Public Draft Feasibility Report

SAFER Bay Project

Strategy to Advance
Flood protection, Ecosystems and
Recreation along San Francisco Bay

East Palo Alto and Menlo Park

(Task Order 1)

October 2016

SFCJPA.ORG

San Francisquito Creek
Joint Powers Authority

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Menlo Park, CA 94025

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SAFER BAY

East Palo Alto and Menlo Park

Project No. 222952-028

Task Order No. 1

PUBLIC DRAFT FEASIBILITY REPORT

October 2016

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Acronyms and Abbreviations

Alternative	A combination of reach options that satisfies project objectives in all reaches.
BFE	Base Flood Elevation
Caltrans	California Department of Transportation
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Mate
H:V	Ratio of Horizontal to Vertical
Highway 84 Bridge	Dumbarton Bridge
MHHW	Mean Higher High Water
NAVD	North American Vertical Datum of 1988
Option	A stand-alone feature in any one project reach that will address any of the project objectives. A combination of Options in all reaches (Alternative) is required to satisfy the overall project objectives.
PG&E	Pacific, Gas and Electric Company
Project	SAFER Bay Project
Reach	The project area was initially broken into a total of nine reaches. The proposed alternatives are composed of varying reach options.
ROW	Right-Of-Way
SAFER	Strategy to Advance Flood Protection, Ecosystems and Recreation along the San Francisco Bay
SBSPRP	South Bay Salt Ponds Restoration Project
SFCJPA	San Francisquito Creek Joint Powers Authority
SFHA	Special Flood Hazard Area
SFPUC	San Francisco Public Utilities Commission
SLR	Sea Level Rise
SWL	Still Water Level
UPRR	Union Pacific Railroad
USACE	United States Army Corps of Engineers
US/DS	Upstream/Downstream
WSE	Water Surface Elevation

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1 Introduction

1.1 Background and Overview

San Francisquito Creek Joint Powers Authority (SFCJPA) is a regional government agency founded by the cities of East Palo Alto, Menlo Park, and Palo Alto, the San Mateo County Flood Control District and Santa Clara Valley Water District in 1999 following a major flood the preceding year. The SFCJPA plans, designs and implements capital projects which are comprehensive in terms of geography and function because they cross jurisdictional boundaries and serve to reduce a proven flood threat, enhance ecosystems and recreational opportunities, and connect our communities.

The SFCJPA and its member agencies seek to protect people, property, and public infrastructure within the cities of East Palo Alto, Menlo Park, and Palo Alto from San Francisco Bay coastal flooding (while the focus of this document is on East Palo Alto and Menlo Park, an upcoming Feasibility Report concerns Palo Alto's shoreline). To accomplish this goal, SFCJPA is planning for the construction of new and/or improved flood risk reduction features along the Bay shoreline from the Menlo Park/Redwood City border south to San Francisquito Creek, where another SFCJPA flood protection ecosystem restoration project is under construction along the East Palo Alto/Palo Alto border. In addition to protecting East Palo Alto and Menlo Park, this project will protect neighboring areas of Redwood City and unincorporated San Mateo County, which could be inundated by coastal flooding via Menlo Park. The project, called the Strategy to Address Flood protection, Ecosystems and Recreation along the San Francisco Bay, and known by the acronym SAFER, also seeks to further provide habitat restoration for the Bay's tidal marsh ecosystem, and to enhance recreation opportunities along the Bay shoreline. The project footprint is shown on Figure 1.

Currently, the communities of East Palo Alto and Menlo Park have shorelines that are prone to tidal flooding. As such, many property owners within these communities must purchase flood insurance. The implementation of SAFER would remove these from FEMA's tidal floodplain; see Figure 2 for an overview of the recently released Preliminary FEMA Flood Insurance Rate Map[1] floodplains within the project area. Although the existing salt pond levees provide some degree of protection from coastal flooding, these levees are not certified by FEMA to provide flood protection from a projected 100-year event (that has a 1% annual chance of occurring in any given year).

Additionally, salt pond restoration efforts that require the breaching of outer Bay front levees are limited until flood protection is provided[2]. The SAFER Bay project would allow significant salt pond restoration activities to begin as part of this project and through work by other partnering agencies. For this reason, the South Bay Salt Ponds Restoration Project and the Don Edwards

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[1] Preliminary Flood Insurance Rate Maps were released on August 13, 2015 and may be subject to change.

[2] While the salt pond levees are not certified by FEMA, they reduce the risk of flooding in the study area by muting the tidal effects. Activities to restore habitat through breaching these pond levees will require new flood risk reduction features to at least provide equivalent flood risk reduction that is currently provided by the pond levees.

National Wildlife Refuge have written in support of the SAFER project. The SAFER Bay project will also allow for improved connectivity between communities through enhancement to the recreational Bay Trail and other local trails.

Many agencies provided input in the development of this Feasibility Report, including:

- City of Menlo Park
- City of East Palo Alto
- City of Redwood City
- U.S. Fish and Wildlife Service
- Don Edwards National Wildlife Refuge
- California Department of Fish and Wildlife
- South Bay Salt Ponds Restoration Project (SBSPRP)
- California Department of Transportation (Caltrans)
- San Francisco Public Utilities Commission (SFPUC)
- Midpeninsula Regional Open Space District
- Pacific Gas and Electric (PG&E)
- Facebook, Inc.
- California Coastal Conservancy
- Bay Conservation and Development Commission (BCDC)

Public outreach was also conducted by the SFCJPA during the development of this Feasibility Report. Public outreach included presentations to the city councils of Menlo Park and East Palo Alto, to neighborhood associations, meetings in early 2015 and early 2016 hosted by the League of Women Voters of South San Mateo County, and three conferences on sea level rise adaptation hosted by San Mateo County and/or local members of Congress; and the project was covered in multiple local newspaper stories.

1.2 Purpose

The overall purpose of this Feasibility Report is to evaluate the flood protection alternatives along the San Francisco Bay shoreline within the project footprint and provide the justification to support the selection of a preferred alternative that will move forward into the California Environmental Quality Act (CEQA) analysis. The project was divided into nine reaches (designated as Reach 1 through Reach 9)[3] that are based on local geography, as shown on Figure 1. Within each reach; one or more options are presented, as shown on Figures 3 through 10. Typical cross sections for each reach are illustrated on Figures 11 through 24. A qualitative evaluation of each option is presented, and options within each reach are combined to create a range of alternatives that satisfy the overall project objectives. This report presents a preliminary ranking of alternatives based on multiple evaluation factors including construction cost and constructability, operation and maintenance, restoration and recreation benefits.

[3] Reach 6 was merged into Reach 5 after further development of the Reach 5 options.

1.3 Project Objectives

The SAFER Bay project objectives, which take into account the substantial constraints of working in an area between developed land, public infrastructure and sensitive shoreline, serve as the basis to formulate and evaluate options and alternatives. The objectives include:

- Project will reduce the risk of flooding within the cities of East Palo Alto and Menlo Park from San Francisco Bay coastal waters and support the communities' desire to be removed from the FEMA floodplain, and include consideration of three feet of future Sea Level Rise (SLR),
- Project will enable adaptation to our changing climate by utilizing tidal marsh areas for flood protection in a way that sustains marsh habitat and facilitates marsh restoration associated with the South Bay Salt Ponds Restoration Project (SBSPRP) and other restoration efforts.
- Project will expand opportunities for recreation and community connectivity in collaboration with the Bay Trail Program and efforts to enhance local trails.
- Project will minimize future maintenance requirements.
- Project will create opportunities for partnership with agencies and organizations pursuing similar goals and objectives and with assets to be protected by the project.
- Project will not rely on projects by other entities to achieve these objectives.

Additionally, the SFCJPA plans for the SAFER project to align with regional efforts that promote adaption for sea level rise in the context of our developed shoreline areas. Thus SAFER's objectives support the objectives of documents such as the San Francisco Estuary Partnership's 2016 *Comprehensive Conservation and Management Plan*.

1.4 Constraints

The project constraints identify assets that options (or alternatives) cannot impact without recommending a way to minimize, maintain or improve the existing condition through the project. Project constraints set the boundaries for development of project features and can affect the project's ability to meet its objectives. The project constraints include:

- Wetlands
- Habitat for endangered species
- Existing roadways
- Interior drainage
- Existing utility infrastructure
- Property within and adjacent to the levee alignment

1.5 Design Criteria

The project design identifies the specific technical requirements of the study (feasibility phase). The project design criteria will satisfy:

- Current FEMA coastal flood protection requirements, which is the existing 100-year event (that has a 1% annual chance of occurring in any given year) with required freeboard for FEMA accreditation; and
- An additional three feet of tidal elevation to account for anticipated sea level rise.

Additional discussion of FEMA's design criteria, such as the evaluation of settlement and structural stability, applicable to the project components are summarized in more detail in Section 2.0.

1.6 Report Organization

Following the introduction in this section, this report is organized as follows:

- Section 2 provides a summary of the project technical considerations and requirements that each of the reach options must satisfy.
- Section 3 provides a summary of each reach and the potential options considered.
- Section 4 summarizes the screening and evaluation for each of the options.
- Section 5 presents development of the preliminary alternatives from the identified reach options.
- Section 6 presents the feasibility evaluation scoring matrix and calculation methodology.
- Section 7 presents feasibility level cost estimates for each alternative.
- Section 8 summarizes the overall results and preliminary ranking.
- Section 9 presents a list of references used for the preparation of this report.

2 Technical Considerations and Requirements

Project technical considerations and requirements have been identified to inform and direct the development of options in each reach. These requirements were based on project objectives and project constraints.

2.1 Coastal Hydraulics and Sea Level Rise

The current effective FEMA Flood Insurance Rate Maps (FIRMs) designate the entire East Palo Alto and Menlo Park's Bay shoreline within its Special Flood Hazard Area (SFHA) for the 100-year (1% annual chance) coastal flood event. This designation indicates that these communities are at risk of flooding and property owners with a federally backed mortgage are required to pay a premium to participate in FEMA's National Flood Insurance Program. Although a network of existing embankments provides some degree of protection from coastal flooding, these embankments are not currently certifiable as per FEMA's 44 Code of Federal Regulations (CFR) Section 65.10. The crest elevations are below FEMA's 100-year coastal flood event freeboard requirements and they do not meet FEMA's geotechnical requirements. Riverine flooding and SFHA floodplains associated with San Francisquito Creek are being addressed through a separate flood improvement project under construction through 2018.

In 2015, FEMA issued preliminary FIRMs for much of the Bay shoreline, including the SAFER project area, and this latest information has been incorporated into this Feasibility Report. The floodplain area shown in this Preliminary FEMA Flood Insurance Rate Map (FIRM) (Figure 2) is larger in extent and inundation depth than the effective FIRM.

The preliminary FEMA results for just offshore of the SAFER project area estimates the 100-year still water level (SWL) to be 11 ft (DHI, 2013), measured using the standard North American Vertical Datum of 1988 (NAVD 88). Per FEMA, the SWL is defined as including the effects of the astronomical tide, storm surge, and wave setup. For the SAFER Bay project area west of Willow Road, this is an increase of one foot from the existing base flood elevation (BFE) of 10 ft NAVD (FEMA, 2012). The existing SFHA is delineated by projecting the water surface elevation inland to where it intersects the ground surface elevation. For the SAFER Bay project area just north of Highway 84, also known as the Bayfront Expressway, and at the PG&E substation and east of University Avenue, the preliminary FEMA results increased the existing BFE of 11 ft NAVD (FEMA, 2012) to 12 ft NAVD.

FEMA's preliminary results also assess the contribution of wave runup, which is added to the SWL. Per FEMA, wave runup is defined as the maximum elevation of a wave breaking onto a beach. Both the SWL and wave runup are important elevations to determine crest elevations of flood control features. FEMA's Typical Transect Schematic is included in Figure 2a below, which illustrates the differences in types of coastal flooding and the applied FEMA zoning.

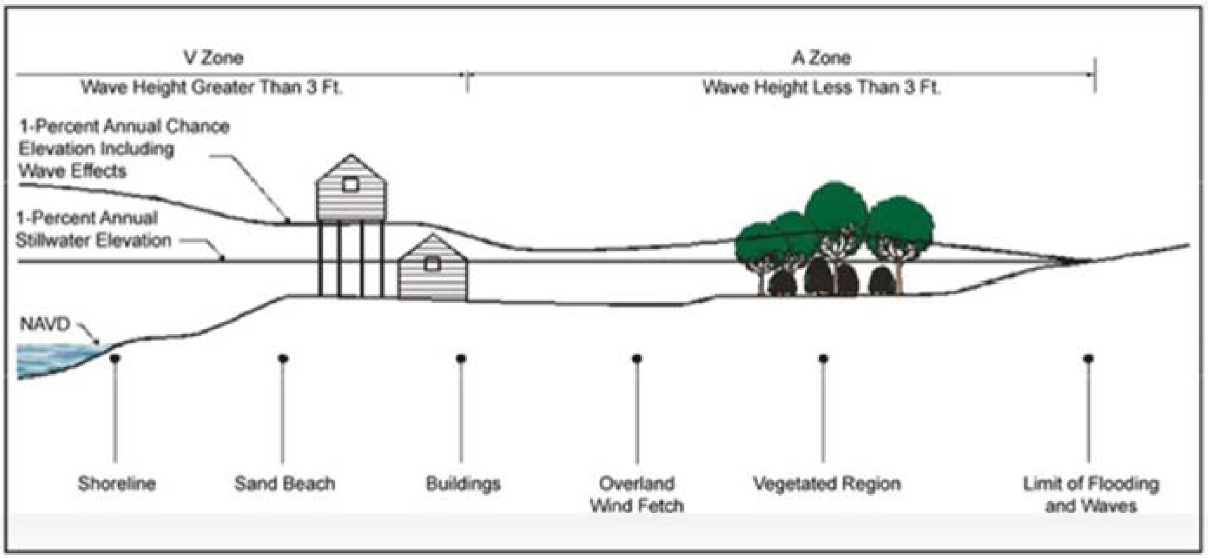

Figure 2a – FEMA's Typical Transect Schematic

To provide a margin of safety, FEMA requires that the crest top elevation of a certified levee be built above the 100-year water level by an additional amount called 'freeboard'. The FEMA freeboard requirement for coastal levees is a minimum of:

- Two feet above the SWL

and higher if either of the following two wave-influenced elevations exceeds two feet:

- One foot above the 100-year wave crest elevation, or
- One foot above the maximum wave runup elevation

Although FEMA does not currently consider sea level rise in its flood mapping, the SAFER Bay project design criteria includes consideration of three feet sea level rise and is shown in Minimum Design Elevation section of Tables 1 and 2. Planning for sea level rise is part of the California design guidelines (OPC, 2013) and the Bay Conservation and Development Commission (BCDC, 2011). BCDC in partnership with San Mateo County and the Coastal Conservancy released the *Final Report for Sea Level Rise and Overtopping Analysis for San Mateo County's Bayshore* in May 2016. The Final Report included sea level rise inundation maps for multiple events. Figures 2b and 2c have been included in this report for reference depicting the inundation for 36" of SLR with Mean Higher High Water (MHHW) elevation and 78" of SLR with MHHW, respectively.

Incorporating three feet of sea level rise into the design is consistent with the SAFER Bay project time frame (five decades) and the range of sea level rise projections over this time. For instance, NRC (2012), which was developed particularly for California and whose findings have been adopted by the state, projects three feet of sea level rise occurring between 2075 to 2105. In addition, the U.S. Army Corps of Engineers projects three feet of sea level rise to occur in a similar time period, between 2075 to 2095 (USACE, 2011).

Based on the predictions of extreme water level and wave events, as well as considering three feet of sea level rise, the approximate design elevations for the SAFER Bay project's levee crests are presented in Table 1. Beyond its relation to sea level rise, SAFER's minimum design elevation would protect people against a tide almost nine feet above the current daily high tide.

Table 1. Preliminary Minimum Design Elevations for Reaches 1,2,3,4,6,7,8,9

Minimum design elevation (1% SWL only)		
Elevation[2] or Height	Existing Conditions	Considering 3 ft of SLR
1% SWL elevation (100-year tidal floodplain)[1]	11.0 ft	14.0 ft
Required freeboard above the SWL	2.0 ft	2.0 ft
Minimum design elevation[3]	***13.0 ft***	***16.0 ft***

Note: SWL = still water level; TWL = total water level
[1] As depicted on the San Mateo FEMA Preliminary Flood Insurance Rate Maps dated August 13, 2015.
[2] All elevations are provided in NAVD 88.
[3] Elevation provided is ultimate design elevation and does not account for settlement. Levees will be built to a higher elevation to account for settlement, which will occur over the first year after construction.

Table 2. Preliminary Minimum Design Elevations for Reach 5

Minimum design elevation (1% SWL only)		
Elevation[2] or Height	Existing Conditions	Considering 3 ft of SLR
1% SWL elevation (100-year tidal floodplain)[1]	12.0 ft	15.0 ft
Required freeboard above the SWL	2.0 ft	2.0 ft
Minimum design elevation[3]	***14.0 ft***	***17.0 ft***

Note: SWL = still water level; TWL = total water level
[1] As depicted on the San Mateo FEMA Preliminary Flood Insurance Rate Maps dated August 13, 2015.
[2] All elevations are provided in NAVD 88.
[3] Elevation provided is ultimate design elevation and does not account for settlement. Levees will be built to a higher elevation to account for settlement, which will occur over the first year after construction.

The potential need for higher levee crest elevations to account for waves is verified by the technical documentation supporting the recent FEMA map revision process (e.g. Table 11 in BakerAECOM (2014)). This documentation, which also guides the design of new levees at Foster City (Schaaf & Wheeler, 2015), estimates levee height requirements up to three feet higher than the minimum SWL levee height. It is assumed that the SAFER Bay project has reduced wave exposure due to the proposed levee alignments location landward of the former salt ponds and less exposure than Foster City's levees.

In addition to wave exposure, wave runup depends on ground surface elevation, slope, and vegetation. By constructing a gentle slope in front of a proposed levee, the SAFER Bay project may be able to reduce or eliminate the influence of waves on raising the water elevation. However, FEMA certification of levees that use a gentle slope and reduce the levee top elevation is untested and thus will require additional evaluation and close coordination with FEMA during project design in order to obtain FEMA certification.

The need for assuming wave attenuation to achieve FEMA certification will depend on other considerations, including SAFER's ability to establish new tidal marsh from existing salt ponds, which would also attenuate waves. Maximum design elevations provided in Table 3 and 4 provide the maximum water surface elevation if enhanced levee slopes and/or future SBSPRP projects do not reduce the wave runup onto the proposed levee/floodwall slope. The presented maximum water surface elevation will be refined during the design phase.

Table 3. Preliminary Maximum Design Elevations for Reaches 1,2,3,4,6,7,8,9 dependent upon Future Salt Pond Restoration Activities

Maximum Design Elevation (1% SWL & Waves)		
Elevation[3] or Height	Existing Conditions	With 3 ft of SLR
1% SWL elevation (100-year tidal floodplain)[1]	11.0 ft	14.0 ft
Wave runup[2]	3.0 ft	3.0 ft
Required freeboard above the TWL	1.0 ft	1.0 ft
Maximum design elevation[4]	***15.0 ft***	***18.0 ft***

Note: SWL = still water level; TWL = total water level
[1] As depicted on the San Mateo FEMA Preliminary Flood Insurance Rate Maps dated August 13, 2015.
[2] Initial wave runup, based on initial review of BakerAECOM (2014). Subject to change with future analysis.
[3] All elevations are provided in NAVD 88.
[4] Elevation provided is ultimate design elevation and does not account for settlement. Levees will be built to a higher elevation to account for settlement, which will occur over the first year after construction.

Table 4. Preliminary Maximum Design Elevations for Reach 5 dependent upon Future Salt Pond Restoration Activities

Maximum Design Elevation (1% SWL & Waves)		
Elevation[3] or Height	Existing Conditions	With 3 ft of SLR
1% SWL elevation (100-year tidal floodplain)[1]	12.0 ft	15.0 ft
Wave runup[2]	3.0 ft	3.0 ft
Required freeboard above the TWL	1.0 ft	1.0 ft
Maximum design elevation[4]	***16.0 ft***	***19.0 ft***

Note: SWL = still water level; TWL = total water level
[1] As depicted on the San Mateo FEMA Preliminary Flood Insurance Rate Maps dated August 13, 2015.
[2] Initial wave runup, based on initial review of BakerAECOM (2014). Subject to change with future analysis.
[3] All elevations are provided in NAVD 88.
[4] Elevation provided is ultimate design elevation and does not account for settlement. Levees will be built to a higher elevation to account for settlement, which will occur over the first year after construction.

2.2 Interior Drainage

There are several existing interior drainage channels that are located along the proposed levee alignments. These stormwater facilities are primarily manmade structures that have been constructed both above and below grade to convey stormwater. The interior drainage system in Menlo Park and East Palo Alto is initially collected by an underground storm drain piped network that discharge into these open channels which then eventually discharge into the San Francisco Bay. These open ditches are carefully managed by a series of gates and pump stations, which balance water surface elevations between the stormwater runoff and tidal cycle events.

These interior drainage structures will need to be evaluated during the design phase to verify that they are satisfying FEMA's 44 CFR Section 65.10 requirements and will function properly, without increasing stormwater flooding from the existing condition, with the SAFER Bay flood control levees and floodwalls installed. If issues with the structures are identified, remediation improvements will be included within the project design. These channels may also require relocation as appropriate to meet regulatory requirements because of the potential threat they pose to levee integrity and the potential obstruction of maintenance activities. Where such relocation is not feasible, measures should be taken to protect the levee/floodwall and pipe/conduit.

The implementation of water pollution prevention programs and low impact development features at the County and City level are critical to reduce stormwater runoff and flooding. With the expansion of these programs, such as San Mateo's Green Streets and www.flowstobay.org, a reduction of stormwater runoff can reduce the volume of water that is eventually pumped or diverted into the San Francisco Bay.

2.3 Geotechnical Considerations

For additional geotechnical analysis information and recommendations, please refer to Appendix A – Geotechnical Report for the Feasibility Phase, dated May 2016.

The proposed flood protection earthen levees/floodwalls are located along the southwestern fringe of San Francisco Bay. A review of subsurface explorations collected as part of the search for existing information, and published information on geologic and geotechnical conditions in the site area indicate that beneath a fill layer, the area is underlain by soil deposits commonly referred to as Young Bay Mud. This soil is soft, weak and highly compressible. This was verified by performing geotechnical borings along the proposed alignments. The Young Bay Mud may also contain intermediate sand layers and lenses that could be potential underseepage paths or be susceptible to liquefaction during an earthquake. The available information indicates that the thickness of the Young Bay Mud layer is on the order of 10 to 20 feet throughout much of the alignment area. The thickness of the Young Bay Mud is greater in the area of the approach to the Dumbarton Bridge, possibly on the order of 40 feet or more.

The additional load from levee raises creates a number of considerations on the underlying soil, and in particular the Young Bay Mud, that need to be analyzed. The key considerations are as follows:

Stability – Depending on the height of new levee fill needed and the strength of the underlying soil, the Young Bay Mud may be too weak to allow the levees to be constructed to their final target heights without special considerations. Stability failures can occur if too much soil load is placed over a short period of time. This may mean that levees will need to be raised in stages to allow for time for the underlying soil to gain strength before additional fill is placed. Alternatively, measures may be needed to strengthen weak underlying soil or accelerate its strength gain.

Seepage – During periods when there is water against the levees, seepage can occur both through the levee embankment and through more pervious layers beneath the levee (under seepage). Both through seepage and under seepage can lead to levee erosion, piping and other detrimental consequences. Mitigation measures could include the proper specification and compaction of levee fill materials for through seepage control and the installation of seepage cutoff walls, pressure relief or drainage elements.

Settlement – The additional loading from new levees or levee raises will cause settlement over time due to the consolidation of the underlying Young Bay Mud. Levees will need to be initially built to heights greater than their final elevations, to meet the required final design crest elevations.

2.4 Levees

It is possible and perhaps likely that levees would be constructed and raised in stages over the course of many years due to long-term impacts of SLR and budget limitations. Regardless of the timing or staging of levee raisings, a sufficient width along the alignment should be available to accommodate the full width of the levee that would eventually be constructed. Further, the base of the levee should be constructed to this full width so that future raises can be performed on top of the levee without the need for future lateral expansion.

For the purpose of evaluating alignment options, levees with the following minimum geometry have been considered:

- Minimum crest width of 20 feet.
- Waterside and landside slopes of 3H:1V (horizontal to vertical).
- Final levee crest height at Elevation 16-17[4] feet NAVD 88.

To account for levee settlement, overbuild of levee heights should also be considered in establishing levee geometries. It was computed that 1-3 ft of overbuild will be required throughout Reaches 1-9. At the Dumbarton Bridge, a maximum 3 ft of overbuild is recommended due to the thicker Young Bay Mud. Typical cross sections, Figure 11 – 24, document the computed the maximum overbuild required for each reach if the levee was constructed to account for SLR. For planning purposes, a 100-foot wide linear base area would be needed to accommodate a levee that will ultimately be built to these dimensions.

2.5 Floodwalls

Where spatial or other constraints exist that do not allow for the construction of a levee, floodwalls can be considered. Even though a floodwall needs much less lateral space than a levee, some amount of space would still be needed for the wall footing. For the purpose of evaluating options, we have considered an inverted T-shaped floodwall, where the footing width is approximately equal to the wall height. Thus, a 12-foot high floodwall would require a 12-foot wide footing plus additional width for construction access.

2.6 Flood Risk Reduction Structures

There are several existing roadways that cross the proposed flood protection alignment. Where it is impractical to raise these roadways to an elevation sufficient to provide flood protection, a passive flood risk reduction structure, such as a flood gate has been considered[5]. A passive structure is defined as a feature that can be closed at beginning of a storm event and left alone without any additional management except to reopen at the end of the storm event. FEMA certified flood risk reduction structures, including passive and active roadway gates, railroad

[4] Elevation 17 NAVD 88 only applies to Reach 5
[5] The existing grade elevation at the proposed flood gate locations, based on available LiDAR data, is at or above the projected MHHW elevation with SLR for the study horizon (50 years).

gates, and tide gates, have been constructed throughout the United States by the USACE and non-federal flood control agencies. The flood risk reduction structures will be designed to provide the same level of protection as the surrounding levees and floodwalls. Access waterside of the structures would be limited while the structures are closed. The selection of gate structures will require further discussions with the SFCJPA and local agency staff during the design phase of each reach to select the type and preferences of the gated structures.

Additionally, tidal gates were also considered at locations where the levee/floodwall alignment crossed the existing drainage ditch system. There are several existing tidal gates that will be impacted by the proposed flood protection alignment. These tidal gates manage water surface elevations between stormwater runoff and changing tidal conditions. Tidal gates are typically defined as active structures that require some type of management during a storm event to manage flood water elevations. Additionally, operations of these gates may require modification as sea levels continues to rise.

2.7 Penetrations

Penetrations and encroachments (pipelines, power poles, mail boxes, planter boxes, etc.) into the levee prism are generally not recommended, although they may be necessary. Where crossings occur, they will ideally be located above the design water surface elevation, within the freeboard area of the levee. Additional alternatives may be considered if raising the penetration above the design water surface elevation is not feasible.

2.7.1 Pipes and Conduits

It is generally not recommended that pipes and conduits be located beneath or within 10 feet of the toes of levees or floodwalls. Such pipes and conduits can serve as pathways that increase the potential for seepage, erosion and other related consequences that can impact the integrity of the levee or floodwall. Consideration should be given to relocating existing pipes and conduits that are within this zone to other areas. Where such relocation is not feasible, measures should be taken to protect the levee/floodwall and pipe/conduit. Pipeline utilities that may be of concern include existing and/or abandoned stormwater, sewer, electrical, fiber optic, and water underground pipelines. Additional coordination with the pipelines owners to determine impacts to the pipeline will be investigated during the future design phase.

2.7.2 Utility Poles and Towers

It is not recommended that utility poles and towers be located within 10 feet of the toes of levees or floodwalls. Such encroachments can serve as pathways that increase the potential for seepage, erosion and other related consequences that can impact the integrity of the levee or floodwall. The presence of such encroachments can also interfere with access for normal maintenance and operations and flood-fighting activities. Consideration should be given to relocating such existing elements that are within this zone to other areas. Where such relocation is not feasible, measures should be taken to protect the levee/floodwall and utility poles and towers.

2.8 Bay Trail

In locations where the proposed flood risk reduction alignment overlaps or indirectly impacts the Bay Trail, reconstruction and improvements of the trail may be necessary.

2.9 Maintenance

As a standard of practice, a minimum easement for maintenance, inspection and flood-fighting of 10 to 20 feet is required on the landside of levees. It is recommended that minimum 10-foot wide easements be obtained along the landside toe of the project, where the land is not already held in fee title by a member agency of the SFCJPA and space is limited. As an alternative to this, in areas where there are space limitations, an access road along the levee crown with intermittent access ramps to access points along the landside toe may suffice.

Temporary construction easements will also be required for this project, and have been assumed to be 15 additional feet beyond the limits of the maintenance easement. In areas where the landside toe of the proposed levee lands within existing structures or property, there may be an opportunity to minimize required temporary easements by performing construction activities on the levee crown. This design variance will require further investigation during final design.

2.10 Real Estate

The SFCJPA is responsible for procurement of all lands, easements, relocations, rights-of-way, and disposal areas that are necessary for construction, operation, and maintenance of the project. During the design phase for each reach, real estate easements will be established and coordinated through the JPA to its member agencies. A public outreach strategy will be developed with the JPA and member agencies to discuss most appropriate outreach methods to discuss impacts to private property owners.

2.11 Borrow Locations

Borrow material is required to complete the levee construction in the proposed alternative alignments. This borrow material will be obtained locally wherever possible and must meet specific suitable fill requirements. It was assumed that the levee borrow can be collected on a 50 mile round trip.

2.12 Disposal and Storage Area

Any excess levee cut material is expected to be used for construction of transition zones. Any excess will be stored on site for use in future restoration work. Site identification for excess storage will be determined during the design phase.

2.13 Staging Area

Potential staging areas will be identified during the design phase.

2.14 Transition Zone Habitat

Transition zone habitat restoration on the outboard levee slope is an important component of the SAFER Bay project's ecosystem restoration approach. The transition zone provides multiple beneficial functions for both flood risk reduction (e.g., erosion protection for outboard levee slope, wave energy dissipation) and tidal marshes (e.g., high-tide refuge habitat for California

Ridgway's rails [*Rallus obsoletus obsoletus*][6], and salt marsh harvest mice [*Reithrodontomys raviventris*]). Transition zone habitat also provides accommodation space for transgression of the adjacent tidal marshes in response to SLR.

In particular, the Restoration Alternative would include the construction of transition zone habitat at Ponds R1/R2 and potentially at the Mosley Tract (Figure 28). This would both provide high tide refuge habitat along restored marshes at R1/R2 and enhance future tidal marsh habitat that will eventually colonize the City of San Jose-owned Mosley Tract. The project is evaluating varying transition zone slopes, up to slopes consistent with the *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* (USFWS 2013), and this location may allow a large, gentle slope because the majority of the transition zone fill would be placed in existing salt pond/open water habitat, with little impact to tidal marsh.

The project should also consider, in collaboration with the resource agencies, the installation of transition zone habitat adjacent to existing tidal marshes in reaches 7 (Cooley Landing Marsh), 8 (Laumeister Marsh), and 9 (Faber Marsh). These marshes provide suitable habitat for Ridgway's rail and salt marsh harvest mouse; Laumeister and Faber Marshes currently support a relatively high abundance of Ridgway's rail among South San Francisco Bay marshes. While these marshes (especially Laumeister and Faber) do contain marsh gumplant dominated, high tide refuge habitat in their interiors, they lack a broad transition zone along the landward edge. Therefore, as sea level rises high tide refuge habitat in these marshes will likely decline in the absence of restored transition zone along their landward edges. Figure 30 shows the footprint of what a representative transition zone would occupy adjacent to SAFER Bay's levee alignment. The slope shown on Figure 30 (15H:1V with a width of 150 ft) to provides new transitional habitat and results in short-term impacts on existing tidal marsh.

2.14.1 Ecological Importance of the Transition Zone

Historically, nearly 70 percent of the transition zone between tidal and terrestrial habitats in the South Bay was composed of low-gradient seasonal wetlands grading into tidal marsh. The transition zone ranged in width from hundreds to thousands of feet wide and provided essential habitat for numerous species (Goals Project 1999; Beller et al. 2013; Goals Project 2015). Today, the transition zone around San Francisco Bay marshes consists almost entirely of a narrow area about ten feet wide that starts with high marsh and is severely constrained by steep artificial levee faces (Collins and Goodman-Collins 2010). The SAFER Bay project provides a rare opportunity to increase the amount of low-gradient transition zone habitat in the South Bay.

A number of guiding documents strongly recommend increasing the abundance of transition zone habitat adjacent to tidal marshes, including, the *Salt Marsh Harvest Mouse and California Clapper Rail Recovery Plan* (USFWS 1984), the *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* (USFWS 2013), *Living with a Rising Bay: Vulnerability and Adaptation in San Francisco Bay and on its Shoreline* (BCDC 2011), *The Baylands Ecosystem Habitat Goals* (Goals Project 1999), and *The Baylands and Climate Change* (Goals Project 2015). This is primarily because:

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[6] formerly California clapper rail [Rallus longirostris obsoletus]

- Broad transition zones are essential for the survival and recovery of the endangered salt marsh harvest mouse and California Ridgway's rail because they provide refugia from predators during high tides (USFWS 1984; Shellhammer 2012; USFWS 2013). Transition zones are most critical during extreme high-tide events when tidal marshes are inundated and predation pressure is highest.
- Transition zones provide essential habitat for endangered marsh plants, including salt marsh bird's beak (*Chloropyron molle* ssp*. molle*) and California sea blight (*Suaeda californica*),
- Transition zones increase the habitat diversity and biodiversity (including a higher number of species) of the tidal marsh edge because multiple plant and animal communities overlap along the hydrologic gradient provided within a broad transition zone. (USFWS 2013; Goals Project 1999).
- Transition zones provide accommodation space for the landward transgression of tidal marsh with sea level rise.

2.14.2 Importance of the Transition Zone to Levee Function and Sustainability

Building broad transition zones adjacent to tidal marshes will also increase the flood protection capacity and sustainability of the project levees. These zones dissipate destructive wave energy and thereby reduce flood risk and erosion to the outboard levee slope. Furthermore, stormwater or treated wastewater could be discharged over or through the low-gradient outboard levee slope and used to recreate seasonal wetland/bayland ecotone habitats that occurred historically, thereby further increasing the habitat diversity and ecological function of the transition zone.

2.14.3 Horizontal Levee-Transition Zone Slope Alternatives and Trade-Offs

The *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* recommends that transition zones should be constructed when levees adjacent to marshes are rebuilt in order to provide endangered species with appropriate habitat under a range of sea-level rise scenarios (USFWS 2013). Where feasible, the SAFER Bay project will propose horizontal levees to enable the restoration of a diverse suite of transition zone habitats, including alkali meadow/grassland, seasonal wetlands, salinas, and coastal scrub as shown on Figure 25. This habitat mosaic is based upon historical ecological investigations in the South Bay (Collins and Grossinger 2004; Grossinger et al 2007; Grossinger 2009) and upon collaboration between H. T. Harvey & Associates and the San Francisco Estuary Institute (H. T. Harvey & Associates and SFEI 2012). This habitat mosaic would provide high tide refugia cover for endangered species including the salt marsh harvest mouse and California Ridgway's rail during extreme high tides, and these benefits would persist as sea level rises. Habitat diversity and ecological functions/services increase as outboard levee slopes decrease or become gentler, as shown on Figure 26.

2.14.4 Integration with the South Bay Salt Pond Restoration Project and Project Permitting

As described above, the incorporation of transition zone features into the SAFER Bay project will provide crucial habitat and further the recovery goals for endangered species. In addition to incorporating habitat restoration opportunities along specific reaches, the project will facilitate the implementation of future phases of the SBSPRP by providing crucial flood protection in areas where tidal restoration and managed ponds associated with the SBSPRP are planned. This nexus is an essential element of the project's tidal marsh mitigation/permitting strategy. As noted above, Reach 5 between Highway 84 and Pond R2 could provide the best opportunity for this vital nexus.

Also, levees associated with the SAFER Bay project will provide the foundations for installation of transition zone habitats within SBSPRP restoration areas. This coupling of wetland restoration and enhancement with the project will also facilitate project permitting, as the integration of tidal marsh and transition zone habitat restoration into the project is expected to offset impacts to wetland and endangered species habitats.

2.15 Tidal Marsh Restoration and Enhancement

Hereafter, the term "tidal marsh restoration" refers to the establishment of tidal marsh habitat and functions where tidal marsh previously existed, resulting in a net gain in tidal marsh surface area (USACE 2015). In contrast, the term "tidal marsh enhancement" includes the improvement of existing tidal marsh habitat functions with no change in tidal marsh surface area (USACE 2015). The SAFER Bay project includes several large-scale opportunities for both the restoration and enhancement of high quality tidal marsh habitat on the bayward side of proposed flood protection. Such opportunities will be incorporated into the project description both to restore the flood risk reduction functions of tidal marshes and to create a self-mitigating project with net, long-term benefits to sensitive bayland habitats and species. The primary restoration opportunity involves integrating, into the SAFER Bay project, a portion of the SBSPRP's proposed tidal marsh restoration within the Ravenswood Pond Complex. The SAFER Bay project also provides unique, large-scale opportunities to enhance existing tidal marshes by constructing extensive transition zone habitat adjacent to these marshes. As described above (see Section 2.11 Transition Zone Habitat), the SAFER Bay project will consider incorporating transition zone habitat into the project to further endangered species recovery goals (Ridgway's rail and salt marsh harvest mouse) and increase the resilience of existing marshes to climate change. The overall quantity and quality of wetland habitats in the South Bay will increase significantly due to the large-scale restoration efforts associated with the SBSPRP that will be further enhanced by restoration associated with the SAFER Bay project. The collaborative effort between these two projects will increase the resilience of the South Bay's wetland habitats and the populations of wildlife that depend on those habitats.

2.15.1 Integration with the South Bay Salt Pond Restoration Project, Highway 84, and the PG&E Ravenswood Electrical Substation

The SAFER Bay project will facilitate the implementation of portions of the SBSPRP by providing crucial flood risk reduction at the Ravenswood Pond Complex in areas where the SBSPRP proposes both tidal marsh restoration and pond management. This nexus is an essential element of the project's tidal marsh mitigation/permitting strategy. Between Highway 84 and Ponds R1 and R2, provides the best opportunity for this vital nexus. The SBSPRP proposes to restore Ponds R1 and R2 to tidal marsh under both the Tidal Habitat Emphasis and Managed Pond Emphasis alternatives (EDAW 2007). However, this restoration cannot increase flood risk to Highway 84 and the PG&E substation north of the Highway. To implement this restoration of approximately 613 acres of tidal marsh within R1 and R2, the SAFER Bay project would protect Highway 84 and the PG&E substation to at least the same level of flood protection as currently provided by the outboard (Bay front) levees around Ponds R1 and R2. Alternatively, SAFER could protect these assets to the project's overall objectives of FEMA certification plus sea level rise. This magnitude of restoration would be more than adequate to compensate for the project's unavoidable impacts to jurisdictional tidal marsh and managed pond habitats.

Therefore, the SAFER Bay project description should incorporate tidal marsh restoration of Ponds R1 and R2 into the project in partnership with the SBSPRP. All SAFER Bay project alternatives considered (Refer to Section 5 discussion and development of alternatives) would provide the flood risk reduction necessary for tidal marsh restoration at Ponds R1 and R2. However, the Restoration and Recreation Alternatives would also provide the opportunity for future tidal marsh restoration within the bayward pond cell (53 acres) at Pond SF2, improving tidal marsh connectivity along the bayshore.

3 Development of Options

The project area was divided into nine reaches to group similar topography, hydraulic conditions and constraints within each reach. In each reach, options were identified that satisfied one or more of the study objectives. Options that satisfied at least one study objective without violating study constraints were retained for further evaluation and formulation of overall study alternatives. Options that violated study constraints or were deemed infeasible were dropped from further consideration. The options identified in each reach are described in this section.

3.1 Reach 1 – Haven Area

Reach 1 begins at the border of a San Mateo County unincorporated area, Menlo Park and Redwood City and ends at Marsh Road. See Figure 3.

3.1.1 Option 1

Option 1 consists of a floodwall along the west side of Marsh Road, extending from the Reach 2 levee across the Silicon Valley Clean Water pump station property to the existing high ground near the Highway 101/84 Interchange. A flood gate with the same crest elevation as the floodwall will be provided across Haven Avenue. This option does not provide flood protection for the portion of Menlo Park situated north of Highway 101 and west of Marsh Road and will require coordination with Redwood City and Menlo Park if it is to be selected for implementation.

3.1.2 Option 2

Option 2 consists of raising the existing levee located along the Bayfront Canal from Reach 2 to the Redwood City border and a floodwall along Sleepy Hollow Lane and Haven Avenue (between the industrial center and RV Park), that will tie into the existing flood proofed sound wall located along Highway 101 near East Bayshore Road. See Typical Sections A and B on Figures 11 and 12 for cross sections of this option. A flood gate with the same crest elevation as the floodwall will be provided across East Bayshore Road. If Redwood City were to construct a flood risk reduction levee outboard of Bayfront Canal that connects to the east-west portion of this option, then the floodwall along Sleepy Hallow Lane and Haven Avenue would not be necessary.

The Bayfront Canal and Atherton Channel (see Figure 3) will require new water control structures to maintain existing conveyance capacity and provide interior drainage.

3.2 Reach 2 – Bedwell Bayfront Park

Reach 2 extends from Marsh Road to South Bay Salt Pond R3. See Figure 4.

3.2.1 Option 1

Option 1 consists of two levees, a western levee along Marsh Road from Reach 1 to high ground within Bedwell Bayfront Park and an eastern levee from the western limit of Reach 3 to the existing high ground within the Bedwell Bayfront Park[7]. Tidal gates between Ponds R5 and R4 and between Ponds S5 and R3 are planned by SBSPRP to allow a balance and transfer of flows. Water control structures will be required to maintain interior drainage from the Caltrans ditch and Bayfront Canal. Additional geotechnical assessment will be required during the design phase to verify the levee tie-in. See Typical Sections A and B on Figures 13 and 14 for cross sections of this option.

The two levees will allow for SBSPRP restoration activities to occur. Levee construction between Ponds R5/S5 and Ponds R3/R4 would be compatible with restoration actions planned by the Phase 2 of the SBSPRP. This includes protection of Ponds R5 and S5 from potential coastal flooding from Pond R4, as R4 is planned for tidal restoration and Ponds R5 and S5 are slated to be managed habitat in the SBSPRP programmatic plan. Moreover, levee construction along Pond R4 would dovetail with the SBSPRP's Phase 2 design to construct transition zone habitat along this reach of Pond R4 by providing an engineered levee along which the SBSPRP could construct transition zone habitat. Transition zone habitat will allow for restored marsh in Pond R4 to be more resilient to SLR, consistent with the long-term goals of the SBSPRP. Transition zone habitat in this location would create high-tide refugia for California Ridgway's rails and salt marsh harvest mice and thereby help meet the objectives of the *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* (U.S. Fish and Wildlife Service [USFWS] 2013; referred to as *Tidal Marsh Recovery Plan).*

3.2.2 Option 2

Option 2 would raise the existing levee located adjacent to the Bayfront Expressway and Pond S5. This option's alignment would be constrained by the existing drainage channel, which collects water from the Bayfront Expressway and the Menlo Park neighborhood just south of the Bayfront Expressway via the Chrysler Pump Station. This option would not result in the ecological benefits of Option 1 because this option would integrate less directly with the SBSPRP restoration actions by not providing a levee separating tidal marsh restoration actions from the managed Pond S5. It would also result in fewer opportunities to create transition zone habitat.

3.3 Reach 3 – South Bay Salt Pond Ravenswood Pond R3

Reach 3 extends from South Bay Salt Pond R3 to the existing pedestrian/bicycle undercrossing near the Facebook campus. See Figure 5.

3.3.1 Option 1

Reach 3 only consists of one option as there is only one feasible alignment in this area. This option consists of raising the existing levee located adjacent to the Bayfront Expressway. Levee construction along the southern extent of Pond R3 would facilitate management actions compatible with the SBSPRP by improving flood protection for the existing managed pond.

[7] The levee will incorporate in-kind traveled way surfacing and tie into high ground along Marsh Road and the SBSPRP levee to maintain access. Flood protection will not be provided to the wastewater equalization basins.

Moreover, the SBSPRP's tidal habitat emphasis option calls for tidal habitat restoration in Pond R3 and the restoration of transition zone habitat along the landward/southern edge of Pond R3. Therefore, levee construction along the southern extent of Pond R3 would facilitate the SBSPRP's tidal marsh emphasis option. The creation of transition zone habitat along Pond R3 would allow for marsh resiliency to SLR and would help meet the objectives of the *Tidal Marsh Recovery Plan* by creating high-tide refugia for California Ridgway's rails and salt marsh harvest mice, particularly if transition zone habitat were included in Pond R3 restoration design See Typical Section on Figure 15 for a cross section of this option

3.4 Reach 4 – Facebook Campus

Reach 4 extends from the pedestrian/bicycle under crossing near the Facebook campus, traverses around the campus, and ends at the before the Ravenswood Pump Station Outfall. Reach 4 protects the existing Facebook campus by providing flood protection along the perimeter boundaries to the west, north and east. Both options would preserve the existing pedestrian/bicycle undercrossing near Willow Road and Highway 84, and maintain function of the Ravenswood Pump Station. See Figure 6.

3.4.1 Option 1

Option 1 augments the existing levee surrounding the campus with a floodwall. A raised recreational pathway would be constructed along either the inboard or outboard side of the floodwall. See Typical Section B, Option 1 on Figure 17 for a cross section of this option.

Floodwall construction would reduce impacts to existing tidal marsh habitat, but would preclude the incorporation of high quality transition zone habitat into flood-protection for the Facebook campus. This will limit the transition zone habitat quality associated with the SBSPRP's potential tidal restoration of Pond R3.

3.4.2 Option 2

Option 2 would raise the existing levee to provide the required flood protection for the campus. Widening required for the levee raise could occur either bayward into the tidal marsh of Ravenswood Slough (see Typical Section A, Option 2 on Figure 16 for a cross section of this option) or setback, where feasible into the Facebook access road (Hacker Way). Such a setback levee would minimize tidal marsh impacts, but would require reconfiguration of Hacker Way and the adjacent Facebook parking lot. Therefore, a setback into the Facebook access road is very unlikely and was not presented in a cross section diagram.

Although widening the levee bayward in this location may result in a loss of tidal marsh and transition zone habitat, the slough dead-ends at Highway 84, and is not currently high-quality tidal marsh. The current levee is steep but does provide some transitional habitat due to recent revegetation efforts. However, construction of a new levee would allow for the creation of a broader transition zone that meets the goals of the *Tidal Marsh Recovery Plan* and the SBSPRP, should the SBSPRP move forward with tidal restoration of Pond R3. If the SBSPRP were to eventually restore tidal marsh in Pond R3, the levee between Pond R3 and Ravenswood Slough could be removed, restoring a large tidal marsh contiguous with Ravenswood Slough and the SAFER levee. The Facebook levee could then be used to create a large, gradual transition zone that will make the current management of non-tidal pond habitat or future tidal marsh restoration in Pond R3 more resilient to SLR. Therefore, this option provides a greater opportunity to restore transition zone habitat that would be more resilient to SLR compared to the floodwall described in Option 1.

3.5 Reach 5 – Highway 84

Reach 5 extends from the eastern extent of Reach 4 at the Ravenswood Pump Station Outfall, along Highway 84, either following around the PG&E Ravenswood Electrical Substation or in front of the substation entrance with a flood gate. This reach would then cross Highway 84 and then connect at the Union Pacific Railroad (UPRR) right-of-way (ROW). Depending of the selection of the Reach 5 option, Reach 6 may or may not be required. See Figure 7.

The decision of where to cross Highway 84 – and thus the length of it to additionally protect – and whether SAFER replicates the roadway's existing protection or provides substantially greater protection against a 100-year tide plus sea level rise, will be determined based on factors such as cost, marsh impacts and restoration benefits, and the level of involvement by project partners. The crossing locations described in the following paragraphs include: at University Avenue, beneath the Dumbarton Bridge, or at some point in between.

3.5.1 Option 1

Option 1 consists of levees along both sides of Highway 84 and a flood gate that crosses Highway 84. This flood gate would likely only be raised or closed through hydrostatic pressure during tides where there is substantial water on the roadway. This option would also require companion road closure gates at the eastern and western ends of the Dumbarton Bridge and require Caltrans to operate these gates according to a traffic control plan that diverts traffic away from the Highway 84 Bridge (Dumbarton Bridge) when the flood gate is closed. The levees may extend around the PG&E substation. See Typical Section A, Option 1 on Figure 18 for a cross section of this option.

Depending upon the length of levee and/or floodwall, this option could provide a direct collaboration link between the SAFER project and the SBSPRP's restoration of tidal salt marsh habitat. The long-term programmatic plan the SBSPRP calls for tidal habitat restoration in Ponds R1 and R2. The levee along Pond R2 (and potentially around the PG&E substation, should PG&E collaborate with SAFER and SBSPRP) would directly facilitate the SBSPRP's restoration of tidal salt marsh in R1 and R2. Flood protection at least equal to existing protection around Highway 84, its frontage roads, and the PG&E substation is necessary for tidal restoration of R1 and R2. Moreover, transition zone habitat could also be restored on the SAFER levee, further benefiting tidal salt marsh associated species, such as the California Ridgway's rail and harvest mouse, by creating high-tide refugia. Thus, the creation of transition zone habitat along R2 would further the objectives of the *Tidal Marsh Recovery Plan* and allow for marsh resiliency to SLR.

Option 1 would expose SBSPRP's Pond SF2 and the SFPUC Ravenswood Station to more significant coastal flooding.

3.5.2 Option 2

Option 2 consists of levees along both sides of Highway 84, and to limit the extent of these levees, the highway would be raised from the intersection with University Avenue eastward at a maximum 50:1 (horizontal to vertical) slope. The levees would tie into Highway 84 at an elevation required to provide adequate flood protection. A levee would then be constructed along the east side of University Avenue to the UPRR ROW. See Typical Section B, Option 2 on Figure 19 for a cross section of this option.

The levee would provide long-term flood protection to the SAFER project area and a portion of Highway 84. On its own, this alignment would not provide habitat enhancement. Pond SF2 and the SFPUC Ravenswood Station would be more exposed to coastal flooding.

3.5.3 Option 3

Option 3 consists of levees and/or floodwalls along both sides of Highway 84 that tie into the Highway 84 Bridge abutment or cross just beneath the bridge. A flood gate may be required across the entrance to the PG&E substation if it is determined that the PG&E substation will not be protected by levees/floodwalls. The levee/floodwall along the south side of Highway 84 will transition to a levee along the east side of University Ave, extending to the UPRR ROW. See Typical Section B, Option 3 on Figure 19 for a cross section of this option.

This option could provide a direct coordination link between the SAFER project and the SBSPRP's restoration of tidal salt marsh habitat. The long-term programmatic plan the SBSPRP calls for tidal habitat restoration in Ponds R1 and R2. The levee along Pond R2 (and potentially around the PG&E substation, should PG&E collaborate with SAFER and SBSPRP) would directly facilitate the SBSPRP's restoration of tidal salt marsh in R1 and R2. Flood protection around Highway 84, its frontage roads, and the PG&E substation is necessary for tidal restoration of R1 and R2. Moreover, transition zone habitat could also be restored on the SAFER levee, further benefiting tidal salt marsh associated species, such as the California Ridgway's rail and harvest mouse, by creating high-tide refugia. Thus, the creation of transition zone habitat along R2 would further the objectives of the *Tidal Marsh Recovery Plan* and allow for marsh resiliency to SLR.

Pond SF2 and the SFPUC Ravenswood Station would be more exposed to coastal flooding.

3.5.4 Option 4

Option 4 consists of a levee along the north side of Highway 84, crosses the highway either with a floodgate as in Option 1 above or beneath the Dumbarton Bridge as in Option 3 above. From there, it extends across Pond SF2, crosses the UPRR right-of-way, and ties directly into the northern end of Reach 7. Similar to Option 3 and potentially Option 1, this option provides the same direct link to SBSPRP's tidal marsh restoration of R1 and R2; assuming that the PG&E substation is also protected to at least its current level of protection. See Typical Section D, Option 4 on Figure 11 for a cross section of this option.

Although some outboard diked non-tidal marsh would be lost to the east and south of Pond SF2, Option 4 would likely avoid the other options' impacts to habitat at the west and north side of Pond SF2 and improve flood protection to a portion this non-tidal pond managed for shorebird habitat and the Ravenswood Pump Station. Furthermore, a SAFER levee that enables the restoration of Ponds R1 and R2, and especially one that bisects Pond SF2, would open up the South Bay's constriction point at the Dumbarton narrows and thus reduce water surface elevation regionally (the amount of this broader benefit is being studied at this time). Finally, Option 4 would eliminate the need for flood protection in Reach 6. See Typical Sections A, C and D on Figure 18, 20, and 21 for cross sections of this option.

3.5.5 PG&E Ravenswood Electrical Substation

The PG&E Ravenswood Electrical Substation, Figure 7, is located north of Highway 84 near the Dumbarton Bridge between the highway and Pond R2 and is not protected against SAFER's objective of 100 year tide plus FEMA freeboard and SLR. As described in the above options for Reach 5, a collaboration between the SAFER project, SBSPRP and PG&E would result in protection for the substation by a levee constructed around its perimeter that is connected to the parallel levee along Highway 84. An alternate option exists whereby the SAFER project would not install a new levee around the substation that achieves the project's protection objectives and instead install only a floodgate across the PG&E road entrance that connects to the parallel levee along Highway 84. This would reduce SAFER's levee length by over 2,000 feet. Under this option, access to the substation would be maintained through the new floodgate, and the substation would continue to receive the level of protection currently provided by the Ponds rather than protection to SAFER's standard.

3.6 Reach 6 – Northern East Palo Alto

Reach 6 extends from University Avenue to Fordham Street. **Reach 6 was merged into Reach 5** after further development of the Reach 5 options determined that for some of the alternative Reach 6 was not necessary to provide closed flood protection. Cost estimates for this Reach 6 are combined with Reach 5. See Figure 7.

3.6.1 Option 1

Option 1 consists of a new levee beginning at the Reach 6 terminus on University Avenue, continuing down University Avenue with a flood gate at the railroad crossing, then heading east along the SFPUC access road and ending at the northern extent of Reach 7.

3.6.2 Option 2

Option 2 consists of constructing a new levee south of the existing UPRR. This option would require raising a portion of University Avenue to accommodate the new railroad height where the railroad crosses the roadway. A long railroad transition would be required eastward and westward there to eventually match the existing railroad grade at a slope consistent with UPRR standards. See Typical Section D on Figure 21 for cross section of this option.

3.7 Reach 7 - Ravenswood Open Space Preserve

Reach 7 extends from north of Fordham Street to Bay Road, between the Midpeninsula Regional Open Space District's Ravenswood Open Space Preserve and the eastern edge of residential and industrial areas of East Palo Alto. East Palo Alto's Ravenswood / 4 Corners Specific Plan proposed a new loop road connecting University Avenue to Demeter Street which would share a similar alignment as the northern portion of Reach 7's levee (The Planning Center, 2013). Coordination with East Palo Alto will occur during the design phase of Reach 7 to properly bring together plans for the levee and roadway. Additional coordination will need to occur regarding several gravity storm drains that convey water from the East Palo Alto neighborhoods to the Bay. See Figure 8.

3.7.1 Option 1

The Option 1 alignment is located on the western side of 391 Demeter Street, thereby not providing flood protection for this high ground area, but would provide the opportunity to convert the area into transition zone habitat. Creating transition zone habitat would make the adjacent tidal marsh more resilient to SLR and benefit California Ridgway's rail and salt marsh harvest mice by creating high-tide refugia, consistent with the objectives of the *Tidal Marsh Recovery Plan*. The Bay Trail could be re-located from its current alignment to the new levee. Then the former Bay Trail levee could be lowered and breached to provide hydraulic connectivity to the marsh and transition zone to the west. The high ground area is identified as a capped contaminated area and would require additional analysis to verify contaminants did not enter the Bay. See Typical Section on Figure 22 for a cross section of this option.

3.7.2 Option 2

There is an area of existing high ground known as the '391 Demeter Street' parcel. The East Palo Alto Ravenswood / 4 Corners Specific Plan shows that this area is planned for future commercial and industrial development. Option 1 is consistent with the Zoning Plan by providing a new levee on the eastern side of 391 Demeter Street, thereby providing flood protection to the industrial development planned for that area. Transition zone habitat can be incorporated into the levee design that would make adjacent tidal marsh more resilient to SLR and benefit California Ridgway's rail and salt marsh harvest mice by creating high-tide refugia, consistent with the objectives of the Tidal Marsh Recovery Plan. See Typical Section on Figure 22 for a cross section of this option.

3.8 Reach 8 – Laumeister Marsh

Reach 8 extends from Bay Road to Runnymede Street. An overhead power transmission line closely follows this reach and would like require re-location and/or elevation of this line's towers. Both options would require a flood gate across or raising Bay Road to preserve access to the Cooley Landing Park. See Figure 9.

3.8.1 Option 1

Option 1 consists of a new levee, setback from the marsh and into the existing industrial parcels. One drawback of Option 1, compared to Option 2, is that it is situated closer to the former Rhone-Poulenc Superfund site, with increased potential for encountering contaminated soil. See Typical Section Figure 23 for a cross section of this option.

Tidal marsh impacts would be reduced relative to Option 1. The restoration of transition zone habitat adjacent to Laumeister Marsh would significantly enhance California Ridgway's and salt marsh harvest mouse habitat in this area. This option would significantly increase habitat quality and quantity for rails and harvest mice compared to Option 1 due to the greater room for transition zone habitat and reduced impacts to tidal marsh via the levee setback. This would further the objectives of the Tidal Marsh Recovery Plan by creating more high-tide refugia for California Ridgway's rails and salt marsh harvest mice and would significantly increase the adjacent marsh's ability to adapt to SLR.

3.8.2 Option 2

Option 2 consists of a new levee built on the Bay side of the existing levee with restored transition zone habitat along the Baylands Nature Preserve/Laumeister Marsh from Bay Road to Runnymede Street.

The restoration of high-quality transition zone habitat adjacent to the tidal salt marshes of the Laumeister Marsh would significantly enhance California Ridgway's rail and salt marsh harvest mouse habitat in this area by increasing the amount of high-tide refugia for these species, as per the objectives of the Tidal Marsh Recovery Plan. In addition to providing high-tide refugia for rails and harvest mice, a transition zone would allow for improved marsh resiliency to SLR. See Typical Section on Figure 23 for a cross section of this option.

3.9 Reach 9 – Faber Tract

Reach 9 extends from Runnymede Street to the O'Connor Pump Station, which is the terminus of the SFCJPA's Bay to Highway 101 creek project for flood protection, ecosystem restoration and recreation. The issues requiring coordination in this area include Faber marsh habitat and the gravity outfall at the end of Runnymede Street and Runnymede drainage ditch just west of the proposed levee alignment that drains to the O'Connor Pump Station and conveys approximately 40% of East Palo Alto's storm water. See Figure 10.

3.9.1 Option 1

Option 1 consists of a new levee with restored transition zone habitat along the Faber Tract from the Runnymede Street Outfall to the O'Connor Pump Station at Friendship Bridge avoiding the East Palo Alto Sanitary District (EPASD) existing sewer line.

Restoration of transition zone habitat adjacent to Faber Tract would significantly enhance California Ridgway's and salt marsh harvest mouse habitat in this area. The creation of transition zone habitat along the Faber Tract would increase tidal marsh resiliency to SLR and would help meet the objectives of the Tidal Marsh Recovery Plan by creating high-tide refugia for California Ridgway's rails and salt marsh harvest mice. See Typical Section on Figure 24 for a cross section of this option.

3.9.2 Option 2

Option 2 consists of a new levee, setback from the marshes into the Runnymede drainage ditch. Restored transition zone habitat adjacent to the Faber Tract would significantly enhance California Ridgway's rail and salt marsh harvest mouse habitat in this area. This option would increase habitat quality and quantity for rails and harvest mice compared to Option 1. The creation of transitional zone habitat along Faber Tract would allow for greater marsh resiliency to SLR (compared to Option 1) and would help meet the objectives of the Tidal Marsh Recovery Plan by creating high-tide refugia for California Ridgway's rails and salt marsh harvest mice.

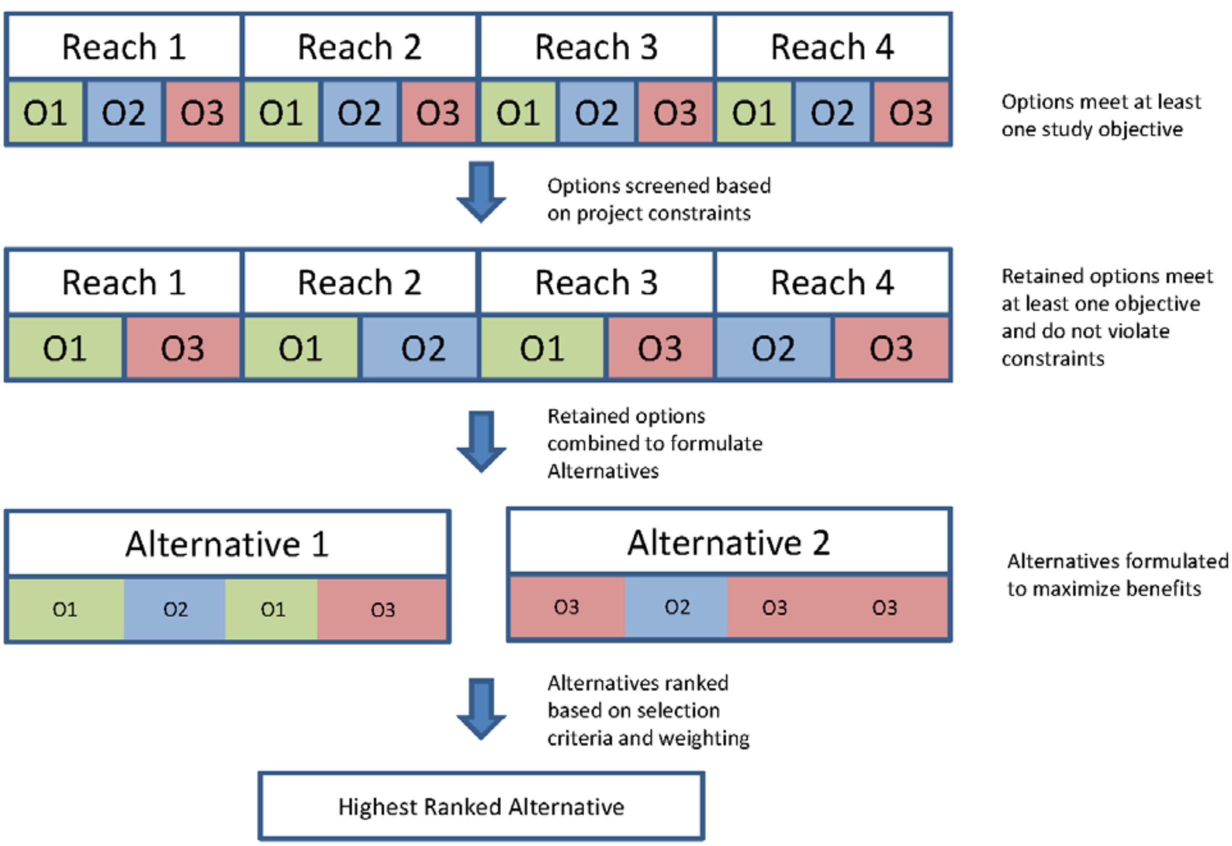
However, this setback would intrude into an existing stormwater drainage channel and storage area for the City of East Palo which is already significantly undersized for the contributing watershed. Any encroachment into the channel and storage area reduces critical stormwater storage and will cause additional flooding elsewhere within the City of East Palo Alto, which is not acceptable. Relocation of the stormwater system is not possible due to the limited available space available or without causing major impacts to residential homeowners. In addition, the sanitary sewer main for East Palo Alto runs along the inboard toe of the existing levee and would need to be relocated. See Typical Section on Figure 24 for a cross section of this option.

4 Evaluation of Options

4.1 Initial Screening and Evaluation of Options

As presented earlier in this study, an option is a stand-alone feature in any individual project reach that will address at least one of the project objectives. An option does not need to satisfy all project objectives, but should not violate project constraints. Alternatives will be formulated by combining retained options so that an alternative addresses all of the project objectives for all of the project reaches (See Flow Chart 1 for an example alternative evaluation process). In Section 5 the alternatives will be evaluated against screening criteria to determine the highest ranking alternative. The reaches and options presented in Section 3 were evaluated to determine which options provide the best relative benefit to the overall objectives of the project, while not violating project constraints. Because of the very large number of option combinations, the strategy was not to develop an exhaustive list of all possible permutations or combinations of all potential options in development of alternatives. Rather, the strategy was to identify options that meet study objectives, constraints, and criteria, and formulate alternatives using a rationale that maximizes the ability to meet overall project objectives and requirements. This section provides a qualitative evaluation of the individual options in each reach, and identifies which are retained for further consideration and which are dropped from further study.

Flow Chart 1. Alternative Formulation and Evaluation Process



4.2 Reach 1

4.2.1 Option 1 (Floodwall at Marsh Road) - *Retained*

Option 1 has a significantly lower cost than option 2 due to a shorter alignment and lack of water control structures. Option 1 is located in an area with numerous existing underground and overhead utilities. Option 1 has no opportunity for recreation or restoration, and will not provide flood protection to all of Menlo Park. It does not intersect with the existing drainage from the Bayfront Canal, but it does intersect the proposed diversion from the Bayfront Canal to Ponds R5 and S5. Redwood City has proposed this diversion to reduce stormwater flooding in Redwood City.

4.2.2 Option 2 (Levee along Bayfront Canal) - *Retained*

This provides recreation by extending the Bay Trail. This option is constrained by two water channels that exist on both sides of the alignment. The Bayfront Canal, the channel on the inboard side, is part of the stormwater drainage system for Redwood City, Atherton, and Menlo Park. Where the levee crosses Bayfront Canal, it would cut off the west-to-east drainage pathway, so an alternative conveyance pathway would need to be identified for the Canal's drainage. A floodwall or combination of levee raise and floodwall may be necessary for this option. A floodwall is not recommended due to negative visual/recreation impacts. A FloodBreak levee topper was ruled out because of the potential cost, required maintenance, and unfamiliarity for the extensive length of this reach. Option 2 allows Redwood City the opportunity to tie their flood protection infrastructure to the SAFER Bay project in the future.

4.3 Reach 2

4.3.1 Option 1 (Levees to Bedwell Bayfront Park) - *Retained*

This appears to be the lower cost option because it is a shorter alignment and set back further from existing infrastructure than Option 2. Option 1 also provides a greater opportunity for restoration because it aligns with the goals of the SBSPRP by providing flood protection to the proposed retention ponds along this reach. The eastern Option 1 levee alignment is also in the location the SBSPRP's proposed transition zone restoration/horizontal levee and could be integrated with this aspect of the SBSPRP.

4.3.2 Option 2 (Levee along Bayfront Expressway) - *Dropped*

This option is constrained by two water channels and would cross potential stormwater diversion from the Bayfront Canal to Ponds R5 and S5. This option was removed from further consideration due to cost and potential habitat impacts caused by the levee fill in the salt pond.

4.4 Reach 3

4.4.1 Option 1 - *Retained*

This is the only option for this reach that is considered viable.

4.5 Reach 4

4.5.1 Option 1 (Floodwall) - *Retained*

This option partially limits the views from the Facebook Campus and the BCDC Shoreline Trail. The floodwall would be approximately 3-4 feet in height on top of the existing levee. A new bike path would be constructed behind the new floodwall, raised in elevation from its current height to retain a view of the bay from the bike path. Option 1 has no opportunity for transition zone restoration, but would reduce impacts to existing tidal marsh habitat in Ravenswood Slough.

4.5.2 Option 2 (Levee) - *Retained*

This option provides opportunity for transition zone habitat restoration, maintains the existing recreation opportunities of the BCDC Shoreline Trail, and can be built at similar cost as Option 1. However, the levee would extend outward from the campus and thus would impact existing tidal marsh habitats. These impacts could be reduced by a slightly steeper outboard levee slope and revegetation of transition zone habitat. Tidal marsh impacts could be further reduced by setting back the levee into the Facebook access road, if feasible.

4.6 Reach 5

4.6.1 Option 1 (Levee along and Flood Gate across Highway 84) - *Retained*

Dependent upon the location of the flood gate crossing, this option could provide protection for Highway 84 and the PG&E substation (should PG&E choose to collaborate with SAFER and the SBSPRP). This option is consistent with the SBSPRP Programmatic EIR/S and would enable tidal restoration of Ponds R1 and R2. There is an existing gas line impacted by this alignment. The section along University Avenue would extend and connect to the Bay Trail. This option would also require companion road closure gates at the eastern and western ends of the Dumbarton Bridge and require Caltrans to operate these gates. The costs of this option will be significantly impacted by the selected location of the flood gate across Highway 84.

4.6.2 Option 2 – (Raise Highway 84) - *Dropped*

Design and construction of this option would require extensive coordination and cooperation with Caltrans to construct while minimizing impacts on Highway 84 traffic. Option 2 was removed from further consideration based on high cost, extensive Caltrans coordination, difficulty of construction, and lack of restoration opportunity. The section along University Avenue would extend and connect to the Bay Trail.

4.6.3 Option 3 (Levee around Highway 84) - *Dropped*

This option provides protection for Highway 84 and the PG&E substation (should PG&E choose to collaborate with SAFER and the SBSPRP). This option is consistent with the SBSPRP Programmatic EIR/S and would enable full tidal restoration of Ponds R1 and R2. An existing gas line, as well as the overall length, would make Option 3 the highest cost option. The section along University Avenue would extend and connect to the Bay Trail. Option 3 was removed from further consideration, as Option 4 provides greater flood risk management opportunities to protect the SFPUC facility and habitat benefits, with less impacts and lower cost.

4.6.4 Option 4 (Levee at Highway 84 and Bay) - *Retained*

This option provides the greatest opportunity for restoration by protecting Highway 84 and potentially the PG&E substation (enabling tidal marsh restoration in Ponds R1 and R2), the eastern portion of Pond SF2 pond, and the SFPUC Ravenswood Station (which may have restoration options due to the new levee). Option 4 would eliminate the need for Reach 6 thereby reducing the overall project cost. Pond SF2 is composed of three pond cells. The levee alignment protects the two landward pond cells, but would allow future tidal marsh restoration of the bayward pond cell. The section along Pond SF2 and SFPUC would provide the best opportunity for recreation by extending and connecting the Bay Trail along the Bay shoreline.

4.7 Reach 6

Reach 6 was merged into Reach 5 after further development of the Reach 5 options.

4.8 Reach 7

4.8.1 Option 1 (Setback Levee) - *Dropped*

This option would reduce tidal marsh impacts and increase transition zone habitat restoration opportunities relative to Option 2. It would convert a property that is planned for commercial development to a combination of transition zone and tidal marsh habitat. However, this option was dropped because of concerns the property may include contaminated fill which would require further treatment. Therefore, it was judged infeasible to restore the site to transition zone habitat.

4.8.2 Option 2 (Outboard Levee) - *Retained*

This option would be less costly because this alignment coincides with the one presented in the East Palo Alto Ravenswood / 4 Corners Specific Plan and minimizes impacts to developable real estate. If a levee is used along the southern portion of this reach, this option would impact the entire tidal marsh area located west of the restored Cooley Landing salt pond by filling this marsh's tidal slough connection to the Bay. A floodwall might be feasible to avoid filling this channel or, if the channel is filled, mitigation might include breaching and/or lowering the current Bay Trail berm to restore tidal connectivity to existing marsh west of the Bay Trail levee.

4.9 Reach 8

4.9.1 Option 1 (Outboard Levee) - *Dropped*

This option reduces tidal marsh impacts and provides a greater opportunity for transition zone habitat restoration. However, this option may have a greater potential for dealing with contaminated soil from the nearby Rhone-Poulenc/Zoecon/Sandoz Superfund site. Additionally, a second hazardous waste facility that underwent closure, the former Romic Environmental Technologies Corporation Facility, has recently developed a conceptual remedial design plan. This option was dropped because there were only minimal differences between the Option 1 and Option 2 levee alignments.

4.9.2 Option 2 (Setback Levee) - *Retained*

This option potentially minimizes impacts to landside real estate. However, this option would have greater tidal marsh impacts to the Laumeister Marsh relative to Option 1. The alignment has since been refined after learning more information regarding the contaminated Rhone-Poulenc/Zoecon/Sandoz soil site. Additional information is needed to determine design impacts near the Romic site. The setback levee is limited to southeast side of the contaminated site.

4.10 Reach 9

4.10.1 Option 1 (Outboard Levee) - *Retained*

This option would be less costly because this alignment avoids an existing drainage channel and sewer main, but has tidal marsh habitat impacts associated with placement of fill in the Faber Tract.

4.10.2 Option 2 (Setback Levee) - *Dropped*

This option minimizes impact to Faber Tract associated with placement of fill and provides greater opportunity for transition zone habitat restoration. However, this option encroaches into the already limited and critical stormwater storage for the City of East Palo Alto and is therefore dropped.

5 Development of Alternatives

Section 5 describes the formulation rationale used to develop the preliminary alternatives from the retained options in each reach, and identifies the preliminary alternatives that will be carried forward for further evaluation and ranking.

5.1 Alternative Formulation Rationale

To efficiently combine retained options into alternatives, the following formulation rationales were developed:

- Cost of Construction – In each reach, the overall cost of each option was qualitatively considered, and the option that had the lower/lowest anticipated overall cost was identified. The "*Low Cost Alternative*" was formulated to combine those options that present the lowest overall cost.
- Wetland Restoration Potential/Wetland Impact Minimization – In each reach, options with higher opportunity for tidal wetland habitat restoration were considered, and the options with the higher/highest potential for restoration (or lowest wetland habitat impact) were identified. The "*Restoration Alternative*" was formulated to combine those options that maximize restoration opportunities.
- Recreation Potential - The San Francisco Bay Trail traverses much of the Project area. In each reach, options with greater opportunity for maintaining or improving the Bay Trail recreation opportunities were considered, and the options with the higher/highest recreation potential were identified. The "*Recreation Alternative*" was formulated to combine those options that maximize recreation opportunities.

All options considered and alternatives formulated meet the objective of reducing flood risk in the study area. The Restoration and Recreation alternatives both satisfy the partnership objectives of the study.

5.2 Summary of Preliminary Alternatives

A summary of the retained options that satisfy the formulation rationale for the lowest cost, greatest opportunity for tidal wetland restoration (or to minimize wetland impact), and the greatest opportunity for recreation are provided in Table 5 below. Overall, Reaches 1, 4 and 5 are the only reaches with more than one retained option for comparison.

In addition to the three alternatives formulated based on the rationale presented in Section 5.1, a fourth alternative was formulated. Following initial review of the Low Cost, Restoration, and Recreation alternatives, the study team determined that there may be an optimized alternative that is a combination of the Low Cost and Recreation/Restoration alternatives. While the Low Cost alternative was found to be much lower in capital cost than the Recreation/Restoration alternatives, a new alternative was developed to provide a lower cost than the Recreation/Restoration alternatives, but provide some level of restoration opportunities that the Low Cost alternative did not. This *Optimized Alternative* was formulated so that the tradeoff between higher project capital cost and restoration opportunities could be evaluated and ranked against the pure Low Cost and Restoration/Recreation alternatives.

Table 5. Summary of Preliminary Alternative Reach Options

	Alternatives	Options by Reach								
	Reach	1	2	3	4	5	6[2]	7	8	9
1	Lowest Cost	Op 1	Op 1	Op 1	Op 1	Op 1	X	Op 2	Op 2	Op 1
2	Restoration[1]	Op 2	Op 1	Op 1	Op 2	Op 4	X	Op 2	Op 2	Op 1
3	Recreation	Op 2	Op 1	Op 1	Op 2	Op 4	X	Op 2	Op 2	Op 1
4	Optimized	Op 1	Op 1	Op 1	Op 2	Op 4	X	Op 2	Op 2	Op 1

X Not applicable

[1] Note that the Restoration Alternative includes construction of transition zone habitat along the bayward side of the new levees in reaches 5, 7, 8, and 9.

[2] Reach 6 was merged into Reach 5 after further development of the Reach 5 options.

6 Evaluation of Alternatives

6.1 Evaluation Methodology

The four alternatives developed in Section 5, lowest cost, greatest opportunity for tidal wetland restoration (or to minimize wetland impact), the greatest opportunity for recreation, and the optimized alternative were compared against Evaluation Factors in a scoring matrix. The scoring matrix utilizes Evaluation Factors and specific qualitative and quantitative Consideration Scoring Metrics and assigned weighting factors to identify the highest ranking alternative.

Evaluation Factors are the primary selection criteria for the preferred plan and were developed based on input from the SFCJPA during the SAFER Bay project kick-off meeting in December of 2013. Each Evaluation Factor was broken down further into Consideration Scoring Metrics. The Consideration Scoring Metrics are the elements that were assessed and scored based on both quantitative and qualitative evaluations. In March of 2016, the SFCJPA and planning team held a workshop to review and refine the Evaluation Factors and Consideration Scoring Metrics, and assign weighting to each. The individual scores for the Consideration Scoring Metrics and applied weighting result in the calculated score at the Evaluation Factor level. The calculated scores for the Evaluation Factors and applied weighting result in the overall alternative ranking.

The final Evaluation Factors, Consideration Scoring Metrics, and percentage weighting factors are summarized in Table 6 below.

Table 6. Feasibility Evaluation Scoring Matrix and Calculation Methodology

Evaluation Factor	Wt %	Consideration Scoring Metric	Wt%
Construction Cost and Constructability	30%	Construction Cost	50%
		Lifecycle Cost	5%
		Construction Schedule	5%
		Construction Considerations and Access	20%
		Real Estate Acquisition	20%
Operation and Maintenance	20%	O&M Cost	30%
		Debris and Sediment Management	30%
		Passive/Active	20%
		Flood Fighting Accessibility	20%
Restoration	30%	Acres of Restored and Enhanced Tidal Marsh Habitat	40%
		Interagency Coordination	20%
		Potential Impacts/Mitigation Requirements	40%
Recreation	20%	Bay Trail	50%
		Interpretive/Viewing	50%

6.2 Consideration Scoring Metrics

The Consideration Scoring Metrics were defined and applied for each reach. A description of each Consideration Scoring Metric is summarized below.

Construction Cost and Constructability Evaluation Factor

- Construction Cost: What reach option is the least expensive and most expensive? (Preliminary costs are summarized in Section 7 and Appendix C.)
- Lifecycle Performance: What is the anticipated lifecycle performance of the proposed flood risk reduction feature? Will the proposed feature need replacement in a set number of years more quickly than another proposed feature?
- Construction Schedule: How quickly will the reach option be able to be constructed? Is there significant coordination, permit and/or environmental challenges that may slow down the construction schedule?
- Construction Considerations: Are there construction considerations that make the reach option difficult to construct? Will construction access be challenging due present water, nearby traffic, limited right-of-way? Is there complex levee/floodwall tie-in overlap?
- Real Estate and Access: Who is impacted by the required real estate and access for the proposed flood risk reduction feature? Does the reach option utilize existing SFCJPA member owned right-of-way or will private real estate need to be acquired? Is access adjacent to the toe of levee or floodwall clear from obstructions or will more right-of-way needs to be acquired?

Operation and Maintenance Evaluation Factor

- Operation and Maintenance (O&M) Performance: Will the flood risk reduction feature require significant management from O&M staff or will it only require periodic inspection? What skill set of staff or agency would be required to perform the O&M?
- Debris and Sediment Management: Will the proposed flood risk reduction feature collect debris or sediment? Will additional clean out maintenance be required?
- Passive/Active: Will the constructed flood risk reduction feature require staff to open/close flood gates during flooding events? A passive system would include a levee or floodwall that does not require any action (other than monitoring) during an event. Active system includes some sort of structure that must be managed during the event in order for it to provide and maintain flood protection.
- Flood Fighting Accessibility: How easy will it be to have O&M staff inspect, access, evaluate and flood fight during a major flood event? Is the landside toe of the levee visible during flooding? Is there a drainage ditch/canal that runs along parallel with the levee hiding the toe? Will there be water on both sides of the levee during an event? Are there homes or other structures right adjacent to the levee? How will vehicles access the levees?

Restoration Evaluation Factor

- Acres of Enhanced Tidal Marsh Habitat: How much potential acres of enhanced tidal marsh habitat are potentially available with the proposed reach option?
- Interagency Coordination: What interagency coordination will be required if this reach option is selected? Will this reach option require additional permits due to interagency oversight? Are there any foreseen challenges with coordination?
- Potential Impacts/Mitigation Requirements: What potential environmental impacts are impacted by the proposed alternative? Wetlands, plants, harvest mouse, clapper rail, etc.? What type and where would we consider mitigation requirements?

Recreation Evaluation Factor

- Bay Trail: Will the Bay Trail access, safety, and/or overall pedestrian experience decrease with the proposed reach option?
- Interpretive Viewing: Will the viewshed be impacted by the proposed reach flood risk reduction feature?

