City of Foster City
Levee Protection Planning Study

Updated July 2015

Schaaf & Wheeler
CONSULTING CIVIL ENGINEERS
years of excellence, commitment and value

870 Market Street, Suite 1278
San Francisco, California 94102

Table of Contents

1. Executive Summary 1
Purpose 1
Summary of Findings 1
2. Introduction 3
Flood Hazard Mitigation in Foster City 3
History of Levee System 5
Levee Accreditation 5
Code of Federal Regulations 5
Levee Accreditation Status 7
3. San Mateo County Coastal Hazard Study 8
California Coastal Analysis and Mapping Project 8
CCAMP Results 10
Potential Regulatory Flood Hazards 10
Vertical Datum Conversions 11
4. Evaluation of Existing Levees 12
100-year Stillwater and Wave Runup Elevations 12
Sources of Levee Elevation Data 12
Wilsey Ham Survey 12
Towill Survey 13
LiDAR 13
Bathymetry Data 13
Required Coastal Levee Elevations for Continued FEMA Accreditation 13
Belmont Slough Levee 14
Evidence for Coastal Hazard Control 14
Freeboard Requirements 16
Marina Lagoon Levee 16
Foster City Central Lagoon 16
5. Evaluation of Future Sea Level Rise 17
Sea Level Rise in the Bay Area 17
Local Planning Policies 18
San Francisco Bay Conservation and Development Commission (BCDC) 18
California Climate Change Center (CCC) 18
City and County of San Francisco 19
Adopted Sea Level Rise Projections for Foster City Levees 19
6. Levee Improvement Alternatives 20
Raise Earthen Levees 20
Settlement Allowance 22
Seepage Protection 22
Lightweight Levee Fill 22
Structural Floodwalls 23
Aesthetics 24
Permitting Challenges 24
Bay Trail Access during Construction 25
Adaptive Management Techniques for Sea Level Rise 25

7. Cost Estimates 26
Basis of Estimates 26
Earthen Levee Fill 27
Lightweight Fill Levee 27
Structural Floodwalls 27
Right-of-Way Costs 27
Construction Management 28
Environmental Mitigation 28
Additional Contingencies 28
Estimated Costs to Maintain FEMA Levee Accreditation 28
Funding 28
FEMA Mapping Procedures for Non-Accredited Levees 29
Flood Risk Zone D 29
8. Next Steps 32
Flood Insurance Rate Maps 32
Levee Seclusion Mapping 32
Zone A99 32
Advanced Levee Planning and Design 33
9. Conclusions 34

Attachment 1 Levee Deficiency Profiles
Attachment 2 Bibliography
Attachment 3 Cost Estimate Tables

Figures

Figure 1-1. Foster City Levee System Deficiencies ... 2
Figure 2-1. Foster City Levee System ... 4
Figure 2-2. Foster City Levee Recertification Map ... 7
Figure 3-1. San Mateo County Flood Hazard Mapping Timeline ... 8
Figure 3-2. Definition of Coastal Flood Hazards ... 8
Figure 3-3. Foster City Transects from FEMA Coastal Study of San Francisco Bay ... 9
Figure 3-4. Vertical Datum Conversions ... 11
Figure 4-1: Wilsey Ham Survey Extent ... 13
Figure 4-2. HEC-RAS model of Belmont Slough ... 15
Figure 4-3. HEC-RAS Model Profiles for MHHW and 100yr Coincident Tides ... 16
Figure 5-1. Uncertainty in Sea Level Rise Projections ... 17
Figure 6-1. Horizontal Levee ... 20
Figure 6-2. Foster City Levee Section with Adjacent Levee Crest Higher than Pedway ... 21
Figure 6-3. Foster City Levee Section with Levee Crest Compromised ... 21
Figure 6-4. Typical Earthen Levee Cross Section ... 22
Figure 6-5. Floodwall along Belmont Slough ... 23
Figure 6-6. Typical Floodwall Cross Section ... 24
Figure 6-7. Adaptive Design on Treasure Island for Sea Level Rise ... 25
Figure 7-1. Unit Cost Comparison of Raising Levee Systems ... 26
Figure 7-2. Sound Levee Reach ... 30
Figure 7-3: Freeboard Deficient Levee Reach ... 30
Figure 7-4. Levee Overtopping Analysis ... 31
Figure 7-5. Structurally Deficient Levee Breach Analysis ... 31

Tables

Table 2-1. Findings from the 1988 Born Report ... 5
Table 3-1. Coastal Flood Hazards along Foster City Shoreline ... 10
Table 4-1. CCAMP Results for Foster City Levee System ... 12
Table 4-2. Levee Deficiencies and Required Levee Crest Elevations ... 14
Table 5-1. Summary of NRC Sea Level Rise Scenarios ... 18
Table 5-2. San Francisco's Adopted Sea Level Rise Estimates ... 19
Table 7-1. Unit Cost Comparison of Raising Levee Systems ... 27
Table 7-2. Cost Estimates for FEMA Accreditation of Entire Levee System ... 28

1. Executive Summary

Purpose

Foster City is protected from flooding hazards by approximately 43,000 feet (8 miles) of levees that surround the perimeter of the city. The purpose of this study is to provide the City with a comprehensible framework as to how its flood risk is impacted by the newly released coastal study results for San Francisco Bay and the recent levee crest survey. This includes outlining:

- The potential impact on levee accreditation;
- Potential regulatory constraints the City may face as it improves its levee system;
- How the levee system can be adapted to future estimates of sea level rise and the uncertainty inherent in those estimates;
- Potential levee improvement alternatives that may be used to retain FEMA levee accreditation per 44 CFR 65.10; and
- Planning level cost estimates to retain the accredited status of the levee system.

This study does not include an evaluation of the geotechnical stability of the levees per USACE's levee system evaluation criteria for the National Flood Insurance Program (NFIP).

Summary of Findings

Based on the revised FEMA coastal flood hazard study, roughly 85 percent of Foster City's levees do not meet the required freeboard elevation per 44 CFR 65.10 and therefore, will not retain their accredited status when FEMA remaps San Mateo County for coastal flood hazards. In addition, four percent of the levee system is overtopped by the one-percent (100-year) stillwater tide. The average freeboard elevation deficiency across the levee system is approximately 2 feet, with a maximum deficiency of 4 feet. Figure 1-1 shows on overview of the entire Foster City levee system with color coded segments that are freeboard deficient (yellow), overtopped by the one-percent stillwater tide (red) and meet the required elevation for accreditation (green). Levee status is discussed in detail throughout the report and detailed profiles of the required levee crest elevations to meet FEMA accreditation and compliance per 44 CFR 65.10 are provided as plan and profile sheets are divided into 3,000 feet long sections of the levee starting at Station 0+00 at the San Mateo City Limit, and generally increasing toward the south and the terminus of the outboard levee system adjacent to Belmont Slough near the Belmont and San Mateo City Limits.

Marina Lagoon forms Foster City's western boundary and controls runoff from Laurel Creek, the 16th Avenue Drainage Channel and the 19th Avenue Drainage Channel in neighboring San Mateo. There is no regulatory threat of flooding from this facility based on a recently approved appeal to the Flood Insurance Rate Map. Similarly there is no regulatory risk of flooding from Foster City's Central Lagoon, which controls storm water runoff on the interior side of the levee system, as determined by FEMA through a recent appeal made by Foster City to the Flood Insurance Rate Map.

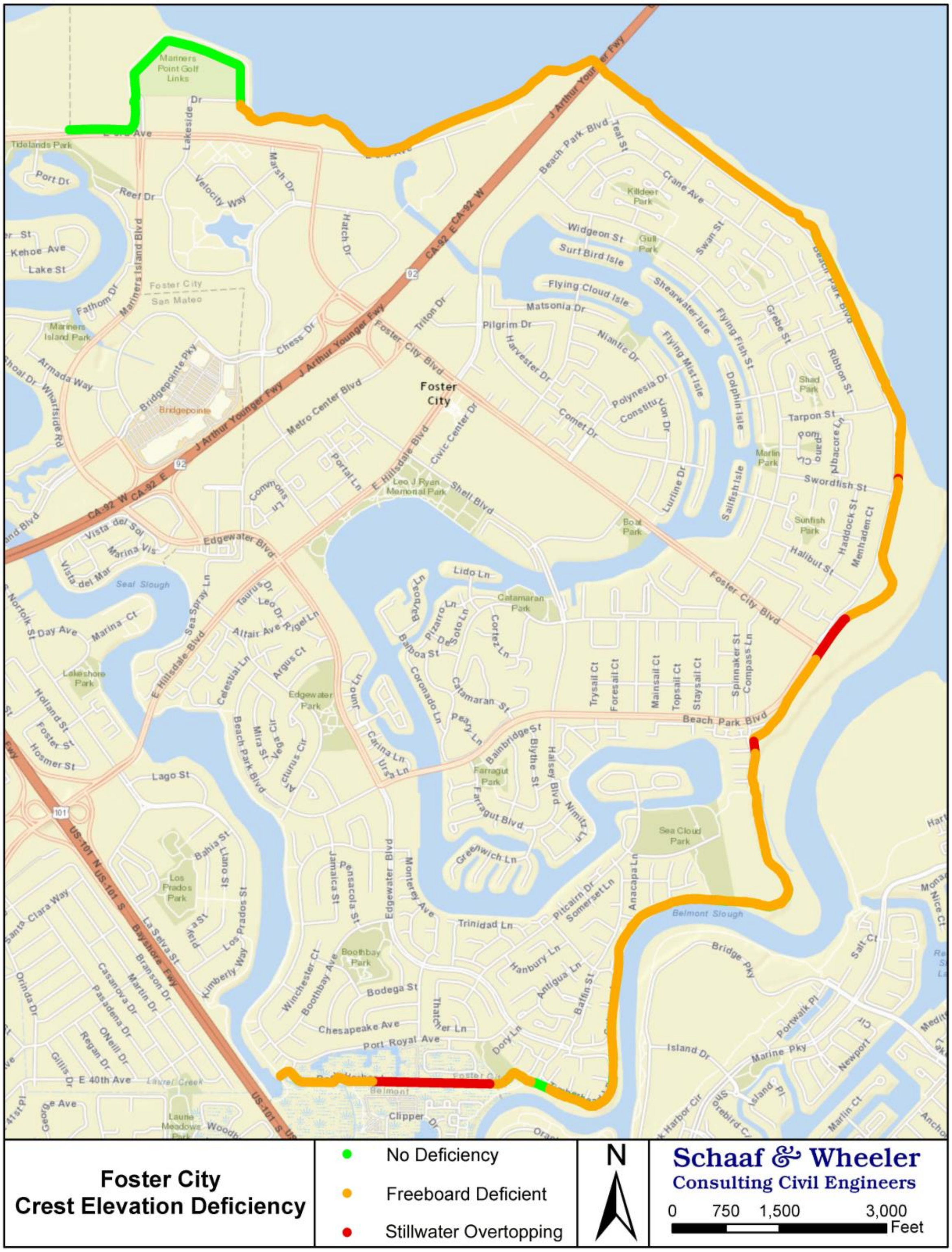


Figure 1-1. Foster City Levee System Deficiencies

2. Introduction

Flood Hazard Mitigation in Foster City

Approximately 9,000 properties in Foster City are protected from the one-percent annual chance of flooding by a 43,000 feet long outboard levee system that was primarily designed for flood protection. This represents nearly 8 miles of earthen levees. An additional 8,000 properties in the City of San Mateo are also protected by the Foster City levee system. Conversely, properties in Foster City are protected from the one-percent flood by San Mateo's levee and floodwall systems south of San Mateo Creek.

The U.S. Department of Homeland Security, Federal Emergency Management Agency (FEMA) certified Foster City's levee in 2007 as providing protection from the one-percent annual chance (base) flood. This flood is often called the "100-year flood", but should not be confused with an event that is expected to occur only once every 100 years. It is the event that has the one-percent chance of occurring every year.

Currently land within the Foster City limits is classified as Shaded Zone X, where mandatory flood insurance is not required. While flood insurance is not mandatory, FEMA does encourage homeowners to purchase flood insurance through the National Flood Insurance Program (NFIP) to insure against flood losses.

Foster City is also protected from flooding by the Bayfront levee system in the City of San Mateo. In 2011 the City of San Mateo improved their levee system south of San Mateo Creek and received FEMA accreditation in March 2012. This accreditation is still recognized.

FEMA recently updated its analysis of the flood hazards posed by San Francisco Bay through the California Coastal Analysis and Mapping Program (CCAMP). Details of this study are provided in Chapter 3. Once new maps become effective (anticipated in 2016), Foster City's levees will no longer be considered accredited against coastal flood hazards. Changing this outcome will require levee re-certification as discussed herein.

The levee system also provides recreational uses for the community and these uses must be considered in any advanced levee planning. Residents enjoy walking, running, bicycling and skating on the levee pathway, which also forms part of the San Francisco Bay Trail system for the greater Bay Area community. Figure 2-1 shows an aerial extent of the Foster City levee system. The figure also shows the levee system broken up into sections which correspond to more detailed levee plan and profile sheets that are provided as Attachment 1.

Although the flood protection is provided by a number of levee segments that might differ in elevation and cross section, the segments are considered as an integrated system by FEMA when they establish levee accreditation and Special Flood Hazard Areas (SFHA) for Foster City. It may be noted, however, that the published CCAMP report on San Mateo County coastal (Bayfront) flood hazards does not specifically address the levees adjacent to Marina Lagoon or Belmont Slough.

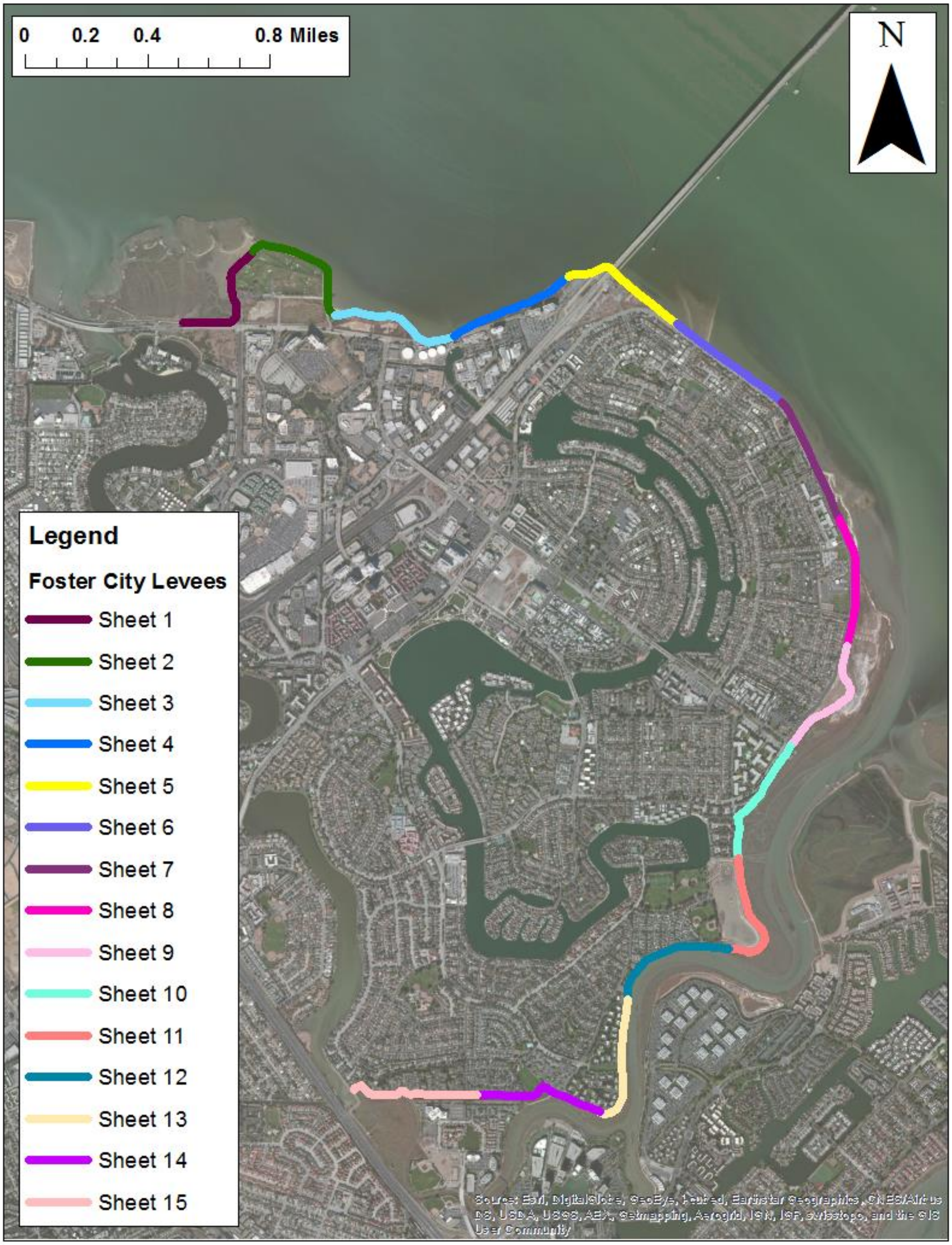


Figure 2-1. Foster City Levee System

History of Levee System

The original perimeter levee system in Foster City was put in place in the early 1900s to reclaim tidal mud flats for agricultural use. The levees were formed with dredged bay mud deposited on the outboard side of a perimeter channel system formed by the dredging. The development of Foster City in the 1960s made use of the existing perimeter levee system to provide protection for the new development. It is believed that some upgrades to the levee system were performed at this time; however, paper records have not been identified. The perimeter channels were filled with dredged material from the interior lagoon.

In 1984 FEMA issued new Flood Insurance Rate Map (FIRM) for the City which significantly altered the presumed level of flood protection provided by the levee system. The City appealed the new maps and hired Robert H. Born Consulting Engineers, Inc. Mr. Born compiled information and analyses into a report that is referred to as the "Born Report."[1] The Born Report includes analyses on coastal flooding, 100-year riverine flooding, and presents the results of a geotechnical investigation by J.H. Kleinfelder and Associates.

The Born Report recommends the City appeal to FEMA that a relaxed levee freeboard requirement be accepted for the Foster City perimeter levee system. Born considered a freeboard allowance of no more than two feet as reasonable for the riverine levee along Belmont Slough (in contrast to three feet for riverine levees that is required by FEMA), and two feet above the 100-year stillwater elevation would be reasonable for the coastal levees. Born's original recommendations are summarized by Table 2-1.

Table 2-1. Findings from the 1988 Born Report

Criteria	North levee[1]	East levee[1]	Belmont Slough levee[2]
100-yr stillwater elevation (ft, NAVD)	9.7	9.7	9.7
Maximum wave runup (ft, NAVD)	11.7	11.7	-
100-yr flood level (ft, NAVD)	-	-	9.7 to 10.2
Freeboard (ft)	1.0	1.0	2.0
Required crown elevation (ft, NAVD)	12.7	12.7	12.7 to 13.2

1. North levee from San Mateo City border to San Mateo Bridge, East levee from San Mateo Bridge to Belmont Slough
2. Analyzed as riverine levee – Minimum 3ft of freeboard above the 100-yr flood level, however recommended that only 2-ft of freeboard be required

Foster City raised their levee system by about 18 inches in 1995 in response to the recommendations made in the Born Report. The cost estimate for this work was $1.3 million in 1987 dollars.

Levee Accreditation

Code of Federal Regulations

Title 44 of the Code of Federal Regulations (44 CFR) Section 65.10 provides the minimum design, operation, and maintenance standards levee systems must meet and continue to meet in order to be recognized as providing protection from the base flood on a Flood Insurance Rate Map.

[1] *Robert H. Born Consulting Engineers, Inc., "Report on Analysis of Foster City Levees," June 15, 1988.*

For levees to be recognized by FEMA, evidence that adequate design and operation and maintenance systems are in place to provide reasonable assurance that protection from the base flood exists must be provided. The following requirements must be met:

Freeboard Requirements

For riverine levees, the freeboard must be established at three feet above the water surface level of the base flood.

For coastal levees, the freeboard must be established at one foot above the height of the one percent wave or the maximum wave runup (whichever is greater) associated with the 100-year stillwater surge elevation at the site. In Foster City the criterion for 1 foot of freeboard above the maximum wave runup elevation generally controls the levee elevation requirements for those levee segments exposed to wind-waves from San Francisco Bay. A freeboard of less than two feet above the 100-year stillwater surge elevation will not be accepted for an accredited levee by FEMA.

Geotechnical Requirements

In addition to required freeboard, levee systems must be evaluated for their ability to resist the various loads placed on them, and with earthen levee systems, meeting geotechnical performance standards is paramount. These standards are also explicitly stated in 44 CFR 65.10. While not the primary focus of this planning level study, these standards are listed herein as they help inform planning alternatives and cost estimates.

Embankment protection. Engineering analyses must be submitted that demonstrate that no appreciable erosion of the levee embankment can be expected during the base flood, as a result of either currents or waves.

Embankment and foundation stability. Engineering analyses must evaluate levee embankment stability must be submitted. The analyses shall evaluate expected seepage during loading conditions associated with the base flood and shall demonstrate that seepage into or through the levee foundation and embankment will not jeopardize embankment or foundation stability.

Settlement. Engineering analyses must be submitted that assess the potential and magnitude of future losses of freeboard as a result of levee settlement and demonstrate that freeboard will be maintained within the minimum standards.

Other Requirements

Closures. All openings must be provided with closure devices that are structural parts of the system during operation and design according to sound engineering practice

Interior drainage. An analysis must be submitted that identifies the source(s) of such flooding, the extent of the flooded area, and, if the average depth is greater than one foot, the water-surface elevation(s) of the base flood. This work has been completed.[2]

[2] *Schaaf & Wheeler Consulting Civil Engineers, "Foster City Central Lagoon Base Flood Elevation," January 2014.*

Levee Accreditation Status

In July 2007 the Foster City levee system was recertified and accredited by FEMA. The following the data and documentation was submitted to FEMA by Foster City:

- written commentary on the performance of the levee system in an actual flood event; and
- geotechnical information submitted in accordance with 44 CFR 65.10 (b) (4) evaluating expected seepage during conditions associated with the base flood demonstrating that seepage through the levee foundation will not jeopardize stability.

Based on this documentation and data, FEMA found the levee shown in green on Figure 2-2 met the minimum certification criteria outlined in 44 CFR 65.10.

In March of 2012, San Mateo's Bayfront levees were accredited by FEMA which meant that all of Foster City and San Mateo were to be shown on updated maps as Shaded Zone X, which does not require property owners to buy flood insurance.

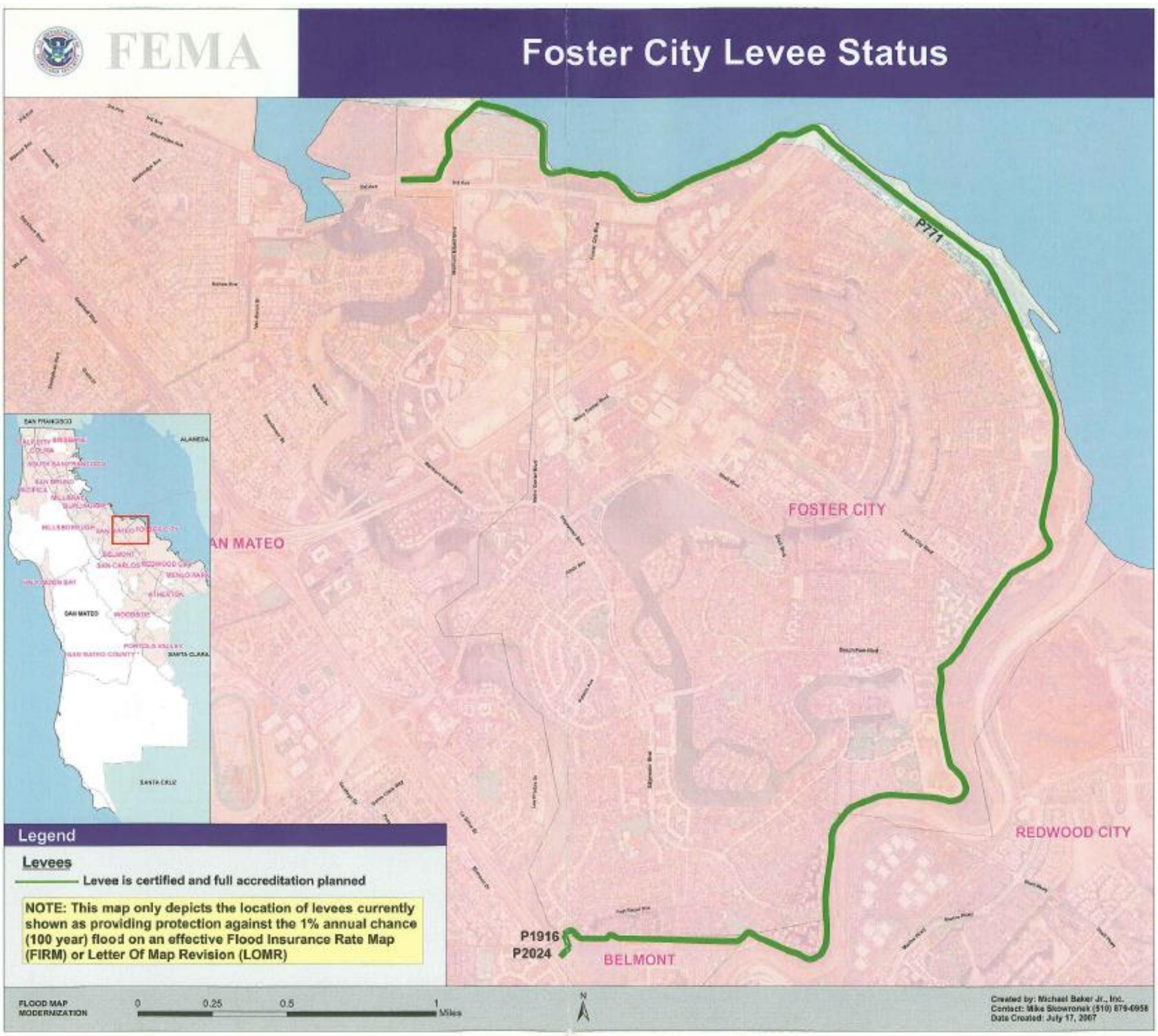


Figure 2-2. Foster City Levee Recertification Map

3. San Mateo County Coastal Hazard Study

One primary driver of this levee planning study is FEMA's California Coastal Analysis and Mapping Program (CCAMP). This study will revise and update flood and wave data included in the National Flood Insurance Program (NFIP), Flood Insurance Study (FIS) reports, and Flood Insurance Rate Map (FIRM) panels. Foster City regulates its floodplains using the FIRM dated October 16, 2012. FEMA is in the process of updating San Mateo County flood hazard mapping and is following a timetable outlined in Figure 3-1.

