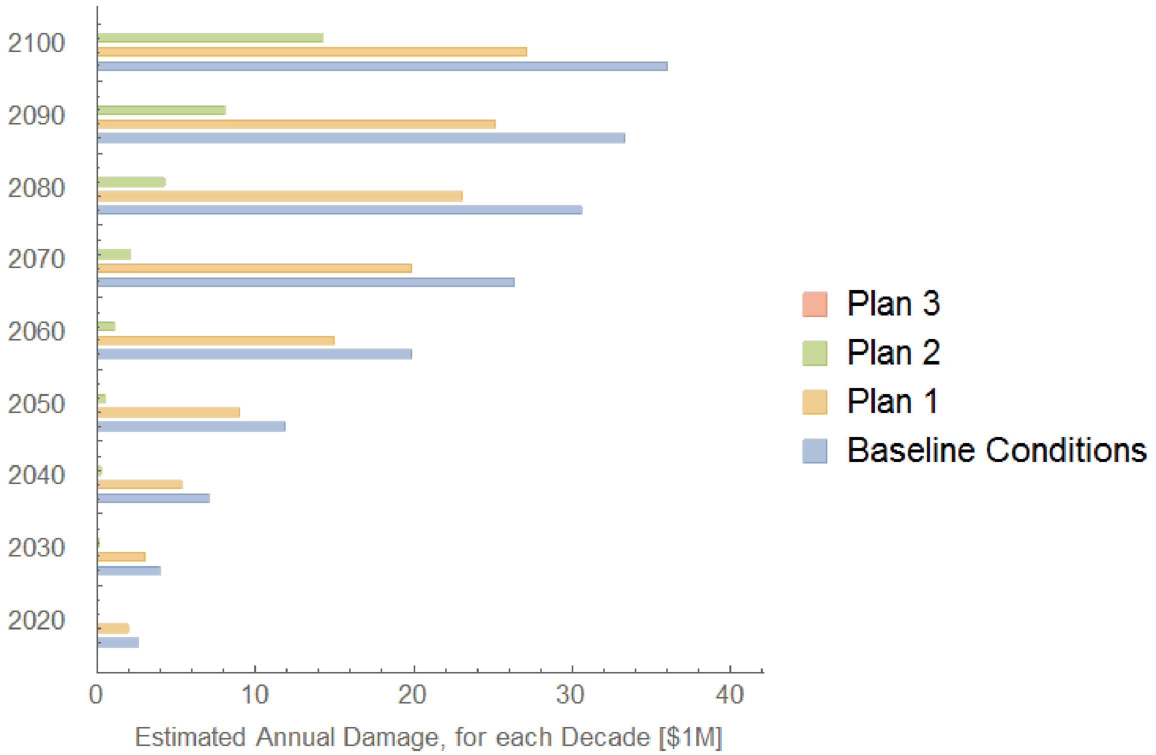

Figure 7 **EAD shown at the beginning of each decade, for the Plan considered in the project, for the "high" emissions SLR trajectory.**