For each Consideration Scoring Metric, a score of 1 through 5 was applied to each reach option considering the qualitative or quantitative benefit that each reach option provides. The scoring matrix was also populated by utilizing feasibility level cost estimates summarized in Section 7 to determine the final scoring and highest ranking alternative. Table 7 illustrates how scores of 1 through 5 were assigned for each Consideration Scoring Metric.

The scoring matrix was normalized utilizing the point score of 1 through 5 and then by applying the weighting factors shown in Table 6. The individual reach calculation tables are included in Appendix B.

Table 7. Feasibility Evaluation Factors and Consideration Scoring Metrics

7 Feasibility Level Cost Estimates

Feasibility level opinions of probable construction cost were developed for each option and summarized for each alternative. Quantities were based on output from Civil3D as well as typical cross sections determined from averaged levee heights and design geometry captured in Figures 11 through 24. Cost opinions assume that the levee is constructed to a full height accounting for SLR. Fill volumes account for settlement which is documented on each typical cross section figure. Gate type structures (road crossing and tide) are assumed to be same average cost for similar type. Total cost for each alternative assuming a 30% contingency is summarized in Table 8. Individual Reach Feasibility Level Cost Estimates and quantity breakdown is included in Appendix C.

Table 8. Feasibility Level Cost Estimates per Alternative

Alternatives[1]		Total Estimated Cost (assuming 30% contingency)
1	Lowest Cost	$89,747,000
2	Restoration	$115,790,000
3	Recreation	$115,790,000
4	Optimized	$104,860,000

1 The cost of constructing transition zones is not included within these provided costs.

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8 Summary of Results and Preliminary Ranking

Each option was ranked 1-5, averaged, and tabulated into Table 9 below. The lowest cost alternative received an average score of 3.1 and is illustrated in Figure 31. The restoration alternative received and average weighted score of 3.0 and is illustrated in Figure 32. The recreation alternative received an average weighted scope of 3.0 and is illustrated in Figure 33. The optimized alternative received an average score of 3.2 and is illustrated in Figure 34. The optimized alternative was the highest ranking alternative.

Table 9. Feasibility Evaluation Factors and Consideration Scoring Metrics

Feasibility Scoring Matrix and Calculation				**Low Cost**	**Restoration**	**Recreation**	**Optimized**
Evaluation Factor	Wt %	Considerations	Wt%	Alt 1	Alt 2	Alt 3	Alt 4
Construction Cost and Constructability	30%	Construction Cost	50%	2.6	2.0	2.0	2.5
		Lifecycle Cost	5%	4.4	3.9	3.9	4.3
		Construction Schedule	5%	3.0	2.8	2.8	2.9
		Construction Considerations and Access	20%	3.6	3.8	3.8	3.6
		Real Estate Acquisition	20%	3.0	3.0	3.0	3.0
				3.0	2.7	2.7	2.9
Operation and Maintenance	20%	O&M Cost	30%	4.4	3.9	3.9	4.3
		Debris and Sediment Management	30%	4.3	3.8	3.8	4.1
		Passive/Active	20%	3.3	3.3	3.3	3.3
		Flood Fighting Accessibility	20%	3.1	2.6	2.6	2.9
				3.9	3.5	3.5	3.7
Restoration	30%	Acres of Enhanced Tidal Marsh Habitat	40%	1.5	1.8	1.8	1.8
		Interagency Coordination	20%	3.0	3.4	3.4	3.1
		Potential Impacts/Mitigation Requirements	40%	4.1	4.5	4.5	4.6
				2.9	3.2	3.2	3.2
Recreation	20%	Bay Trail	50%	2.3	2.3	2.3	2.4
		Interpretive/Viewing	50%	3.3	3.6	3.6	3.4
				2.8	2.9	2.9	2.9
Total Alternative Score	**100%**			**3.1**	**3.0**	**3.0**	**3.2**
		Overall Ranking Order:		**2**	**3**	**3**	**1**

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Figures

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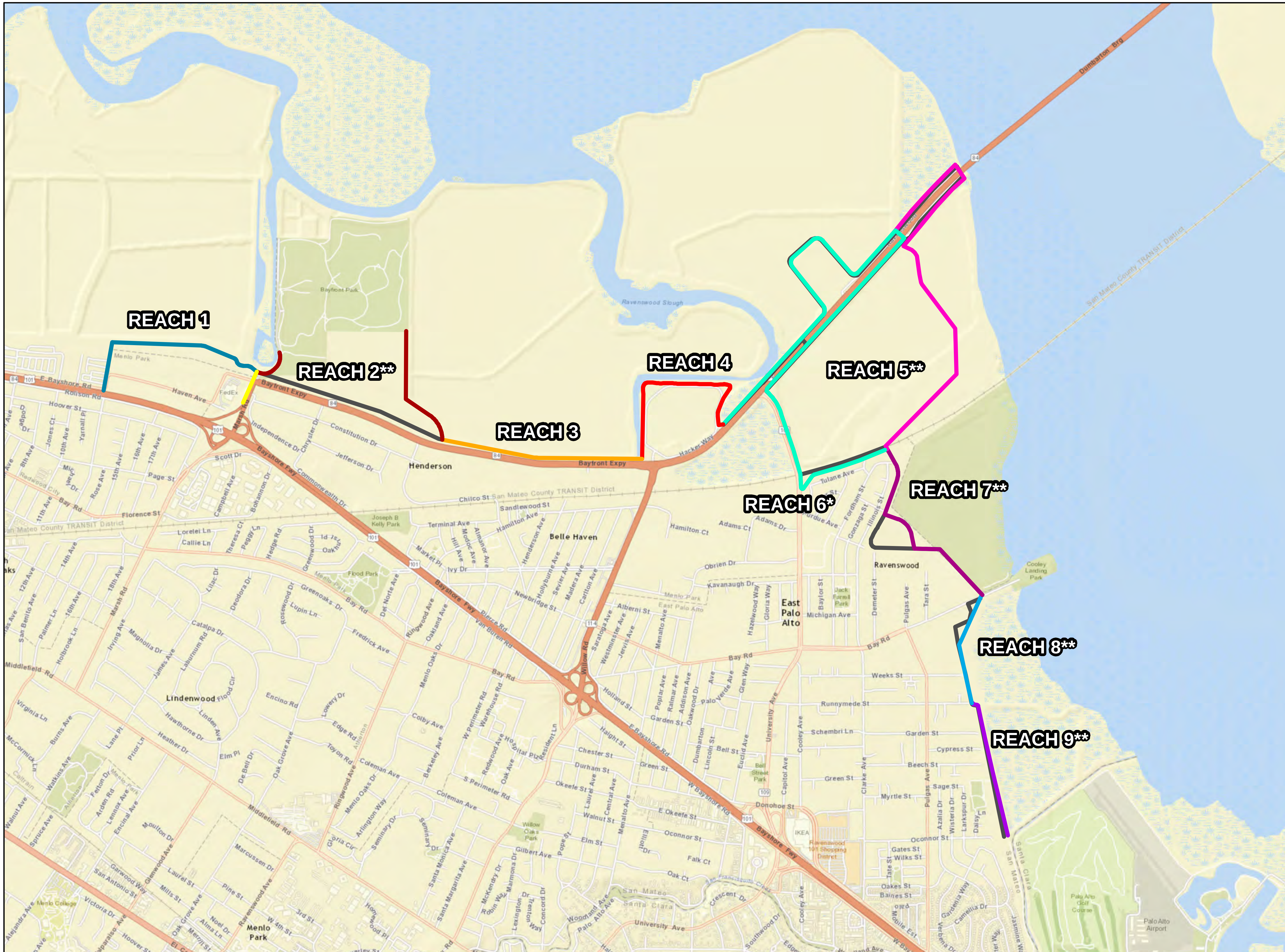


- Reach 1, Option 1
- Reach 1, Option 2
- Reach 2, Option 1
- Reach 2, Option 2
- Reach 3, Option 1
- Reach 4, Option 1 & 2
- Reach 5, Option 1
- Reach 5, Option 2
- Reach 5, Option 3
- Reach 5, Option 4
- Reach 6, Option 1
- Reach 6, Option 2
- Reach 7, Option 1
- Reach 7, Option 2
- Reach 8, Option 1
- Reach 8, Option 2
- Reach 9, Option 1
- Reach 9, Option 2

* Reach 6 has been merged into Reach 5
** Dropped Options shown in Grey

N

0 2,000 Feet

1 inch = 2,000 feet

SAFER Bay

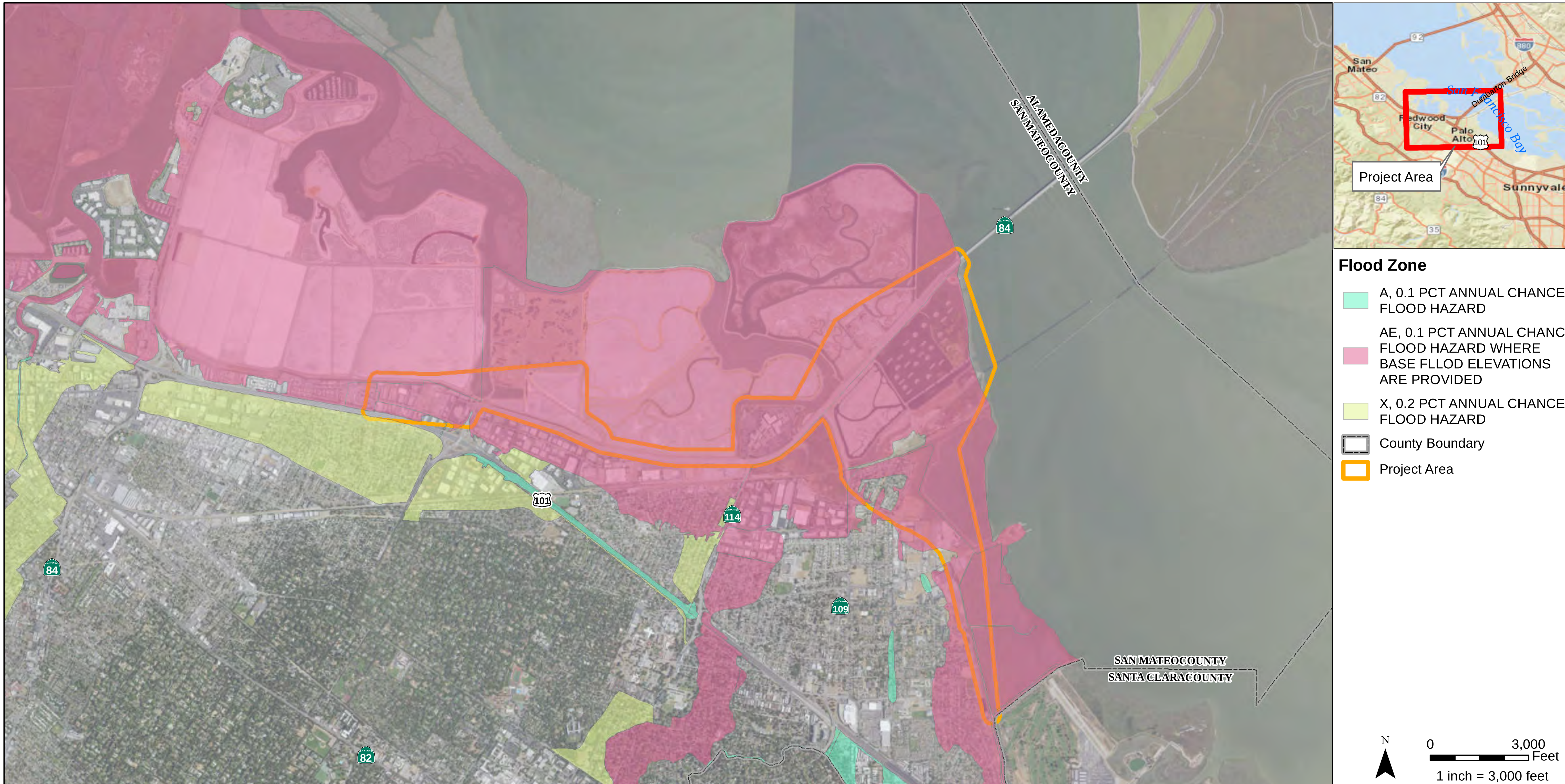
Feasibility Report Project Reaches and Options

Figure 1

Data Sources: Base Map-ESRI Maps and Data 2014; All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

SEPT 2016



SAFER Bay Levee Project

PRELIMENARY FEMA FLOOD INSURANCE RATE MAP FLOODPLAINS (8/13/15)

Figure 2

Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

JUNE 2016

SAN MATEO COUNTY
Inundation Mapping

MHHW + 36” SEA LEVEL RISE

SLR + STORM SURGE SCENARIOS LISTED BELOW COULD BE APPROXIMATED BY THE INUNDATION SHOWN ON THIS MAP.

- 0” SLR + 50-YEAR STORM SURGE
- 6” SLR + 25-YEAR STORM SURGE
- 12” SLR + 10-YEAR STORM SURGE
- 18” SLR + 2-YEAR STORM SURGE
- 24” SLR + 1-YEAR STORM SURGE

Shoreline Overtopping Potential

Depth in Feet

- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

No Overtopping

Sea Level Rise Inundation

Depth in Feet

- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+

Disconnected Areas > 1 Acre

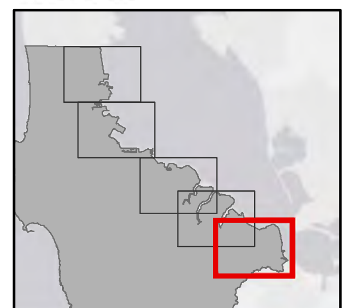
0 0.2 0.4 0.6 0.8 Miles

0 1,000 2,000 3,000 4,000 Feet

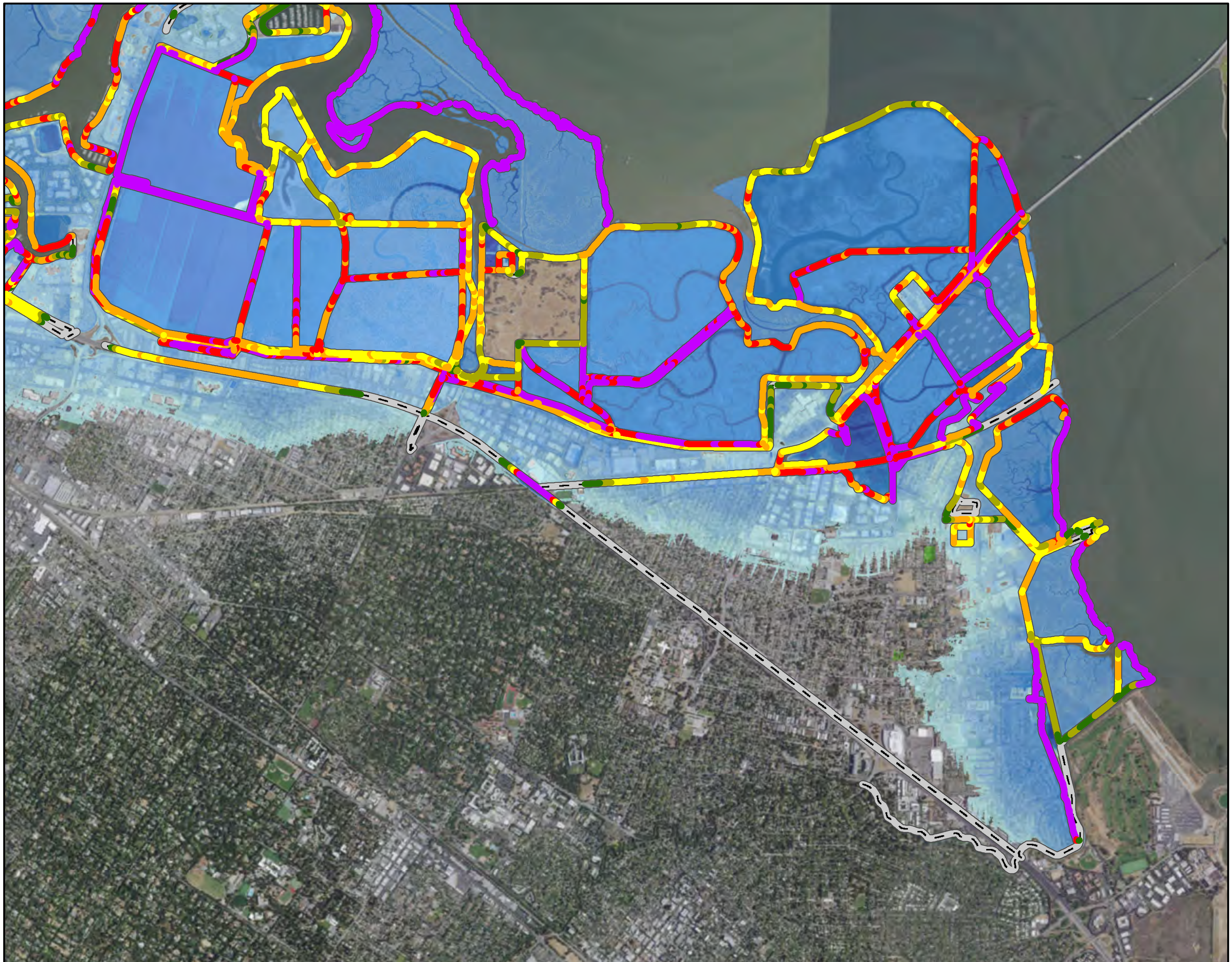
N

Projection:
Universal Transverse Mercator NAD83 Zone 10N

AECOM May, 2016



The inundation maps and the associated analyses provide a regional-scale illustration of inundation and coastal flooding due to specific sea level rise and storm surge scenarios, and are intended to improve sea level rise awareness and preparedness. The maps are not detailed to the parcel-scale and should not be used for navigation, permitting, regulatory, or other legal uses. Flooding due to sea level rise and storm surges is possible in areas outside of those predicted in these maps, and the maps do not guarantee the safety of an individual or structure. Nor do the maps model flooding from other sources, such as riverine or surface water flooding from rainfall-runoff events. The contributors and sponsors of this product do not assume liability for any injury, death, property damage, or other effects of flooding. The maps relied on a 1-meter digital elevation model created from LiDAR data collected in 2010 and additional survey data (where available). Although care was taken to capture all relevant topographic features and coastal structures that may impact coastal inundation, it is possible that structures may not be fully represented, especially those that are narrower than the 1-meter horizontal map scale. The maps are based on model outputs and do not account for all of the complex and dynamic San Francisco Bay processes or future conditions such as erosion, subsidence, future construction or shoreline protection upgrades, or other changes to San Francisco Bay or the region that may occur in response to sea level rise. More context about the maps and analyses, including a description of the data and methods used, are documented in the Sea Level Rise and Overtopping Analysis for San Mateo County's Bayshore Report (May 2016).



SAN MATEO COUNTY
Inundation Mapping

MHHW + 78" WATER LEVEL

SLR + STORM SURGE SCENARIOS LISTED BELOW COULD BE APPROXIMATED BY THE INUNDATION SHOWN ON THIS MAP.

36"SLR + 100-YEAR STORM SURGE
42"SLR + 50-YEAR STORM SURGE
48"SLR + 25-YEAR STORM SURGE
54"SLR + 10-YEAR STORM SURGE
60"SLR + 2-YEAR STORM SURGE
66"SLR + 1-YEAR STORM SURGE

Shoreline Overtopping Potential

Depth in Feet

- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5
- No Overtopping

Sea Level Rise Inundation

Depth in Feet

- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+
- Disconnected Areas > 1 Acre

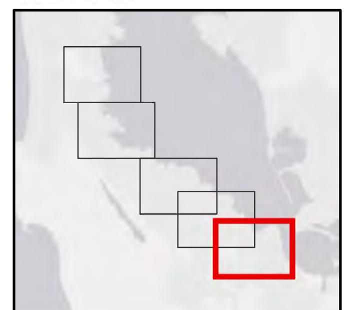
0 0.2 0.4 0.6 0.8 Miles

0 1,000 2,000 3,000 4,000 Feet

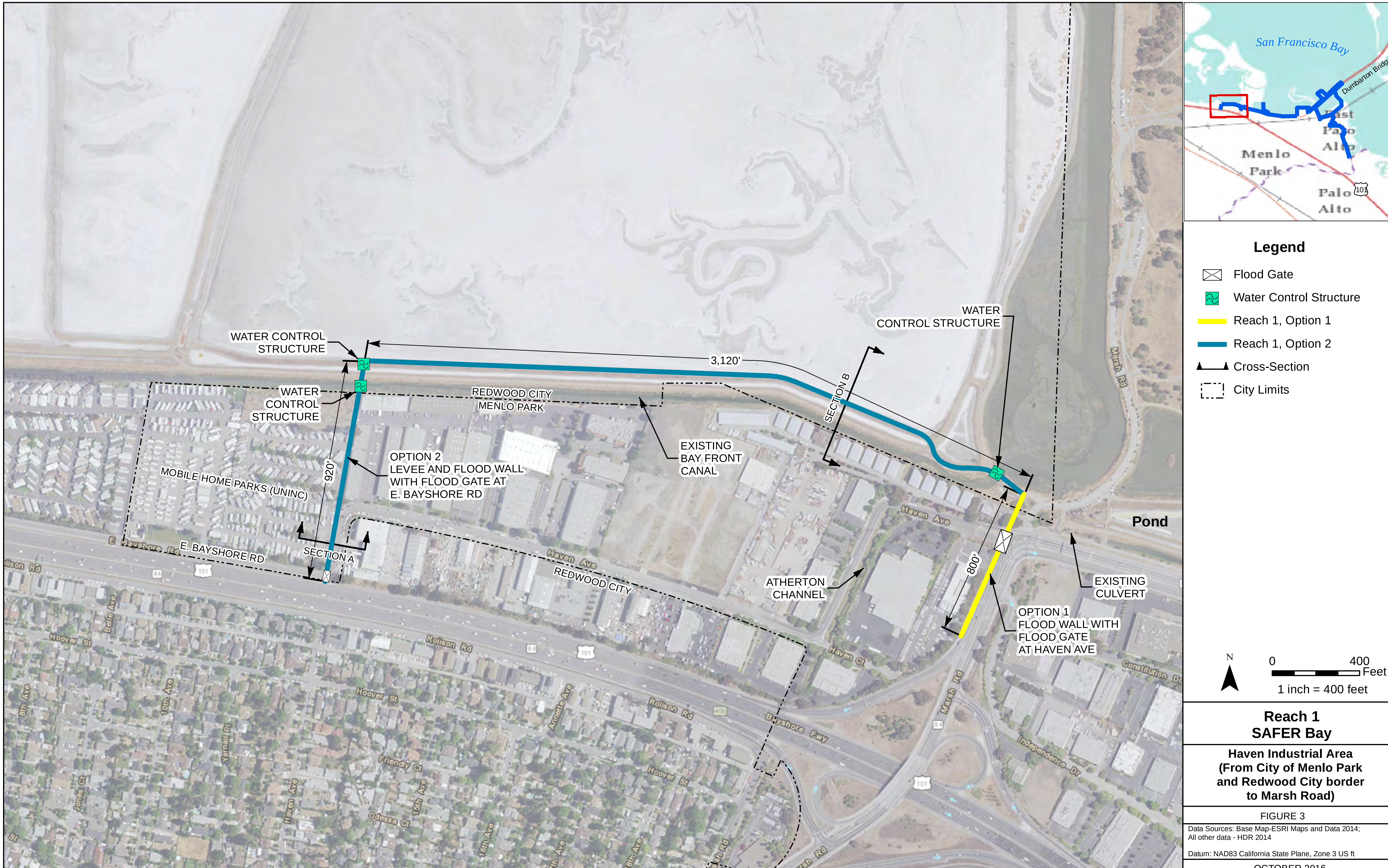
N

Projection:
Universal Transverse Mercator NAD83 Zone 10N

AECOM May, 2016



The inundation maps and the associated analyses provide a regional-scale illustration of inundation and coastal flooding due to specific sea level rise and storm surge scenarios, and are intended to improve sea level rise awareness and preparedness. The maps are not detailed to the parcel-scale and should not be used for navigation, permitting, regulatory, or other legal uses. Flooding due to sea level rise and storm surges is possible in areas outside of those predicted in these maps, and the maps do not guarantee the safety of an individual or structure. Nor do the maps model flooding from other sources, such as riverine or surface water flooding from rainfall-runoff events. The contributors and sponsors of this product do not assume liability for any injury, death, property damage, or other effects of flooding. The maps relied on a 1-meter digital elevation model created from LiDAR data collected in 2010 and additional survey data (where available). Although care was taken to capture all relevant topographic features and coastal structures that may impact coastal inundation, it is possible that structures may not be fully represented, especially those that are narrower than the 1-meter horizontal map scale. The maps are based on model outputs and do not account for all of the complex and dynamic San Francisco Bay processes or future conditions such as erosion, subsidence, future construction or shoreline protection upgrades, or other changes to San Francisco Bay or the region that may occur in response to sea level rise. More context about the maps and analyses, including a description of the data and methods used, are documented in the Sea Level Rise and Overtopping Analysis for San Mateo County's Bayshore Report (May 2016).



Legend

- Flood Gate
- Water Control Structure
- Reach 1, Option 1
- Reach 1, Option 2
- Cross-Section
- City Limits

N

0 400 Feet

1 inch = 400 feet

Reach 1
SAFER Bay

Haven Industrial Area (From City of Menlo Park and Redwood City border to Marsh Road)

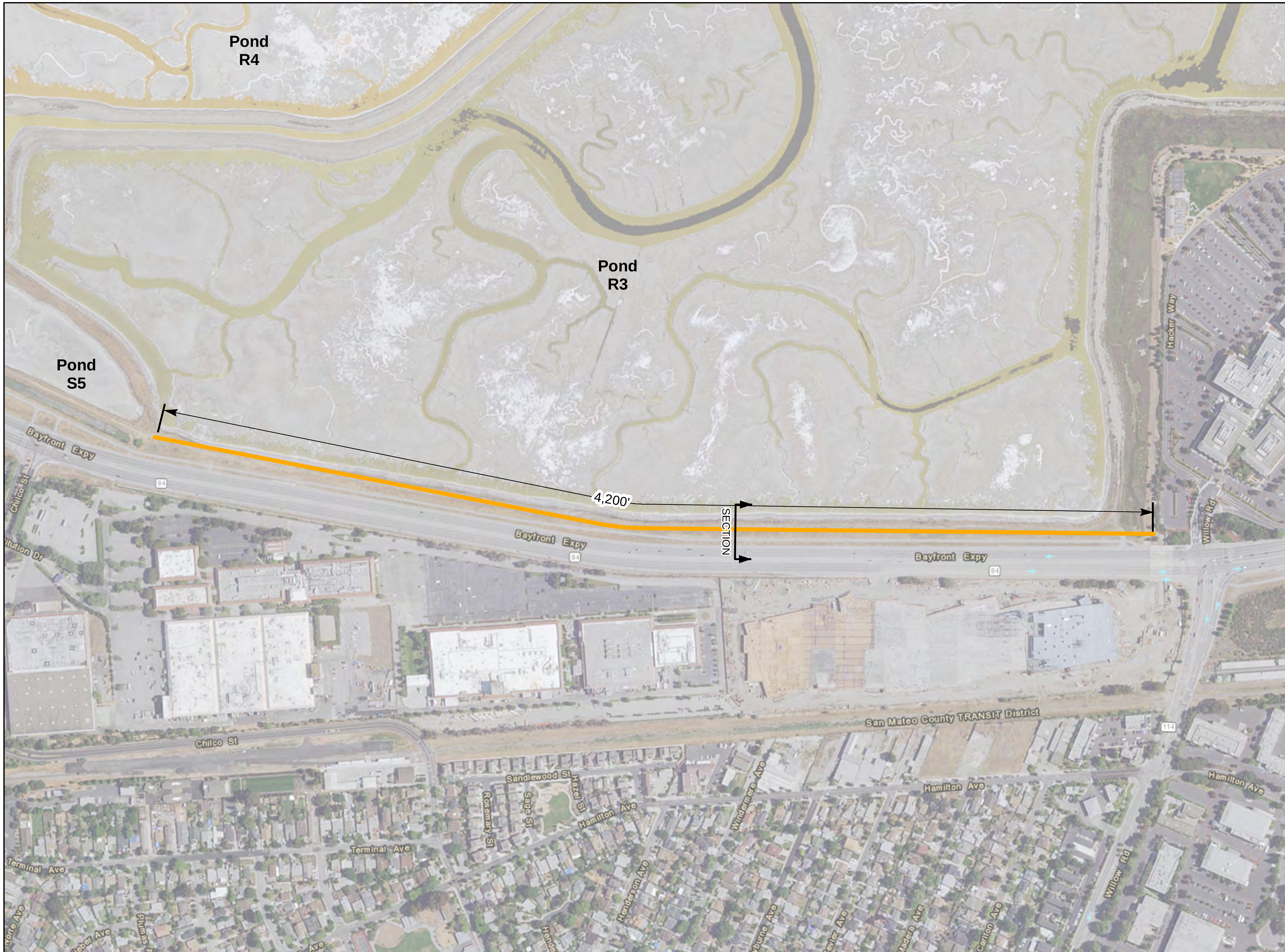
FIGURE 3

Data Sources: Base Map-ESRI Maps and Data 2014; All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

OCTOBER 2016

Bedwell Bayfront Park
EXISTING GATE STRUCTURE
WATER CONTROL STRUCTURE
SECTION A
800'
EXISTING GATE STRUCTURE
Pond
EXISTING CULVERT
JURISDICTIONAL WETLANDS
Pond R5
Pond S5
WATER CONTROL STRUCTURE
Pond R4
1,400'
SECTION B
WATER CONTROL STRUCTURE
Pond R3
1,160'
CHRYSLER PUMP STATION
EXISTING BAY FRONT CANAL
Marsh Rd
Haven Ave
Bayfront Expy
Constitution Dr
Independence Dr
Chrysler Dr
Scott Dr
Bayshore Fwy
Jefferson Dr
Chilco St
San Francisco Bay
Dumbarton Bridge
East Palo Alto
Menlo Park
Palo Alto
Legend
Water Control Structure
Reach 2, Option 1
Reach 2, Option 2 (dropped)
Cross-Section
City Limits
N
0
400
Feet
1 inch = 400 feet
Reach 2
SAFER Bay
Bedwell Bayfront Park
(From Marsh Road
to SBSP Pond R3)
FIGURE 4
Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014
Datum: NAD83 California State Plane, Zone 3 US ft
OCTOBER 2016



Legend

- Reach 3, Option 1
- Cross-Section

N

0 400 Feet

1 inch = 400 feet

Reach 3
SAFER Bay

SBSP Ravenswood Pond R3 (From SBSP R3 to Facebook Campus)

FIGURE 5

Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

OCTOBER 2016

Legend

Reach 4, Option 1 and 2

Cross-Section

N

0 200 Feet

1 inch = 200 feet

Reach 4
SAFER Bay

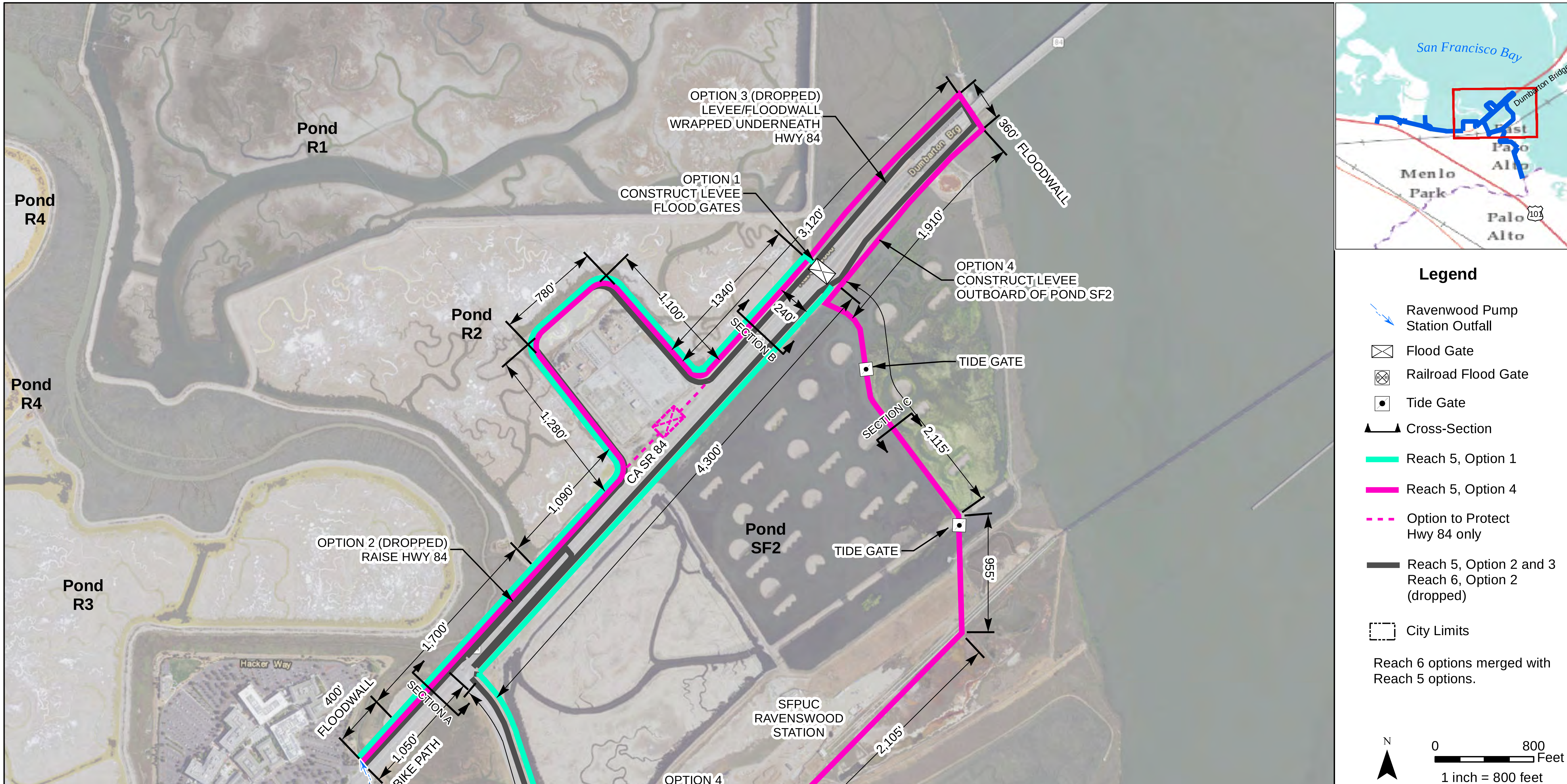
Facebook Campus
(From west edge of Facebook Campus to Ravenswood Pump Station Outfall)

FIGURE 6

Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

OCTOBER 2016



Reach 5
SAFER Bay

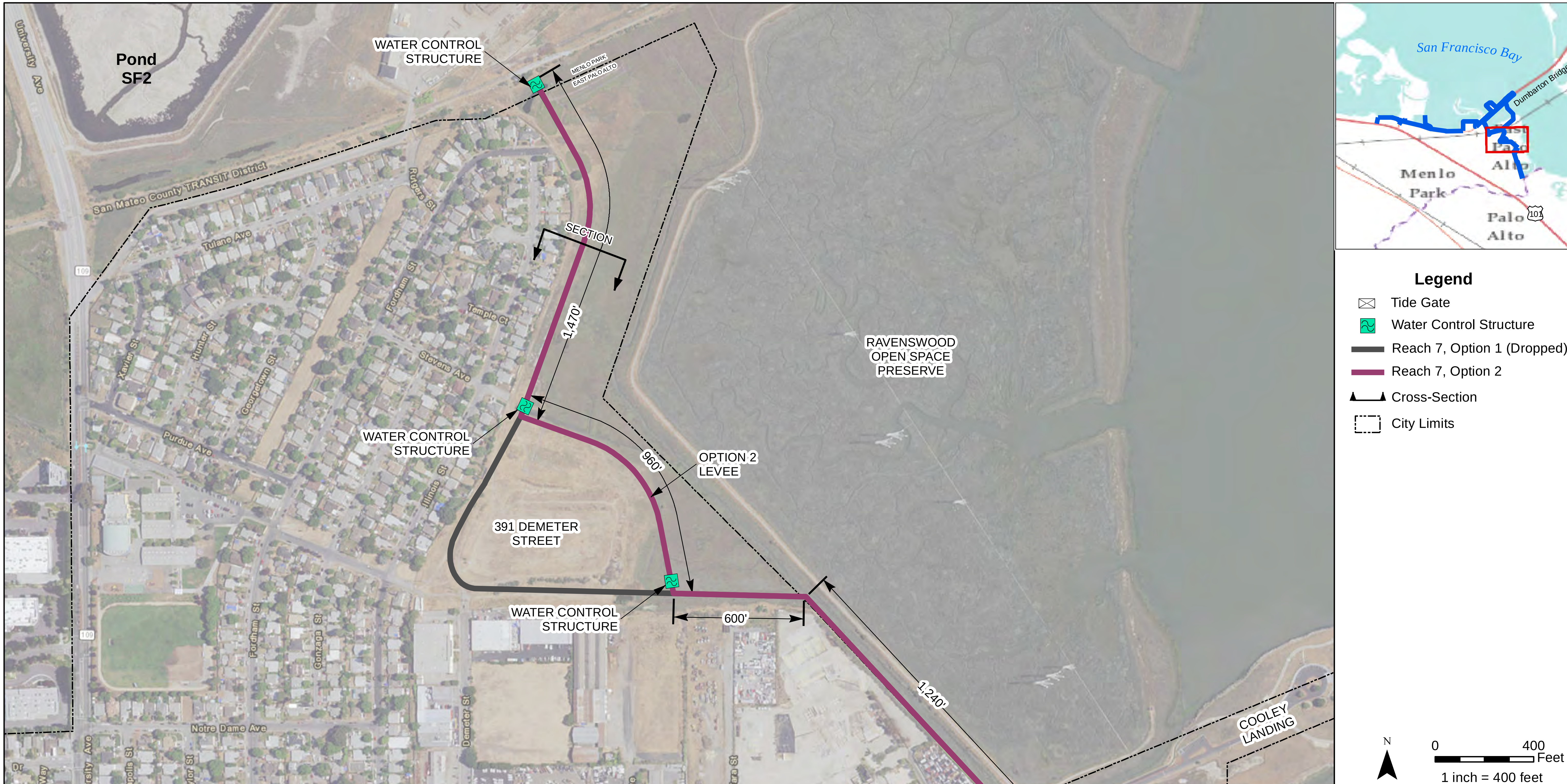
Highway 84
(From Ravenswood Pump Station Outfall to Railroad Crossing)

FIGURE 7

Data Sources: Base Map-ESRI Maps and Data 2014; All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

OCTOBER 2016



Reach 7
SAFER Bay

Existing Tidal Marshes (From end of Fordham Street to Bay Road)

FIGURE 8

Data Sources: Base Map-ESRI Maps and Data 2014; All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

OCTOBER 2016

Legend

- Reach 8, Option 1 (Dropped)
- Reach 8, Option 2
- Cross-Section
- City Limits

N

0 400 Feet

1 inch = 400 feet

Reach 8
SAFER Bay

Laumeister Marsh
(From Bay Road
to Runnymede St)

FIGURE 9

Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

OCTOBER 2016

Reach 9
SAFER Bay

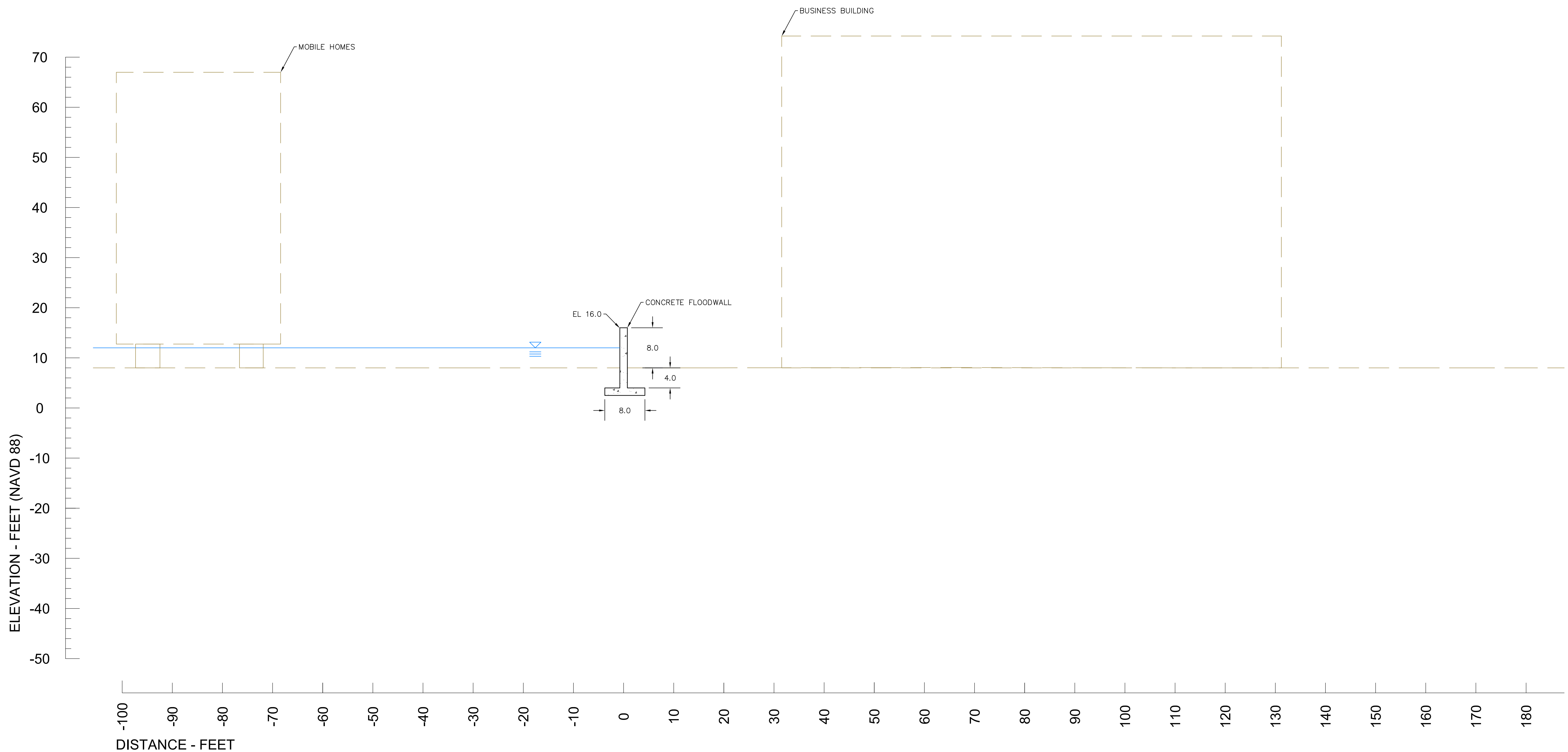
Faber Tract
(From Runnymede St
to O'Connor St)

FIGURE 10

Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

OCTOBER 2016



NOTES:
1. CROSS SECTION LOOKS EASTWARD
2. ALL MEASUREMENTS ARE IN FEET

20 0 20 40
SCALE IN FEET

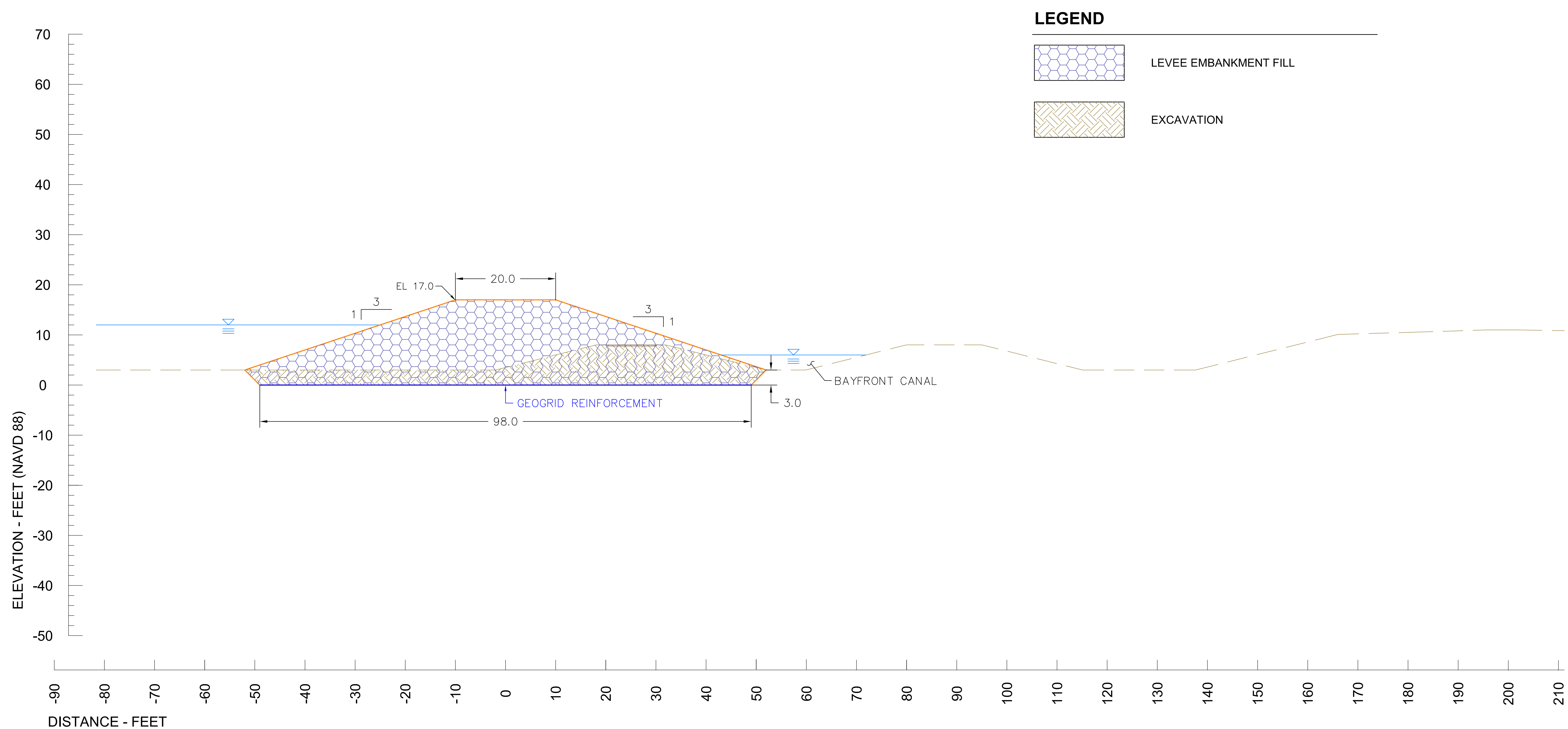
ANALYSIS CROSS-SECTION
REACH 1 - SECTION A

SAFER BAY PROJECT

CALIFORNIA

Date
OCT 2016

Figure
11



NOTES:
1. CROSS SECTION LOOKS EASTWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 1 FT OF POST-CONSTRUTION SETTLEMENT

SCALE IN FEET

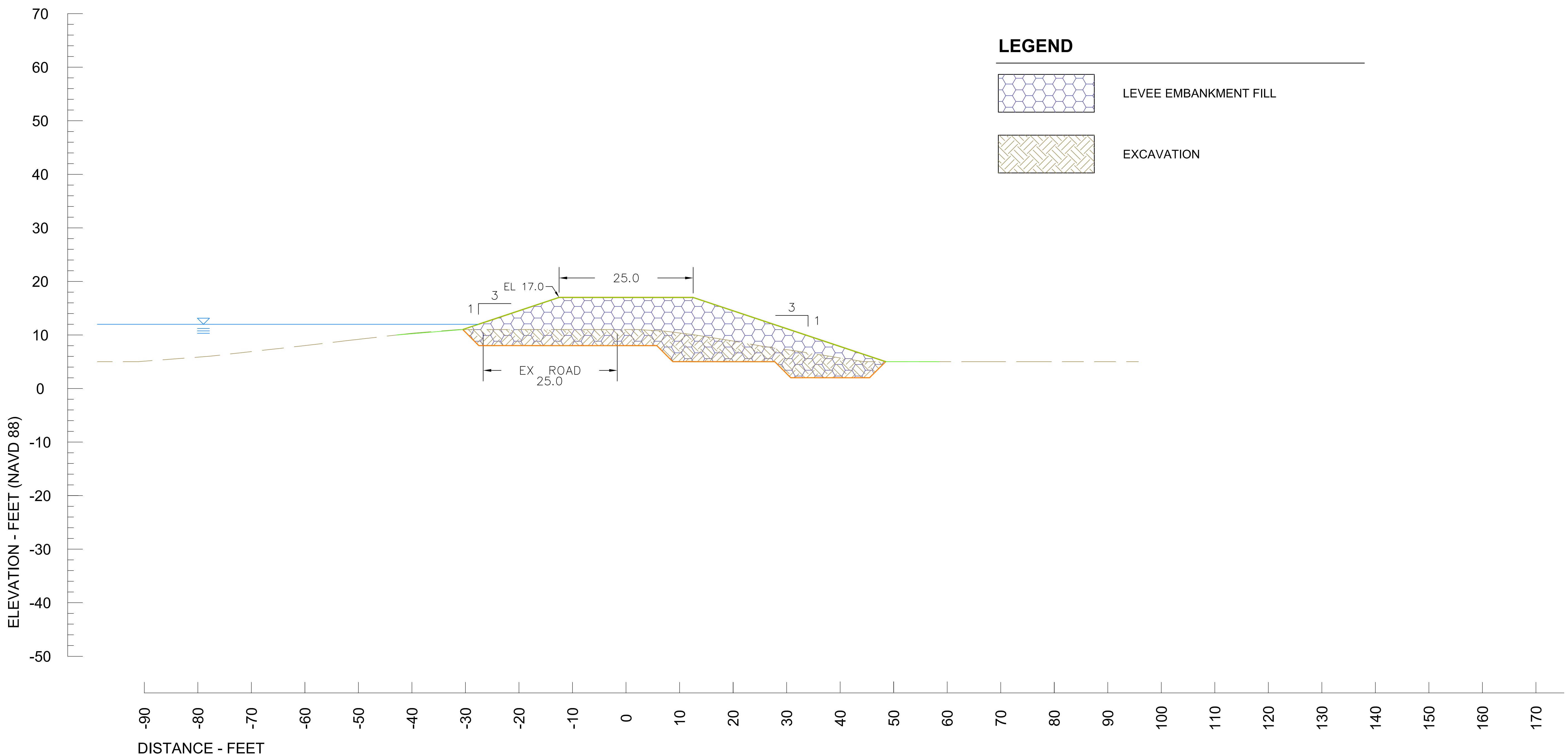
ANALYSIS CROSS-SECTION
REACH 1 - SECTION B

SAFER BAY PROJECT

CALIFORNIA

Date: OCT 2016

Figure: 12



NOTES:
1. CROSS SECTION LOOKS NORTHWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 1 FT OF POST-CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

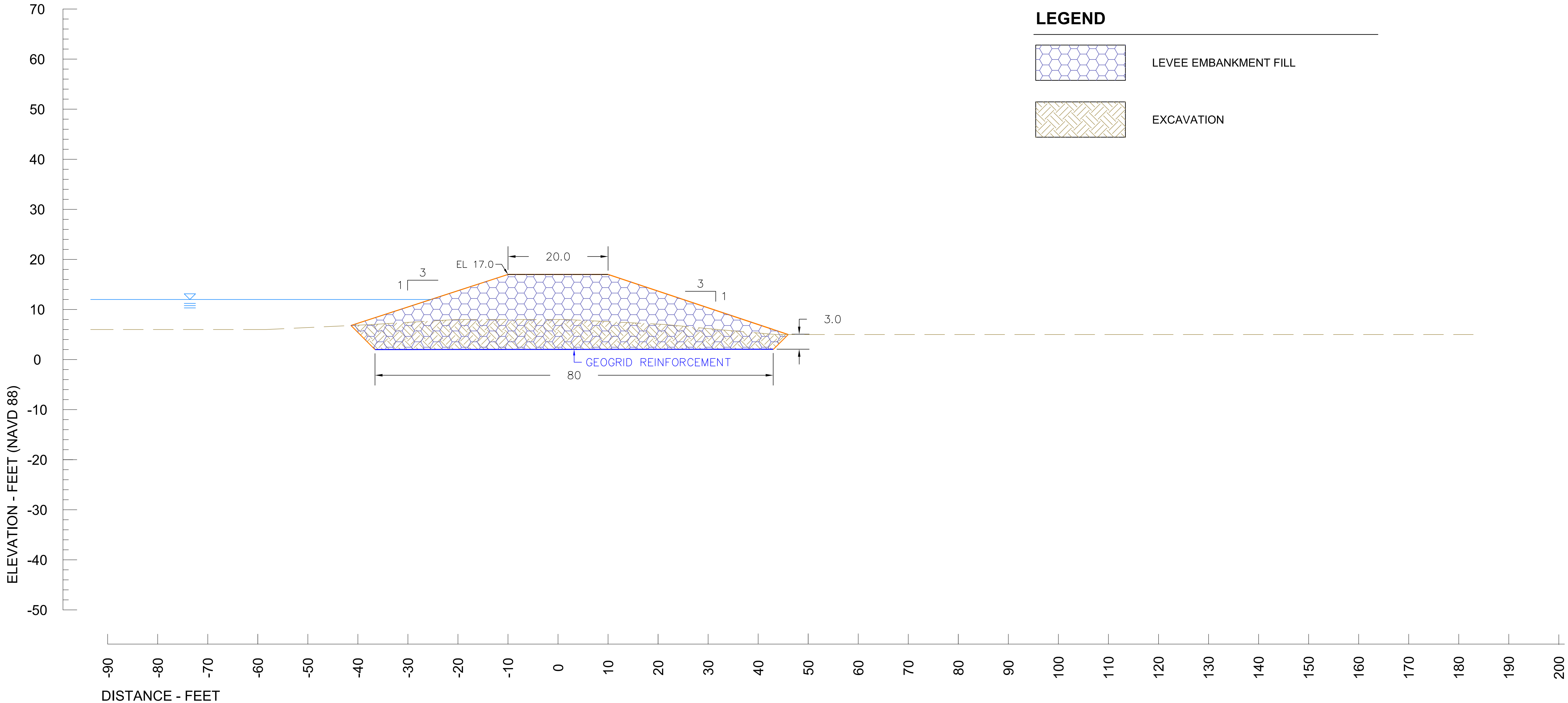
ANALYSIS CROSS-SECTION
REACH 2 - SECTION A

SAFER BAY PROJECT

CALIFORNIA

Date
OCT 2016

Figure
13



NOTES:
1. CROSS SECTION LOOKS NORTHWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 1 FT OF POST-CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

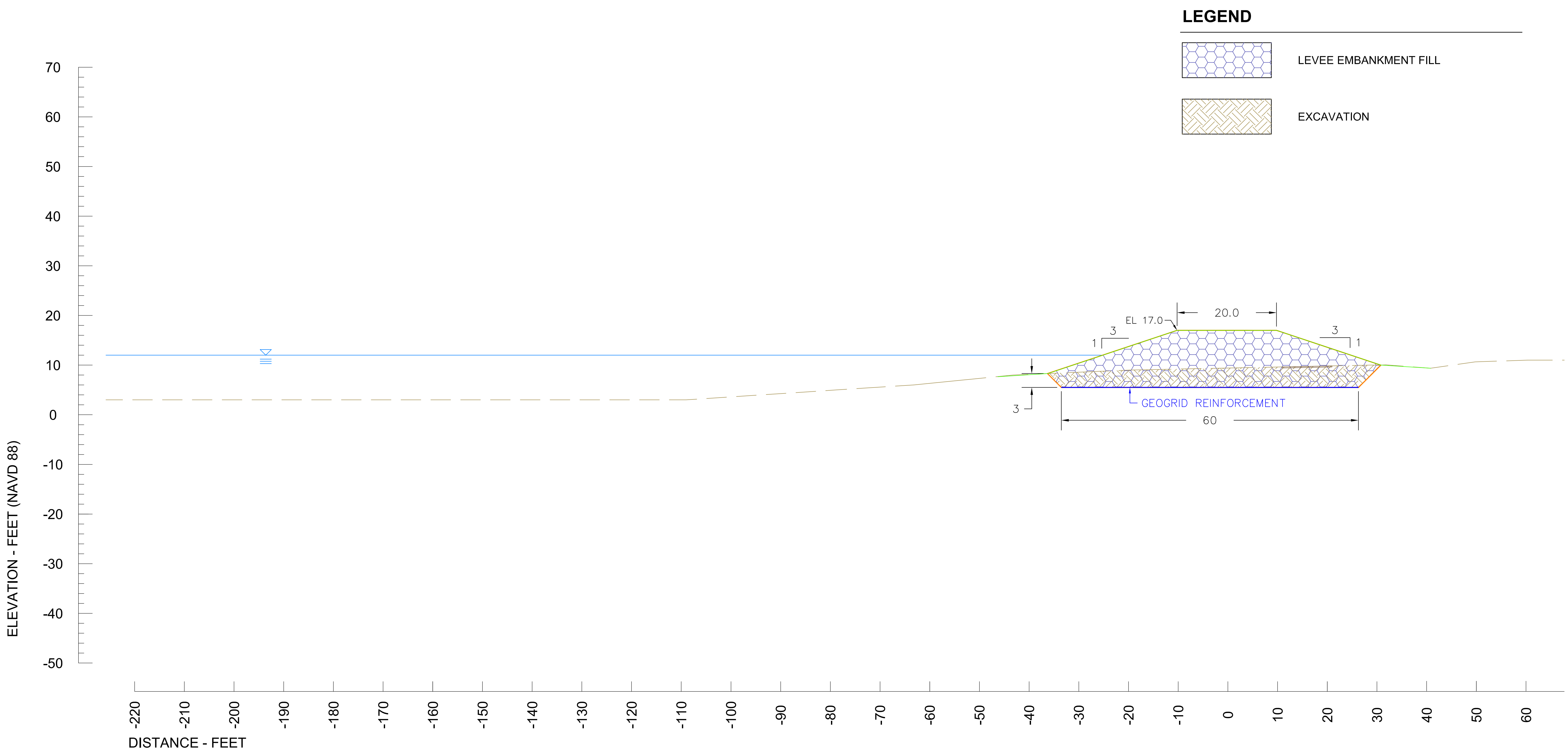
ANALYSIS CROSS-SECTION
REACH 2 - SECTION B

SAFER BAY PROJECT

CALIFORNIA

Date
OCT 2016

Figure
14



NOTES:
1. CROSS SECTION LOOKS EASTWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 1 FT OF POST CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

HDR

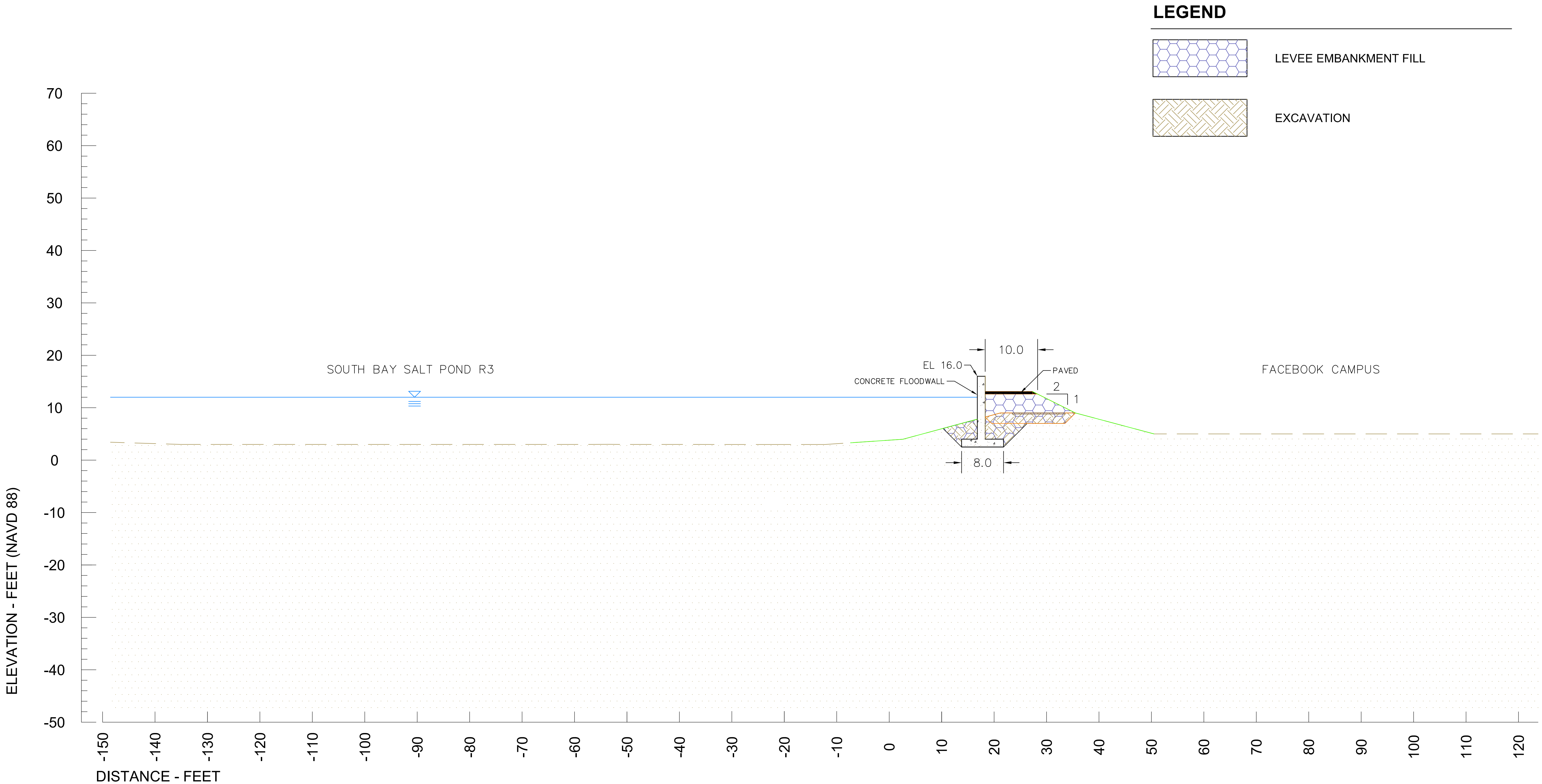
ANALYSIS CROSS-SECTION
REACH 3 - OPTION 1

SAFER BAY PROJECT

CALIFORNIA

Date
OCT 2016

Figure
15



NOTES:
1. CROSS SECTION LOOKS NORTHWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 1 FT OF POST CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

HDR

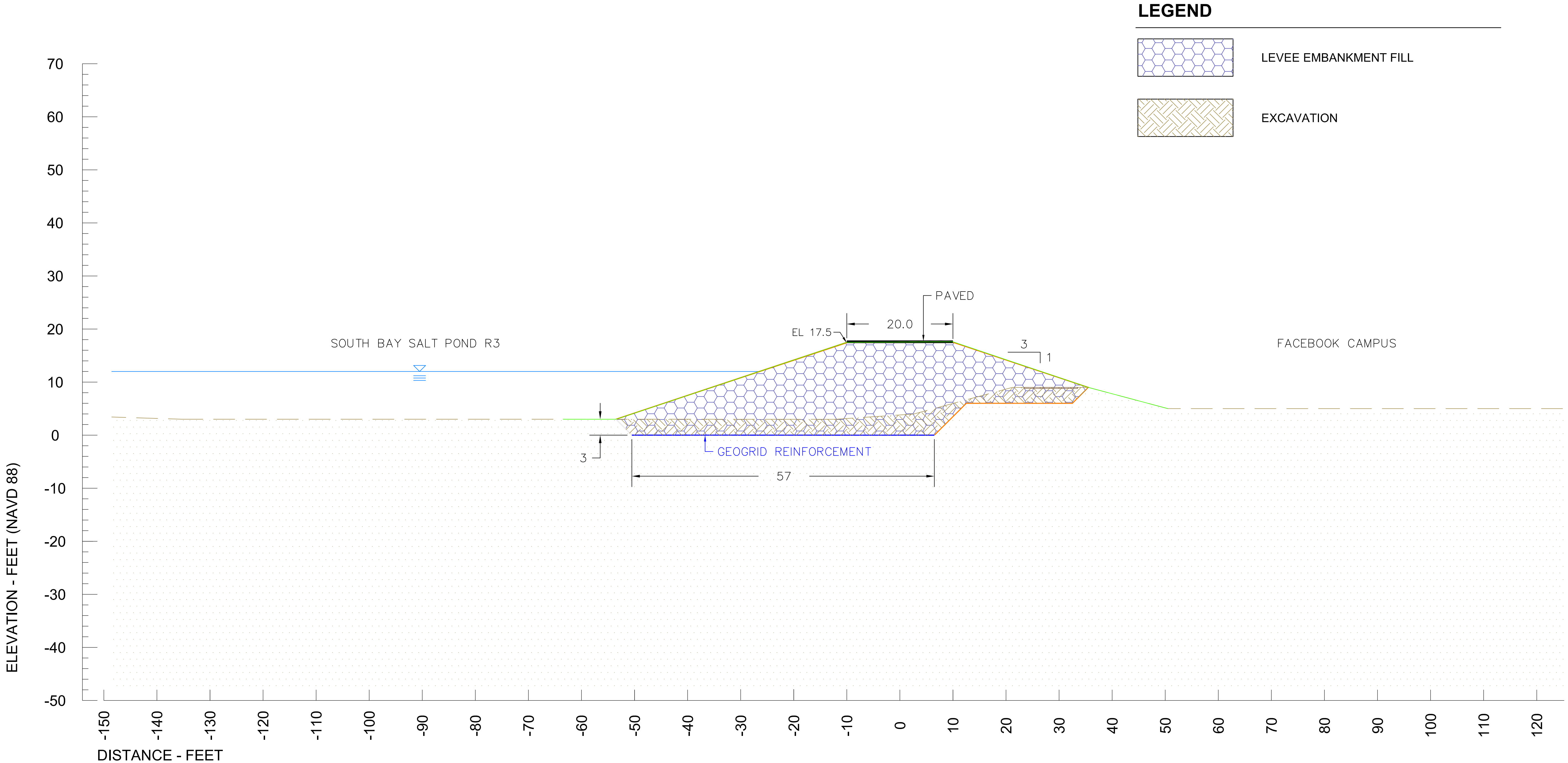
ANALYSIS CROSS-SECTION
REACH 4 - OPTION 1

SAFER BAY PROJECT

CALIFORNIA

Date
OCT 2016

Figure
16



NOTES:
1. CROSS SECTION LOOKS NORTHWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 1.5 FT OF POST CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

HDR

ANALYSIS CROSS-SECTION
REACH 4 - OPTION 2

SAFER BAY PROJECT

CALIFORNIA

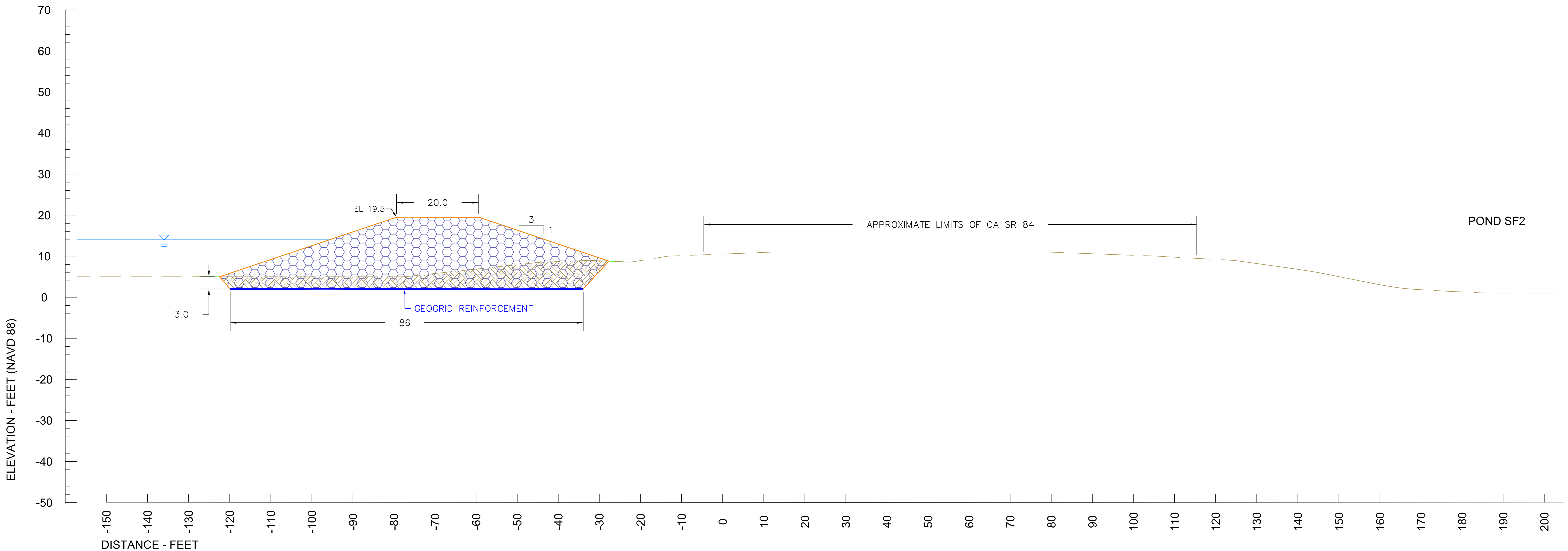
Date
OCT 2016

Figure
17

LEGEND

LEVEE EMBANKMENT FILL

EXCAVATION



NOTES:
1. CROSS SECTION LOOKS EASTWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 2.5 FT OF POST-CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

ANALYSIS CROSS-SECTION
REACH 5 - SECTION A

SAFER BAY PROJECT

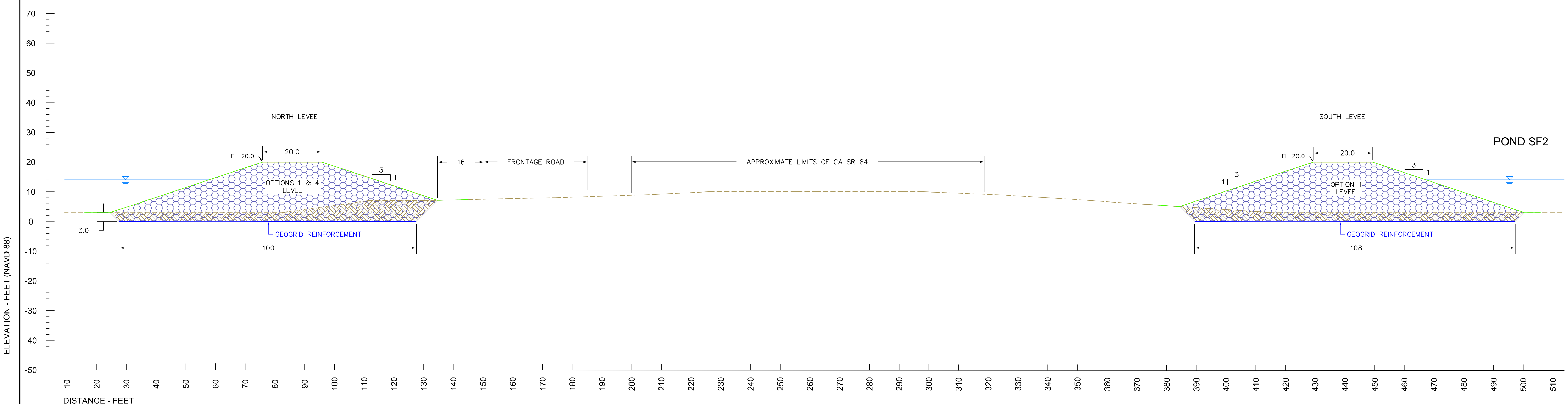
CALIFORNIA

Date
OCT 2016

Figure
18

LEGEND

- LEVEE EMBANKMENT FILL
- EXCAVATION



NOTES:
1. CROSS SECTION LOOKS EASTWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 3 FT OF POST-CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

HDR

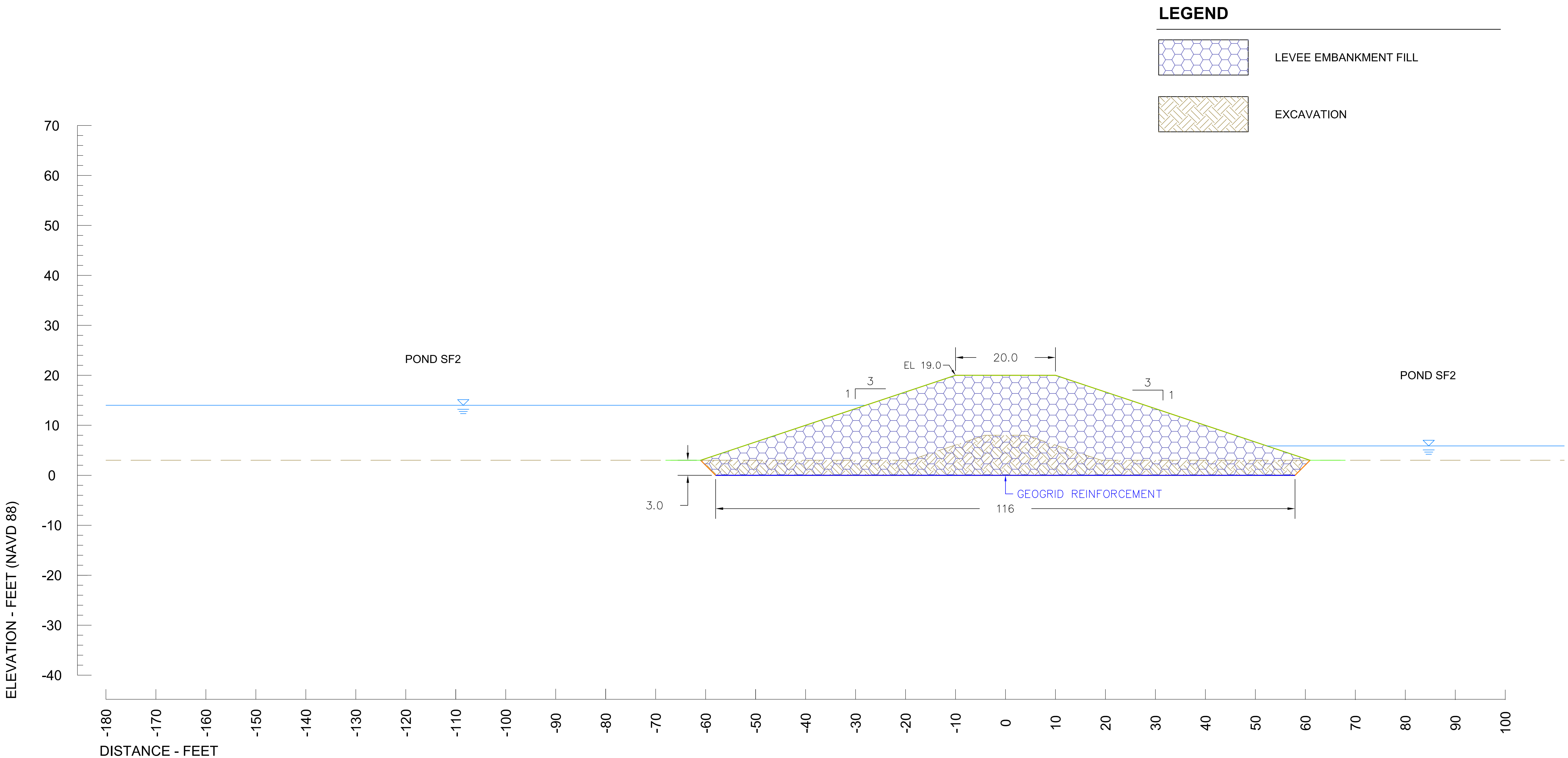
ANALYSIS CROSS-SECTION
REACH 5 - SECTION B

SAFER BAY PROJECT

CALIFORNIA

Date
OCT 2016

Figure
19



NOTES:
1. CROSS SECTION LOOKS SOUTHWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 3 FT OF POST-CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

HDR

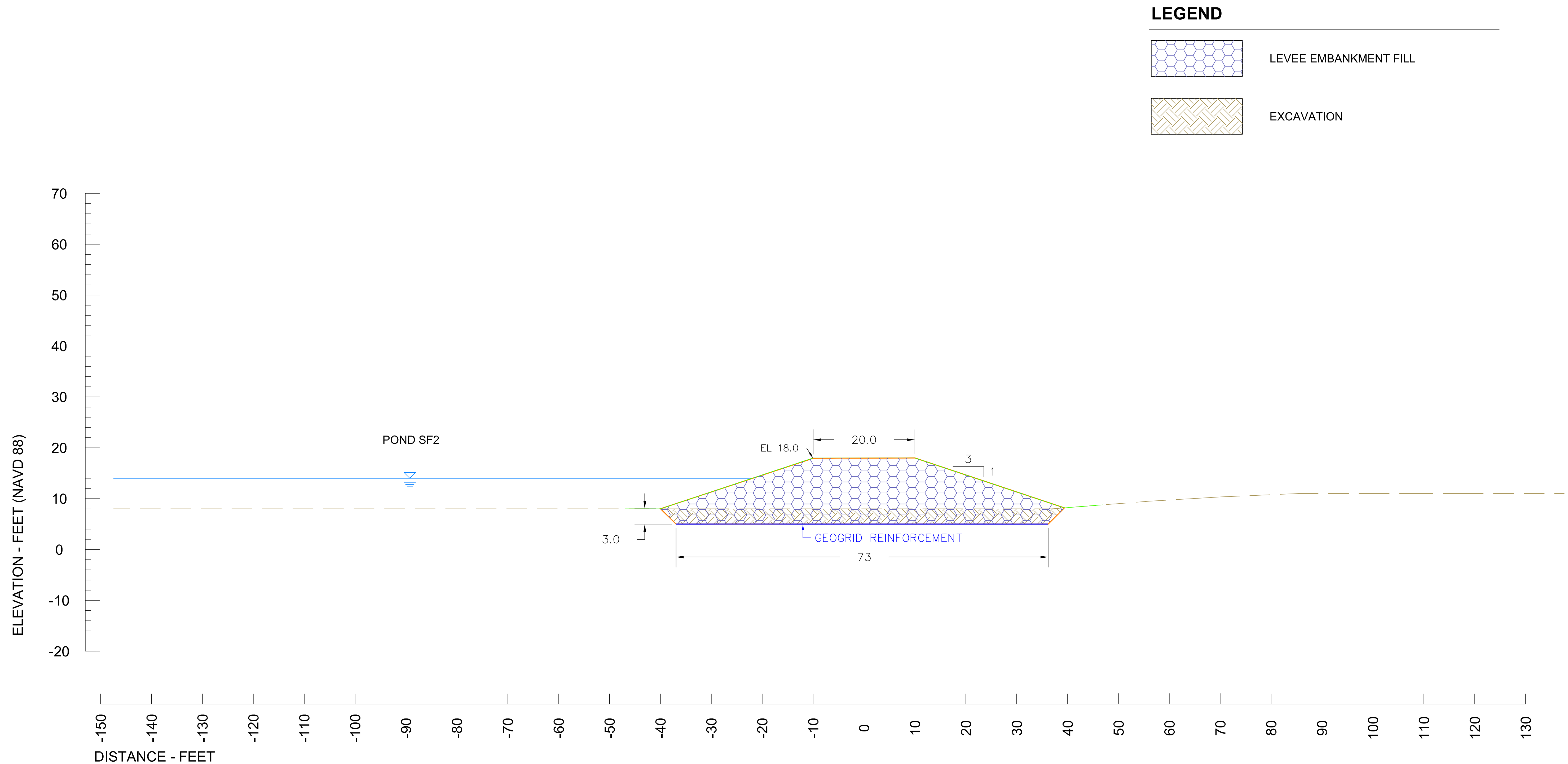
ANALYSIS CROSS-SECTION
REACH 5 - SECTION C

SAFER BAY PROJECT

CALIFORNIA

Date
OCT 2016

Figure
20



NOTES:
1. CROSS SECTION LOOKS EASTWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 1 FT OF POST-CONSTRUCTION SETTLEMENT