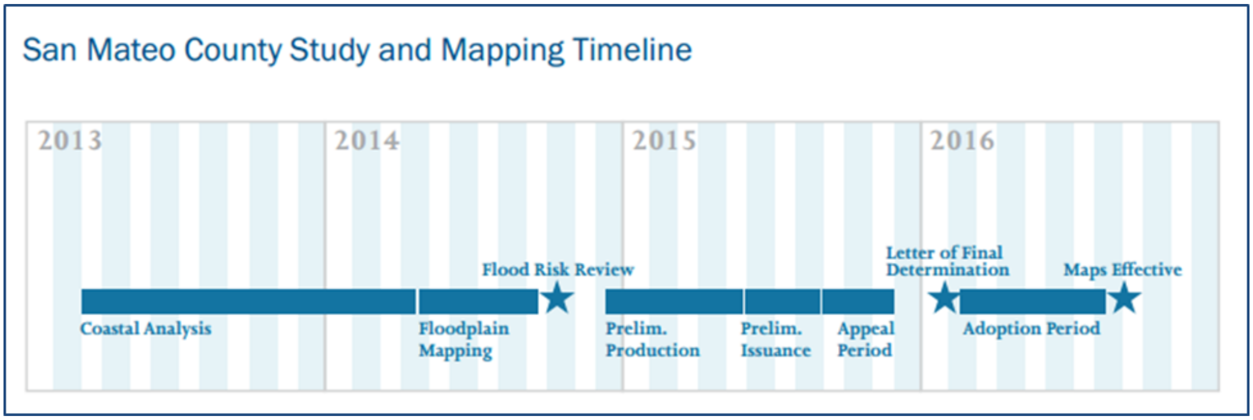


Figure 3-1. San Mateo County Flood Hazard Mapping Timeline

California Coastal Analysis and Mapping Project

FEMA recently completed an engineering study of San Francisco Bay including detailed analyses of coastal hazards as part of the California Coastal Analysis and Mapping Project (CCAMP). Results summarized in the "Central San Francisco Bay Coastal Flood Hazard Study" prepared in July 2014 will be used by FEMA to remap the coastal flood hazards for San Francisco Bay communities including Foster City. Coastal flood hazards are illustrated schematically in Figure 3-2, with relevant terms defined below.

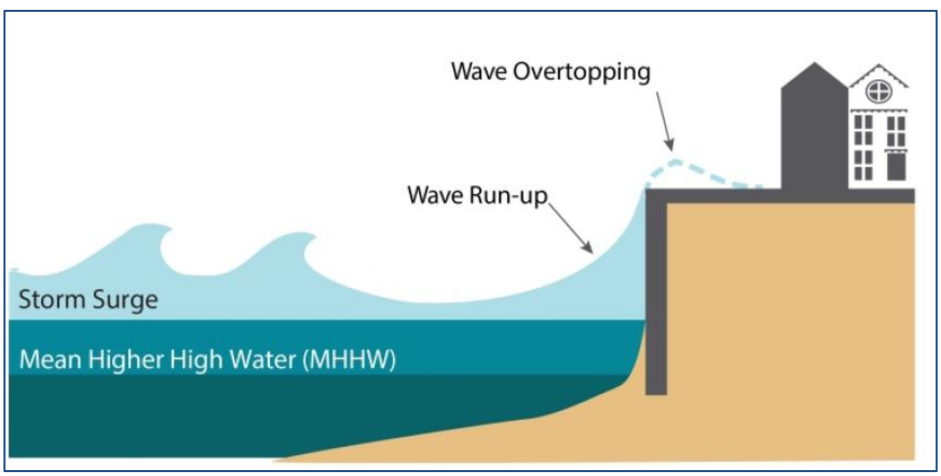


Figure 3-2. Definition of Coastal Flood Hazards (ref. San Francisco PUC)

Mean Higher High Water (MHHW)	The arithmetic average of the elevations of the higher high tides over a specific 19-year period.
Storm Surge	An abnormal rise of water generated by a storm, over and above the predicted astronomical tide. Storm surges may be caused by a combination of low barometric pressure and onshore winds.
Wave Runup	Wave runup occurs when a wave breaks near the shoreline and water is propelled onto the beach or a barrier.
Wave Overtopping	Wave overtopping takes place when waves meet the shore or structure lower than the approximate wave height.

FEMA's technical contractor (BakerAECOM) evaluated coastal flooding hazards from San Francisco Bay with one-dimensional transect-based models to calculate wave setup, runup, overtopping and overland wave propagation. Water levels and wave parameters used in the transect analyses were derived from a regional hydrodynamic and wave model for north and central San Francisco Bay completed by DHI in 2011. These water levels include the effects of tides, storm surge and riverine discharges. Since DHI's hydrodynamic and wave modeling work did not transform the waves at a sufficiently fine discretization to resolve surf zone dynamics including wave breaking and the generation of wave setup, the one-dimensional transects were necessary to establish special flood hazard areas along the shoreline of San Francisco Bay. Transects were placed perpendicular to the shore with consideration of variations in topography, shoreline type and incident wave conditions. Figure 3-3 shows the CCAMP transects in the vicinity of Foster City.

Figure 3-3. Foster City Transects from FEMA Coastal Study of San Francisco Bay

CCAMP Results

Wave runup was calculated for those transects with coastal armoring (e.g. riprap) or steeply sloping ground profiles near the flooded shoreline. Wave setup and runup were combined with coincident water levels from the DHI surge model to develop Total Water Level (TWL) values. As statistical extreme value analysis was performed on TWL estimates over a range of the 54 years modeled to arrive at the one-percent TWL for flood hazard analysis. FEMA's Wave Height Analysis for Flood Insurance Studies (WHAFIS) model was used for overland wave propagation and dissipation by marsh grasses to establish the TWL at Foster City Transect No. 28.

Preliminary coastal hazard maps prepared for CCAMP and summarized by Table 3-1 show Special Flood Hazard Areas on the Foster City shoreline that are up to three feet higher than the currently effective Flood Insurance Rate Map shows. In the absence of levee accreditation Foster City would be shown as subject to 100-year inundation at an elevation of 10 feet NAVD, which is the rounded one-percent stillwater elevation.

Table 3-1. Coastal Flood Hazards along Foster City Shoreline

		CCAMP		Effective FIS		
Location	CCAMP Transect Number	Stillwater Elevation (ft NAVD)	Maximum Wave Runup (ft NAVD)	Stillwater Elevation (ft NAVD)	Maximum Wave Runup (ft NAVD)	Increase in Hazard (feet)
San Mateo City Limit	28	10.4	12.8	10.0	10.0	2.8
Mariner's Point	29	10.4	14.0	10.0	10.0	4.0
Estero WPCP	30	10.4	14.5	10.0	10.0	4.5
Lincoln Center Dr.	31	10.4	14.4	10.0	10.0	4.4
Egret Street	1000	10.2	13.7	10.0	10.0	3.7
Marlin Avenue	1001	10.2	14.1	10.0	10.0	4.1
Swordfish Street	1002	10.2	n/a	10.0	10.0	0.2
Belmont Slough	n/a	10.2	n/a	10.0	n/a	0.2
O'Neill Slough	n/a	10.2	n/a	10.0	n/a	0.2

Potential Regulatory Flood Hazards

The Flood Insurance Rate Map for San Mateo County that became effective October 16, 2012 shows all of Foster City outside of the Central Lagoon in a moderate flood hazard zone (Shaded X). This designation shows the area protected from one-percent flooding by an accredited levee system. As demonstrated by Table 3-1 this status could be in jeopardy.

According to FEMA regulations "under the provisions of the Flood Disaster Protection Act of 1973, individuals, businesses and others buying, building or improving property located in identified areas of special flood hazards within participating communities are required to purchase flood insurance as a prerequisite for receiving any type of direct or indirect federal financial assistance (e.g., any loan, grant, guaranty, insurance, payment, subsidy or disaster assistance) when the building or personal property is the subject of or security for such assistance." The City desires to prevent this burden from being placed on to qualifying property owners located within the area protected by Foster City's levees, which includes all of Foster City and part of San Mateo. There are close to 9,000 parcels within Foster City and an additional 8,000 parcels within San Mateo protected from one-percent tidal flooding by the combined levee system.

Vertical Datum Conversions

A given elevation may be on one or more of the four vertical datums often used in Foster City:

MLLW	Mean Lower Low Water (tidal datum at San Mateo Bridge)
NGVD29	National Geodetic Vertical Datum of 1929
NAVD88	North American Vertical Datum of 1988
CFC	City of Foster City Survey Datum

Depending upon the context and source of information, vertical datums are used interchangeably depending upon the source of information. Figure 3-4 shows the factors used to convert an elevation from one vertical datum to another. Results from the CCAMP study are on the North American Vertical Datum of 1988 (NAVD88) as are FEMA's official mapping products. Earlier studies including the Born Report often refer to the National Geodetic Vertical Datum of 1929 (NGVD29). Tidal elevations are often given as feet MLLW. Finally City staff are often more familiar with the Foster City Datum, which adds 100 feet to the NGVD29 datum, to avoid negative elevations.

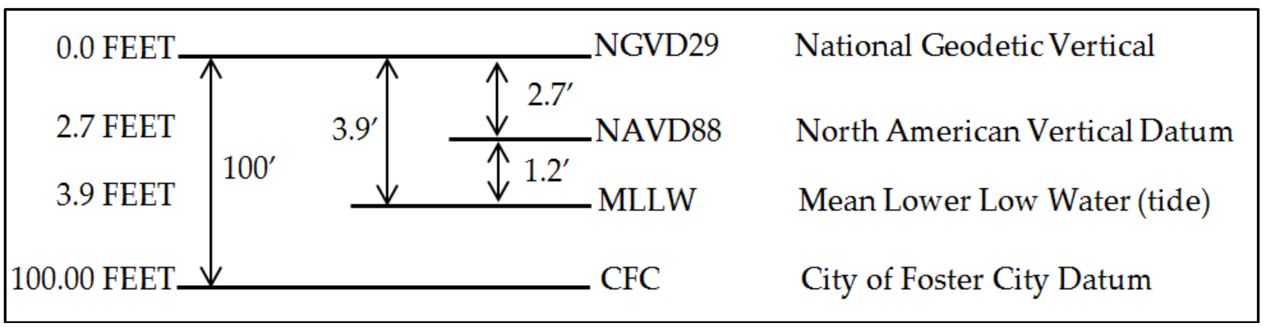


Figure 3-4. Vertical Datum Conversions

4. Evaluation of Existing Levees

The CCAMP report concludes that Foster City's levees do not provide the requisite coastal freeboard as required by 44 CFR 65.10 for levee accreditation, and as such flood hazard mapping for Foster City should not consider the protection provided by the levee system. With this conclusion, the entirety of Foster City and adjacent portions of San Mateo will be shown as within a Special Flood Hazard Area (Zone AE – Elevation 10 feet NAVD).

To further evaluate potential deficiencies in the Foster City levee system, results from the CCAMP (BakerAecom) studies have been compared to the surveyed crest elevations of the existing levee segments using the stated requirements from 44 CFR 65.10 to analyze the current levee system for freeboard based on the 100-year stillwater and maximum wave runup elevations determined by FEMA through CCAMP.

100-year Stillwater and Wave Runup Elevations

Table 4-1 lists the levee crest elevations, one-percent stillwater elevations and maximum wave runup elevations along with their associated levee freeboard criteria at the CCAMP transect locations in Foster City. Transect 28 starts in San Mateo with transect numbering increasing towards Redwood City, ending with transect 1002 at the mouth of Belmont Slough as shown in Figure 3-3.

Table 4-1. CCAMP Results for Foster City Levee System

Transect Number	Levee Crest Elevation (ft NAVD)	Stillwater Elevation (ft NAVD)	Max. Wave Runup Elevation (ft NAVD)	2 ft above Stillwater Elevation (ft NAVD)	Freeboard Criteria Met?	1 ft above Wave Runup (ft NAVD)	Freeboard Criteria Met?
28	14.7	10.4	12.8	12.4	Yes	13.8	Yes
29	11.1	10.4	14.0	12.4	No	15.0	No
30	11.4	10.4	14.5	12.4	No	15.5	No
31	11.6	10.4	14.4	12.4	No	15.4	No
1000	12.1	10.2	13.7	12.2	No	14.7	No
1001	12.3	10.2	14.1	12.2	Yes	15.1	No
1002	11.6	10.2	n/a	12.2	No	n/a	n/a

Sources of Levee Elevation Data

A number of sources of elevation data have been consulted to cross-check existing levee conditions within Foster City and compare crest elevations to freeboard requirements provided by the CCAMP study.

Wilsey Ham Survey

Wilsey Ham conducted a levee pedway and boundary survey in 2008 and 2009. In 2014 the data were re-evaluated through control surveys to ensure the vertical datum was correct. The survey appears to collect the elevations along the edge of pavement for the bike path. The extent of this survey is shown in Figure 4-1.

Figure 4-1: Wilsey Ham Survey Extent

Towill Survey

In 1991 Towill Inc. survey the city and prepared AutoCAD drawings. In addition, orthophotos were taken in 1998 and 2004.

LiDAR

In 2001 NOAA published the 2011 Northern San Francisco Bay Area LiDAR Light Detection and Ranging (LiDAR) dataset. This dataset is available for download at http://earthexplorer.usgs.gov/.

Bathymetry Data

In 2012, the Department of Water Resources Bay Delta Office produced digital elevation model (DEM) of the San Francisco Bay and Sacramento-San Joaquin Delta. A portion of this DEM covers the Belmont Slough. While it is impossible to tell without detailed survey data, the Bathymetry data and LiDAR data seem to be in agreement for the crest elevations that are used in Belmont Slough.

Required Coastal Levee Elevations for Continued FEMA Accreditation

Levee deficiencies have been evaluated by breaking the levee system into 3,000 linear-foot sections, starting at the confluence of the San Mateo and Foster City levees. Transect data are applied to the closest levee section, and interpolated between transect sections. Attachment 1 to this report contains 14 sheets that show the levee crest elevation profile in comparison with FEMA-required levee elevations for accreditation. Based on this analysis, it is found that 36,000 feet or roughly 85 percent of the levee system does not meet FEMA's freeboard requirements. Furthermore, 2,000 feet of the levee system would be overtopped by the one-percent stillwater elevation. The average height increase required is about two feet and the maximum height increase is four feet. These values do not consider sea level rise or settlement, which could amount to an additional 1.5 feet. Table 4-2 summarizes the levee deficiencies and the required levee crest elevations for each levee sheet section, per the requirements of 44 CFR 65.10.

Table 4-2. Levee Deficiencies and Required Levee Crest Elevations

Levee Sheet	Transect Number(s)	Linear Feet of Deficiency	Height Deficiency (ft)	Required Levee Crest Elevation (ft, NAVD)
1	28/29	1000	1	13.8/14.4
2	28/29/30	1000	4	14.4/15.0/15.3
3	30/31/1000	3000	4	15.3/15.5/15.4
4	31/1000	3000	4	15.4/15.1
5	31/1000/1001	3000	3	15.1/14.7/14.9
6	1001/1002	3000	2	14.9/12.2
7	1002	3000	1.5	12.2
8	1002	3000	2	12.2
9	1002	3000	3	12.2
10	1002	3000	2	12.2
11	1002	3000	1.5	12.2
12	1002	3000	1.5	12.2
13	1002	3000	1.5	12.2
14	1002	1000	1	12.2
15	1022	800	1	12.2

The deficiencies presented in table 4-2 are based on calculating the highest crest elevation from LiDAR data. It is believed that the calculated highest crest elevation included the walls along Belmont Slough, however, it is possible that floodwalls may have been missed as the width of the walls (~6 inches) is close to the level of accuracy of the Lidar data. A detailed survey data should be performed to accurately determine the height deficiency throughout the entire levee system.

Belmont Slough Levee

Belmont Slough forms much of the eastern border of Foster City and there is a protective levee along the slough from its mouth of at San Francisco Bay south to the O'Neill Slough tide gate structure operated by the City of San Mateo near U.S. Highway 101. This levee is not evaluated in the CCAMP study since without exposure to wind-wave action from San Francisco Bay, it is not considered to be a coastal hazard. With respect to FEMA levee accreditation, the question is whether this levee is a riverine levee or a coastal levee.

Evidence for Coastal Hazard Control

The currently effective and proposed FIRMs show a level water surface for all of Belmont Slough to its terminus near Highway 101. Unfortunately the effective Flood Insurance Studies for Foster City and Belmont do not define a base flood discharge or water surface profile in Belmont Creek downstream of Highway 101, and it appears there are no published detailed studies or profiles of Belmont Creek.

Consequently, a cursory hydraulic analysis has been conducted for Belmont Slough to assess whether levee freeboard should be set using the coastal standard of two feet above the one-percent stillwater elevation (the minimum allowed) or three feet above the one-percent water surface profile as required for riverine systems. Because there are no published discharges for Belmont Creek, unit discharges previously estimated under separate contract for the immediately adjacent Laurel Creek watershed are used to estimate the 100-year discharge for Belmont Creek, which becomes Belmont Slough at Marine Parkway.

The Laurel Creek watershed is within close proximity of the Belmont Creek watershed and has similar land use characteristics, range of topographic elevation and rainfall. The Laurel Creek watershed is an approximately 4.6 square mile basin that produces approximately 420 cfs/mi^2 during the one-percent storm event (i.e., 100-year unit discharge). The Born Report indicates that the Belmont Slough drains an area of approximately 3.2 square miles. Using the unit discharge per square mile for the Laurel Creek watershed, the estimated Belmont Slough one-percent discharge is about 1,350 cfs.

Cross sections through Belmont Slough have been cut using the same bathymetric data collected in 2012 by FEMA for the South Bay portion of the CCAMP study. Figure 4-2 shows the aerial extent of this bathymetry and cross sections cut to build an HEC-RAS model to establish water surface profiles for Belmont Slough.

Figure 4-2. HEC-RAS model of Belmont Slough

The estimated base flood (100-year) discharge of 1,350 cfs is run in a steady state model against two different downstream tidal boundary conditions. In Foster City the MHHW is 7.5 feet NAVD. The model is also run against what is known as a coincident tide to assess the robustness of levee freeboard with a more conservative assumption. The statistically coincident 100-year tide at the mouth of Belmont Slough is 9.5 feet NAVD. The coincident tide represents the highest tide on the day of the peak annual stormwater runoff event and does not account for the precise timing differences between maximum tide and peak riverine discharge. As such, there is built-in conservatism. These tidal boundary conditions were analyzed in 2014 by Schaaf & Wheeler and described in the report "Foster City Central Lagoon Base Flood Elevation."

HEC-RAS model results show a water surface elevation at the O'Neill Slough Tide Gate of approximately 9.7 feet NAVD for the 100-year coincident tidal boundary condition and 8.2 feet NAVD for the MHHW boundary condition. For riverine flooding, FEMA *Guidelines and Specifications for Flood Hazard Mapping Partners* require that one-percent riverine flooding be evaluated against a mean higher high water (MHHW) tide as the downstream boundary condition. This would indicate a minimum required levee elevation height of 11.2 feet NAVD at the south end of O'Neill Slough. Figure 4-3 shows modeled water surface profiles for the Belmont Slough reach.

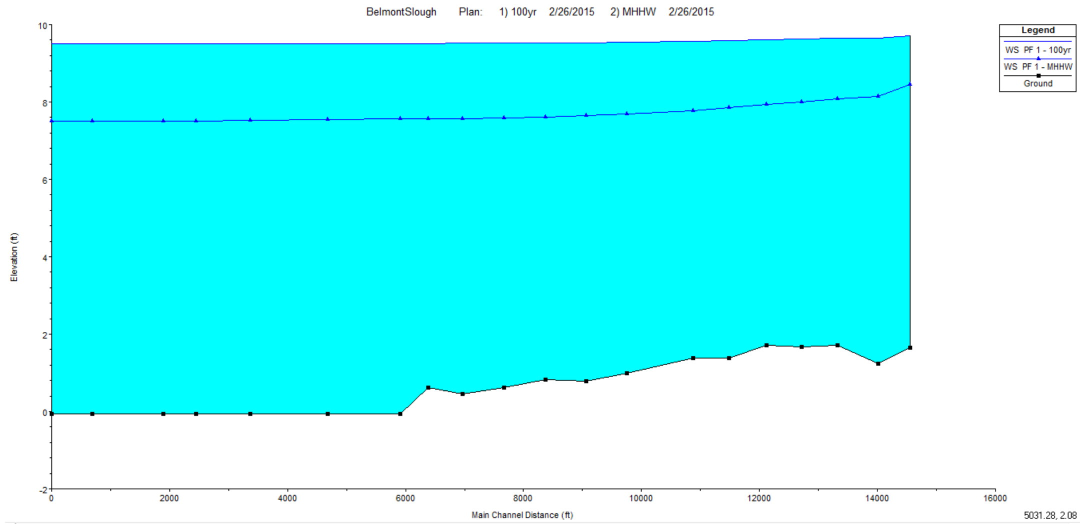


Figure 4-3. HEC-RAS Model Profiles for MHHW and 100yr Coincident Tides

Freeboard Requirements

If Belmont Slough is considered to be a coastal hazard, the levee height requirement is 2 feet above the one-percent stillwater elevation (10.2 feet NAVD), which requires two feet of freeboard and a minimum levee elevation of 12.2 feet NAVD.

Based on this cursory analysis, the coastal levee height is greater, indicating that the coastal process dominates within the Slough and that containment levees should be designed to provide freeboard above the stillwater elevation. When set using this criterion, the resulting levee elevation provides 4 feet of freeboard above the maximum water surface elevation for a 100-year riverine event coincident with a MHHW tide and 2.5 feet of freeboard above the maximum water surface elevation for a 100-year riverine event coincident with a 100-year tide.

Marina Lagoon Levee

The adopted 100-year base flood elevation for the Marina Lagoon, as operated by the City of San Mateo, is 2 feet NAVD. While Foster City is protected from Marina Lagoon by a relatively low height levee, the LiDAR data set indicates that ground elevations on the land side of this levee are on the order of 5 feet NAVD, so the levee is not necessary to protect Foster City from Marina Lagoon flooding and levee accreditation is not an issue.

Foster City Central Lagoon

Interior flood hazard analyses have been completed by Schaaf & Wheeler in January 2014 and subsequently accepted by FEMA. These analyses indicate that the base flood elevation for Foster City inside an accredited levee system is also 2 feet NAVD.

5. Evaluation of Future Sea Level Rise

This section examines the resiliency and adaptability of the Foster City levees to provide flood protection against coastal hazards from San Francisco Bay when considering future sea level rise that may result from global climate change. Resiliency refers to the robustness of a flood protection solution should San Francisco Bay water levels increase over time in response to certain sea level rise scenarios. Adaptability refers to the how easily the protective elements could be altered to accommodate those sea level rise scenarios. Project resiliency and adaptability must be evaluated in light of the large uncertainties regarding future sea level rise. Figure 5-1 provides a generalized graphic illustration of this uncertainty from the Intergovernmental Panel on Climate Change (IPCC).

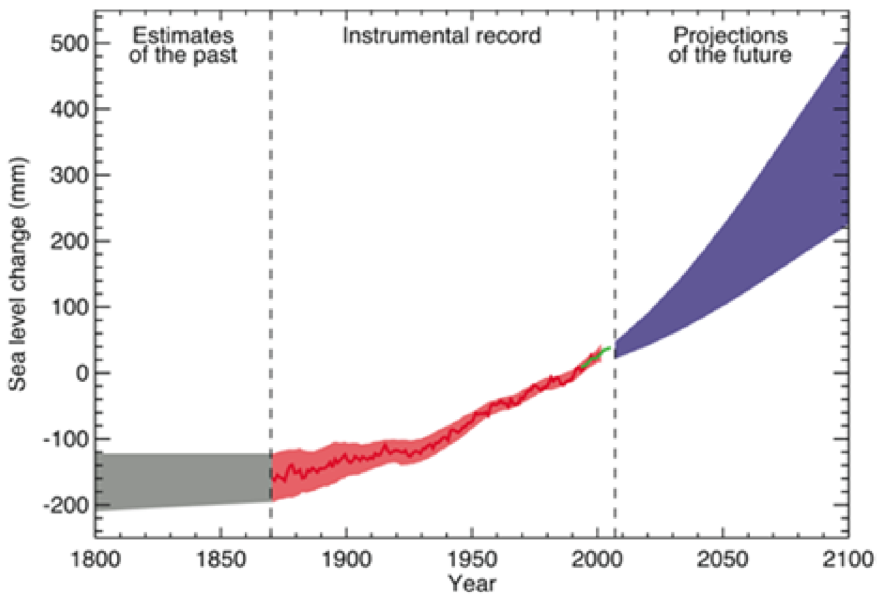


Figure 5-1. Uncertainty in Sea Level Rise Projections (ref. IPCC)

Sea Level Rise in the Bay Area

The science associated with sea level rise is continually being updated, revised, and strengthened. Although there is no doubt that sea levels have risen and will continue to rise at an accelerated rate over the coming century, it is difficult to predict with certainty what amount of sea level rise will occur at any given time in the future. The uncertainty increases over time (e.g. the uncertainties associated with 2100 projections are greater than with 2050 projections) because of uncertainties in future greenhouse gas emissions trends, the evolving understanding of the sensitivity of climate conditions to GHG concentrations, and the overall skill of climate models.