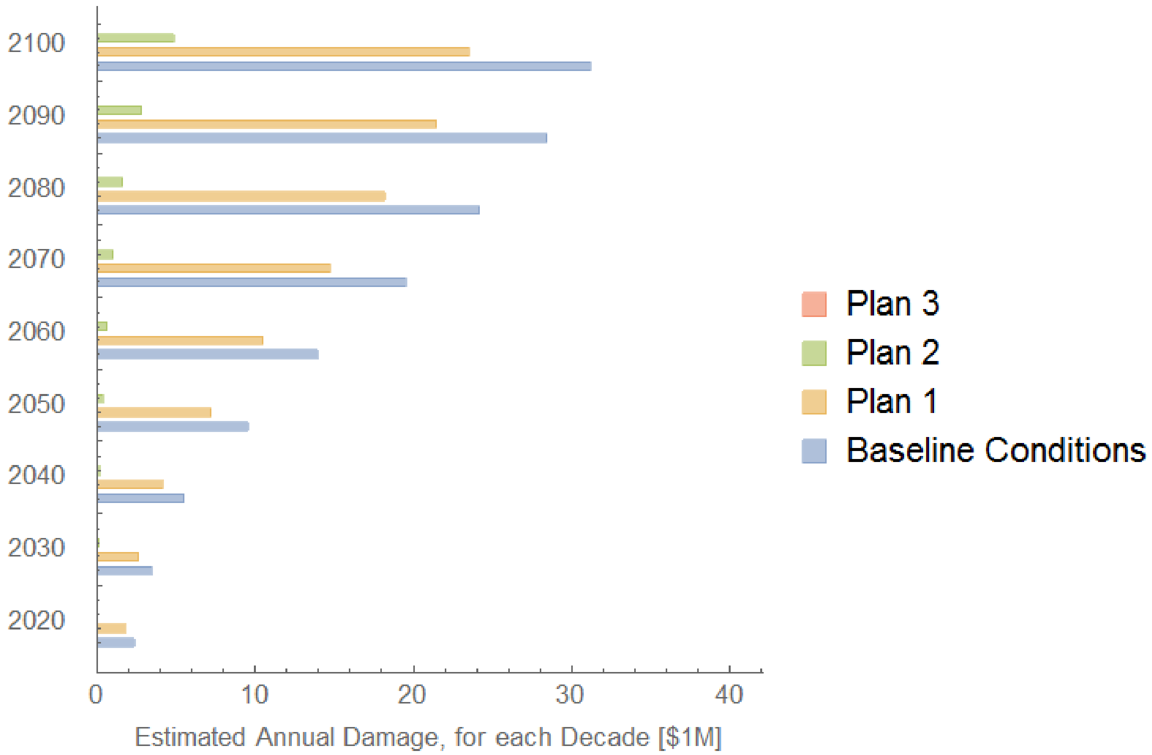

Figure 8 EAD shown at the beginning of each decade, for the Plan considered in the project, for the "low" emissions SLR trajectory.

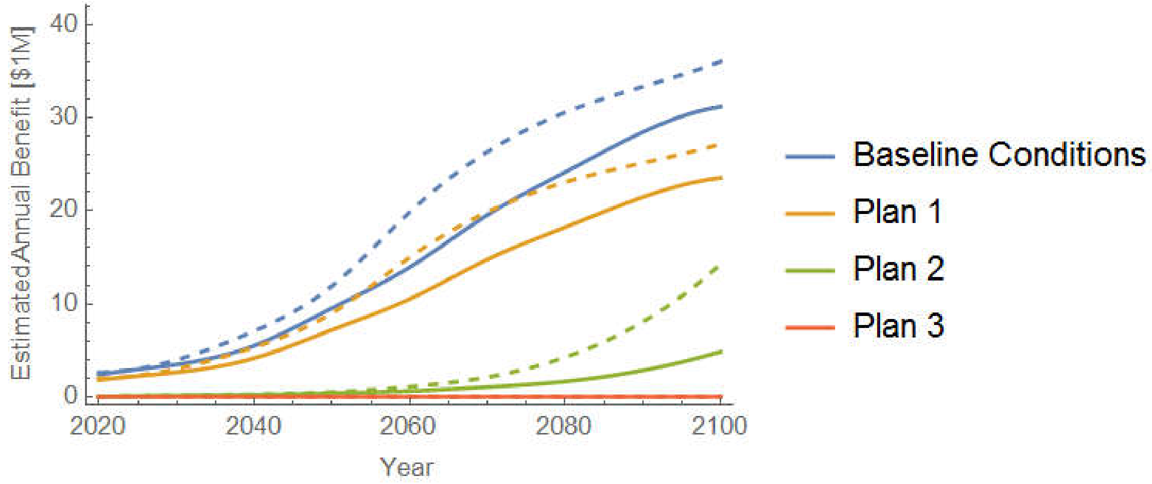

Figure 9 Evolution of EAD over time of each Plan based on a the "low" (solid line) and "high" (dashed line) SLR trajectory.