HDR

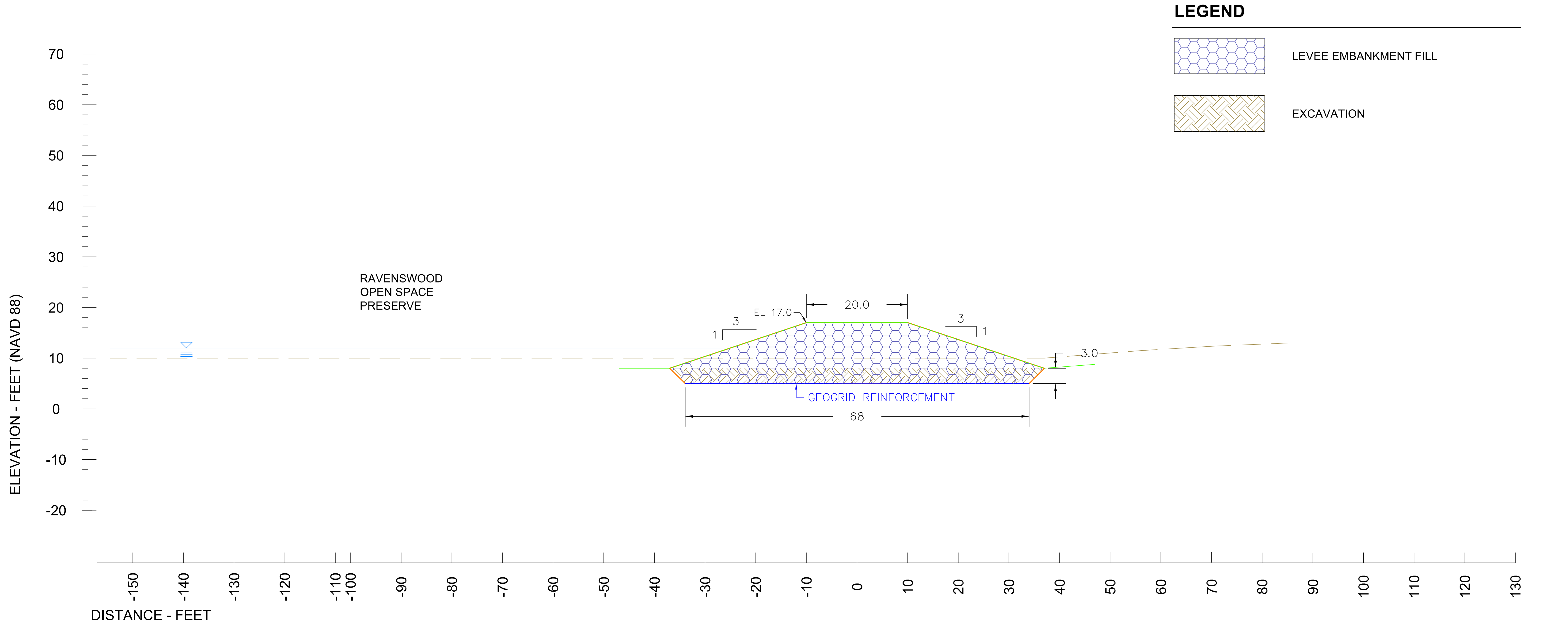
ANALYSIS CROSS-SECTION
REACH 5 - SECTION D

SAFER BAY PROJECT

CALIFORNIA

Date
OCT 2016

Figure
21



NOTES:
1. CROSS SECTION LOOKS SOUTHWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 1 FT OF POST-CONSTRUCTION SETTLEMENT

HDR

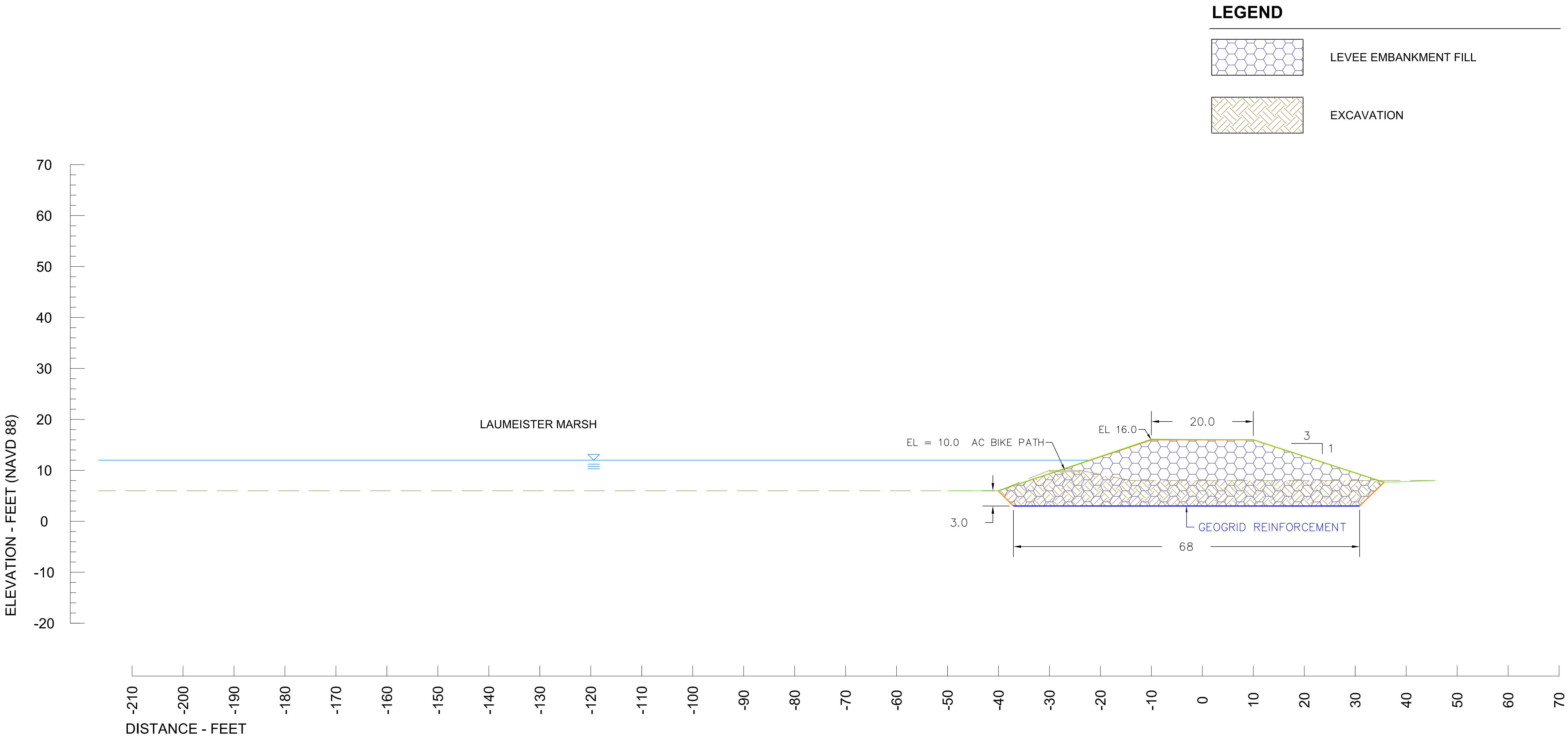
ANALYSIS CROSS-SECTION
REACH 7 - OPTION 2

SAFER BAY PROJECT

CALIFORNIA

Date
OCT 2016

Figure
22



NOTES:
1. CROSS SECTION LOOKS SOUTHWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 1 FT OF POST-CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

HDR

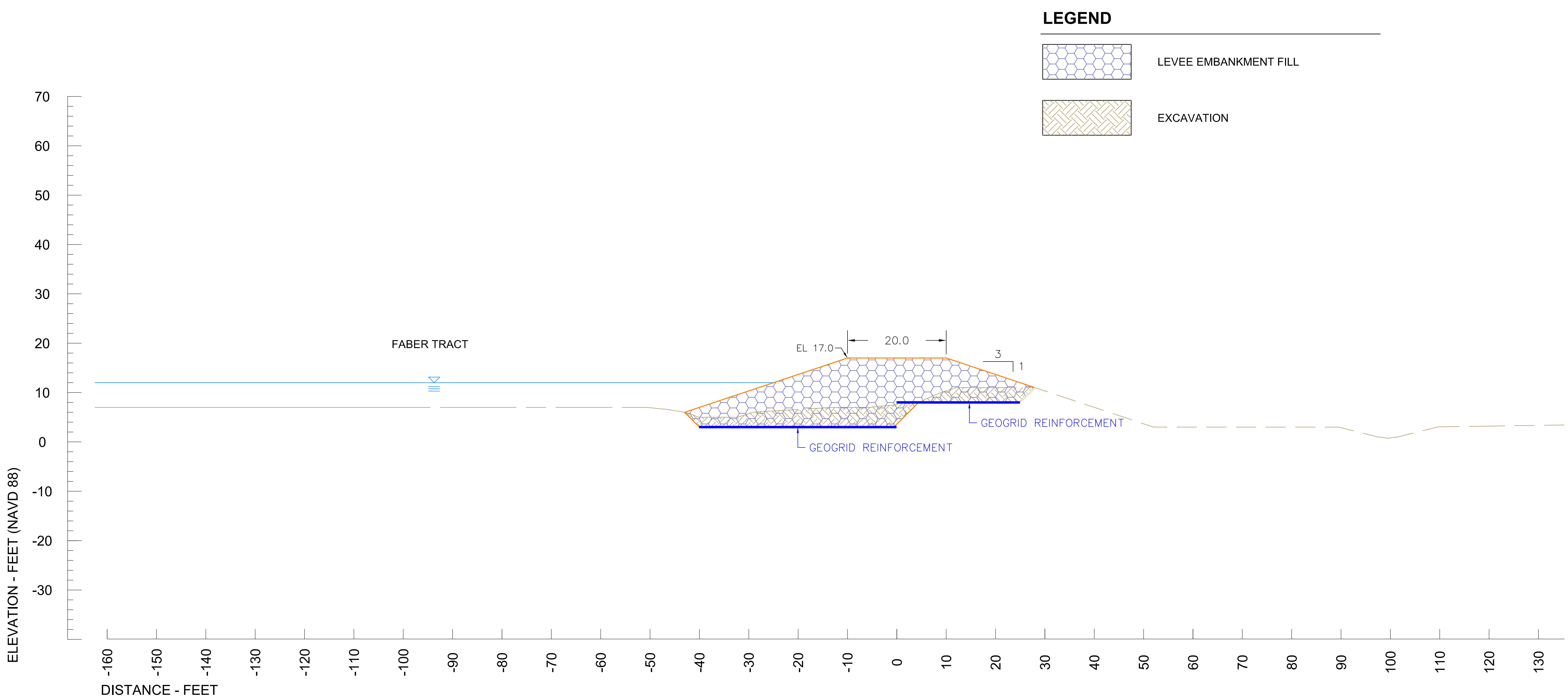
ANALYSIS CROSS-SECTION
REACH 8 - OPTION 2

SAFER BAY PROJECT

CALIFORNIA

Date
OCT 2016

Figure
23



NOTES:
1. CROSS SECTION LOOKS SOUTHWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 1 FT OF POST-CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

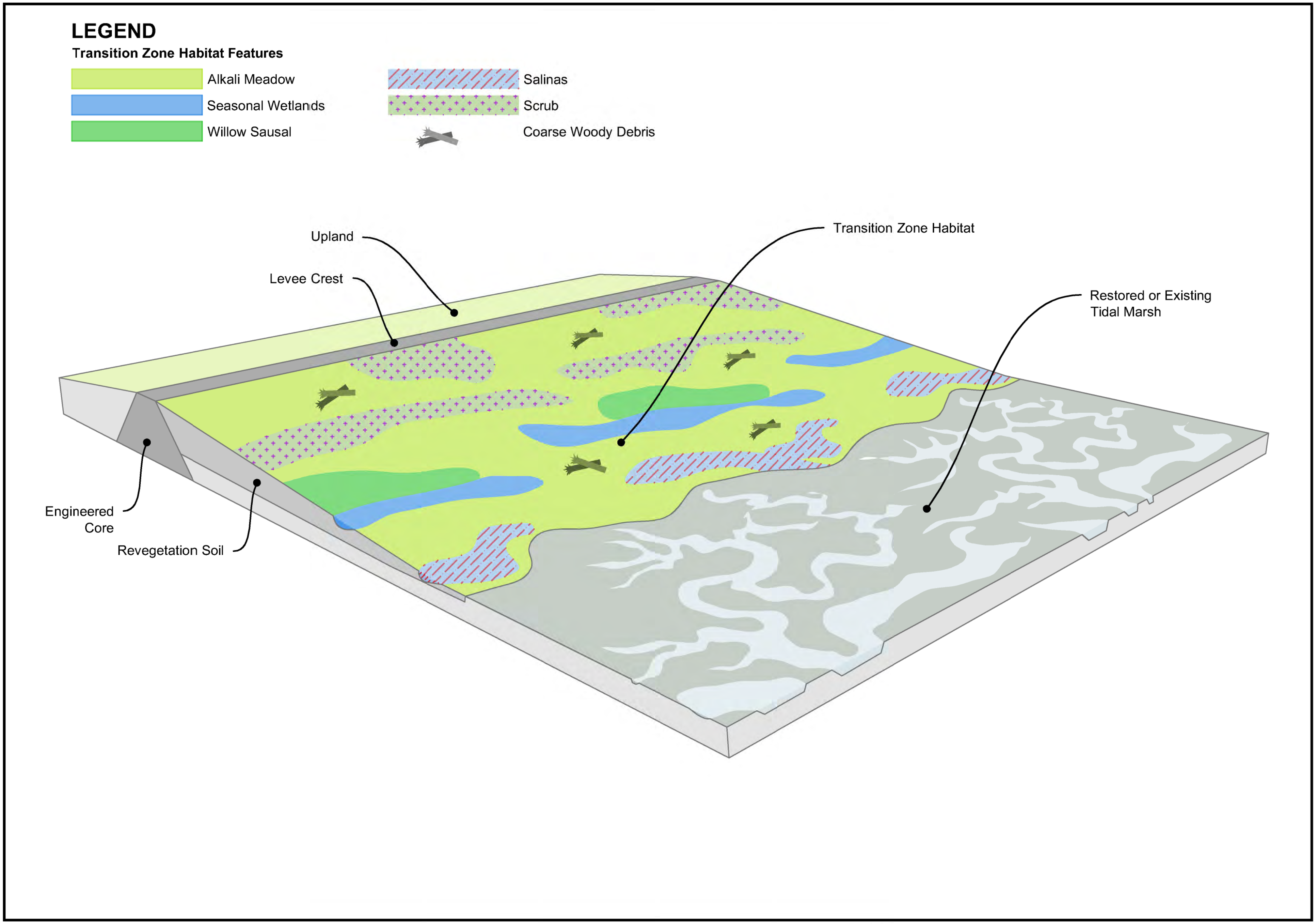
ANALYSIS CROSS-SECTION
REACH 9 - OPTION 1

SAFER BAY PROJECT

CALIFORNIA

Date
OCT 2016

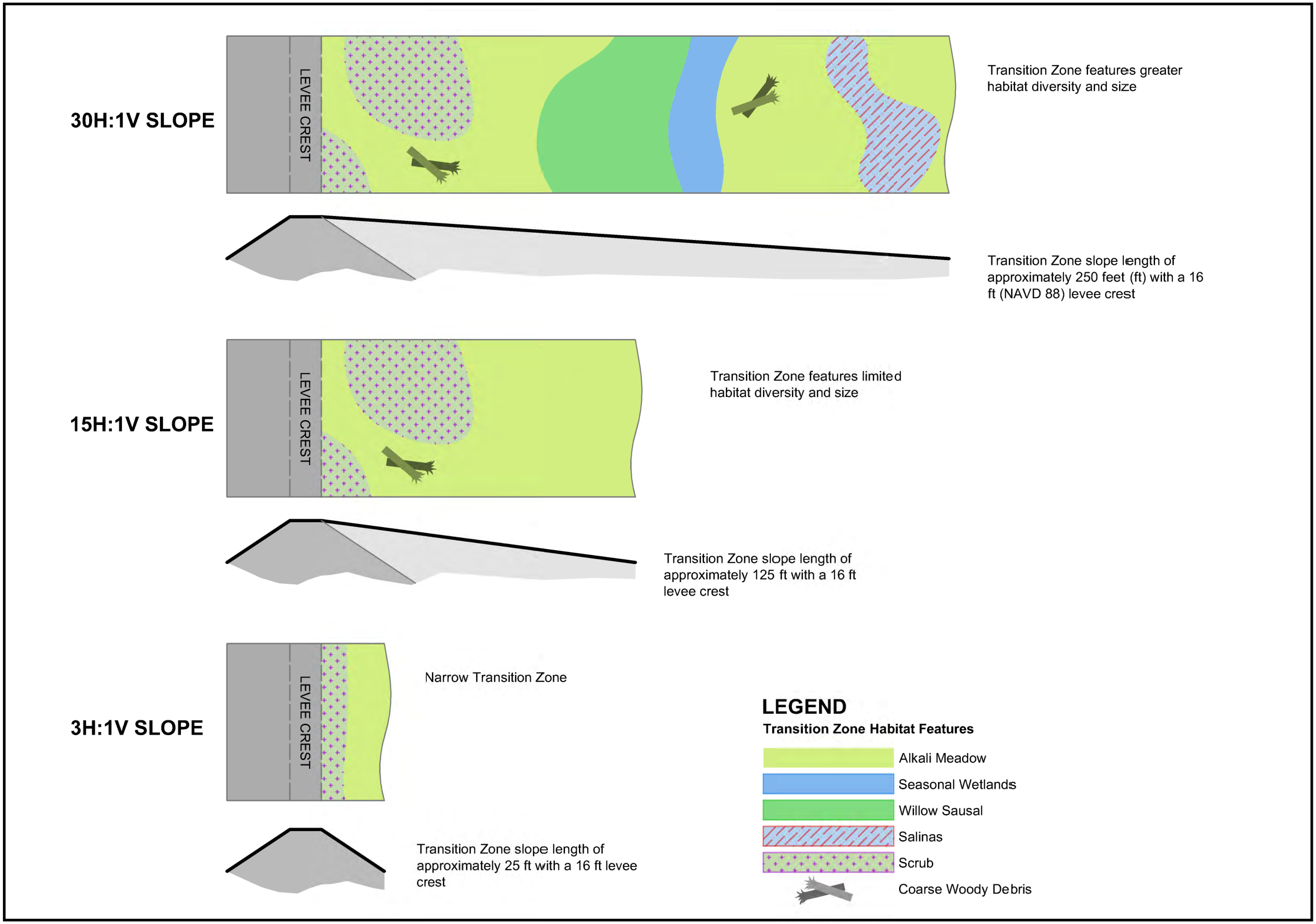
Figure
24



H.T. HARVEY & ASSOCIATES
Ecological Consultants

Figure 25: **Transition Zone Habitat Features**

SAFER Bay Project (3550-01)
August 2014



G:\Active Projects\3550, SAFER BAY East PA & Menlo Prk\01, Restoration\Graphics\Report Figures\QC Plan

H.T. HARVEY & ASSOCIATES
Ecological Consultants

Figure 26: **Example Transition Zone Slopes and Habitat Diversity**

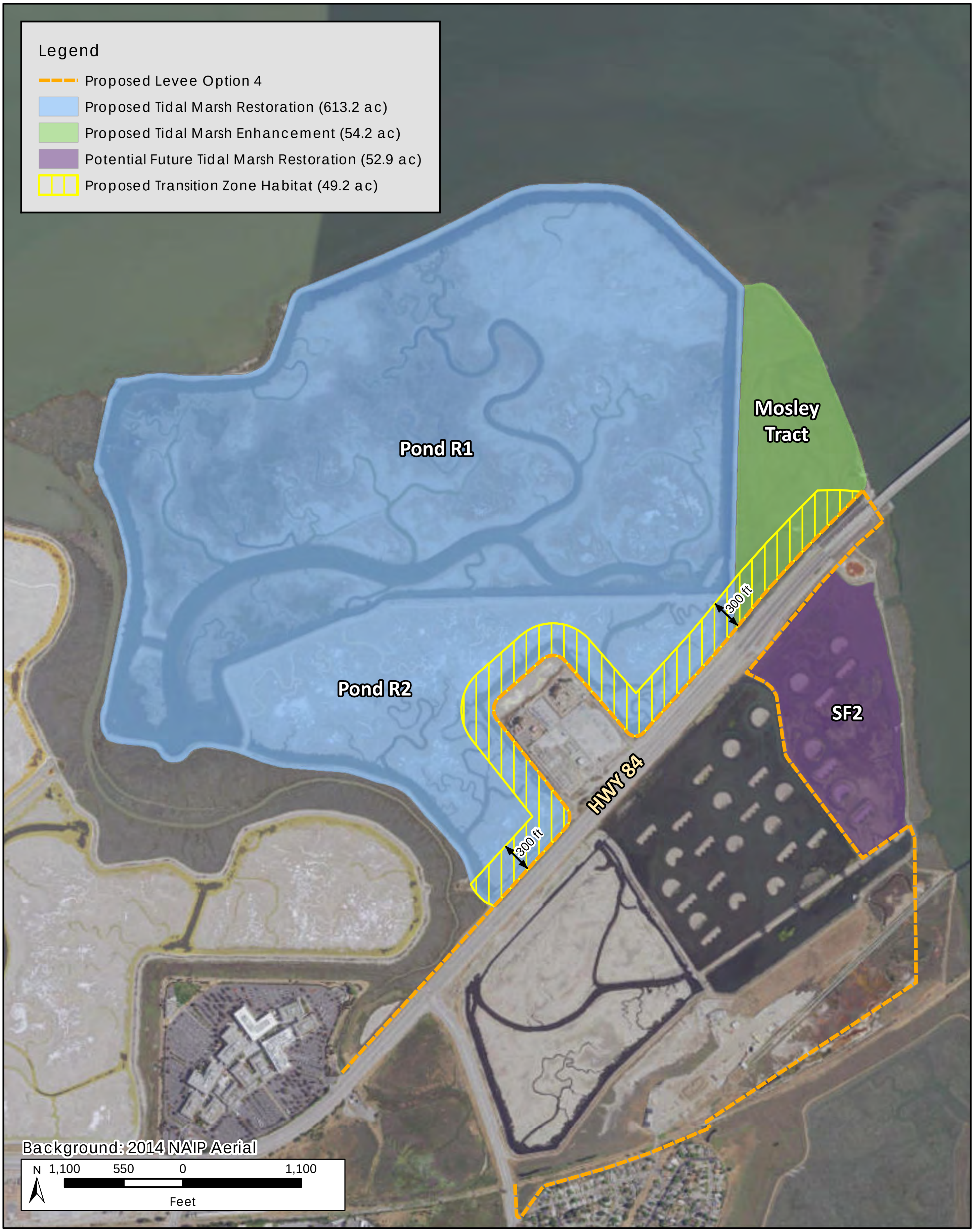
SAFER Bay Project (3550-01)

August 2014

N:\Projects3500\3550-01\Reports\Fig Xa Reach 5 - Option 1.mxd

H. T. HARVEY & ASSOCIATES
Ecological Consultants

Figure **27** - Low Cost Alternative - Proposed Tidal Marsh Restoration
Reach 5, Option 1
SAFER Bay Project (3550-01)
October 2016



N:\Projects3500\3550-01\Reports\Fig Xb Reach 5 - Option 4.mxd

H. T. HARVEY & ASSOCIATES
Ecological Consultants

Figure **28** - Restoration Alternative - Proposed Tidal Marsh Enhancement and Transition Zone Habitat Areas - Reach 5, Option 4
SAFER Bay Project (3550-01)
October 2016

H. T. HARVEY & ASSOCIATES
Ecological Consultants

Figure **29** - Recreation Alternative - Proposed Tidal Marsh Restoration and Transition Zone Habitat Areas - Reach 5, Option 4

SAFER Bay Project (3550-01)

October 2016

H. T. HARVEY & ASSOCIATES
Ecological Consultants

Figure **30-** Restoration Alternative - Proposed Tidal Marsh Enhancement and Transition Zone Habitat Areas - Reach 7, 8 & 9
SAFER Bay Project (3550-01)
October 2016

SAFER Bay

Feasibility Report
Low Cost
Altenative

Figure 31

Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

JUNE 2016

SAFER Bay

Feasibility Report
Restoration
Altenative

Figure 32

Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

JUNE 2016

SAFER Bay

Feasibility Report
Recreation
Altenative

Figure 33

Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

JUNE 2016

SAFER Bay

Feasibility Report
Optimized
Altenative

Figure 34

Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

SEPT 2016

Appendix A - Geotechnical Report for the Feasibility Phase, May 2016

Geotechnical Report for the Feasibility Phase

SAFER Bay Project
Task Order No. 1

San Francisquito Creek Joint Powers Authority

May 2016

SAN FRANCISQUITO CREEK
JOINT POWERS AUTHORITY
SFCJPA.ORG

San Francisquito Creek
Joint Powers Authority
615 B Menlo Avenue
Menlo Park, CA 94025

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SAFER BAY PROJECT

Project No. 222952-028

Task Order No. 1

GEOTECHNICAL REPORT FOR THE FEASIBILITY PHASE

May 2016

Prepared By:
Victor Crosariol, Edwin Woo

Reviewed By:
Mark Stanley

Approved By:
Sergio Jimenez

HDR
1111 Broadway, Suite 1670, Oakland, CA 94607

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Table of Contents

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Figures

Appendices

1 Introduction

1.1 Background

San Francisquito Creek Joint Powers Authority (SFCJPA) and its member agencies seek to protect the City of East Palo Alto and the City of Menlo Park from San Francisco Bay coastal flooding. To accomplish this goal, SFCJPA is undertaking what is referred to as the SAFER Bay (Strategy to Advance Flood protection, Ecosystems and Recreation along the Bay) project. SFCJPA is planning for the construction of new and/or improved flood control features along the Bay shoreline from the Menlo Park/Redwood City border (including unincorporated areas) south to San Francisquito Creek. In addition to protecting East Palo Alto and Menlo Park, this project will contribute to regional coastal flood protection for the neighboring City of Redwood City which could be inundated by coastal flooding via the Haven Court/Marsh Road area of Menlo Park. The project also seeks to further habitat restoration for the Bay's tidal marsh ecosystem, and to enhance recreation opportunities along the Bay shoreline.

The project team performed a preliminary alignment alternatives evaluation for the project, the results of which were presented in a Preliminary Alternatives Report dated February 2015 (revision 1). The purpose of the preliminary alternatives evaluation was to develop, evaluate and present conceptual flood protection alternatives along the Bay shoreline within the project footprint. The project has been divided into nine reaches based on local geography, geology and site topographic features (Figure 1). Within each reach (designated Reach 1 through Reach 9), one or more flood protection options were considered. The alignment alternatives were generally located along the interface of developed and undeveloped (such as marsh and pond) areas, with the purpose of providing flood protection to developed areas. The primary flood protection system considered was levees. Where spatial or other constraints exist, alternative flood protection systems, such as floodwalls or flood gates, were considered. More detailed discussion of the alignment alternatives and flood protection systems considered were presented in the Preliminary Alternatives Report.

The set of preliminary alternatives has been brought forward to the Feasibility Study Phase, which is the current phase of the project. During this phase, the preliminary alternatives are being evaluated, incorporating the results of this geotechnical study, to identify recommended flood protection alternative(s) that will be carried forward for more detailed study, and eventual implementation during subsequent project phases. The results of the feasibility study will be presented in a Feasibility Study Report, which is being prepared concurrently with this Geotechnical Feasibility Report.

1.2 Purpose and Scope of Services

The purpose of the Geotechnical Feasibility Report is to present geotechnical findings and considerations for the identified flood protection alternatives, in support of the overall Feasibility Study.

The scope of geotechnical services included:

- Collecting and reviewing available information on subsurface geotechnical conditions along the project alignment, including logs of past borings and laboratory test results;
- Performing a feasibility level subsurface exploration program consisting of test borings and cone penetrometer tests (CPTs) at selected locations, and laboratory testing, to obtain additional information on subsurface conditions along the proposed alignments;
- Performing geotechnical analyses to support the development of feasibility level designs for the flood protection alternatives being considered;
- Developing and presenting feasibility level geotechnical considerations and recommendations for the flood protection alternatives being considered.

2 Coastal Flood Protection Considerations and Requirements

As described in more detail in the Preliminary Alternatives Report, flood protection elements of the project are to satisfy:

- Current FEMA coastal flood protection requirements, which is the existing 100-year (or 1% annual chance of exceedance) frequency flood event with required freeboard; and
- An additional three feet of tidal elevation to account for anticipated Sea Level Rise (SLR).

As discussed in the Preliminary Alternatives Report, the existing FEMA flood study places all of East Palo Alto's and Menlo Park's Bay shoreline within the Special Flood Hazard Area (SPHA) for the 1% annual chance of exceedance coastal flood event. FEMA is currently revising its coastal flood maps for the Bay, and it is anticipated that the area mapped into the floodplain is likely to increase in size, inundation depth, and possibly destructive power. Results from the first step in the flood map revision process, offshore still water level and wave conditions, have been released by FEMA (DHI, 2013). Just offshore of the SAFER project area, this FEMA study estimates that the 1% annual chance of exceedance still water level to be 11 feet, North American Vertical Datum of 1988 (NAVD). This is an increase of one foot from the existing base flood elevation (BFE) in this area which is 10 feet NAVD (FEMA, 2012). The existing SFHA is delineated by projecting the 10 feet NAVD BFE inland to where it intersects the ground surface elevation. In addition to increasing the BFE from 10 feet NAVD to 11 feet NAVD when continuing the map revision inland, the map revision will also assess the contribution of waves. Waves are added to the still water level to predict the 1% annual chance of exceedance total water level. If the total water level is more than one foot higher than the still water level, the required levee crest elevation will also need to be higher.

The FEMA freeboard requirements for coastal levees are the higher of:

- Two feet above the 1% annual chance of exceedance still water level

OR

- One foot above the higher of 1% annual chance of exceedance wave crest elevation or the maximum wave run up elevation

Hydraulic analyses will need to be undertaken in future phases of the project to estimate the wave run up elevations that will be used for design. The design wave run up elevations will also be affected by improvements that are being planned for the areas on the bayside of the project alignment. Such improvements may include the addition of transition zones, or broad areas of gently sloping fill that are constructed to serve as transitions between tidal and terrestrial habitat areas. Until such hydraulic analyses are performed, it cannot be determined whether the still water or wave run up elevation will control the design. For the purpose of this geotechnical feasibility study, we have based the design water surface elevations on the still water elevations. If the wave run up elevations result in higher flood protection requirements, then adjustments will need to be made at a later time.

HDR

Although FEMA does not currently consider sea level rise in its flood mapping, the study design criteria include consideration of three feet sea level rise. Based on the predictions of extreme events and the projections for future sea level rise, the approximate design elevations for the SAFER project's levee crests (and tops of flood walls where these are used in lieu of levees) are presented in Table 1.

Table 1. Preliminary Coastal Hydraulic Analysis Elevations and Heights

Elevation or Height	Existing	With 3 feet SLR
1% SWL elevation	11.0 feet NAVD	14.0
Freeboard for SWL	2.0 feet	2.0 feet
SWL + freeboard	13.0 feet NAVD	16.0 feet NAVD
Minimum design elevation (rounded to 0.5')	**13 feet NAVD**	**16 feet NAVD**
Wave run up	TBD	TBD
TWL=SWL+ run up	TBD	TBD
Freeboard for TWL	1.0 feet	1.0 feet
TWL + freeboard	TBD	TBD
Maximum design elevation (rounded to 0.5')	TBD	TBD

Note: SWL = still water level; TWL = total water level; TBD = to be determined; NAVD = North American Vertical Datum, 1988; SLR = Sea Level Rise

3 Data Review and Field Exploration

3.1 Review of Existing Data

Prior to conducting the field exploration, efforts were made to obtain boring logs of historical exploration and laboratory test data from the member agencies of SFCJPA, Caltrans, and those publicly available through GeoTracker (an online environmental database managed by the State of California Water Resources Control Board). The locations, depths, quality, and relevance of available previous exploration data were taken into consideration in planning our subsurface investigation. These past explorations are summarized in Table 2 below and their approximate locations are shown on Figures 2a through 2d.

Table 2. Existing Data Considered for Feasibility Level Evaluations

Data Source	Type	Original Exploration Designation	Project Boring Designation	Boring Depth (feet)	Date Advanced
URS Corporation (2014)	Geotechnical Boring	B-06 B-13	URS-B-06 URS-B-13	61.5 52.5	October 2014
GEI Consultants, Inc. (2012)	Geotechnical Boring	B-5 B-6	GEI-B-5 GEI-B-6	51.5 51.5	February 2010
	Cone Penetration Test	CPT-4	GEI-CPT-4	80.1	January 2010
Geomatrix Consultants, Inc. (2008)	Geotechnical Boring	SF2-2 SF2-3 SF2-3	SF2-2 SF2-3 SF2-3	49.5 26.5 52.5	September 2007
Erler & Kalinowski, Inc. (2005)	Environmental Monitoring Well	FHW-1 FHW-2	FHW-1 FHW-2	21.5 21.5	September 2005
Lowney Associates (2002)	Geotechnical Boring	EB-5	LNY-EB-5	40.0	February 2002
Earth Systems Consultants (1983)	Geotechnical Boring	B-1 B-4 B-5 B-6 B-7 B-8	ES-B-1 ES-B-4 ES-B-5 ES-B-6 ES-B-7 ES-B-8	44.5 24.0 50.0 25.0 20.0 20.0	September 1983
Caltrans (1999)	Geotechnical Boring	ST-1 PB-1 PB-4 PB-15 PB-16 PB-17 PB-18 PB-5	ST-1 PB-1 PB-4 PB-15 PB-16 PB-17 PB-18 PB-5	19.7 32.2 32.0 32.2 32.2 32.2 26.9 27.6	November 1999 May 1999 April 1999
Caltrans (1994)	Geotechnical Boring	P-2	P-2	41.5	March 1994
Caltrans (1980)	Geotechnical Boring	B-1 B-2	RPS-B-1 RPS-B-2	86.5 81.5	September 1979 January 1980

3.2 Field Exploration

HDR's field investigation consisted of advancing five test borings and five cone penetrometer tests (CPTs) along the proposed alignments in areas of identified data gaps to obtain information on subsurface conditions for geotechnical characterization of the site. Prior to performing the subsurface investigations, HDR obtained the required San Mateo County

Environmental Health Services Division (SMCEHSD) geotechnical drilling permits, and property owner access permissions specific to each exploration location. HDR also contacted Underground Service Alert (USA) to check for the presence of underground utilities.

As this is a feasibility level geotechnical investigation, only a limited number of relatively widely spaced explorations were undertaken. Further, there are data gaps along portions of the project alignment where site access could not be obtained. These include the area north of Marsh Road to the Menlo Park/Redwood City border where site access was not granted by the property owner, and the area between Bay Road (Cooley Landing) and Runnymede Street in East Palo Alto. In this area, site access could not be obtained due to concerns from the property owner about conducting explorations near the former Rhone-Poulenc property that was designated a Super Fund site.

Pitcher Drilling Company (Pitcher) advanced five test borings, designated B-01 through B-03, B-05, and B-06, from January 18 through 22, 2016. Borings B-02 and B-06 were advanced using track-mounted Fraste XL drilling equipment, and Borings B-01, B-03, and B-05 were advanced using truck-mounted Failing 1500 drilling equipment. All borings were drilled using rotary wash drilling methods to depths ranging from 41.5 to 56.5 feet. Test borings were backfilled with cement grout in accordance with SMCEHSD geotechnical drilling permit conditions.

Representative soil samples were collected at approximately 2- to 5-foot intervals, as appropriate to the soil type and stratification encountered. Disturbed samples were obtained by driving either a Standard Penetration Test (SPT) split-barrel sampler without liners or a Modified California split-barrel sampler with 6-inch long liners. Resistance blow counts were obtained with both Modified California and SPT samplers by dropping a 140-pound automatic trip hammer through a 30-inch free fall. Relatively undisturbed Shelby Tube samples were obtained using direct push or Pitcher Barrel rotary sampling methods, as appropriate to soils encountered in the borings. Soil samples collected from the borings were initially classified and described by an HDR field engineer in general accordance with ASTM D2488. The samples were transported to our sample storage area and a geotechnical laboratory for further examination, laboratory testing, and confirmation of classification. The field log classifications were then edited based upon the results of the laboratory examination and testing, as necessary.

Gregg Drilling and Testing, Inc. (Gregg) advanced five CPTs, designated C-02 through C-06, on January 11 and 12, 2016. A 30-ton truck-mounted CPT rig was used to advance the CPTs to a depth of approximately 60 to 70 feet. All CPTs were backfilled with cement grout in accordance with SMCEHSD geotechnical drilling permit conditions. An HDR engineer was on-site to facilitate and observe the CPT activities.

The approximate locations of the test borings and CPTs are shown on Figures 2a through 2d. The locations of the explorations were determined by tape measuring from existing site features and are accurate only to the degree implied by the method used. Logs of the test borings and CPTs and additional details of the exploration program are presented in Appendix A.

3.3 Laboratory Testing

Selected soil samples obtained from the test borings were delivered to Cooper Testing Laboratory (Cooper) in Palo Alto, California for geotechnical laboratory testing. Laboratory testing included index testing for soil classification and advanced testing to evaluate geotechnical engineering properties. Field soil descriptions were updated as needed based on laboratory testing results in accordance with ASTM D2487. The laboratory tests performed included the following:

- Sieve Analysis and Hydrometer (ASTM D422)
- Percent Passing No. 200 Sieve (ASTM D1140)
- Atterberg Limits (ASTM D4318)
- Moisture Content and Density (ASTM D7263b)
- Triaxial Compression – Unconsolidated Undrained (ASTM D2850)
- Consolidation (ASTM D2435)

The results of the laboratory tests are presented on the boring logs at the appropriate sample depths and/or in Appendix B.

4 Geologic Setting

4.1 Regional Geology

The project site is located in the southern part of the San Francisco Bay Area in the Coast Ranges geomorphic province of California, which is characterized by northwest-southeast trending valleys and ridges. These valleys and ridges are controlled by folds and faults that resulted from the collision of the Pacific and North American plates, subduction of the Pacific Plate beneath the North American Plate, and subsequent strike-slip faulting along the San Andreas Fault zone and the plate boundary fault systems. Bedrock underlying the region is primarily of the Franciscan Complex, characterized by a diverse assemblage of sandstone, shale, chert, greenstone and mélange.

Geologic formations in the San Francisco Bay Region range in age from Jurassic (190 to 135 million years ago) to recent Holocene (less than 11 thousand years ago). The Franciscan Complex is the oldest, and underlies younger surficial deposits throughout the San Francisco Bay Region. The Franciscan Complex consists mainly of marine-deposited sedimentary and volcanic rocks in close association with bodies of serpentine. Following deposition, the Franciscan rocks were regionally uplifted and, in the process, extensively faulted and folded.

The Bay Area has experienced several episodes of uplift and faulting during late Tertiary time (about 25 to 2 million years ago). This produced a series of northwest-trending valleys and mountain ranges, including the Berkeley Hills, the San Francisco Peninsula and the intervening San Francisco Bay. Uplifted areas were eroded, and as a result, Pleistocene and recent marine sediments were deposited in the San Francisco Bay and stream and marshland sediments were deposited in low-lying areas adjacent to the Bay.

4.2 Regional Seismicity

Geologists and seismologists recognize the San Francisco Bay Area as one of the most active seismic regions in the United States. Active faults extending through the Bay Area have produced 11 large (moment magnitude, M_w 6.0 or greater) earthquakes over the last two centuries that have damaged buildings and other infrastructure. Most recently, the August 24, 2014 M_w 6.0 South Napa Earthquake caused extensive damage to the local built environment. The faults causing such earthquakes are part of a system of faults along the boundary of the Pacific and North American plates and locally include the San Andreas, Calaveras, and Hayward faults. The major fault in the system is the San Andreas Fault that extends for at least 450 miles along the coast of California.

The 2014 Working Group on California Earthquake Probabilities (WGCEP) published an updated report evaluating the probabilities of significant earthquakes occurring in the Bay Area over the next three decades (Field et al, 2015). The WGCEP estimated that there is a 72 percent probability that at least one moment magnitude 6.7 or greater earthquake will occur in the San Francisco Bay region before 2044. This probability is an aggregate value that considers principal Bay Area fault systems and unknown faults (background values) including the potential for multi-fault ruptures. The principal active faults in the Bay Area include the San Andreas, Hayward, Calaveras, and the San Gregorio faults. Earthquakes occurring along these faults are capable of generating strong ground shaking at the project site.

Table 3 summarizes the approximate distances between the site and the six closest known mapped active or potentially active faults based on the 2008 update to the United States National Seismic Hazard Maps online Fault Parameter database (USGS, 2008a). The online information is documented by the United States Geological Survey (USGS) Open File Report 2008–1128 (Petersen et al., 2008). The project site is not located within an Alquist-Priolo Earthquake Fault Zone.

Table 3. Regional Faults and Seismicity

Fault (segments)	Approximate Distance from Site, mi (km)	Direction from Site	Maximum Moment Magnitude
Monte Vista –Shannon	4.8 (7.7)	Southwest	6.5
[1]San Andreas (SAO+SAN+SAP+SAS)	6.2 (9.8)	Southwest	7.9
[2]Hayward-Rodgers Creek (RC+HN+HS)	9.8 (15.8)	Northeast	7.3
[3]Calaveras (CN+CC+CS)	15.3 (24.6)	Northeast	7.0
San Gregorio Connected	15.3 (24.6)	Southwest	7.5
Zayante-Vergeles	27.0 (43.4)	South	7.0

1. San Andreas segments: SAO = Offshore, SAN = North Coast, SAP = Peninsula, SAS = Santa Cruz Mountains
2. Hayward-Rodgers Creek segments: RC = Rodgers Creek, HN = North Hayward, HS = South Hayward
3. Calaveras segments: CN = Northern, CC = Central, CS = Southern

Earthquakes on these or other active faults (including unmapped faults) could cause strong ground shaking at the site. Earthquake intensities vary throughout the Bay Area depending upon the magnitude of the earthquake, the distance of the site from the causative fault, the type of materials underlying the site, and other factors.

5 Site Conditions

5.1 Surface Conditions

The proposed project alignment is located along the bay margin of the Cities of Menlo Park and East Palo Alto, and extends from the Redwood City/Menlo Park border to San Francisquito Creek. The proposed alignment is generally located along the edge of developed areas. Areas on the bayside of the alignment generally consist of salt ponds, marsh or other open space. Areas on the landside of the alignment are generally developed with features that include roadways, commercial and residential development, and some open space. A berm, levee, or trail exists along the proposed alignment, and consists of asphalt concrete paved, gravel or unpaved segments. Where the flood protection system is to consist of levees (the majority of the alignment), it is anticipated that the levee footprint will generally span over the existing berm, levee or trail, and extend bayward into drainages, salt ponds, marsh or open space. A project survey has not yet been performed. Based on publically available topographic information, existing site grades along the berm, levee or trail of the proposed alignment generally range from about Elevation 7 to 11 feet (USGS, 2011). Existing site grades in the adjacent salt ponds, marsh or open space are generally comparable or lower than those in the adjacent berms, levees, or trails, but are estimated to range from about Elevation 3 to 9 feet. Bathymetry is not available for the salt pond and marsh areas. Thus, much of the data reported for the lower elevation areas (below approximately Elevation 5 feet) are rough approximations and need to be verified during subsequent phases of the project.

5.2 Site Geology

Brabb et al (1998) mapped surficial deposits beneath the fill along the project alignment as Holocene age Bay Mud deposits consisting predominantly of gray, green and blue clay and silty clay. This is consistent with an older map by Dibblee (1966), who mapped surficial deposits along the project alignment as Recent Quaternary age Bay Mud and clay deposits. Dibblee mapped surficial deposits along a small segment of the alignment coinciding approximately with an area of existing high ground known as ‘391 Demeter Street’ as Recent Quaternary alluvium. The ‘391 Demeter Street’ parcel is located along the western portion of the Ravenswood Open Space Reserve as shown on Figure 2c.

5.3 Subsurface Conditions

Fill was encountered in all of the borings and CPTs performed for this feasibility study, as well as in the past borings by others in the immediate project area. Fill was encountered to depths ranging from about 5 to 8 feet at their respective exploration locations. The fill encountered is variable in composition but generally consists of medium stiff to stiff lean to fat clay, and sandy lean to fat clay, with loose to dense sand and gravel, and clayey sand. Except for Boring B-05, which was drilled at the northern end of Demeter Street near the 391 Demeter Street parcel noted above, Young Bay Mud (YBM) was encountered beneath the fill in all of the explorations performed. The YBM generally consists of very soft to medium stiff fat clay with sand, and elastic silt. The thickness of the YBM layer varies considerably along the project alignment, ranging from about 4 to 33 feet, as summarized by reach in Table 4. Beneath the YBM, or beneath the fill in Boring B-05, alluvial deposits generally consisting of interlayered stiff to very stiff lean clay with varying amounts of sand and silt, and loose to dense clayey sand and sand with clay and gravel, were encountered to the maximum depth explored of about 56.5 feet.

Table 4. Summary of YBM Thickness

Reach	Approximate YBM Thickness (feet)	Explorations
Reaches 1/2	4 to 5 feet	B-01 and PB-1
Reach 3	5 to 10 feet	C-02, C-03, PB-4, PB-5 and PB-15
Reach 4	12 feet	B-02
Reach 5	13 feet 19 to 20 feet 25 to 33 feet	CPT-05 CPT-04, RPS-B-2 B-03, SF2-2, SF2-4
Reach 7	20 feet	CPT-06
Reach 8	Not determined but estimated to be on the order of 10 feet	No explorations conducted in this reach
Reach 9	10 to 12 feet	B-06, ES-B-4, LNY-EB-5. GEI-CPT-4

5.4 Groundwater

The depth to groundwater could not be determined in all of the borings performed for this feasibility study because of the rotary wash drilling methods used. Groundwater was encountered at the time of drilling at depths of about 6.5, 3 and 5 feet, corresponding to Elevations 3.5, 7, and 6 feet, in Borings B-01, B-03, and B-05, respectively. We note that these borings may not have been left open for a sufficient period of time to establish equilibrium ground water conditions. These groundwater levels are generally consistent with those reported on the past Caltrans boring logs. Given the proximity of the project alignment to the bay, it is anticipated that groundwater levels are likely to be tidally influenced. Fluctuations in the ground water level could occur due to changes in seasons, variations in rainfall, and other factors.

6 Feasibility Level Analyses and Conclusions

6.1 Geotechnical Considerations

As described above, the proposed project alignment is located along the margin of San Francisco Bay. The geotechnical explorations performed for this feasibility study and past explorations by others indicate that beneath the fill layer, the large majority of the area is underlain by YBM. This soil is soft, weak and highly compressible. The YBM also contains intermediate sand layers and lenses that, if continuous, could be potential underseepage paths.

To provide for coastal flood protection, new levees will be constructed or existing levees will be raised and broadened with earthen embankments. Where spatial or other constraints exist, alternative flood protection systems, such as floodwalls, may be required.

Placement of fill to build new levees or raise levee crown elevations may impact the underlying soil, and in particular the YBM. Three key considerations to be evaluated are:

Settlement – The additional loading from new levees or levee raises will cause settlement over time primarily due to the consolidation of the underlying YBM. The levees will need to be initially built to heights greater than their final target elevations, in order to meet their design crest elevations.

Stability – Depending on the height of new levee fill needed and the strength of the underlying soil, the YBM may be too weak to allow the levees to be constructed to their target elevations without special considerations. Stability failures can occur if too much soil load is placed over a short period of time. This may mean that levees will need to be raised in stages to allow for sufficient time for the underlying soil to gain strength before additional fill is placed. Alternatively, measures may be needed to strengthen the weak underlying soil or accelerate its strength gain.

Seepage – During periods when there is water against the levees, seepage can occur both through the levee embankment and through more pervious layers beneath the levee (under seepage). Both through seepage and under seepage can lead to levee erosion, piping and other detrimental consequences. Mitigation measures could include the proper specification and compaction of levee fill materials for through seepage control and the installation of seepage cutoff walls, pressure relief or drainage elements for underseepage control.

6.2 Levee Design Criteria

Project geotechnical design criteria were established to evaluate the levees for acceptable performance with respect to levee height/settlement, stability, and underseepage. The criteria used are based on published federal and state regulations and technical guidance documents. For levees to be accredited by FEMA, evidence must be provided that adequate design and operation and maintenance (O&M) systems are in place to provide reasonable assurance that protection from the base flood with a 1-percent annual chance of exceedance (i.e., 100-year flood) exists. These requirements are outlined in the Code of Federal Regulations, 44CFR65.10 (FEMA, 2006), and in the California Code Regulations (CCR), Title 23 (CVFPB, 2009).

In general, the United States Army Corps of Engineers (USACE) criteria were followed for the design of levees, as presented in USACE Engineering Manual 1110-2-1913 *Design and*

Construction of Levees (USACE, 2000), based on the requirements of 44CFR65.10. State guidelines, as presented in the State of California Department of Water Resources (DWR) Urban Levee Design Criteria (2012), were also referenced. These include design criteria for levee height/settlement, stability, through seepage/underseepage, summarized as follows.

Levee height/settlement – As discussed in Section 2, levees are to be designed to achieve a minimum levee crest height of Elevation 13 feet to meet FEMA 100-year event flood protection requirements, and Elevation 16 feet to provide an additional 3 feet of freeboard for sea level rise. As settlement is expected over time, levees were evaluated for additional overbuild heights as necessary, to achieve a minimum initial crest height of Elevation 13 feet, and minimum final crest height of Elevation 16 feet 25 years after the initial construction.

Stability – Levee stability analyses were performed for the following conditions and for the required minimum factors of safety:

- End of Construction: minimum factor of safety of 1.3;
- During a flood event, with the water level set at Elevation 14 feet (FEMA 100-year flood elevation plus 3 feet for sea level rise) and steady-state seepage conditions: minimum factor of safety of 1.4; and
- For rapid drawdown conditions, where the water level drops from Elevation 14 feet to the waterside ground surface elevation: minimum factor of safety of 1.0.

Through Seepage/Underseepage – If the phreatic surface daylights on the landside levee slope during an analysis of steady-state seepage conditions (also referred to as breakout), it may indicate that there is a potential for through seepage. Potential detrimental effects of through seepage include a reduction in slope stability, sloughing and erosion of the landside levee slope surface, and internal erosion through piping. Low-plasticity soils are more susceptible to erosion than soils with medium to high plasticity. As these levees will primarily consist of new levees and the materials used for their construction yet to be determined, through seepage analysis was not explicitly performed. In future phases of the project, material property requirements for levee fill will need to be established taking into consideration their potential for through seepage. For underseepage, an average exit gradient at the landside levee toe of 0.5 or less, for a flood event with the water level set at Elevation 14 feet and steady-state seepage conditions, was taken as the acceptable criterion.

6.3 Cross Sections for Geotechnical Analysis

The project alignment was divided into nine reaches as described above. Based on the site and subsurface conditions, cross sections were developed for geotechnical analysis at eight locations, to represent this range of conditions. The locations of these representative cross sections, denoted G1 through G8, are shown on Figures 2a through 2d. The analysis cross sections are shown on Figures 3a through 3h. A summary of each cross section and the reach limits that it represents is presented as follows:

- Cross section G1 – Located within Reach 1, and represents Reach 1, Option 2 and the western segment of Reach 2, Option 1.

- Cross section G2 – Located within Reach 3, and represents the eastern segment of Reach 2, Option 1 and Reach 3, Option 1.
- Cross section G3 – Located within and represents Reach 4.
- Cross section G4 – Located within the western portion of Reach 5/6, Option 1 and Reach 5, Option 4, and represents the segment along Ravenswood Slough (between Reach 4 and the western edge of Pond R2), and the segment of Reach 5/6, Option 1 on the south side of Highway 84 from about 1,000 feet northeast of University Avenue to Reach 7.
- Cross section G5 – Located east of the PG&E substation within Reach 5/6, Option 1 and Reach 5, Option 4, and represents the segment of both options along Pond R2 and the segment of Reach 5/6, Option 1 on the south side of Highway 84 from the Dumbarton Bridge abutment to about 1,000 feet northeast of University Avenue.
- Cross section G6 – Located within Pond SF2 of Reach 5, Option 4, and represents the segment of Reach 5, Option 4 from Pond R2 to Reach 7.
- Cross section G7 – Located within and represents Reach 7.
- Cross section G8 – Located within Reach 9 and represents Reaches 8 and 9.

The levee geometries were developed based upon the standard levee template adjusted for settlement as described in the following section.

6.4 Levee Geometry Template

For the purpose of evaluating alignment options, levees with the following minimum geometry have been considered:

- Minimum crest width of 20 feet.
- Waterside and landside slopes of 3H:1V (horizontal to vertical).
- Final levee crest height at Elevation 16 feet.
- Extend at least 3 feet below existing grade, following excavation of a trench across the base of the levee.

The minimum levee template was modified where appropriate based upon levee settlement and stability analyses. Analysis was performed for each representative cross section to evaluate the magnitude of settlement and height of levee overbuild to meet the levee crown target elevation and meet the minimum levee stability criteria. For the reasons discussed in the Section 6.1, as well as economic reasons, it is possible that levees would be constructed and raised in stages over the course of many years. Regardless of the timing or staging of levee raisings, a sufficient width along the alignment should be available to accommodate the full width of the levee that would eventually be constructed. Further, the base of the levee should be constructed to this full width so that future raises can be performed on top of the levee without the need for future lateral expansion.

Transition zone habitat restoration on the outboard levee slope is an important component of the SAFER Bay Project's ecosystem restoration approach. Along the portions of the project alignment where transition zones are being considered, they have been included in the geotechnical models for analyzing settlement. Waterside transition zone fills are being considered in Pond R3 (along Reach 2, Option 1 eastern segment and Reach 3, Option 1), Pond R2 (along portions of Reach 5/6, Option 1 and Reach 5, Option 4 that are along this pond), Ravenswood Open Space Preserve (along Reach 7), Laumeister Marsh (along Reach 8), and Faber Tract (along Reach 9), as represented on Figures 3b, 3e, 3g, and 3h, respectively. In these reaches the top of the transition zone fill was assumed to be constructed to Elevation 14 feet where it meets the slope of the levee. The transition zone slope was then assumed to grade downward at an inclination of 15:1 (horizontal to vertical) toward the bay to where it meets the estimated existing grade. We understand that the actual inclination of the transition zones may be steeper or flatter than 15:1, ranging from about 7:1 to 30:1. However, since the transition zone fill will still be relatively flat compared to the levee, the effect of this range in the slope of the transition zone fill on the settlement of the levee will be relatively small. Thus, for a feasibility level analysis, we judge that representing the transition zone with one inclination of 15:1 to assess settlement is acceptable.

6.5 Levee Settlement

Overbuilding of levees was considered in establishing levee geometries for analyses to account for consolidation of the underlying YBM. For example, for a location where the existing ground surface is at Elevation 8 feet, and 2 feet of settlement is estimated, a 10-foot high levee would need to be constructed to an initial levee crest elevation of 18 feet that, over time, will settle to the target crest Elevation of 16 feet.

Based on our settlement analyses, it is estimated that the levees would need to be overbuilt by about 1 to 3 feet, to achieve a target crest elevation of 16 feet. In general, the required overbuild heights are greatest within Reach 5 (in the vicinity of the Dumbarton Bridge approach) where the thickest YBM was encountered. Feasibility level recommendations of the required overbuild heights along each reach are presented in Section 7 below.

6.6 Levee Stability

Slope stability analysis was performed for each representative cross section using the limit equilibrium software program SLOPE/W (GEO-SLOPE, 2015). Stability analyses were performed for the following three conditions:

- Levee end-of-construction condition, prior to the construction of the transition zone (where these are planned) as this was judged to be the most critical condition for stability. The weight of the levees will induce consolidation settlement and strength gain in the YBM with time, which will also increase levee stability with time.

- Stability of the levee during a flood event with design water level set at Elevation 14 feet (FEMA 100-year flood elevation plus 3 feet for sea level rise). These analyses were performed assuming steady-state seepage conditions (seepage analyses discussed below), with the levee at its greatest constructed height at the end of construction, and without a transition zone – all conservative assumptions.

- For rapid drawdown conditions, where the water level is assumed to suddenly drop from the design flood level of Elevation 14 feet to the waterside ground surface, with no transition zone.

For each representative cross section, the end-of-construction levee stability was analyzed for a configuration that assumes that the levee will be constructed to its final target crest elevation in one stage, plus additional overbuild height to account for settlement. Thus, stability analysis was performed for levees constructed to initial crest heights of Elevation 17 to 19 feet. The analyses have been performed based on engineering judgment to select fine grained (clay) levee fill soil strength properties that are typical for levees in the South Bay. These properties will need to be verified once a borrow source is identified during final design.

These feasibility level analyses indicate that all of the proposed levees, except those in Reach 5, can be constructed to their target crest heights while maintaining the target factor of safety against end-of-construction stability failure. Reach 5 contains greater thicknesses of YBM than elsewhere along the project alignment and may need to be constructed in two stages to allow for consolidation and associated foundation strength gain to construct the levee to its target height. To better define the limits of the staged construction, three cross sections, designated G4, G5, and G6, were developed and analyzed for Reach 5 to better characterize the range of subsurface conditions encountered. The analyses indicate that at cross sections G4 and G5, the levees can be constructed to their target crest heights in one stage and maintain a marginally adequate factor of safety of slightly greater than 1.3. However, at cross section G6, construction of the levee in one stage results in a factor of safety of slightly less than 1.3. As a measure to improve end-of-construction stability in Reach 5, a layer of geotextile or geogrid was included at the base of the levee in the analysis, which improved the base stability and increased the levee stability to slightly greater than 1.3 in all cases. This suggests that within Reach 5, special measures such as the inclusion of geotextiles or geogrids may be needed to improve levee stability. Additional field exploration, laboratory testing, and analyses will be required in future phases of the project to determine if the Reach 5 levees can be constructed in one stage, from a geotechnical perspective. Alternatively, levee construction would need to be performed in two stages along this reach. Two-stage construction was also analyzed for these three cross sections. With this approach, the first stage of fill was assumed to be placed to Elevations 14.5 (Section G4), 15 (Section G5), and 15.5 feet (Section G6) and allowed to essentially complete its consolidation settlement (a period on the order of 25 years). In the second stage, additional fill was placed to up to Elevation 17, in order to meet the final target crest height at Elevation 16 feet. Analyses indicate the required factors of safety can be achieved using a two-stage construction approach and allowing sufficient time between stages to achieve the needed strength gain in the underlying YBM.

Landside long-term static stability analyses were performed for a design water surface at Elevation 14 feet and steady-state seepage conditions. The development of steady-state seepage models and the corresponding steady-state pore pressures used for these stability analyses are discussed below in Section 6-7. On this basis, these feasibility level analyses indicate that all of the proposed levee configurations meet the USACE minimum factor of safety of 1.4 for this analysis condition (USACE, 2000). In the case of Sections G1 and G8, the addition of a geotextile or geogrid along the base of the levee was needed to improve the calculated factor of safety to at least 1.4.

Waterside rapid drawdown was performed using the staged undrained strength method (Duncan, Wright, and Wong, 1990), which has been incorporated into SLOPE/W. According to USACE (2000), a factor of safety of 1.0 is appropriate for waterside levee slopes following a relatively short duration flood stage, which we consider to be appropriate for these analyses. On this basis, feasibility level analyses indicate that all of the proposed levee configurations meet this factor of safety. As indicated above, Sections G1, G4, G5, G6, and G8 may require geogrid or geotextile to meet adequate factors of safety for end-of-construction or long-term stability. For these sections, a geogrid or geotextile was included at the base of the levee for evaluating waterside rapid drawdown stability. The rapid drawdown stability criteria should be revisited after the system hydraulic loading is better defined to confirm that the feasibility level criteria are appropriate for final design.

Table 5 and Figures C-1 through C-41 present factor of safety results for end-of-construction, steady-state, and waterside rapid drawdown stability analyses.

Table 5. Slope Stability Analysis Results

Analysis Cross Section	End-of-Construction Allowable FOS = 1.3				Landside Steady-state Stability Allowable FOS = 1.4	Waterside Rapid Drawdown Allowable FOS = 1.0	Geogrid or Geotextile Included for Steady-state and Waterside Rapid Drawdown?
	Full Levee Without Geogrid or Geotextile	Full Levee With Geogrid or Geotextile	Staged Construction Without Geogrid or Geotextile				
			Stage 1	Stage 2			
G1	--	1.97	--	--	1.59	1.62	Yes
G2	2.37	--	--	--	2.51	1.88	No
G3	1.58	--	--	--	1.72	1.19	No
G4	1.33	1.42	1.64	1.48	2.15	1.17	Yes
G5	1.30	1.38	1.59	1.46	2.40	1.21	Yes
G6	1.25	1.32	1.56	1.39	1.74	1.20	Yes
G7	2.19	--	--	--	2.37	1.67	No
G8	--	1.54	--	--	1.49	1.93	Yes

6.7 Levee Seepage and Underseepage

Steady-state seepage analyses were performed for each representative cross section for a design water surface at Elevation 14 feet, using the finite element computer program SEEP/W (GEO-SLOPE, 2015). Boundary conditions used for the SEEP/W modeling are as follows:

- Nodes along the waterside ground surface and levee slope were set to a constant-head of 14 feet, corresponding to the design water surface.
- Nodes along the waterside vertical edge were set to a no flow boundary condition.
- Nodes along the bottom of the model were set to a no flow boundary condition.

- Nodes on the landside vertical edge were set to a constant head equal to the lower of the landside levee toe elevation or the elevation of the landside edge of the model.
- Nodes on the landside levee slope and the landside ground surface were modeled as potential seepage surfaces.
- The Section G1 seepage model contains the following exceptions to the above general boundary conditions due to the presence of two parallel ditches of unknown depth located landside of the levee. For the purpose of these feasibility analyses, the ditch bottoms were assumed to be at Elevation 3 feet.
  - The landside vertical edge was set to a constant head of 4 feet, corresponding to the estimated typical groundwater elevation within the landside area.
  - Constant head boundary conditions equal to 4 feet were set within the ditches to simulate being filled with water up to Elevation 4 feet.

For each cross section, the soil stratigraphy used for end-of-construction and rapid drawdown stability analysis was also used for steady-state seepage and stability analyses. The one exception to this was at cross section G6 where some of the current and past explorations in the area encountered sandy soil within the YBM. To account for the potential effects of seepage through such material, a sandy sublayer was incorporated into the YBM layer for seepage and subsequent landside steady-state stability analyses. The analyses have been performed based on engineering judgment to select fine grained (clay) levee fill soil permeability properties that are typical for levees in the South Bay. These properties will need to be verified once a borrow source is identified during final design.

The results of the seepage analyses are presented in Table 5 and Figures D-1 through D-16. The analysis results indicate that the average vertical exit gradients at the landside levee toe are less than 0.5, which is the USACE criterion (USACE, 2000). Based on these analyses, it is anticipated that levee seepage and underseepage will not be significant issues for these proposed levees. However, more detailed subsurface explorations meeting minimum FEMA and USACE guidance will need to be performed as part of final design. Remedial measures to address underseepage deficiencies may be required.

Table 6. Underseepage Analysis Results

Analysis Cross Section	Gradient Calculation Location	Calculated Average Exit Gradient
G1	Levee toe Drainage ditch landward of levee toe	0.40 0.31
G2	Low point near levee toe	0.03
G3	Levee toe	0.13
G4	Low point near levee toe	0.04
G5	Levee toe	< 0.01
G6	Levee toe	0.10
G7	Levee toe	< 0.01
G8	Levee toe Drainage ditch landward of levee toe	0.30 0.46

6.8 Seismic Considerations

6.8.1 Seismicity

The site is located in a seismically active region of California. Significant earthquakes in the Bay Area have been associated with movements along well-defined fault zones. Earthquakes occurring along any of a number of other Bay Area faults have the potential to produce strong ground shaking at the site.

6.8.2 Liquefaction and Seismic Stability

Soil liquefaction is a phenomenon in which saturated (submerged), cohesionless soil experiences a temporary loss of strength due to buildup of excess pore water pressure during cyclic loading induced by an earthquake. The soils most susceptible to liquefaction are loose, clean, saturated, poorly (uniformly) graded sand, and non- to low-plasticity silt or silty sand. Denser soils are more resistant to seismic liquefaction than looser soils. Soils with significant fines content are more resistant to seismic liquefaction than clean sands. Also, during an earthquake, unsaturated granular soils (above the groundwater table) might experience dynamic densification due to reorientation and compaction of the soil particles.

The majority of the current and past explorations performed along the project alignment indicate that the site is predominantly underlain by soil with relatively high clay content and/or consists of relatively dense granular (sand and gravel) material that is considered to have a low potential for liquefaction. Zones of loose to medium dense granular material were encountered in some of the borings and CPTs. As these zones were only encountered in some of the borings and CPTs, and at various depths, it is judged that these zones of potentially liquefiable soil are of limited lateral extent.

Following the guidance presented in the Urban Levee Design Criteria (ULDC, 2012) by the California Department of Water Resources (DWR), the potential for liquefaction was evaluated using a 100-year return period seismic event corresponding to the 100-year return period event used for flood protection assessment. A 100-year return period event with a peak ground acceleration of 0.27 times the acceleration of gravity (0.27g) corresponding to an M_w 6.6 earthquake was selected for analyses. These input values were selected using the USGS 2008 PSHA Interactive Deaggregation tool with a $V_{s,30}$ (average shearwave velocity in the top 30 meters of the soil profile) of 183 m/s (600 ft/s) (USGS, 2008b). On this basis, we estimate liquefaction-induced settlements of less than 0.25 inches to about 1 inch could occur in explorations CPTs C-02, -03, -04, and -05 and Borings B-01, -02, -03, -06. In explorations CPT C-06 and Boring B-05, along Reach 7, we estimate liquefaction induced settlements of up to 1.5 inches could occur. Developing estimates of the magnitudes of vertical or lateral deformations due to liquefaction is beyond the scope of this feasibility level study. However, because of the isolated nature of these potentially liquefiable soil zones, we judge that the effects of liquefaction and other seismically-induced vertical or lateral deformations on the proposed levees (and floodwalls) would be relatively small. We note that even if the effects of liquefaction or other seismically-induced deformations were more severe, the ULDC does not recommend that mitigation of the levee and underlying soil must be undertaken. Rather, it recommends that a rough estimate of the seismic damage to the levee (or floodwall) system be made, and a post-earthquake remediation plan be prepared and put in place including immediate restoration of flood protection to a minimum 10–year event and plans restore full protection in a period of 6 months or prior to the next flood season, whichever is less. The ability to restore flood protection for levees underlain by YBM needs to be carefully evaluated and if needed, measures to improve seismic stability may be appropriate.

7 Feasibility Level Recommendations

7.1 Levees

From a geotechnical perspective, earthen levees can be used to provide flood protection along the majority of the proposed project alignment. There are relatively short segments where levees are not practical and alternative flood protection systems may be required. Such systems consist primarily of floodwalls and floodgates, and are discussed below.

Our feasibility level levee recommendations from a geotechnical perspective are summarized below, by project reach. There may be other design, permit and construction considerations that could modify these recommendations and should be addressed during future phases of the project. For each reach, the estimated target crest elevation is presented. This target crest elevation is presented on the assumption described in Section 6 and that the levees will be constructed in one stage and includes an overbuild amount to account for settlement, with the goal that the levee will have final crest height at Elevation 16 feet. The minimum levee geometry (crest width, slope inclination and extent below existing ground surface following trench excavation) should be established following the guidance outlined above in Section 6.4.

- Reach 1, Option 2 – Along Cargill salt pond, construct levee to a crest height at Elevation 17 feet.
- Reach 2, Option 1 – Construct levee to a crest height at Elevation 17 feet. If included, construct transition zone to a height of Elevation 14 feet at the levee, and sloping away from the levee.
- Reach 2, Option 2 – This option was dropped from consideration.
- Reach 3 - Construct levee to a crest height at Elevation 17 feet. If included, construct transition zone to a height of Elevation 14 feet at the levee, and sloping away from the levee.
- Reach 4 – Construct levee to a crest height at Elevation 17.5 feet.
- Reach 5/6, Option 1– i) Between Reach 4 and the east end of Ravenswood Slough: Construct levee to a crest height at Elevation 18 feet; ii) Between east end of Ravenswood Slough and east end of Pond R2: Construct levee to a crest height at Elevation 18.5 feet, and transition zone to a height of Elevation 14 feet at the levee, and sloping away from the levee; iii) Along south side of Highway 84, between intermediate levee in Pond SF2 and a point about 1,000 feet northeast of University Avenue: Construct levee to a crest height at Elevation 18.5 feet; iv) Along south side of Highway 84, between a point about 1,000 feet northeast of University Avenue to Reach 7: Construct levee to a crest height at Elevation 18 feet.
- Reach 5, Option 4 – i) Between Reach 4 and the east end of Ravenswood Slough: Construct levee to a crest height at Elevation 18 feet; ii) Between east end of Ravenswood Slough and east end of Pond R2: Construct levee to a crest height at

Elevation 18.5 feet, and transition zone to a height of Elevation 14 feet at the levee, and sloping away from the levee; iii) Between east end of Pond R2 and Reach 7: Construct levee to a crest height at Elevation 19 feet (except where floodwall is anticipated as discussed in Section 7.2).

- Reaches 7, 8 and 9 - Construct levee to a crest height at Elevation 17 feet. If included, construct transition zone to a height of Elevation 14 feet at the levee, and sloping away from the levee.

7.2 Floodwalls

Where spatial or other constraints exist that do not allow for the construction of levees, floodwalls can be considered. Even though a floodwall needs much less lateral space than a levee, some amount of space would still be needed for the wall footing as well as for construction. For feasibility level planning purposes, we anticipate that flood walls be considered in lieu of levees for the following segments:

- Reach 1, Option 1 – Along Marsh Road to the on ramp to Highway 101.
- Reach 1, Option 2 – Along the Redwood City/Menlo Park border, from the levee along the southern edge of the Cargill salt pond and the Highway 101 sound wall.
- Reach 5, Option 4 – Around the end of the embankment of the Dumbarton Bridge approach.

For the purpose of evaluating options, an inverted T-shaped floodwall can be considered, where the footing width is approximately equal to the wall height. Thus, a 12-foot high floodwall (measured from the bottom of the wall foundation to the top of the wall) would require a 12-foot wide footing plus additional width for construction. Special considerations will be required where floodwalls transition into levees, which are beyond the scope of these feasibility level studies.

7.3 Floodgates

There are several existing roadways that cross the proposed flood protection alignments. Where it is impractical to raise these roadways to an elevation sufficient to provide flood protection, a passive flood gate structure, capable of providing the required flood protection, should be considered. Floodgate transitions to floodwalls and levees require special considerations, which are beyond the scope of these feasibility level studies.

7.4 Penetrations

Penetrations and encroachments into the levee prism are generally not recommended, although they may be necessary. Where crossings occur, they should be located above the design water surface elevation, within the freeboard area of the levee. An assessment of all levee penetrations should be conducted to determine their location, depth, material type and age, and to determine if penetrations will require remediation/relocation as part of the flood protection system.

It is generally not recommended that pipes and conduits be located beneath or within 10 feet of the toes of levees or floodwalls. Such pipes and conduits can serve as pathways that increase the potential for seepage, erosion and other related consequences that can impact the integrity of the levee or floodwall. Consideration should be given to relocating existing pipes and conduits that are within this zone to other areas. Where such relocation is not feasible, measures should be taken to protect the levee/floodwall and pipe/conduit.

7.5 Open Channels

There are several existing drainage channels that are located along the proposed levee alignments. These ditches may need to be relocated as appropriate to meet drainage and/or regulatory requirements.

7.6 Utility Poles and Towers

It is generally not recommended that utility poles and towers be located within 10 feet of the toes of levees or floodwalls. Such encroachments can serve as pathways that increase the potential for seepage, erosion and other related consequences that can impact the integrity of the levee or floodwall. The presence of such encroachments can also interfere with access for normal maintenance and operations and flood-fighting activities. Consideration should be given to relocating such existing elements that are within this zone to other areas. Where such relocation is not feasible, measures should be taken to protect the levee/floodwall and utility poles and towers.

7.7 Maintenance

As a standard of practice, a minimum easement for maintenance, inspection and flood-fighting of 10 to 20 feet is required on the landside of levees. It is recommended that minimum 10-foot wide easements be obtained along the landside toe of the project, where the land is not already held in fee title by a member agency of the SFCJPA. As an alternative to this, in areas where there are space limitations, an access road along the levee crown with intermittent access ramps to access points along the landside toe may suffice.

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Figures

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Figure 1	Overall Project Site Plan
Figures 2a through 2d	Site Plans
Figures 3a through 3h	Analysis Cross-Sections

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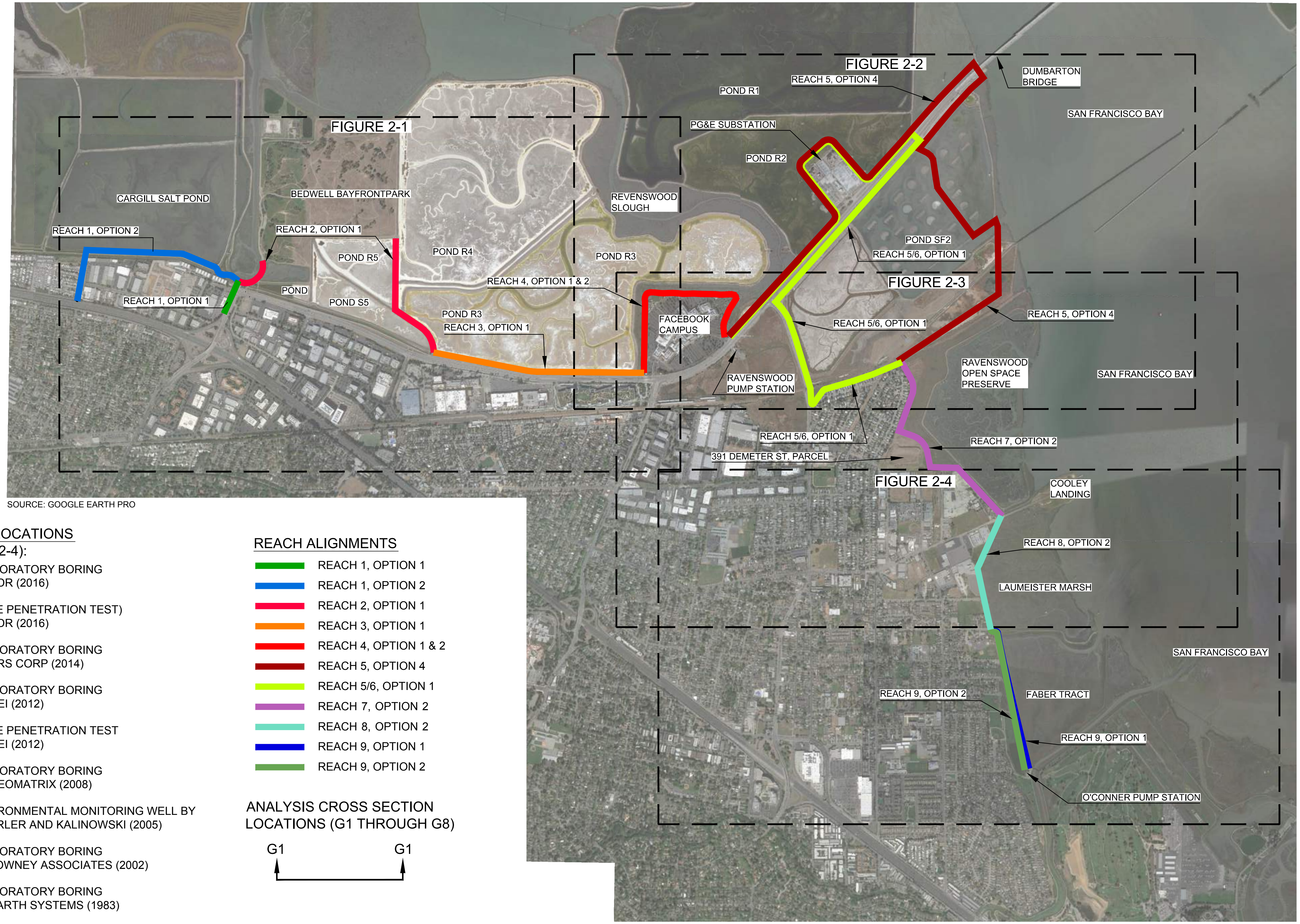


EXPLORATION LOCATIONS (FIGURE 2-1 TO 2-4):

- B-01 — EXPLORATORY BORING BY HDR (2016)
- C-02 — CONE PENETRATION TEST) BY HDR (2016)
- URS-B-13 — EXPLORATORY BORING BY URS CORP (2014)
- GEI-B-5 — EXPLORATORY BORING BY GEI (2012)
- GEI-CPT-4 — CONE PENETRATION TEST BY GEI (2012)
- SF2-2 — EXPLORATORY BORING BY GEOMATRIX (2008)
- FHW-1 — ENVIRONMENTAL MONITORING WELL BY BY ERLER AND KALINOWSKI (2005)
- LNY-EB-5 — EXPLORATORY BORING BY LOWNEY ASSOCIATES (2002)
- ES-B-5 — EXPLORATORY BORING BY EARTH SYSTEMS (1983)
- RPS-B-1, P-2, PB-18, ST-1 — EXPLORATORY BORINGS BY CALTRANS (1980 [RPS], 1994 [P], 1999 [PB,ST])

NOTE: ALL EXPLORATION LOCATIONS SHOWN ON FOLLOWING FIGURES ARE APPROXIMATE. LOCATIONS WERE ESTIMATED USING A COMBINATION OF GPS COORDINATES, OLD SITE PLANS, AERIAL PHOTOGRAPHY, AND FIELD MEASUREMENTS (NONE OF THE LOCATIONS HAVE BEEN SURVEYED BY HDR OR ITS CONSULTANTS).