In March 2013, the State of California adopted the 2012 National Research Council Report, *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past Present and Future* (NRC Report), as the best available science on sea level rise for the state and published guidance on incorporating sea level rise into state planning. The California Coastal Commission (CCC) also supported the use of the NRC Report as best available current science. The CCC also noted that the science of sea level rise is continually advancing, and future research may enhance the scientific understanding of how the climate is changing, resulting in the need to regularly update sea level rise projections. The NRC Report includes discussions of historic sea level observations, three projections of likely sea level rise for the coming century, high and low extremes for sea level rise in the coming century, and consideration of local conditions along the California, Oregon, and Washington coast that contribute to "relative sea level rise."

Low and high range of the projections are both used to reflect the uncertainty bounds inherent in developing the projections and applying them to a single location. Table 5-1 provides a summary of the range of SLR projections contained in the 2012 NRC document.

Table 5-1. Summary of NRC Sea Level Rise Scenarios

Time Period	Low Range SLR (inches)	High Range SLR (inches)
2000 – 2030	2	12
2000 – 2050	5	24
2000 – 2100	17	66

Local Planning Policies

Local agencies have been formed to protect the San Francisco Bay from development. California's two coastal zone management agencies are the San Francisco Bay Conservation and Development Commission (BCDC) and the California Coastal Commission (CCC). These agencies are required to ensure that projects and plans subject to their jurisdiction avoid or minimize hazards related to sea level rise. In 2014, the City and County of San Francisco adopted a guidance document for incorporating sea level rise into capital planning. While other jurisdictions have also produced guiding documents, the City and County of San Francisco's guidance is the most recent.

San Francisco Bay Conservation and Development Commission (BCDC)

BCDC has permit jurisdiction over San Francisco Bay and the land lying between the Bay shoreline and a line drawn parallel to, and 100 feet from, the Bay shoreline known as the 100-foot shoreline band. In October 2011, BCDC adopted amendments to the San Francisco Bay Plan addressing sea level rise. These policies require sea level rise risk assessments when planning in shoreline areas or designing larger shoreline projects. If sea level rise and storm surge levels that are expected to occur during the life of the project would result in public safety risks, the project must be designed to cope with flood levels expected by mid-century. If it is likely that the project will remain in place longer than midcentury, the applicant must have a plan to address the flood risks expected at the end of the century.

California Climate Change Center (CCC)

All public and private projects in the City's coastal zone must be undertaken in accordance with an approved coastal development permit from either the City Planning Department or the CCC. The CCC oversees a grant program to support local government planning efforts addressing sea level rise, and released Draft Sea-Level Rise Policy Guidance for public review and comment on October 14, 2013. In that Draft Guidance, consistent with this CCSF Guidance, the CCC considers the NRC 2012 report as the best available science on sea level rise in California, though this Guidance treats the NRC 2012 report somewhat differently than the draft CCC Guidance.

City and County of San Francisco

The City and County of San Francisco released *Guidance for Incorporating Sea Level Rise into Capital Planning in San Francisco* (Guidance) in 2014. This Guidance document presents a framework for considering sea level rise within the capital planning process. The Guidance also outlines some key issues related to sea level rise adaptation planning; however, specific adaptation strategies and approaches are not provided. The range of available potential adaptation strategies is ever increasing, and selecting the appropriate adaptation measures requires site and project specific information that will best emerge at a departmental level, informed by this Guidance, and coordinated through the City and County capital planning processes. This Guidance provides direction from the Capital Planning Committee (CPC) to all departments on how to incorporate sea level rise into new construction, capital improvement, and maintenance projects. The Guidance identifies and describes key steps for assessing and adapting to the effects of sea level rise in capital planning including the vulnerability to risk and means for adapting to changing conditions.

Table 5-2 presents the NRC Report's sea level rise estimates for San Francisco relative to the year 2000 that the City and County have adopted. The table comes from the Guidance document and presents the local projections (mean ± 1 standard deviation) from the NRC Report. These projections (for example, 36 ± 10 inches in 2100) represent the likely sea level rise values based on a moderate level of greenhouse gas emissions and extrapolation of continued accelerating land ice melt patterns, plus or minus 1 standard deviation. The extreme limits of the ranges (for example, 17 and 66 inches for 2100) represent unlikely but possible levels of sea level rise using both very low and very high emissions scenarios and, at the high end, including significant land ice melt that is currently not anticipated but could occur.

Table 5-2. San Francisco's Adopted Sea Level Rise Estimates from Guidance Document

Time Period	Projections (inches)	Ranges (inches)
2000 – 2030	6±2	2 to 12
2000 – 2050	11±4	5 to 24
2000 – 2100	36±10	17 to 66

Adopted Sea Level Rise Projections for Foster City Levees

San Mateo County is one of the most vulnerable regions of the Bay Area to the problem of rising sea levels from climate change. As a result, a multi-stakeholder working group spearheaded by Supervisor Dave Pine has been established in order to develop a vulnerability assessment for the entire County. The working group has been established and meets regularly, but has not yet published a guidance document for San Mateo County. It is anticipated that the working group will model any guidance after what has been established in San Francisco County. For this reason, it is recommended SLR planning scenarios for Foster City are 0.5 foot by 2030, 1 foot by 2050 and 3 feet by 2100 (from Table 4-2). Corrective action taken to restore FEMA accreditation should include an extra one foot of freeboard with levee or floodwall foundations built to accommodate an extra two feet of freeboard in the future. This is based on the understanding that the levee improvements will be built to last at least until 2050 and likely longer. So the inclusion of an extra one foot of freeboard should prolong future improvements to incorporate SLR.

6. Levee Improvement Alternatives

Three basic alternatives are described in this study as alternatives for City consideration to meet FEMA levee accreditation requirements as outlined in the CCAMP study: earthen levees, lightweight fill levees, and floodwalls. An alternative known as the "horizontal levee" (that is, new marsh and/or beach creation to help reduce the height of maximum wave runup) has also been considered (Figure 6-1), but due to the space required and regulatory permitting issues associated with adding substantial new fill into the Bay, horizontal levees are not recommended as a typical levee improvement alternative for Foster City at this time. It is also suggested that as much work as possible be conducted on the landward side of the levee to limit the amount of disturbance on the Bay side of the existing levee. While this approach will not eliminate the need for regulatory approval, it should help alleviate significant permitting delays and compensatory mitigation requirements.

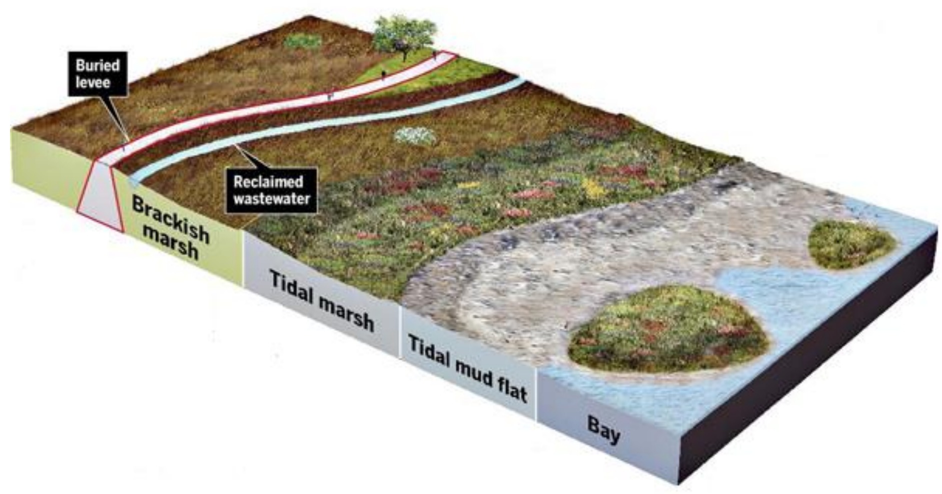


Figure 6-1. Horizontal Levee (ref. San Francisco Estuary Partnership)

Raise Earthen Levees

The existing levee system is an earthen levee with a pedway on or near the top of levee. In some sections there is rip rap on the bay side of the levee, but in no sections is there backside protection. The pedway provides erosion control on the top of the levee. Levee fill embankments exposed to wave action need to include rock slope protection on the Bay side.

In many areas, particularly along the Belmont Slough Levee, there is a mound that is slightly higher than the pedway. This mound might have been placed in 1995 as part of the levee raising project to raise the levees 18 inches and is assumed to be the levee crest elevation in the profiles attached to this report. As shown in Figure 6-2, this "levee" section may not necessarily conform to good engineering practice for levee design as the levee is narrow and lacks erosion protection. Field reconnaissance indicates several locations where this narrow levee crest has been compromised (lowered) as pedestrian and bicycle traffic have worn through the levee. An example is shown in Figure 6-3. Ideally, the paved pedway would be located at the crest of the raised earthen levees with a width of 10 feet with one foot of shoulder on each side, so the total top width of the levee would be 12 feet.

Figure 6-2. Foster City Levee Section with Adjacent Levee Crest Higher than Pedway

Figure 6-3. Foster City Levee Section with Levee Crest Compromised (yellow)

In general, the height of an earthen levee cannot be increased without widening the base of the levee. The Foster City levee system appears to have sufficient rights-of-way to increase the footprint of the levee system without having to tear down streets. There appears to be sufficient vegetation between the streets and the levee system that could be used to increase the levee footprint. The constraint will be on increasing the levee footprint into the Bay as permitting will become an issue due to sensitive habitats and endangered species. If possible, all widening of levees should be done within the right-of-way and landward side of the levee and not extending levee out into the Bay. Figure 6-4 shows a typical cross section of an earthen levee (note for Foster City the top width proposed is 12 feet to include a 10 feet wide paved path and 1-foot shoulders on each side).

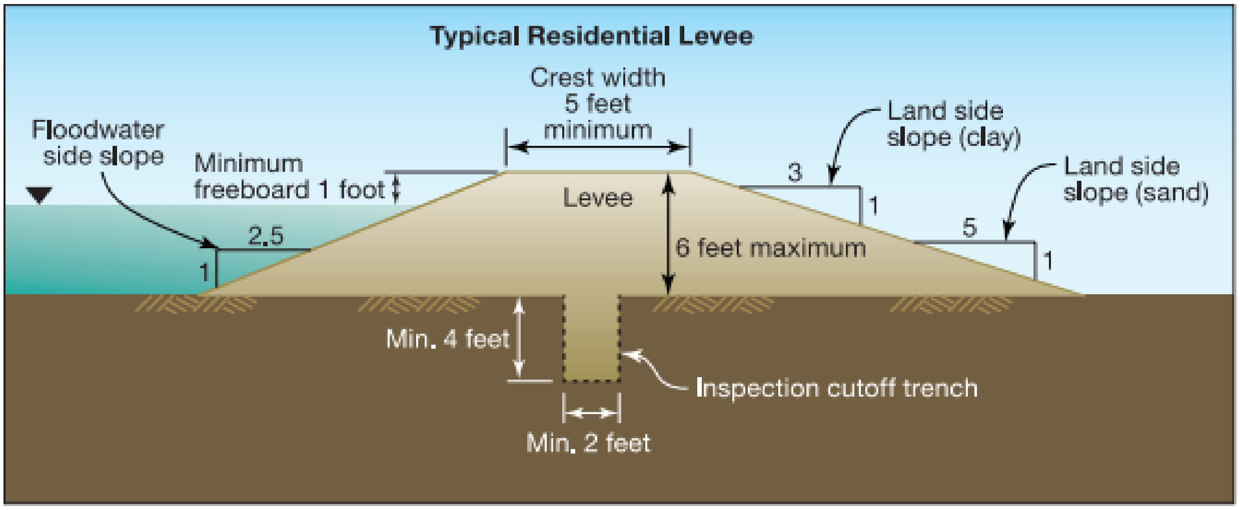


Figure 6-4. Typical Earthen Levee Cross Section (ref. FEMA)

Settlement Allowance

Based on local experience with projects in Foster City, Bay Mud thickness may range from 40 to 70 feet. Usually the Bay Mud is thicker along the waterfront. If new earthen fill is placed outside the limit of the existing levee on native marsh land, 6 to 8 inches of settlement per foot of new fill placed can be expected. It is typically recommended to place new fill on native tidal land in one- to two-foot intervals with 3:1 (h:v) or flatter bank slopes, since rapid loading from fill placement may cause shoreline instability. For new fills placed on top of an existing levee, settlement will generally be in the range of 3 to 5 inches per foot of new fill. (Moreover, up to 3 feet of fill can be placed at once within the limits of the existing levee with a 3:1 side slope should be relatively stable.)

Levee improvement profiles included with this report do not show a settlement allowance. The actual settlement allowance required is a function of levee location, the underlying stratigraphy and Bay Mud thickness. These parameters need to be identified with a thorough program of subsurface exploration, laboratory testing, and geotechnical engineering during more advanced planning and design phases and cannot be specifically known at this time. Rather, for preliminary cost estimating purposes it is assumed that the amount of earthen fill to be placed must be doubled to ultimately result in the levee profiles needed to retain FEMA levee accreditation. This assumption essentially reflects a settlement allowance of 6 inches for every foot of levee fill added as well as a remobilization cost since only so much fill can be placed at one time while maintaining system stability.

Seepage Protection

For the raised earthen levees alternative, seepage protection is provided by the fill material itself. As part of the Born Report, Kleinfelder indicated that the previously placed embankment material was suitably impermeable for a levee application. New fill material specifications would provide for compatible impermeability, including the possibility for blending with the existing levee fill.

Lightweight Levee Fill

The construction of levee improvements, but with lightweight fill, would be very similar to that of an earthen levee using a specified fill material from volcanic sources that has a unit weight on the order of 70 to 90 pounds per cubic foot compared to a saturated unit weight of 125 pounds per cubic foot for conventional levee fill material. Using lightweight fill material could reduce the total settlement of the levee to one-third or one-half that of a conventional raised levee.

Lightweight fill material must be imported from distance and is more expensive due to the cost of the fill material itself and the ancillary seepage cutoff wall required (lightweight fill, even when blended with more conventional fill, is relatively porous), but there is the significant added benefit that the raised levee will not experience as much settlement as a conventional earthen levee, and single-pass construction can be used. That is, a second phase of construction will not be necessary to maintain levee accreditation as may be the case with conventional levee fill. San Mateo selected this alternative for their Bayfront Levee Improvement Project in 2011.

Structural Floodwalls

While the majority of the Bayfront flood protection system is made up of earthen levees, there are a few newer sections that do contain floodwalls along Belmont Slough (Figure 6-5). Floodwalls can be placed on the Bay side or the landward side of the pedway. If floodwalls are placed on the landward side, access ramps over the wall or closure devices are required for pedestrians and bikers to access the trail. However, if floodwalls are placed on the Bay side, permitting may be more complex and require additional coordination with agencies such as BCDC and the USACE. In addition, a floodwall on the Bay side may detract from the trails appeal as it may limit the view into the Bay.

Figure 6-5. Floodwall along Belmont Slough

Figure 6-6 shows a conceptual cross section of a typical floodwall that could be placed on the Bay or land side of the existing earthen levee to meet freeboard requirements for FEMA accreditation. Floodwalls do not require widening of the existing levee as much as raising earthen levees, and therefore lessen the burden of additional land. Floodwalls do have an added benefit that they are generally easier to increase in height in the future (without a commensurate increase in footprint) and may be considered more readily adaptable to sea level rise than an earthen levee. While floodwalls will not experience as much settlement as earthen levees, a wall on a shallow spread footing may experience three to six inches of settlement that should be added to the height of the wall to compensate.

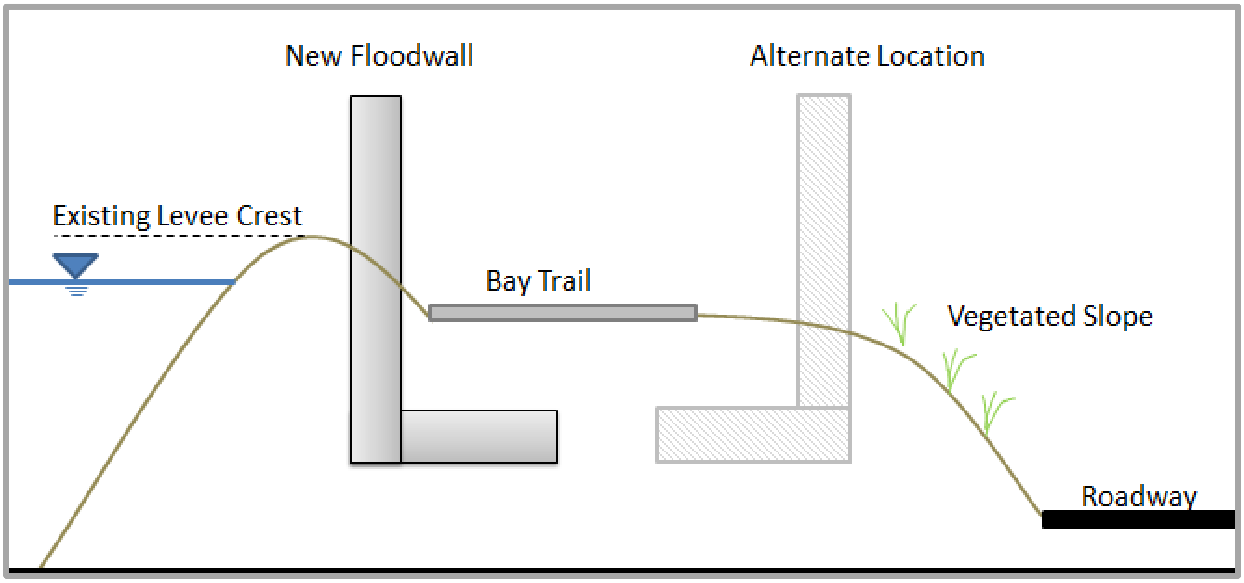


Figure 6-6. Typical Floodwall Cross Section (not drawn to scale)

Aesthetics

The trail that runs along the existing levees is part of the San Francisco Bay Trail. Part of the appeal of Foster City is the ready access to its waterfront. Raising the levees or constructing a structural floodwall may impact the ease of access and the visibility of the Bay from the trail and surrounding area. The existing levees are raised from surrounding ground and already block views from low lying areas, but the additional levee elevation will need to be acknowledged during the CEQA and permit processes. Levee accreditation requirements are considered superior to aesthetic considerations.

Permitting Challenges

The San Francisco Bay area of Foster City is a sensitive habitat and may be home to endangered species. The City of San Mateo Bayfront Levee Project endangered species assessment noted that the project could impact the native California Clapper Rail. In the 1990s, Redwood City and the USACE determined that the Redwood Shores levees needed to be raised. Environmental reports for this work indicated the presence of California Clapper rail and the salt marsh harvest mouse on the outside wetlands of the levee system.

Prior to any sort of construction project to raise the height of the levees and the commensurate footprint required for geotechnical stability, the California Environmental Quality Act (CEQA) requires documentation to identify sensitive habitats and species that might be impacted by levee construction and compensatory mitigation measures that render those impacts less than significant. Permits will also need to be obtained from entities such as the United States Army Corps of Engineers (USACE) and Bay Area Conservation and Development Commission (BCDC). The following is an indication of the types of agencies that will required permits to improve the levee system:

- Local
  - San Francisco Bay Conservation and Development Commission (BCDC)
  - Regional Water Quality Control Board (RWQCB)

- State
  - California Environmental Quality Act (CEQA)
  - California Department of Fish and Wildlife (CDFW)
- Federal
  - Corps of Engineers Section 10 permit (USACE)
  - Corps of Engineers Section 404 permit (USACE)
  - United States Fish and Wildlife (USFWS)
  - National Marine Fisheries (NMFS)

Bay Trail Access during Construction

Since access to the Bay Trail will be limited for the duration of the levee construction/modification, a comprehensive detour plan will need to be addressed in the CEQA document and Joint Aquatic Resource Permit Application (JARPA). JARPA is used to apply for regulatory approval of projects that take place along the San Francisco Bay and the coastline. The San Francisco BCDC will be keenly interested in Bay Trail access during construction.

Adaptive Management Techniques for Sea Level Rise

It is recommended that the priority for improvements is placed on meeting accreditation based on the 2014 FEMA coastal flood hazard risk study. If feasible, levee improvement planning and design should consider additional freeboard for future sea level rise projections. This entails increasing the base width of earthen levees and increasing the footing of floodwalls. In general, it is easier to raise the height of floodwalls in the future. In addition, if earthen levees are selected initially, a short wall can be built on top of the previously raised levee to meet sea level estimates. The ultimate lifespan of inert substances such as earth and concrete should approach or exceed 100 years.

Given the uncertainty in sea level rise projection, provisions for 1 foot of sea level rise by 2050 should be incorporated into the design now with design considerations (i.e. wider base foundation) for an additional 2 feet of sea level rise by 2100. Figure 6-7 illustrates how the developers of Treasure Island are building levees that are adaptable to future sea level rise.

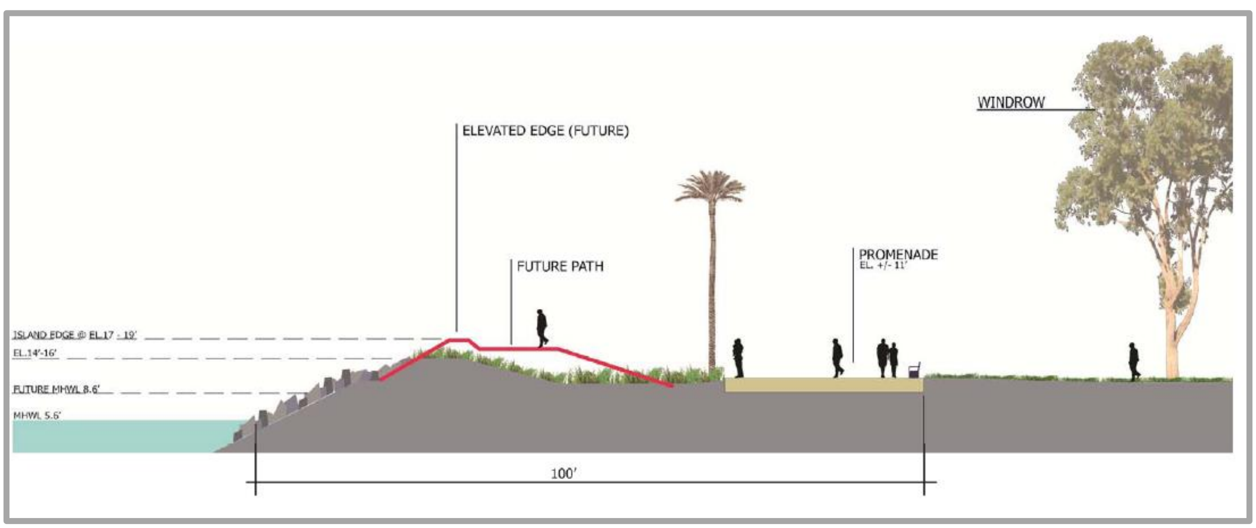


Figure 6-7. Adaptive Design on Treasure Island for Sea Level Rise (ref. Moffatt & Nichol)

7. Cost Estimates

Basis of Estimates

Preliminary capital costs for a range of alternatives have been estimated to meet FEMA accreditation: raising levees or constructing floodwalls. These estimates are meant to serve as order-of-magnitude estimates to gage the potential scale of this effort. Cost estimates are based on existing information from local jurisdictions such as San Mateo, San Francisco International Airport, and Redwood City that have recently completed significant levee improvements.

It is understood that one alternative will not meet all challenges in all locations. Earthen levee improvements may be used in conjunction with structural floodwalls. Even if structural floodwalls are selected for the majority of the levee system improvements, earthen levee modifications may still be needed where local pedestrian trails access the Bay Trail, to avoid the need for closure structures in the floodwall.

The cost estimating methodology is to first calculate the unit cost per foot of levee to raise an earthen levee in elevation by 1 foot to 5 feet, or to construct a floodwall 1 to 5 feet in height, including settlement and near-term sea level rise allowances. This provides a preliminary estimate as to the associated costs of raising levees of the various heights that will be encountered in Foster City compared to constructing floodwalls, which are done in Figure 7-1 and Table 7-1. (Geotechnical investigations into current levee conditions will be required to achieve more precise estimates.) Secondly, the levee improvement profiles attached to this report are used to disaggregate the levee system by the height of required improvement and distance. The unit costs per foot by height are then multiplied by the total length of levee improvement at that height to estimate total capital costs.