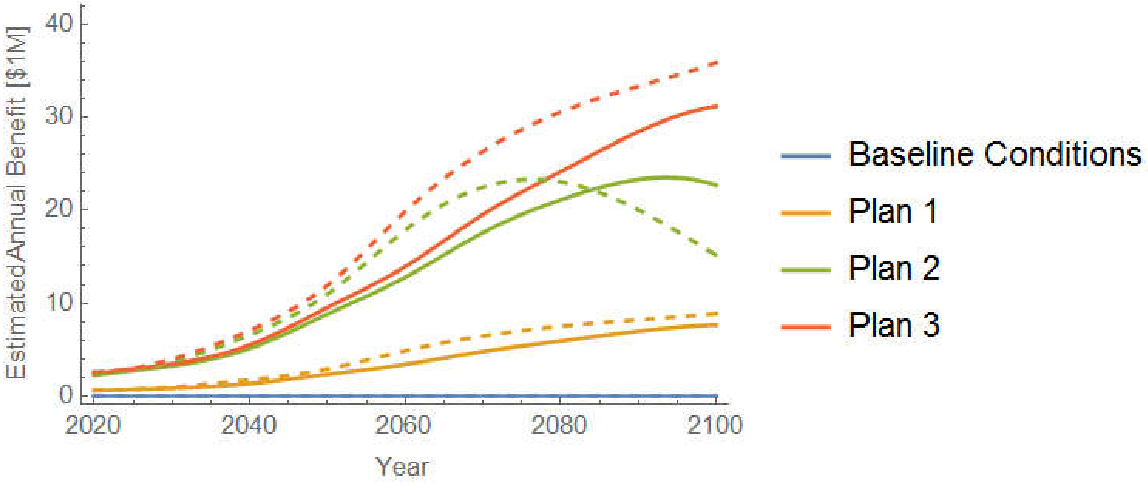

Figure 10 Evolution of EAB over time of each Plan based on a the “low” (solid line) and “high” (dashed line) SLR trajectory. By definition the EAB of baseline conditions are zero.

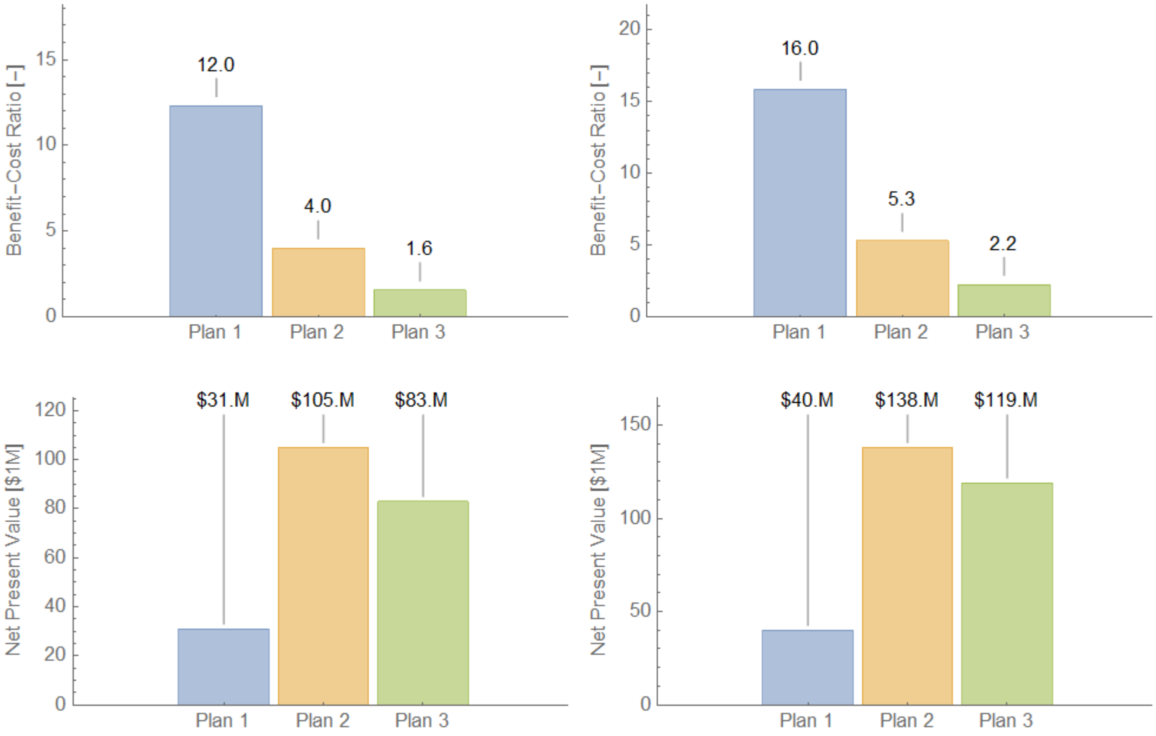

Figure 11 **Top row: BCR of each Plan shown for the “low” (left) and “high” (right) emissions SLR trajectory; bottom row: same but shown as NPV.**