REACH ALIGNMENTS

- REACH 1, OPTION 1
- REACH 1, OPTION 2
- REACH 2, OPTION 1
- REACH 3, OPTION 1
- REACH 4, OPTION 1 & 2
- REACH 5, OPTION 4
- REACH 5/6, OPTION 1
- REACH 7, OPTION 2
- REACH 8, OPTION 2
- REACH 9, OPTION 1
- REACH 9, OPTION 2

ANALYSIS CROSS SECTION LOCATIONS (G1 THROUGH G8)

G1 G1

SCALE: 1"=2,000'

2,000 0 2,000 4,000

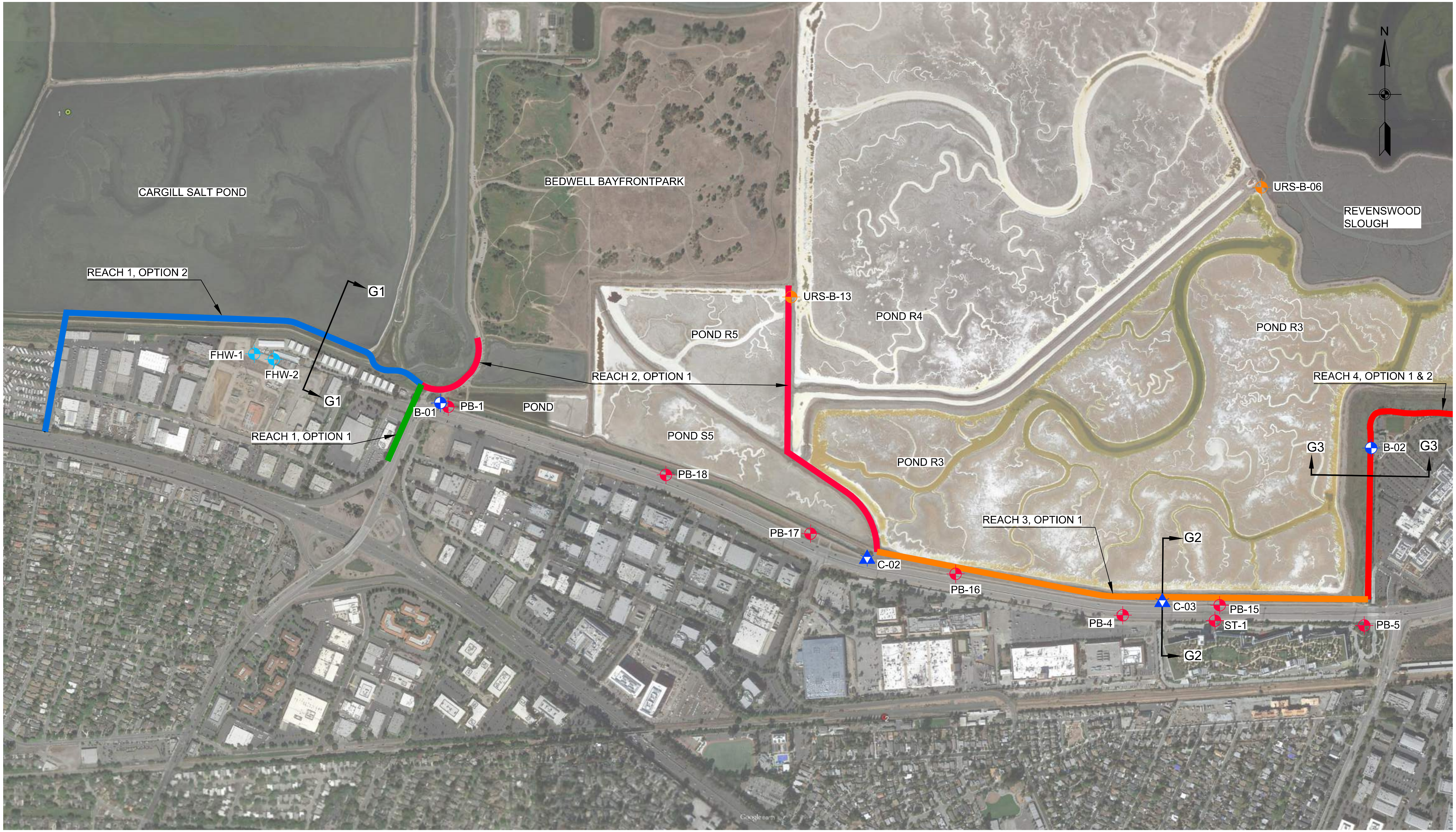
SCALE IN FEET

HDR

OVERALL PROJECT SITE PLAN

SAFER BAY PROJECT
TASK ORDER NO. 1
MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date	Figure
MAY 2016	1



SOURCE: GOOGLE EARTH PRO

NOTE: REFER TO FIGURE 1 FOR AN EXPLANATION OF EXPLORATION LOCATION SYMBOLS

SCALE: 1"=800'

800 0 800 1,600

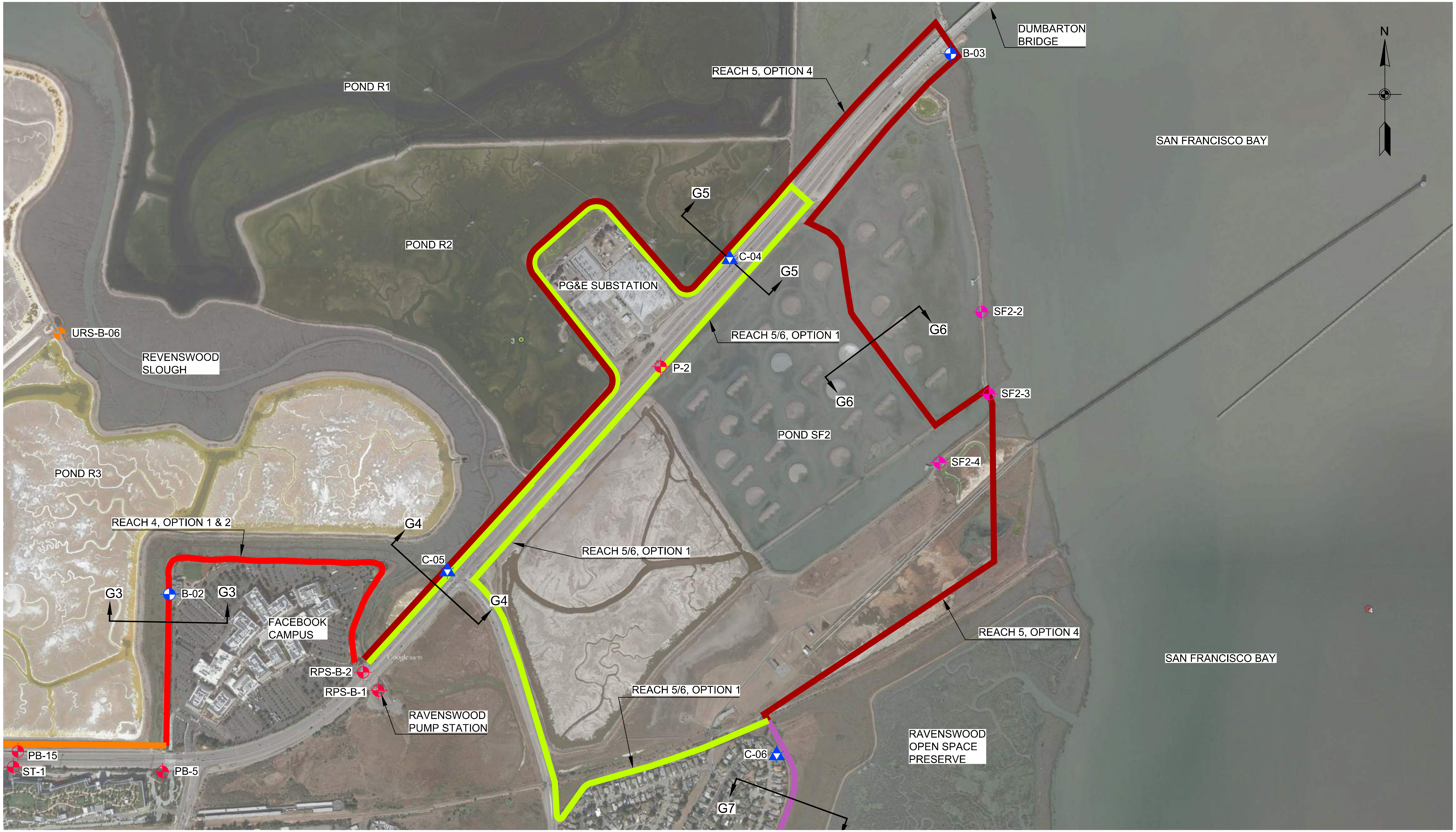
SCALE IN FEET

SITE PLAN
REACHES 1, 2 AND 3

SAFER BAY PROJECT
TASK ORDER NO. 1
MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date
MAY 2016

Figure
2a



SOURCE: GOOGLE EARTH PRO

NOTE: REFER TO FIGURE 1 FOR AN EXPLANATION OF EXPLORATION LOCATION SYMBOLS

SCALE: 1"=800'

800 0 800 1,600

SCALE IN FEET

HDR

SITE PLAN
REACHES 4, 5, AND 6

SAFER BAY PROJECT
TASK ORDER NO. 1
MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date	Figure
MAY 2016	2b

SOURCE: GOOGLE EARTH PRO

NOTE: REFER TO FIGURE 1 FOR AN EXPLANATION OF EXPLORATION LOCATION SYMBOLS

SCALE: 1"=800'

800 0 800 1,600

SCALE IN FEET

HDR

SITE PLAN
REACH 7

SAFER BAY PROJECT
TASK ORDER NO. 1
MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date	Figure
MAY 2016	2c

SOURCE: GOOGLE EARTH PRO

NOTE: REFER TO FIGURE 1 FOR AN EXPLANATION OF EXPLORATION LOCATION SYMBOLS

SCALE: 1"=800'

800 0 800 1,600

SCALE IN FEET

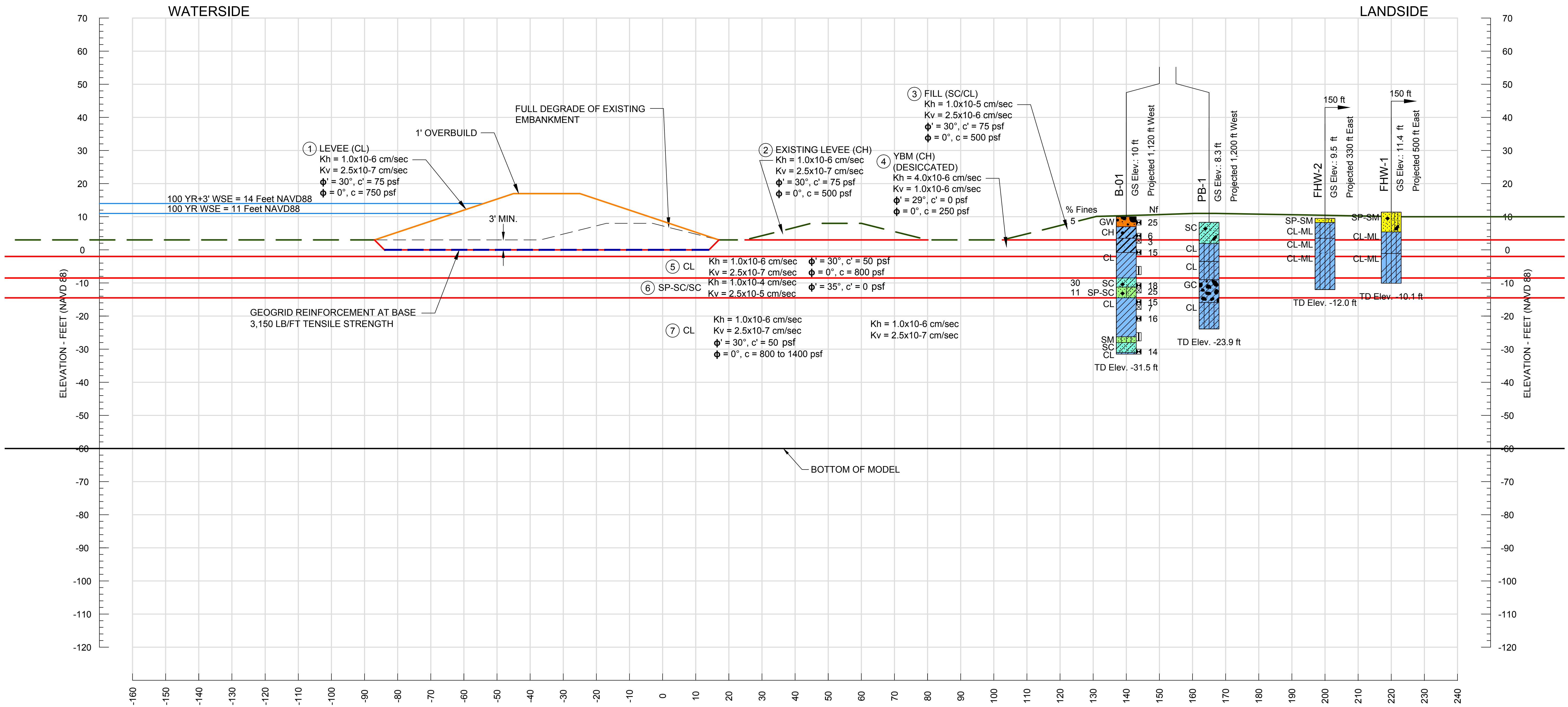
HDR

SITE PLAN
REACHES 8 AND 9

SAFER BAY PROJECT
TASK ORDER NO. 1
MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date: MAY 2016

Figure: 2d



NOTES:

1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.
2. GEOGRID REINFORCEMENT INCLUDED PRIMARILY TO IMPROVE LANDSIDE STEADY-STATE STABILITY.

1" = 30 FEET

30

SCALE IN FEET

HDR

ANALYSIS CROSS SECTION G1

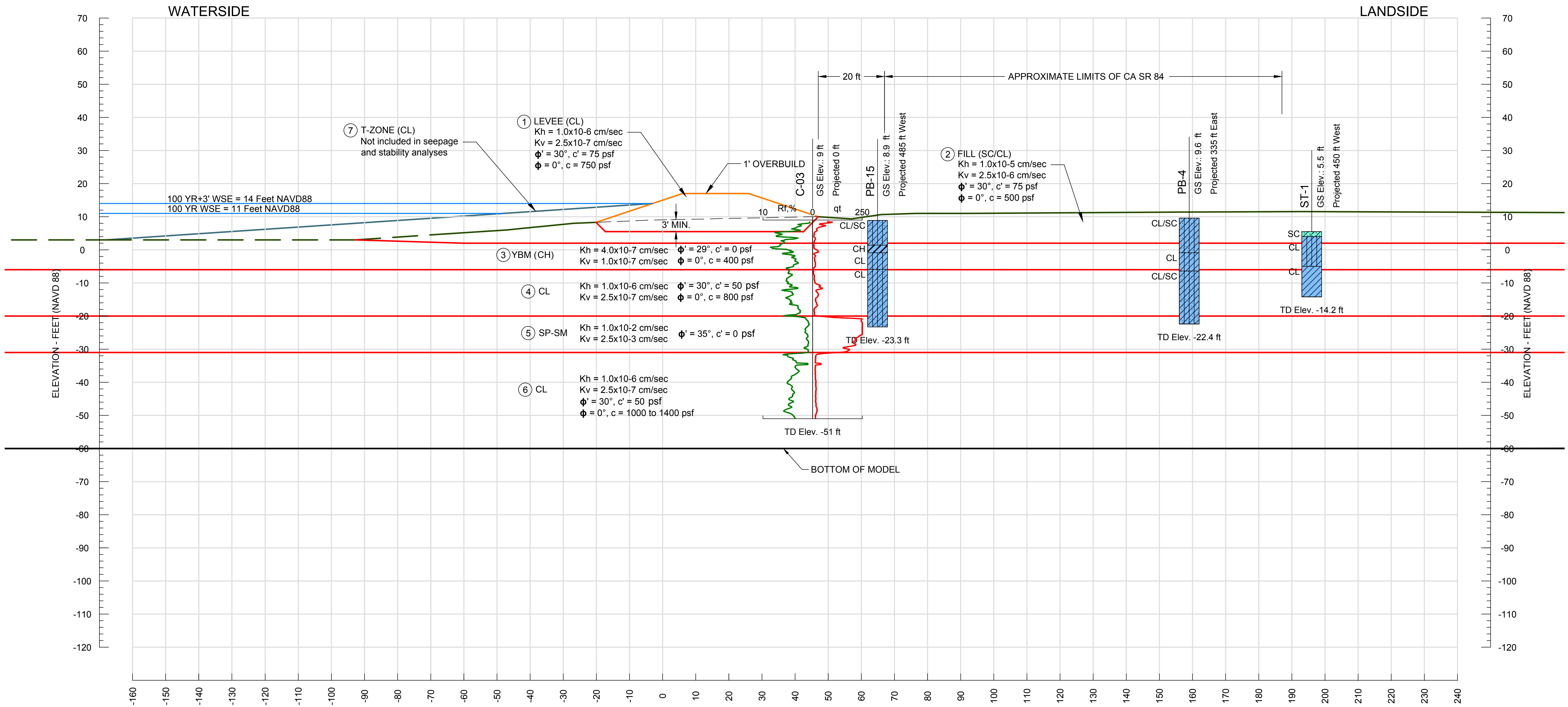
SAFER BAY PROJECT
TASK ORDER NO. 1
MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date
MAY 2016

Figure
3a

60

300



NOTES:
1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.

1" = 30 FEET

30

SCALE IN FEET

HDR

ANALYSIS CROSS SECTION G2

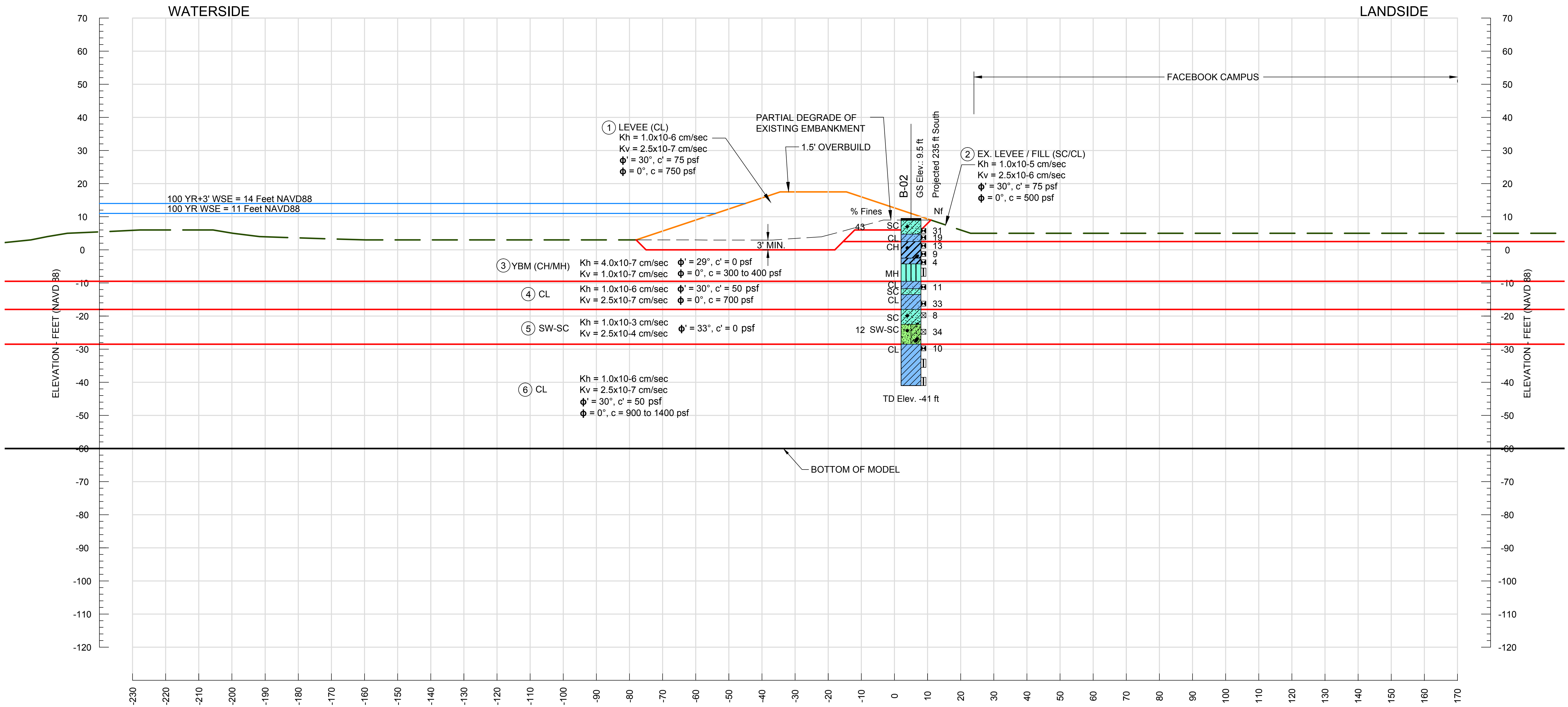
SAFER BAY PROJECT
TASK ORDER NO. 1
MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date
MAY 2016

Figure
3b

60

300



NOTES:
1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.

1" = 30 FEET

30

SCALE IN FEET

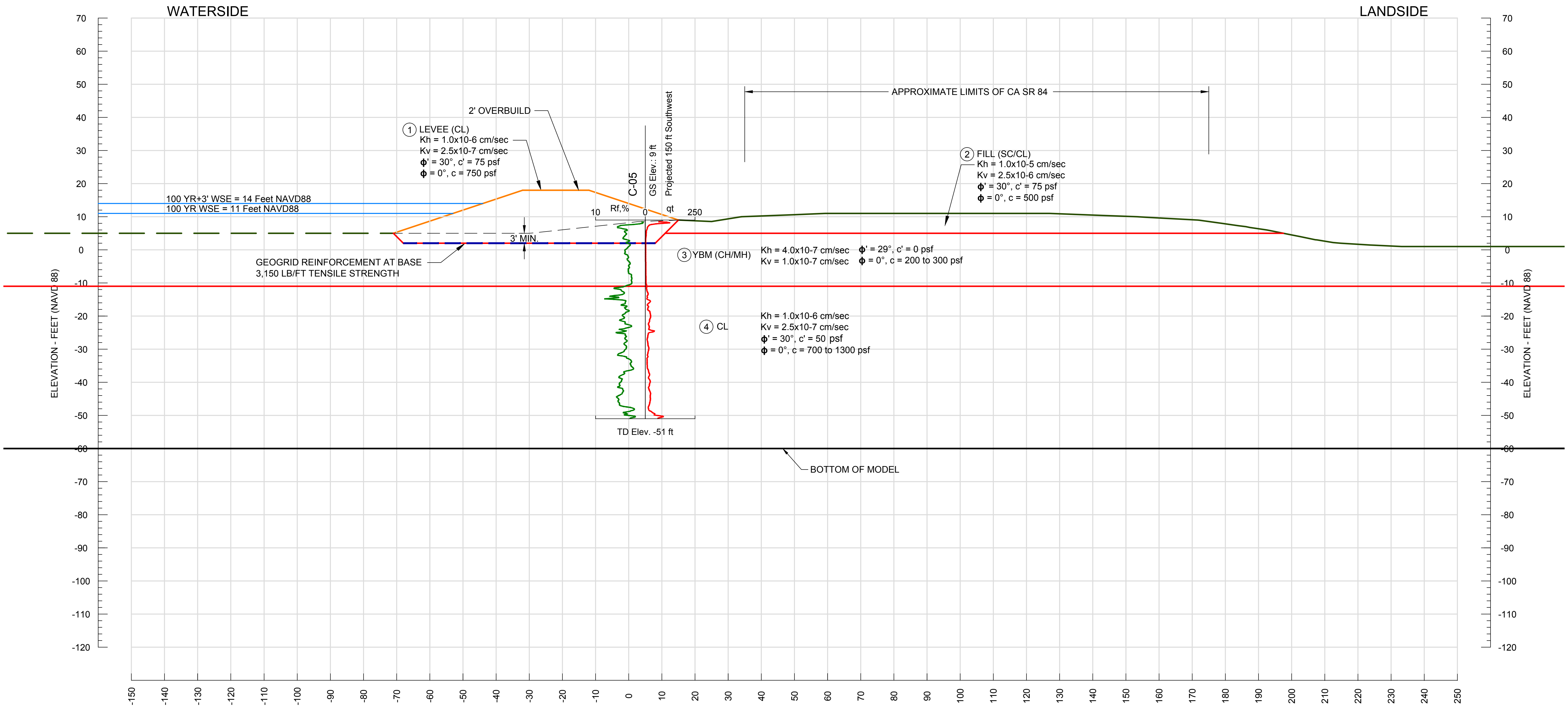
HDR

ANALYSIS CROSS SECTION G3

SAFER BAY PROJECT
TASK ORDER NO. 1
MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date
MAY 2016

Figure
3c



NOTES:
1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.
2. GEOGRID REINFORCEMENT INCLUDED PRIMARILY TO IMPROVE END-OF-CONSTRUCTION STABILITY

1" = 30 FEET

30

SCALE IN FEET

HDR

ANALYSIS CROSS SECTION G4

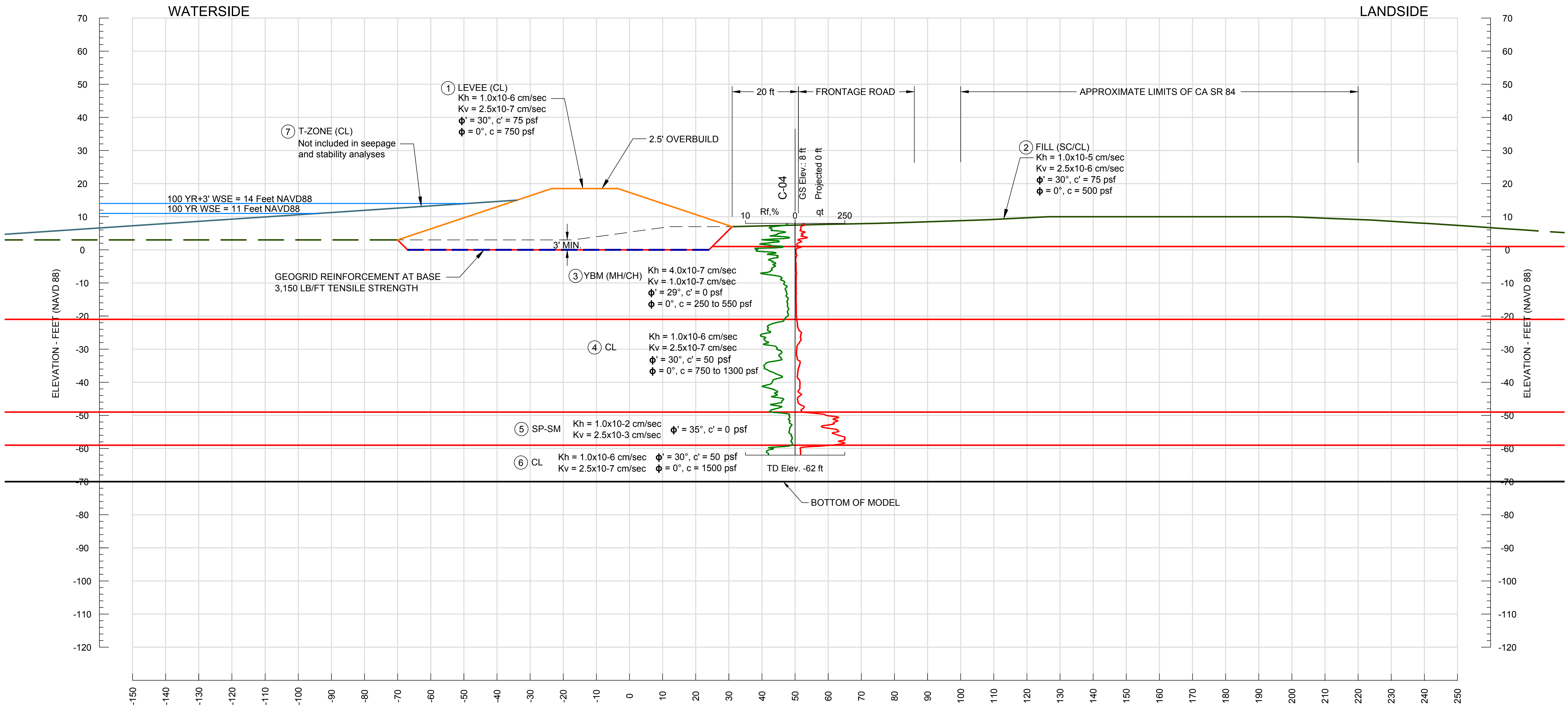
SAFER BAY PROJECT
TASK ORDER NO. 1
MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date
MAY 2016

Figure
3d

60

300



NOTES:

1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.
2. GEOGRID REINFORCEMENT INCLUDED PRIMARILY TO IMPROVE END-OF-CONSTRUCTION STABILITY

1" = 30 FEET

30

SCALE IN FEET

HDR

ANALYSIS CROSS SECTION G5

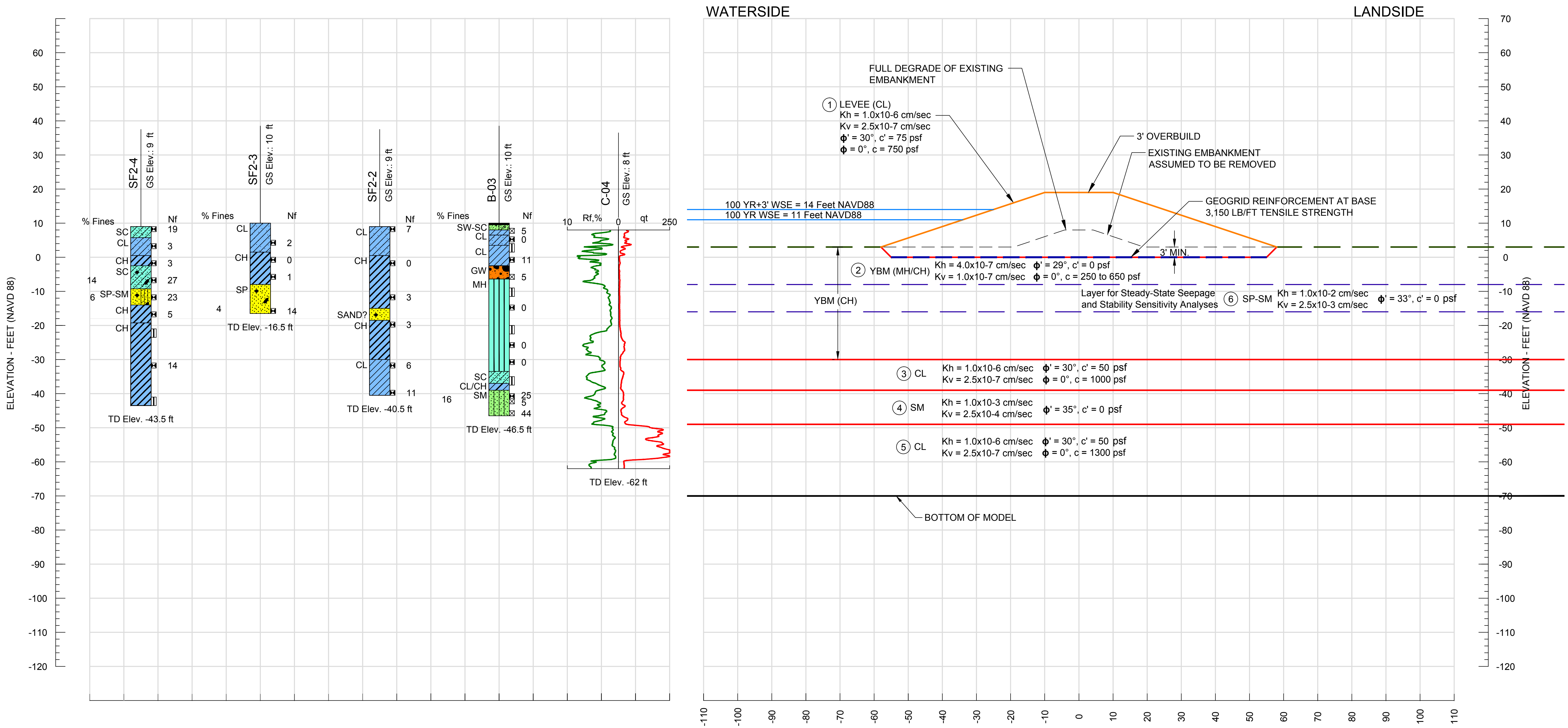
SAFER BAY PROJECT
TASK ORDER NO. 1
MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date: MAY 2016

Figure: 3e

60

300



NOTES:

1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.
2. GEOGRID REINFORCEMENT INCLUDED PRIMARILY TO IMPROVE END-OF-CONSTRUCTION STABILITY

1" = 30 FEET

30

SCALE IN FEET

HDR

ANALYSIS CROSS SECTION G6

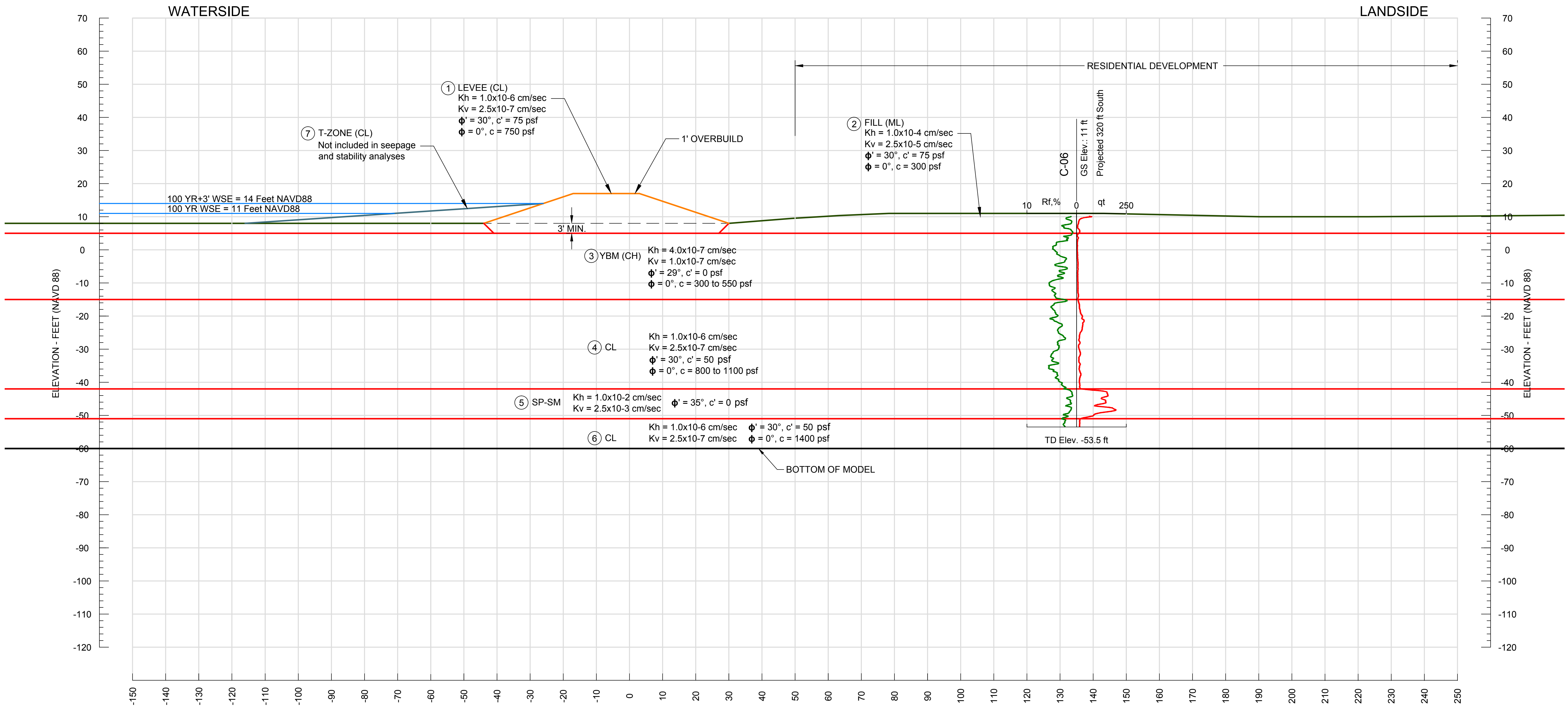
SAFER BAY PROJECT
TASK ORDER NO. 1
MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date
MAY 2016

Figure
3f

60

300



NOTES:
1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.

1" = 30 FEET

30

SCALE IN FEET

HDR

ANALYSIS CROSS SECTION G7

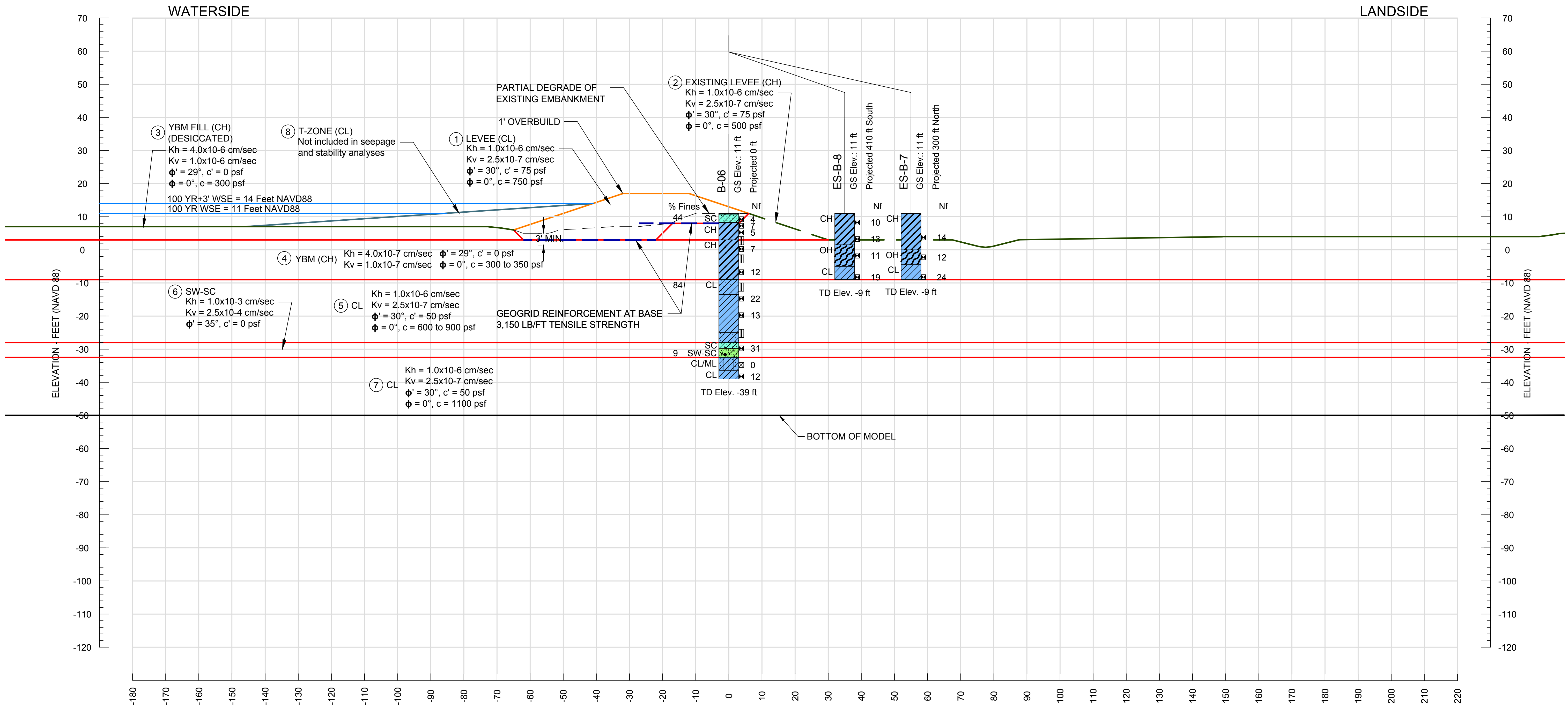
SAFER BAY PROJECT
TASK ORDER NO. 1
MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date
MAY 2016

Figure
3g

60

300



NOTES:

1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.
2. GEOGRID REINFORCEMENT INCLUDED PRIMARILY TO IMPROVE LANDSIDE STEADY-STATE STABILITY.

1" = 30 FEET

30

SCALE IN FEET

HDR

ANALYSIS CROSS SECTION G8

SAFER BAY PROJECT
TASK ORDER NO. 1
MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date: MAY 2016

Figure: 3h

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Appendix A
Logs of Test Borings and Cone Penetrometer Tests

1111 Broadway, Suite 1670, Oakland, CA **hdrinc.com**
P 510-285-1123

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UNIFIED SOIL CLASSIFICATION SYSTEM (ASTM D-2487)

MATERIAL TYPES	CRITERIA FOR ASSIGNING SOIL GROUP NAMES			GROUP SYMBOL	SOIL GROUP NAMES & LEGEND
COARSE-GRAINED SOILS >50% RETAINED ON NO. 200 SIEVE	GRAVELS >50% OF COARSE FRACTION RETAINED ON NO 4. SIEVE	CLEAN GRAVELS <5% FINES	$C_u \geq 4$ AND $1 \leq C_c \leq 3$	GW	WELL-GRADED GRAVEL
			$C_u < 4$ AND/OR $1 > C_c > 3$	GP	POORLY-GRADED GRAVEL
		GRAVELS WITH FINES >12% FINES	FINES CLASSIFY AS ML OR MH	GM	SILTY GRAVEL
			FINES CLASSIFY AS CL OR CH	GC	CLAYEY GRAVEL
	SANDS >50% OF COARSE FRACTION PASSES NO 4. SIEVE	CLEAN SANDS <5% FINES	$C_u \geq 6$ AND $1 \leq C_c \leq 3$	SW	WELL-GRADED SAND
			$C_u < 6$ AND/OR $1 > C_c > 3$	SP	POORLY-GRADED SAND
		SANDS AND FINES >12% FINES	FINES CLASSIFY AS ML OR MH	SM	SILTY SAND
			FINES CLASSIFY AS CL OR CH	SC	CLAYEY SAND
FINE-GRAINED SOILS >50% PASSES NO. 200 SIEVE	SILTS AND CLAYS LIQUID LIMIT<50	INORGANIC	PI>7 AND PLOTS>"A" LINE	CL	LEAN CLAY
			PI<4 OR PLOTS<"A" LINE	ML	SILT
		ORGANIC	LL (oven dried)/LL (not dried)<0.75	OL	ORGANIC CLAY OR SILT
	SILTS AND CLAYS LIQUID LIMIT>50	INORGANIC	PI PLOTS >"A" LINE	CH	FAT CLAY
			PI PLOTS <"A" LINE	MH	ELASTIC SILT
		ORGANIC	LL (oven dried)/LL (not dried)<0.75	OH	ORGANIC CLAY OR SILT
HIGHLY ORGANIC SOILS		PRIMARILY ORGANIC MATTER, DARK IN COLOR, AND ORGANIC ODOR		PT	PEAT

OTHER SYMBOLS

MATERIALS

- Asphalt
- Aggregate Base
- Boulders & Cobbles
- Fill
- Topsoil

SAMPLERS

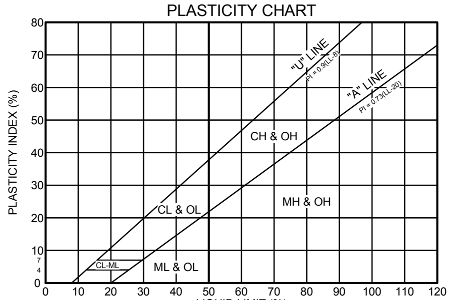
- SPT (2" OD)
- Modified California (3" OD)
- California (2.5" OD)
- Shelby Tube
- Pitcher Barrel
- HQ Core
- Grab/Bulk

PIEZOMETER

- Concrete Grout/Fill
- Bentonite/Grout Seal
- Sand Pack + Solid Pipe
- Sand Pack + Slotted Pipe

INITIAL WATER LEVEL MEASUREMENT(WITH DATE)

STABILIZED WATER LEVEL MEASUREMENT(WITH DATE)



GRAIN SIZES

U.S. STANDARD SIEVE	200	40	10	4	3/4"	3"	12"
SILTS AND CLAYS	SAND			GRAVEL		COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	COARSE		

PENETRATION RESISTANCE

SAND & GRAVEL		SILT & CLAY		
RELATIVE DENSITY	BLOWS/FOOT*	CONSISTENCY	BLOWS/FOOT*	UNC. COMP. STRENGTH (KSF)
VERY LOOSE	0 - 4	VERY SOFT	0 - 1	0 - 1/2
LOOSE	5 - 10	SOFT	2 - 4	1/2 - 1
MEDIUM DENSE	11 - 30	MEDIUM STIFF	5 - 8	1 - 2
DENSE	31 - 50	STIFF	9 - 15	2 - 4
VERY DENSE	OVER 50	VERY STIFF	16 - 30	4 - 8
		HARD	OVER 30	OVER 8

* NUMBER OF BLOWS OF 140 LB HAMMER FALLING 30 INCHES TO DRIVE A 2 INCH O.D. (1-3/8 INCH I.D.) SPLIT-BARREL SAMPLER THE LAST 12 INCHES OF AN 18-INCH DRIVE (ASTM-1586 STANDARD PENETRATION TEST).

LABORATORY TESTS

AT	ATTERBERG LIMITS
CD	CONSOLIDATED DRAINED TRIAXIAL
CN	CONSOLIDATION
CR	CORROSIVITY
CU	CONSOLIDATED UNDRAINED TRIAXIAL
DS	DIRECT SHEAR
HY	HYDROMETER
PR	PERMEABILITY
RV	R-VALUE
SA	SIEVE ANALYSIS
TC	CYCLIC TRIAXIAL
UC	UNCONFINED COMPRESSION
UU	UNCONSOLIDATED UNDRAINED TRIAXIAL
-200	% PASSING NO. 200 SIEVE

PROPERTIES

c	COHESION
DD	DRY DENSITY
EI	EXPANSION INDEX
LL	LIQUID LIMIT
MC	MOISTURE CONTENT
N_f	FIELD BLOW COUNT
PI	PLASTICITY INDEX
Su	UNDRAINED STRENGTH

UNDRAINED SHEAR STRENGTH

V	FIELD VANE
P	POCKET PENETROMETER
T	TORVANE
Q	UNCONFINED COMPRESSION
U	UNCONSOLIDATED UNDRAINED TRIAXIAL

INCREASING VISUAL MOISTURE CONTENT

WET
MOIST
DRY

HDR

Boring Legend

SAFER Bay, Task Order 1
Menlo Park and East Palo Alto, CA

Date

Figure
A-1

LEGEND_APR 2016 222952 AND 243911_SAFER BAY_WITH LAB_20160404.GPJ FOLSOM_OAKLAND_FEB 2016_WIP.GDT 4/13/16

HDR	Project: SAFER Bay, Task Order 1 Project Location: Menlo Park and East Palo Alto, CA Project Number: 028-222952	Boring ID: B-01	Sheet 1 of 2 Sheets
Start Date: 1/20/2016	End Date: 1/20/2016	Logged By: V. Crosariol	Checked By: E. Woo / Date Checked: 3/14/2016
Drilling Company (Rig Type): Pitcher Drilling Co. (Failing 1500)	Inspector: San Mateo County	Weather Conditions: Clear, moderate	
Drill Method: SFA / Mud Rotary	Drilled By: Oscar Espinosa	Elevation Top of Boring: 10.0 ft. Vertical Datum: NAVD88	
Drill Bit (Type/Size): Drag Bit / 4 7/8"	Total Depth Drilled: 41.5 ft.	Latitude: 37.486587° Longitude: -122.178338° Horizontal Datum: NAD83	
Hammer Type: Automatic	Hole Backfill: Cement grout	Northing: 2,004,008 ft. Easting: 6,074,734 ft. Coordinate System: California State Plane Zone 3	
Hammer Efficiency: 67 % / Rod Type: FEDP	Total Number of Samples: 19 Disturbed: 17 Undisturbed: 2	Initial Groundwater Depth: 6.5 ft (1/25/2016; 2:30 P) Static Groundwater Depth: Not Established	

ELEV	DEPTH	SAMPLE	Blows/6" or Press.	N_f	LEGEND	DESCRIPTION OF MATERIALS	% REC	Samp No.	Laboratory: Fines	LL	PI	DD	MC	Su (ksf)	REMARKS
						6" Aggregate Base.									Begin drilling with 6" SFA.
			6 12 13	25		**FILL (af)** Well-Graded GRAVEL with Sand (GW): medium dense, dark grayish brown mottled olive brown, moist, fine- to coarse sand, fine to coarse subangular to rounded gravel, trace medium plasticity (clay) fines.	78	L1 L2	5						Driller extracted 5" concrete chunk at 2.5' with auger.
						SANDY FAT CLAY with Gravel (CH): stiff, dark grayish brown mottled reddish brown and black, moist, high plasticity, fine to coarse sand, fine to coarse angular to subrounded gravel.		S1						1.5 P	
5	5		3 3 3	6		- medium stiff, 2" pocket of sand with silt.	50	S2 L3		54	37	103	25		
			0 1 2	3		**BAY MUD FILL OR YOUNG BAY MUD?** FAT CLAY with Sand (CH): very soft to soft, dark grayish brown mottled reddish brown and black, moist, high plasticity, fine to coarse sand, trace fine angular gravel.	0							0.5 P	Groundwater encountered at 6.5'. No recovery with SPT. Install casing to 8.5'; change to mud rotary with 4-7/8" drag bit.
0	10		1 5 10	15		**ALLUVIUM (Qal)** LEAN CLAY (CL): stiff to very stiff, gray mottled reddish brown, moist, medium plasticity, trace coarse sand and fine gravel, trace white specks.	83	L4 L5				103	24	1.8 P 1.3 T 3.5 P	
-5	15		175- 450 psi			- very stiff, increased sand content.	100	L6		35	19	104 101	20 20	3.0 P 1.3 U	UU and CN tests at 17'.
						CLAYEY SAND with Gravel (SC): medium dense, dark grayish brown, moist, fine to coarse sand, fine subangular to rounded black gravel, medium plasticity fines.									
-10	20		4 8 10	18			67	L7 L8 S4	30 11						
			4 10 15	25		Poorly Graded SAND with Clay and Gravel (SP-SC): medium dense, dark grayish brown, wet, fine to coarse sand, fine subangular to rounded gravel, medium plasticity fines.	83								
						LEAN CLAY (CL): stiff, olive brown with black specks, moist, medium plasticity, trace coarse sand, trace gravel.									Driller reported material change at 24.5'.
-15	25		6 7 8	15		- little to no gravel at 26'.	50	S5 L9						1.5 P 1.2 T 0.8 T	
			2 2 5	7			0								No recovery with SPT; driller reported slough in bottom of hole.

HDR SOIL BORING LOG_2016_R2; 222952 AND 243911_SAFER BAY_WITH LAB_20160404.GPJ; HDR_FOLSOM_OAKLAND_APRIL 2016_WIP.GLB; 4/13/16

Project: SAFER Bay, Task Order 1	Boring ID:	Sheet
Project Location: Menlo Park and East Palo Alto, CA	B-01	2 of 2 Sheets
Project Number: 028-222952		

ELEV	DEPTH	SAMPLE	Blows/6" or Press.	N_f	LEGEND	DESCRIPTION OF MATERIALS	% REC	Samp No.	Fines	LL	PI	DD	MC	Su (ksf)	REMARKS
			7 7 9	16		- with gravel at 30.5'. - gray with black specks, little to no gravel at 31'.	53	L10 L11				96	29	1.1 T 1.5 P 1.2 T	
-25	35					- olive brown.		L12							
			100- 340 psi			SILTY SAND (SM): dark grayish brown, moist, very fine sand, low plasticity fines.	100								Driller reported material change down to 38'.
						CLAYEY SAND (SC): stiff, grayish brown, moist, fine to coarse sand, medium plasticity fines.									
-30	40		2 6 8	14		SANDY LEAN CLAY (CL): stiff, grayish brown, moist, medium plasticity, fine to medium sand.	56	L13 L14	44	41	19	96	29	1.8 P 1.8 T	

Bottom of boring at 41.5 feet depth.

HDR SOIL BORING LOG_2016_R2; 222952 AND 243911_SAFER BAY_WITH LAB_20160404.GPJ; HDR_FOLSOM_OAKLAND_APRIL 2016_WIP.GLB; 4/13/16

HDR	Project: SAFER Bay, Task Order 1 Project Location: Menlo Park and East Palo Alto, CA Project Number: 028-222952	Boring ID: **B-02**	Sheet 1 of 2 Sheets
Start Date: 1/18/2016	End Date: 1/18/2016 · Logged By: V. Crosariol	Checked By: E. Woo	Date Checked: 3/14/2016
Drilling Company (Rig Type): Pitcher Drilling Co. (Fraste XL)	Inspector: San Mateo County	Weather Conditions: Overcast, cool	
Drill Method: Mud Rotary	Drilled By: Will Halai	Elevation Top of Boring: 9.5 ft. Vertical Datum: NAVD88	
Drill Bit (Type/Size): Drag Bit / 3" : Tri-cone / 5"	Total Depth Drilled: 50.5 ft.	Latitude: 37.485922° Longitude: -122.151043° Horizontal Datum: NAD83	
Hammer Type: Automatic	Hole Backfill: Cement grout	Northing: 2,003,625 ft. Easting: 6,082,648 ft. Coordinate System: California State Plane Zone 3	
Hammer Efficiency: 84 % · Rod Type: NWJ	Total Number of Samples: 21 Disturbed: 18 Undisturbed: 3	Initial Groundwater Depth: Not Established Static Groundwater Depth: Not Established	

ELEV	DEPTH	Blows/6" or Press.	N_f	DESCRIPTION OF MATERIALS	% REC	Samp No.	Fines	LL	PI	DD	MC	Su (ksf)	REMARKS
				2" Asphalt Concrete over 5" Aggregate Base.									Begin drilling with 6" Core Barrel.
				FILL (af) CLAYEY SAND with Gravel (SC): fine to coarse sand, fine to coarse gravel, medium plasticity fines.		S1	43						
5		11 15 16	31	- thin lens of SILT with Sand (ML) at 3.5'. - very stiff, reddish brown mottled olive brown, decreased gravel content.	89	L1 L2						4.5+ P 2.5 P	Install casing to 3'; change to mud rotary with 3" drag bit.
	5	8 10 9	19	SANDY LEAN CLAY (CL): stiff to very stiff, very dark gray mottled dark brown, moist, medium plasticity, fine to coarse sand, fine gravel.	50	L3		50	25	108	22	2.5 P 3.5 P	Change to 5" tri-cone bit at 5'.
		3 5 8	13	**YOUNG BAY MUD (Qbm)** FAT CLAY with Gravel (CH): stiff, very dark gray, moist, high plasticity, fine to coarse angular to rounded gravel, trace fine sand.	44	L4						1.3 T 1.5 P	Finish advancing casing at 9'.
0	10	3 4 5	9	- medium stiff.	22	L5				121	14		
		1 2 2	4	SANDY FAT CLAY (CH): soft, gray, moist, high plasticity, fine to coarse sand, fine angular gravel.	50	S2 L6 S3						0.3 T	
-5	15			ELASTIC SILT (MH): soft, very dark gray to black, moist, high plasticity, slight organic odor.		L7							Change to 3" drag bit at 15'.
				- soft to medium stiff, dark gray.	87			113	67	48 49	90 89	0.6 U 0.6 T	Shelby tube advanced with verylow (negligible) pressure. UU and CN tests at 17'.
-10	20	3 5 6	11	**ALLUVIUM (Qal)** LEAN CLAY with Sand (CL): medium stiff, gray, moist, medium plasticity, fine to medium sand.	50	S4 L8 S5						1.0 T	
				CLAYEY SAND (SC): gray, moist, fine to medium sand, medium plasticity fines.									Clay cuttings in drilling fluid at 23'.
-15	25	7 12 21	33	LEAN CLAY with Sand (CL): very stiff, yellowish brown mottled light gray, moist, medium to high plasticity, fine to coarse sand, trace oxidation staining.	67	L9 L10				115	18	3.5 P 4.0 P	Sand and gravel in drilling fluid at 27.5'.
-20		3 4 4	8	CLAYEY SAND with Gravel (SC): loose, grayish brown mottled yellow, moist, fine to coarse sand, fine subangular to subrounded gravel, medium plasticity fines.	56	S6							

Project: SAFER Bay, Task Order 1	Boring ID: B-02	Sheet 2 of 2 Sheets
Project Location: Menlo Park and East Palo Alto, CA		
Project Number: 028-222952		

ELEV	DEPTH	SAMPLE	Blows/6" or Press.	N_f	LEGEND	DESCRIPTION OF MATERIALS	% REC	Samp No.	Laboratory: Fines	LL	PI	DD	MC	Su (ksf)	REMARKS
															Drill chatter.
-25	35		14 16 18	34		Well-Graded SAND with Clay and Gravel (SW-SC): dense, grayish brown, moist, fine to coarse sand, fine angular to subrounded gravel, medium plasticity fines.	72	S7	12						
-30	40		4 4 6	10		LEAN CLAY (CL): stiff, yellowish brown, moist, medium plasticity, trace fine subrounded gravel.	28	S8							Sand and gravel in drilling fluid at 38'.
-35	45		50 psi			- medium stiff, olive gray, trace medium to coarse sand, little to no gravel.	50			49	28	91	31	1.4 U 0.9 T	Discarded 12" of gravelly slough in top of Shelby Tube sample. UU test at 44.5'.
-40	50		100-400 psi			- stiff.	80							1.1 T	Gravelly slough in top of Shelby Tube sample.

Bottom of boring at 50.5 feet depth.

HDR SOIL BORING LOG_2016_R2; 222952 AND 243911_SAFER BAY_WITH LAB_20160404.GPJ; HDR_FOLSOM_OAKLAND_APRIL 2016_WIP.GLB; 4/13/16

HDR

Project:	SAFER Bay, Task Order 1
Project Location:	Menlo Park and East Palo Alto, CA
Project Number:	028-222952
Boring ID:	B-03
Sheet	1 of 2 Sheets
Start Date:	1/22/2016
End Date:	1/22/2016
Logged By:	V. Crosariol
Checked By:	E. Woo
Date Checked:	3/14/2016
Drilling Company (Rig Type):	Pitcher Drilling Co. (Failing 1500)
Inspector:	San Mateo County
Weather Conditions:	Cloudy, drizzle
Drill Method:	SFA / Mud Rotary
Drilled By:	Oscar Espinosa
Elevation Top of Boring:	10.0 ft.
Vertical Datum:	NAVD88
Drill Bit (Type/Size):	Drag Bit / 4 7/8"
Total Depth Drilled:	56.5 ft.
Latitude:	37.498862°
Longitude:	-122.128429°
Horizontal Datum:	NAD83
Hammer Type:	Automatic
Hole Backfill:	Cement grout
Northing:	2,008,221 ft.
Easting:	6,089,290 ft.
Coordinate System:	California State Plane Zone 3
Hammer Efficiency:	67 %
Rod Type:	FEDP
Total Number of Samples:	24
Disturbed:	20
Undisturbed:	4
Initial Groundwater Depth:	3 ft (1/22/2016; 7:55 A)
Static Groundwater Depth:	Not Established

ELEV	DEPTH	SAMPLE	Blows/6" or Press.	N_f	LEGEND	DESCRIPTION OF MATERIALS	% REC	Samp No.	Fines	LL	PI	DD	MC	Su (ksf)	REMARKS
	0					2.5" Asphalt Concrete over 3.5" Aggregate Base.									Begin drilling with 6" Core Barrel. SW-SC Layer logged from cuttings.
						FILL (af) Well-Graded SAND with Clay and Gravel (SW-SC): brown, moist, fine to coarse sand, fine gravel, medium plasticity.									
			2 2 3	5			78	S1 S2							
						LEAN CLAY (CL): medium stiff, dark brown, moist, medium to high plasticity, trace fine sand.									Change to 6" SFA at 3'. Groundwater encountered at 3'.
						SANDY LEAN CLAY (CL): very soft, brown, wet, medium plasticity, trace fine sand, trace pockets of dark gray organics.									
5	5		0 0 0	0			100	L1 L2 L3		33	15	94	31	0.1 T	
								L4							
			100 psi 285 psi			LEAN CLAY (CL): stiff, yellowish brown mottled dark gray, moist, medium plasticity, trace fine sand.	73					108	21	1.9 U	Soft slough in top of Shelby Tube sample; material contact assumed from push pressure; UU test at 7'.
														2.3 P 1.4 T	Install casing to 8.5'; change to mud rotary with 4-7/8" drag bit.
0	10		0 5 6	11		- low plasticity, brown mottled dark gray at 11'. - medium plasticity at 11.5'.	39	L5						2.0 P 1.3 T	
						Well-Graded GRAVEL with Sand (GW): loose, dark gray, wet, fine to coarse angular to subangular gravel (up to 1.5"), fine to coarse sand.									Driller reported material change at 12.5'. Gravel size resembles that of railroad ballast.
-5	15		4 3 2	5			50	S3							A portion of Sample S3 may be gravel slough.
						YOUNG BAY MUD (Qbm) ELASTIC SILT (MH): soft, gray, moist, high plasticity, little to no sand, trace organics, moderate organic odor.		S4							Advance casing to 18' to prevent caving of gravel layer; 4" tri-cone bit used to clean gravel out of hole.
								L6		85	44	57	71	0.3 T	Change to 4-7/8" drag bit at 19'.
-10	20		0-100 psi				100								
												55	78	0.7 U 0.4 T	UU and CN tests at 21'.
-15	25		0 0 0	0			100	L7 L8 L9				56	76	0.3 T	

ELEV	DEPTH	SAMPLE	Blows/6" or Press.	N_f	LEGEND	DESCRIPTION OF MATERIALS	% REC	Samp No.	Laboratory Fines	LL	PI	DD	MC	Su (ksf)	REMARKS
			0- 200 psi			- soft to medium stiff, trace shell fragments.	100	L10						0.6 T	
										74	39	63	61	0.8 U 0.6 T	UU test at 32.5'.
-25	35		0 0 0	0		- soft, slight organic odor.	100	L7 L12 L13						0.4 T 0.4 T	
-30	40		0 0 0	0			100	L14 L15				65	61	0.3 T	
						CLAYEY SAND (SC): gray, moist, fine sand, low to medium plasticity fines, rapid dilatancy.									
-35	45		100 psi 200 psi				93	L16		35	13	94	27		Material contact at 47' assumed from Shelby Tube push pressure.
						LEAN to FAT CLAY (CL/CH): medium stiff, olive gray, moist, medium to high plasticity, little to no sand, trace organics, slight organic odor, trace organics.								0.9 P 0.7 T	
-40	50		5 10 15	25		**ALLUVIUM (Qal)** SILTY SAND (SM): medium dense, very dark gray, moist, fine to medium sand, low plasticity fines, occasional pockets with higher silt content. - decreased sand content.	83	L17 L18 S5	16						
			0 0 5	5			50								SPT blowcounts of 0 assumed to be due to soil disturbance.
-45	55		13 16 28	44		- dense, trace subrounded gravel.	100	S6							

Bottom of boring at 56.5 feet depth.

HDR	Project: SAFER Bay, Task Order 1 Project Location: Menlo Park and East Palo Alto, CA Project Number: 028-222952		Boring ID: B-05	Sheet 1 of 2 Sheets
Start Date: 1/20/2016	End Date: 1/20/2016	Logged By: V. Crosariol	Checked By: E. Woo	Date Checked: 3/14/2016
Drilling Company (Rig Type): Pitcher Drilling Co. (Failing 1500)		Inspector: San Mateo County	Weather Conditions: Clear, moderate	
Drill Method: SFA / Mud Rotary		Drilled By: Oscar Espinosa	Elevation Top of Boring: 11.0 ft. Vertical Datum: NAVD88	
Drill Bit (Type/Size): Drag Bit / 4 7/8"		Total Depth Drilled: 41.5 ft.	Latitude: 37.477112° Longitude: -122.134228° Horizontal Datum: NAD83	
Hammer Type: Automatic		Hole Backfill: Cement grout	Northing: 2,000,332 ft. Easting: 6,087,470 ft. Coordinate System: California State Plane Zone 3	
Hammer Efficiency: 67 %	Rod Type: FEDP	Total Number of Samples: 28 Disturbed: 26 Undisturbed: 2	Initial Groundwater Depth: 5 ft (1/20/2016; 9:00 A) Static Groundwater Depth: Not Established	

ELEV	DEPTH	Blows/6" or Press.	N_f	DESCRIPTION OF MATERIALS	% REC	Samp No.	Fines	LL	PI	DD	MC	Su (ksf)	REMARKS
				9" Asphalt Concrete.									Begin drilling with 6" Core Barrel.
10		5 11 13	24	**FILL (af)** SANDY LEAN CLAY (CL): stiff, very dark brown mottled red, moist, medium to high plasticity, fine sand.	47	S1 L1 L2		43	22	101	24	2.0 P 2.3 T	Change to 6" SFA at 1.5'
5	5	1 3 4	7	LEAN CLAY (CL): medium stiff, brown, moist, medium plasticity, trace fine sand.	67	L3 L4						0.7 T	Groundwater encountered at 5'.
						L5						0.8 P	
		100- 225 psi		SILTY SAND (SM): loose, brown, wet, fine sand, low plasticity fines.			49			102	23		Install casing to 8.5'; change to mud rotary with 4-7/8" drag bit.
	10	0 2 5	7		56	S2							
0				Poorly Graded SAND with Silt (SP-SM): loose, brown, wet, fine to medium sand.		S3							
		0 2 2	4	SILTY SAND (SM): loose, brown, wet, mostly fine sand.	100	S4 S5	30						
				SILT with Sand (ML): soft, brown, moist, low plasticity, fine sand.		S6							
				SILTY SAND with Gravel (SM): loose, brown, wet, medium to coarse sand, fine gravel (up to 3/8"), trace black asphalt fragments.									Driller reported material change at 14.5'.
-5	15	0 5 7	12	**ALLUVIUM (Qal)** LEAN CLAY (CL): stiff, dark grayish brown mottled brown, moist, medium plasticity, little to no sand.	50	L6 L7				89	34	0.7 P 1.2 T 1.1 T	
		2 7 10	17	- very stiff.	67	L8 L9						1.1 T 2.4 T	
	20			- stiff, dark grayish brown.		L10		48	27	97	26	1.5 T	
-10		125- 325 psi		LEAN CLAY (CL): medium stiff to stiff, olive gray mottled reddish yellow (oxidation staining), moist, medium plasticity, trace fine gravel (cemented sand), trace black inclusions.	100					94	27	1.0 U 0.8 P 1.0 T	UU test at 21.5'. CN test at 22'.
-15	25	11 15 20	35	- olive gray mottled dark brown at 25.5'. - very stiff, olive gray mottled yellow at 26'.	72	L11 L12				109	22	1.0 T 3.5 P 2.5 P	

ELEV	DEPTH	SAMPLE	Blows/6" or Press.	N_f	LEGEND	DESCRIPTION OF MATERIALS	% REC	Samp No.	Laboratory: Fines	LL	PI	DD	MC	Su (ksf)	REMARKS
-20			1 3 4	7		- medium stiff.	83	L13 L14		32	12	101	25	0.7 T	
-25	35		19 20 19	39		Poorly Graded SAND with Clay and Gravel (SP-SC): dense, dark grayish brown, moist, fine to coarse sand, fine gravel, trace medium plasticity fines.	83	L15 L16	8						Driller reported material change at 34.5'.
			5 8 27	35		- fine to medium sand, decreased gravel content. - lens of silty sand from 37.2' - 37.5'. LEAN CLAY (CL): hard, grayish green with reddish yellow banding (oxidation staining), moist, medium plasticity, trace coarse sand.	83	S7 S8 S9							
-30	40		24 35 42	77		- interbedded with dark gray brown and black SILTY SAND (SM) (fine to coarse sand). Poorly Graded SAND with Silt (SP-SM): dense to very dense, dark grayish brown, moist, fine to coarse sand, low plasticity fines.	89	S10 L17 L18							

Bottom of boring at 41.5 feet depth.

HDR SOIL BORING LOG_2016_R2; 222952 AND 243911_SAFER BAY_WITH LAB_20160404.GPJ; HDR_FOLSOM_OAKLAND_APRIL 2016_WIP.GLB; 4/13/16

HDR	Project: SAFER Bay, Task Order 1 Project Location: Menlo Park and East Palo Alto, CA Project Number: 028-222952	Boring ID: B-06	Sheet 1 of 2 Sheets

Start Date: 1/19/2016	End Date: 1/19/2016	Logged By: V. Crosariol	Checked By: E. Woo	Date Checked: 3/14/2016
Drilling Company (Rig Type): Pitcher Drilling Co. (Fraste XL)		Inspector: San Mateo County	Weather Conditions: Cloudy, rain, wind	
Drill Method: Mud Rotary		Drilled By: Will Halai	Elevation Top of Boring: 11.0 ft. Vertical Datum: NAVD88	
Drill Bit (Type/Size): Drag Bit / 3" : Tri-cone / 5"		Total Depth Drilled: 50 ft.	Latitude: 37.465580° Longitude: -122.125688° Horizontal Datum: NAD83	
Hammer Type: Automatic		Hole Backfill: Cement grout	Northing: 1,996,091 ft. Easting: 6,089,875 ft. Coordinate System: California State Plane Zone 3	
Hammer Efficiency: 84 %	Rod Type: NWJ	Total Number of Samples: 20 Disturbed: 16 Undisturbed: 4	Initial Groundwater Depth: Not Established Static Groundwater Depth: Not Established	

ELEV	DEPTH	Blows/6" or Press.	N_f	DESCRIPTION OF MATERIALS	% REC	Samp No.	Fines	LL	PI	DD	MC	Su (ksf)	REMARKS
				1" Asphalt Concrete over 2" Aggregate Base.									Begin drilling with 6" Core Barrel.
10		1 2 2	4	**FILL (af)** CLAYEY SAND with Gravel (SC): medium stiff, dark brown mottled light brown, moist, fine to coarse sand, fine to coarse angular gravel (up to 1.5"), high plasticity clay fines, red brick fragments.	78	S1 S2	44						
		1 3 4	7	FAT CLAY (CH): medium stiff, dark brown slightly mottled light brown, moist, high plasticity, trace sand.	28	L1				86	35	0.7 T	Install casing to 3'; change to mud rotary with 5" tri-cone bit.
5	5	0 2 3	5	- stiff, dark brown mottled grayish brown.	50	L2 L3						0.9 T 1.3 T	
				- trace fine gravel.		L4							
		<50 psi		**YOUNG BAY MUD (Qbm)** FAT CLAY (CH): medium stiff, greenish gray, moist, high plasticity, trace fine to coarse sand, trace fine angular gravel, trace organics, slight organic odor.	80			73	44	77	41	0.7 U 0.6 T 1.0 T	UU test at 8'. Change to 3" drag bit at 10'.
0	10	0 3 4	7	- greenish gray mottled very dark brown at 11'. - very dark brown to black at 11.5'.	39	L5							
		<50 psi		- greenish gray.	97	L6		54	28	80	41		
-5	15									79	41	0.5 U 0.8 T	UU test at 14.5'. CN test at 15'. Finish advancing casing at 15'.
		3 6 6	12	- stiff, dark gray. - dark greenish gray.	44	L7				97	27	2.2 T 1.8 P 2.0 T	
-10	20	300 psi		**ALLUVIUM (Qal)** LEAN CLAY with Sand (CL): stiff, olive, moist, medium plasticity, fine to coarse sand, trace fine angular gravel (up to 1/4").	100	L8	84	34	17	102	23	0.9 U 1.4 T	UU test at 21'.
-15	25	6 11 11	22	LEAN CLAY (CL): stiff to very stiff, olive mottled brown, moist, medium plasticity, trace fine to coarse sand.	67	L9 L10						3.0 T 2.0 T	

Project: SAFER Bay, Task Order 1	Boring ID:	Sheet
Project Location: Menlo Park and East Palo Alto, CA	B-06	2 of 2 Sheets
Project Number: 028-222952		

ELEV	DEPTH	SAMPLE	Blows/6" or Press.	Nf	LEGEND	DESCRIPTION OF MATERIALS	% REC	Samp No.	Laboratory: Fines	LL	PI	DD	MC	Su (ksf)	REMARKS
-20			3 6 7	13		- medium stiff to stiff, light brown mottled olive.	56	L11 L12				103	25	1.4 T 0.9 T	
	35							L13							
-25			200 psi			SANDY LEAN CLAY (CL): stiff, olive gray mottled strong brown, moist, medium plasticity, fine to coarse sand, trace fine angular gravel.	97							1.3 P	
	40					CLAYEY SAND with Gravel (SC): medium dense, grayish brown, wet, fine to coarse sand, fine angular gravel, medium plasticity fines.									
-30			11 17 14	31		Well-Graded SAND with Clay and Gravel (SW-SC): medium dense, very dark brown to black, wet, fine to coarse sand, fine subangular to rounded gravel, trace fines.	67	L14 L15	9						
-35	45		0 0 0	0		SILT with Sand to LEAN CLAY with Sand (CL/ML): very soft, grayish brown mottled strong brown, moist, low plasticity, fast dilatancy, trace fine sand.	83	S3		37	13		37		Zero blows (weight of hammer) indicates potential soil disturbance during drilling.
	50		4 5 7	12		LEAN CLAY (CL): stiff, greenish gray, moist, medium plasticity, trace fine sand.	61	L16 L17						1.6 T	

Bottom of boring at 50.0 feet depth.

HDR SOIL BORING LOG_2016_R2; 222952 AND 243911_SAFER BAY_WITH LAB_20160404.GPJ; HDR_FOLSOM_OAKLAND_APRIL 2016_WIP.GLB; 4/13/16

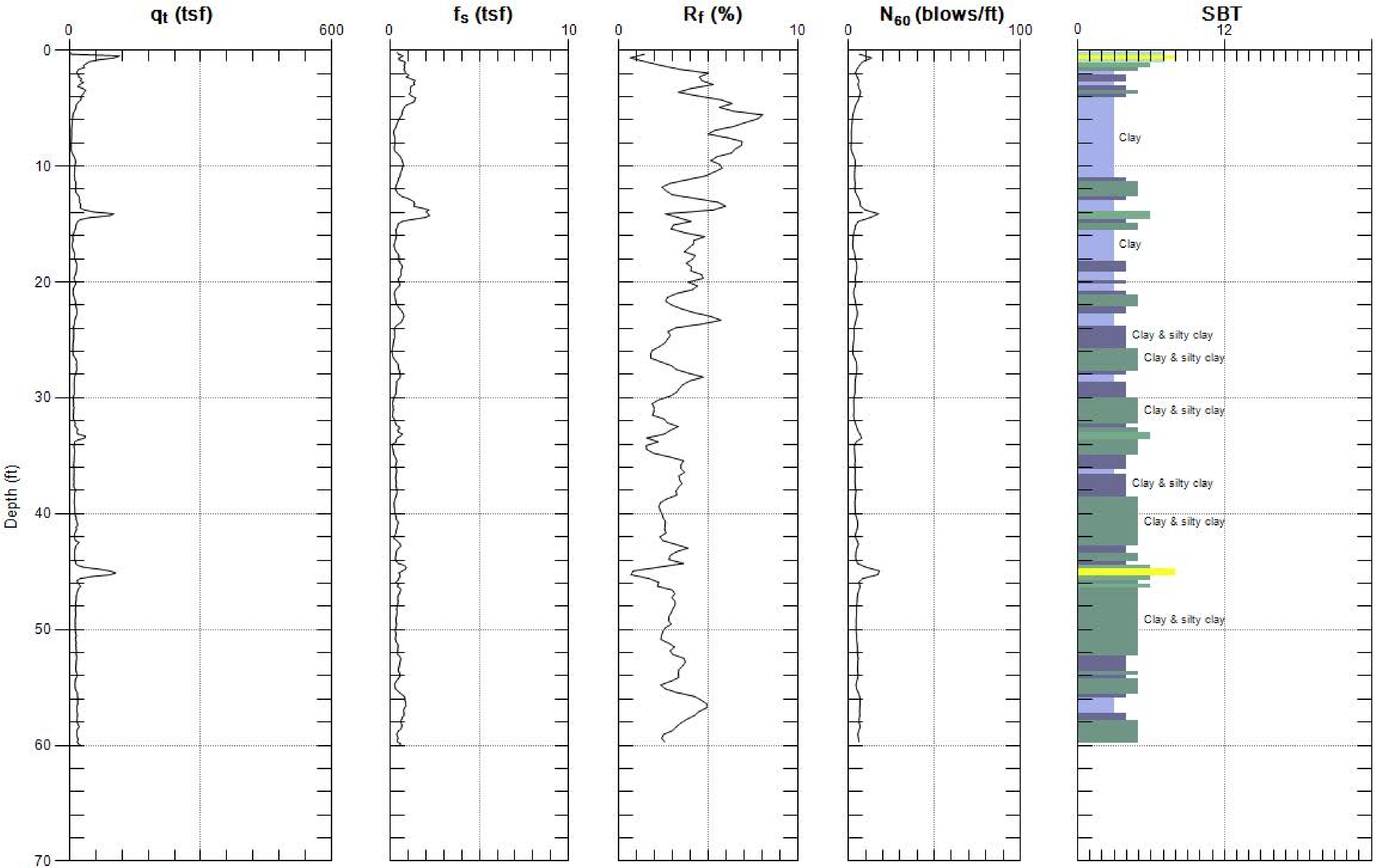
GREGG HDR

Site: SAFER BAY

Sounding: C-02

Engineer: V.CROSARIOL

Date: 1/11/2016 10:00



Max. Depth: 60.039 (ft)

Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

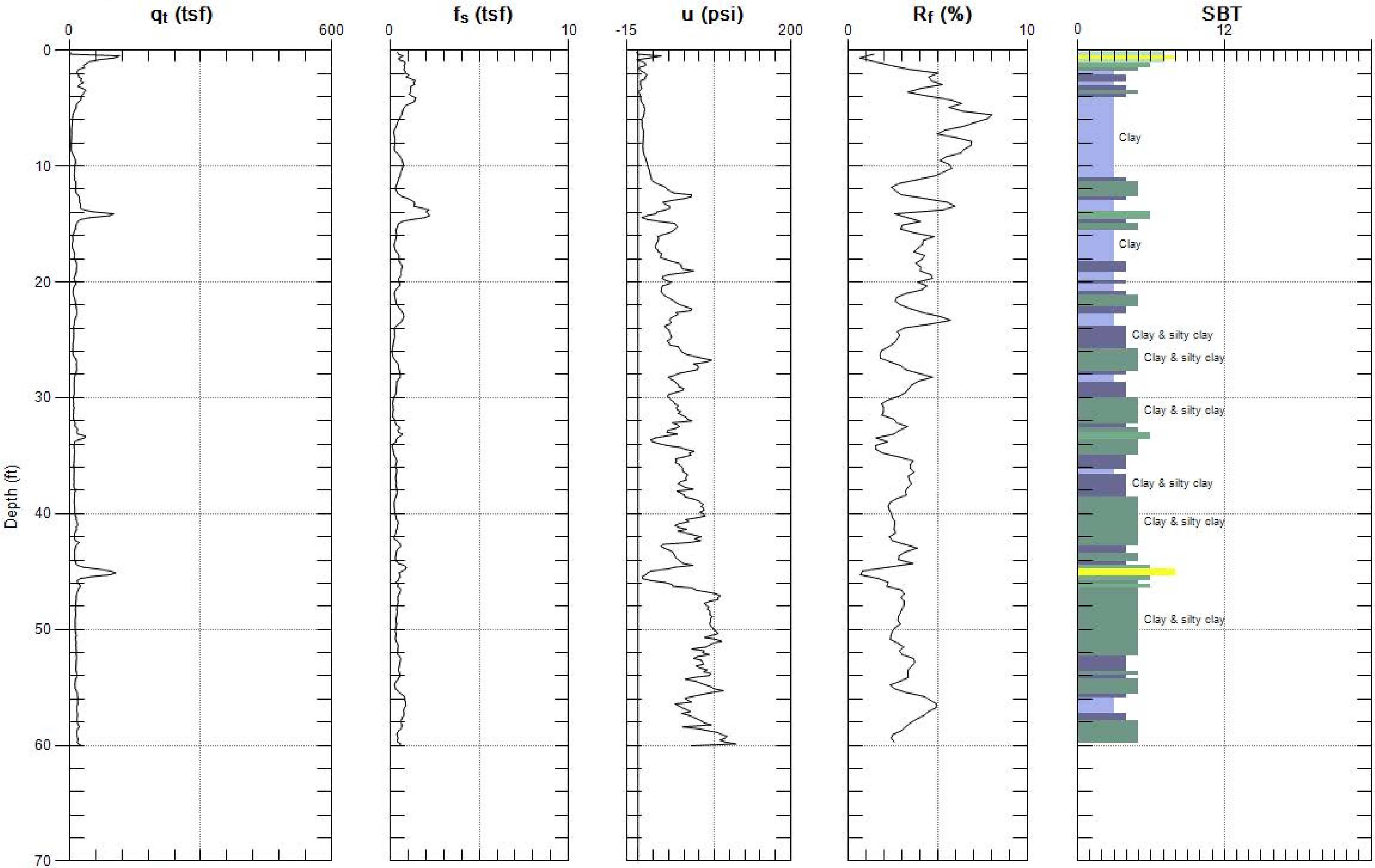
HDR

Site: SAFER BAY

Sounding: C-02

Engineer: V.CROSARIOL

Date: 1/11/2016 10:00

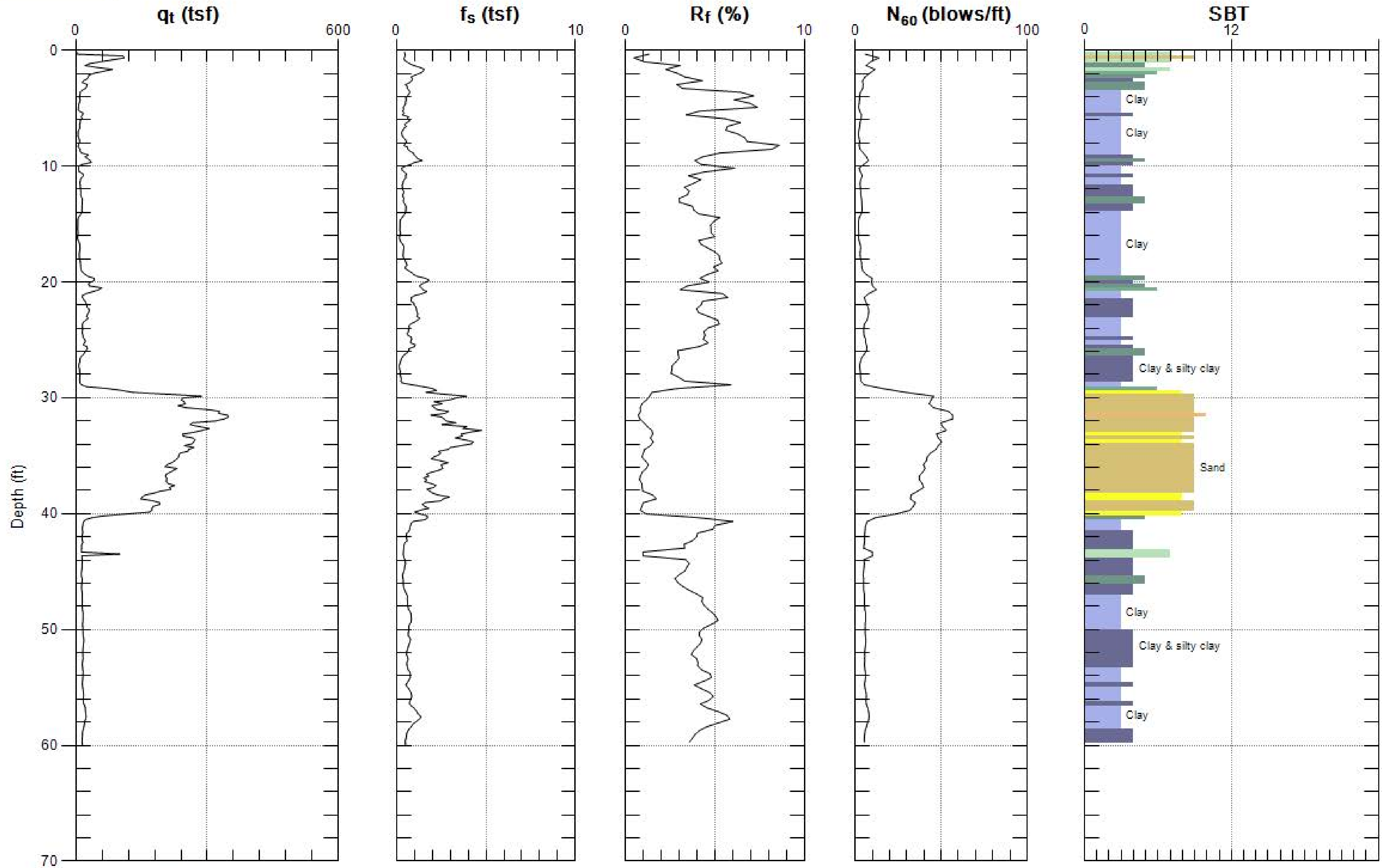


Max. Depth: 60.039 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

GREGG **HDR**

Site: SAFER BAY
Sounding: C-03
Engineer: V.CROSARIOL
Date: 1/11/2016 08:02



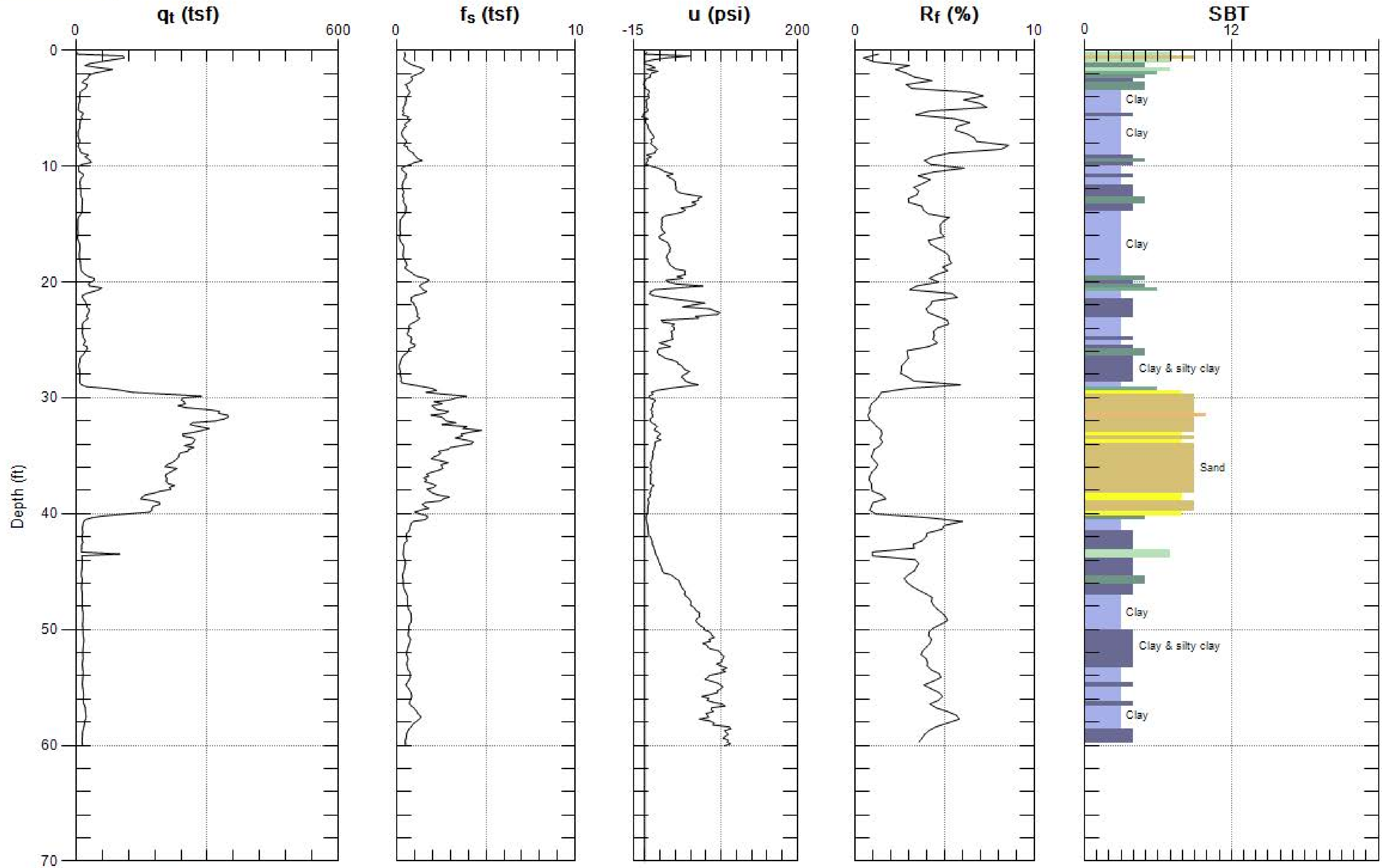
Max. Depth: 60.039 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