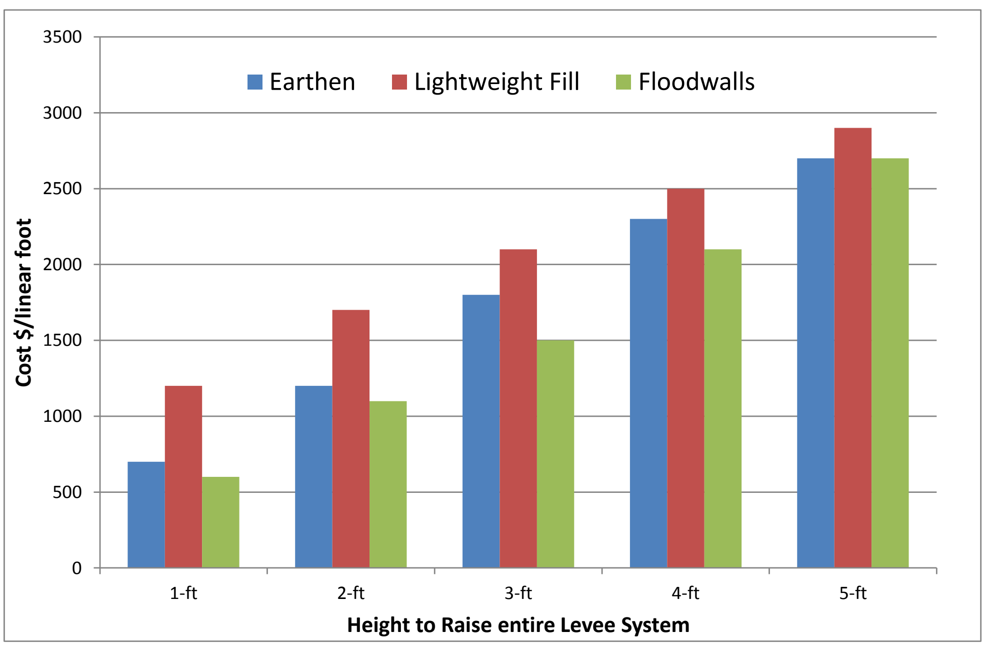


Figure 7-1. Unit Cost Comparison of Raising Levee Systems

Table 7-1. Unit Cost Comparison of Raising Levee Systems ($/linear foot/levee height increase)

Height Increase	Conventional Earthen Levee ($/linear ft)	Lightweight Fill Earthen Levee ($/linear ft)	Structural Floodwall ($/linear ft)
1 foot	$700	$1,200	$600
2 feet	$1,200	$1,700	$1,100
3 feet	$1,800	$2,100	$1,500
4 feet	$2,300	$2,500	$,2100
5 feet	$2,700	$2,900	$2,700

Earthen Levee Fill

Cost estimates have been completed for two types of levee fill with an assumed levee top width of 12 feet to accommodate a 10 foot wide trail with one foot of shoulder on each side. The first levee estimate is for the cost of an earthen fill levee. Since the levee is built on top of the poor soils known as "Bay Mud", a newly placed earthen levee is expected to settle. The settlement of raised levee sections will also require additional fill to be placed 1-2 years after initial fill placement as previously described to prevent levee instability. The additional cost to place extra fill is included in the rough estimate as additional mobilization and fill costs.

Lightweight Levee Fill

The second levee estimate is for the cost of a lightweight levee fill. Lightweight fill typically consists of permeable volcanic rock, requiring the installation of vinyl sheet piles to prevent water seepage through the levee. Lightweight fill levees settle less than conventional earthen levees and therefore require less fill material; however, they are more costly due to the addition of sheet piles.

Structural Floodwalls

The cost estimate for structural floodwalls is calculated assuming the use of a shallow foundation. Since the exact soil conditions are not known, structural floodwall costs may increase if soil conditions deem the use of deep foundations necessary, noting that any deep foundation needs to penetrate through the total Bay Mud thickness to solid foundation material, to prevent Bay Mud from dragging the foundation down. An estimated six inches of settlement is expected to occur, so the cost assumes the height is increased by six inches to reach the desired height. Also, the cost of concrete and rebar may change depending on market price at the time of construction.

Right-of-Way Costs

It appears there will no significant right-of-way issues for levee construction and modification since San Francisco Bay is on one side and public right-of-way the other. (Private adjacent rights-of-way are more prevalent along Belmont Slough.) Right-of-way cost markup is therefore estimated to be approximately 5% of the total project cost. This cost is anticipated to be mostly for temporary easements for construction laydown and staging areas.

Construction Management

Construction Management markups of 10% are added to the overall cost of each option. The added cost accounts for construction mobilization, the purchase of bonds and insurance, pedestrian and traffic control, and construction planning and submittals.

Environmental Mitigation

Environmental mitigation markup is estimated to be approximately 10% of total project cost. This amount can vary greatly depending on environmental conditions of the site and the ultimate footprint of levee improvements.

Additional Contingencies

A design contingency of 40% was added to unit costs as well as escalation, bonds, general conditions, and O/H/P. The total increase of unit costs for miscellaneous contingencies is about 65% of the estimated construction cost.

Estimated Costs to Maintain FEMA Levee Accreditation

Sections of levee are summarized by the required height increase to maintain FEMA levee accreditation and costs are estimated considering that one alternative would be used for the entire levee system improvement. In reality a combination of different alternatives might be more appropriate and will need to be studied in more detail. Table 7-2 shows the cost estimates to raise the height of the existing levee system to meet FEMA freeboard requirements for accreditation using each of the alternatives described herein along the entire levee system. Table 7-2 also includes the cost estimate to maintain FEMA levee accreditation and to include one foot of SLR freeboard to meet the 2050 SLR projection.

Table 7-2. Cost Estimates for FEMA Accreditation of Entire Levee System in 2015 Dollars

Alternative	Estimated Cost for Accreditation	Estimated Cost including SLR[3]
Raise Earthen Levee[1]	$50,000,000	$67,000,000
Lightweight Fill Levee	$62,000,000	$75,000,000
Floodwalls[2]	$44,000,000	$64,000,000

1. *Earthen levee cost estimates assumes a double quantity of fill is required due to long-term settlement.*
2. *Floodwall cost estimates include six inches of settlement.*
3. *Additional one foot of freeboard added for SLR allowance to 2050.*

Funding

While beyond the scope of this planning study, Foster City has the option of establishing an Assessment District to collect the requisite fees or taxes to finance the levee improvements. In this situation, since all of Foster City will benefit from flood protection, the entire City could be considered an Assessment District with benefits proportional to the increased value of each property that results from accredited levee protection. More than 8,000 properties in San Mateo also benefit from Foster City levee improvements, noting that those properties are currently assessed for the San Mateo Bayfront Levee Improvement Project, which also benefits the entirety of Foster City.

FEMA Mapping Procedures for Non-Accredited Levees

FEMA will not recognize the flood protection provided by a levee unless it is certified to meet design requirements related to geotechnical, freeboard, and maintenance criteria as outlined in 44 CFR §65.10, which deal specifically with the design and physical condition of the levee, and are the responsibility of the levee owner or community in charge of the levee's operation and maintenance. Certification must be completed for the levee to be eligible for accreditation by FEMA. Once a levee is certified as meeting the requirements of 44 CFR §65.10, FEMA can accredit the levee and show the area behind it as being a moderate-risk area on a Flood Insurance Rate Map (FIRM).

It is recognized that maintaining FEMA accreditation will be a significant endeavor in Foster City. In the interim those levee systems that do not meet all of the requisite criteria for certification are termed to be "non-accredited" or "uncertified". The performance of a levee system, particularly its status related to FEMA certification, can have a profound impact on mapped flood hazards.

FEMA has updated the methodology used to analyze the behavior of non-accredited (uncertified) levee systems and released revised procedures for the treatment of non-certified levees that provide a more flexible approach to the technical hydraulic analysis of non-certified levees that is based on the actual data available. FEMA's "Analysis and Mapping Procedures for Non-Accredited Levees" (aka Levee Analysis and Mapping Procedures or LAMP, published July 2013) provides an alternative procedure for levees that lack FEMA accreditation status. FEMA representatives indicate that these methods, originally formulated for riverine systems, can be adapted to coastal levee analysis.

Flood Risk Zone D

Placement within a Special Flood Hazard Area (SFHA) designated as Zone A is the traditional mapping outcome for high hazard areas protected by non-accredited levee systems. The level of flood risk is indicated on the FIRM by a letter. For example the high-risk SFHAs are designated by the letters A or V. Moderate- and low-risk areas are represented with the letters B, C or X. The Zone D designation is used for areas where there are possible but undetermined flood hazards. FEMA's LAMP allows for flood hazards within areas protected by non-accredited levee systems to be designated as Zone D.

Flood insurance is available but not federally required by lenders for loans on properties within a Zone D. Flood insurance rates for properties with a Zone D designation are commensurate with the uncertainty of flood risk. Zone D premiums can be higher than a standard low-risk zone premium and significantly higher than Preferred Risk Policy (PRP) premiums. As an example,[3] someone with a post-FIRM PRP might see a typical premium increase from $200 per year in Shaded Zone X to $950 per year after the change in designation to Zone D.

As an interim measure the City may feel that a Zone D designation is preferable to Zone AE (Elevation 10 feet NAVD) and the mandatory insurance requirement. If so, individual levee reaches need to be evaluated geotechnically along with their freeboard deficiencies (described herein) to determine the proper designation as described subsequently. Predicted levee overtopping volumes would be traced through city streets and adjacent properties to the Central Lagoon, with average flow depths in excess of one foot mapped as SFHAs. Central Lagoon operation would also be analyzed with coincident levee overtopping volumes to re-establish its base flood elevation.

[3] *National Flood Insurance Program, "Fact Sheet for Stakeholders: Understanding Zone D," August 2011.*

Sound Reach

A sound reach is a reach of levee designed, constructed, and maintain to withstand and reduce base flood hazards using sound engineering practices. To be considered a sound reach, the levee must be owned, operated, and maintained by a responsible agency or party who provides an operations and maintenance plan that discusses closures, interior drainage management and the stability, elevation, and overall integrity of the levee and its associated structures and systems. This designation generally applies to levees that could be certified but are not yet accredited, with sufficient freeboard in conformance with 44 CFR §65.10 as illustrated in Figure 7-2.

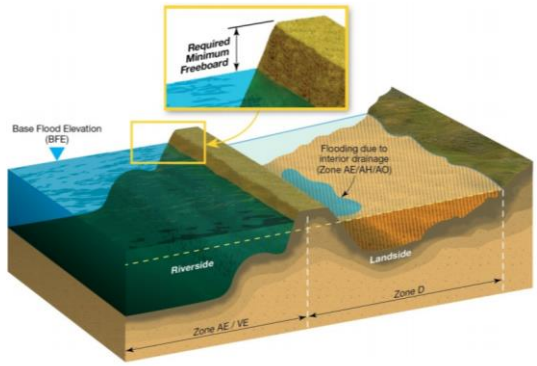


Figure 7-2. Sound Levee Reach (ref. FEMA)

Freeboard Deficient Levees

To be eligible for NFIP accreditation through FEMA, a levee must provide at least two feet of freeboard above the one-percent still water elevation or at least one foot of freeboard above the one-percent total water elevation; whichever resulting freeboard elevation is higher. FEMA will now apply a "Freeboard Deficient Procedure" to those levee systems that meet all the requirements of 44 CFR §65.10 other than the requisite freeboard. Figure 7-3 illustrates this case.

If Foster City can provide documentation demonstrating that the levee system is structurally sound and the top of levee elevation is higher than the base flood elevation, the affected area can be mapped on the landward side of the levee as Zone D based on the Natural Valley Procedure, including any residual interior flooding. In this case the entirety of Foster City would be mapped as Zone D. San Mateo from the Foster City limit to San Mateo Creek would also be mapped as Zone D, from San Francisco Bay to the elevation contour reflecting a stillwater elevation of 10.4 feet NAVD.

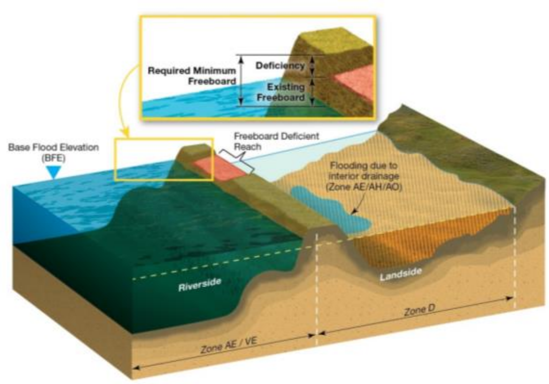


Figure 7-3: Freeboard Deficient Levee Reach (ref. FEMA)

Levee Overtopping

The overtopping condition applies where the base flood elevation is above the top of levee or floodwall, but there is armoring to protect against erosion, or the levee is otherwise certifiable and the amount and duration of overflow is limited. This would generally apply to overflows from wave runup of limited duration, where the levee is expected to remain intact as illustrated by Figure 7-4. The volume of overflow would be calculated based on wave setup and added to the residual interior flow at the Central Lagoon, with potential impacts to the calculated base flood elevation of the lagoon.

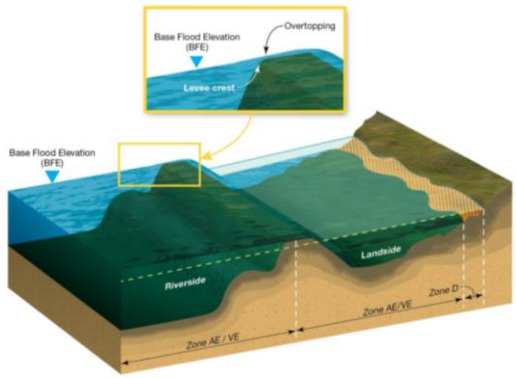


Figure 7-4. Levee Overtopping Analysis (ref. FEMA)

FEMA's procedures for analyzing a non-accredited levee that is overtopped without adequate erosion protection consider that reach to be structurally deficient and the levee is analyzed as breached to the levee toe as illustrated generically by Figure 7-5. If enough of the levee is considered to be breached, it would be as if the levee does not exist and Foster City would be mapped as Zone AE (Elevation 10 feet NAVD).

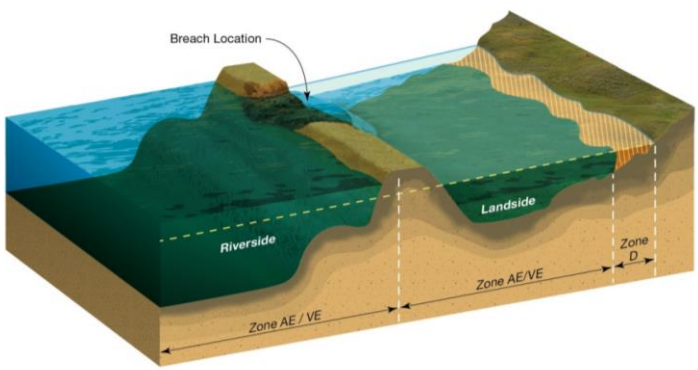


Figure 7-5. Structurally Deficient Levee Breach Analysis (ref. FEMA/BakerAECOM)

8. Next Steps

Flood Insurance Rate Maps

For Foster City to be able to retain their Zone X destination while the levee modifications are being made, the City has accepted levee seclusion mapping and could apply for a Zone A99 designation as the levee improvements progress. The goal of these designations is to "buy time" for the City to raise funds, complete design, and start construction on improvements without impacting the residents with mandatory flood insurance policy requirements.

Levee Seclusion Mapping

Seclusion mapping was developed by FEMA as a process to allow the release of impacted FIRM updates prior to conducting a more detailed analysis on non-accredited levee systems. Levee seclusion mapping will maintain the flood hazard information as depicted on the current effective FIRM with map notes explaining that these flood hazards will be updated at a later time when the updated levee analysis and mapping approach is applied.

Foster City and the City of San Mateo have both accepted the levee seclusion mapping designation, which will first be shown on the preliminary maps due in mid-August 2015.

Zone A99

Once the levee system construction project reaches certain completion milestones, the City may choose to submit data and documentation to request that FEMA make an "adequate progress" determination for the construction project and revise the effective FIRM to designate the impacted area as Zone A99. To qualify for an "adequate progress" determination, Foster City has to meet the following requirements:

- One hundred percent of the total financial project cost of the completed flood control system has been authorized;
- At least 60 percent of the total financial project cost of the completed flood control system has been appropriated;
- At least 50 percent of the total financial project cost of the completed flood control system has been expended;
- All critical features of the flood control system, as identified by FEMA, are under construction, and each critical feature is 50 percent complete, as measured by the actual expenditure of the estimated construction budget funds; and
- The community has not been responsible for any delay in the completion of the system

Properties located in Zone A99 will be charged the same standard flood insurance premium rates that would be applicable once the project is complete (i.e., Zone X).

Advanced Levee Planning and Design

Once the City has elected to re-establish FEMA levee accreditation in light of the newly published coastal flood hazards, the following steps need to be completed when funding is available:

1. Obtain a detailed survey of the entire levee frontage, most likely through aerial photogrammetry. This will allow for definitive levee and/or floodwall improvement design including an evaluation of the improved levee footprints, right-of-way needs, and potential environmental impact.
2. Prepare a detailed design for levee and floodwall improvements to meet freeboard requirements.
3. Evaluate the proposed levee improvement design for geotechnical stability using the requirements of 44 CFR 65.10 as previously described. This will include subsurface exploration, laboratory testing, and engineering. Refine levee improvement design as appropriate.
4. Prepare CEQA documentation and apply for regulatory approval.
5. Complete construction documents suitable for public bid.
6. Construct levee improvements.
7. Apply for FEMA accreditation.
8. Celebrate with ribbon cutting ceremony.

9. Conclusions

FEMA indicates that it no longer considers the existing levee system that protects Foster City from San Francisco Bay floodwaters to meet the requirements for levee accreditation as set forth in the National Flood Insurance Program and 44 CFR 65.10.

If Foster City does nothing, the entire City, including parts of the City of San Mateo, is subject to placement within a high-risk Special Flood Hazard Area and property owners with federally backed loans will be required to buy flood insurance at higher rates.

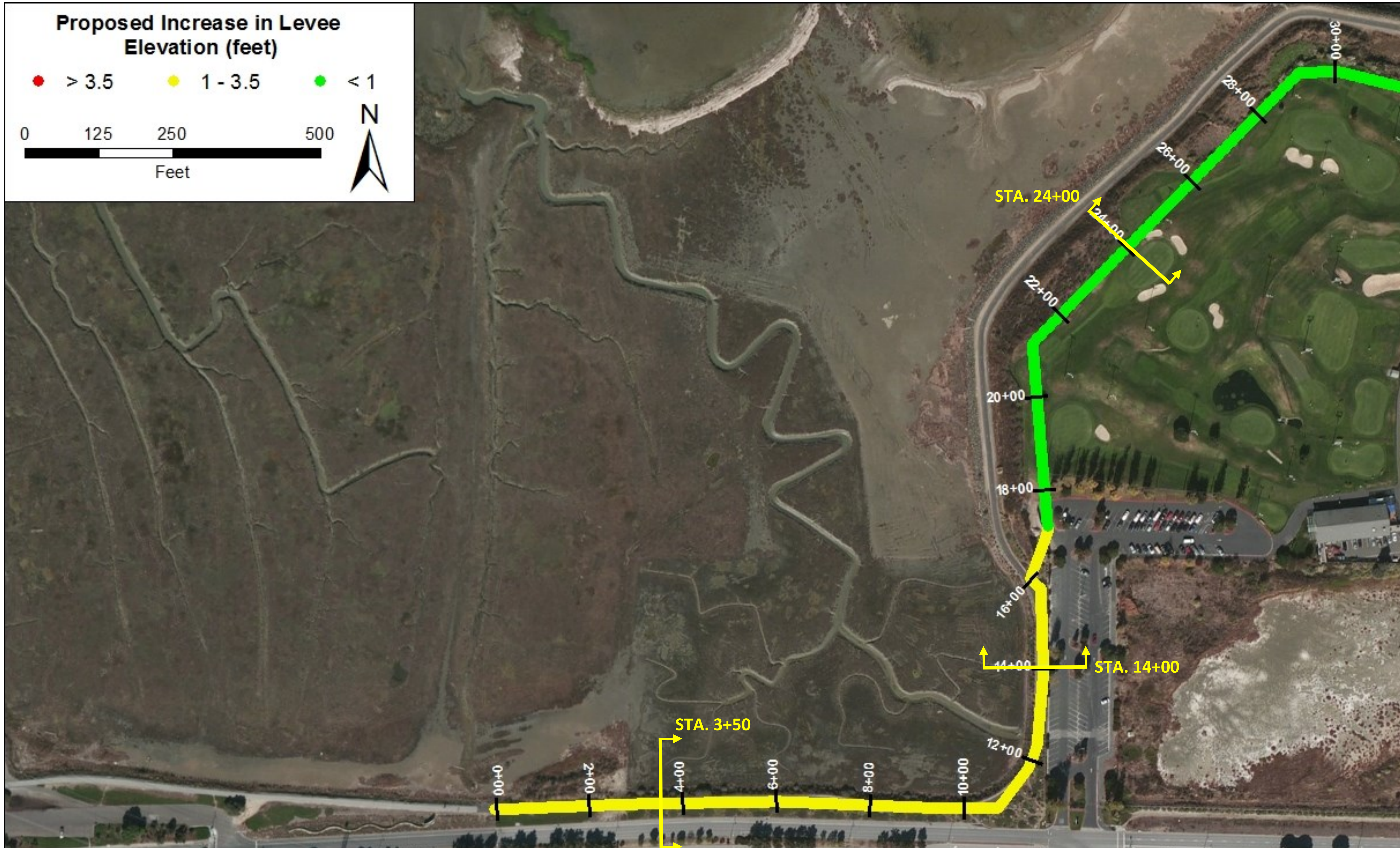
Raising at least 85 percent of the City's levee system to restore its accredited status will be a multi-million dollar project and may take several years to design, permit, construct and accredit. The City should consider investigating available programs such as seclusion mapping and A99 mapping to delay or avert remapping while raising the funds to design and complete the necessary levee system improvements. Both of these mapping programs would allow the City to be mapped as a low-risk Zone X or an uncertain-risk Zone D, which do not necessarily require property owners to buy flood insurance, although they may be advised to purchase flood insurance at discounted rates until levee accreditation is restored.

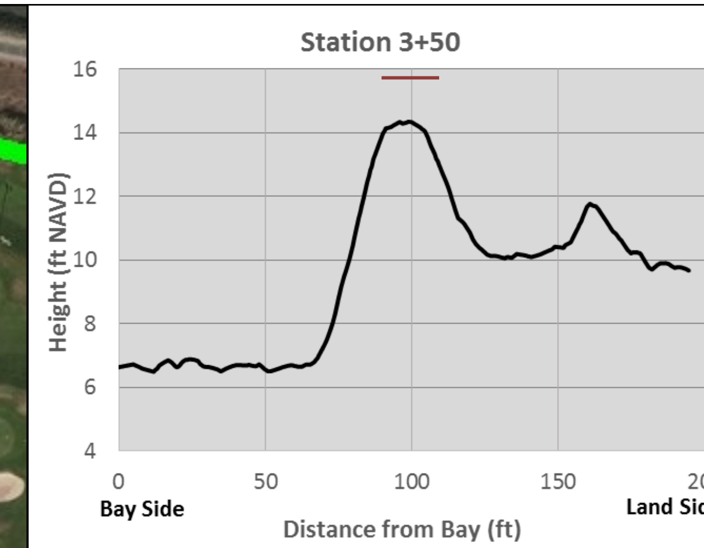
Based on the current data available, the maximum levee freeboard deficiency is about four feet and the average deficiency over the approximately 43,000 feet of levees is two feet. There are about 6,000 linear feet of levee that meet the FEMA required height, but the rest of the system is at least freeboard deficient if not overtopped by the one-percent tidal stillwater or wave runup. Improved levees need to be further increased in elevation to accommodate some long-term settlement and sea level rise. Levee designs should adaptively incorporate future increases in elevation without significant reconstruction or environmental impact.

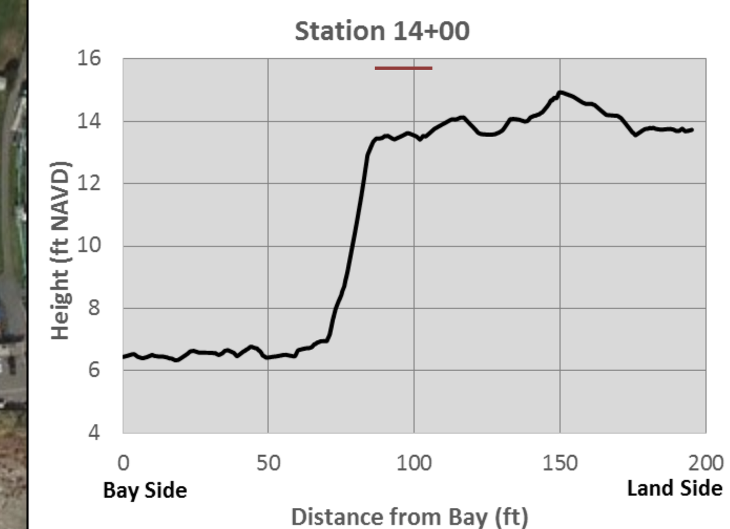
This study is focused on the freeboard deficiencies identified of the levee system and does not include a geotechnical study. The City should consider a detailed levee system elevation survey and geotechnical study of the levee system prior to moving forward with alternative designs for improving the levee system to a condition that can be accredited by FEMA.