GREGG HDR

Site: SAFER BAY
Sounding: C-03

Engineer: V.CROSARIOL
Date: 1/11/2016 08:02



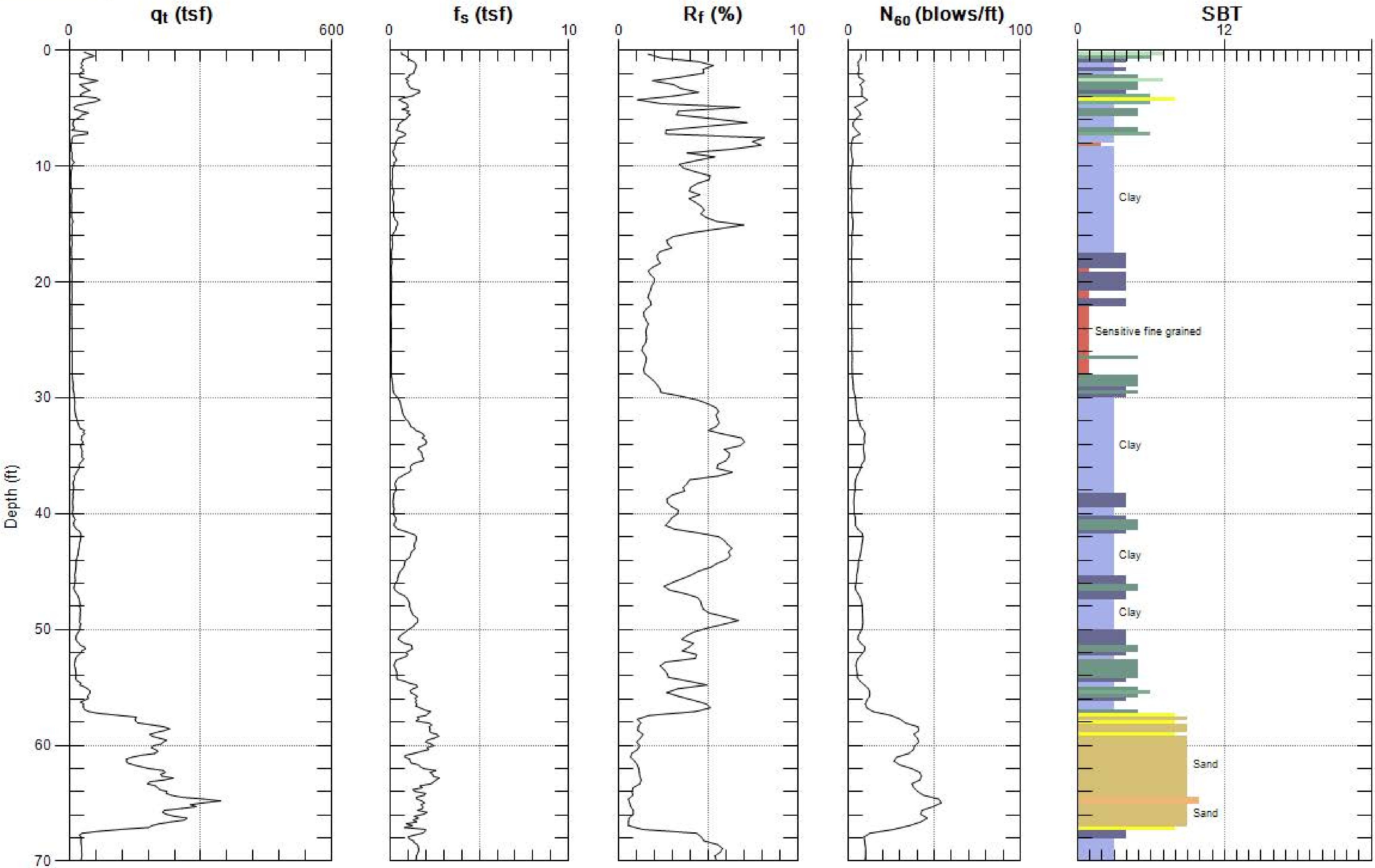
Max. Depth: 60.039 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

GREGG **HDR**

Site: SAFER BAY
Sounding: C-04

Engineer: V.CROSARIOL
Date: 1/11/2016 11:31



Max. Depth: 70.046 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

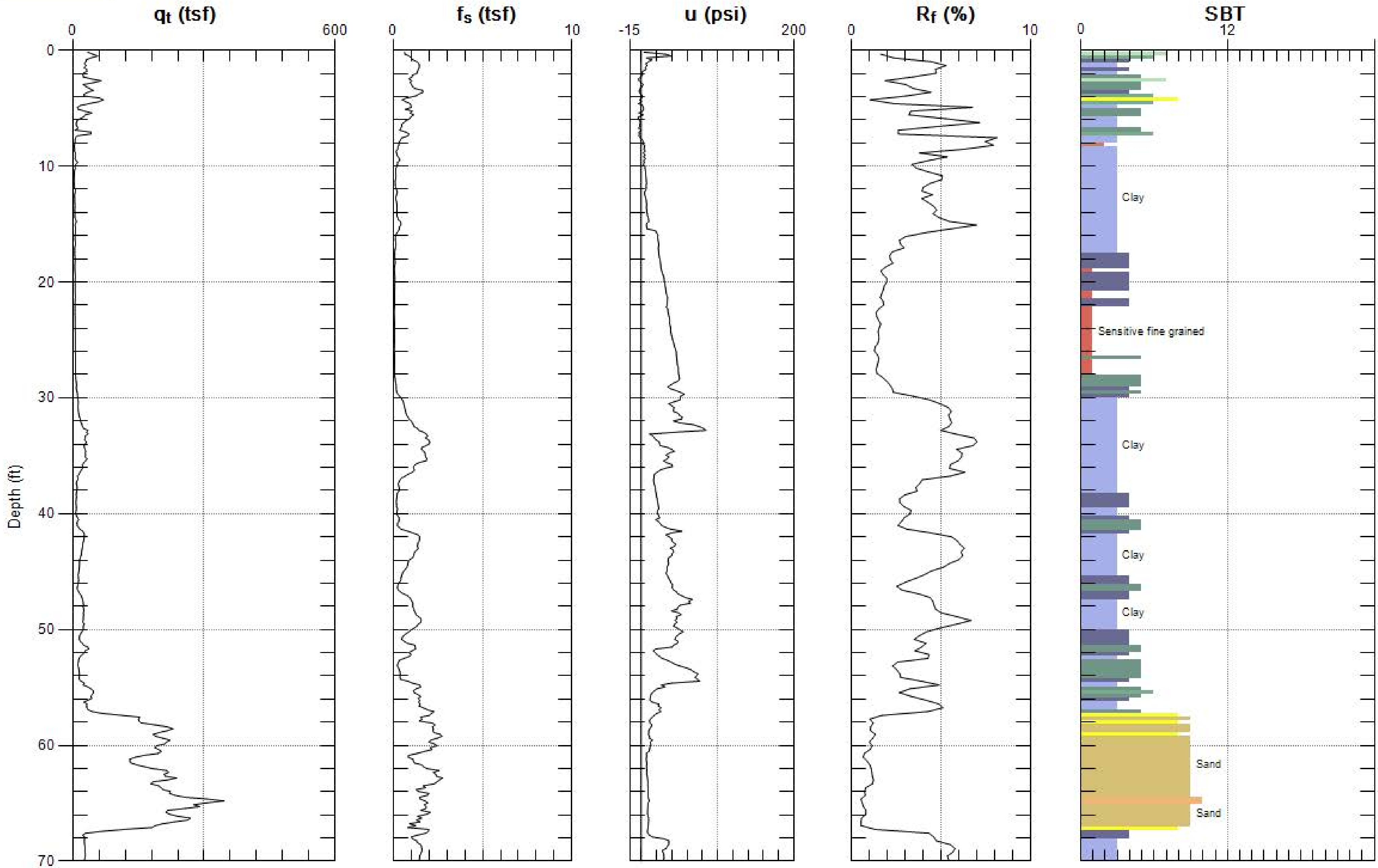
GREGG HDR

Site: SAFER BAY

Sounding: C-04

Engineer: V.CROSARIOL

Date: 1/11/2016 11:31



Max. Depth: 70.046 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

GREGG

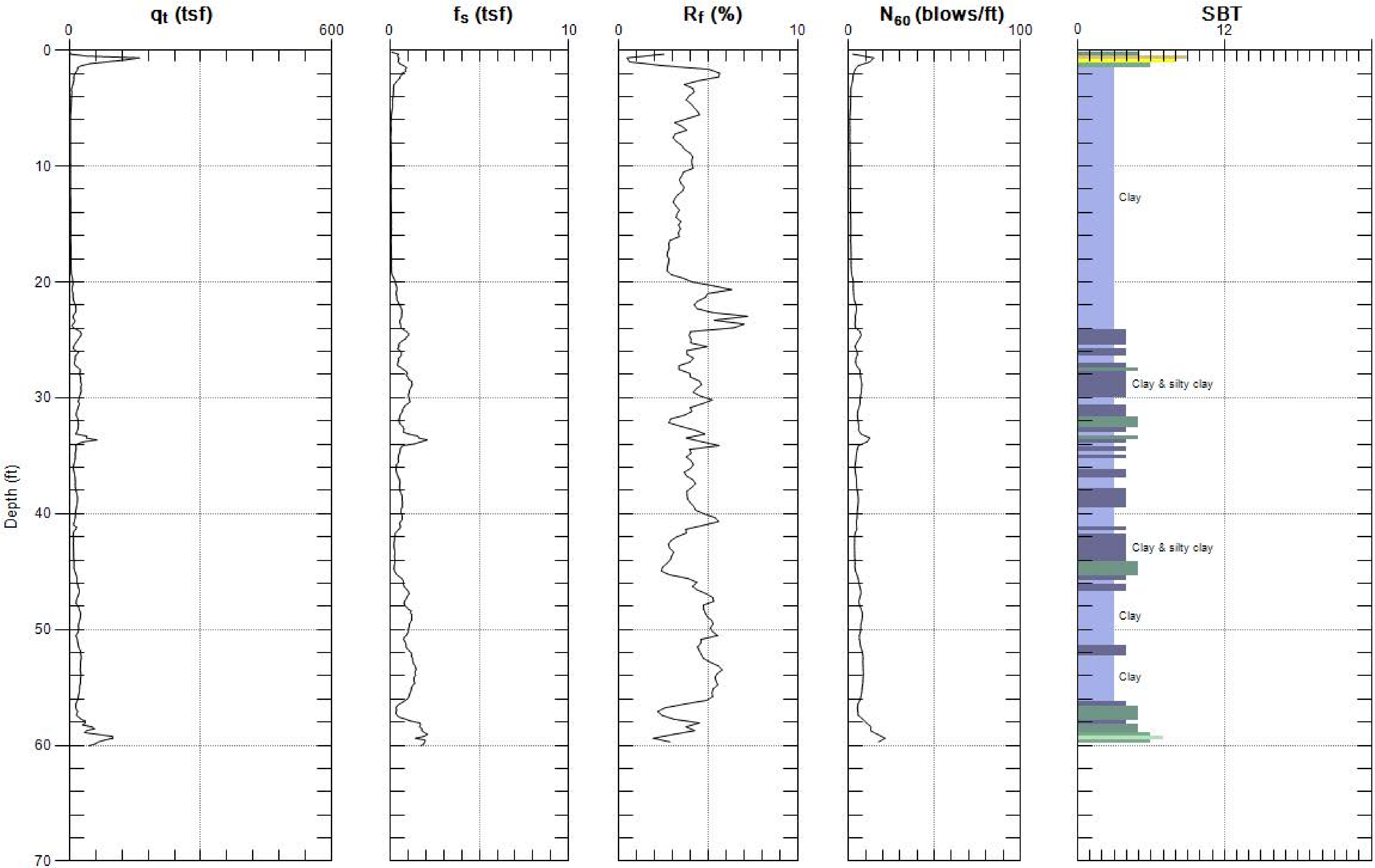
HDR

Site: SAFER BAY

Sounding: C-05

Engineer: V.CROSARIOL

Date: 1/11/2016 01:34



Max. Depth: 60.039 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

GREGG

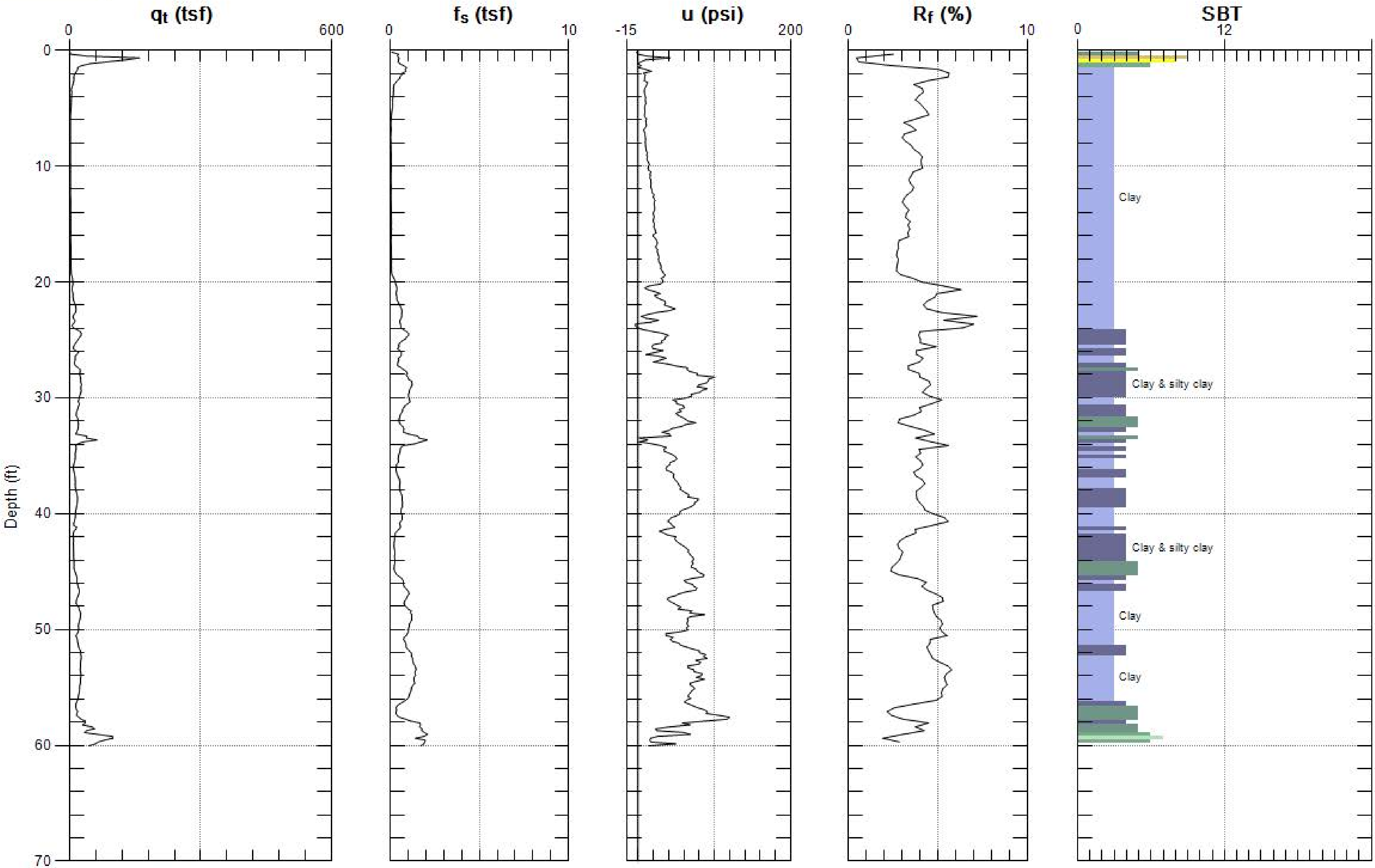
HDR

Site: SAFER BAY

Sounding: C-05

Engineer: V.CROSARIOL

Date: 1/11/2016 01:34



Max. Depth: 60.039 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

GREGG

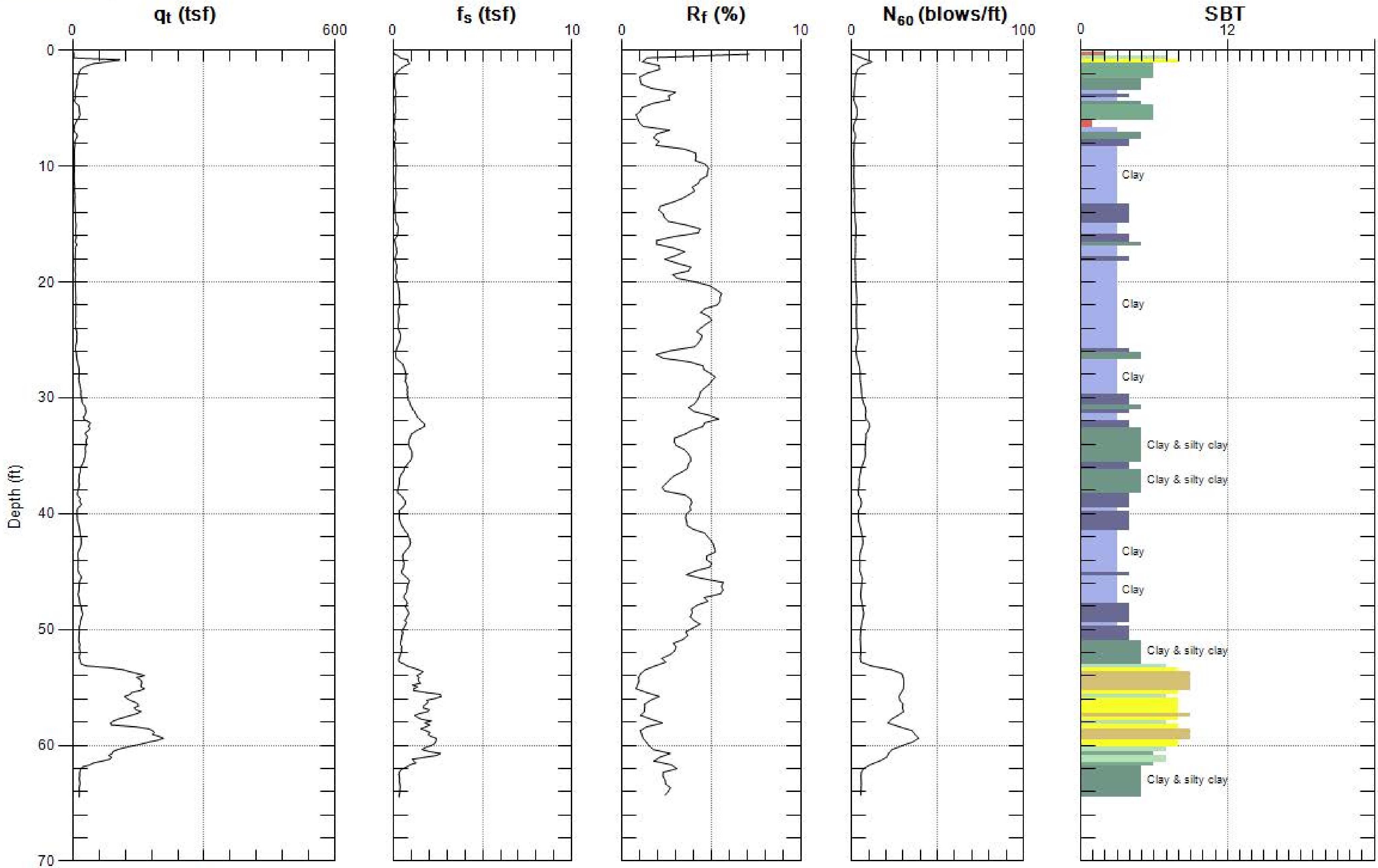
HDR

Site: SAFER BAY

Sounding: C-06

Engineer: V.CROSARIOL

Date: 1/12/2016 02:17



Max. Depth: 64.469 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

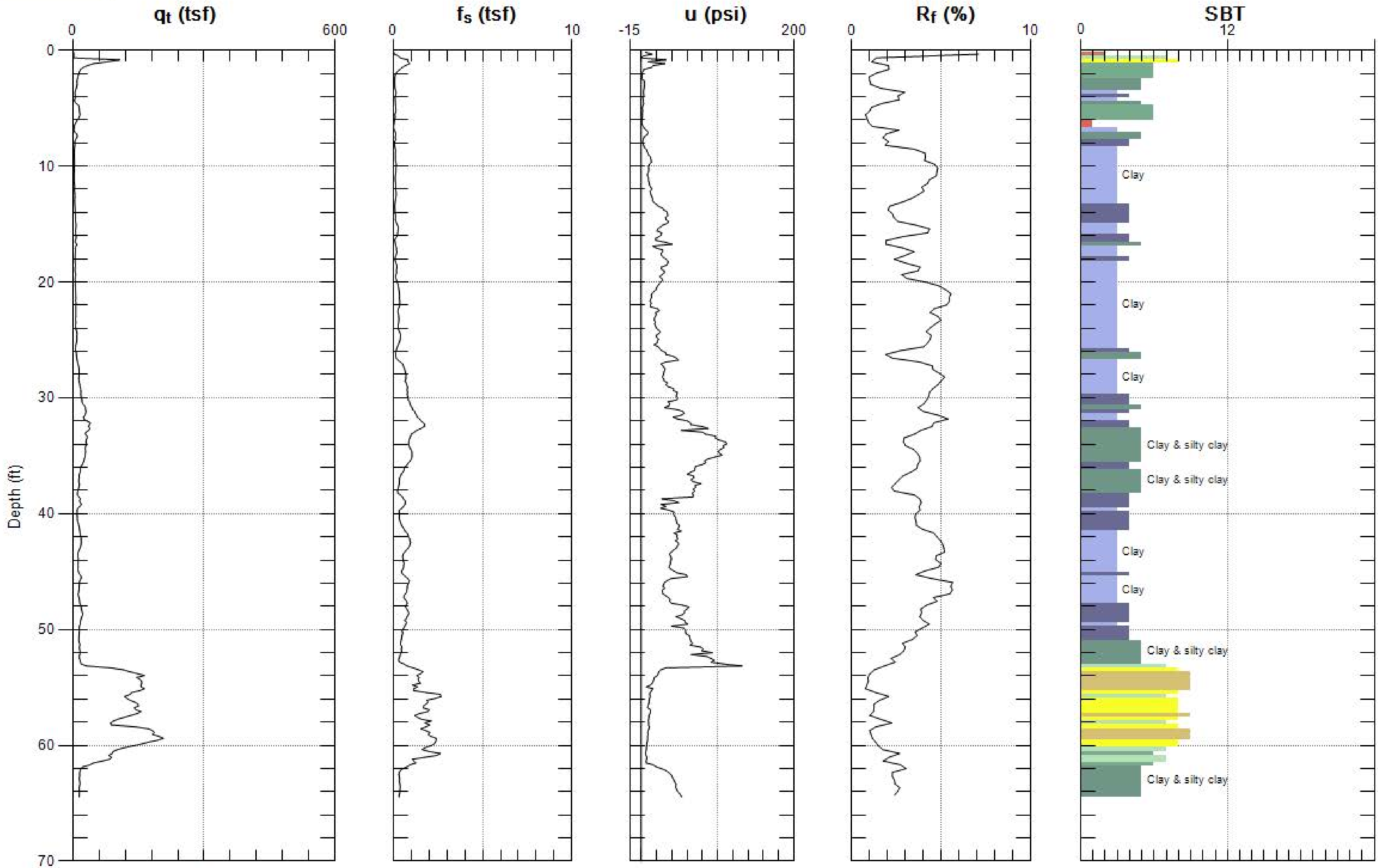
HDR

Site: SAFER BAY

Sounding: C-06

Engineer: V.CROSARIOL

Date: 1/12/2016 02:17



Max. Depth: 64.469 (ft)
Avg. Interval: 0.328 (ft)

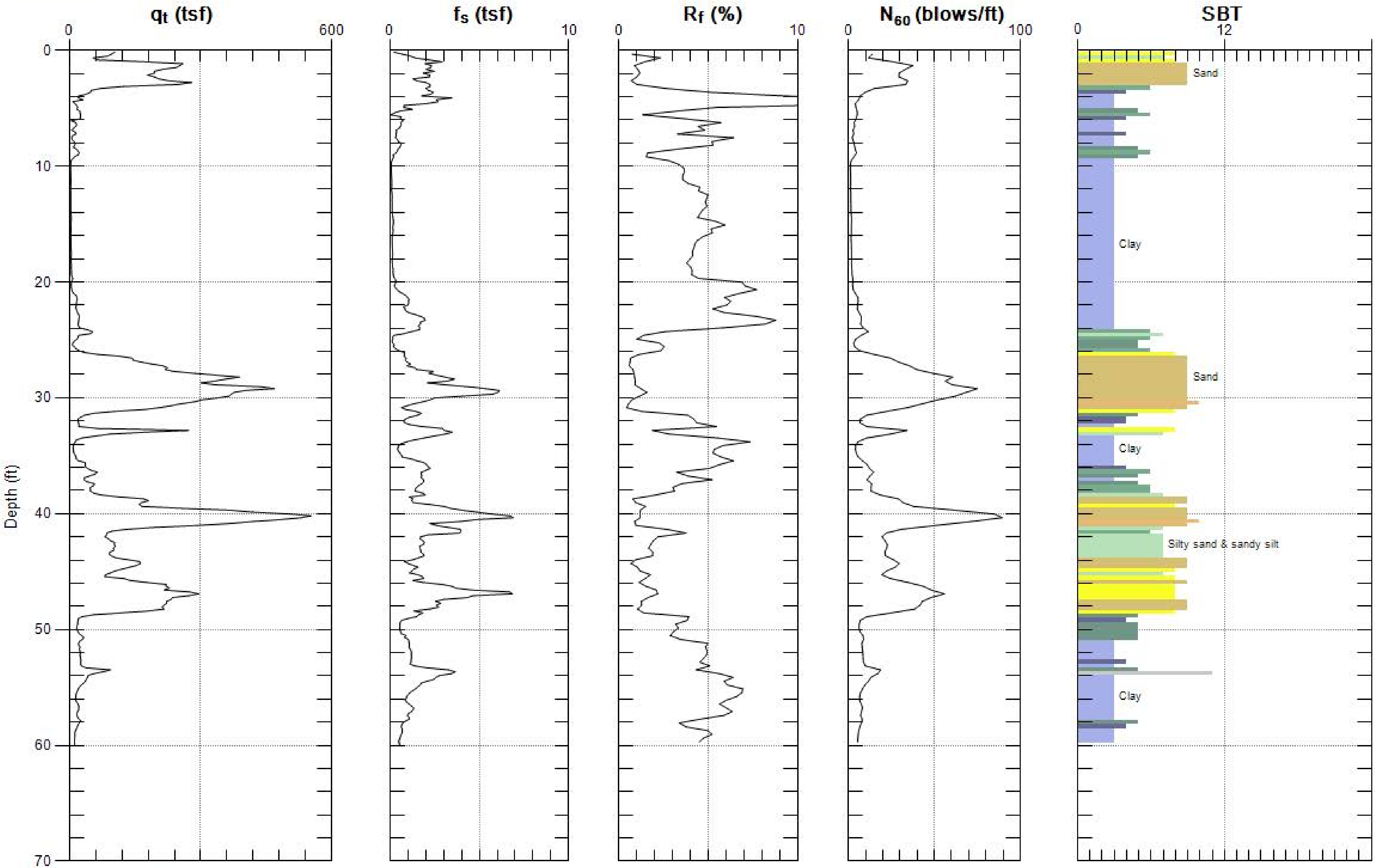
SBT: Soil Behavior Type (Robertson 1990)

GREGG

HDR

Site: SAFER BAY
Sounding: C-09

Engineer: V.CROSARIOL
Date: 1/12/2016 12:42



Max. Depth: 60.039 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

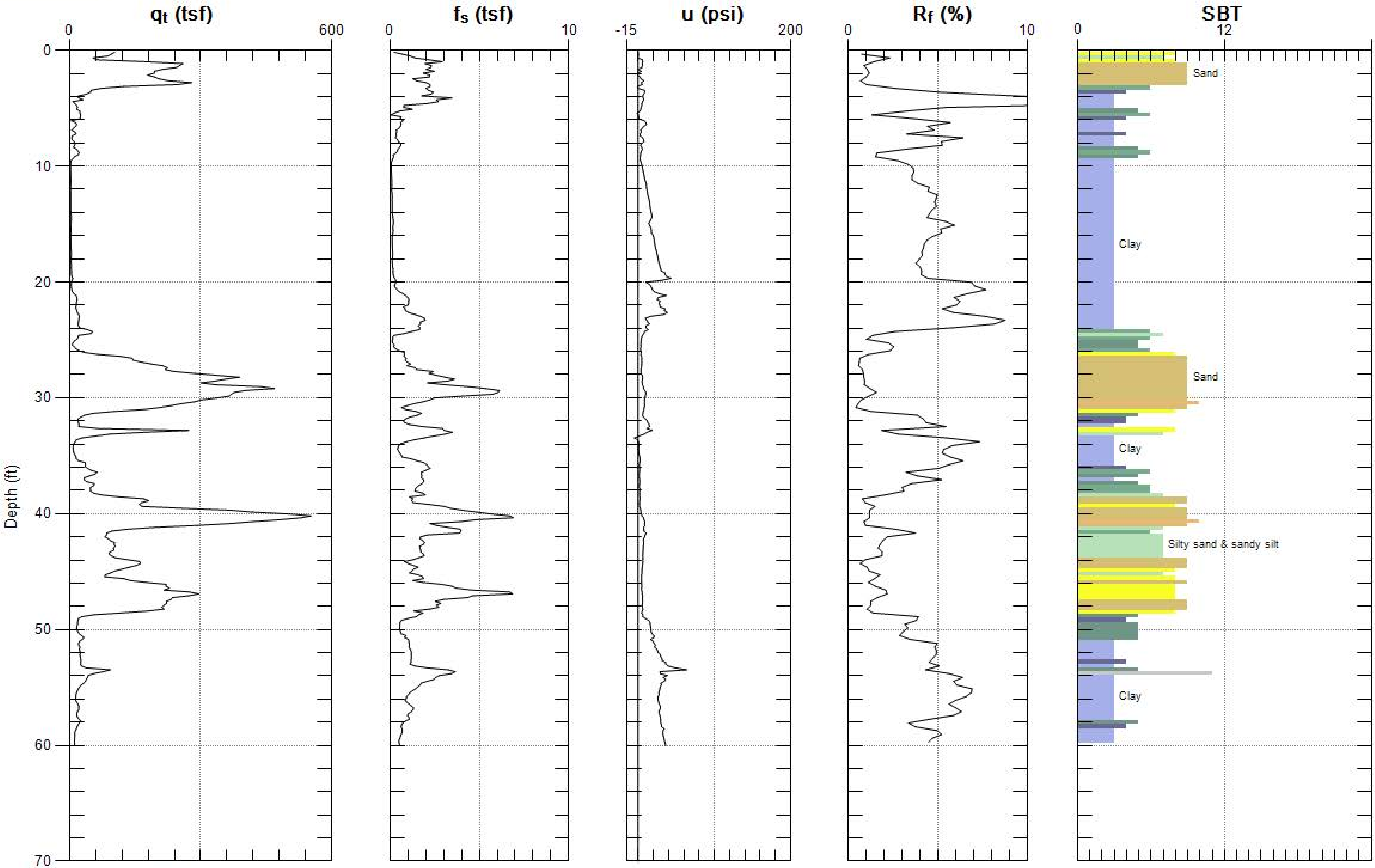
GREGG **HDR**

Site: SAFER BAY

Sounding: C-09

Engineer: V.CROSARIOL

Date: 1/12/2016 12:42



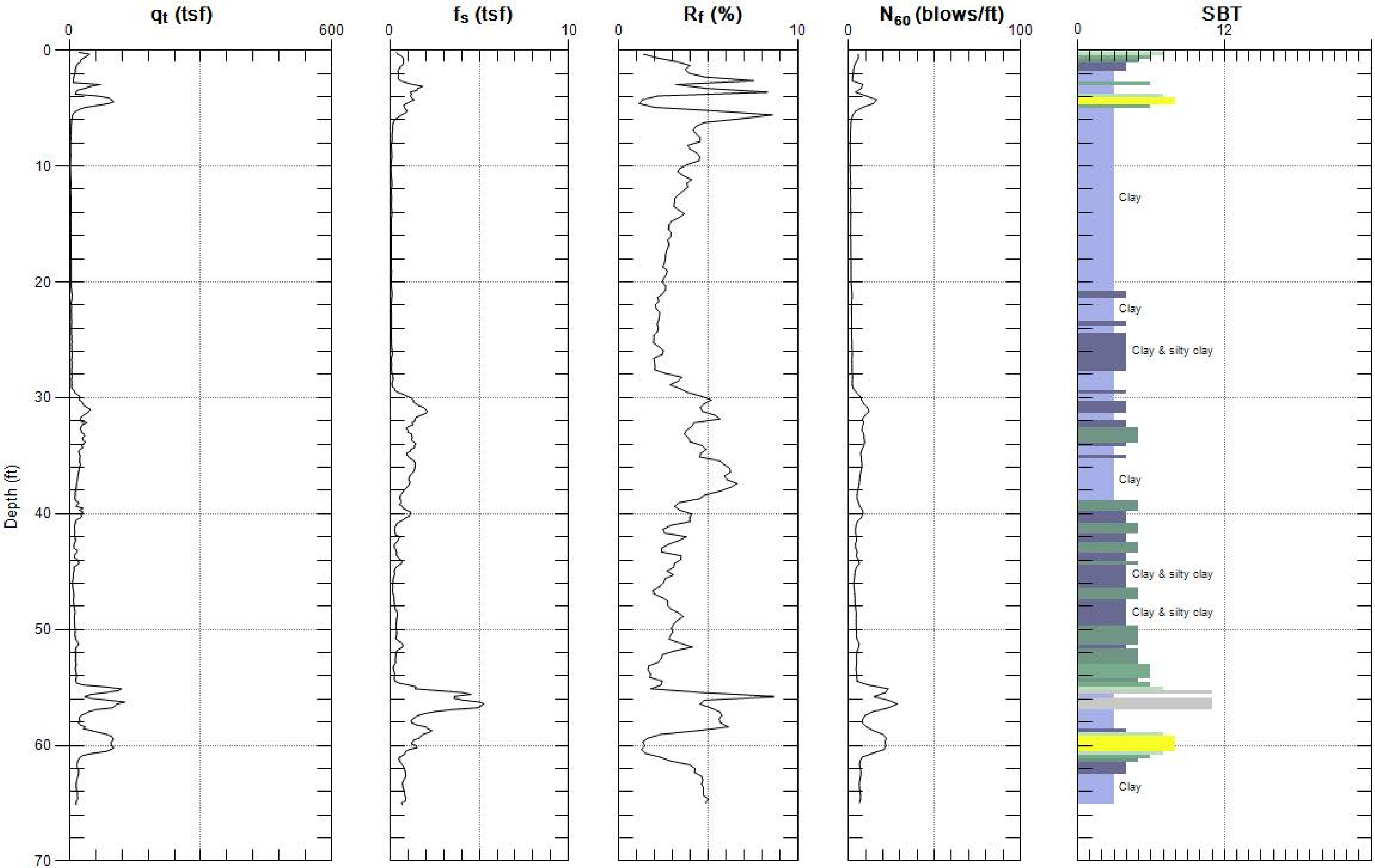
Max. Depth: 60.039 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

GREGG **HDR**

Site: SAFER BAY
Sounding: C-10

Engineer: V.CROSARIOL
Date: 1/12/2016 10:12



Max. Depth: 65.125 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

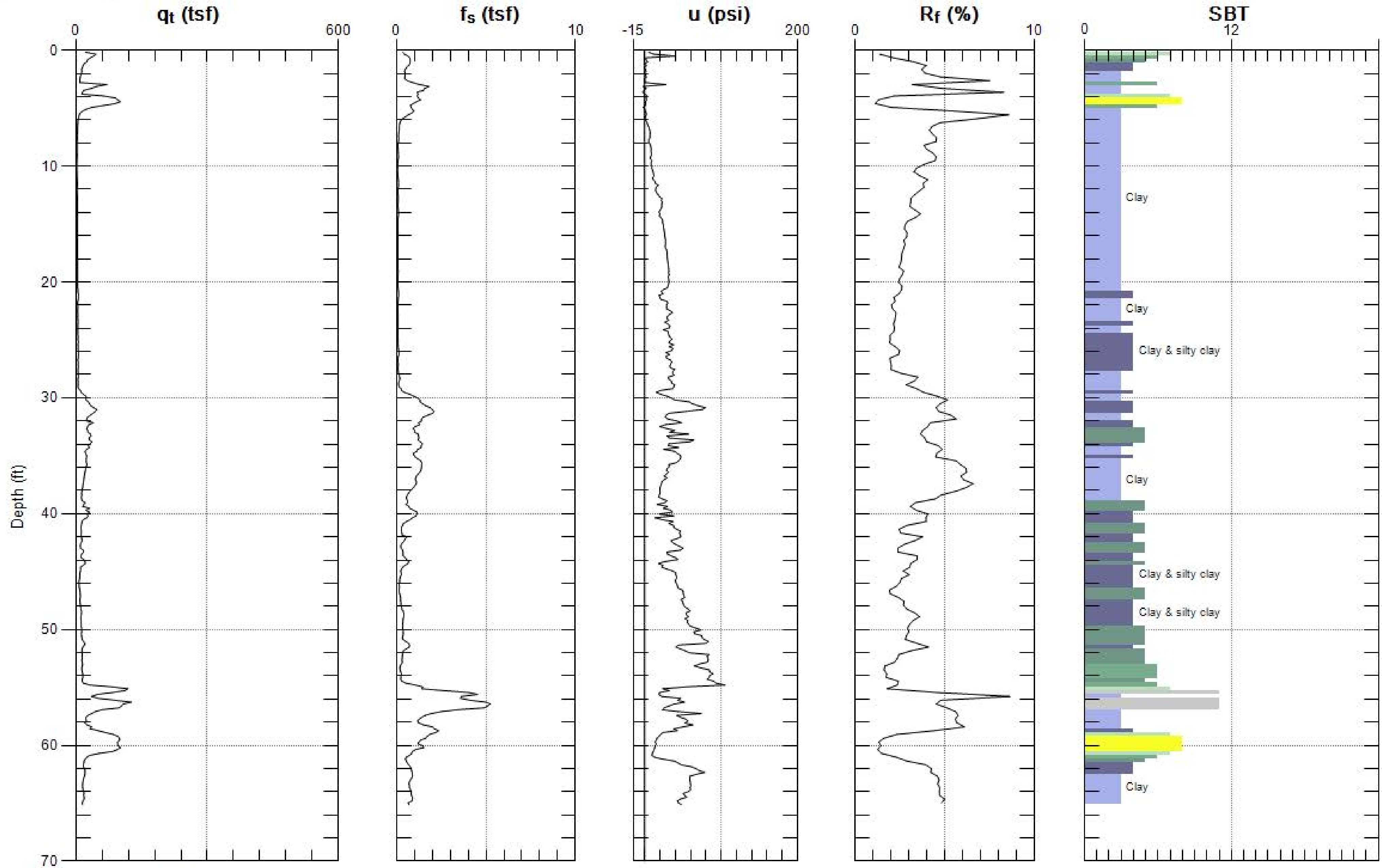
HDR

Site: SAFER BAY

Sounding: C-10

Engineer: V.CROSARIOL

Date: 1/12/2016 10:12



Max. Depth: 65.125 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

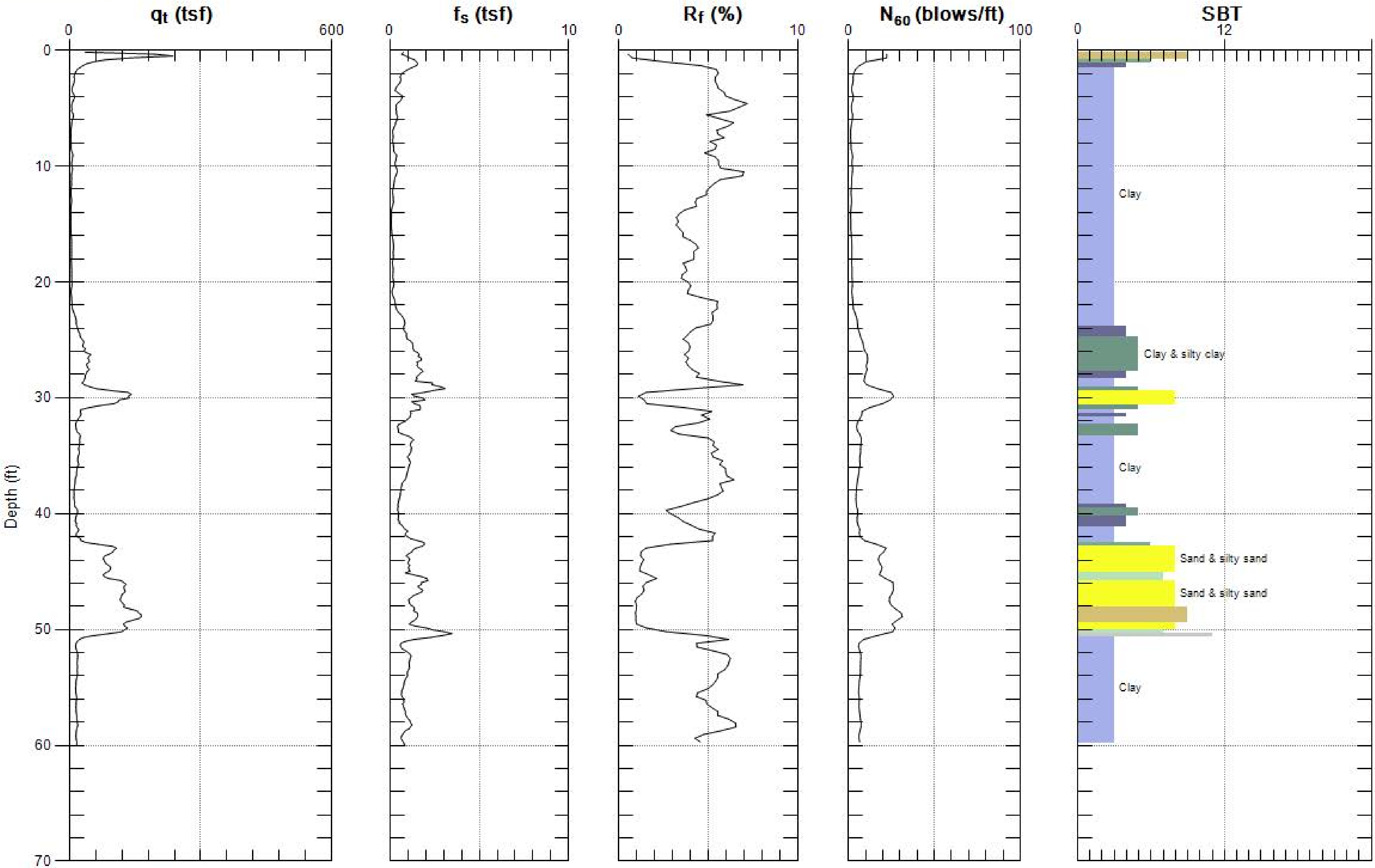
GREGG HDR

Site: SAFER BAY

Sounding: C-11

Engineer: V.CROSARIOL

Date: 1/12/2016 08:43



Max. Depth: 60.039 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

GREGG

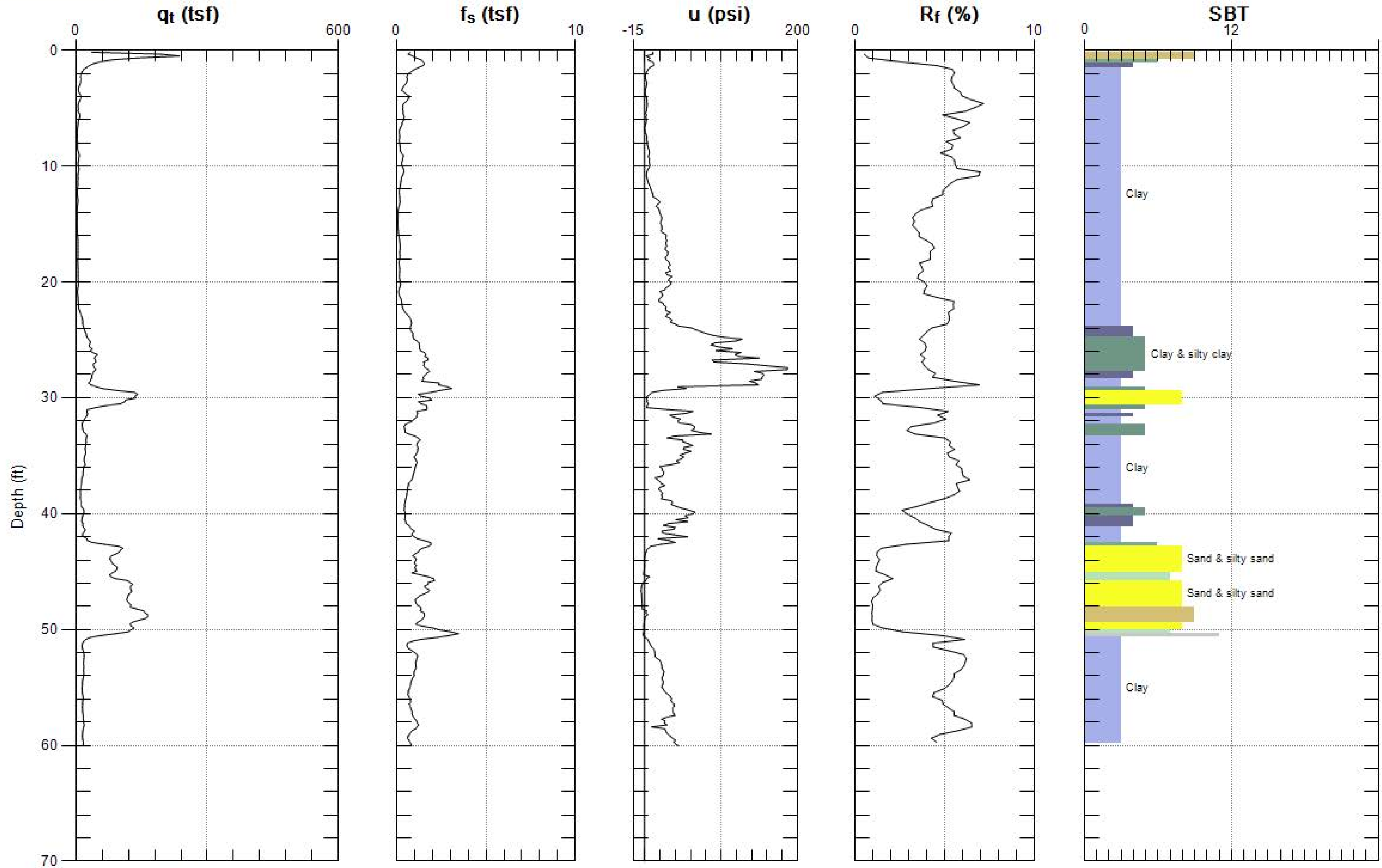
HDR

Site: SAFER BAY

Sounding: C-11

Engineer: V.CROSARIOL

Date: 1/12/2016 08:43



Max. Depth: 60.039 (ft)
Avg. Interval: 0.328 (ft)

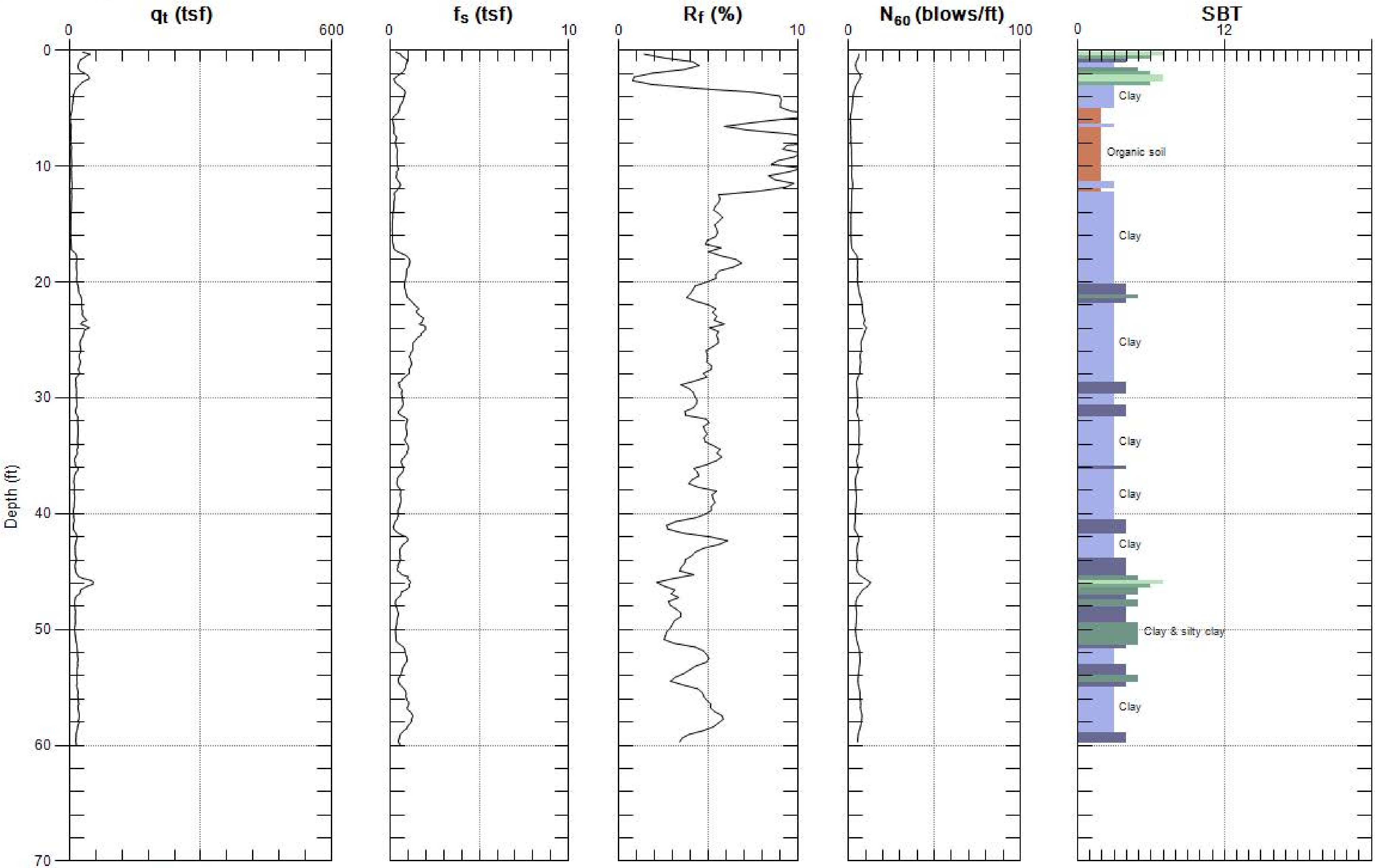
SBT: Soil Behavior Type (Robertson 1990)

GREGG

HDR

Site: SAFER BAY
Sounding: C-12

Engineer: V.CROSARIOL
Date: 1/12/2016 07:20



Max. Depth: 60.039 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

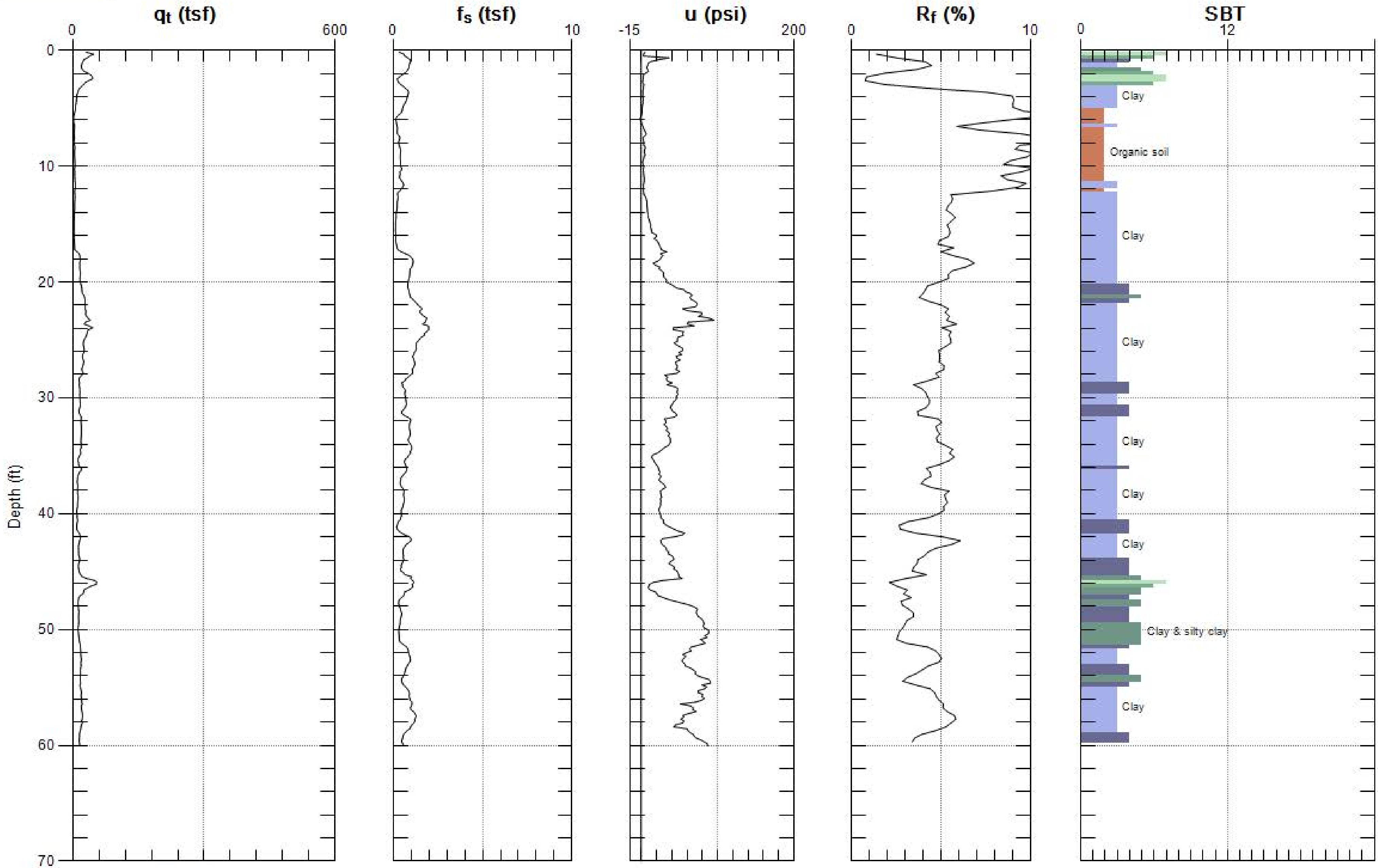
HDR

Site: SAFER BAY

Sounding: C-12

Engineer: V.CROSARIOL

Date: 1/12/2016 07:20



Max. Depth: 60.039 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

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Appendix B
Laboratory Test Results

1111 Broadway, Suite 1670, Oakland, CA
P 510-285-1123
hdrinc.com

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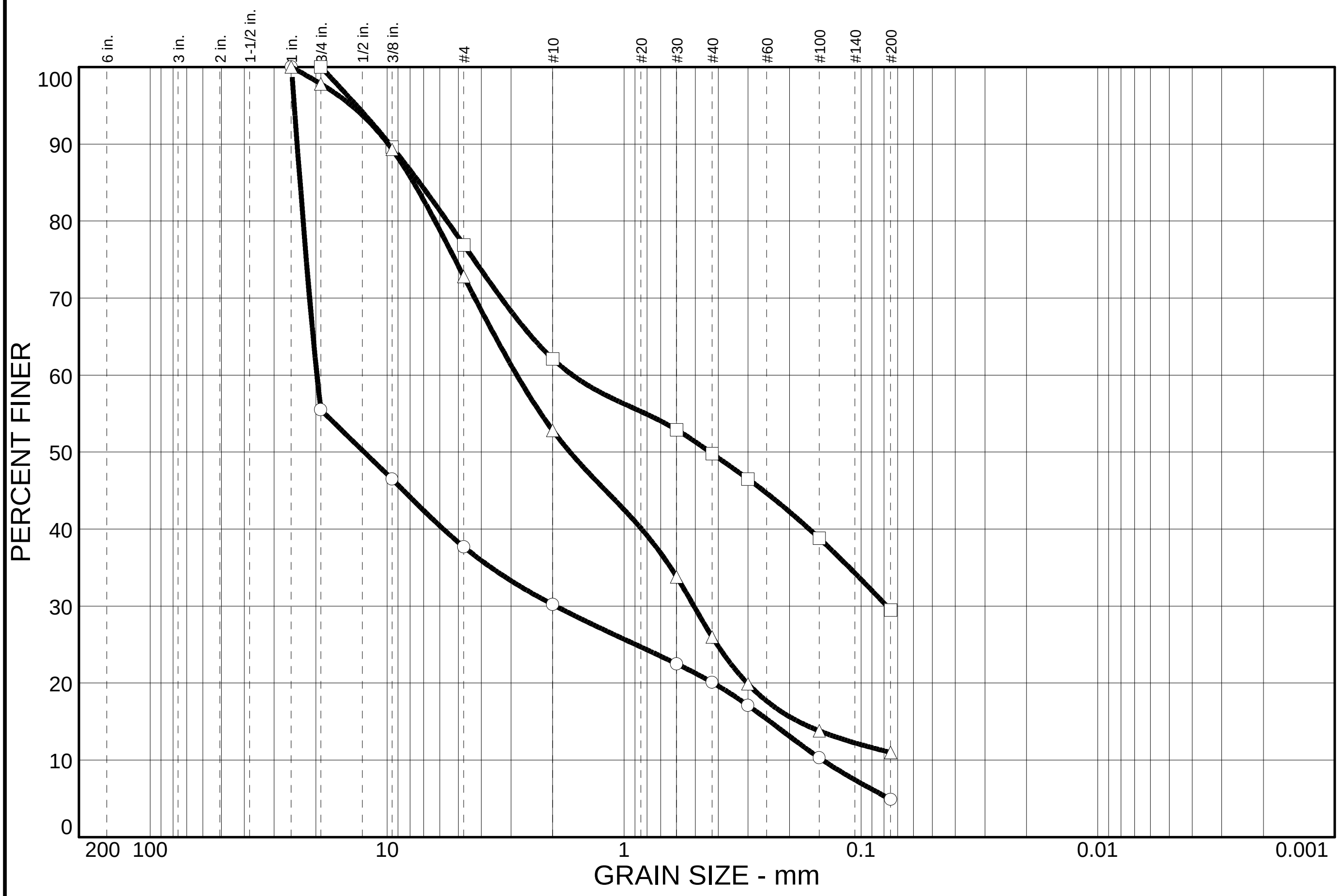
Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		62.3	32.8	4.9					
□		23.1	47.4	29.5					
△		27.2	61.8	11.0					

SIEVE inches size	PERCENT FINER ○	□	△
1"	100.0		100.0
3/4"	55.5	100.0	97.8
3/8"	46.5	89.6	89.3
	GRAIN SIZE		
D_{60}	19.8	1.65	2.84
D_{30}	1.94	0.0777	0.507
D_{10}	0.145		
	COEFFICIENTS		
C_c	1.32		
C_u	136.45		

SIEVE number size	PERCENT FINER ○	□	△
#4	37.7	76.9	72.8
#10	30.2	62.1	52.8
#30	22.5	52.9	33.8
#40	20.1	49.8	26.0
#50	17.1	46.5	19.9
#100	10.3	38.8	13.8
#200	4.9	29.5	11.0

SOIL DESCRIPTION

○ Dark Olive Brown Well-Graded GRAVEL w/ Sand

□ Olive Clayey SAND w/ Gravel

△ Olive Brown Poorly Graded SAND w/ Clay & Gravel

REMARKS:

○ Due to the small sample size, relative to the largest particle size, this data should be considered to be approximate.

□

△ Due to the small sample size, relative to the largest particle size, this data should be considered to be approximate.

○ Source: B-01 Sample No.: L1+L2 Elev./Depth: 1.5-2.5'

□ Source: B-01 Sample No.: L7 Elev./Depth: 20.5-21'

△ Source: B-01 Sample No.: S4 Elev./Depth: 21.5-23'

COOPER TESTING LABORATORY

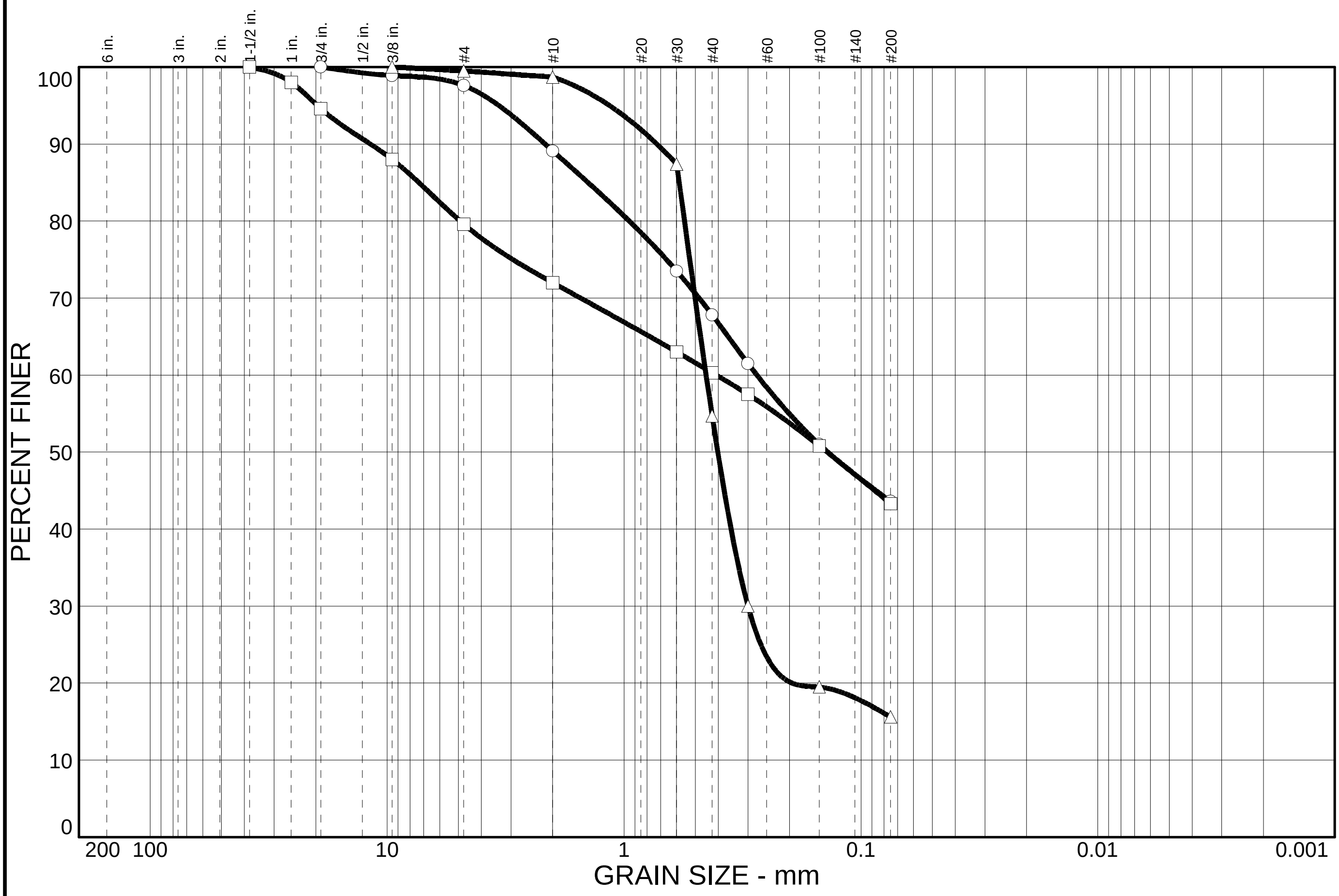
Client: HDR Engineering, Inc.

Project: SAFER Bay-Task Order 1 - 028-222952

Project No.: 855-013

Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		2.4	54.0	43.6					
□		20.4	36.3	43.3					
△		0.5	83.9	15.6					

SIEVE inches size	PERCENT FINER ○	□	△
1.5"		100.0	
1"		98.0	
3/4"	100.0	94.6	
3/8"	98.9	88.0	100.0
	GRAIN SIZE		
D_{60}	0.275	0.409	0.451
D_{30}			0.300
D_{10}			
	COEFFICIENTS		
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	□	△
#4	97.6	79.6	99.5
#10	89.1	72.0	98.7
#30	73.5	63.0	87.4
#40	67.8	60.3	54.7
#50	61.5	57.5	30.0
#100	51.0	50.8	19.5
#200	43.6	43.3	15.6

SOIL DESCRIPTION

○ Dark Yellowish Brown Clayey SAND

□ Olive Brown Clayey SAND w/ Gravel

△ Very Dark Gray Silty SAND

REMARKS:

○

□

△

○ Source: B-01 Sample No.: L13 Elev./Depth: 40.5-41'

□ Source: B-02 Sample No.: S1 Elev./Depth: 1.5-2.5'

△ Source: B-03 Sample No.: S5 Elev./Depth: 51.5-53'

COOPER TESTING LABORATORY

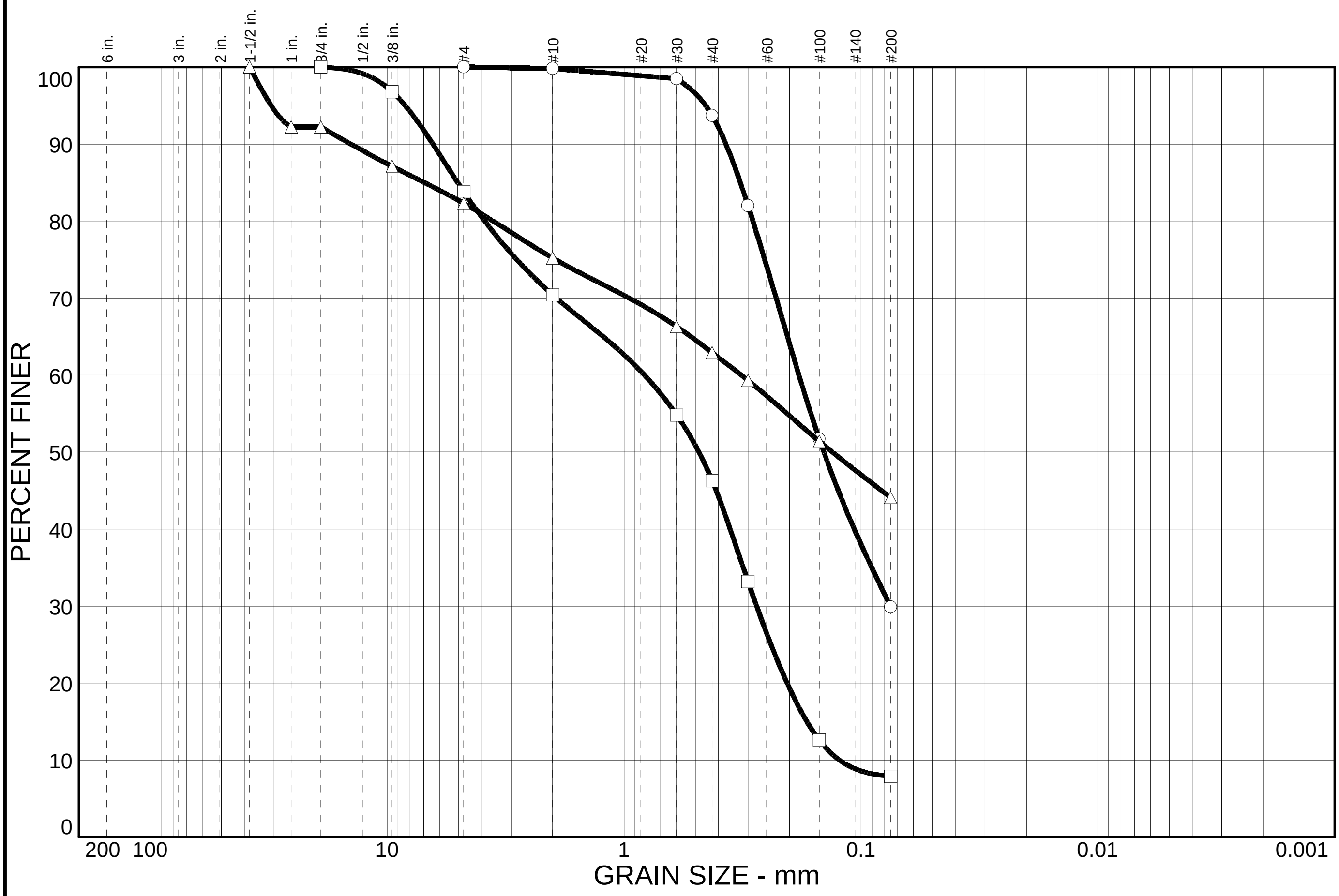
Client: HDR Engineering, Inc.

Project: SAFER Bay-Task Order 1 - 028-222952

Project No.: 855-013

Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○			70.1	29.9					
□		16.2	75.9	7.9					
△		17.7	38.2	44.1					

SIEVE inches size	PERCENT FINER ○	□	△
1.5"			100.0
1"			92.2
3/4"		100.0	92.2
3/8"		96.8	87.1
	GRAIN SIZE		
D_{60}	0.183	0.820	0.320
D_{30}	0.0753	0.276	
D_{10}		0.123	
	COEFFICIENTS		
C_c		0.75	
C_u		6.66	

SIEVE number size	PERCENT FINER ○	□	△
#4	100.0	83.8	82.3
#10	99.8	70.4	75.2
#30	98.5	54.8	66.3
#40	93.7	46.3	62.9
#50	82.0	33.2	59.3
#100	51.7	12.6	51.4
#200	29.9	7.9	44.1

SOIL DESCRIPTION

○ Olive Brown Clayey SAND

□ Olive Brown Poorly Graded SAND w/ Clay & Gravel

△ Dark Reddish Brown Clayey SAND w/ Gravel

REMARKS:

○

□

△ Due to the small sample size, relative to the largest particle size, this data should be considered to be approximate.

○ Source: B-05 Sample No.: S4 Elev./Depth: 11.5-12.2'

□ Source: B-05 Sample No.: L15+L46 Elev./Depth: 35.5-36.5'

△ Source: B-06 Sample No.: S1 Elev./Depth: 0.5-1.0'

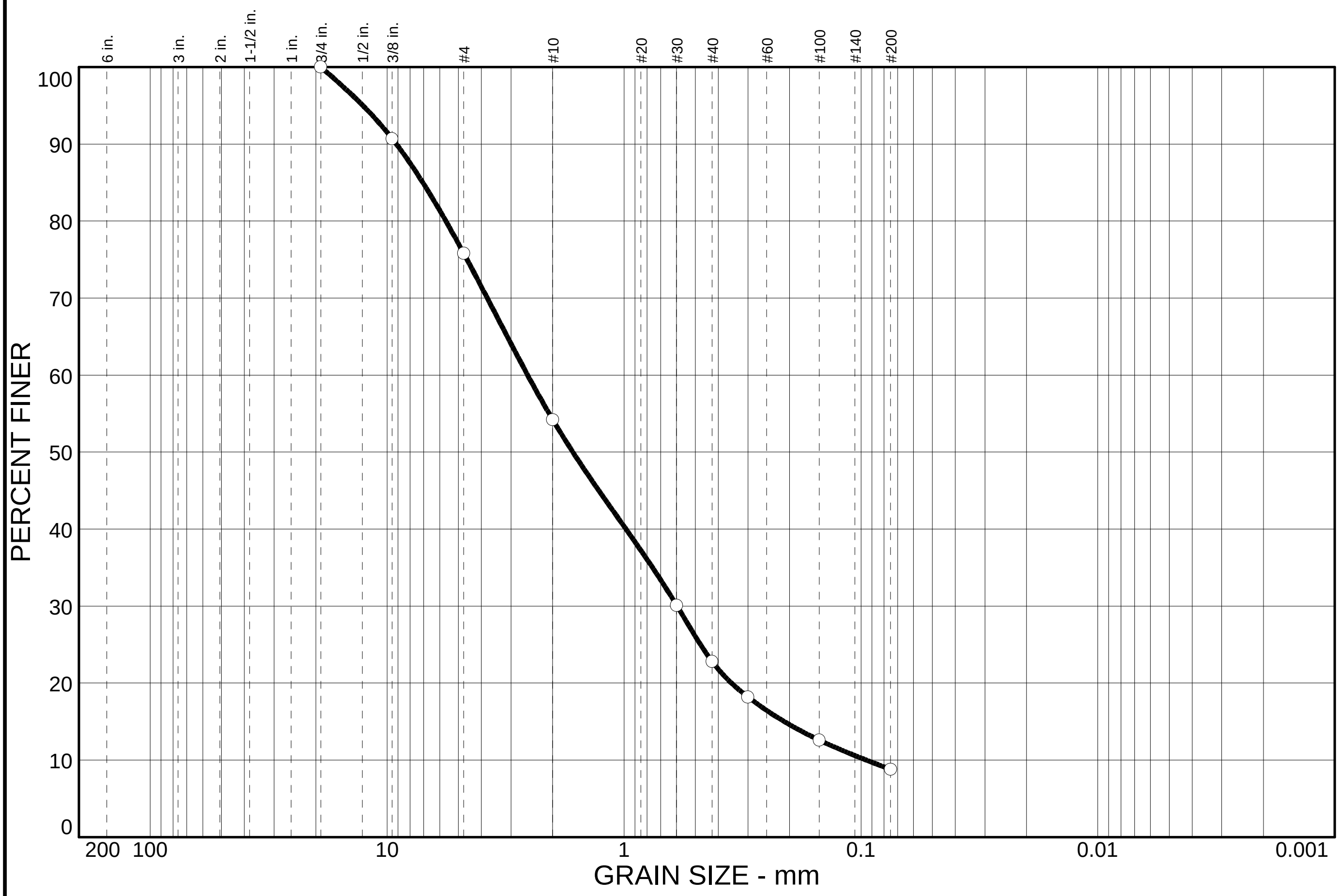
COOPER TESTING LABORATORY

Client: HDR Engineering, Inc.

Project: SAFER Bay-Task Order 1 - 028-222952

Project No.: 855-013 Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		24.2	67.0	8.8					

SIEVE inches size	PERCENT FINER ○		
3/4"	100.0		
3/8"	90.7		
	GRAIN SIZE		
D_{60}	2.55		
D_{30}	0.597		
D_{10}	0.0949		
	COEFFICIENTS		
C_c	1.47		
C_u	26.90		

SIEVE number size	PERCENT FINER ○		
#4	75.8		
#10	54.2		
#30	30.1		
#40	22.8		
#50	18.2		
#100	12.6		
#200	8.8		

SOIL DESCRIPTION

○ Olive Brown Well-Graded SAND w/ Clay & Gravel

REMARKS:

○

○ Source: B-06 Sample No.: L15 Elev./Depth: 41-41.5'

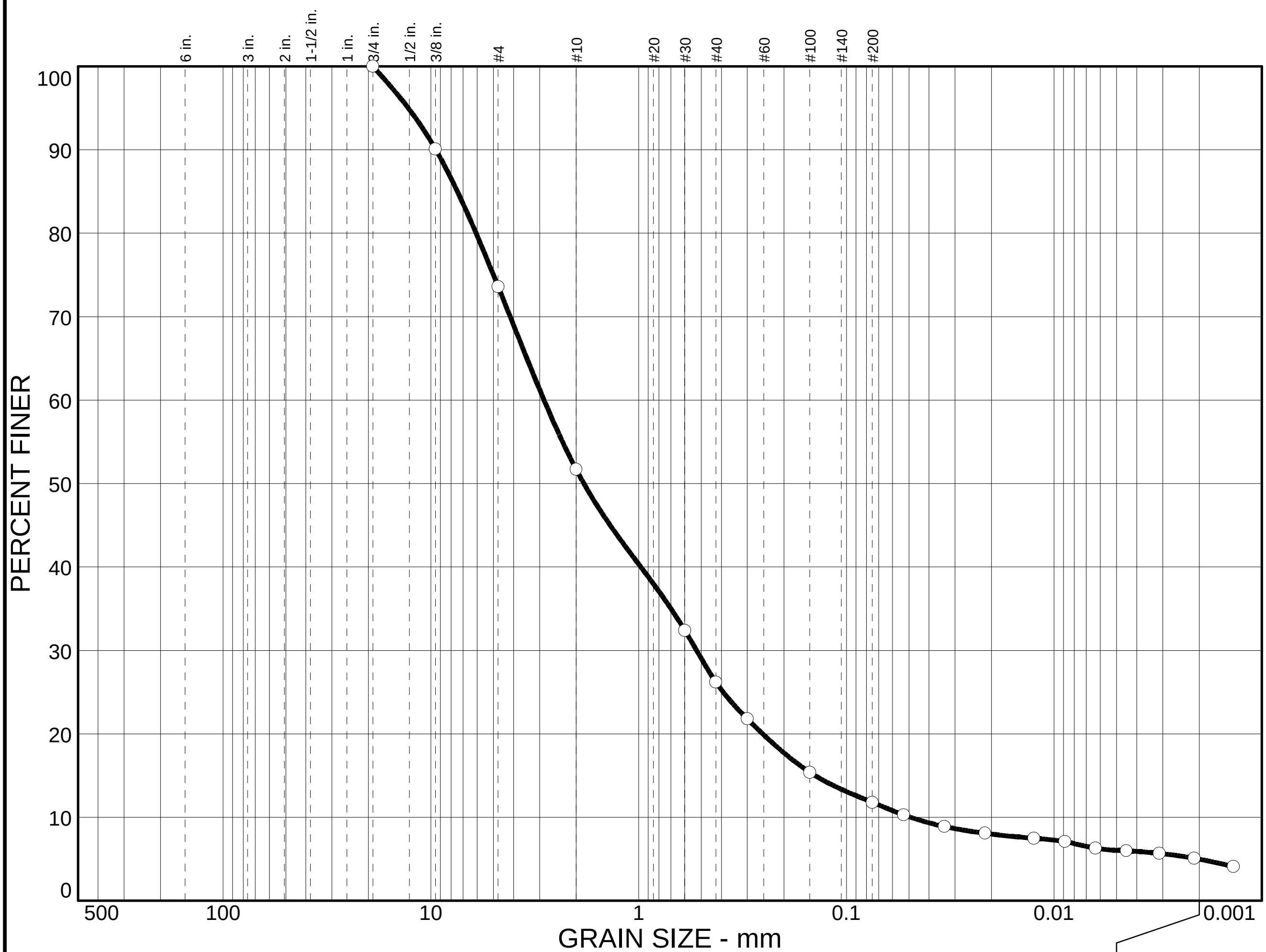
COOPER TESTING LABORATORY

Client: HDR Engineering, Inc.

Project: SAFER Bay-Task Order 1 - 028-222952

Project No.: 855-013 Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	26.4	61.8	6.8	5.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
3/8 in.	90.1		
#4	73.6		
#10	51.7		
#30	32.4		
#40	26.2		
#50	21.8		
#100	15.4		
#200	11.8		
#270	10.3		
0.0337 mm.	8.9		
0.0215 mm.	8.1		
0.0125 mm.	7.5		
0.0089 mm.	7.1		
0.0063 mm.	6.3		
0.0045 mm.	6.0		
0.0031 mm.	5.7		
0.0021 mm.	5.1		
0.0014 mm.	4.1		

* (no specification provided)

Soil Description

Olive Brown Well-Graded SAND w/ Silt & Gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 7.46 D_{60}= 2.86 D_{50}= 1.84
D_{30}= 0.527 D_{15}= 0.141 D_{10}= 0.0489
C_u= 58.34 C_c= 1.99

Classification

USCS= AASHTO=

Remarks

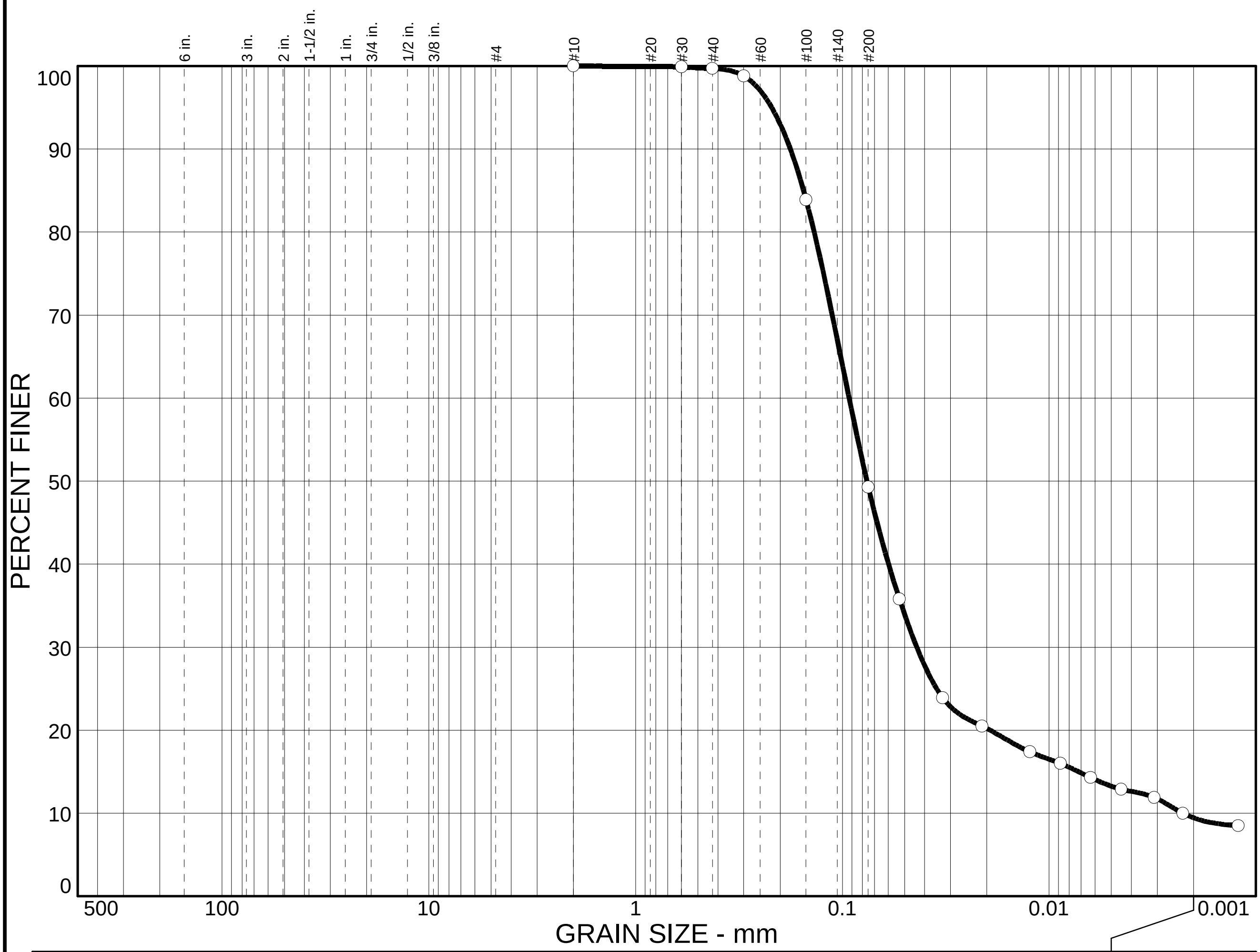
Sample No.: S7 **Source of Sample:** B-02 **Date:** 2/22/16
Location: **Elev./Depth:** 33.5-35'

COOPER TESTING LABORATORY

Client: HDR Engineering, Inc.
Project: SAFER Bay-Task Order 1 - 028-222952

Project No: 855-013 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	50.7	39.9	9.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#30	99.9		
#40	99.7		
#50	98.8		
#100	83.9		
#200	49.3		
#270	35.8		
0.0327 mm.	23.9		
0.0211 mm.	20.5		
0.0124 mm.	17.4		
0.0088 mm.	16.0		
0.0063 mm.	14.3		
0.0045 mm.	12.9		
0.0031 mm.	11.9		
0.0023 mm.	10.0		
0.0012 mm.	8.5		

* (no specification provided)

Soil Description

Olive Brown Silty SAND

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.154 D_{60}= 0.0928 D_{50}= 0.0761
D_{30}= 0.0437 D_{15}= 0.0072 D_{10}= 0.0023
C_u= 41.20 C_c= 9.13

Classification

USCS= AASHTO=

Remarks

Sample No.: L5 **Source of Sample:** B-05 **Date:** 3/1/16
Location: **Elev./Depth:** 6.5-9'

COOPER TESTING LABORATORY

Client: HDR Engineering, Inc.
Project: SAFER Bay-Task Order 1 - 028-222952

Project No: 855-013 **Figure**

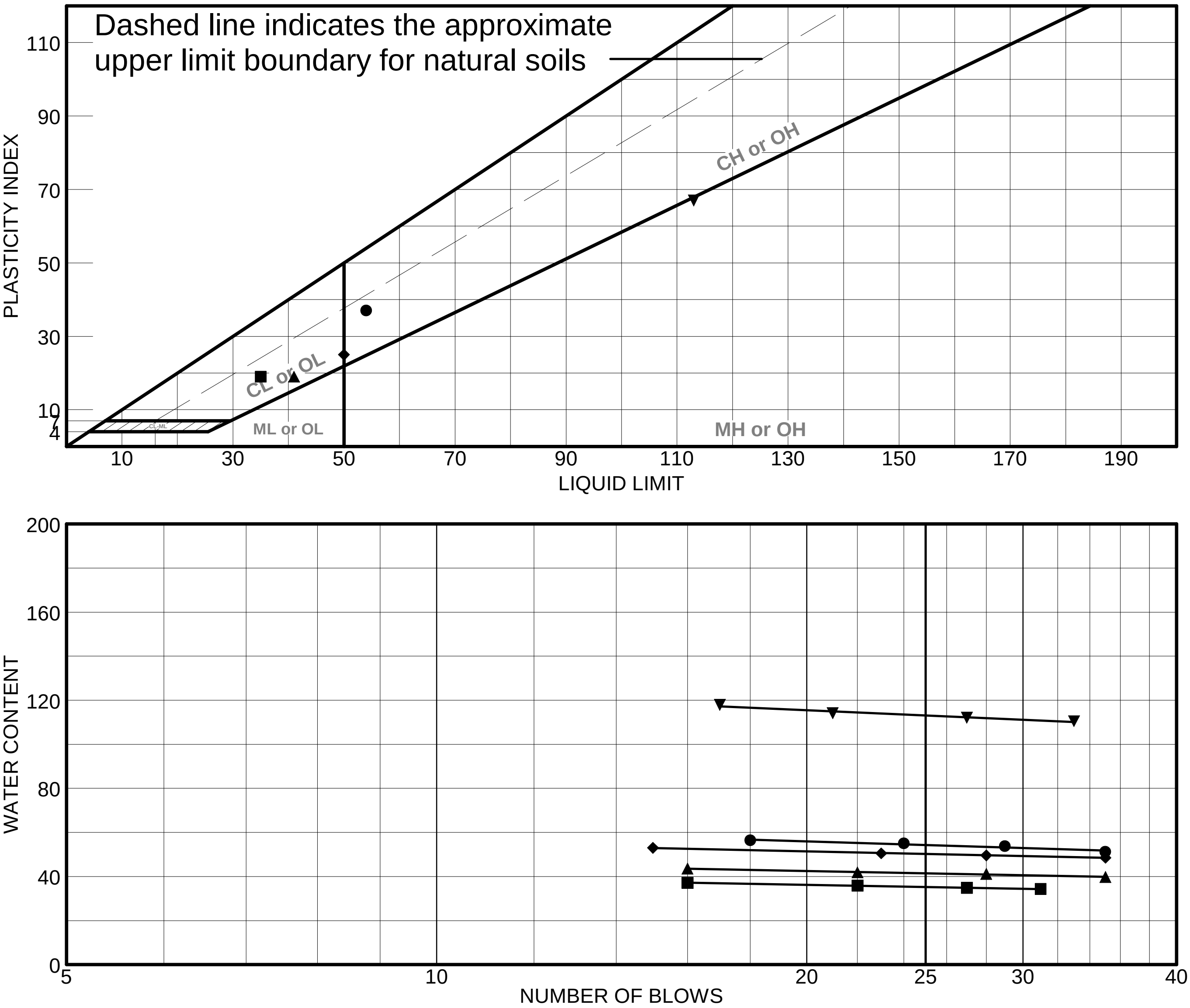
#200 Sieve Wash Analysis
ASTM D 1140

Job No.:	855-013	**Project No.:**	028-222952	**Run By:**	MD
Client:	HDR Engineering, Inc.	**Date:**	3/3/2016	**Checked By:**	DC
Project:	SAFER Bay-Task Order 1				

Boring:	B-06							
Sample:	L8							
Depth, ft.:	21-23.5							
Soil Type:	Greenish Gray Lean CLAY w/ Sand							
Wt of Dish & Dry Soil, gm	634.3							
Weight of Dish, gm	304.4							
Weight of Dry Soil, gm	329.9							
Wt. Ret. on #4 Sieve, gm	0.5							
Wt. Ret. on #200 Sieve, gm	53.0							
% Gravel	**0.2**							
% Sand	**15.9**							
% Silt & Clay	**83.9**							

Remarks: As an added benefit to our clients, the gravel fraction may be included in this report. Whether or not it is included is dependent upon both the technician's time available and if there is a significant enough amount of gravel. The gravel is always included in the percent retained on the #200 sieve but may not be weighed separately to determine the percentage, especially if there is only a trace amount, (5% or less).

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Olive Brown Fat Clayey SAND w/ Gravel	54	17	37			
■	Olive Sandy Lean CLAY/ Lean Clayey SAND w/ Gravel	35	16	19			
▲	Olive Gray Sandy Lean CLAY	41	22	19			
◆	Dark Olive Brown Lean Clayey SAND w/ Gravel	50	25	25			
▼	Dark Gray Elastic SILT (Bay Mud)	113	46	67			

Project No. 855-013 **Client:** HDR Engineering, Inc.

Project: SAFER Bay-Task Order 1 - 028-222952

● **Source:** B-01 **Sample No.:** L3 **Elev./Depth:** 6-6.5'

■ **Source:** B-01 **Sample No.:** L6 **Elev./Depth:** 15-16.5'

▲ **Source:** B-01 **Sample No.:** L14 **Elev./Depth:** 41-41.5'

◆ **Source:** B-02 **Sample No.:** L3 **Elev./Depth:** 6-6.5'

▼ **Source:** B-02 **Sample No.:** L7 **Elev./Depth:** 15-17.5'

Remarks:

● Sample was prepared using the wet prep method.

■

▲

◆ Sample was prepared using the wet prep method.

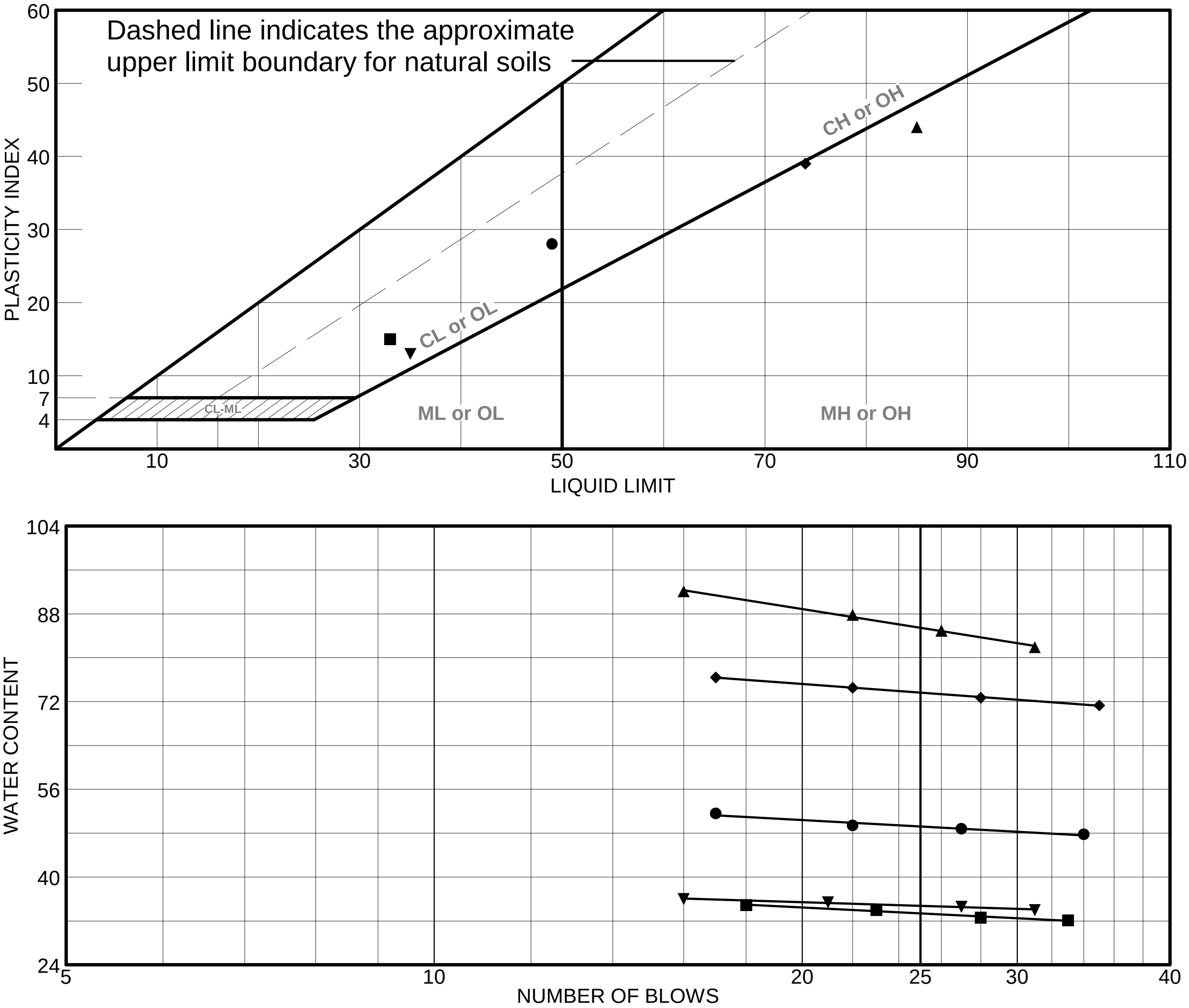
▼ Sample was prepared using the wet prep method.

LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Greenish Gray Lean CLAY	49	21	28			
■	Reddish Brown Sandy Lean CLAY	33	18	15			
▲	Greenish Gray Elastic SILT (Bay Mud)	85	41	44			
◆	Greenish Gray Elastic SILT (Bay Mud)	74	35	39			
▼	Gray Lean Clayey SAND w/ shells	35	22	13			

Project No. 855-013 **Client:** HDR Engineering, Inc.

Project: SAFER Bay-Task Order 1 - 028-222952

● **Source:** B-02 **Sample No.:** L11 **Elev./Depth:** 43.7-45'

■ **Source:** B-03 **Sample No.:** L3 **Elev./Depth:** 5-5.5'

▲ **Source:** B-03 **Sample No.:** L6 **Elev./Depth:** 19-21.5'

◆ **Source:** B-03 **Sample No.:** L10 **Elev./Depth:** 30-32.5(Tip-

▼ **Source:** B-03 **Sample No.:** L16 **Elev./Depth:** 45-47.5(Tip-

Remarks:

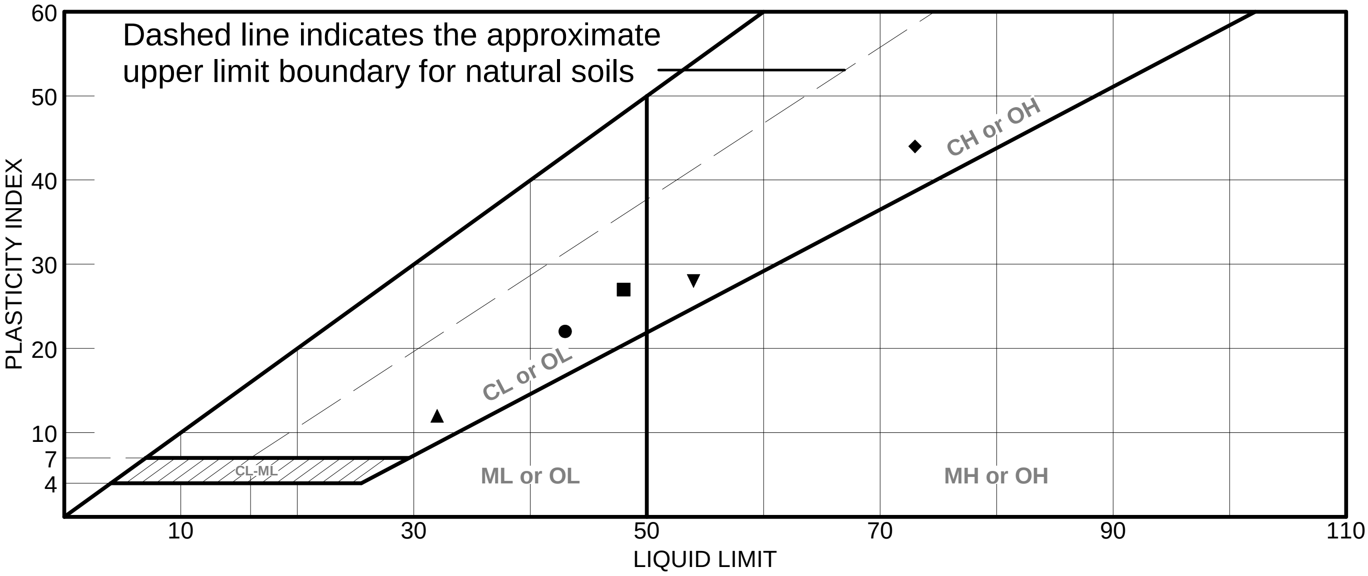
- ● Sample was prepared using the wet prep method.
- ■ Sample was prepared using the wet prep method.
- ▲ Sample was prepared using the wet prep method.
- ◆ Sample was prepared using the wet prep method.
- ▼ Sample was prepared using the wet prep method.

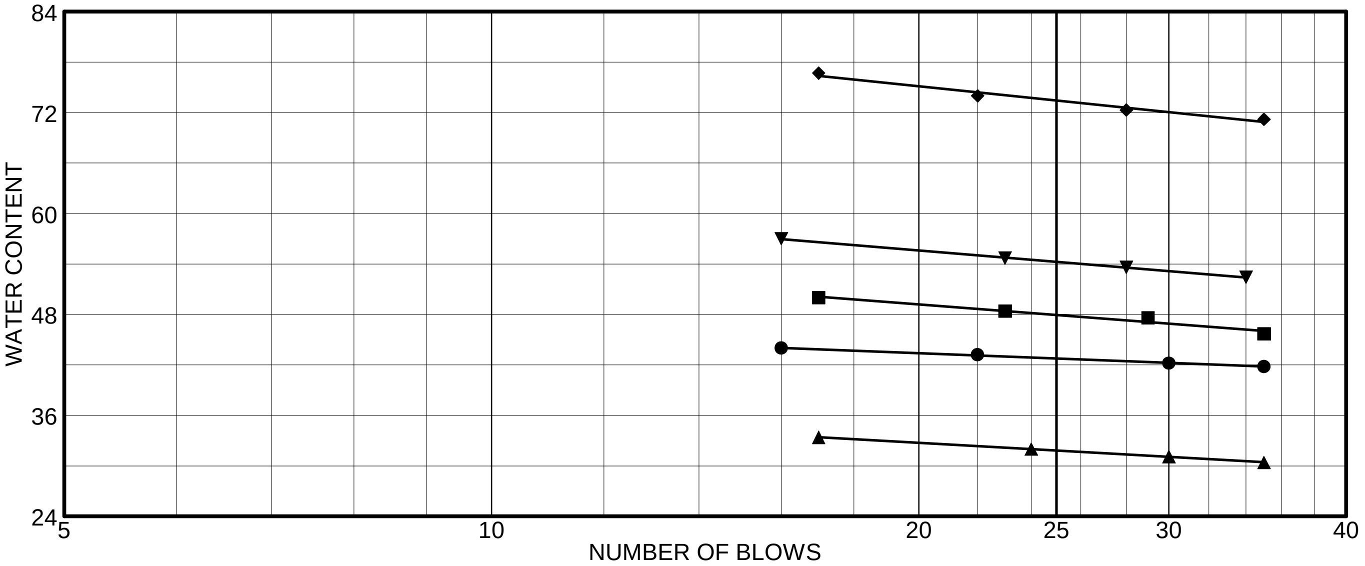
LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Dark Olive Brown Sandy Lean CLAY	43	21	22			
■	Dark Grayish Brown Lean CLAY	48	21	27			
▲	Olive Brown Lean CLAY w/ Sand	32	20	12			
◆	Dark Gray Fat CLAY	73	29	44			
▼	Dark Greenish Gray Fat CLAY (Bay Mud)	54	26	28			

Project No. 855-013 **Client:** HDR Engineering, Inc.

Project: SAFER Bay-Task Order 1 - 028-222952

	Source	Sample No.	Elev./Depth
●	**Source:** B-05	**Sample No.:** L2	**Elev./Depth:** 2.5-3'
■	**Source:** B-05	**Sample No.:** L10	**Elev./Depth:** 20-22.5'
▲	**Source:** B-05	**Sample No.:** L14	**Elev./Depth:** 31-31.5'
◆	**Source:** B-06	**Sample No.:** L4	**Elev./Depth:** 7-9.5(Tip-14")
▼	**Source:** B-06	**Sample No.:** L6	**Elev./Depth:** 12.5-15'

Remarks:

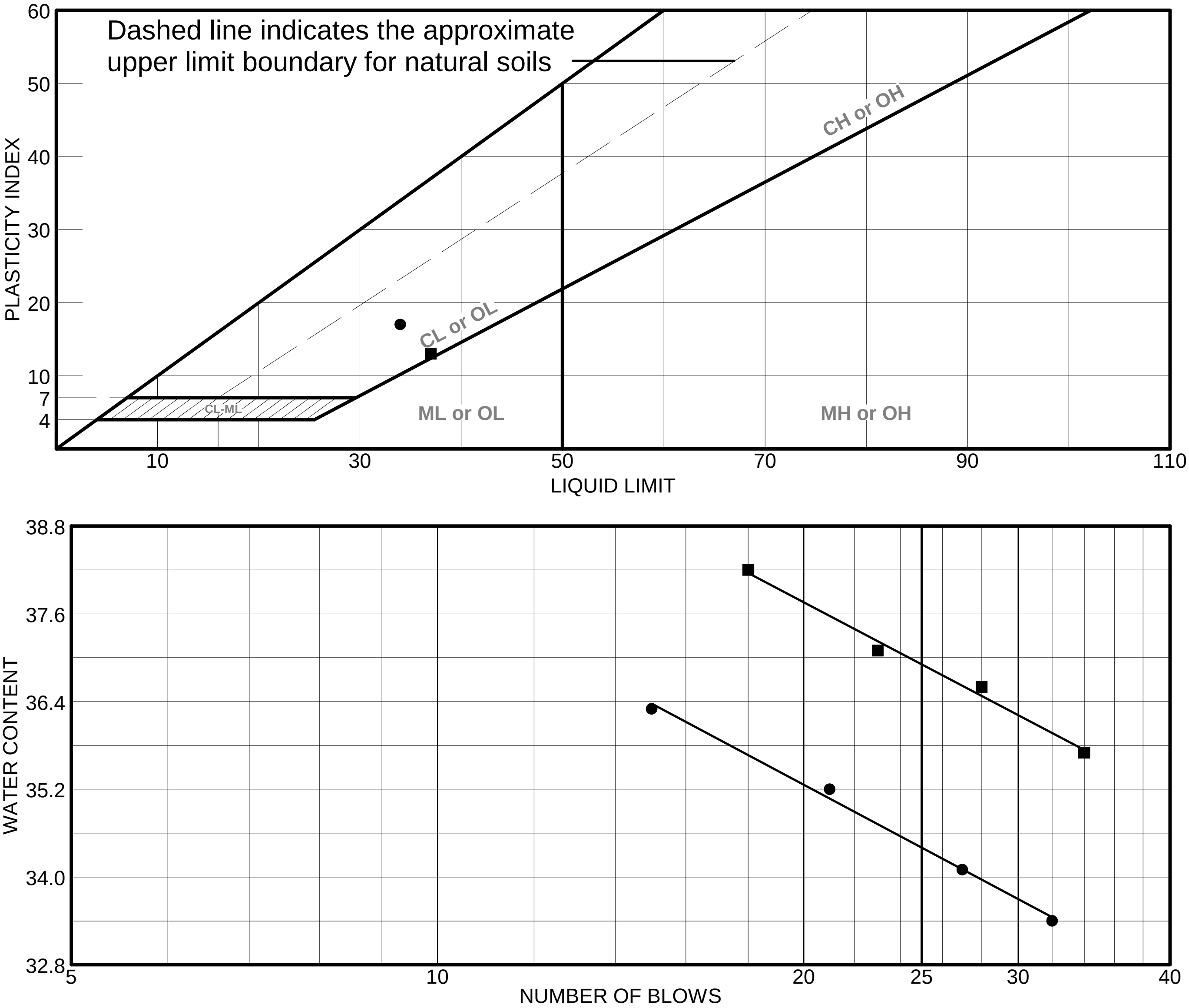
- ● Sample was prepared using the wet prep method.
- ■ Sample was prepared using the wet prep method.
- ▲ Sample was prepared using the wet prep method.
- ◆ Sample was prepared using the wet prep method.
- ▼ Sample was prepared using the wet prep method.

LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Greenish Gray Lean CLAY w/ Sand	34	17	17			
■	Olive Brown Lean CLAY w/ Sand	37	24	13			

Project No. 855-013 **Client:** HDR Engineering, Inc.

Project: SAFER Bay-Task Order 1 - 028-222952

● **Source:** B-06 **Sample No.:** L8 **Elev./Depth:** 21-23.5'

■ **Source:** B-06 **Sample No.:** S3 **Elev./Depth:** 45-46.5'

Remarks:

● Sample was prepared using the wet prep method.

■

LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

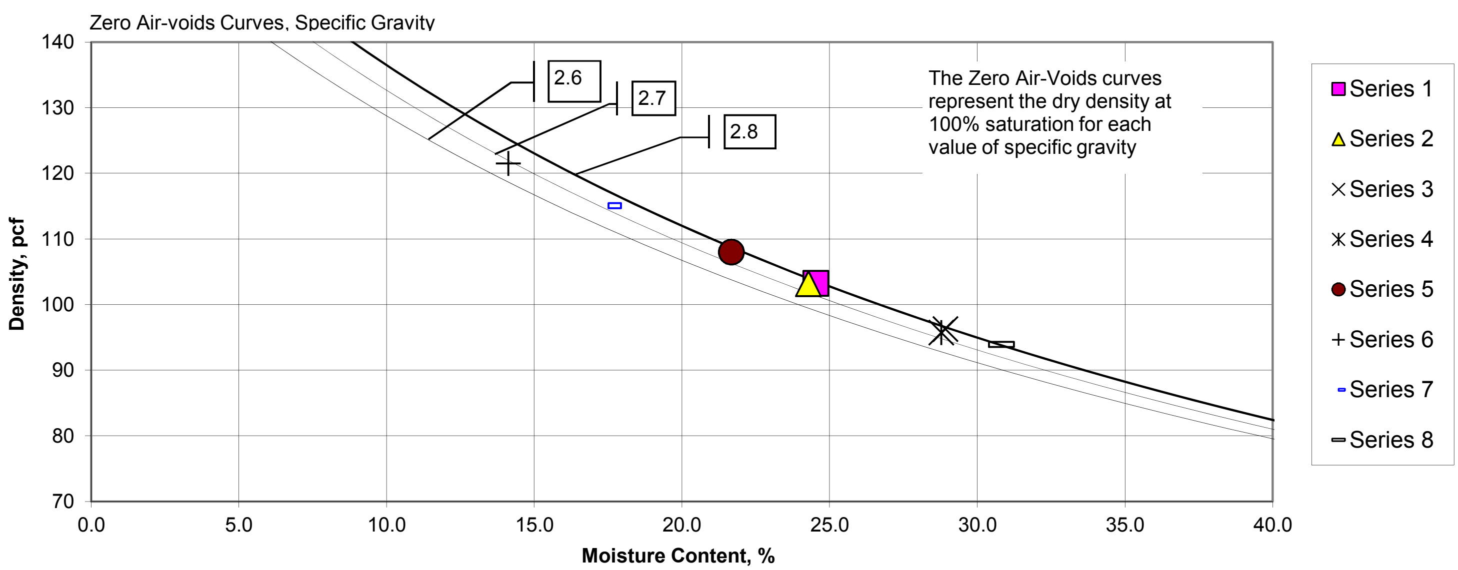
Moisture-Density-Porosity Report
Cooper Testing Labs, Inc. (ASTM D7263b)

CTL Job No:	855-013a	**Project No.**	028-222952	**By:**	RU
Client:	HDR Engineering, Inc.	**Date:**	02/22/16		
Project Name:	SAFER Bay-Task Order 1	**Remarks:**			

Boring:	B-01	B-01	B-01	B-01	B-02	B-02	B-02	B-03
Sample:	L3	L5	L11	L14	L3	L5	L10	L3
Depth, ft:	6-6.5	11-11.5	31-31.5	41-41.5	6-6.5	11-11.5	26-26.5	5-5.5
Visual Description:	Olive Brown Fat Clayey SAND w/ Gravel	Olive Brown Sandy CLAY	Light Olive Brown Sandy CLAY	Olive Gray Sandy Lean CLAY	Dark Olive Brown Lean Clayey SAND w/ Gravel	Black Sandy CLAY w/ Gravel	Olive Brown Clayey SAND	Reddish Brown Sandy Lean CLAY
Actual G_s								
Assumed G_s	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80
Moisture, %	24.5	24.3	28.9	28.8	21.7	14.1	17.5	30.8
Wet Unit wt, pcf	128.5	128.2	124.1	123.3	131.4	138.6	135.2	122.8
Dry Unit wt, pcf	103.2	103.2	96.2	95.7	108.0	121.5	115.0	93.9
Dry Bulk Dens.pb, (g/cc)	1.65	1.65	1.54	1.53	1.73	1.95	1.84	1.50
Saturation, %	98.8	97.7	99.0	97.4	97.8	89.8	94.1	99.9
Total Porosity, %	41.0	41.0	45.0	45.3	38.3	30.6	34.2	46.3
Volumetric Water Cont,Өw,%	40.5	40.1	44.5	44.1	37.5	27.5	32.2	46.3
Volumetric Air Cont., Өa,%	0.5	0.9	0.5	1.2	0.8	3.1	2.0	0.0
Void Ratio	0.70	0.70	0.82	0.83	0.62	0.44	0.52	0.86
Series	1	2	3	4	5	6	7	8

Note: All reported parameters are from the as-received sample condition unless otherwise noted. If an assumed specific gravity (Gs) was used then the saturation, porosities, and void ratio should be considered approximate.

Moisture-Density

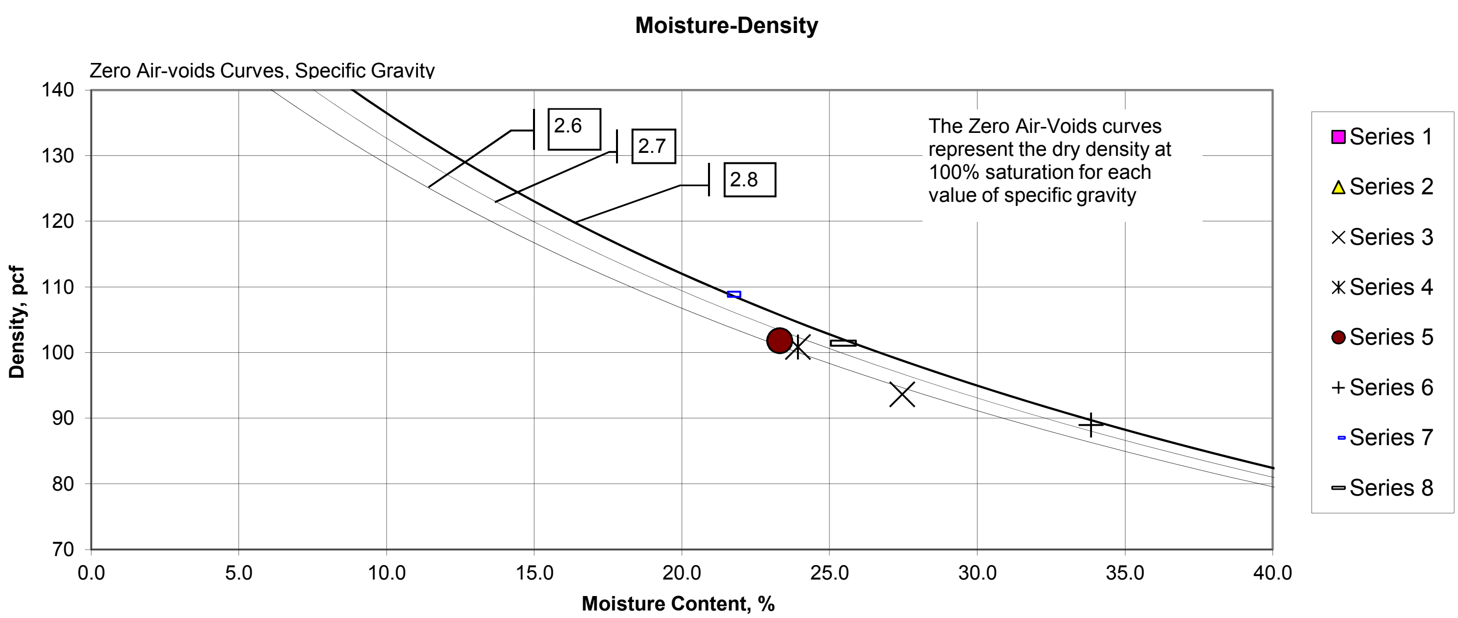


Moisture-Density-Porosity Report
Cooper Testing Labs, Inc. (ASTM D7263b)

CTL Job No: 855-013b **Project No.** 028-222952 **By:** RU
Client: HDR Engineering, Inc **Date:** 02/22/16
Project Name: SAFER Bay-Task Order 1 **Remarks:**

Boring:	B-03	B-03	B-03	B-05	B-05	B-05	B-05	B-05
Sample:	L9	L15	L16	L2	L5	L7	L12	L14
Depth, ft:	25-25.5	41-41.5	45-47.5(Tip-17")	2.5-3	6.5-9	16-16.5	26-26.5	31-31.5
Visual Description:	Gray CLAY	Gray CLAY w/ shells	Gray Lean Clayey SAND w/ shells	Dark Olive Brown Sandy Lean CLAY	Olive Brown Silty SAND	Dark Olive Brown CLAY w/ Sand	Olive Brown CLAY w/ Sand	Olive Brown Lean CLAY w/ Sand
Actual G_s								
Assumed G_s	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80
Moisture, %	75.6	60.5	27.5	23.9	23.3	33.9	21.6	25.5
Wet Unit wt, pcf	98.2	104.1	119.3	124.9	125.5	119.0	132.3	127.2
Dry Unit wt, pcf	55.9	64.9	93.6	100.8	101.8	88.9	108.8	101.4
Dry Bulk Dens.pb, (g/cc)	0.90	1.04	1.50	1.61	1.63	1.42	1.74	1.62
Saturation, %	99.5	99.8	88.5	91.1	90.8	98.0	99.4	98.3
Total Porosity, %	68.0	62.9	46.5	42.4	41.8	49.2	37.8	42.0
Volumetric Water Cont,Θw,%	67.7	62.8	41.2	38.6	38.0	48.2	37.6	41.3
Volumetric Air Cont., Θa,%	0.3	0.1	5.3	3.8	3.8	1.0	0.2	0.7
Void Ratio	2.13	1.70	0.87	0.74	0.72	0.97	0.61	0.73
Series	1	2	3	4	5	6	7	8

Note: All reported parameters are from the as-received sample condition unless otherwise noted. If an assumed specific gravity (Gs) was used then the saturation, porosities, and void ratio should be considered approximate.

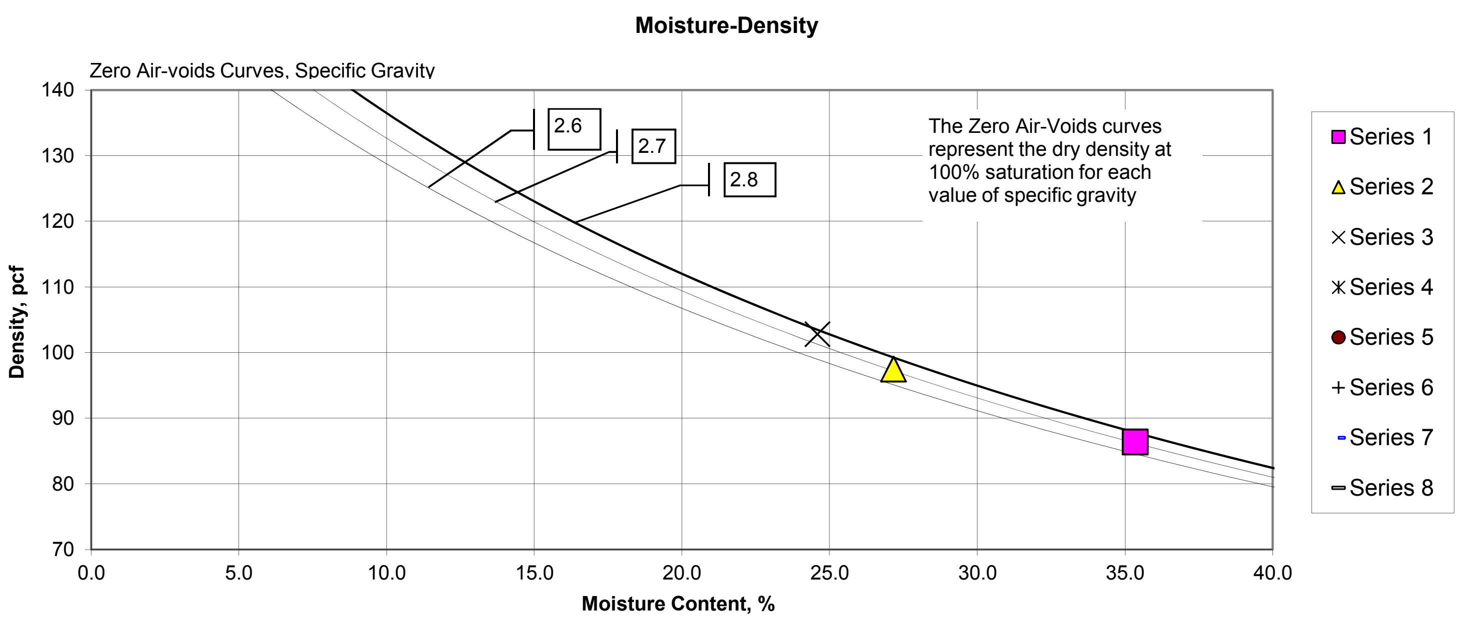


Moisture-Density-Porosity Report
Cooper Testing Labs, Inc. (ASTM D7263b)

CTL Job No:	855-013c	**Project No.**	028-222952	**By:**	RU
Client:	HDR Engineering, Inc.	**Date:**	02/22/16		
Project Name:	SAFER Bay-Task Order 1	**Remarks:**			

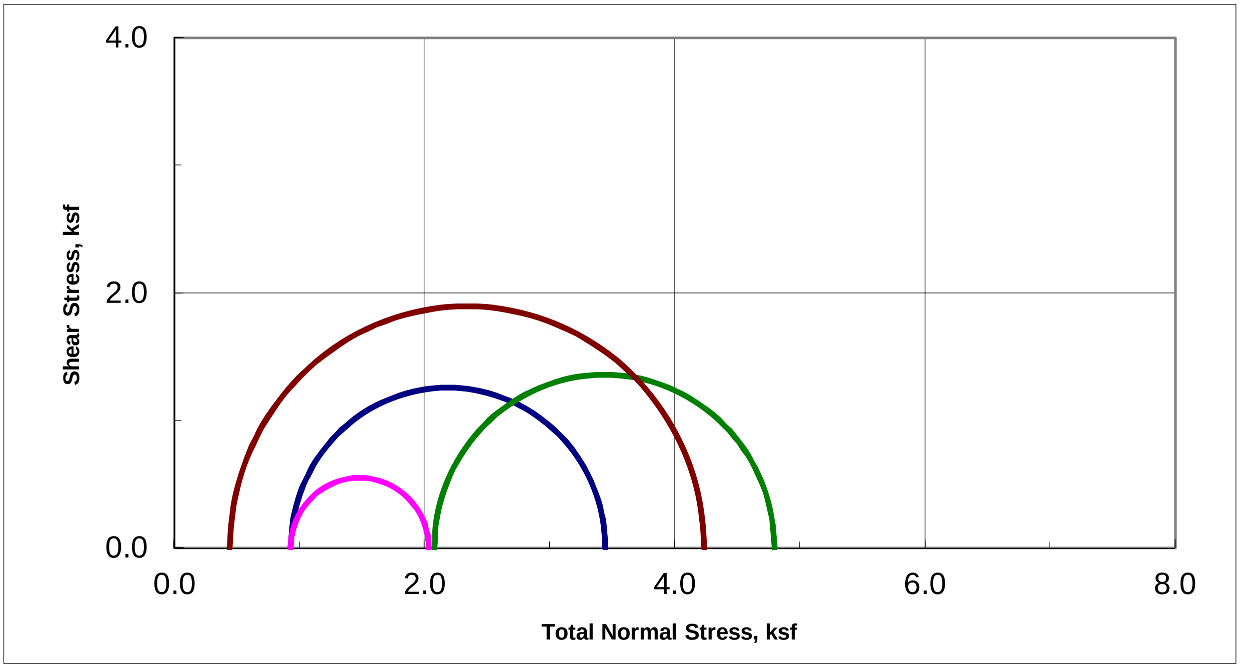
Boring:	B-06	B-06	B-06	B-06				
Sample:	L1	L7	L12	S3				
Depth, ft:	4-4.5	18-18.5	31-31.5	45-46.5				
Visual Description:	Dark Olive Brown Sandy CLAY w/ Gravel	Gray CLAY w/ Sand	Olive Brown Sandy CLAY	Olive Brown Lean CLAY w/ Sand				
Actual G_s								
Assumed G_s	2.80	2.80	2.80					
Moisture, %	35.3	27.2	24.6	37.1				
Wet Unit wt, pcf	116.8	123.9	128.1					
Dry Unit wt, pcf	86.3	97.4	102.8					
Dry Bulk Dens.pb, (g/cc)	1.38	1.56	1.65					
Saturation, %	96.4	95.6	98.1					
Total Porosity, %	50.6	44.3	41.2					
Volumetric Water Cont,Θw,%	48.8	42.4	40.4					
Volumetric Air Cont., Θa,%	1.8	1.9	0.8					
Void Ratio	1.03	0.80	0.70					
Series	1	2	3	4	5	6	7	8

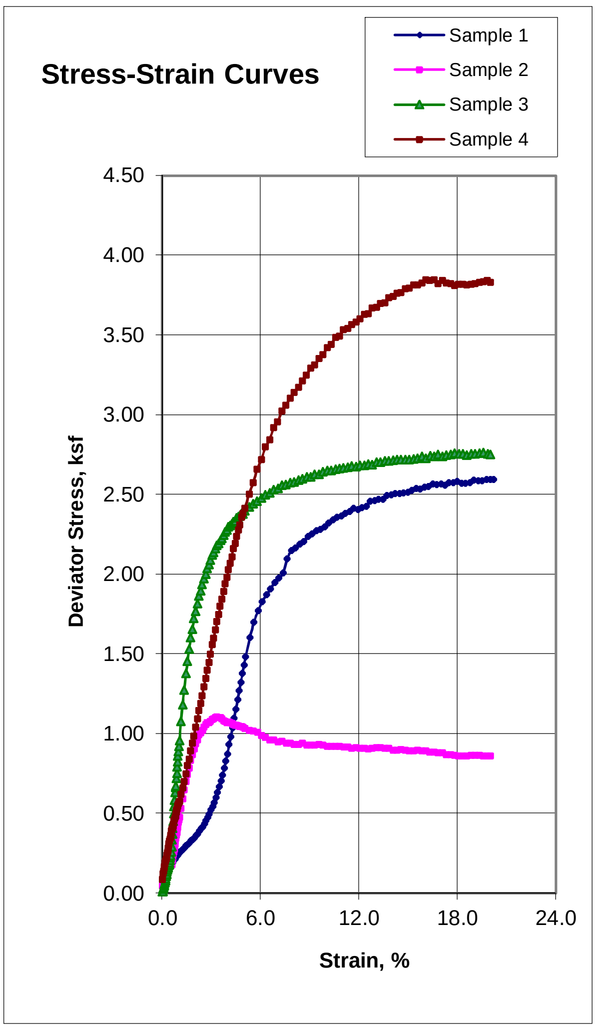
Note: All reported parameters are from the as-received sample condition unless otherwise noted. If an assumed specific gravity (Gs) was used then the saturation, porosities, and void ratio should be considered approximate.



Cooper Testing Labs, Inc.
937 Commercial Street
Palo Alto, CA 94303

Unconsolidated-Undrained Triaxial Test
ASTM D2850





Sample Data				
	1	2	3	4
Moisture %	20.3	90.2	30.9	20.9
Dry Den,pcf	103.9	47.8	91.0	107.6
Void Ratio	0.622	2.523	0.852	0.567
Saturation %	88.2	96.6	97.9	99.6
Height in	6.02	6.12	6.08	6.11
Diameter in	2.85	2.88	2.88	2.86
Cell psi	6.5	6.5	14.4	3.1
Strain %	15.00	3.33	15.00	15.00
Deviator, ksf	2.516	1.105	2.719	3.791
Rate %/min	1.01	1.00	1.00	1.00
in/min	0.061	0.061	0.061	0.061
Job No.:	855-013a			
Client:	HDR Engineering, Inc.			
Project:	028-222952			
Boring:	B-01	B-02	B-02	B-03
Sample:	L6	L7	L11	L4
Depth ft:	15-17.5(Tip-8.5")	15-17.5(Tip-4.5")	43.7-45(Tip-3")	6-8.5

Visual Soil Description

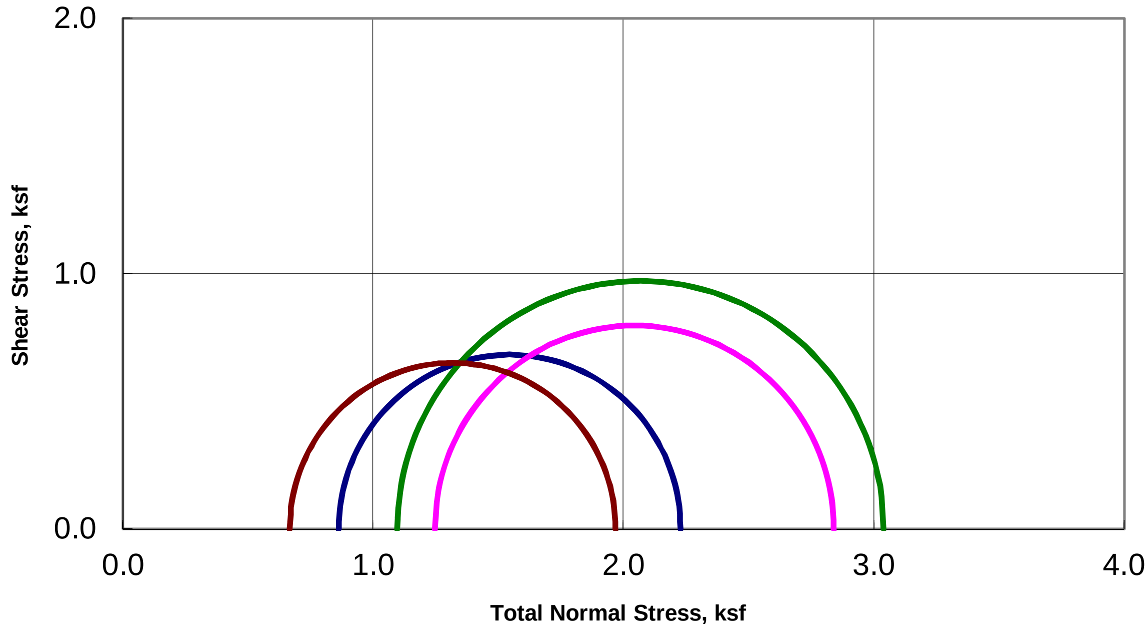
Sample #	
1	Olive Sandy Lean CLAY/ Lean Clayey SAND w/ Gravel
2	Dark Gray Elastic SILT (Bay Mud)
3	Greenish Gray Lean CLAY
4	Grayish Brown Sandy CLAY

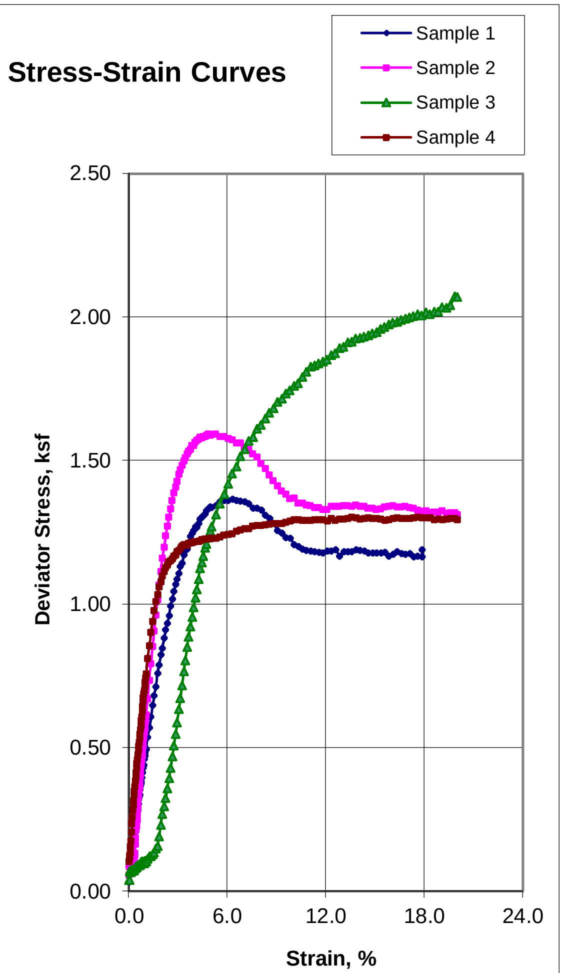
Remarks:

Note: Strengths are picked at the peak deviator stress or 15% strain which ever occurs first per ASTM D2850.

Cooper Testing Labs, Inc.
937 Commercial Street
Palo Alto, CA 94303

Unconsolidated-Undrained Triaxial Test
ASTM D2850





Sample Data	1	2	3	4
Moisture %	71.3	60.9	26.3	41.4
Dry Den,pcf	56.9	63.3	96.8	77.3
Void Ratio	1.960	1.664	0.742	1.181
Saturation %	98.3	98.8	95.7	94.5
Height in	6.14	6.10	6.10	6.09
Diameter in	2.86	2.87	2.86	2.89
Cell psi	6.0	8.7	7.6	4.6
Strain %	6.30	5.29	15.00	13.58
Deviator, ksf	1.367	1.594	1.944	1.302
Rate %/min	1.00	1.00	1.00	1.00
in/min	0.061	0.061	0.061	0.061
Job No.:	855-013b			
Client:	HDR Engineering, Inc.			
Project:	028-222952			
Boring:	B-03	B-03	B-05	B-06
Sample:	L6	L10	L10	L4
Depth ft:	19-21.5	30-32.5(Tip-1")	20-22.5	7-9.5(Tip14")

Visual Soil Description

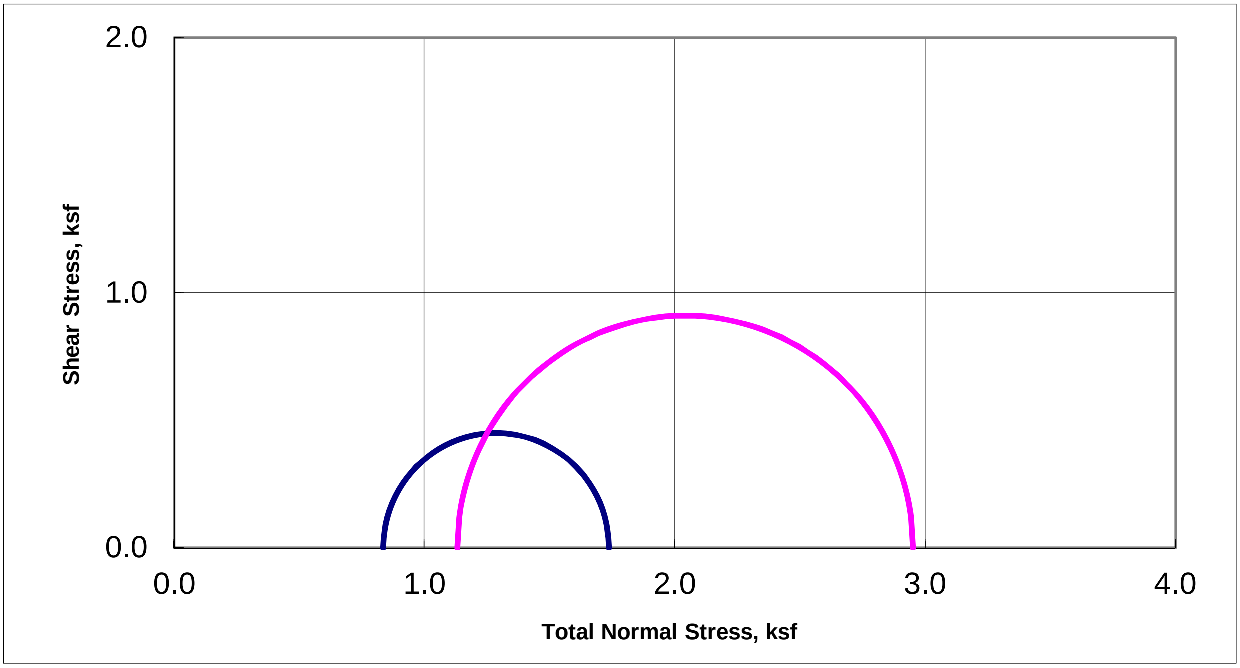
Sample #	
1	Greenish Gray Elastic SILT (Bay Mud)
2	Greenish Gray Elastic SILT (Bay Mud)
3	Dark Grayish Brown Lean CLAY
4	Dark Gray Fat CLAY

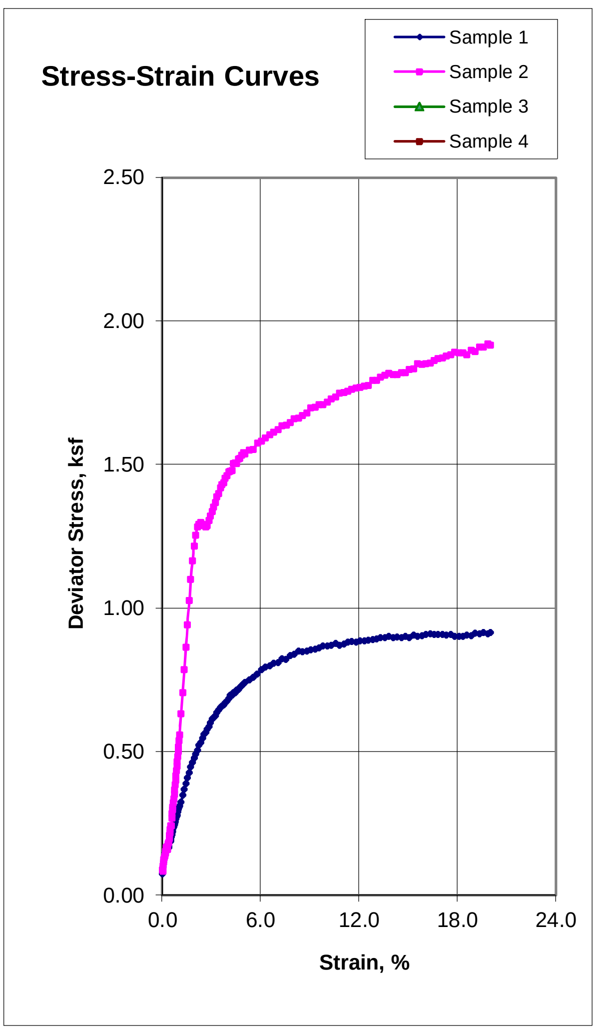
Remarks:

Note: Strengths are picked at the peak deviator stress or 15% strain which ever occurs first per ASTM D2850.

Cooper Testing Labs, Inc.
937 Commercial Street
Palo Alto, CA 94303

Unconsolidated-Undrained Triaxial Test
ASTM D2850





Sample Data				
	1	2	3	4
Moisture %	40.7	22.9		
Dry Den,pcf	79.8	101.9		
Void Ratio	1.112	0.653		
Saturation %	98.8	94.6		
Height in	6.10	6.12		
Diameter in	2.86	2.87		
Cell psi	5.8	7.9		
Strain %	15.00	15.00		
Deviator, ksf	0.901	1.821		
Rate %/min	1.00	1.00		
in/min	0.061	0.061		
Job No.:	**855-013c**			
Client:	**HDR Engineering, Inc.**			
Project:	**028-222952**			
Boring:	B-06	B-06		
Sample:	L6	L8		
Depth ft:	12.5-15	21-23.5		

Visual Soil Description	
Sample #	
1	Dark Greenish Gray Fat CLAY (Bay Mud)
2	Greenish Gray Lean CLAY w/ Sand
3	
4	

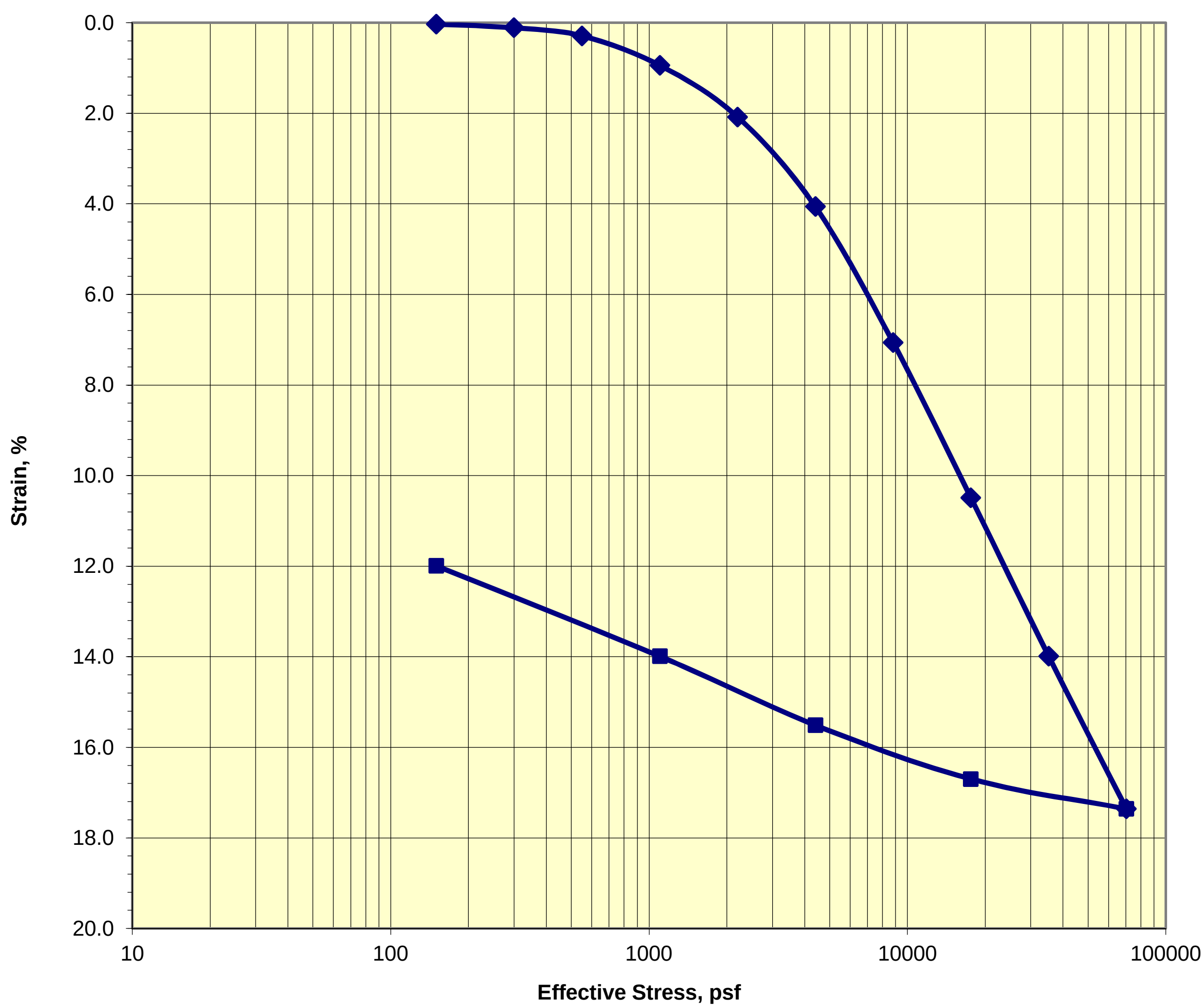
Remarks:

Note: Strengths are picked at the peak deviator stress or 15% strain which ever occurs first per ASTM D2850.

Consolidation Test
ASTM D2435

Job No.:	855-013	**Boring:**	B-01	**Run By:**	MD
Client:	HDR Engineering, Inc.	**Sample:**	L6	**Reduced:**	PJ
Project:	028-222952	**Depth, ft.:**	15-17.5(Tip-7")	**Checked:**	PJ/DC
Soil Type:	Olive Sandy Lean CLAY/ Lean Clayey SAND w/ Gravel			**Date:**	2/25/2016

Strain-Log-P Curve

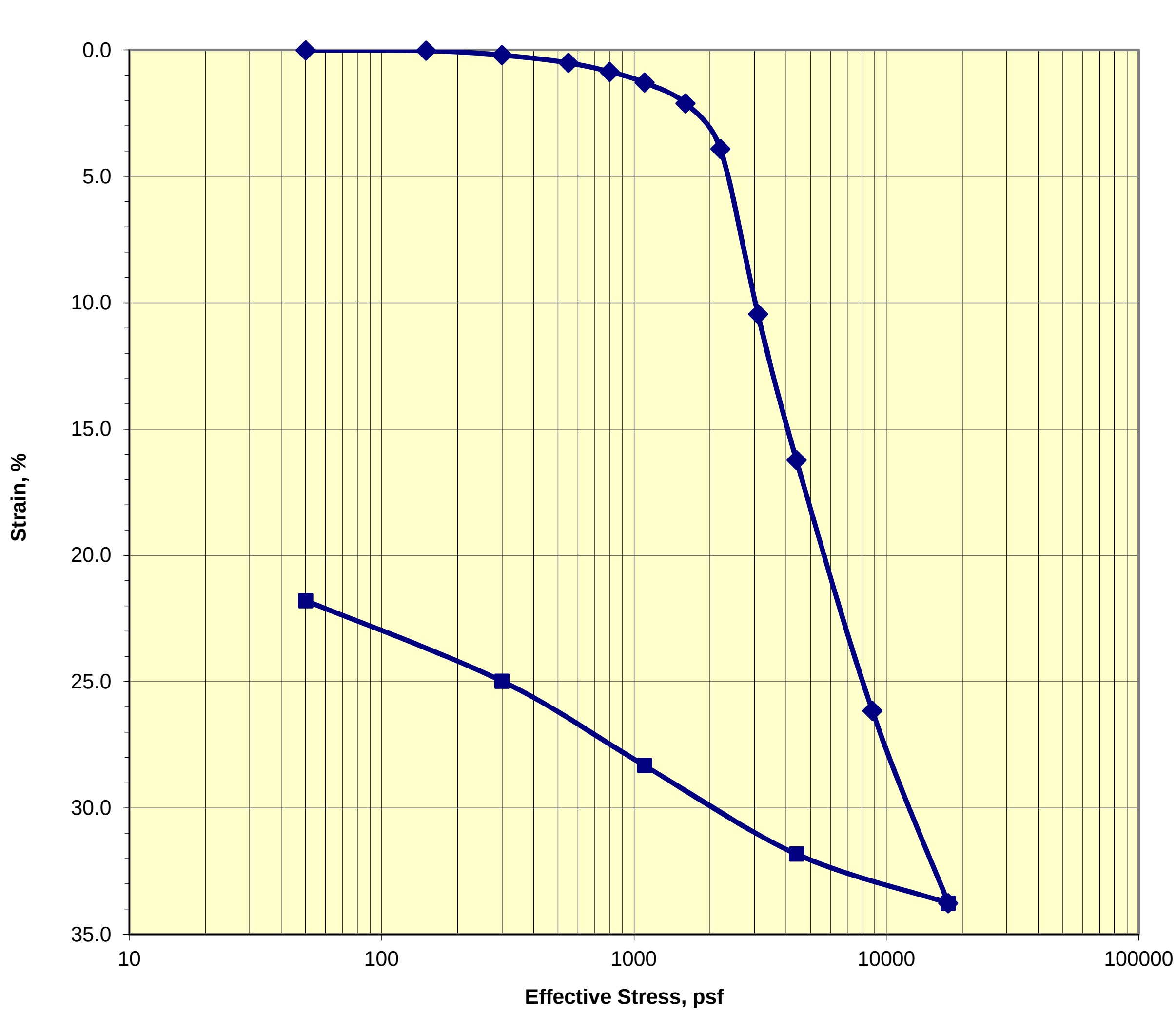


Assumed Gs 2.7	Initial	Final
Moisture %:	20.3	17.6
Dry Density, pcf:	100.8	114.3
Void Ratio:	0.672	0.475
% Saturation:	81.5	100.0

Remarks:

Consolidation Test
ASTM D2435

Job No.:	855-013	**Boring:**	B-02	**Run By:**	MD
Client:	HDR Engineering	**Sample:**	L7	**Reduced:**	PJ
Project:	028-22952	**Depth, ft.:**	15-17.5(Tip-3")	**Checked:**	PJ/DC
Soil Type:	Dark Gray Elastic SILT (Bay Mud)			**Date:**	3/1/2016

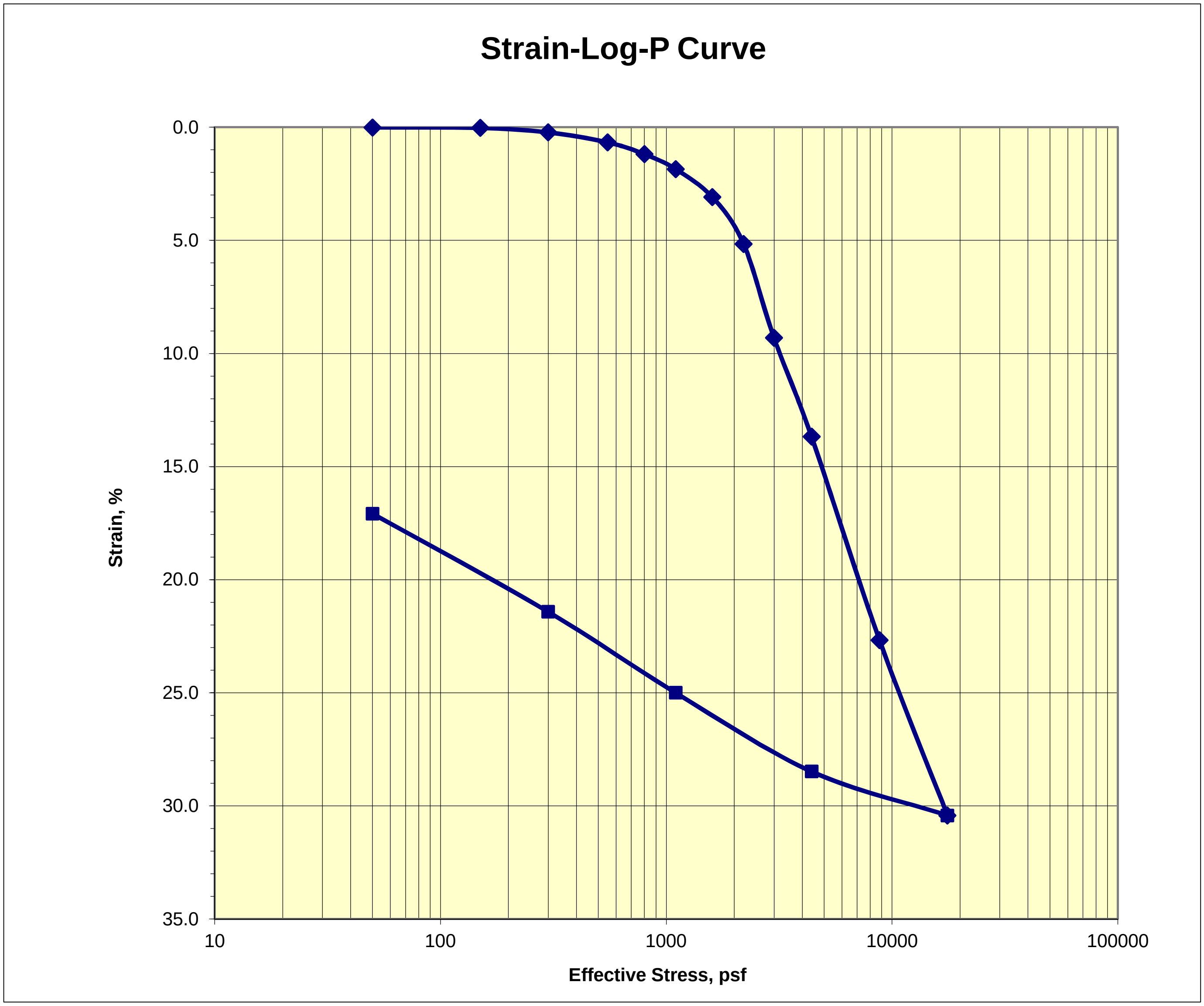


Assumed Gs 2.65	Initial	Final
Moisture %:	89.0	60.9
Dry Density, pcf:	48.9	63.3
Void Ratio:	2.380	1.614
% Saturation:	99.1	100.0

Remarks: The 3000psf point was adjusted to 3100psf to smooth the curve. The pneumatic air regulators can drift over a 24 hour period by as much as 100 psf. Consult lab for uncorrected data.

Consolidation Test
ASTM D2435

Job No.:	855-013	**Boring:**	B-03	**Run By:**	MD
Client:	HDR Engineering	**Sample:**	L6	**Reduced:**	PJ
Project:	028-22952	**Depth, ft.:**	19-21.5(Tip-3")	**Checked:**	PJ/DC
Soil Type:	Greenish Gray Elastic SILT (Bay Mud)			**Date:**	3/1/2016

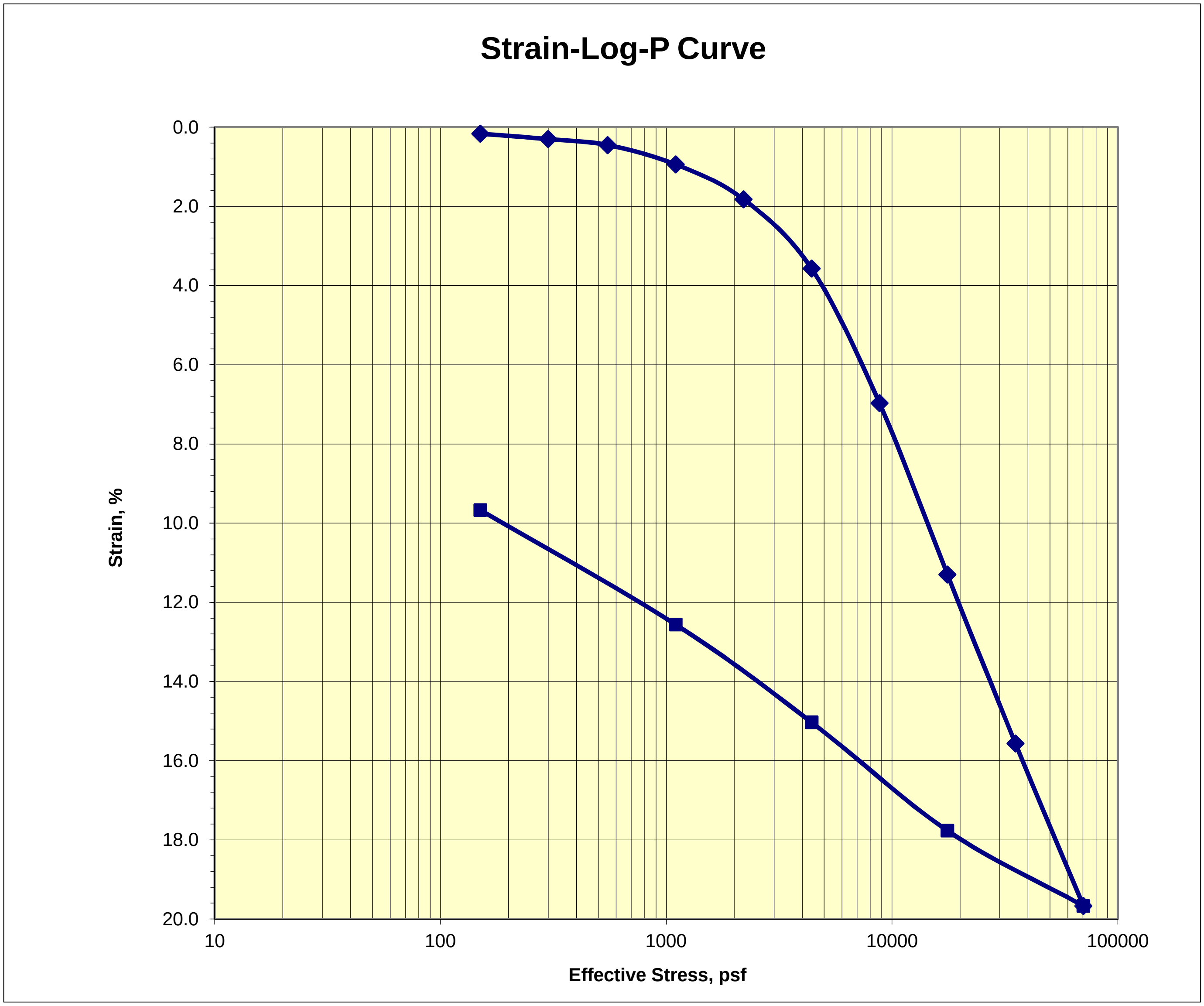


Assumed Gs 2.7	Initial	Final
Moisture %:	78.1	57.5
Dry Density, pcf:	54.7	66.0
Void Ratio:	2.079	1.552
% Saturation:	101.4	100.0

Remarks:

Consolidation Test
ASTM D2435

Job No.:	855-013	**Boring:**	B-05	**Run By:**	MD
Client:	HDR Engineering, Inc.	**Sample:**	L10	**Reduced:**	PJ
Project:	028-222952	**Depth, ft.:**	20-22.5(Tip-9")	**Checked:**	PJ/DC
Soil Type:	Dark Grayish Brown Lean CLAY			**Date:**	3/2/2016

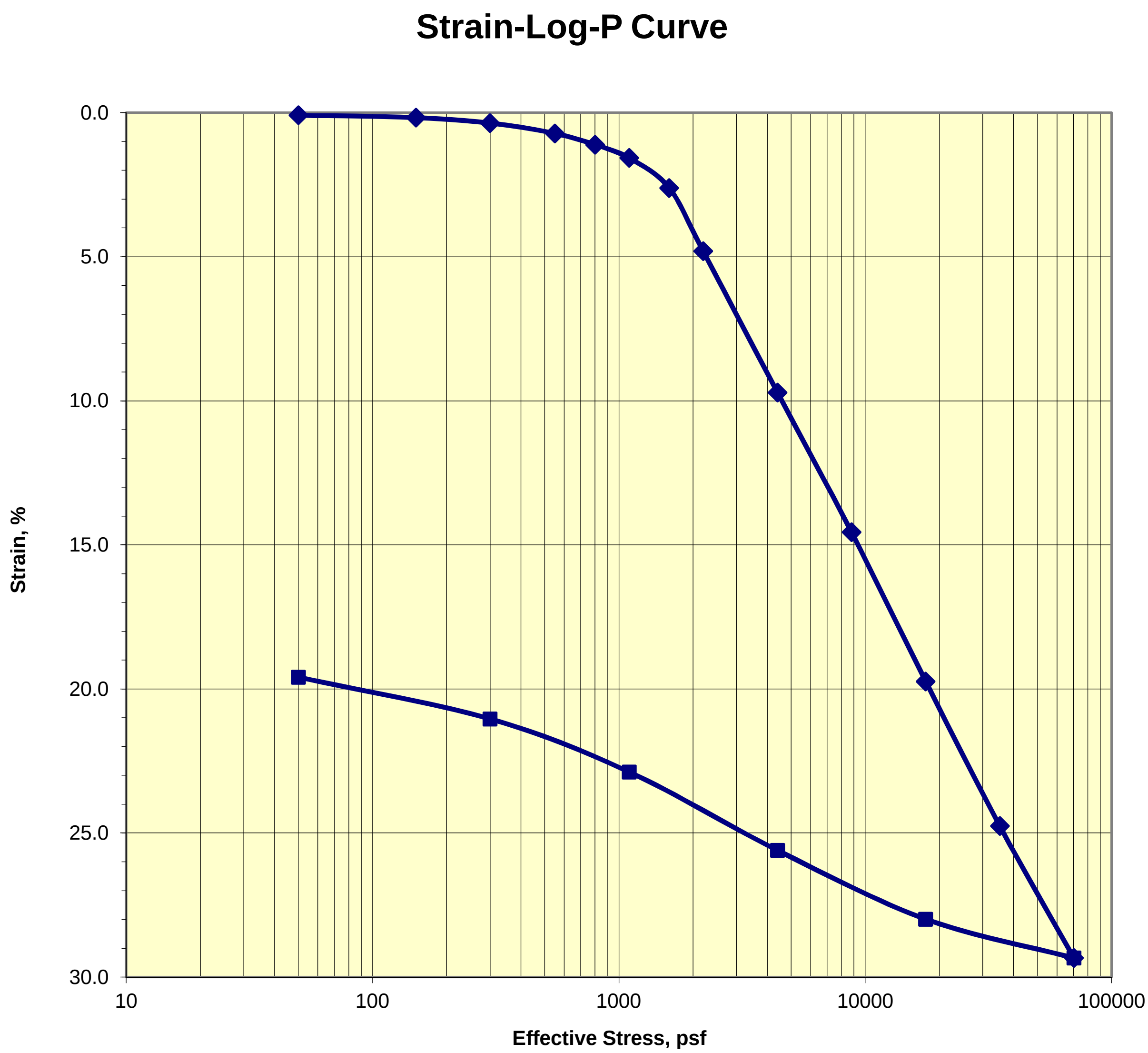


Assumed Gs 2.75	Initial	Final
Moisture %:	27.3	23.7
Dry Density, pcf:	93.8	104.0
Void Ratio:	0.831	0.651
% Saturation:	90.3	100.0

Remarks:

Consolidation Test
ASTM D2435

Job No.:	855-013	**Boring:**	B-06	**Run By:**	MD
Client:	HDR Engineering, Inc.	**Sample:**	L6	**Reduced:**	PJ
Project:	028-222952	**Depth, ft.:**	12.5-15 (tip-3")	**Checked:**	PJ/DC
Soil Type:	Dark Greenish Gray Fat CLAY (Bay Mud)			**Date:**	3/7/2016



Assumed Gs 2.75	**Initial**	**Final**
Moisture %:	41.4	27.9
Dry Density, pcf:	78.7	97.1
Void Ratio:	1.182	0.767
% Saturation:	96.3	100.0

Remarks:

Appendix C
Stability Analyses Results

1111 Broadway, Suite 1670, Oakland, CA
P 510-285-1123
hdrinc.com

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Appendix C contains the following:

Figures C-1 through C-4: Cross Section G1 – Located within Reach 1, and represents Reach 1, Option 2 and the western segment of Reach 2, Option 1.