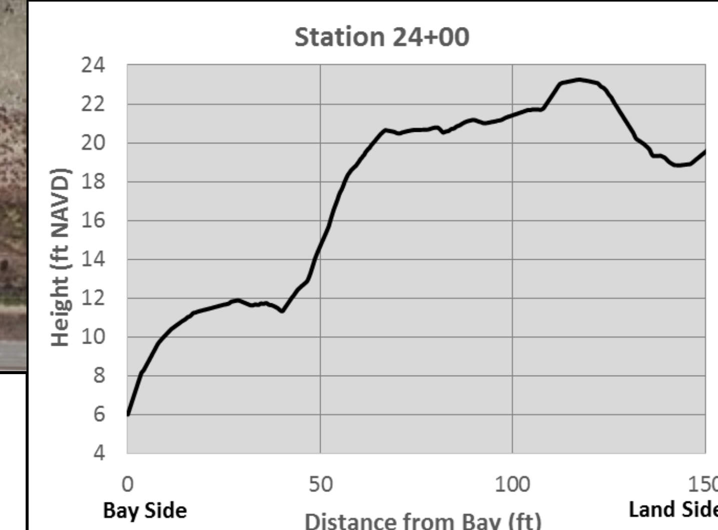
Attachment 1

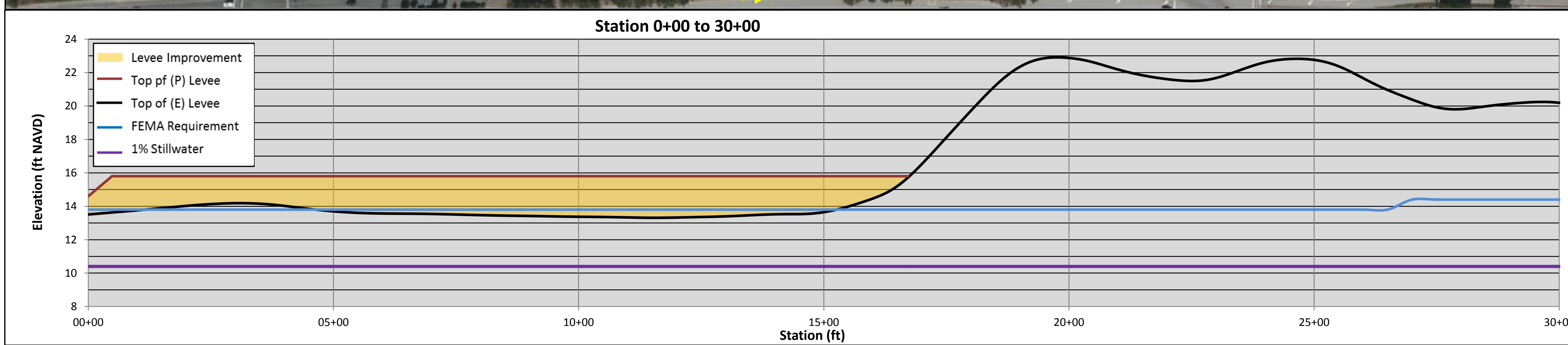
Levee Deficiency Profiles







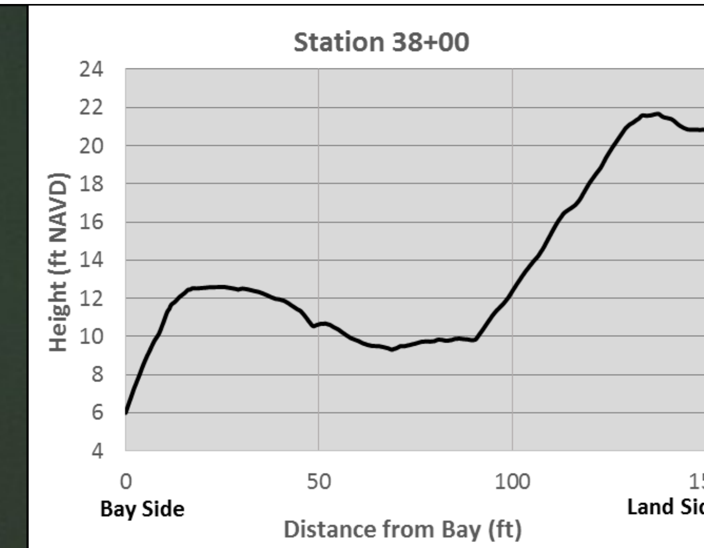


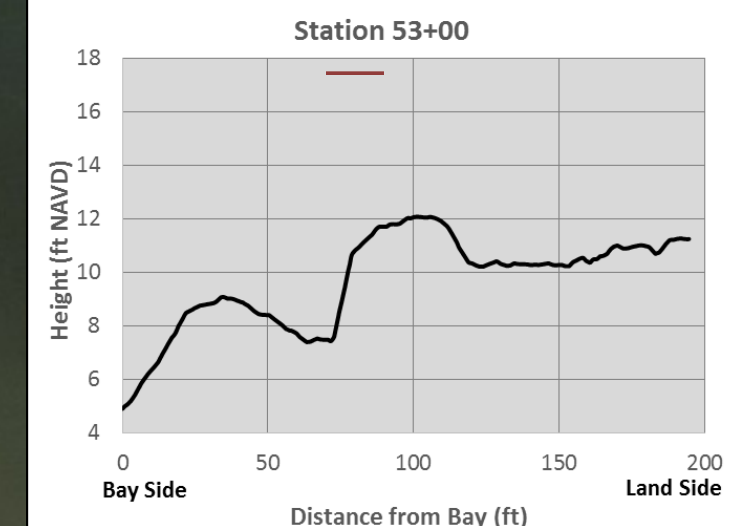


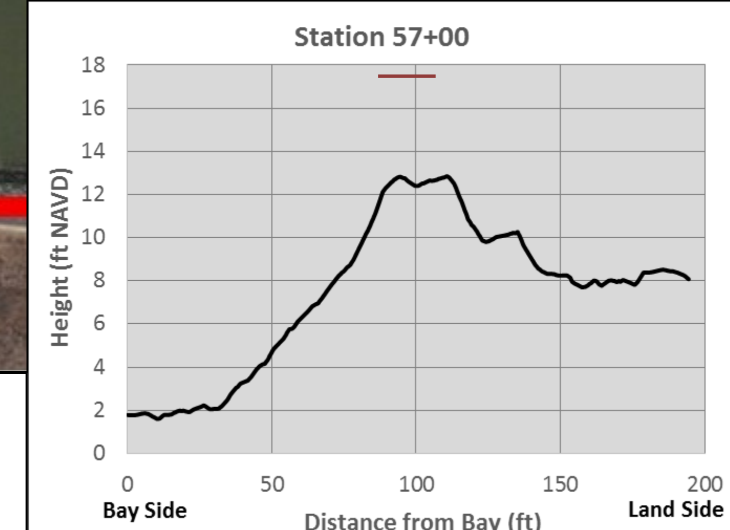
Foster City
Proposed Levee Improvements

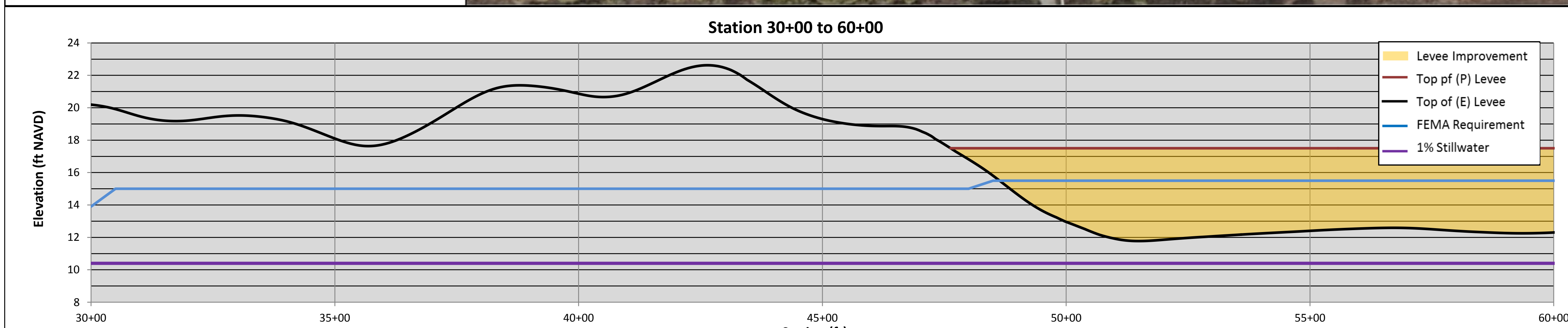
Schaaf & Wheeler
CONSULTING CIVIL ENGINEERS

Sheet 1 of 15







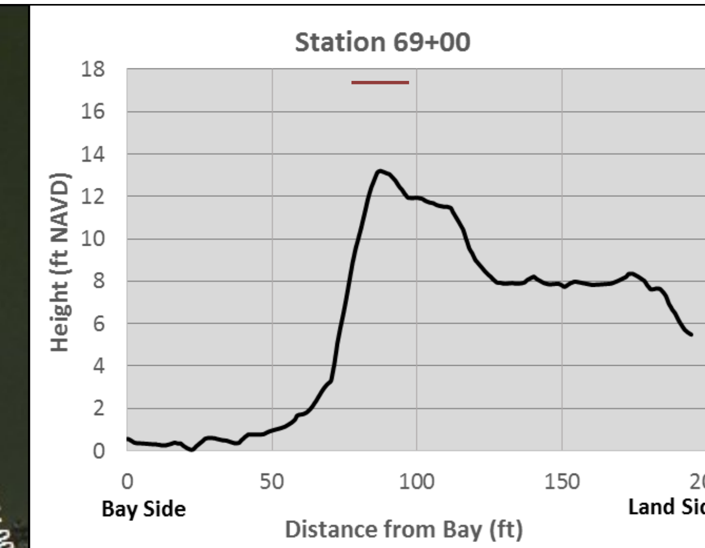


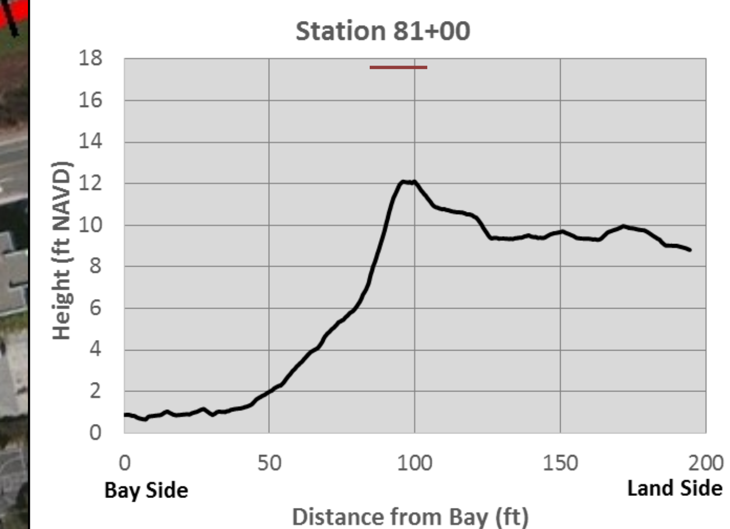
Foster City

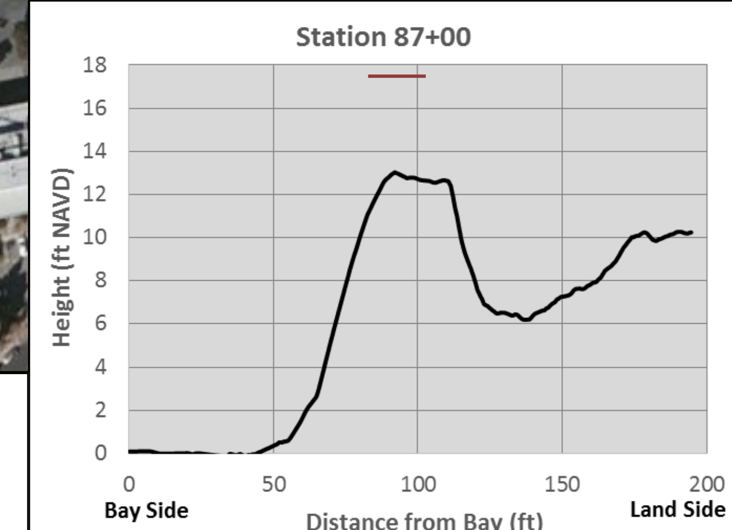
Proposed Levee Improvements

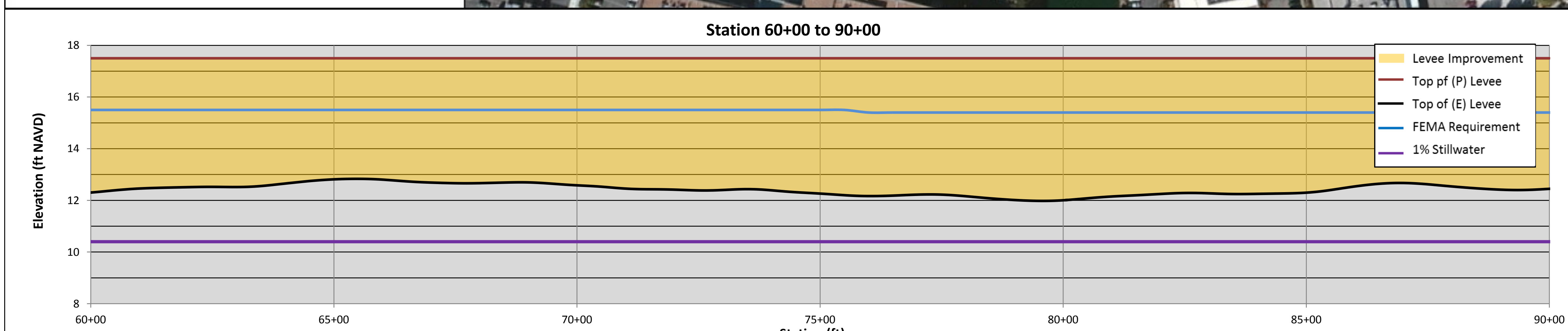
Schaaf & Wheeler
CONSULTING CIVIL ENGINEERS

Sheet 2 of 15





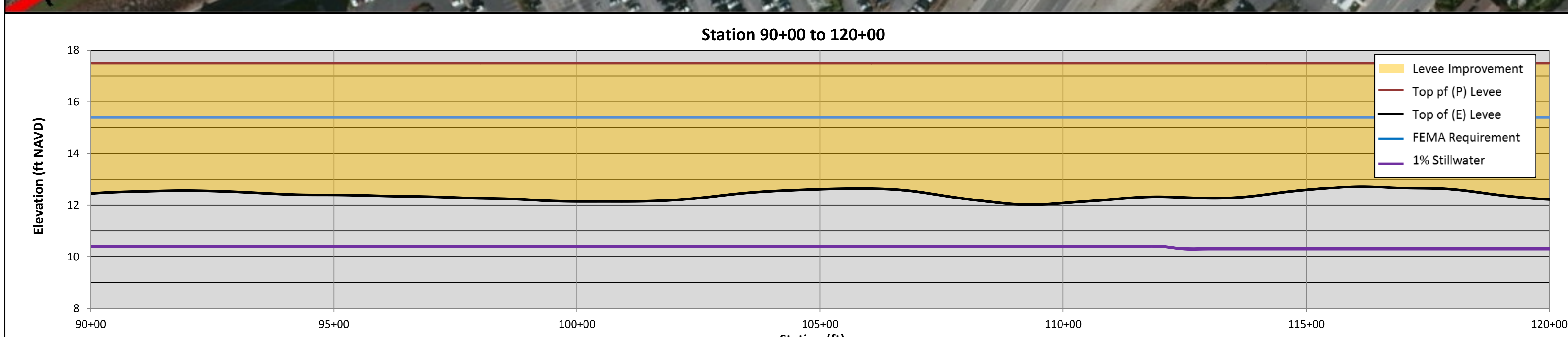


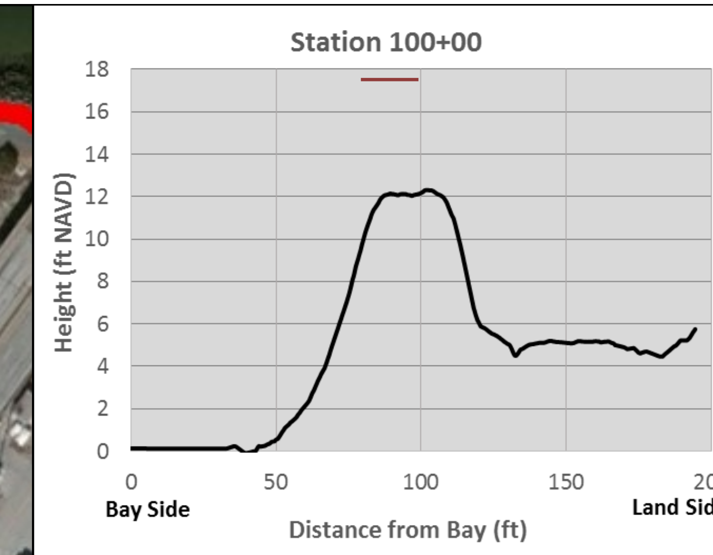


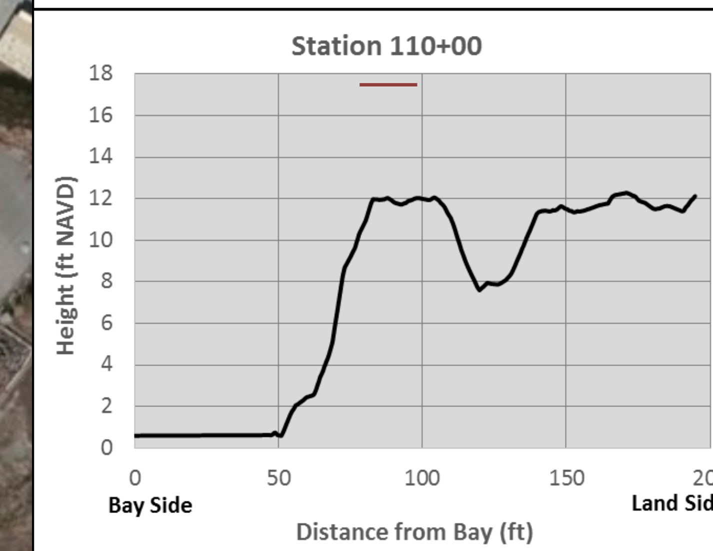
Foster City

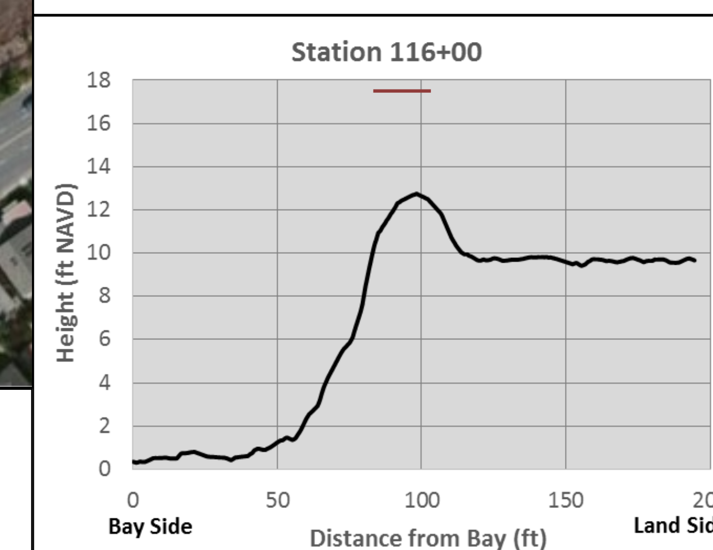
Proposed Levee Improvements

Schaaf & Wheeler
CONSULTING CIVIL ENGINEERS





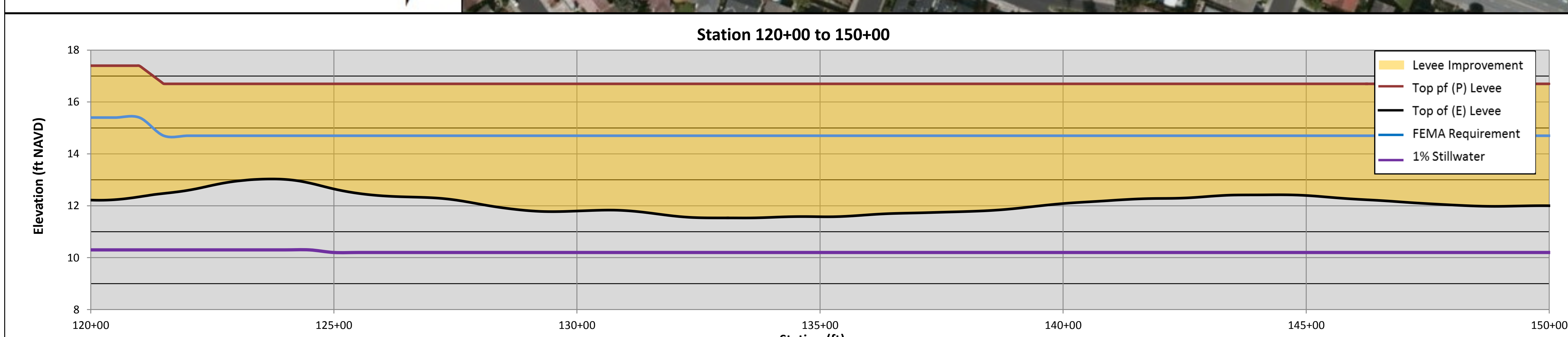


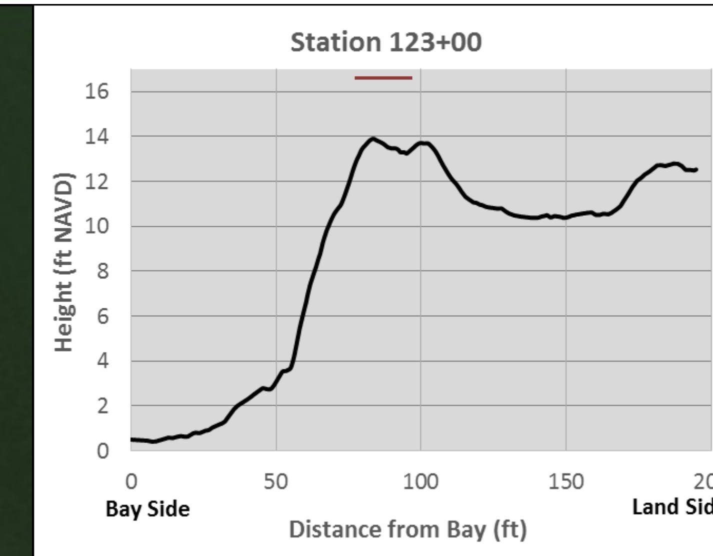


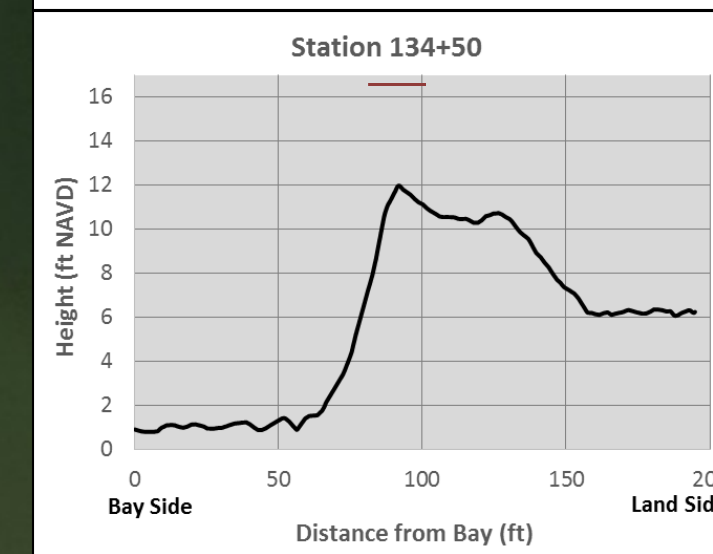
Foster City

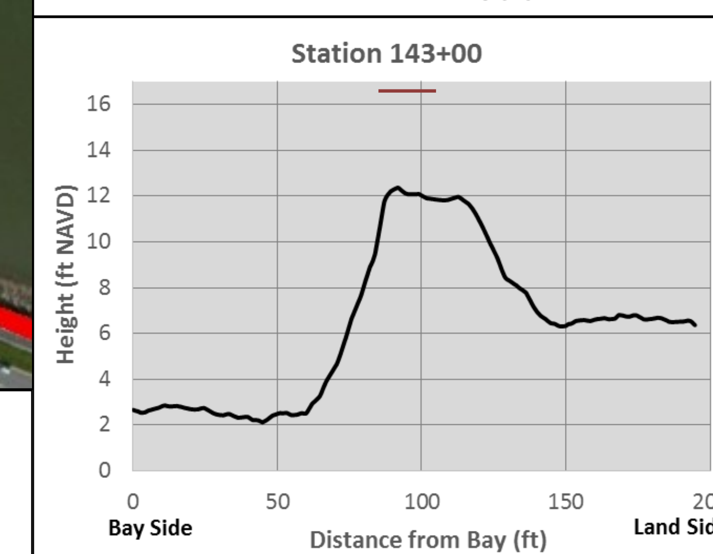
Proposed Levee Improvements

Schaaf & Wheeler
CONSULTING CIVIL ENGINEERS





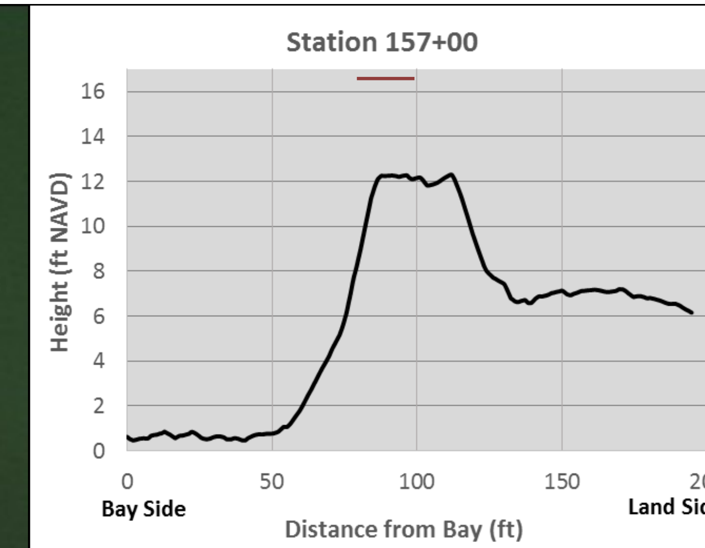


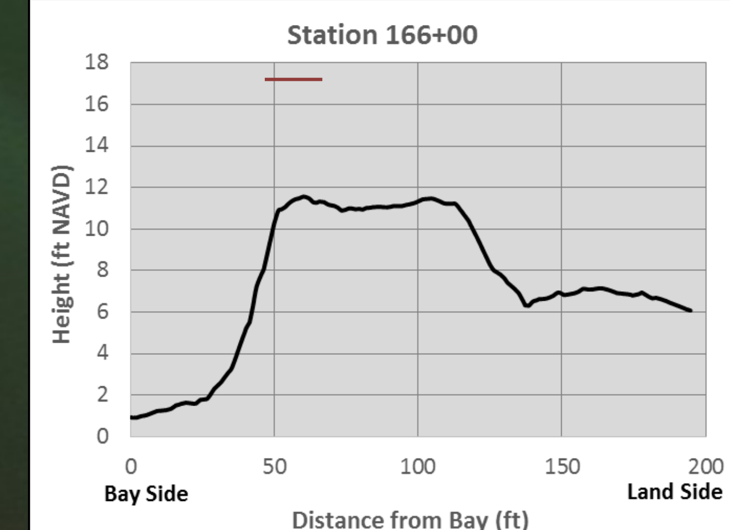


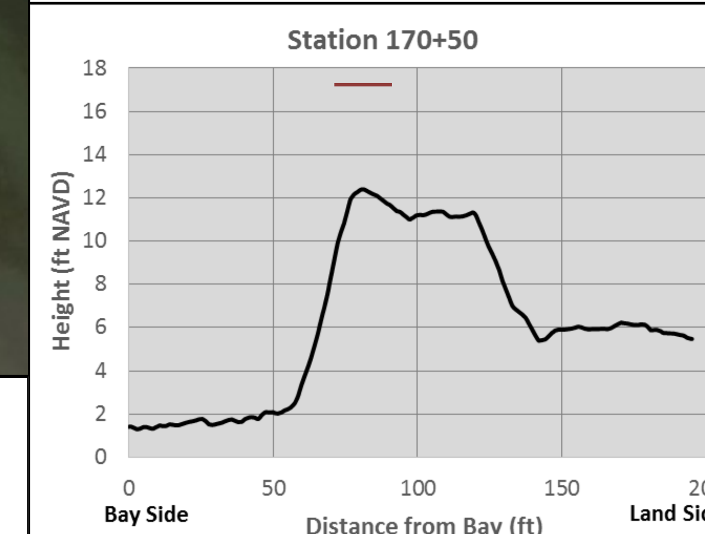
Foster City
Proposed Levee Improvements

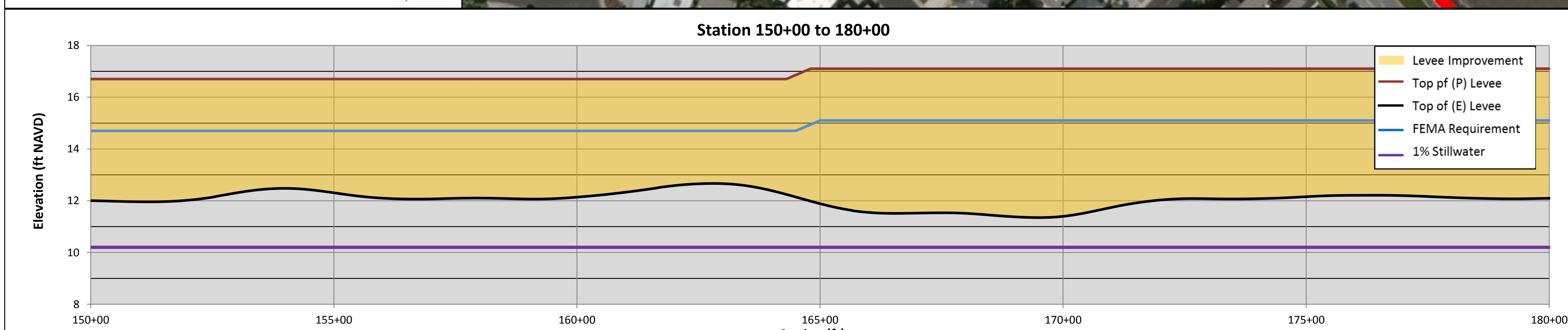
Schaaf & Wheeler
CONSULTING CIVIL ENGINEERS

Sheet 5 of 15





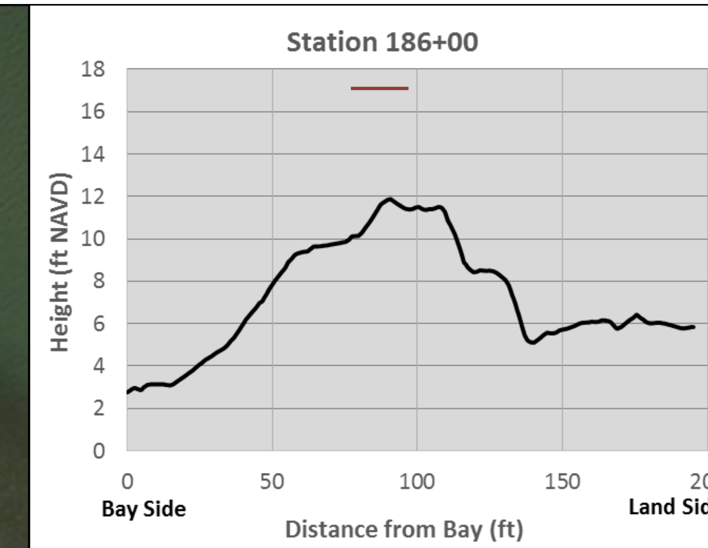


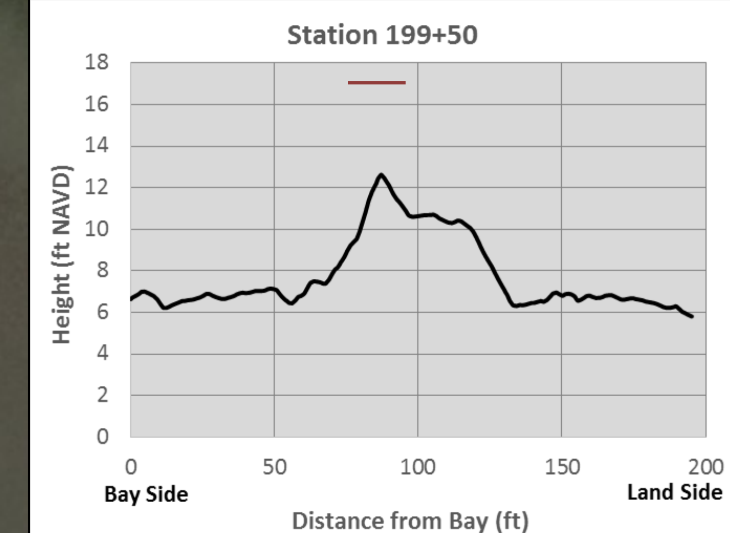


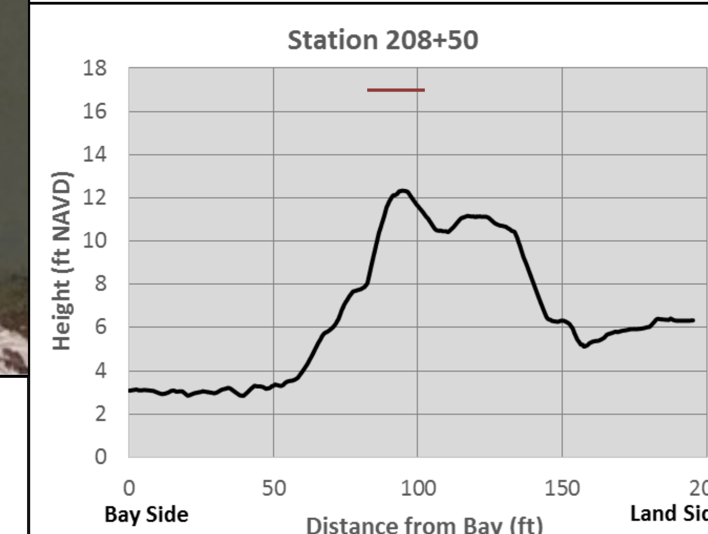
Foster City
Proposed Levee Improvements

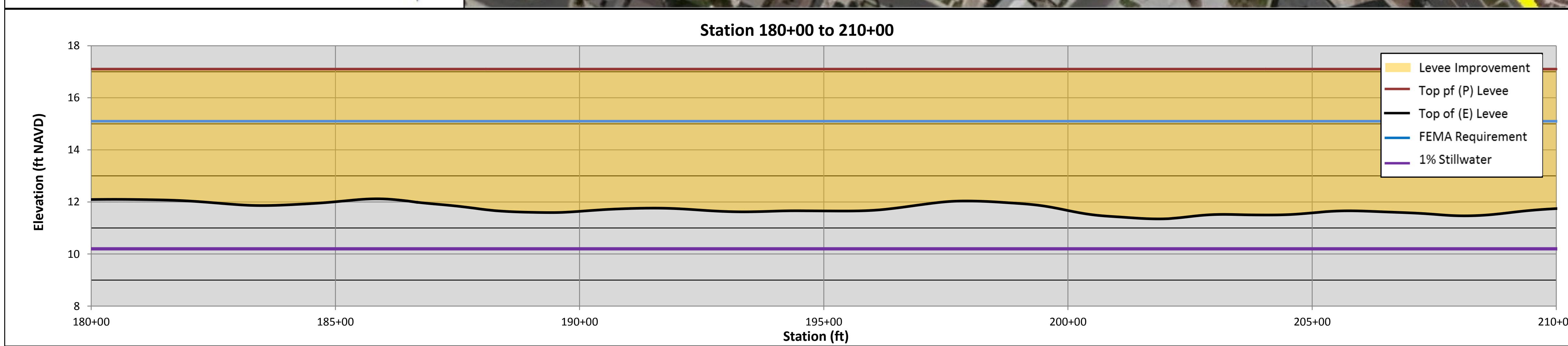
Schaaf & Wheeler
CONSULTING CIVIL ENGINEERS

Sheet 6 of 15





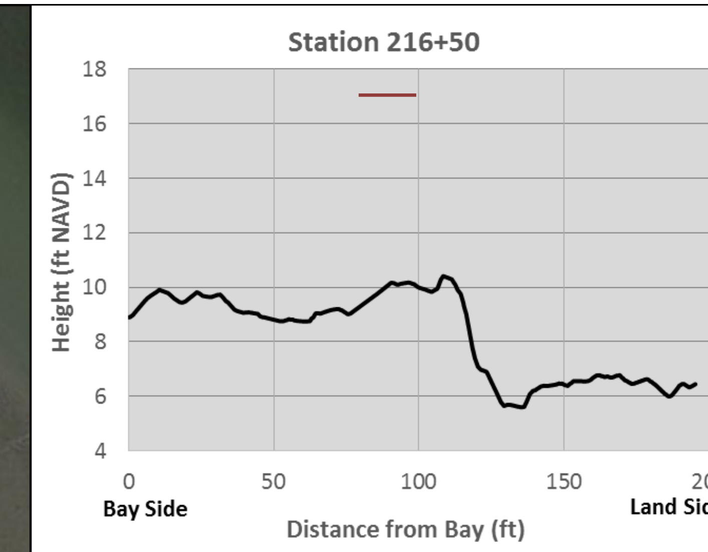


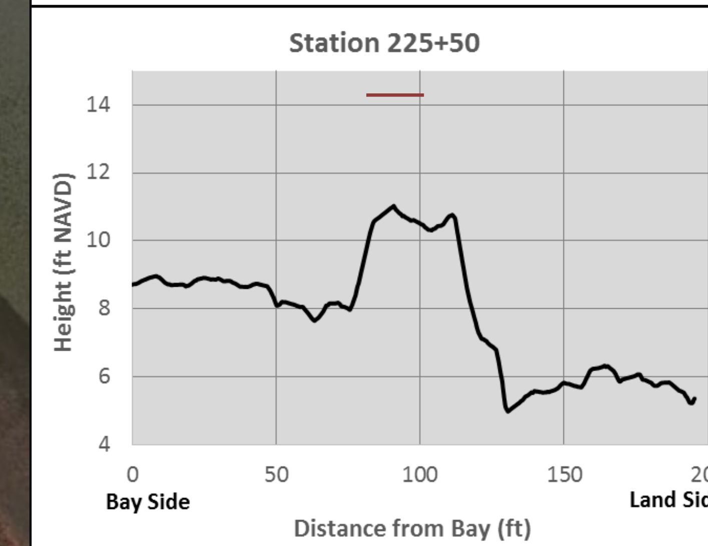


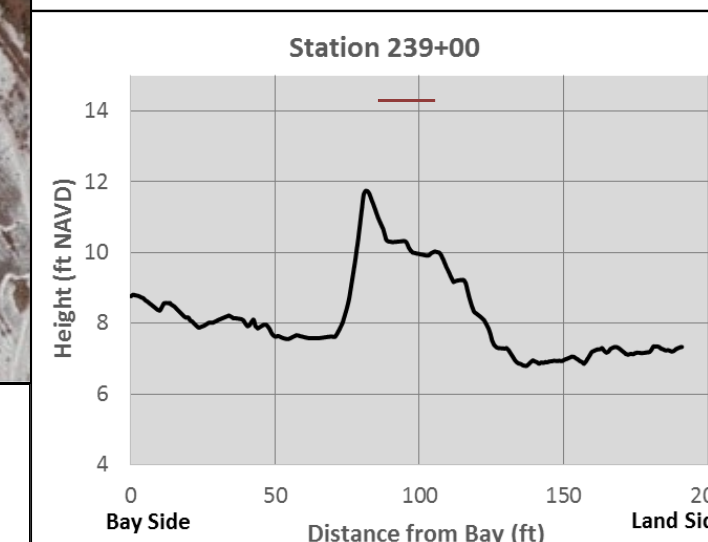
Foster City
Proposed Levee Improvements

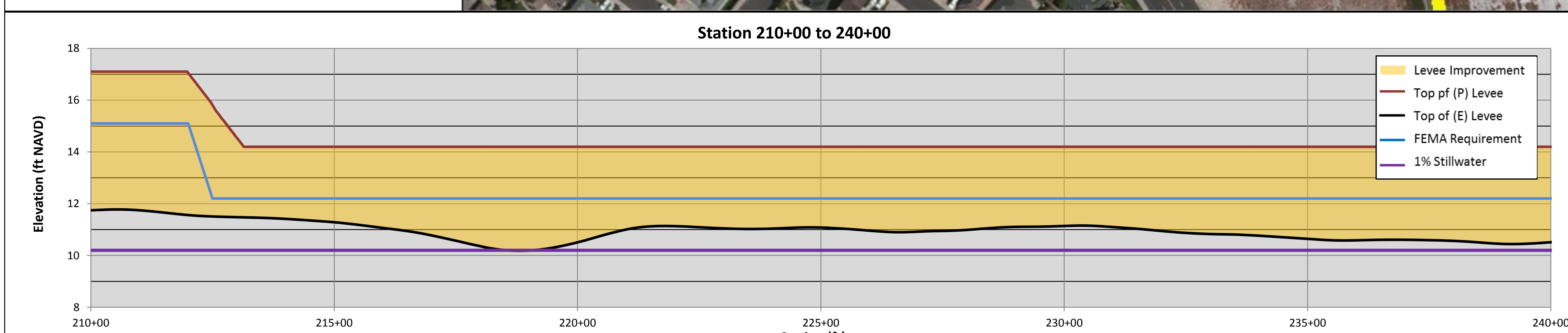
Schaaf & Wheeler
CONSULTING CIVIL ENGINEERS