Figures C-5 through C-8: Cross section G2 – Located within Reach 3, and represents the eastern segment of Reach 2, Option 1 and Reach 3, Option 1.

Figures C-9 through C-12: Cross section G3 – Located within and represents Reach 4.

Figures C-13 through C-19: Cross section G4 – Located within the western portion of Reach 5/6, Option 1 and Reach 5, Option 4, and represents the segment along Ravenswood Slough (between Reach 4 and the western edge of Pond R2), and the segment of Reach 5/6, Option 1 on the south side of Highway 84 from about 1,000 feet northeast of University Avenue to Reach 7.

Figures C-20 through C-26: Located east of the PG&E substation within Reach 5/6, Option 1 and Reach 5, Option 4, and represents the segment of both options along Pond R2 and the segment of Reach 5/6, Option 1 on the south side of Highway 84 from the Dumbarton Bridge abutment to about 1,000 feet northeast of University Avenue.

Figures C-27 through C-33: Cross section G6 – Located within Pond SF2 of Reach 5, Option 4, and represents the segment of Reach 5, Option 4 from Pond R2 to Reach 7.

Figures C-34 through C-37: Cross section G7 – Located within and represents Reach 7.

Figures C-38 through C-41: Cross section G8 – Located within Reach 9 and represents Reaches 8 and 9.

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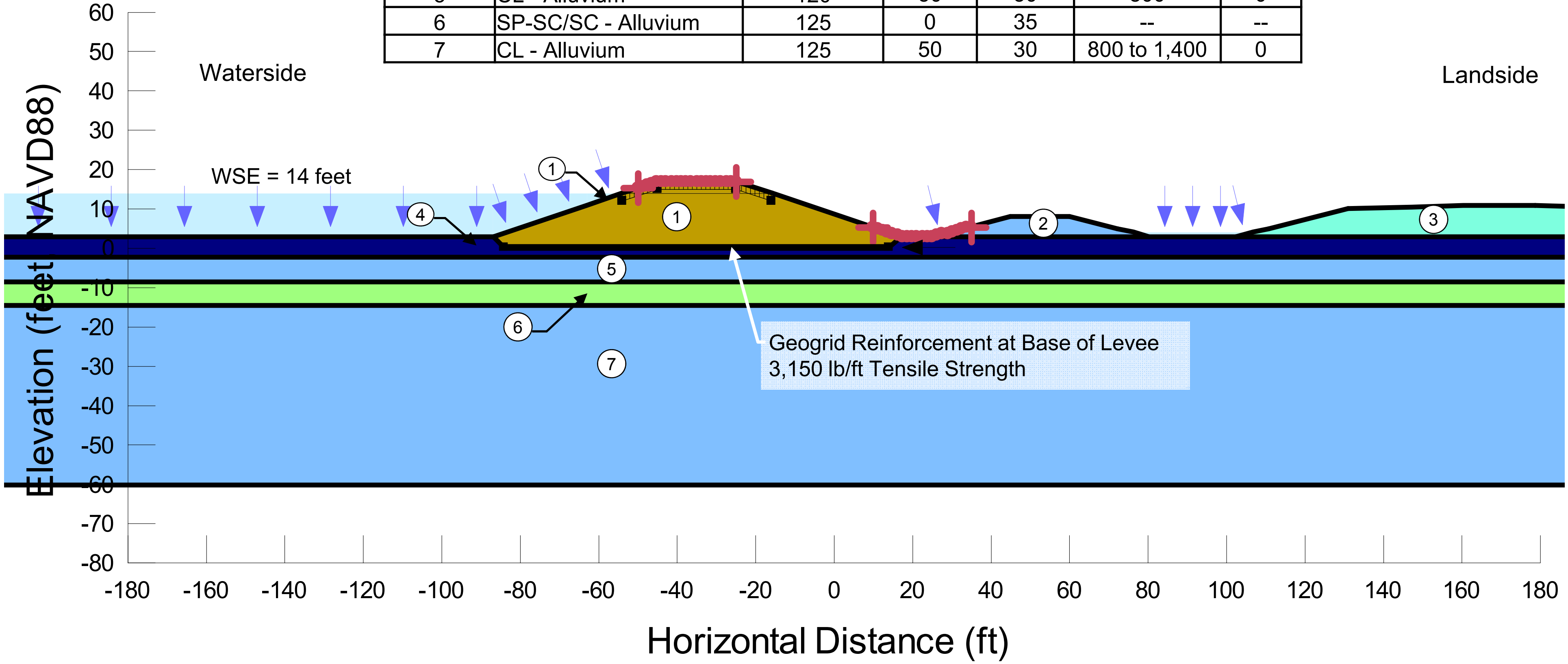
Layer Number	Layer Name	Saturated Unit Weight	Drained Parameters		Undrained Parameters	
			c'	ϕ'	c	ϕ
		(pcf)	(psf)	(deg.)	(psf)	(deg.)
1	CL - Levee Fill	125	75	30	750	0
2	CH - Existing Levee	120	75	30	500	0
3	SC/CL - Fill	120	75	30	500	0
4	CH - YBM	105	0	29	250	0
5	CL - Alluvium	120	50	30	800	0
6	SP-SC/SC - Alluvium	125	0	35	--	--
7	CL - Alluvium	125	50	30	800 to 1,400	0



SAFER Bay Project, Task Order No. 1

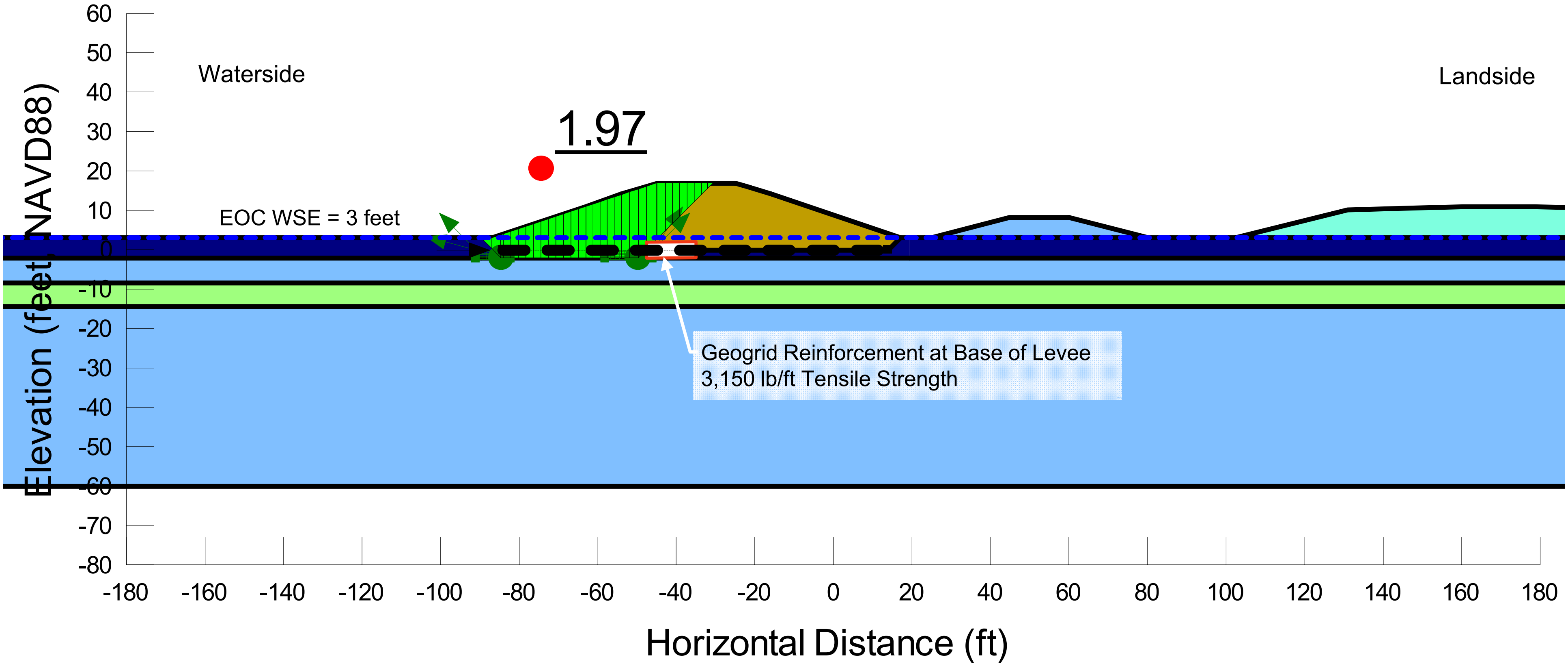
Menlo Park and East Palo Alto, California

HDR

Cross Section G1

Stability Model

May 2016 Figure C-1



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee.
3. A block-type failure surface was assumed due to the presence of a thin weak YBM layer (Layer 4) overlying stiffer alluvium (Layer 5).

SAFER Bay Project, Task Order No. 1

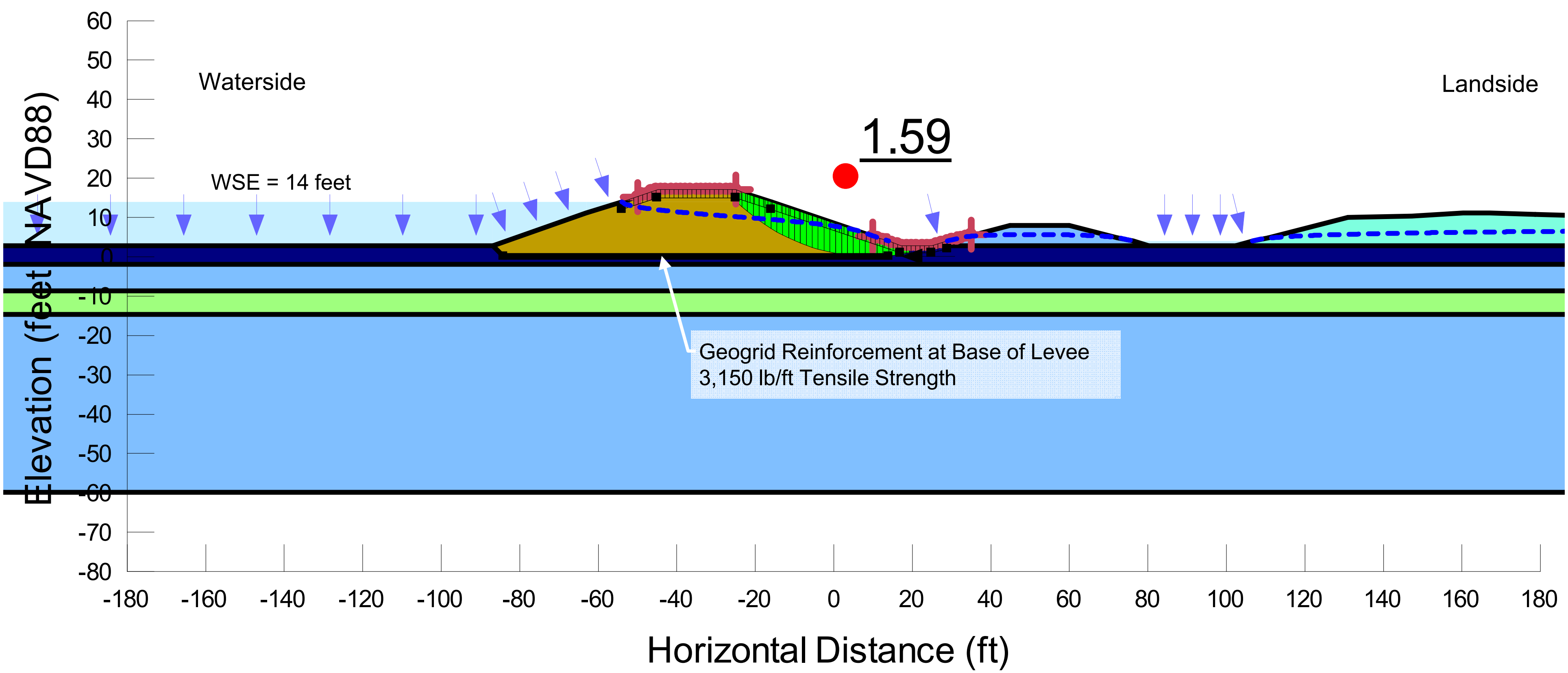
Menlo Park and East Palo Alto, California

Cross Section G1

End-of-Construction
Full Levee

May 2016

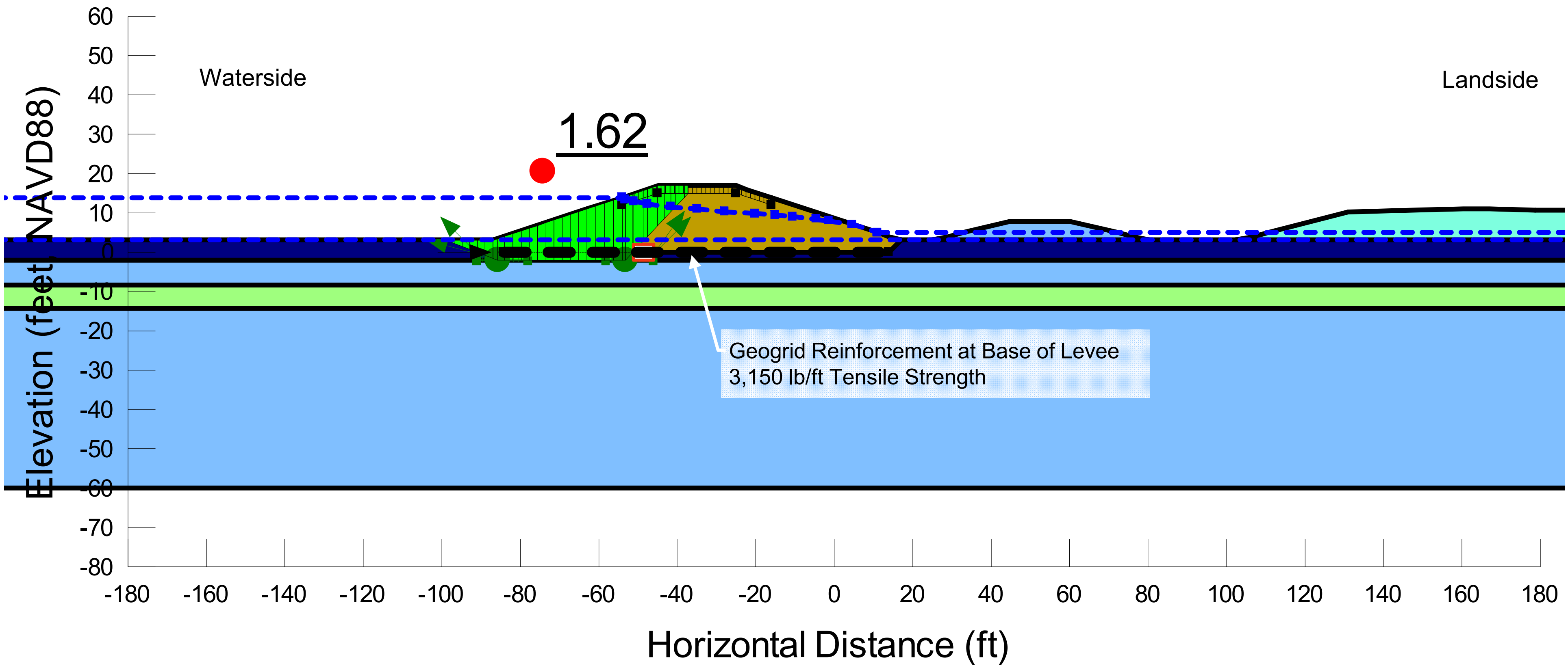
Figure C-2



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. Pore pressures are calculated from the steady-state seepage model with WSE = 14 feet.
3. 2' deep tension cracks filled with water are assumed for landside steady-state stability calculations.

SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G1** Steady-State Stability
Menlo Park and East Palo Alto, California		May 2016 Figure C-3

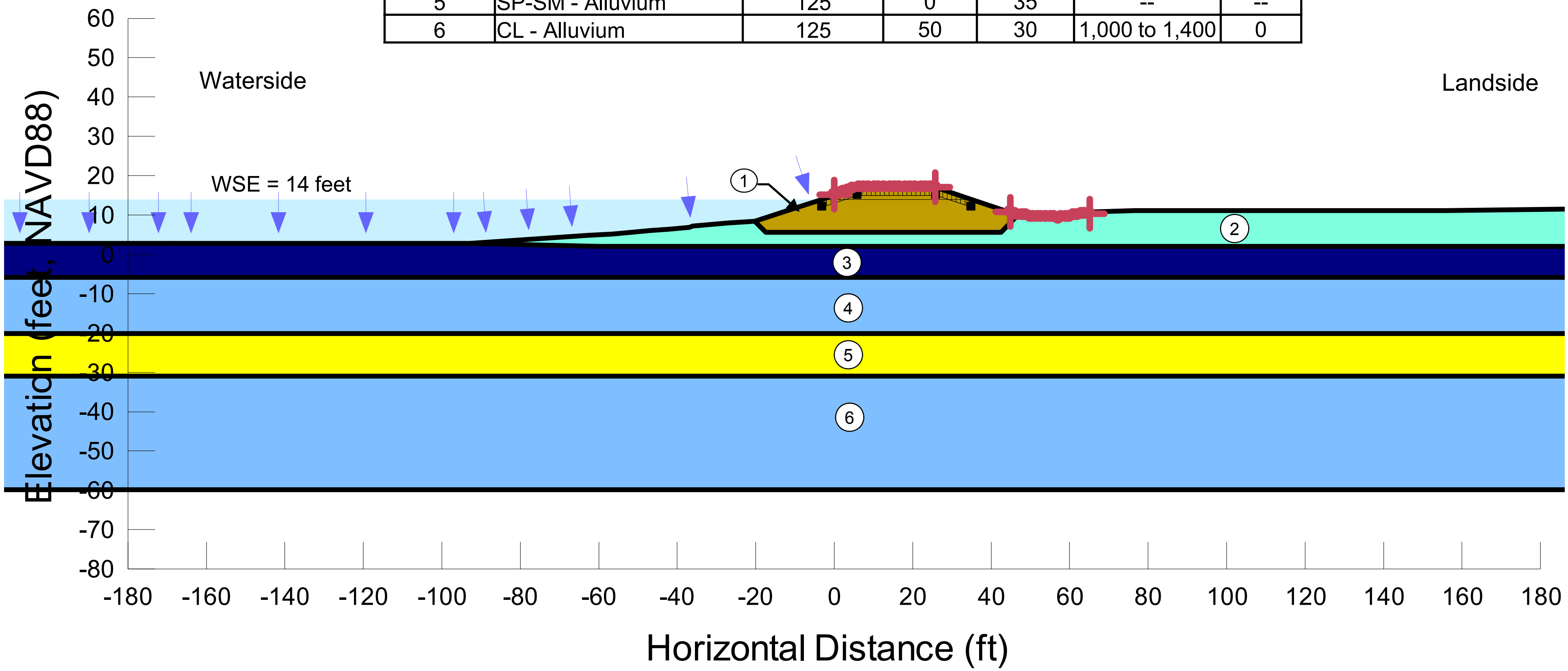


Notes:

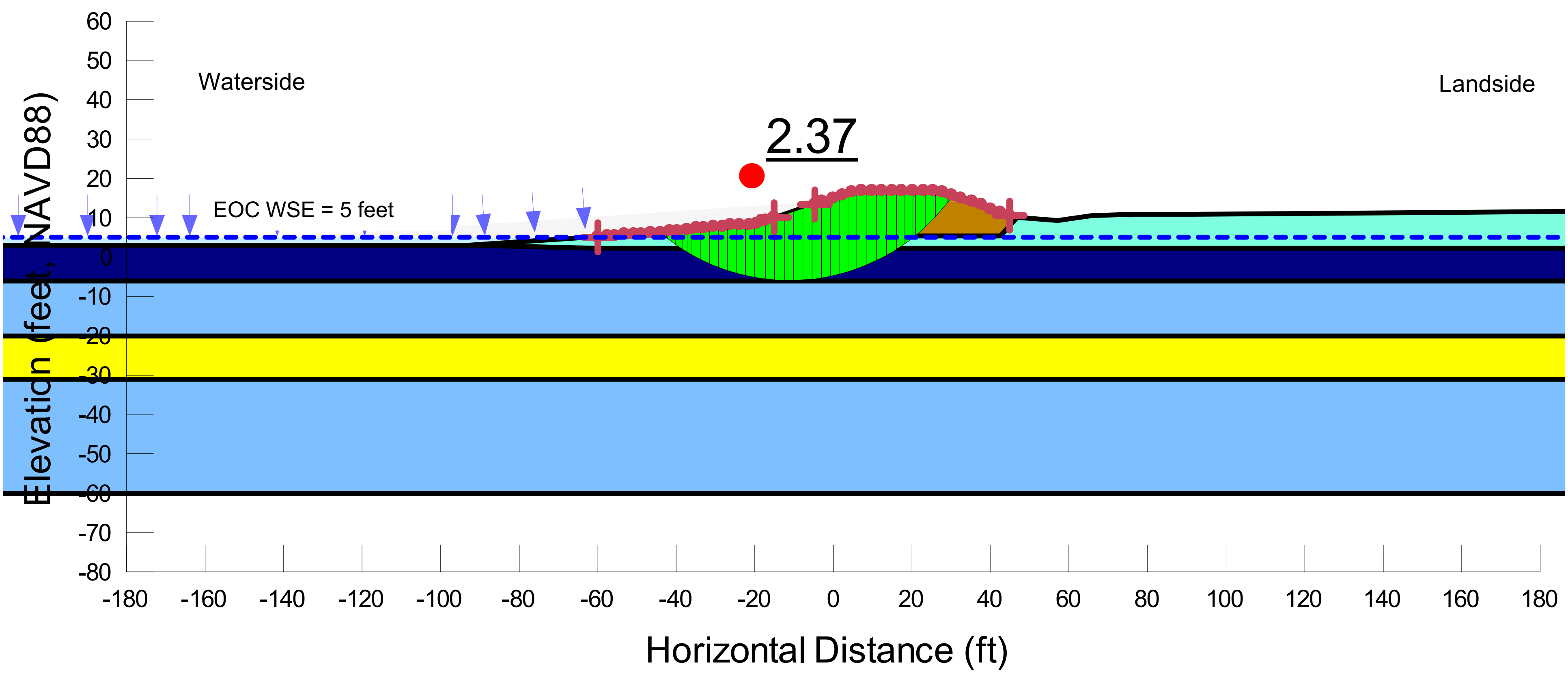
1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. 2' deep tension cracks filled with water are assumed for waterside rapid drawdown stability calculations.
3. A block-type failure surface was assumed due to the presence of a thin weak YBM layer (Layer 4) overlying stiffer alluvium (Layer 5).

SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G1** Waterside Rapid Drawdown
Menlo Park and East Palo Alto, California		May 2016 Figure C-4

Layer Number	Layer Name	Saturated Unit Weight	Drained Parameters		Undrained Parameters	
			c’	ϕ’	c	ϕ
		(pcf)	(psf)	(deg.)	(psf)	(deg.)
1	CL - Levee Fill	125	75	30	750	0
2	SC/CL - Fill	120	75	30	500	0
3	CH - YBM	110	0	29	400	0
4	CL - Alluvium	125	50	30	800	0
5	SP-SM - Alluvium	125	0	35	--	--
6	CL - Alluvium	125	50	30	1,000 to 1,400	0



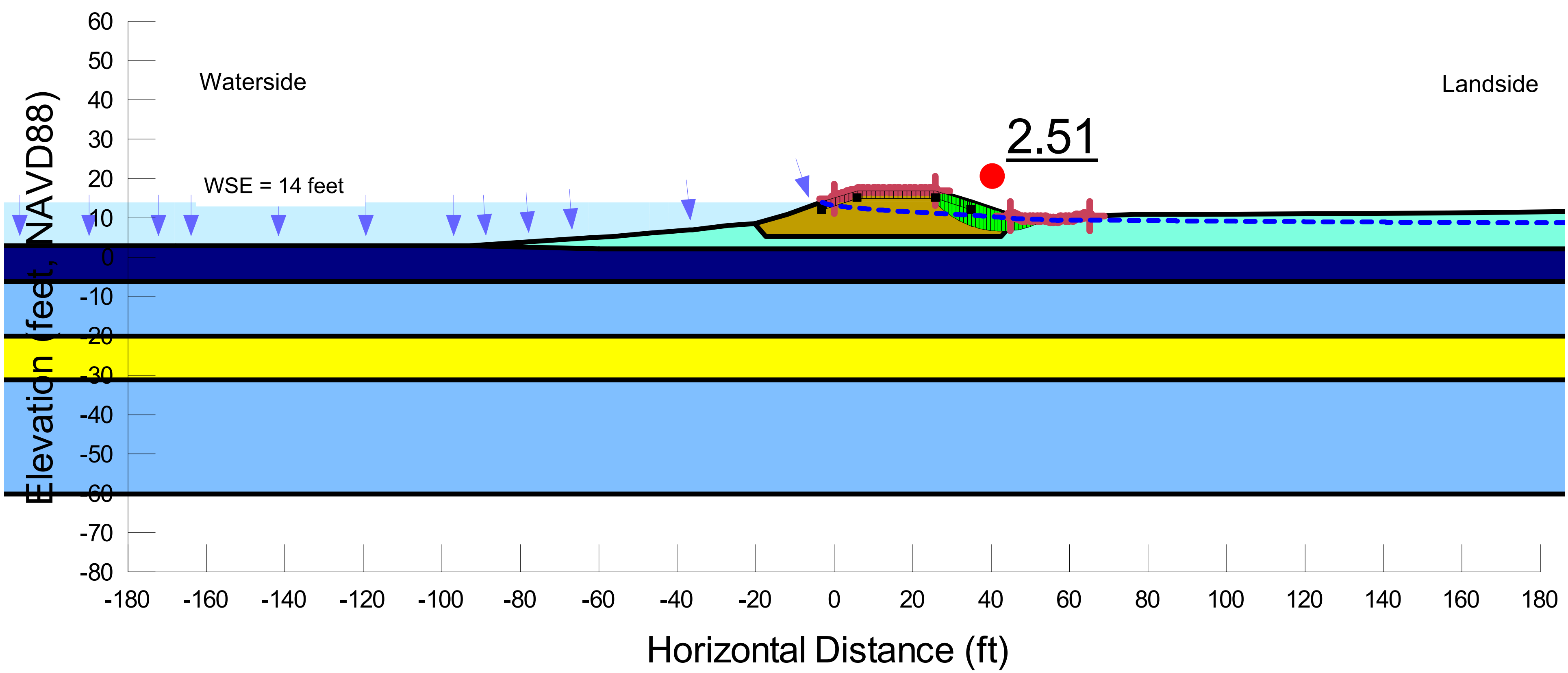
SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G2** Stability Model
Menlo Park and East Palo Alto, California		May 2016 Figure C-5



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

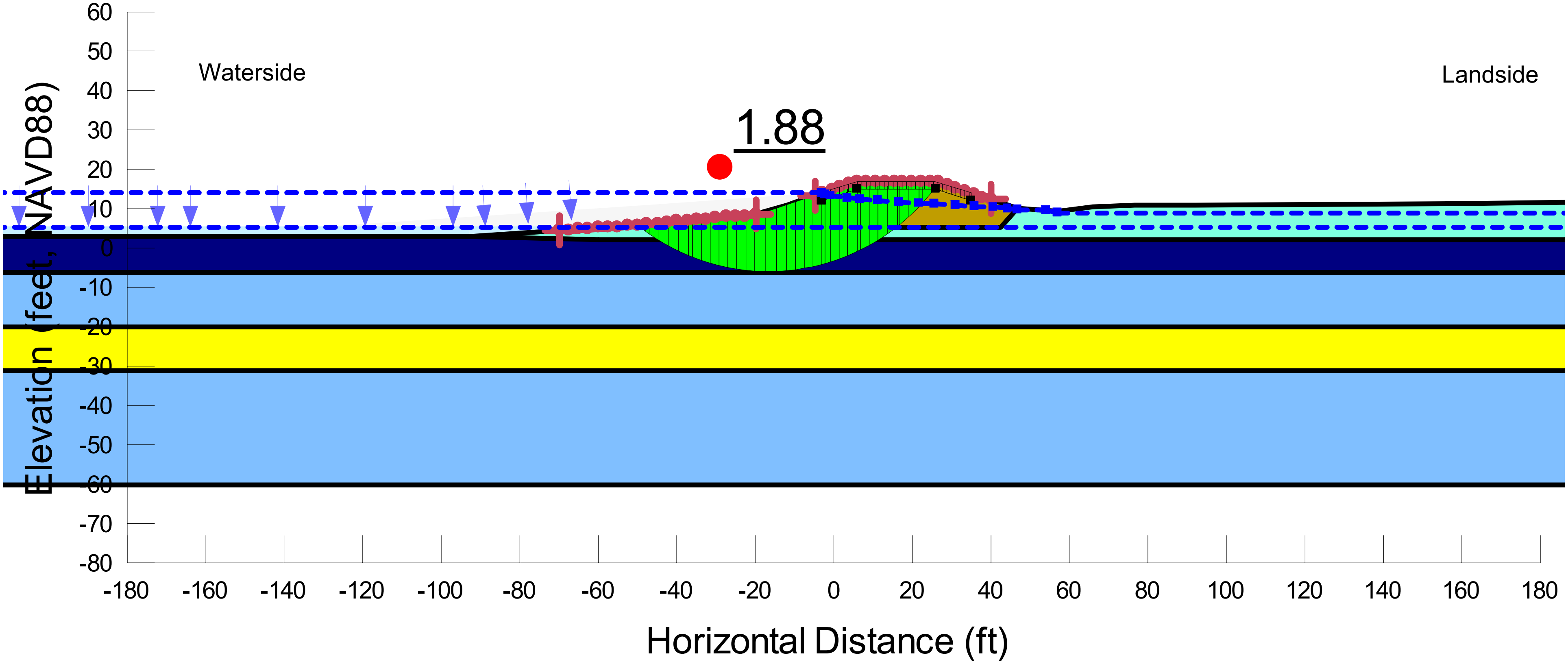
SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G2** End-of-Construction Full Levee
Menlo Park and East Palo Alto, California		May 2016 Figure C-6



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. Pore pressures are calculated from the steady-state seepage model with WSE = 14 feet.
3. 2' deep tension cracks filled with water are assumed for landside steady-state stability calculations.

SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G2** Steady-State Stability
Menlo Park and East Palo Alto, California		May 2016 Figure C-7

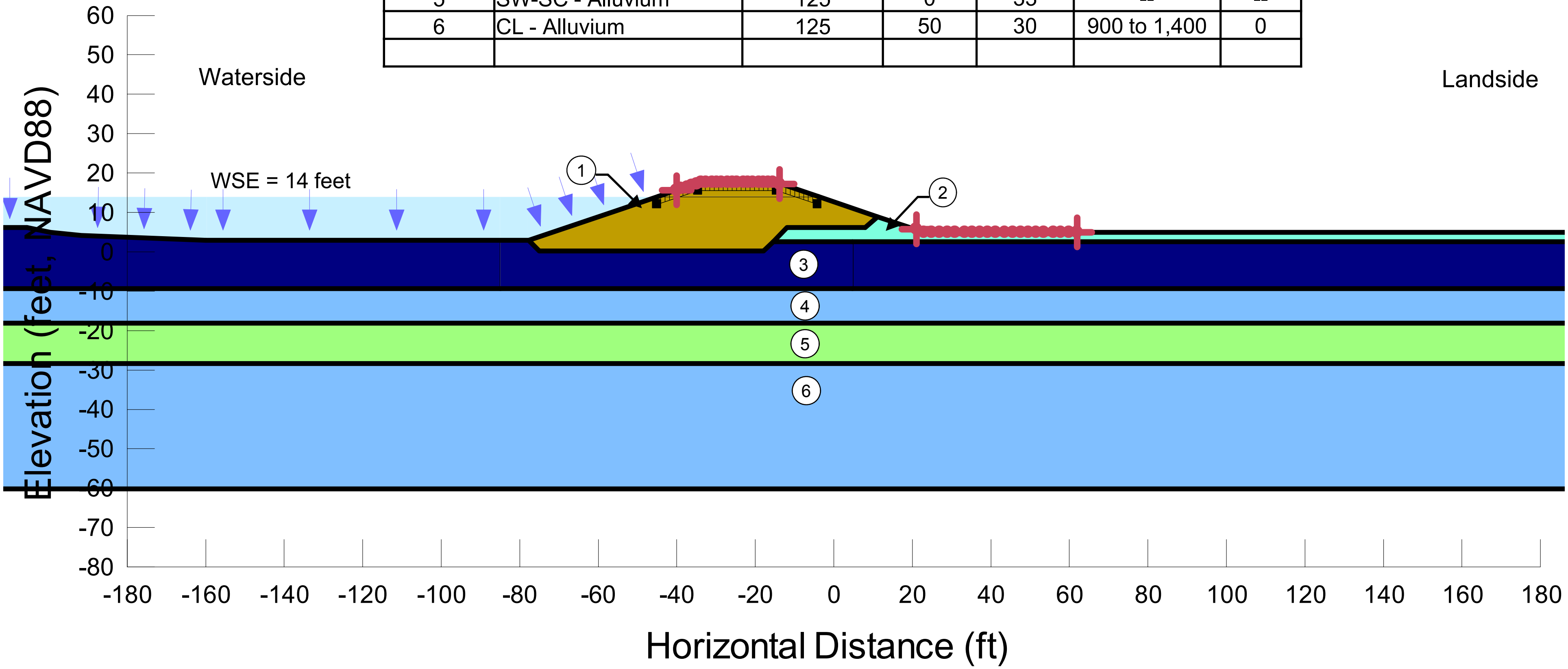


Notes:

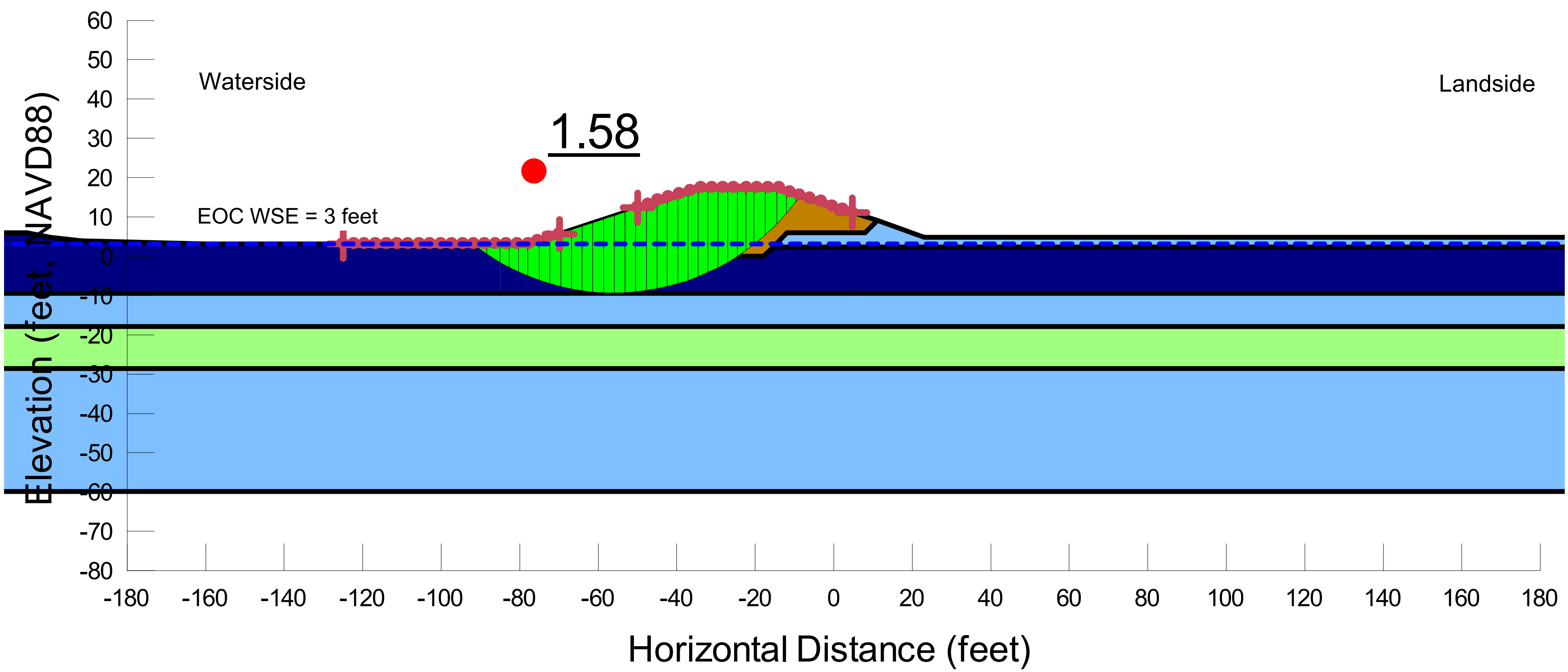
1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. 2' deep tension cracks filled with water are assumed for waterside rapid drawdown stability calculations.

SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G2** Waterside Rapid Drawdown
Menlo Park and East Palo Alto, California		May 2016 Figure C-8

Layer Number	Layer Name	Saturated Unit Weight	Drained Parameters		Undrained Parameters	
			c’	ϕ’	c	ϕ
		(pcf)	(psf)	(deg.)	(psf)	(deg.)
1	CL - Levee	125	75	30	750	0
2	SC/CL - Fill	120	75	30	500	0
3	CH/MH - YBM	95	0	29	300 to 400	0
4	CL - Alluvium	125	50	30	700	0
5	SW-SC - Alluvium	125	0	33	--	--
6	CL - Alluvium	125	50	30	900 to 1,400	0



SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G3** Stability Model
Menlo Park and East Palo Alto, California		May 2016 — Figure C-9



Notes:
1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 1

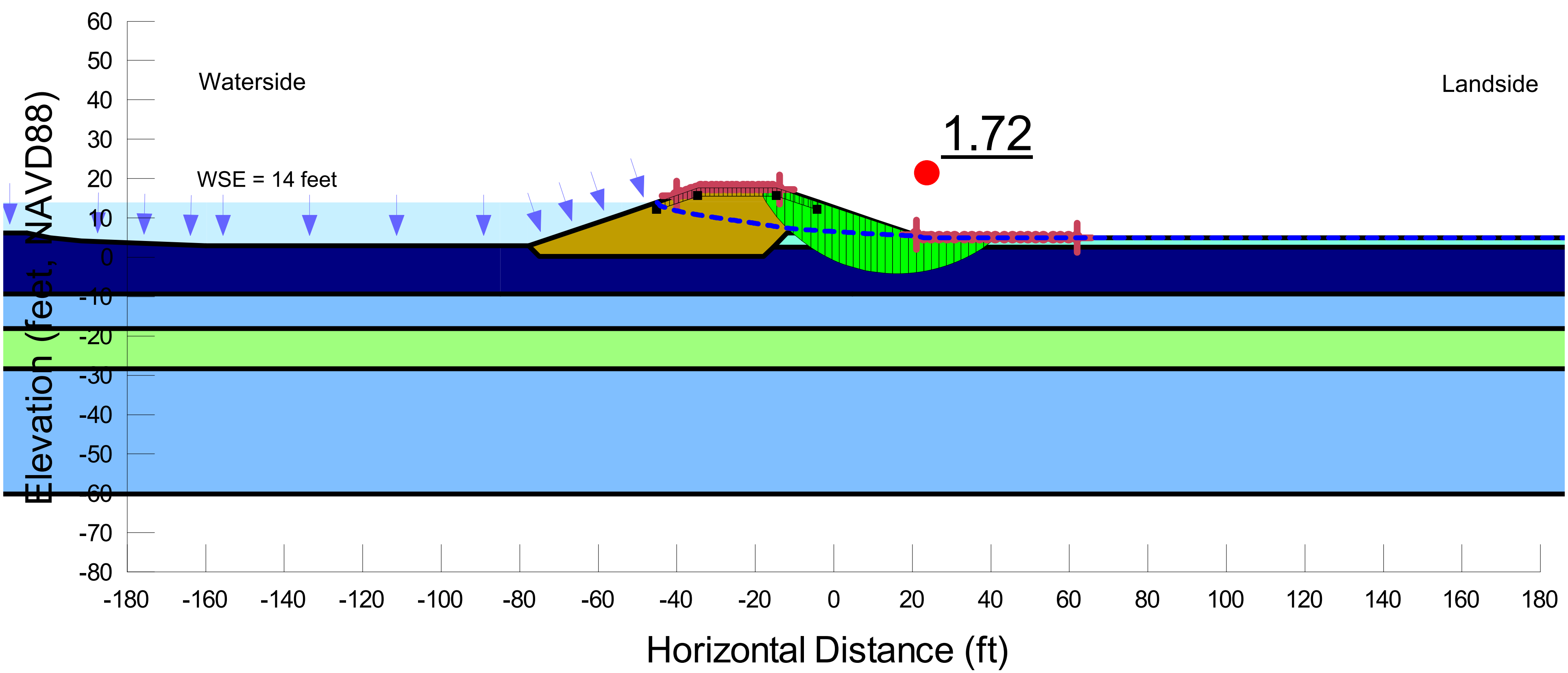
Menlo Park and East Palo Alto, California

Cross Section G3

End-of-Construction
Full Levee

May 2016

Figure C-10



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. Pore pressures are calculated from the steady-state seepage model with WSE = 14 feet.
3. 2' deep tension cracks filled with water are assumed for landside steady-state stability calculations.

SAFER Bay Project, Task Order No. 1

Menlo Park and East Palo Alto, California

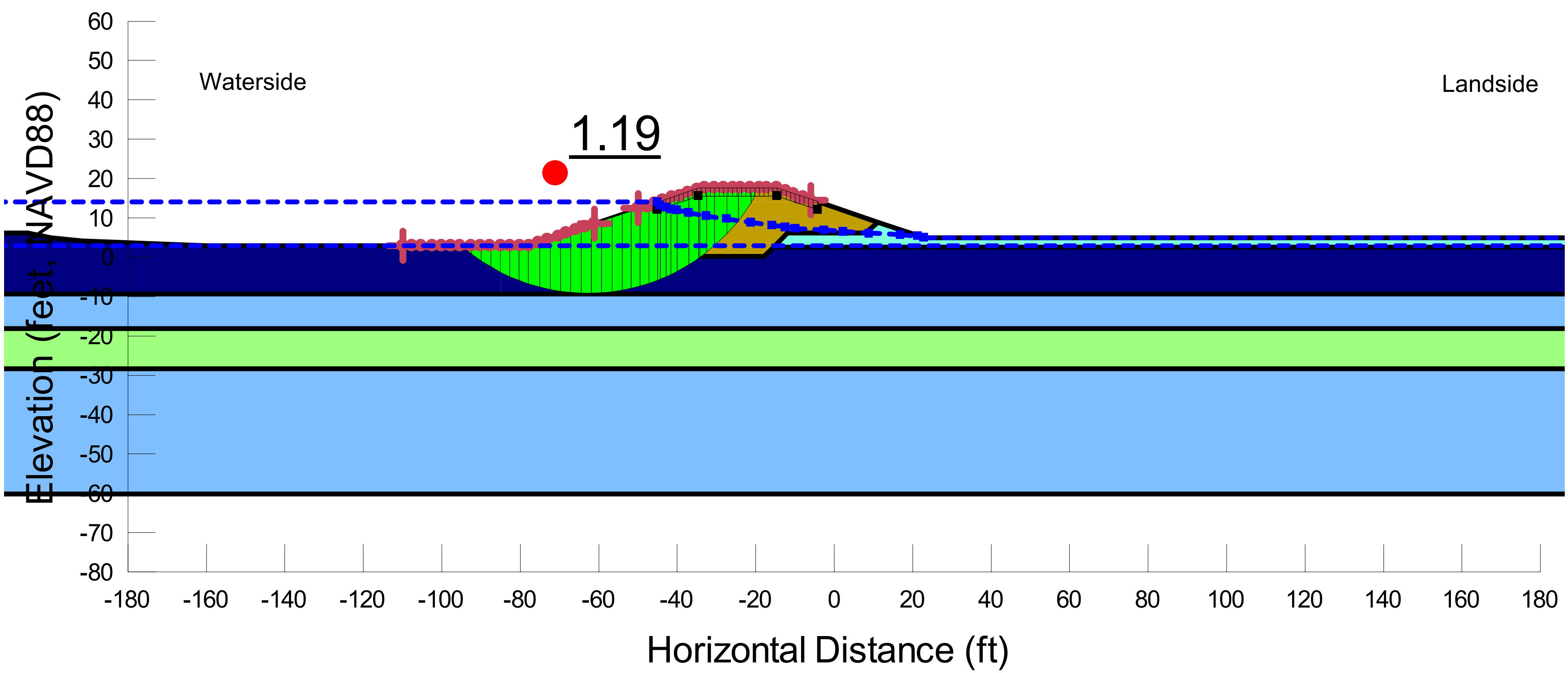
HDR

Cross Section G3

Steady-State Stability

May 2016

Figure C-11



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. 2' deep tension cracks filled with water are assumed for waterside rapid drawdown stability calculations.

SAFER Bay Project, Task Order No. 1

Menlo Park and East Palo Alto, California

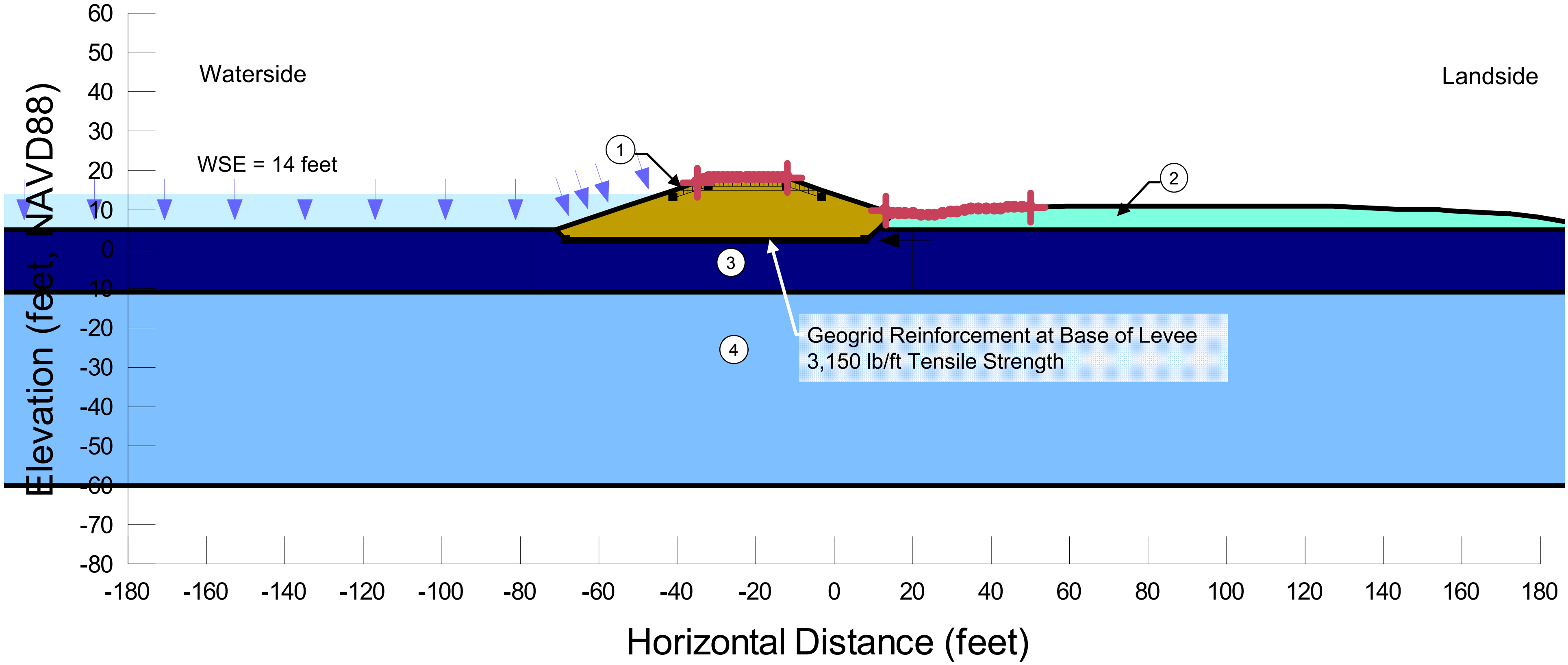
Cross Section G3

Waterside Rapid Drawdown

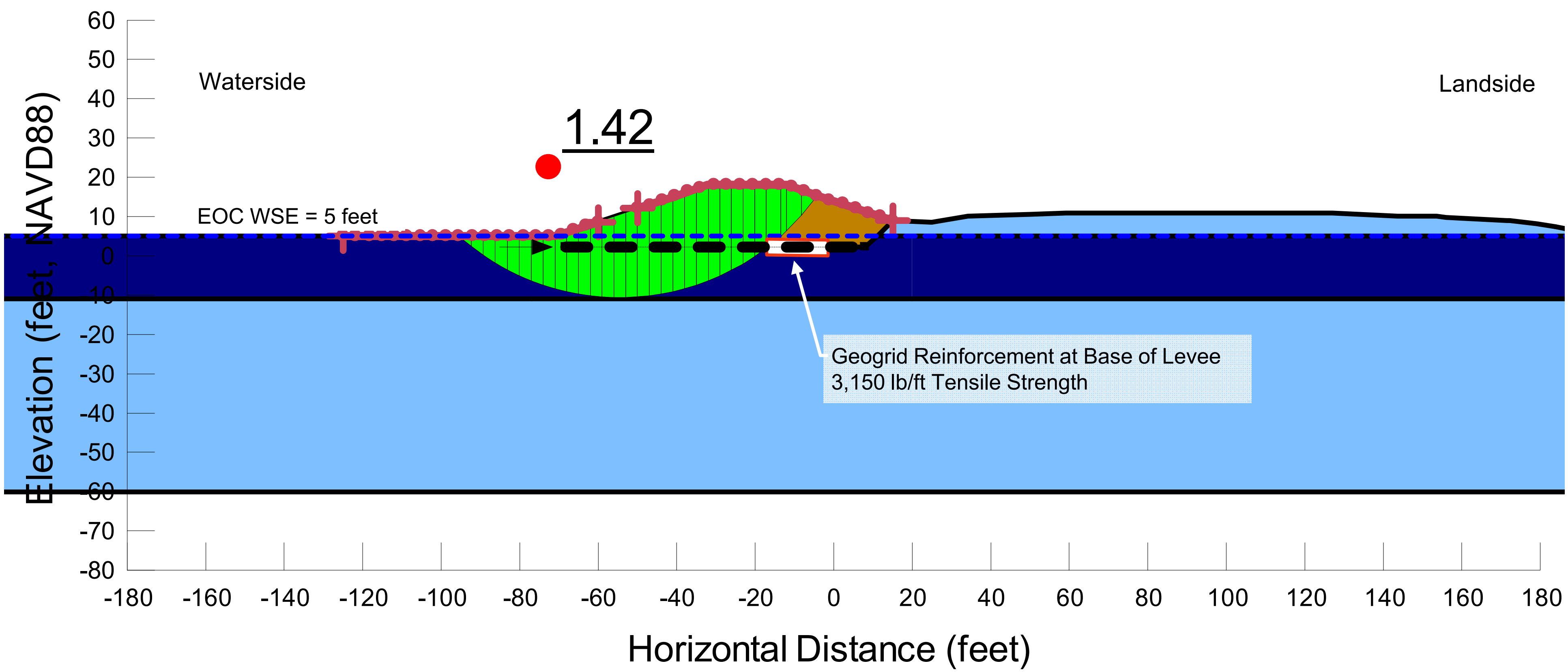
May 2016

Figure C-12

Layer Number	Layer Name	Saturated Unit Weight	Drained Parameters		Undrained Parameters	
			c'	ϕ'	c	ϕ
		(pcf)	(psf)	(deg.)	(psf)	(deg.)
1	CL - Levee	125	75	30	750	0
2	SC/CL - Fill	120	75	30	500	0
3	CH/MH - YBM	95	0	29	200 to 300	0
4	CL - Alluvium	125	50	30	700 to 1,300	0



SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G4** Stability Model
Menlo Park and East Palo Alto, California		May 2016 Figure C-13



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 1

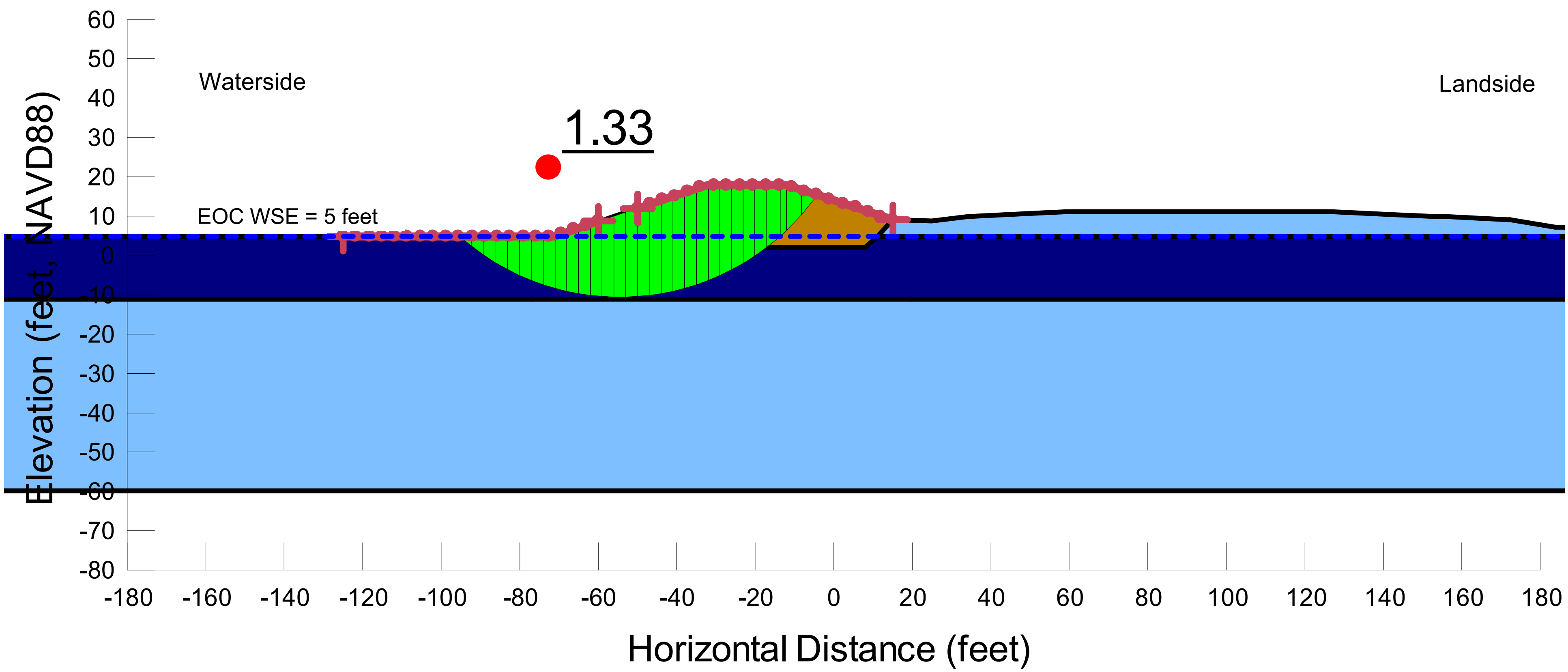
Menlo Park and East Palo Alto, California

Cross Section G4

End-of-Construction
Full Levee with Geogrid

May 2016

Figure C-14



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 1

Menlo Park and East Palo Alto, California

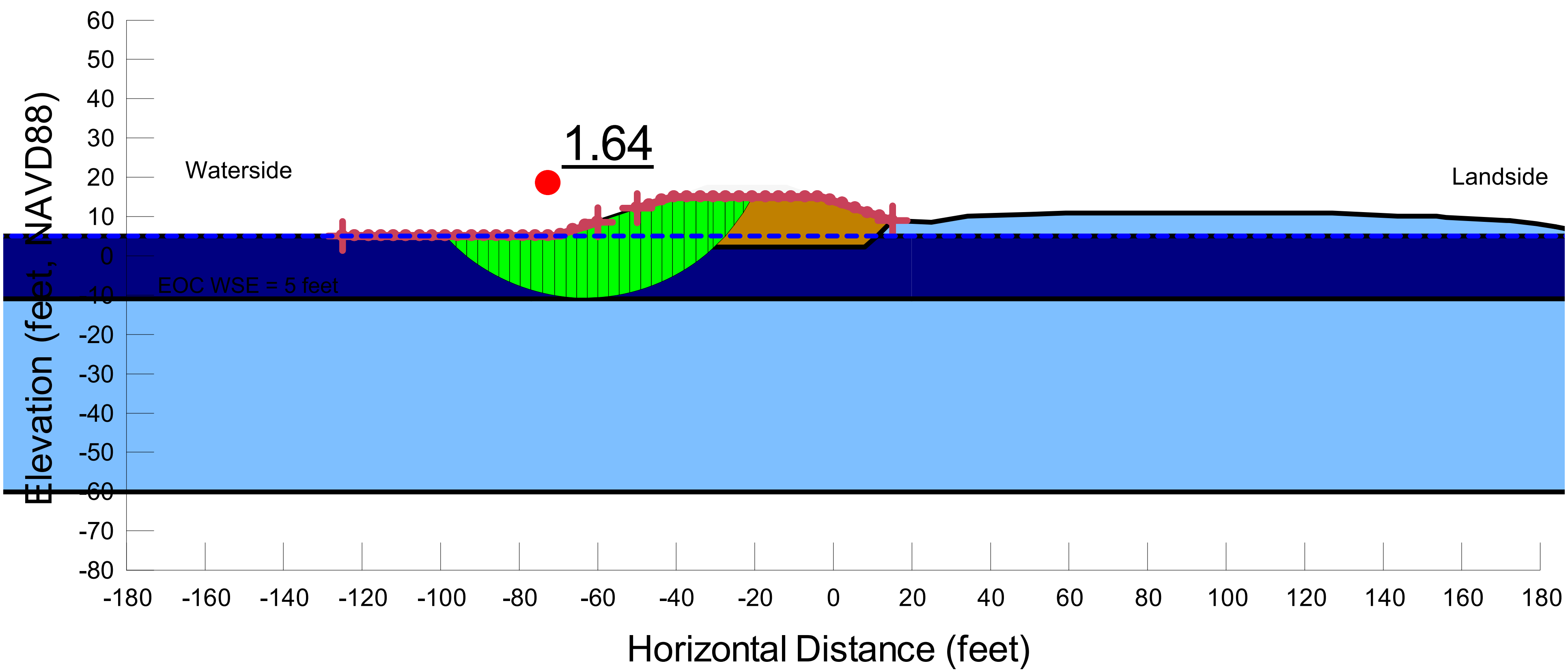
HDR

Cross Section G4

End-of-Construction
Full Levee without Geogrid

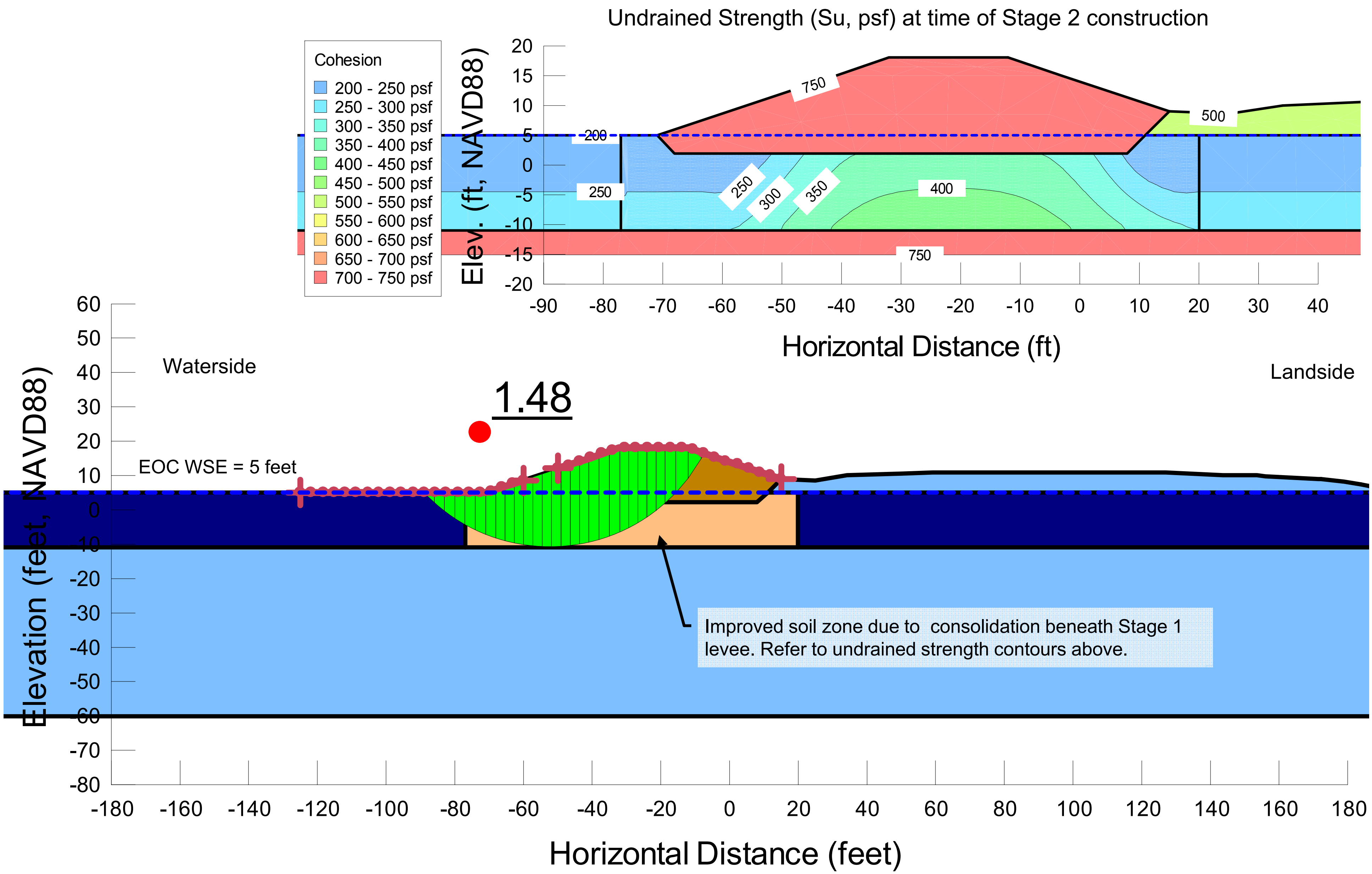
May 2016

Figure C-15



Notes:
1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

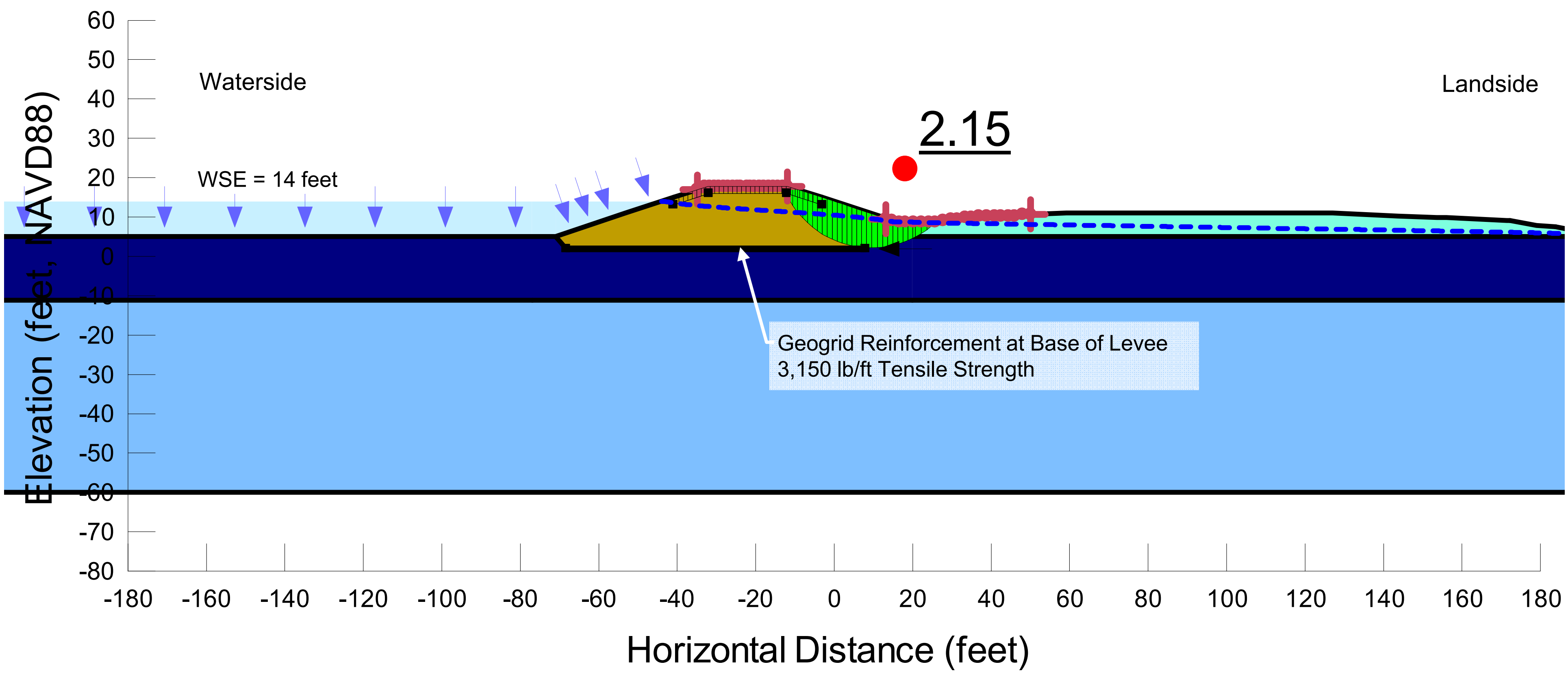
SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G4** End-of-Construction Stage 1 Levee without Geogrid
Menlo Park and East Palo Alto, California		May 2016 Figure C-16



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

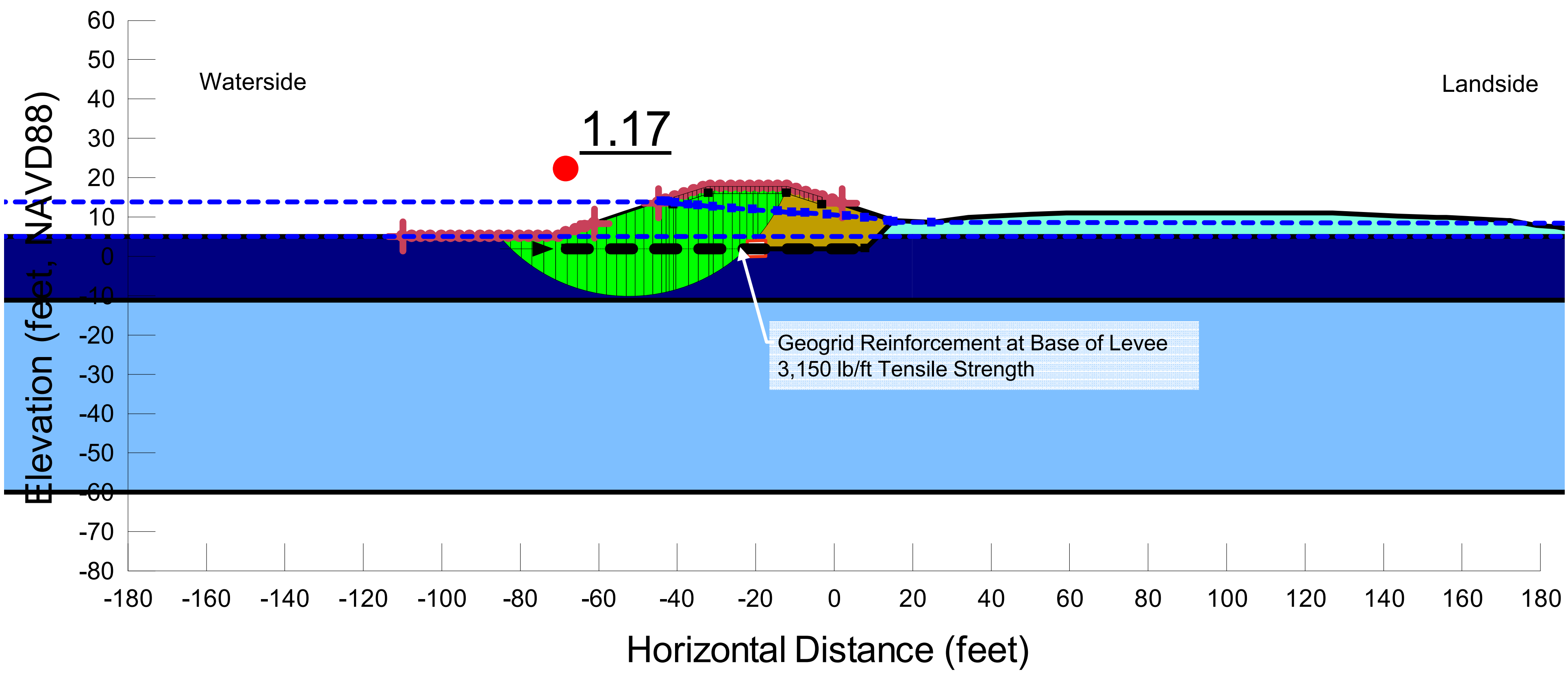
SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G4** End-of-Construction Stage 2 Levee without Geogrid
Menlo Park and East Palo Alto, California		May 2016 Figure C-17



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. Pore pressures are calculated from the steady-state seepage model with WSE = 14 feet.
3. 2' deep tension cracks filled with water are assumed for landside steady-state stability calculations.

SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G4** Steady-State Stability
Menlo Park and East Palo Alto, California		May 2016 Figure C-18



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. 2' deep tension cracks filled with water are assumed for waterside rapid drawdown stability calculations.