Sheet 7 of 15





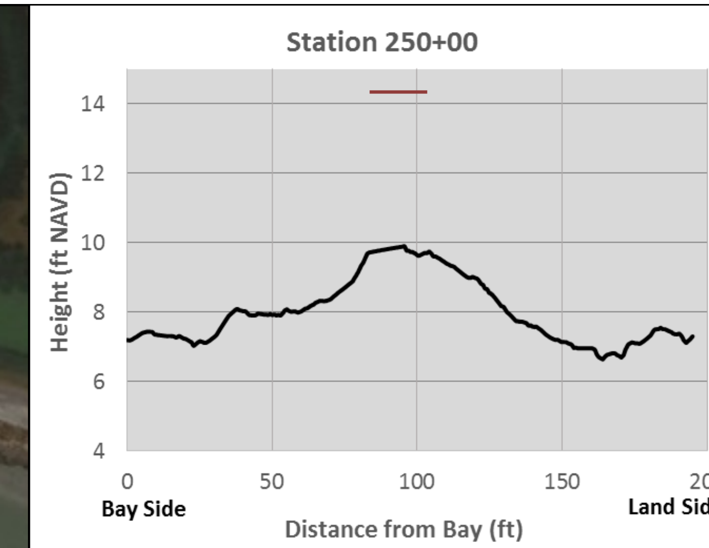


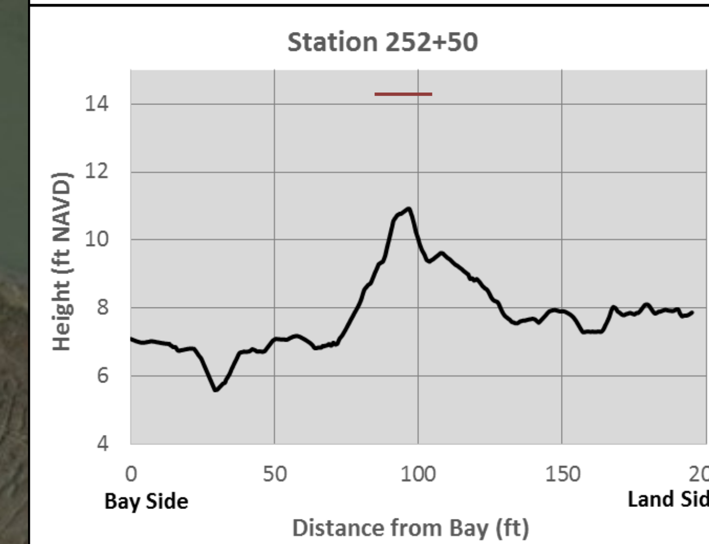


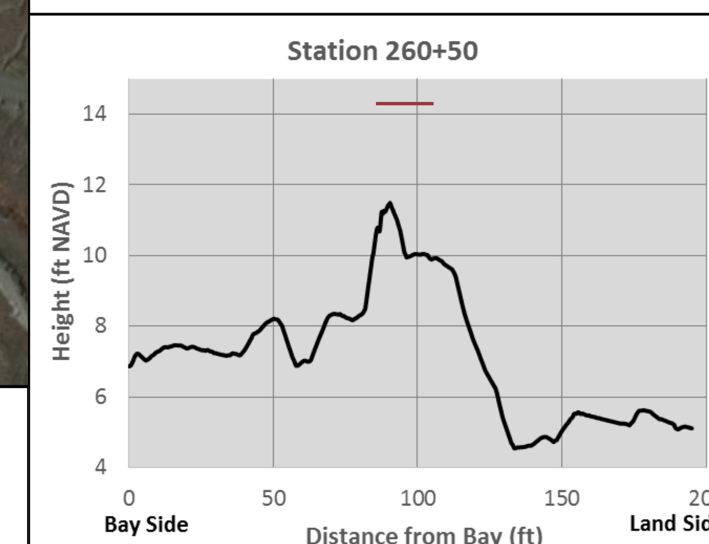
Foster City

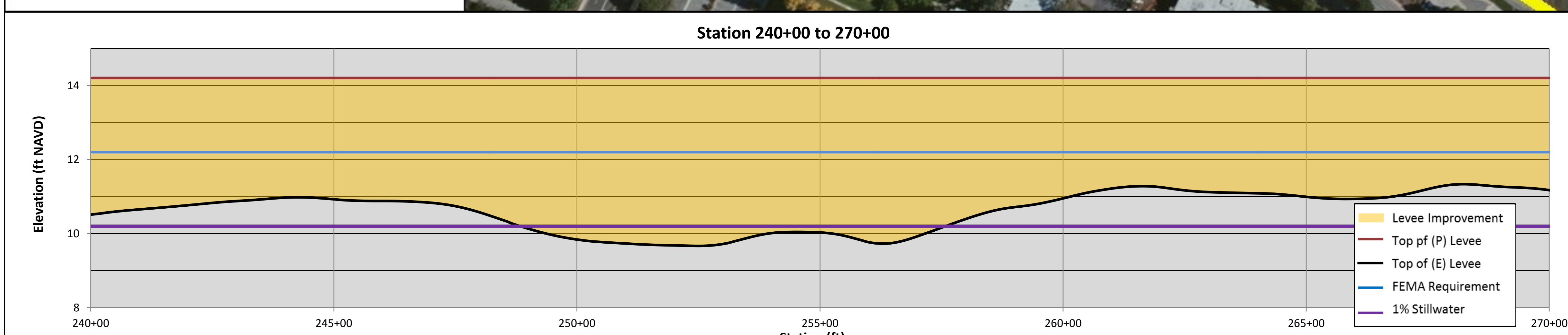
Proposed Levee Improvements

Schaaf & Wheeler
CONSULTING CIVIL ENGINEERS







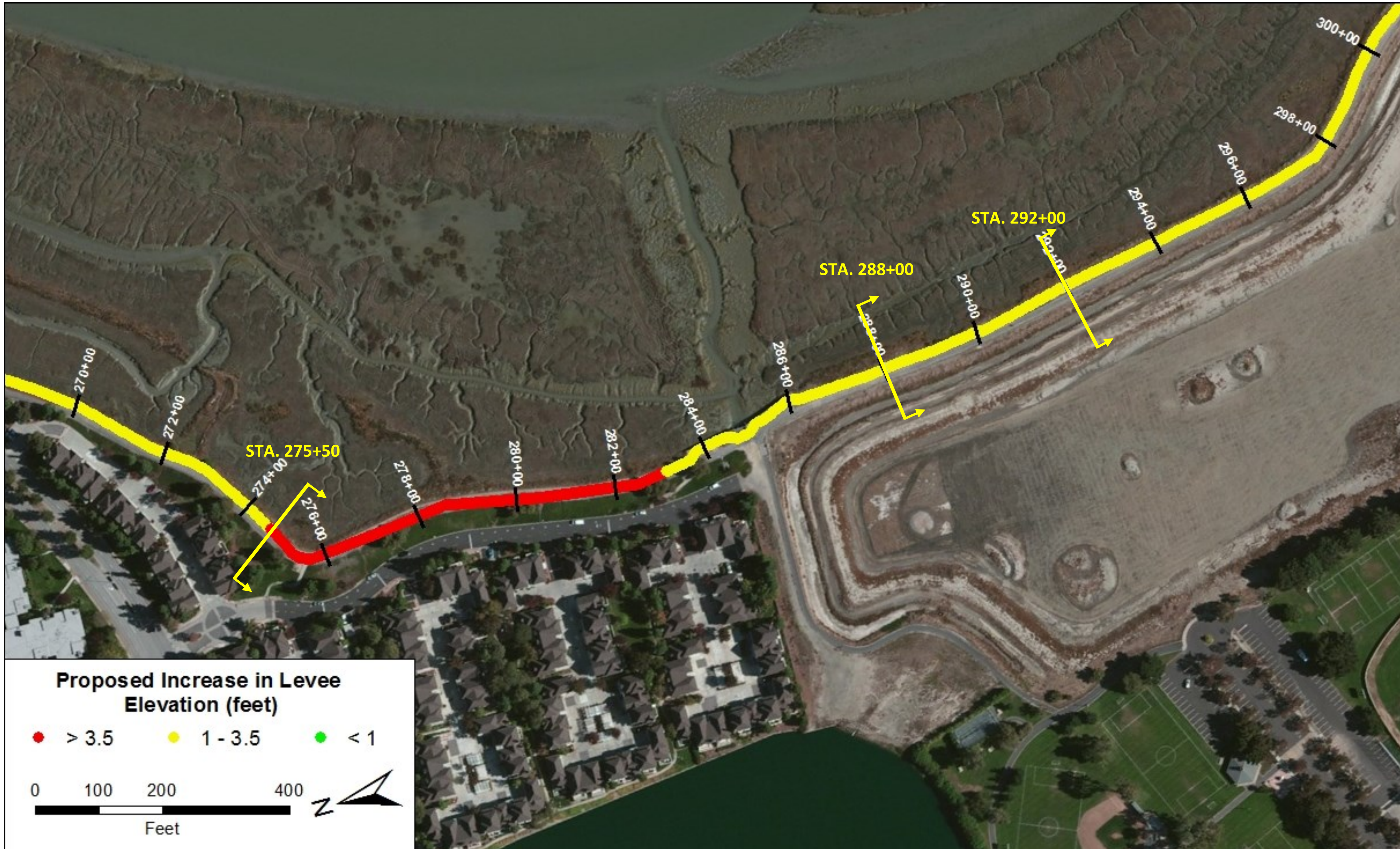


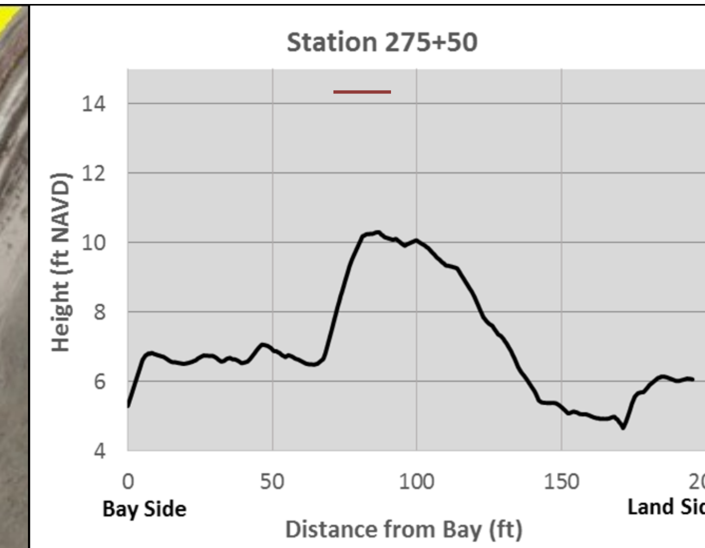
Foster City

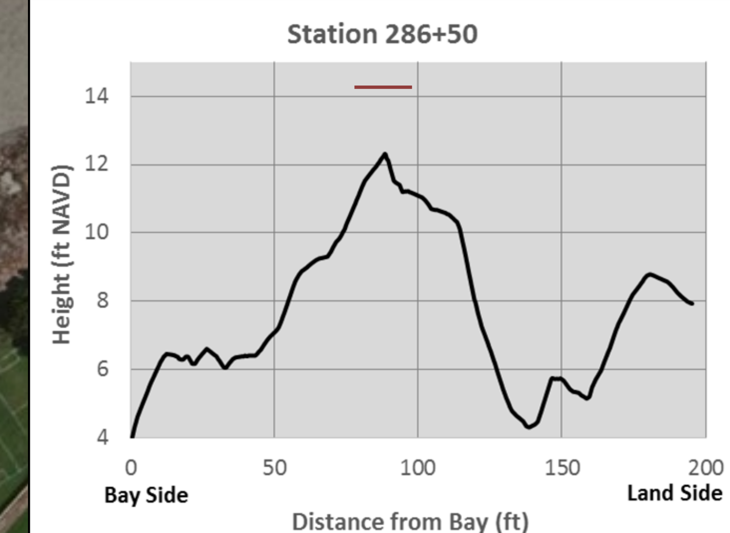
Proposed Levee Improvements

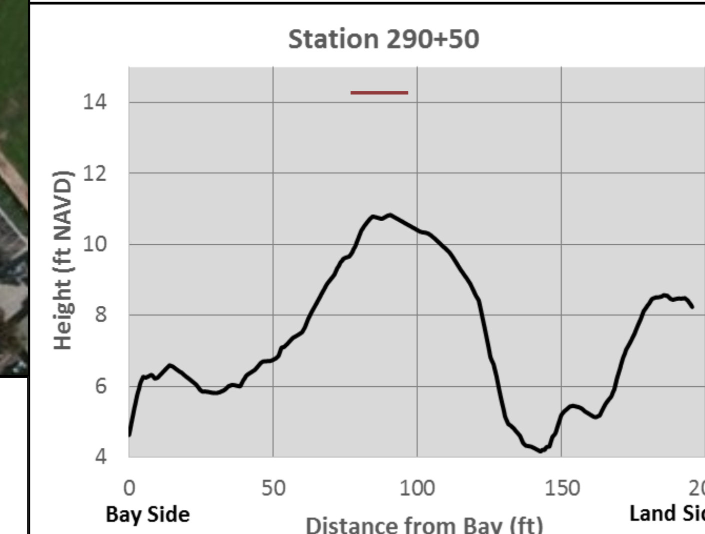
Schaaf & Wheeler
CONSULTING CIVIL ENGINEERS

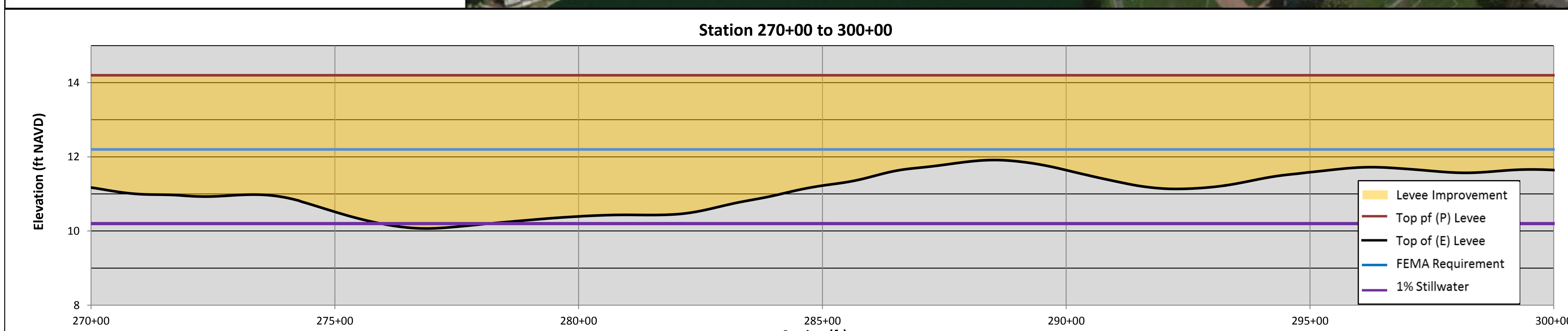
Sheet 9 of 15







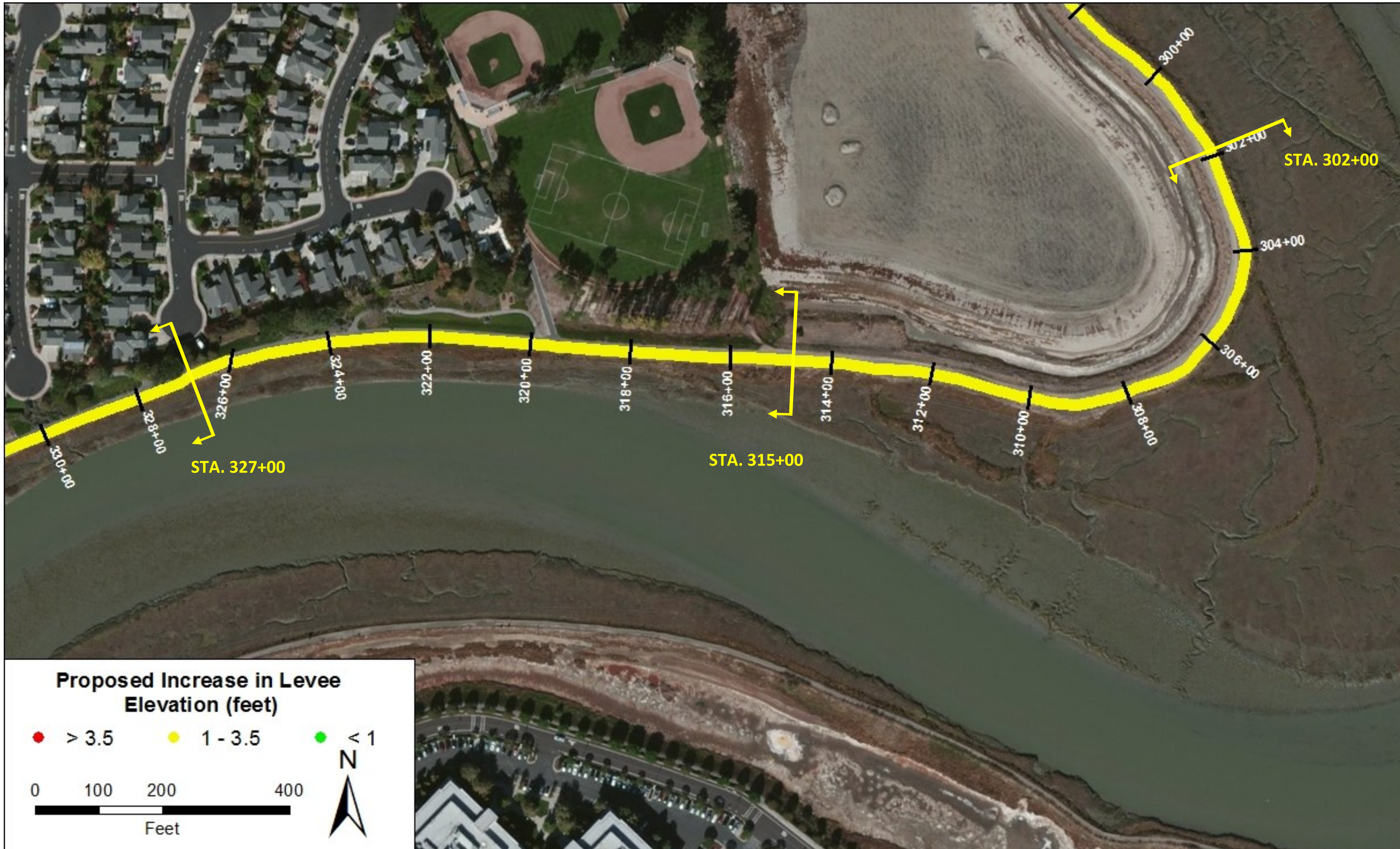


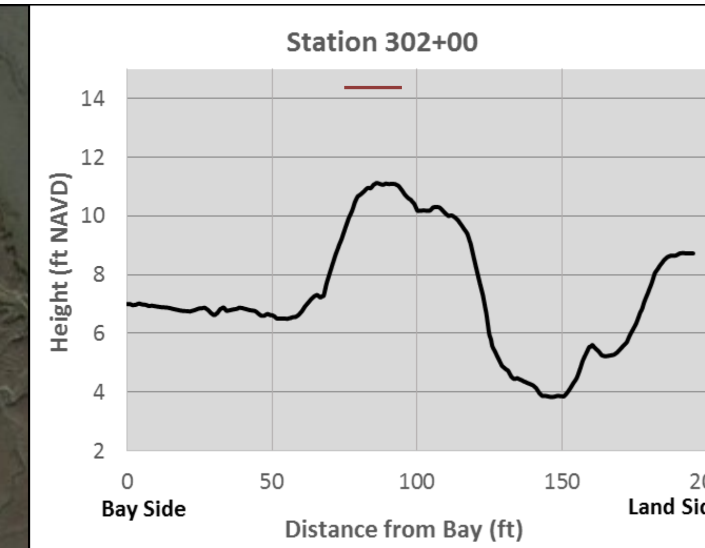


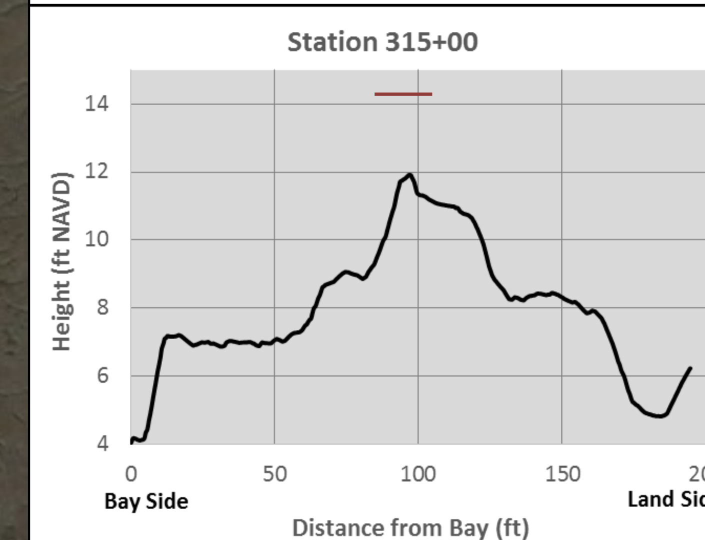
Foster City
Proposed Levee Improvements

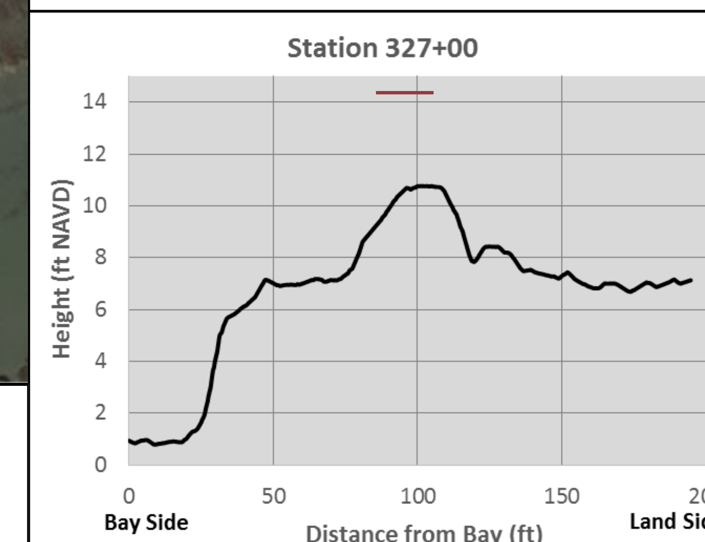
Schaaf & Wheeler
CONSULTING CIVIL ENGINEERS

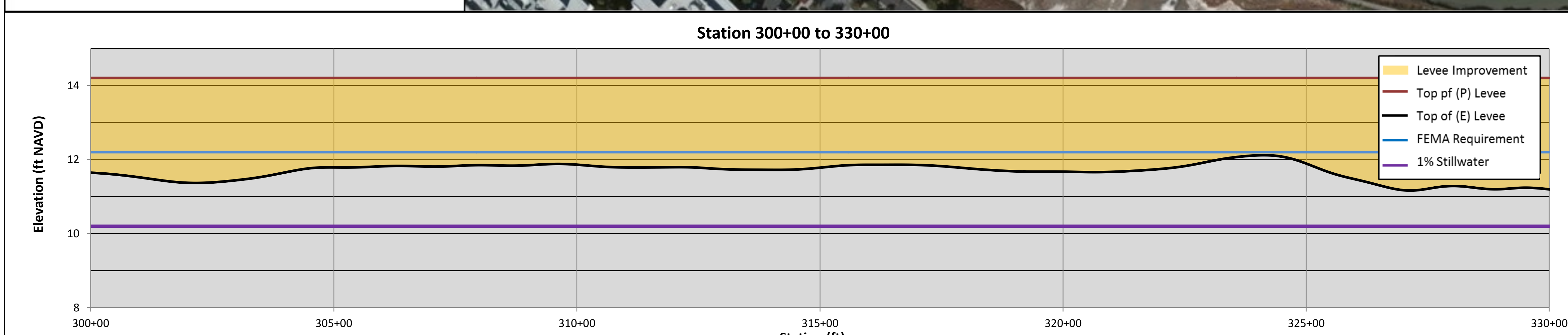
Sheet 10 of 15







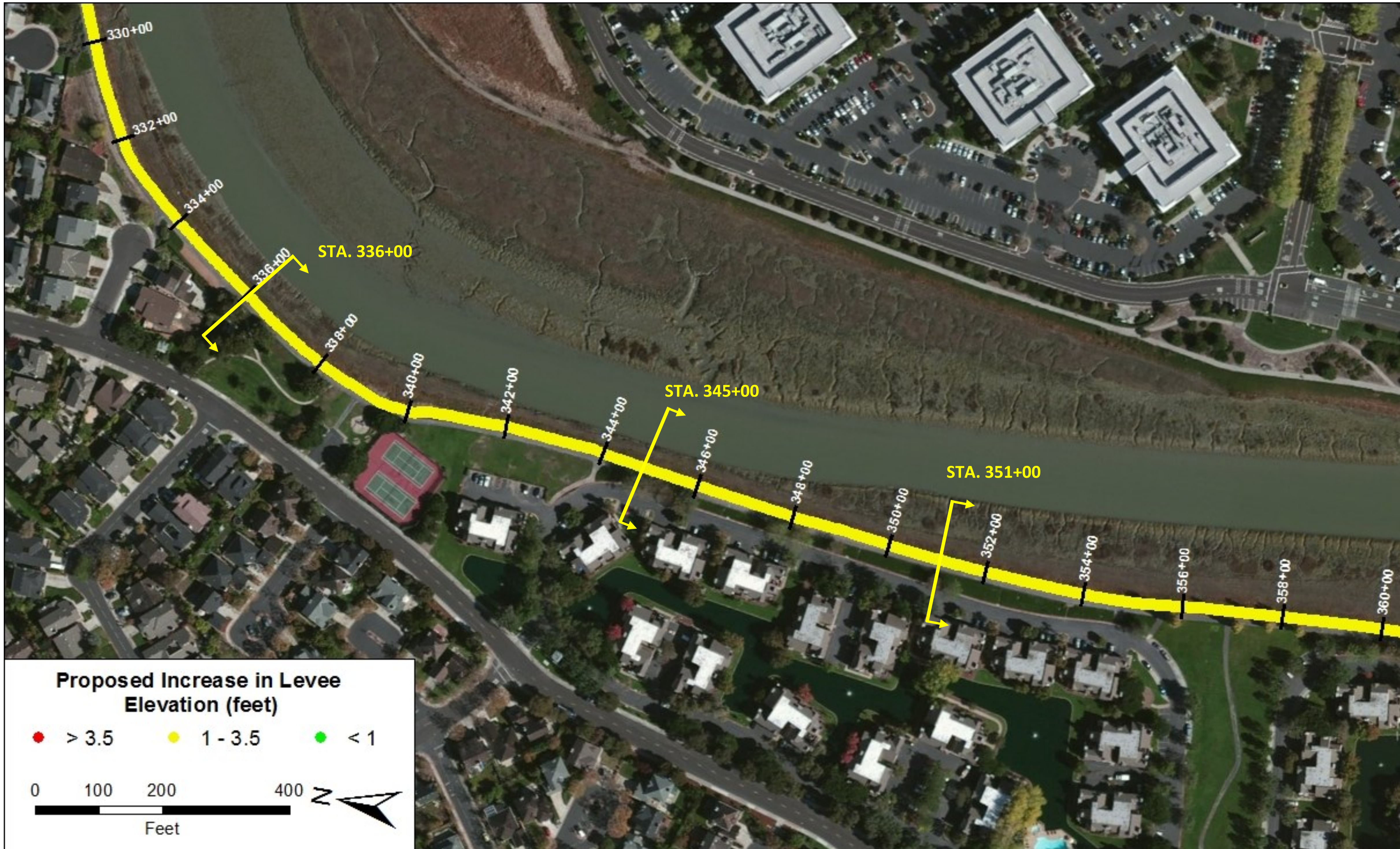


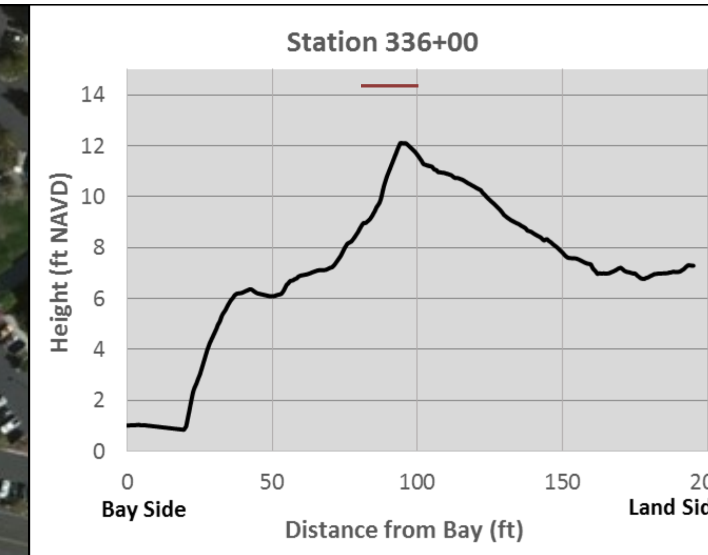


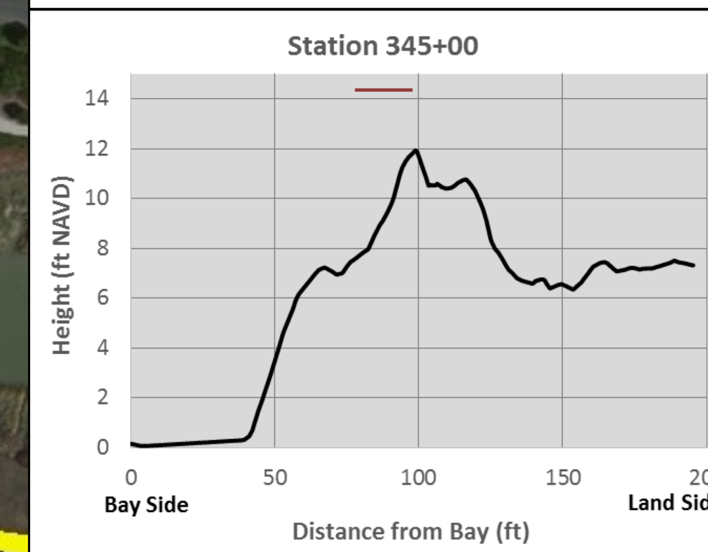
Foster City
Proposed Levee Improvements

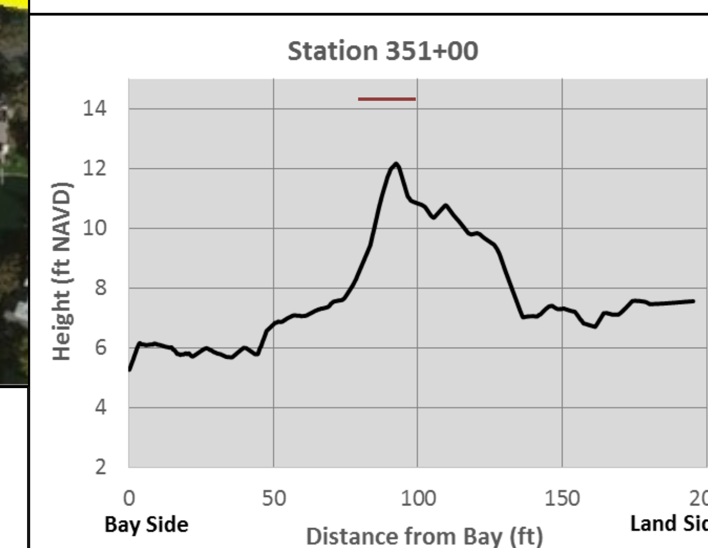
Schaaf & Wheeler
CONSULTING CIVIL ENGINEERS

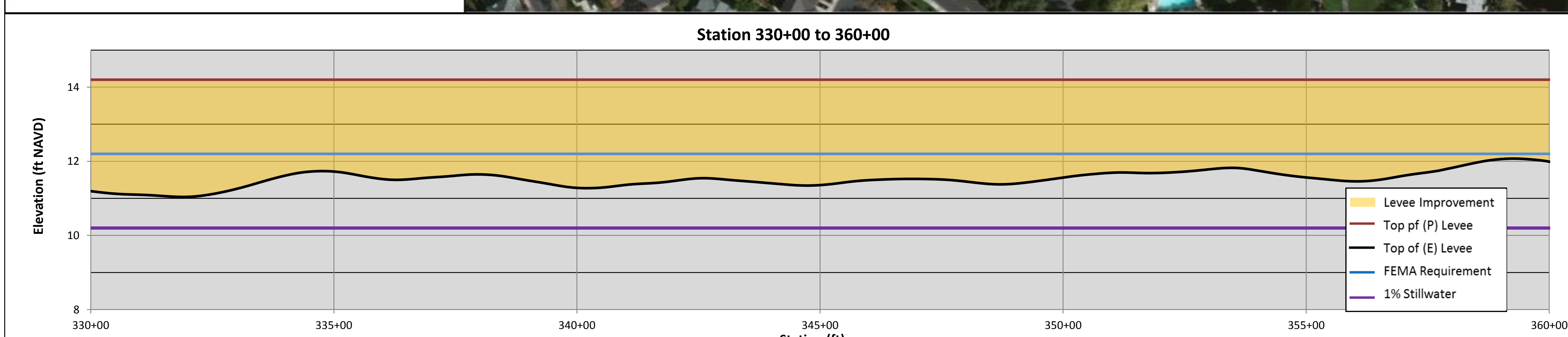
Sheet 11 of 15









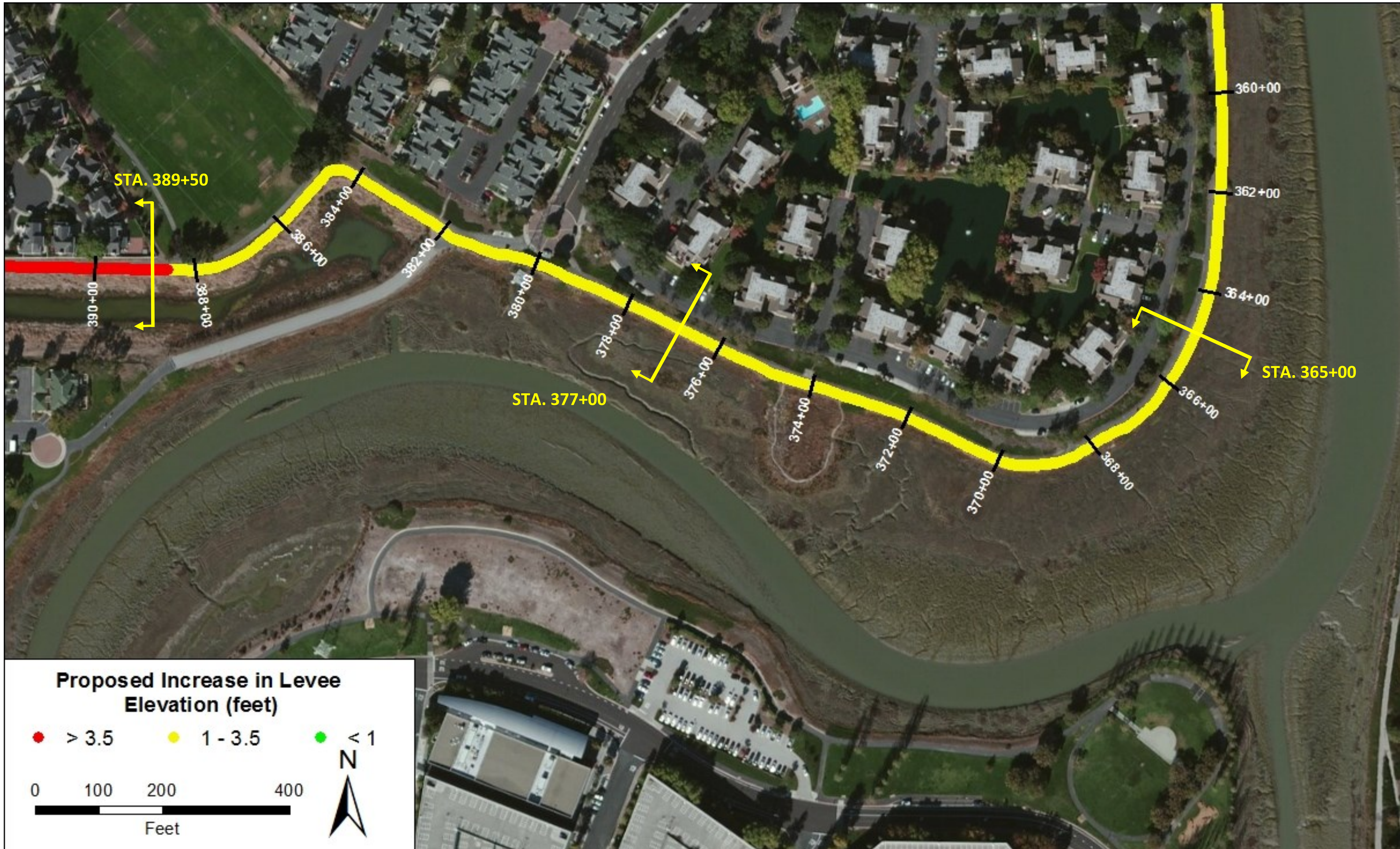


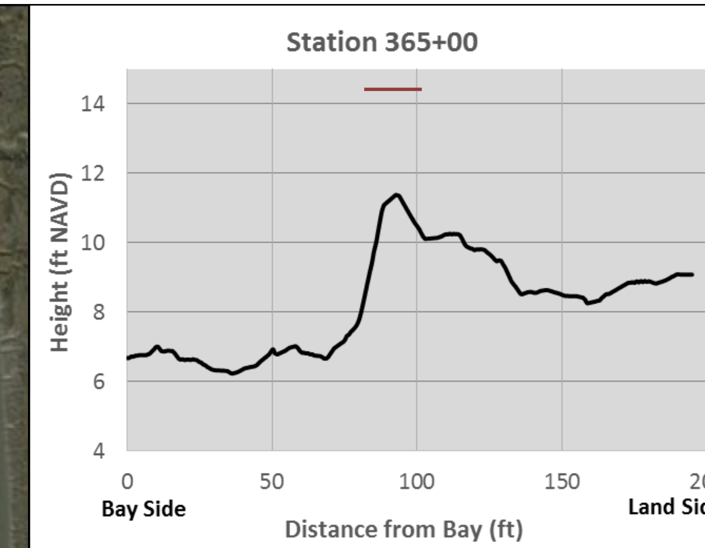
Foster City

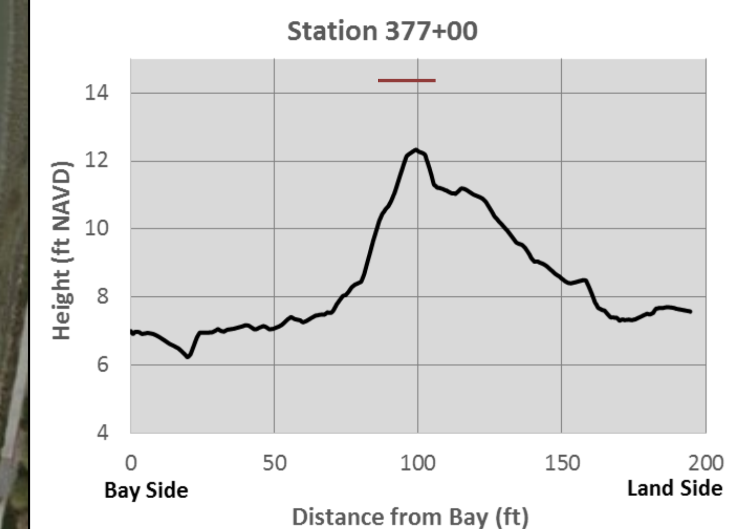
Proposed Levee Improvements

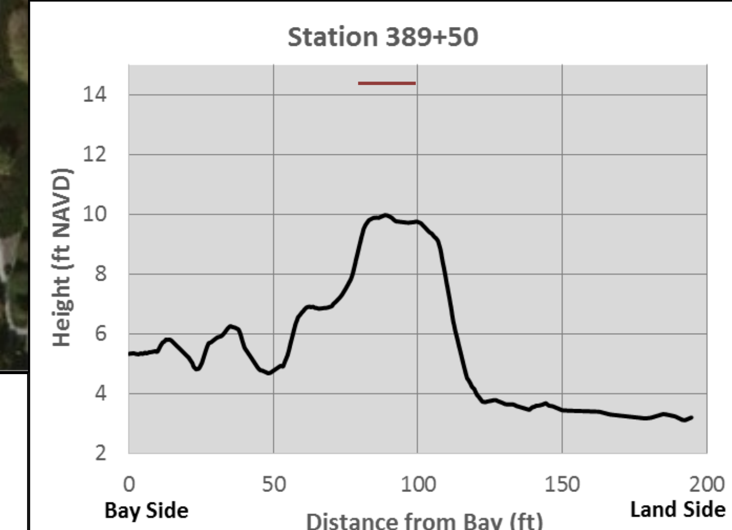
Schaaf & Wheeler
CONSULTING CIVIL ENGINEERS

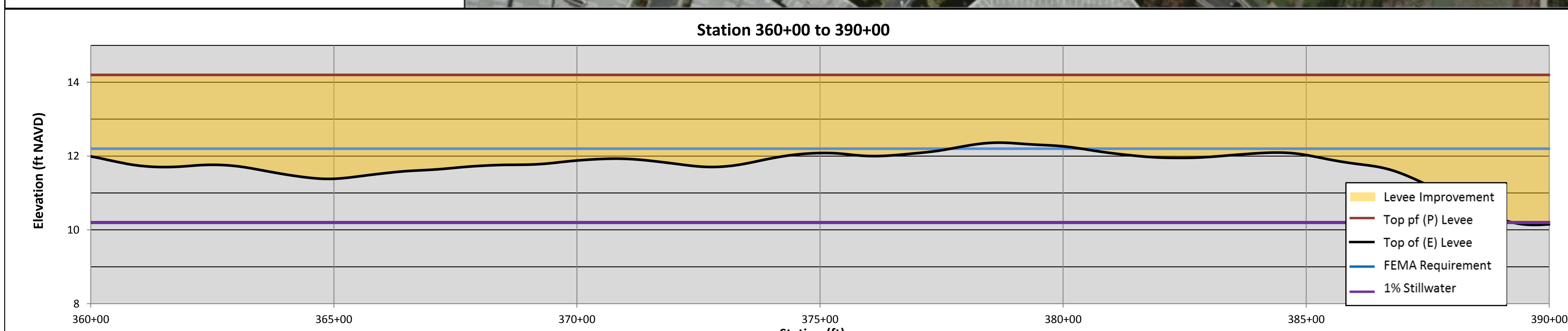
Sheet 12 of 15







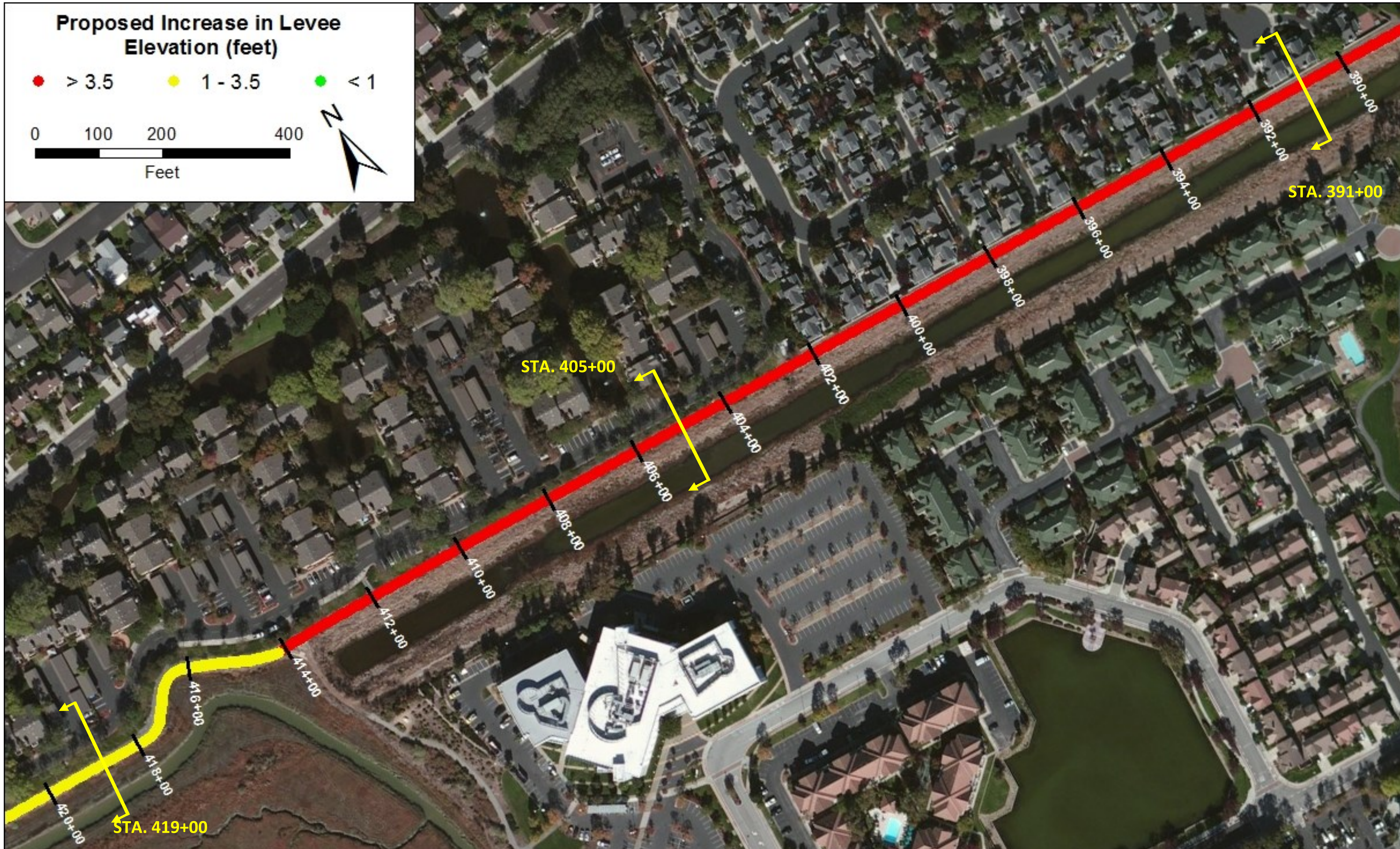


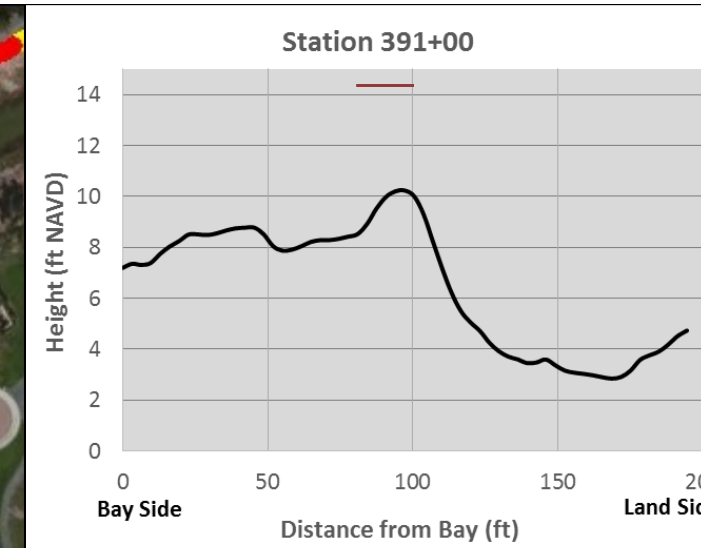


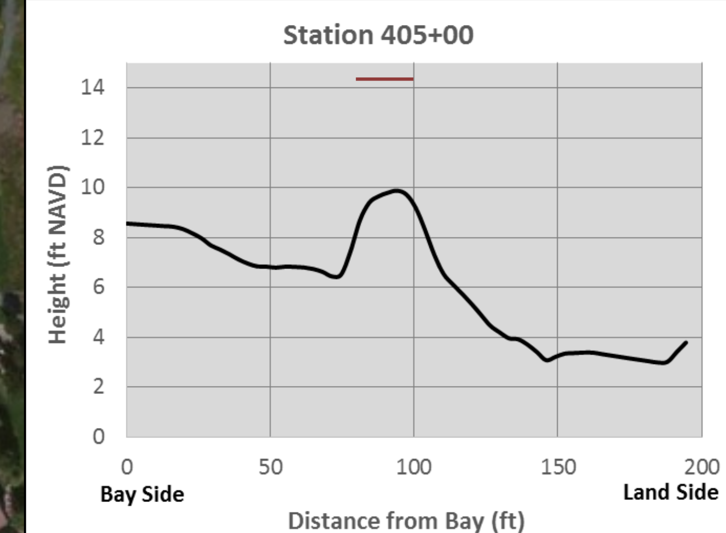
Foster City

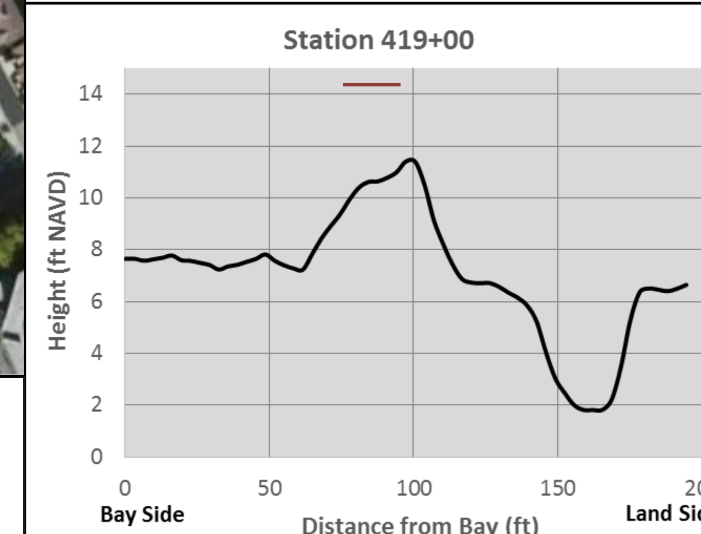
Proposed Levee Improvements

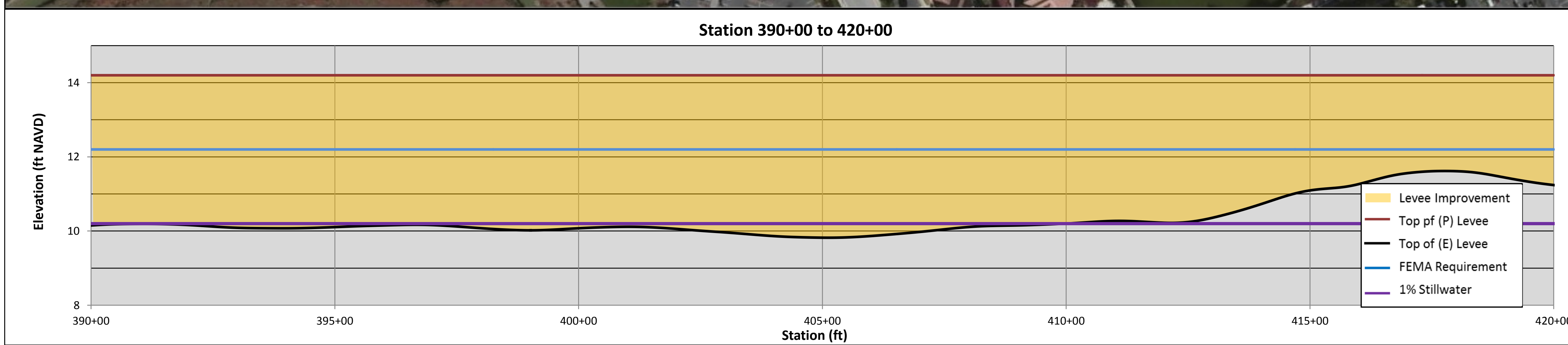
Schaaf & Wheeler
CONSULTING CIVIL ENGINEERS





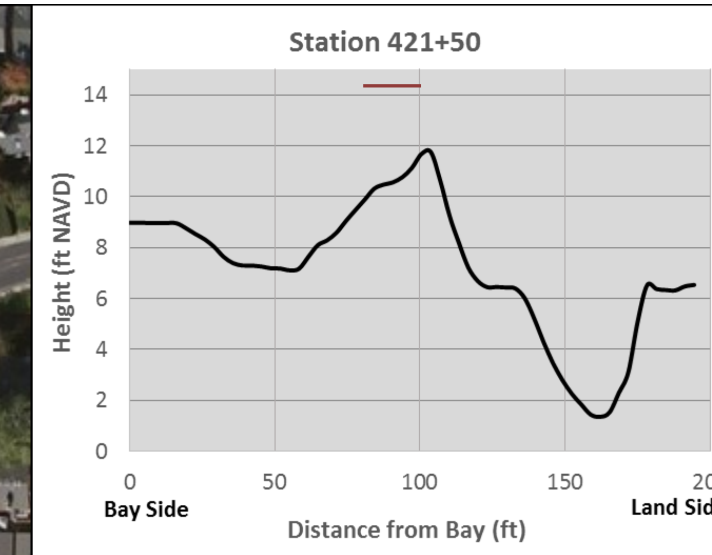


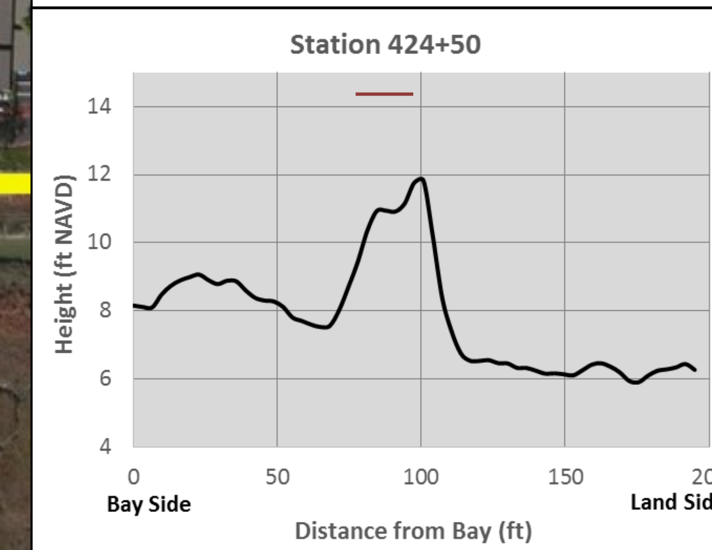


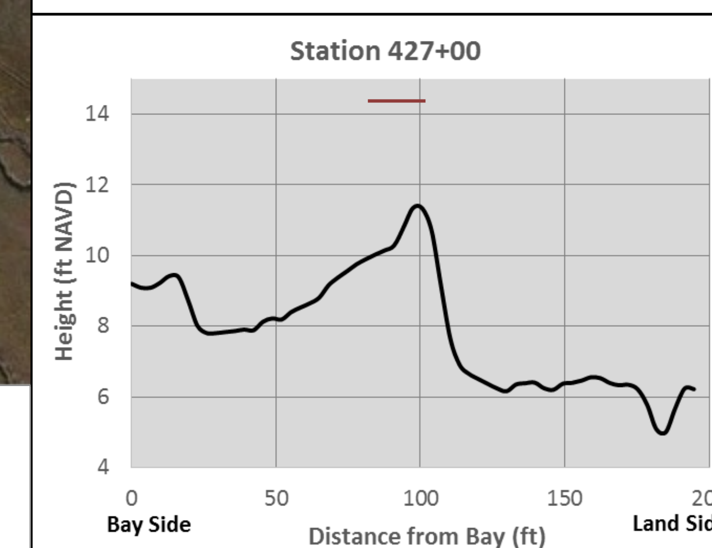


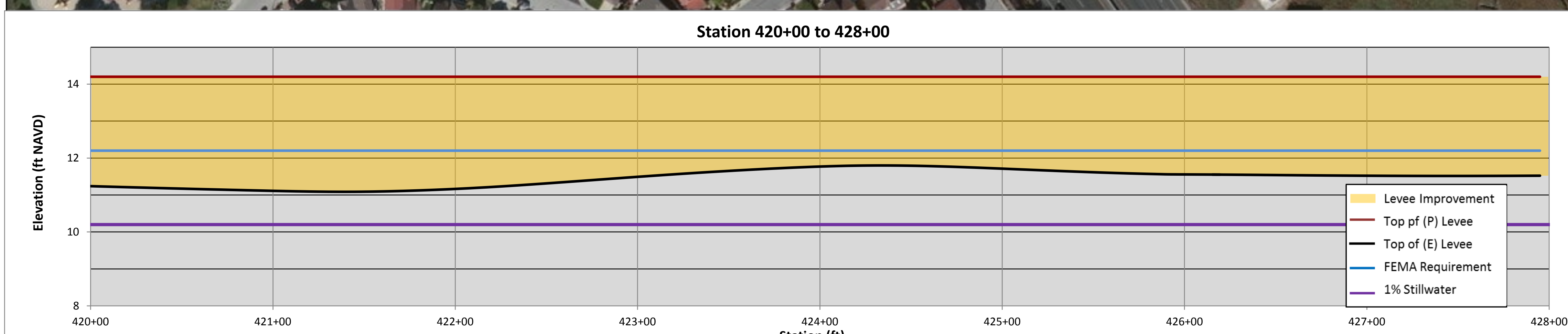
Foster City
Proposed Levee Improvements

Schaaf & Wheeler
CONSULTING CIVIL ENGINEERS









Foster City

Proposed Levee Improvements

Schaaf & Wheeler
CONSULTING CIVIL ENGINEERS

Sheet 15 of 15

Attachment 2

Bibliography

1. Code of Federal Regulations. Title 44 – Emergency Management And Assistance, § 65.10 (2002). http://www.gpo.gov/fdsys/pkg/CFR-2002-title44-vol1/content-detail.html
2. Federal Emergency Management Agency (FEMA). *Recertification Letter: Foster City Levees*. 2007
3. FEMA. Analysis and Mapping Procedures for Non-Accredited Levees. July 2013 http://www.fema.gov/media-library-data/20130726-1922-25045-4455/20130703_approachdocument_508.pdf
4. FEMA. California Coastal Analysis and Mapping Program (CCAMP). 2014 http://www.r9map.org/Pages/CCamp-Main.aspx/
5. National Research Council. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past Present and Future. 2012 http://www.nap.edu/openbook.php?record_id=13389
6. Robert H. Born Consulting Engineerings, Inc. *Report on Analysis of Foster City Levees.* June 15, 1988.
7. Sea Level Rise Committee of SF Adapt. Guidance for Incorporating Sea Level Rise into Capital Planning in San Francisco. 2014 http://www.acfloodcontrol.org/SFBayCHARG/pdf/sf_slr_guidance.pdf
8. Schaaf & Wheeler Consulting Engineers. *Foster City Central Lagoon Base Flood Elevation*. January, 2014.