SAFER Bay Project, Task Order No. 1

Menlo Park and East Palo Alto, California

HDR

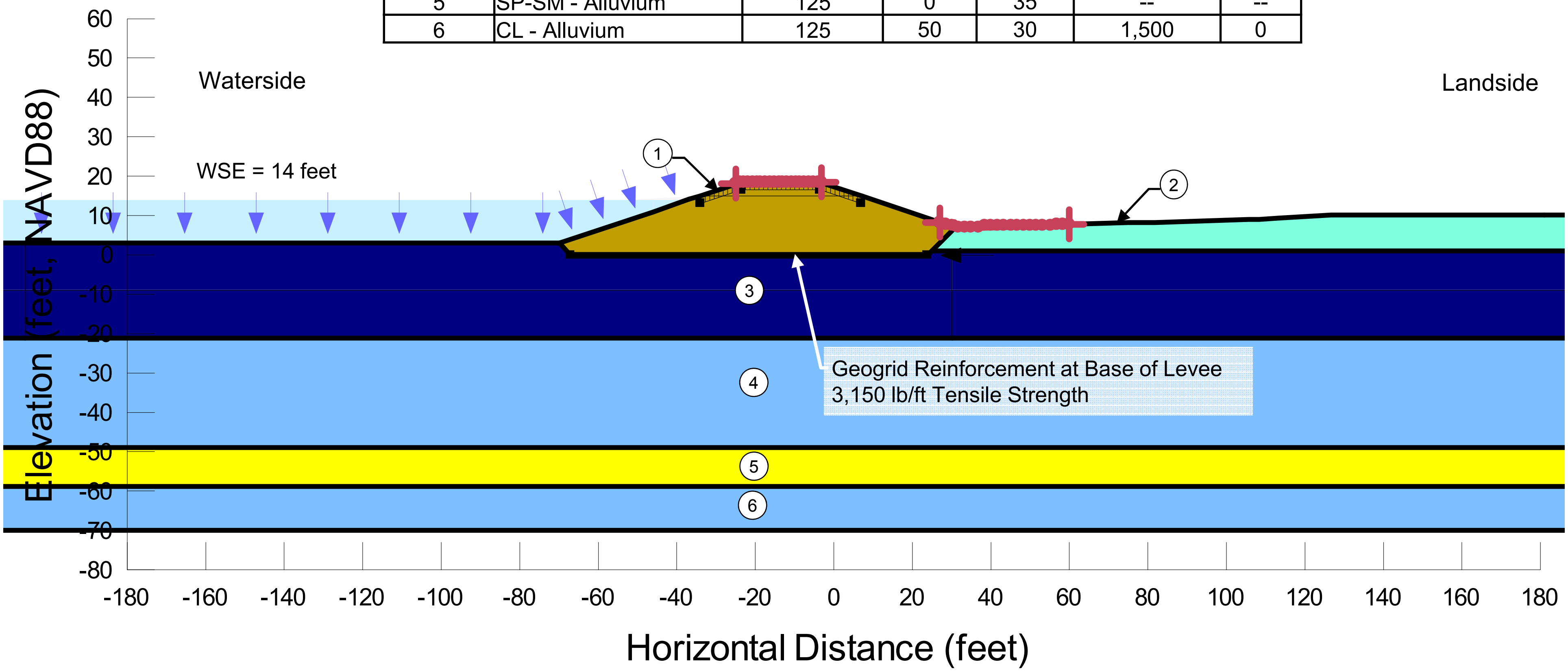
Cross Section G4

Waterside Rapid Drawdown

May 2016

Figure C-19

Layer Number	Layer Name	Saturated Unit Weight	Drained Parameters		Undrained Parameters	
			c'	ϕ'	c	ϕ
		(pcf)	(psf)	(deg.)	(psf)	(deg.)
1	CL - Levee Fill	125	75	30	750	0
2	SC/CL - Fill	120	75	30	500	0
3	MH/CH - YBM	98	0	29	250 to 550	0
4	CL - Alluvium	125	50	30	750 to 1,300	0
5	SP-SM - Alluvium	125	0	35	--	--
6	CL - Alluvium	125	50	30	1,500	0



SAFER Bay Project, Task Order No. 1

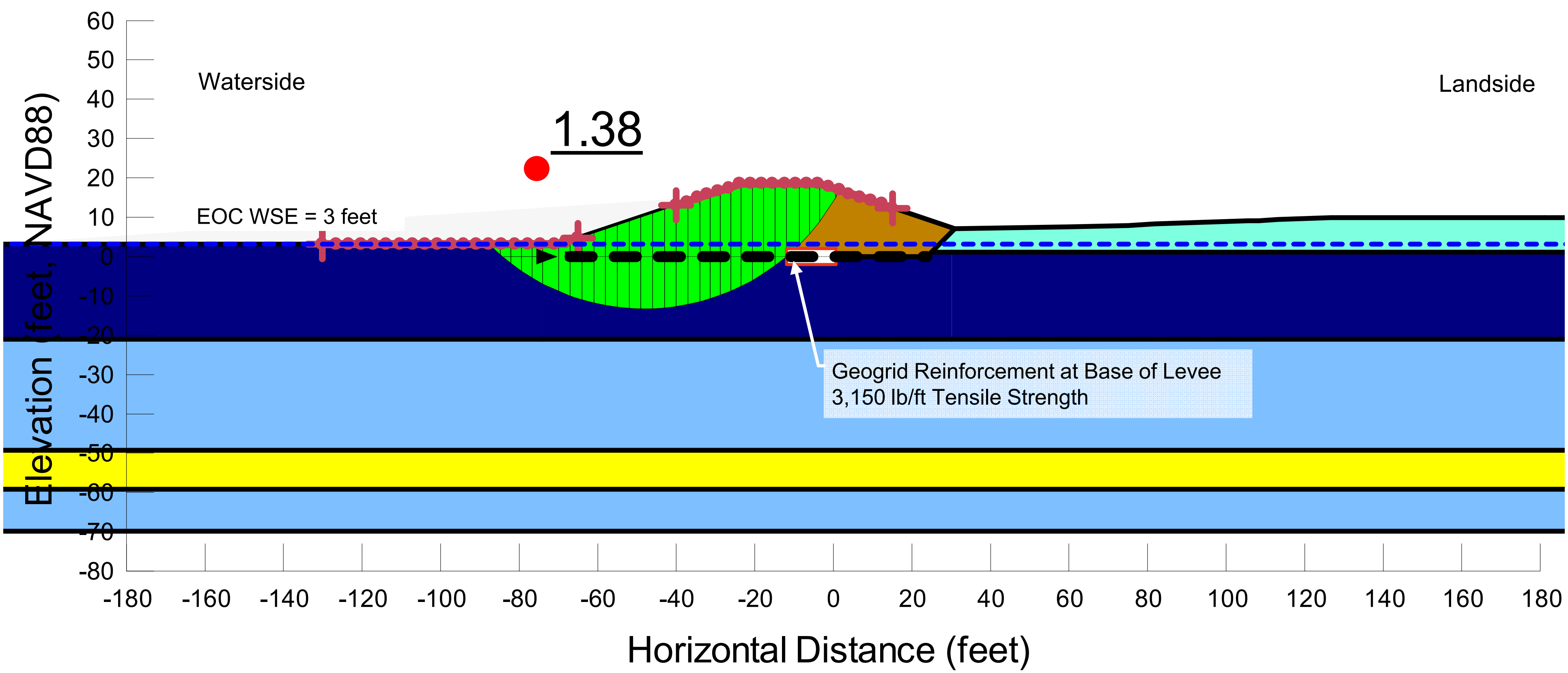
Menlo Park and East Palo Alto, California

Cross Section G5

Stability Model

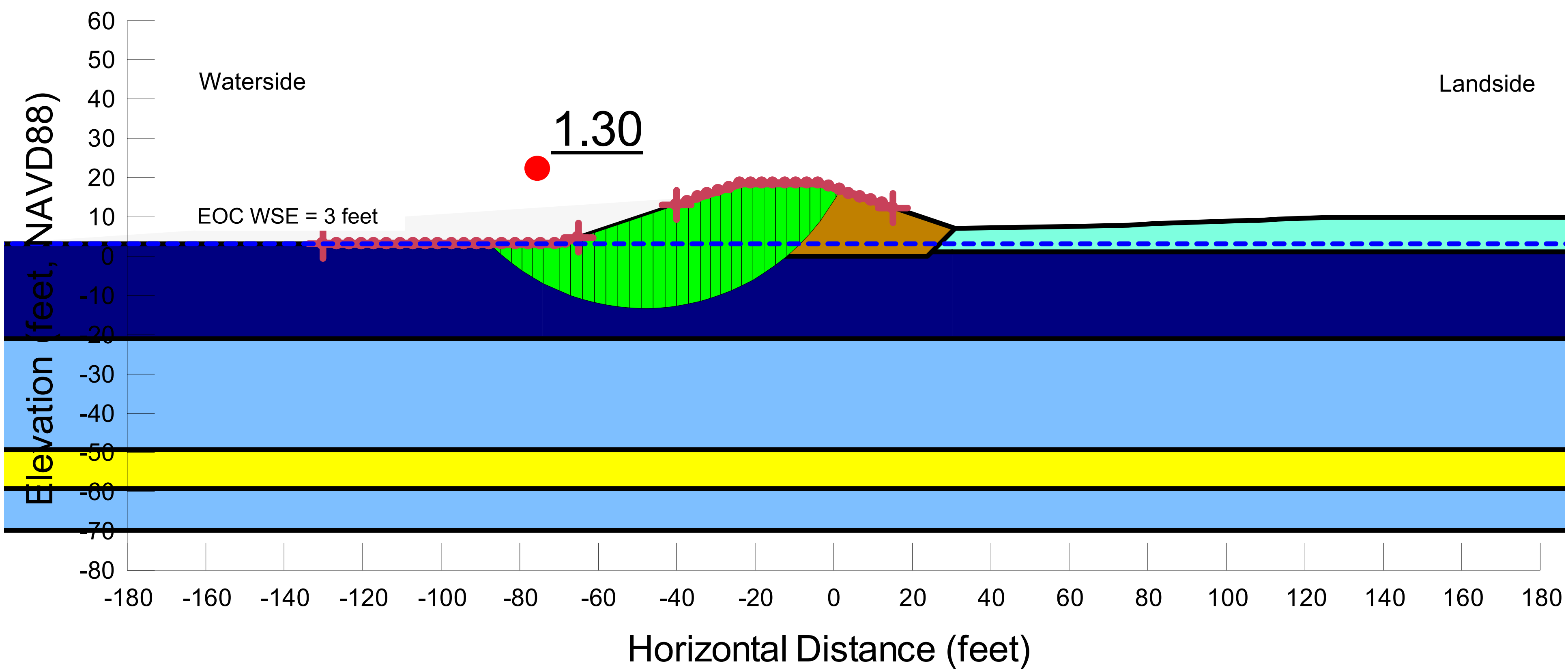
May 2016

Figure C-20



Notes:
1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G5** End-of-Construction Full Levee with Geogrid
Menlo Park and East Palo Alto, California		May 2016 Figure C-21



Notes:
1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 1

Menlo Park and East Palo Alto, California

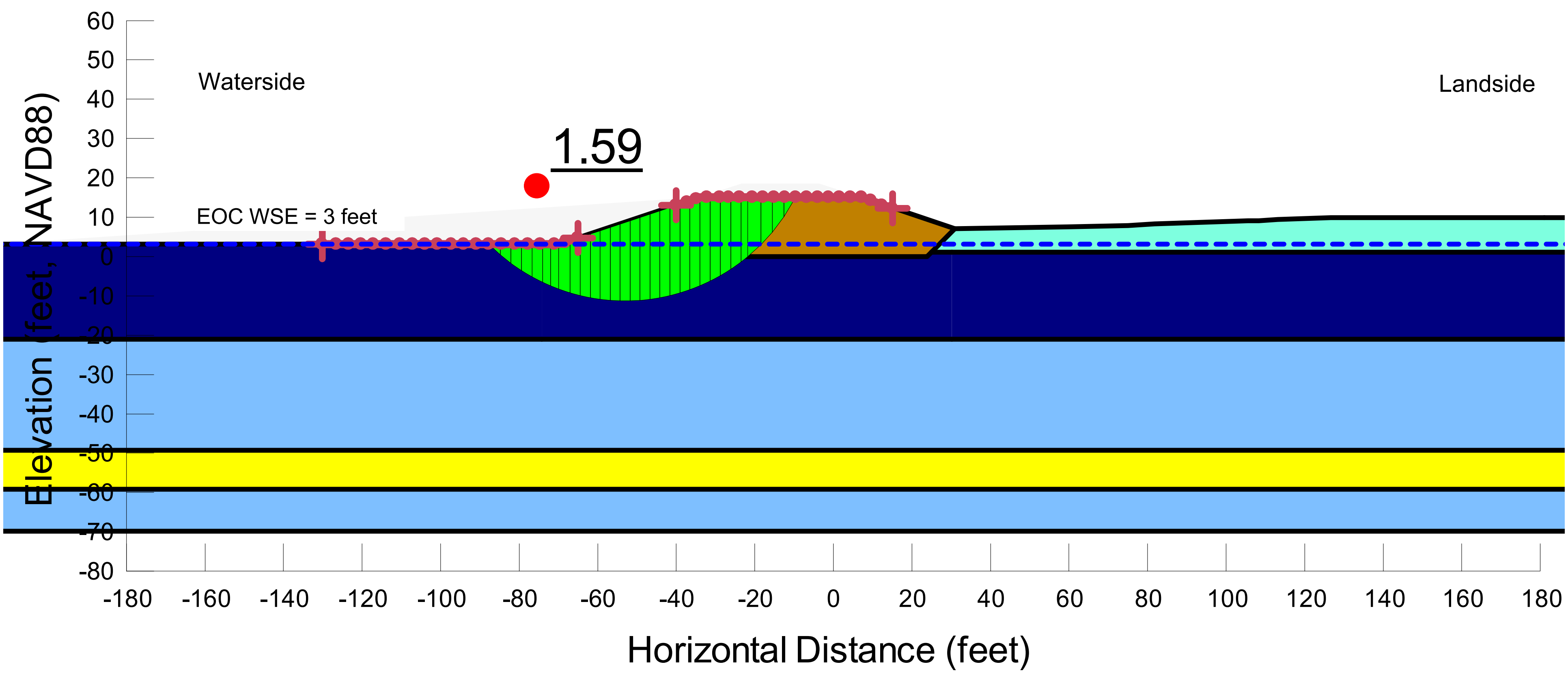
HDR

Cross Section G5

End-of-Construction
Full Levee without Geogrid

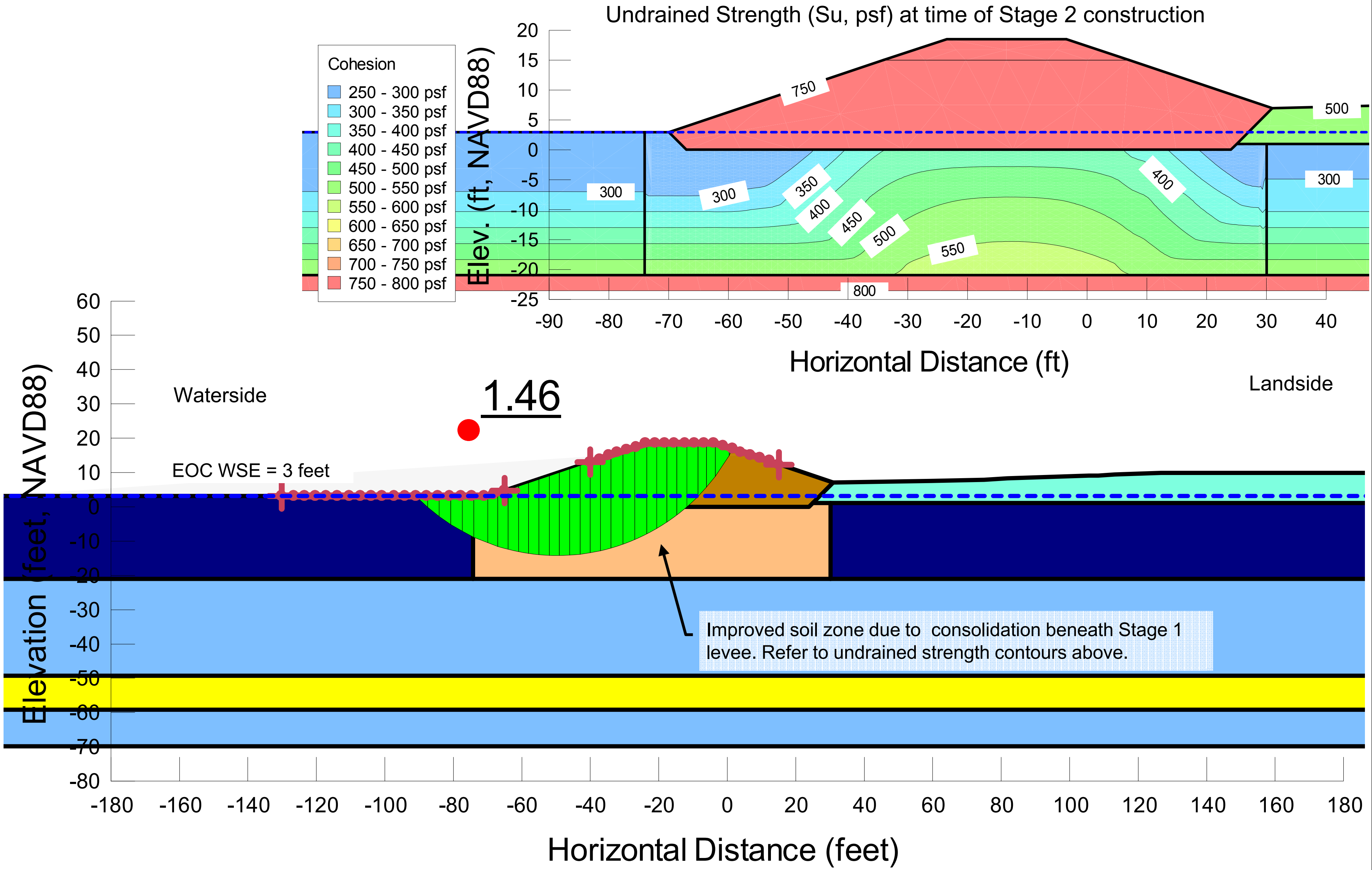
May 2016

Figure C-22



Notes:
1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G5** End-of-Construction Stage 1 Levee without Geogrid
Menlo Park and East Palo Alto, California		May 2016 Figure C-23



Notes:
1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 1

Menlo Park and East Palo Alto, California

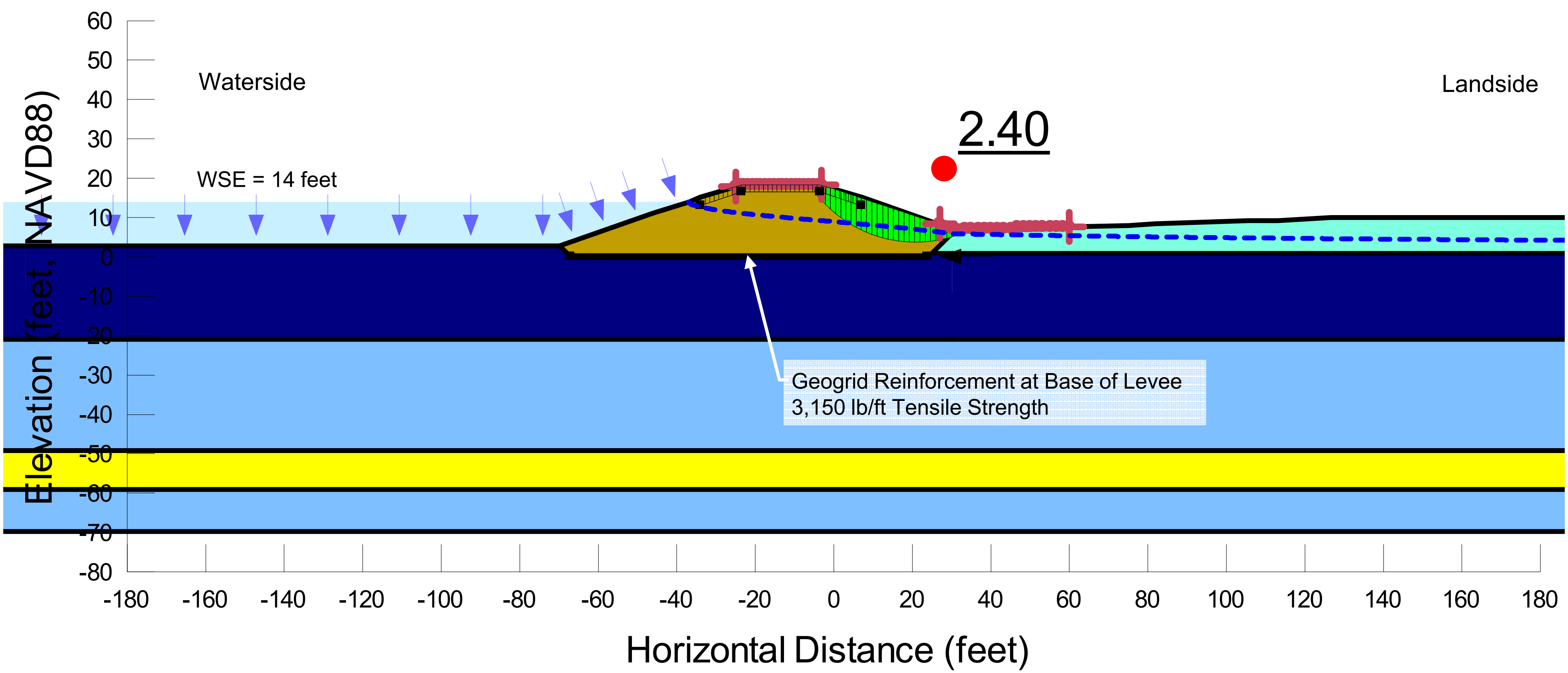
HDR

Cross Section G5

End-of-Construction
Stage 2 Levee without Geogrid

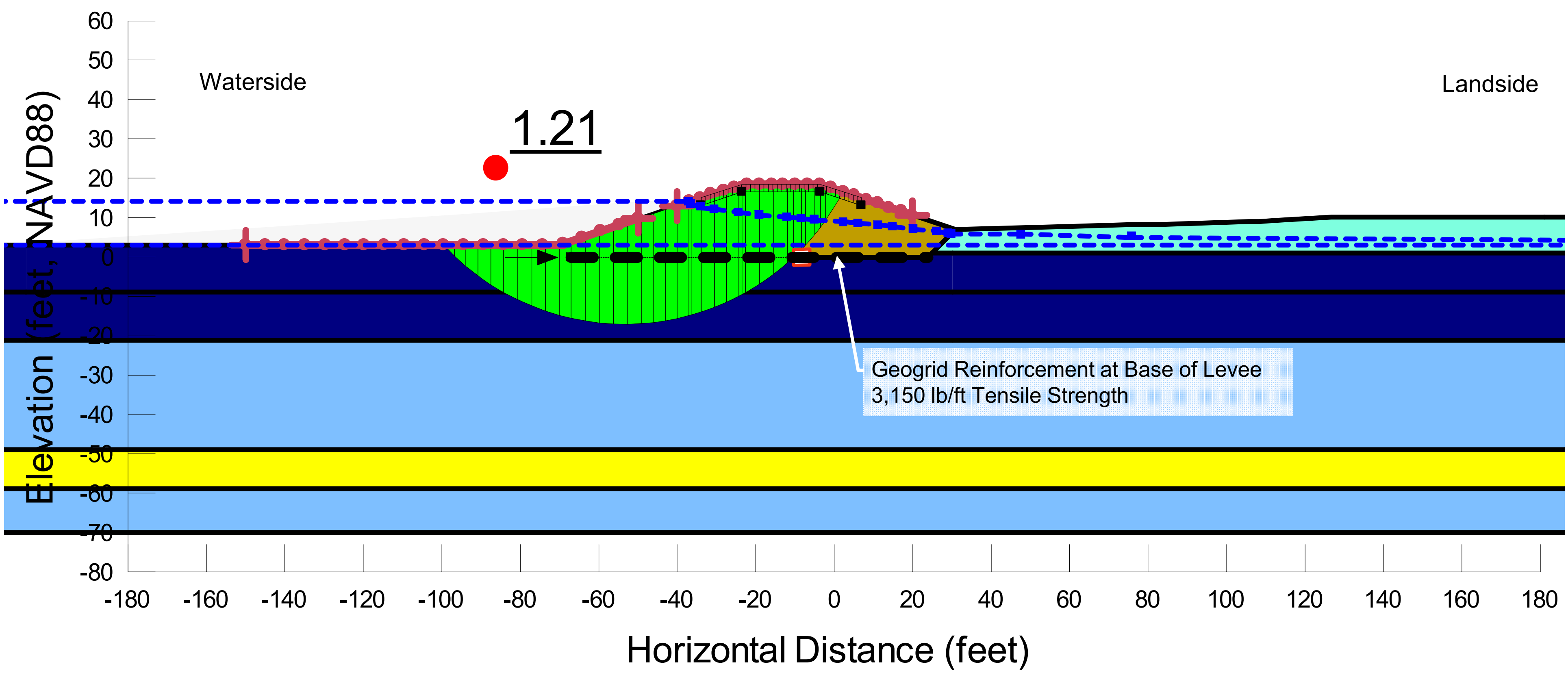
May 2016

Figure C-24



Notes:
1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. Pore pressures are calculated from the steady-state seepage model with WSE = 14 feet.
3. 2' deep tension cracks filled with water are assumed for landside steady-state stability calculations.

SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G5** Steady-State Stability
Menlo Park and East Palo Alto, California		May 2016 Figure C-25

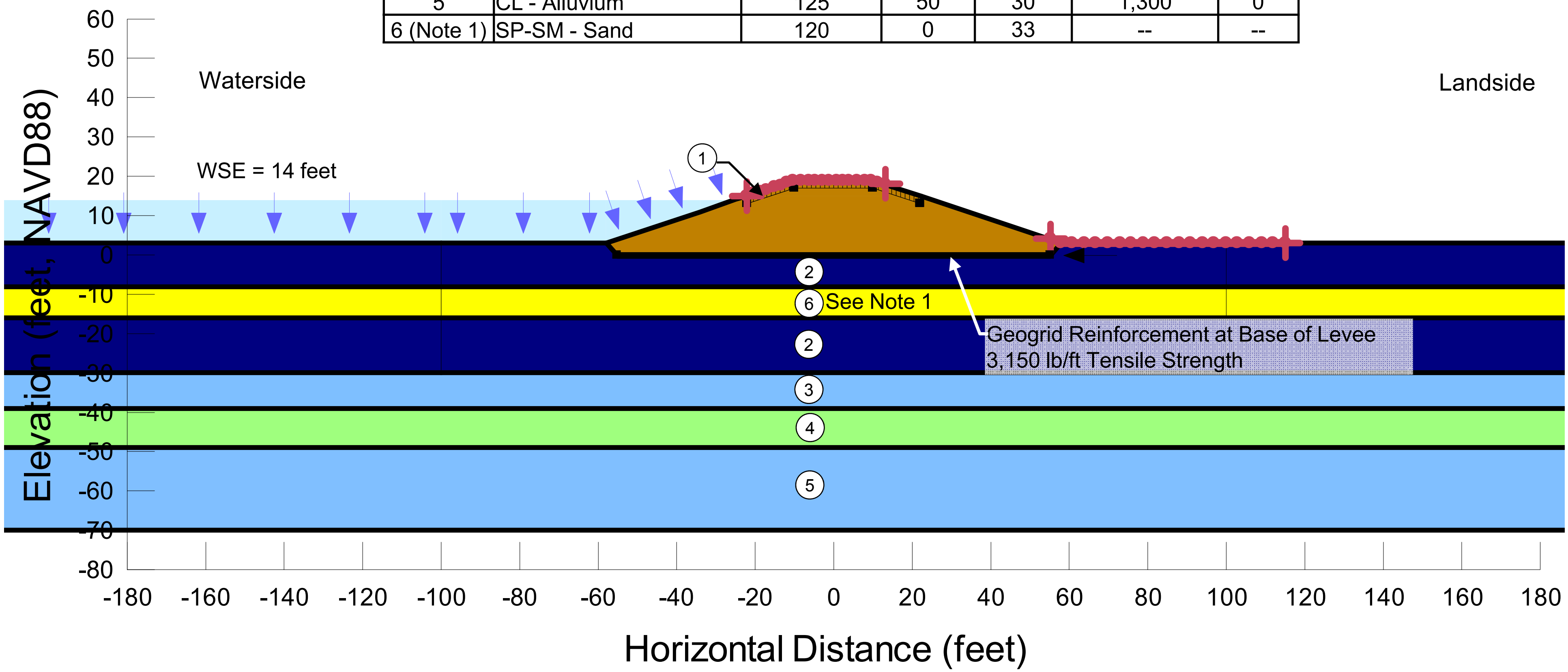


Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. 2' deep tension cracks filled with water are assumed for waterside rapid drawdown stability calculations.

SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G5** Waterside Rapid Drawdown
Menlo Park and East Palo Alto, California		May 2016 Figure C-26

Layer Number	Layer Name	Saturated Unit Weight (pcf)	Drained Parameters c' (psf)	Drained Parameters ϕ' (deg.)	Undrained Parameters c (psf)	Undrained Parameters ϕ (deg.)
1	CL - Levee Fill	125	75	30	750	0
2	MH/CH - YBM	98	0	29	250 to 650	0
3	CL - Alluvium	125	50	30	1,000	0
4	SM - Alluvium	125	0	35	--	--
5	CL - Alluvium	125	50	30	1,300	0
6 (Note 1)	SP-SM - Sand	120	0	33	--	--



Notes:
1. Layer 6 (SP-SM Sand) is only included for steady-state seepage and stability analyses. The layer is omitted for end-of-construction and waterside rapid drawdown stability analyses for conservativeness.

SAFER Bay Project, Task Order No. 1

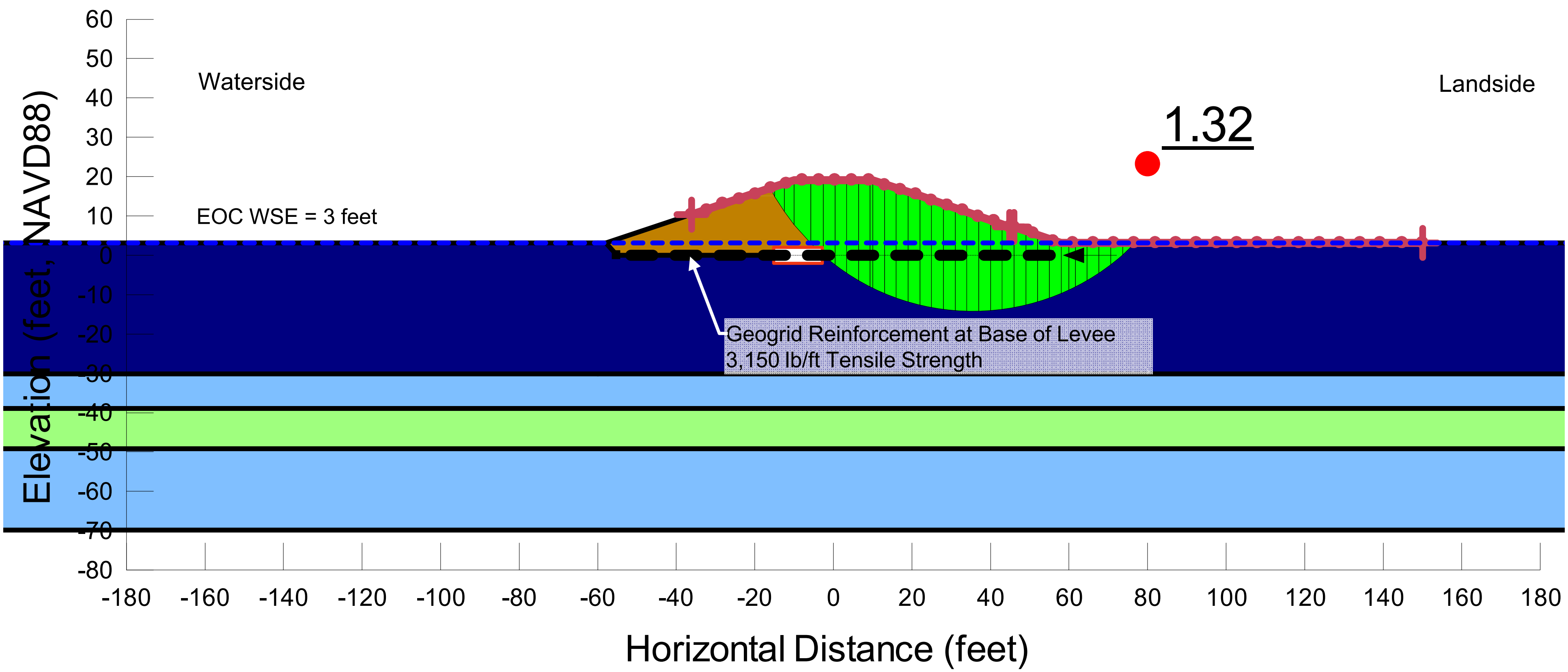
Menlo Park and East Palo Alto, California

Cross Section G6

Stability Model

May 2016

Figure C-27



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 1

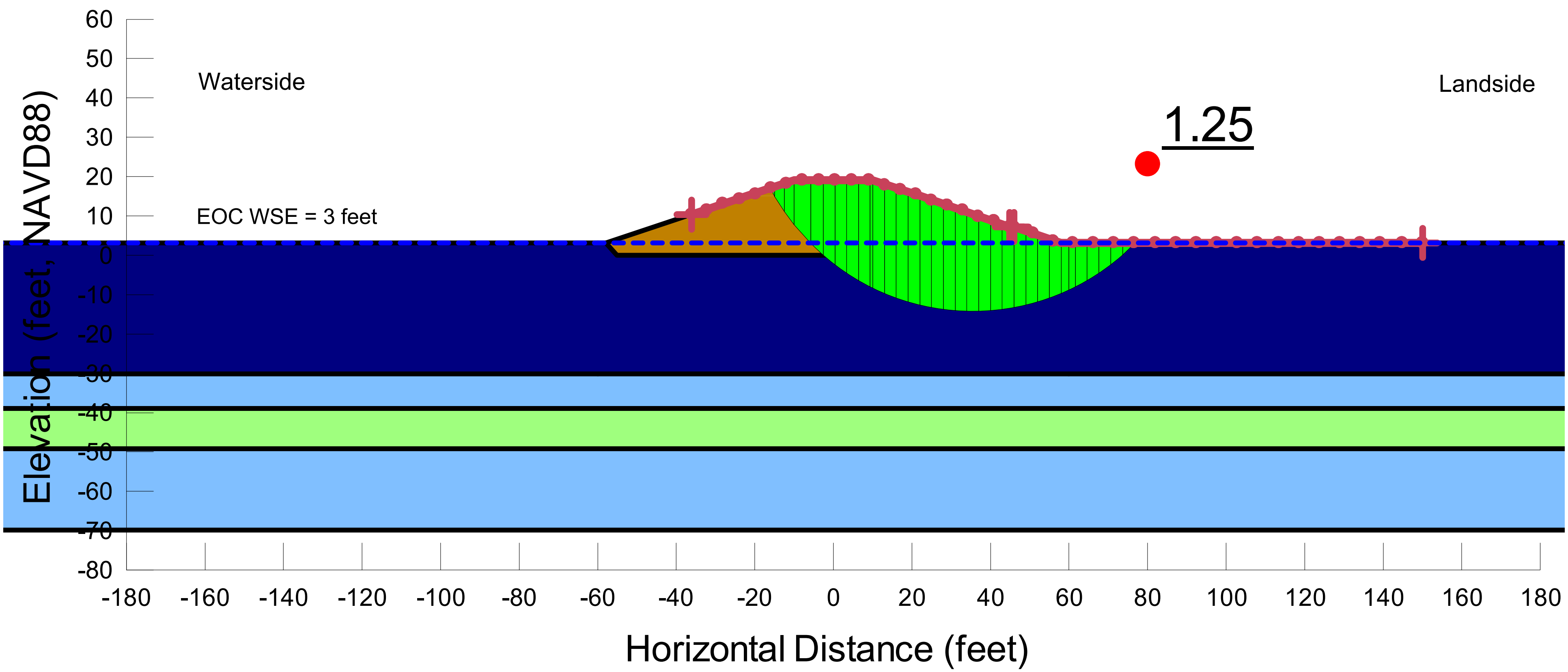
Menlo Park and East Palo Alto, California

Cross Section G6

End-of-Construction
Full Levee with Geogrid

May 2016

Figure C-28



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 1

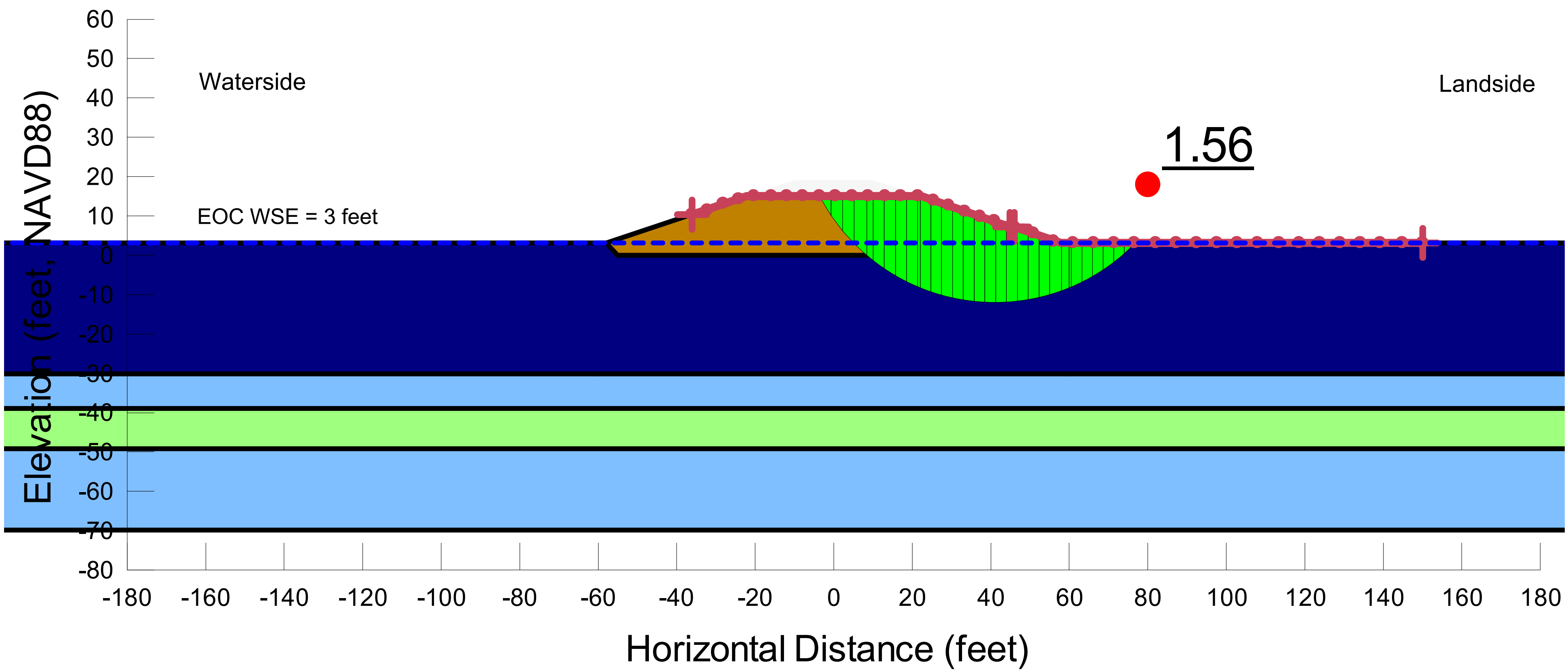
Menlo Park and East Palo Alto, California

Cross Section G6

End-of-Construction
Full Levee without Geogrid

May 2016

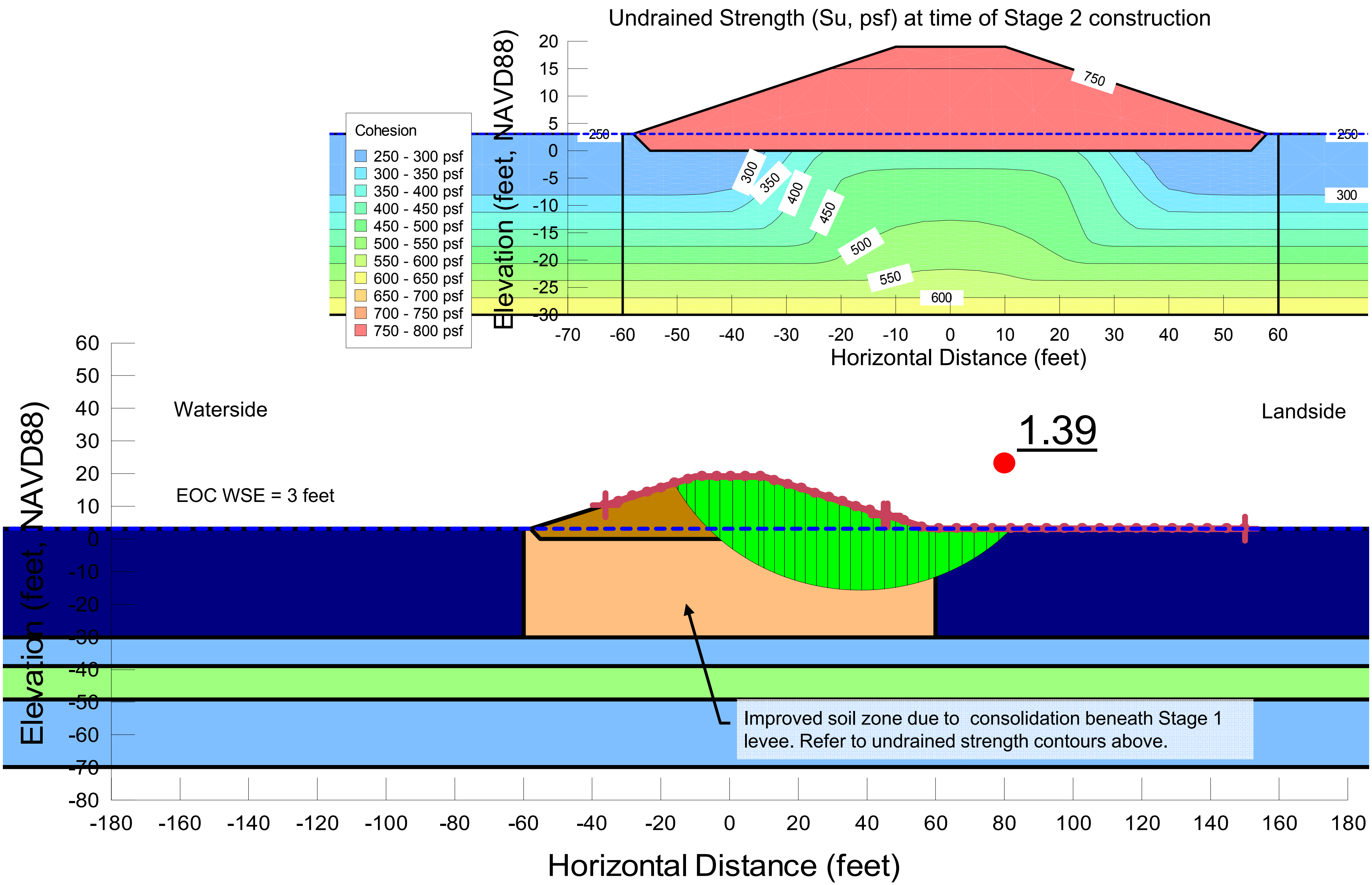
Figure C-29



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G6** End-of-Construction Stage 1 Levee without Geogrid	
Menlo Park and East Palo Alto, California		May 2016	Figure C-30



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 1

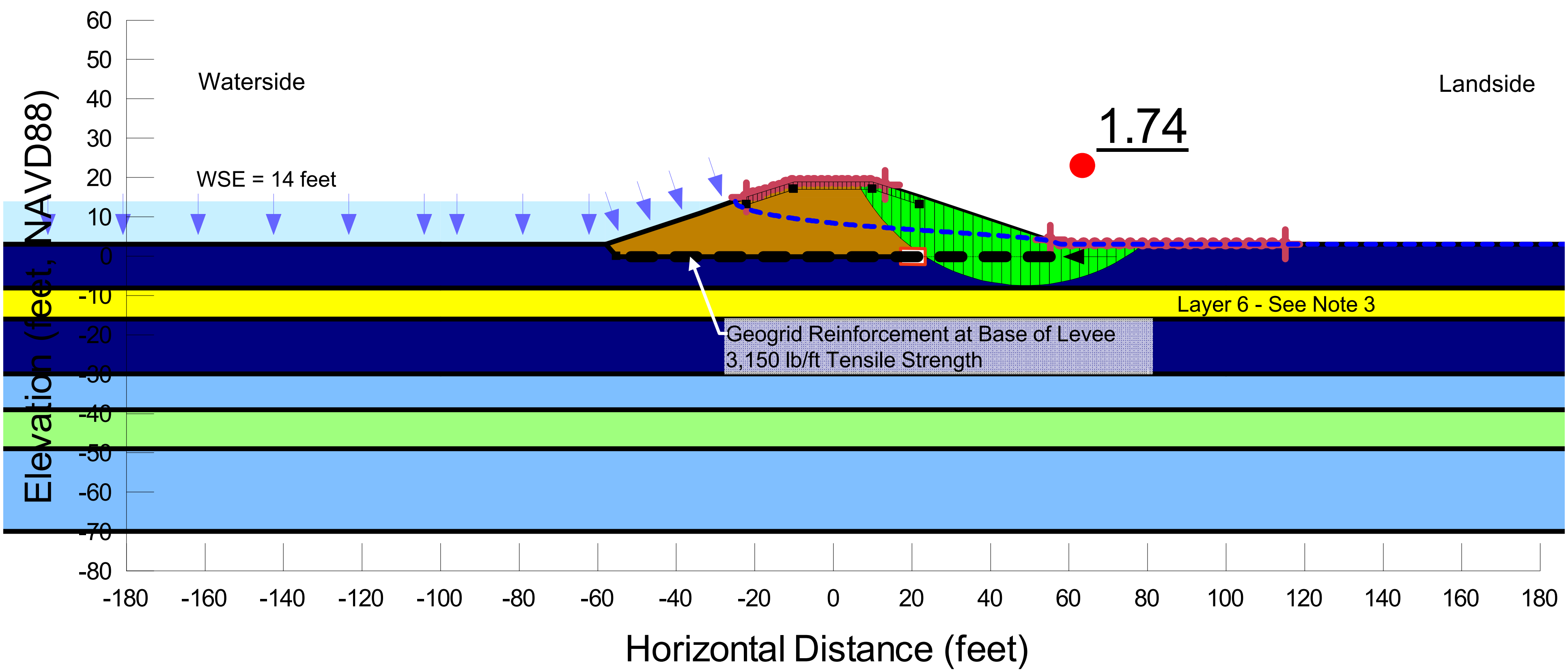
Menlo Park and East Palo Alto, California

Cross Section G6

End-of-Construction
Stage 2 Levee without Geogrid

May 2016

Figure C-31



Notes:
1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. Pore pressures are calculated from the steady-state seepage model with WSE = 14 feet.
3. Layer 6 (SP-SM Sand) is only included for steady-state seepage and stability analyses.
4. 2' deep tension cracks filled with water are assumed for landside steady-state stability calculations.

SAFER Bay Project, Task Order No. 1

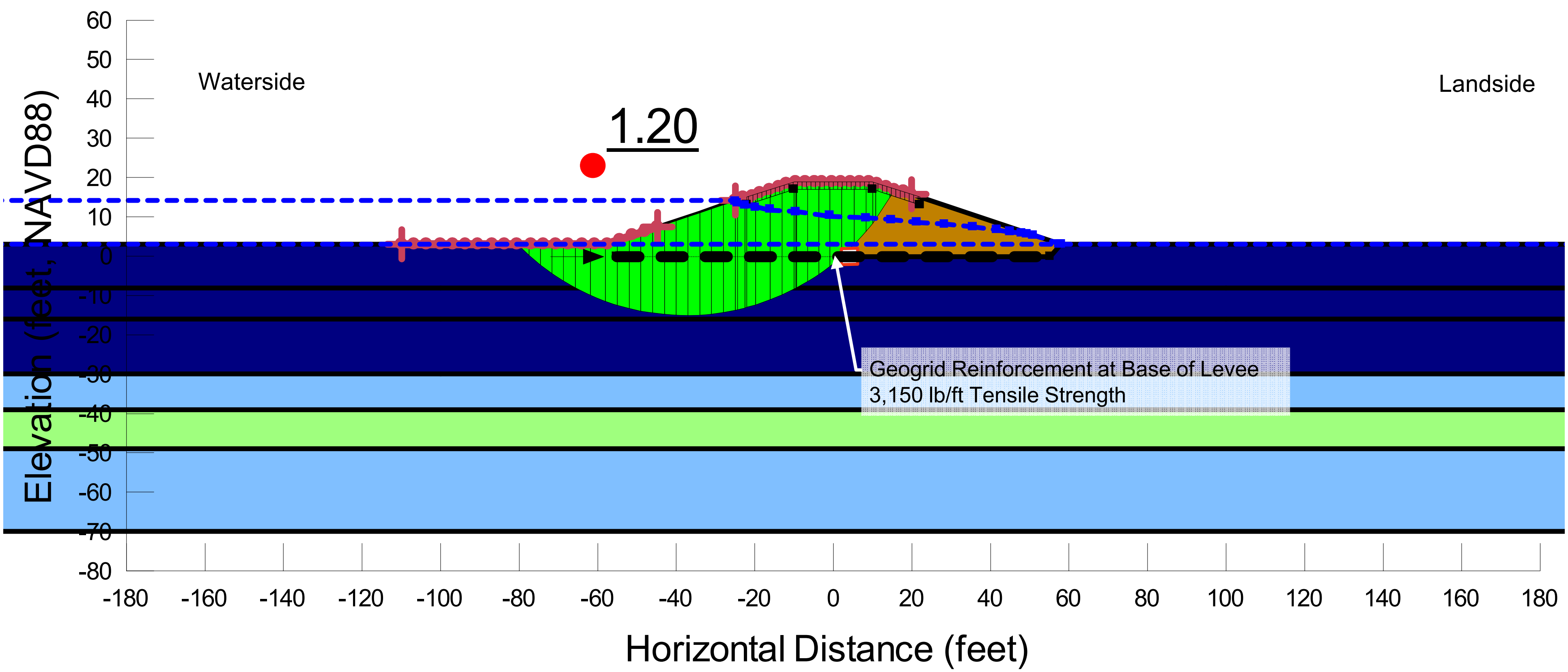
Menlo Park and East Palo Alto, California

Cross Section G6

Steady-State Stability

May 2016

Figure C-32



Notes:
1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. 2' deep tension cracks filled with water are assumed for waterside rapid drawdown stability calculations.

SAFER Bay Project, Task Order No. 1

Menlo Park and East Palo Alto, California

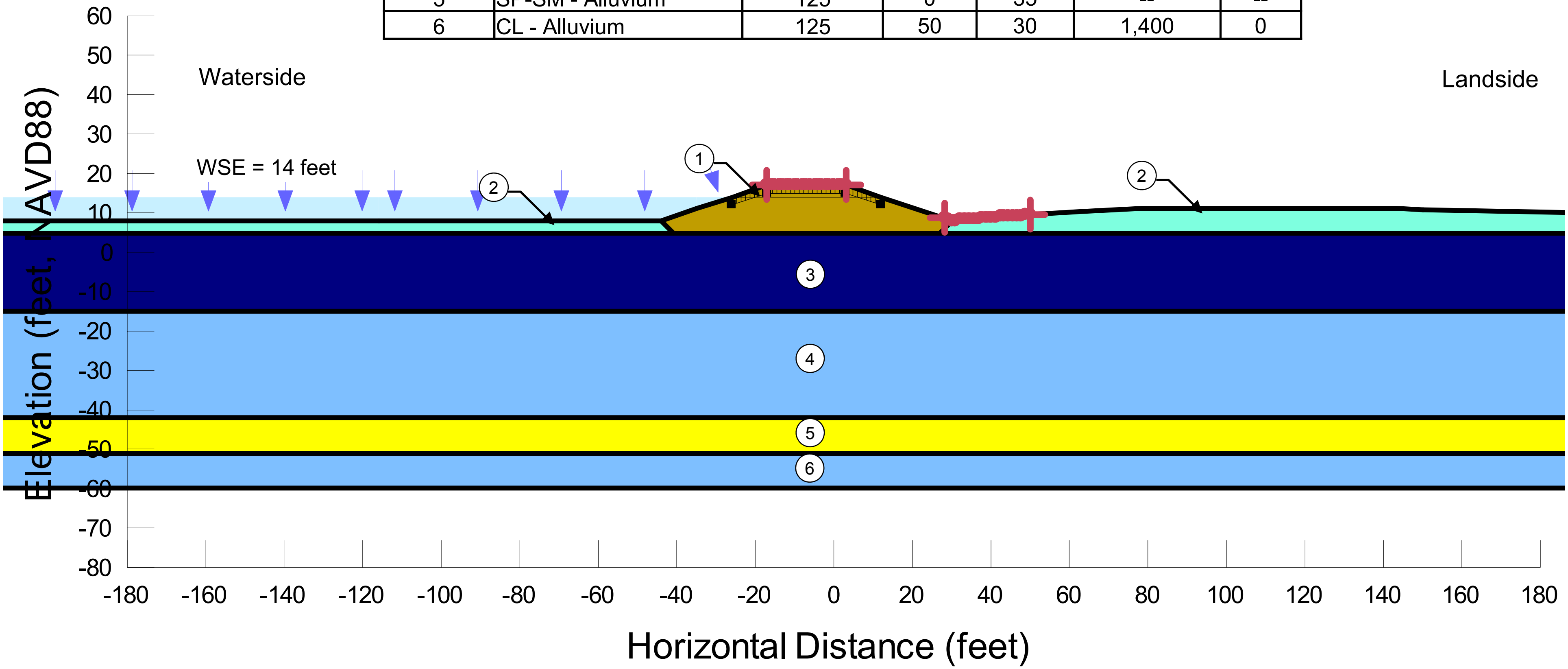
Cross Section G6

Waterside Rapid Drawdown

May 2016

Figure C-33

Layer Number	Layer Name	Saturated Unit Weight	Drained Parameters		Undrained Parameters	
			c’	ϕ’	c	ϕ
		(pcf)	(psf)	(deg.)	(psf)	(deg.)
1	CL - Levee Fill	125	75	30	750	0
2	ML - Fill	120	75	30	300	0
3	CH - YBM	110	0	29	300 to 550	0
4	CL - Alluvium	125	50	30	800 to 1,100	0
5	SP-SM - Alluvium	125	0	35	--	--
6	CL - Alluvium	125	50	30	1,400	0



SAFER Bay Project, Task Order No. 1

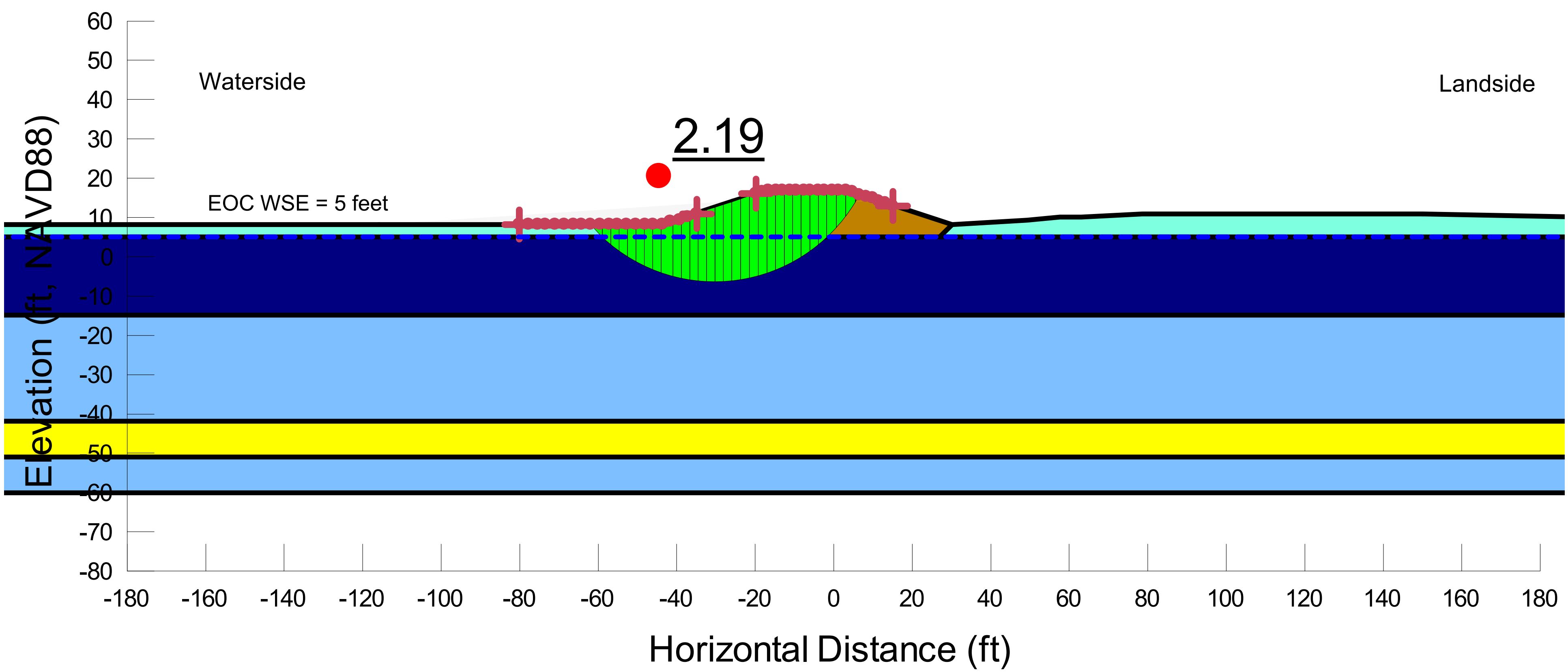
Menlo Park and East Palo Alto, California

Cross Section G7

Stability Model

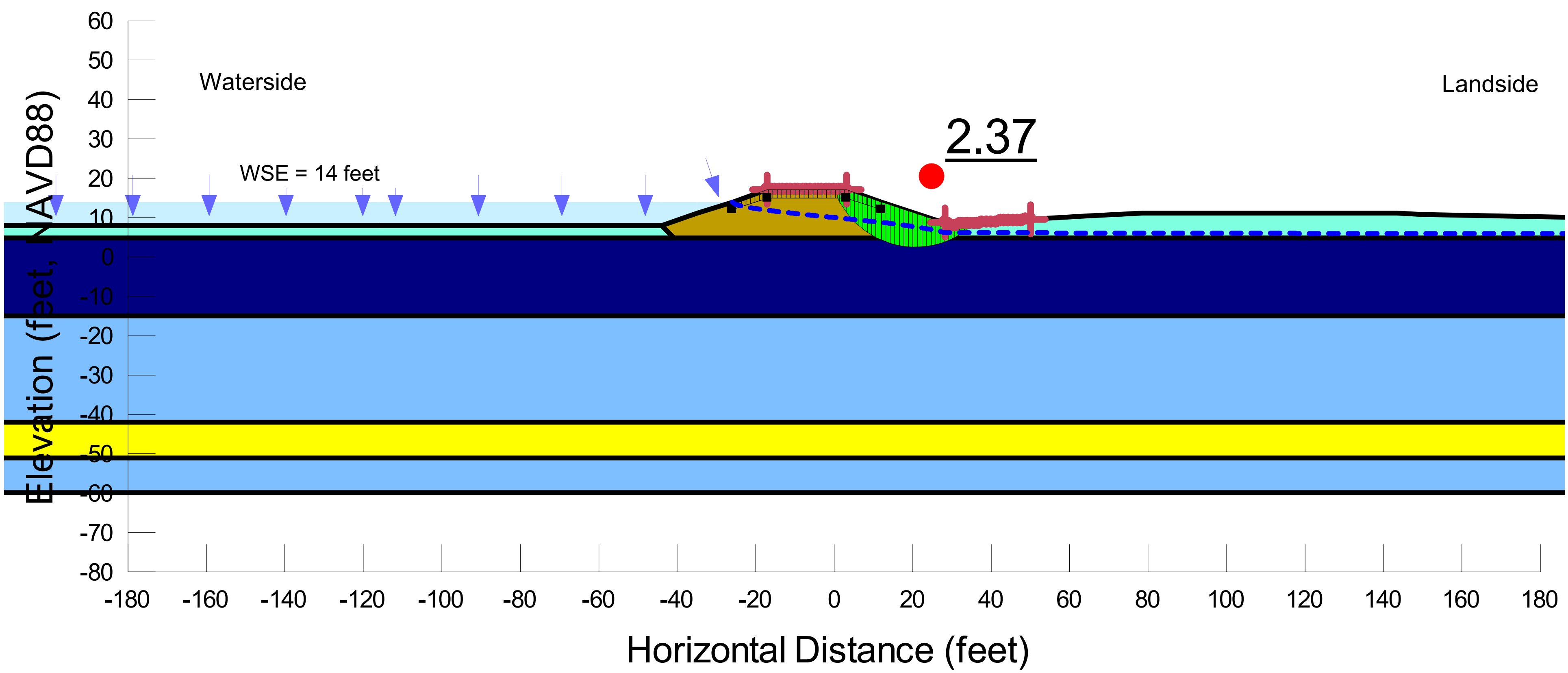
May 2016

Figure C-34



Notes:
1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

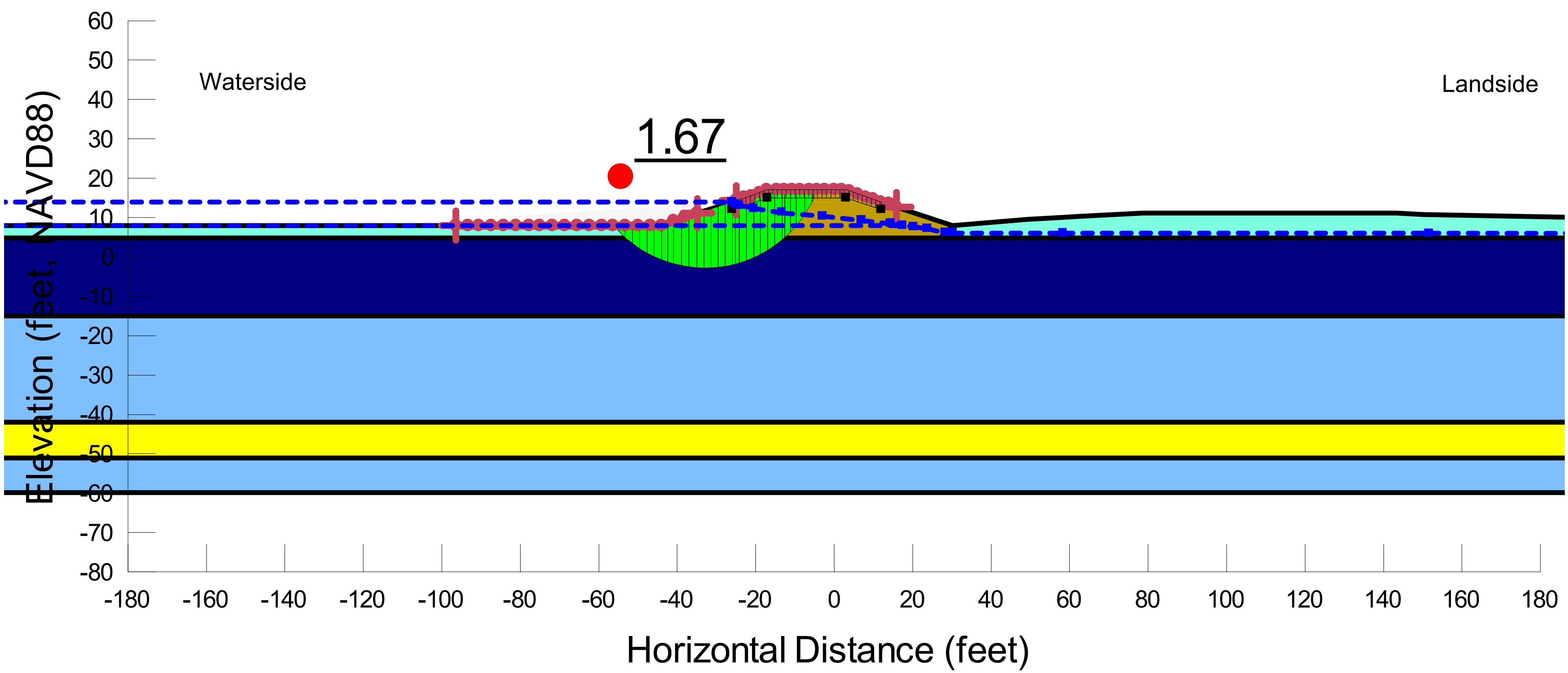
SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G7** End-of-Construction Full Levee
Menlo Park and East Palo Alto, California		May 2016 Figure C-35



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. Pore pressures are calculated from the steady-state seepage model with WSE = 14 feet.
3. 2’ deep tension cracks filled with water are assumed for landside steady-state stability calculations.

SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G7** Steady-State Stability
Menlo Park and East Palo Alto, California		May 2016 Figure C-36



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. 2' deep tension cracks filled with water are assumed for waterside rapid drawdown stability calculations.

SAFER Bay Project, Task Order No. 1

Menlo Park and East Palo Alto, California

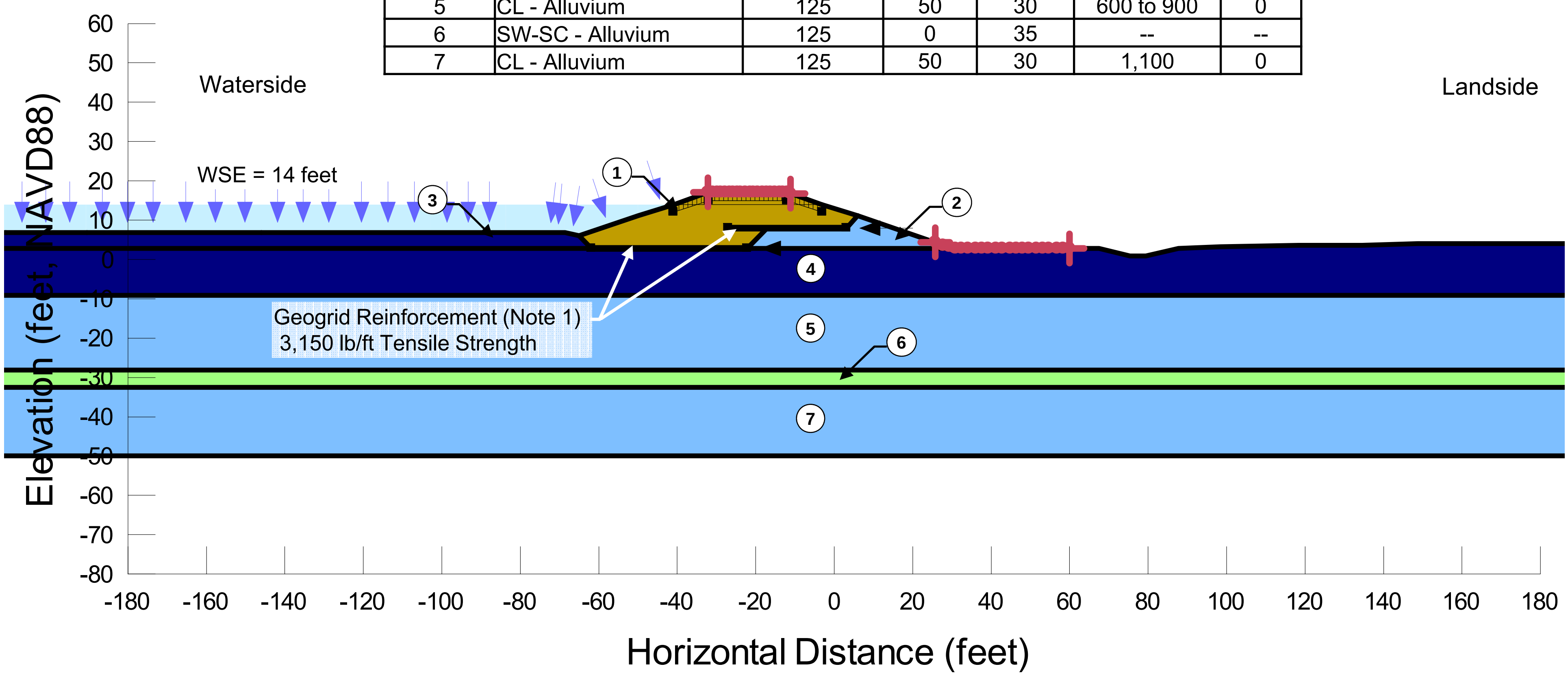
Cross Section G7

Waterside Rapid Drawdown

May 2016

Figure C-37

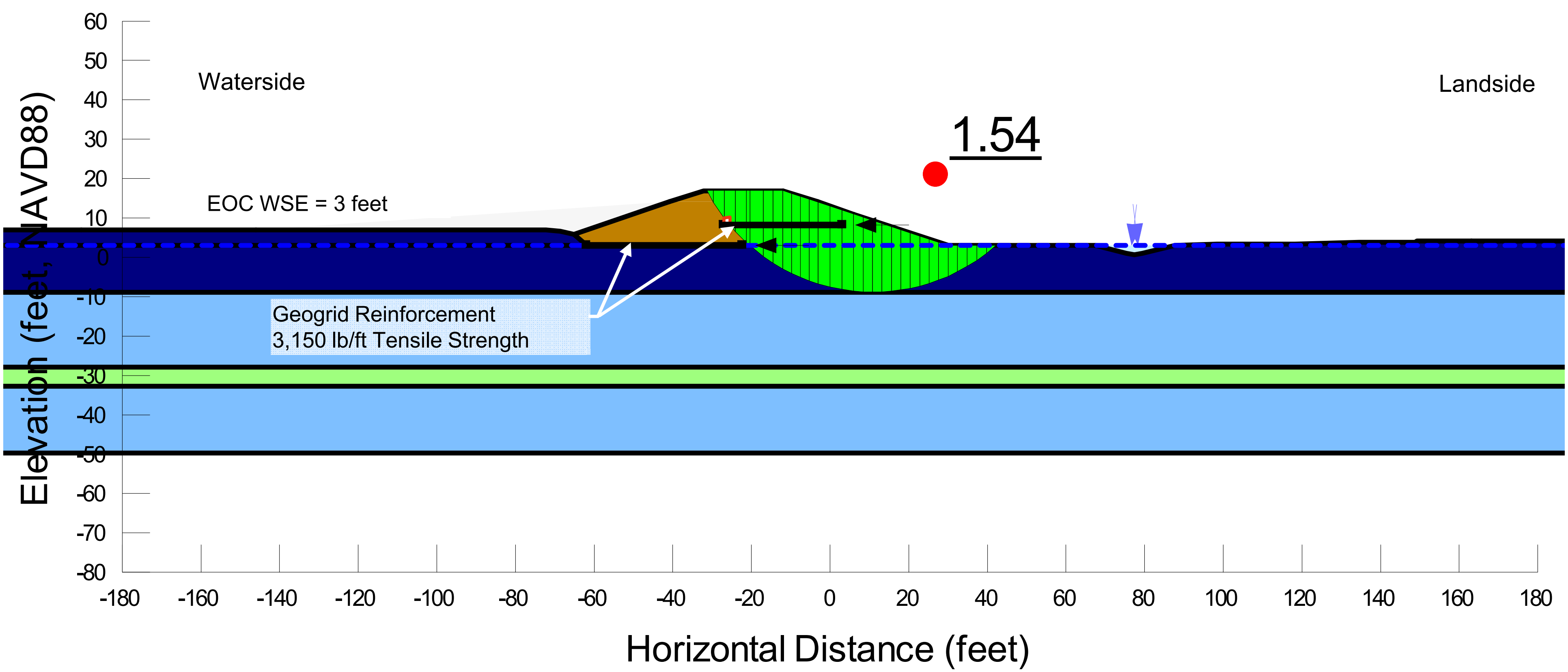
Layer Number	Layer Name	Saturated Unit Weight	Drained Parameters		Undrained Parameters	
			c’	ϕ’	c	ϕ
		(pcf)	(psf)	(deg.)	(psf)	(deg.)
1	CL - Levee Fill	125	75	30	750	0
2	CH - Existing Levee	120	75	30	500	0
3	CH - YBM Fill	110	0	29	300	0
4	CH - YBM	110	0	29	300 to 350	0
5	CL - Alluvium	125	50	30	600 to 900	0
6	SW-SC - Alluvium	125	0	35	--	--
7	CL - Alluvium	125	50	30	1,100	0



Notes:

1. Geogrid reinforcement is shown at the base of the new embankment at both the surface of the Existing Levee Fill (Layer 2) and the surface of the Young Bay Mud (Layer 3). A 5 foot horizontal overlap of the geogrid layers is assumed for these analyses.

SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G8** Stability Model
Menlo Park and East Palo Alto, California		May 2016 Figure C-38



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 1

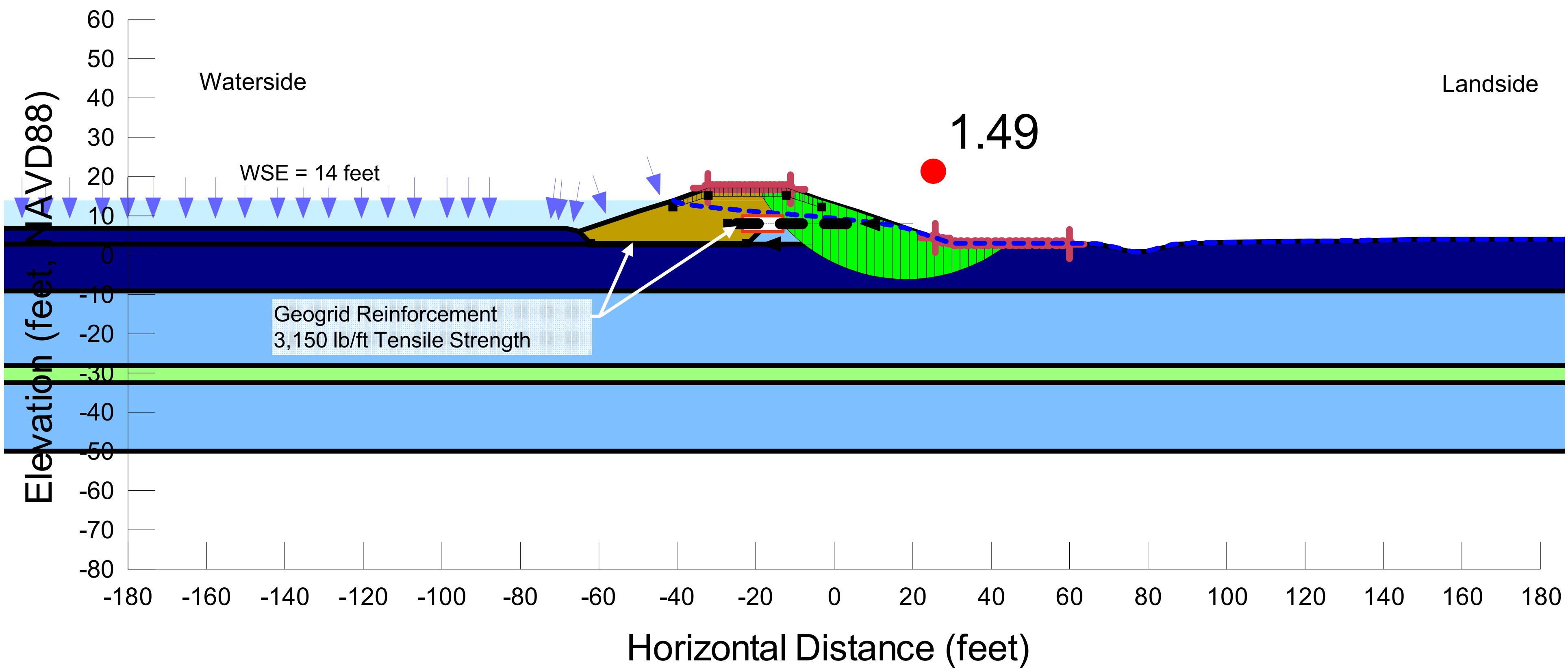
Menlo Park and East Palo Alto, California

Cross Section G8

End-of-Construction
Full Levee

May 2016

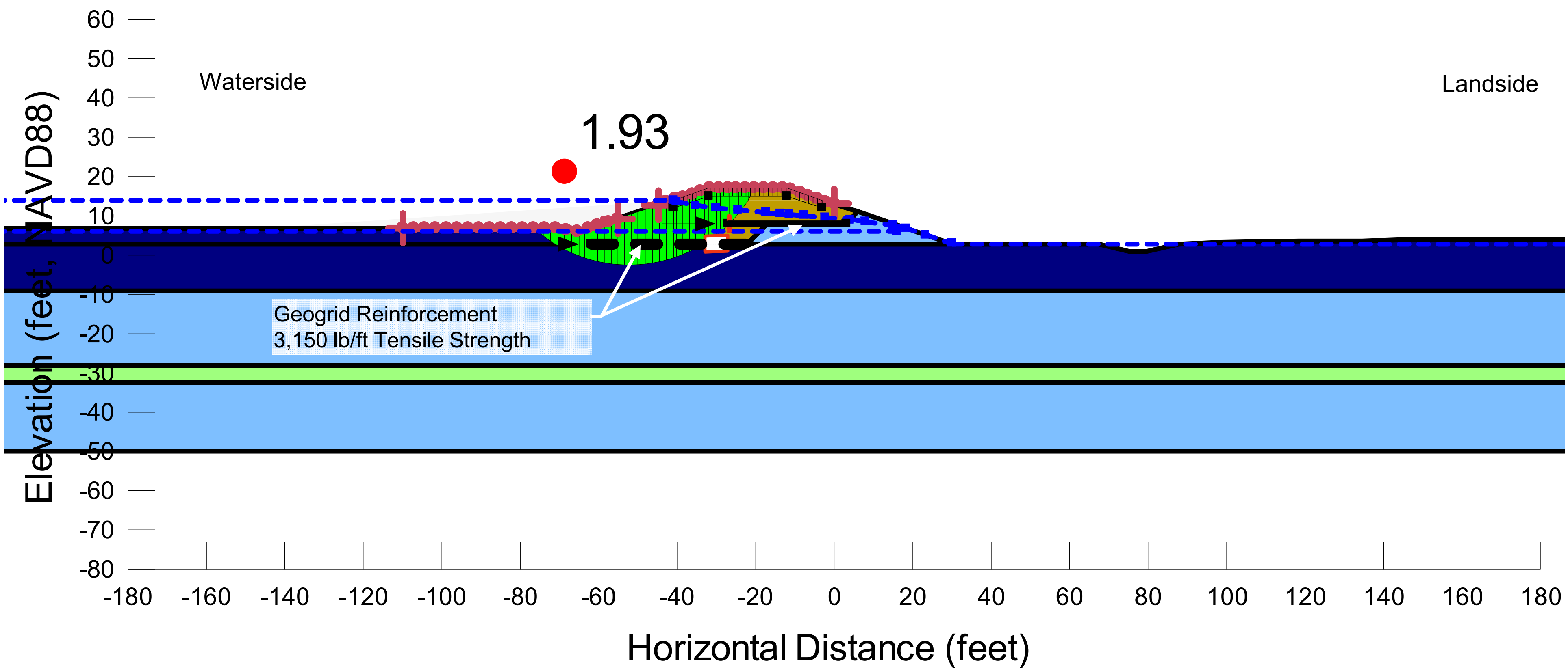
Figure C-39



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. Pore pressures are calculated from the steady-state seepage model with WSE = 14 feet.
3. 2' deep tension cracks filled with water are assumed for landside steady-state stability calculations.

SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G8** Steady-State Stability
Menlo Park and East Palo Alto, California		May 2016 Figure C-40



Notes:
1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. 2' deep tension cracks filled with water are assumed for waterside rapid drawdown stability calculations.

SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G8** Waterside Rapid Drawdown
Menlo Park and East Palo Alto, California		May 2016 Figure C-41

Appendix D
Seepage Analyses Results

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Appendix D contains the following:

Figures D-1 and D-2: Cross Section G1 – Located within Reach 1, and represents Reach 1, Option 2 and the western segment of Reach 2, Option 1.

Figures D-3 and D-4: Cross section G2 – Located within Reach 3, and represents the eastern segment of Reach 2, Option 1 and Reach 3, Option 1.

Figures D-5 and D-6: Cross section G3 – Located within and represents Reach 4.

Figures D-7 and D-8: Cross section G4 – Located within the western portion of Reach 5/6, Option 1 and Reach 5, Option 4, and represents the segment along Ravenswood Slough (between Reach 4 and the western edge of Pond R2), and the segment of Reach 5/6, Option 1 on the south side of Highway 84 from about 1,000 feet northeast of University Avenue to Reach 7.

Figures D-9 and D-10: Located east of the PG&E substation within Reach 5/6, Option 1 and Reach 5, Option 4, and represents the segment of both options along Pond R2 and the segment of Reach 5/6, Option 1 on the south side of Highway 84 from the Dumbarton Bridge abutment to about 1,000 feet northeast of University Avenue.

Figures D-11 and D-12: Cross section G6 – Located within Pond SF2 of Reach 5, Option 4, and represents the segment of Reach 5, Option 4 from Pond R2 to Reach 7.

Figures D-13 and D-14: Cross section G7 – Located within and represents Reach 7.

Figures D-15 and D-16: Cross section G8 – Located within Reach 9 and represents Reaches 8 and 9.

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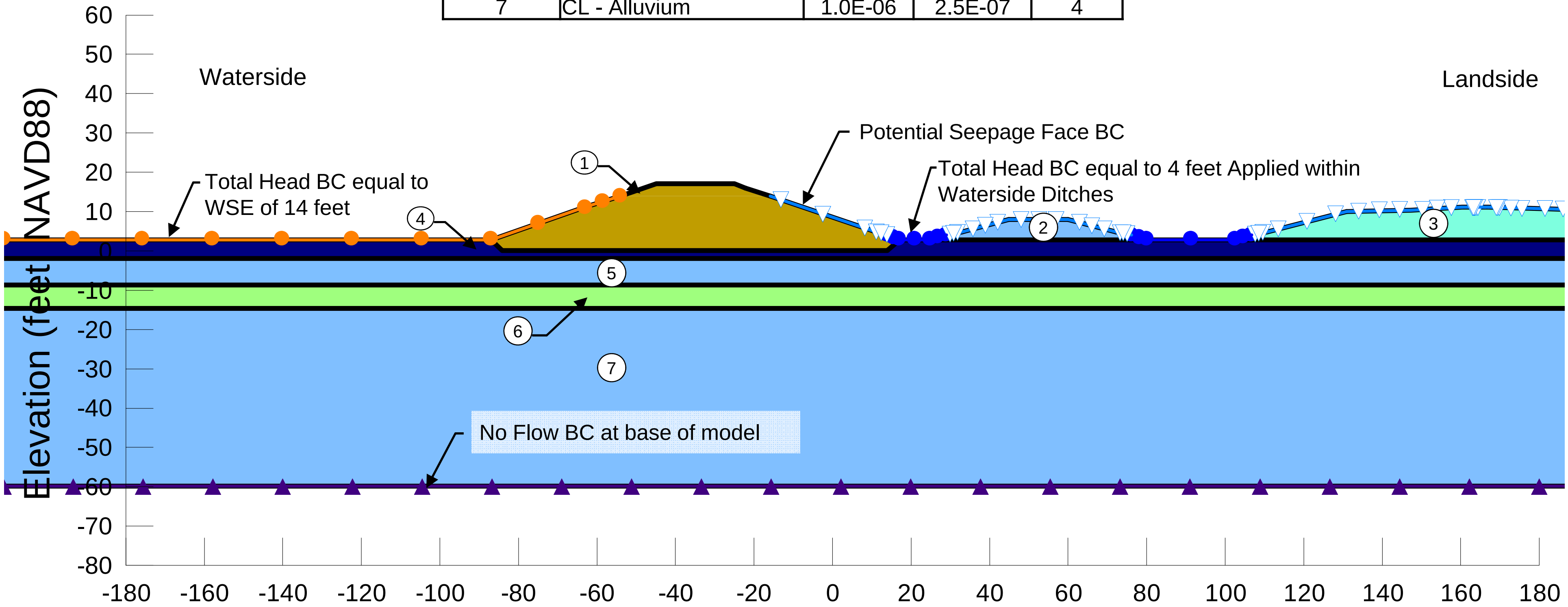
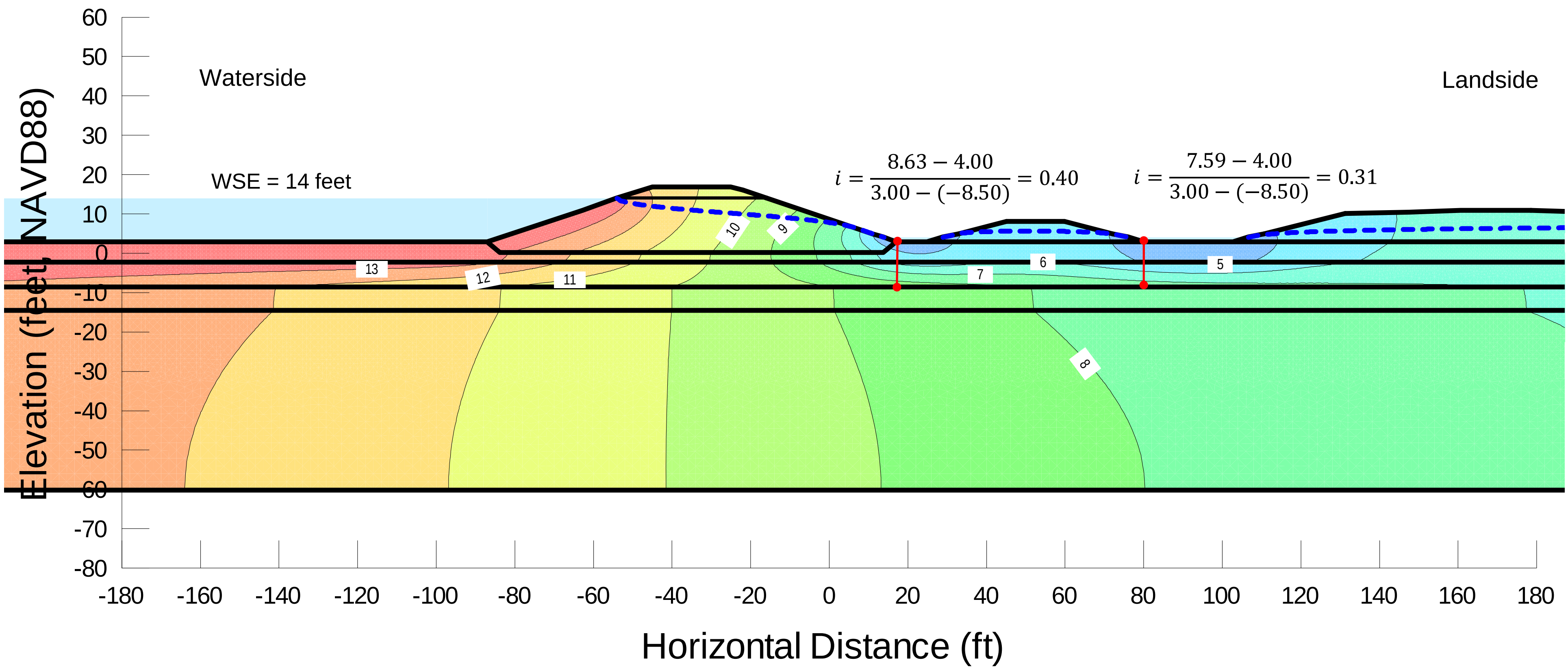
Layer Number	Layer Name	k_h (cm/sec)	k_v (cm/sec)	k_h/k_v (-)
1	CL - Levee Fill	1.0E-06	2.5E-07	4
2	CH - Existing Levee	1.0E-06	2.5E-07	4
3	SC/CL - Fill	1.0E-05	2.5E-06	4
4	CH – YBM (Desiccated)	4.0E-06	1.0E-06	4
5	CL - Alluvium	1.0E-06	2.5E-07	4
6	SP-SC/SC - Alluvium	1.0E-04	2.5E-05	4
7	CL - Alluvium	1.0E-06	2.5E-07	4



← No Flow BC at applied at Waterside Extent (x = -600 feet)

Total Head BC of 4 feet applied at Landside Extent (x = 2,000 feet) →

SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G1** Steady-State Seepage Model
Menlo Park and East Palo Alto, California		May 2016 Figure D-1



SAFER Bay Project, Task Order No. 1

Menlo Park and East Palo Alto, California

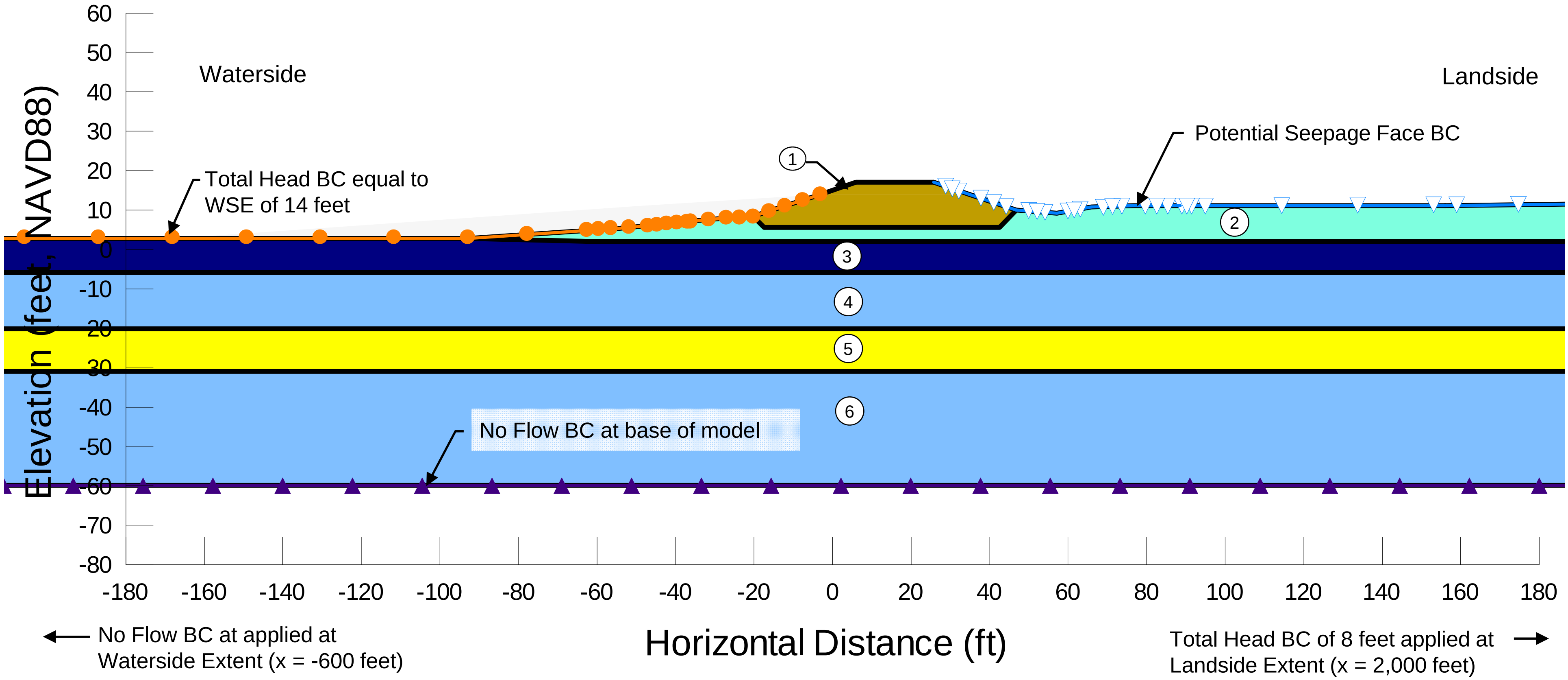
Cross Section G1

Steady-State Seepage Results

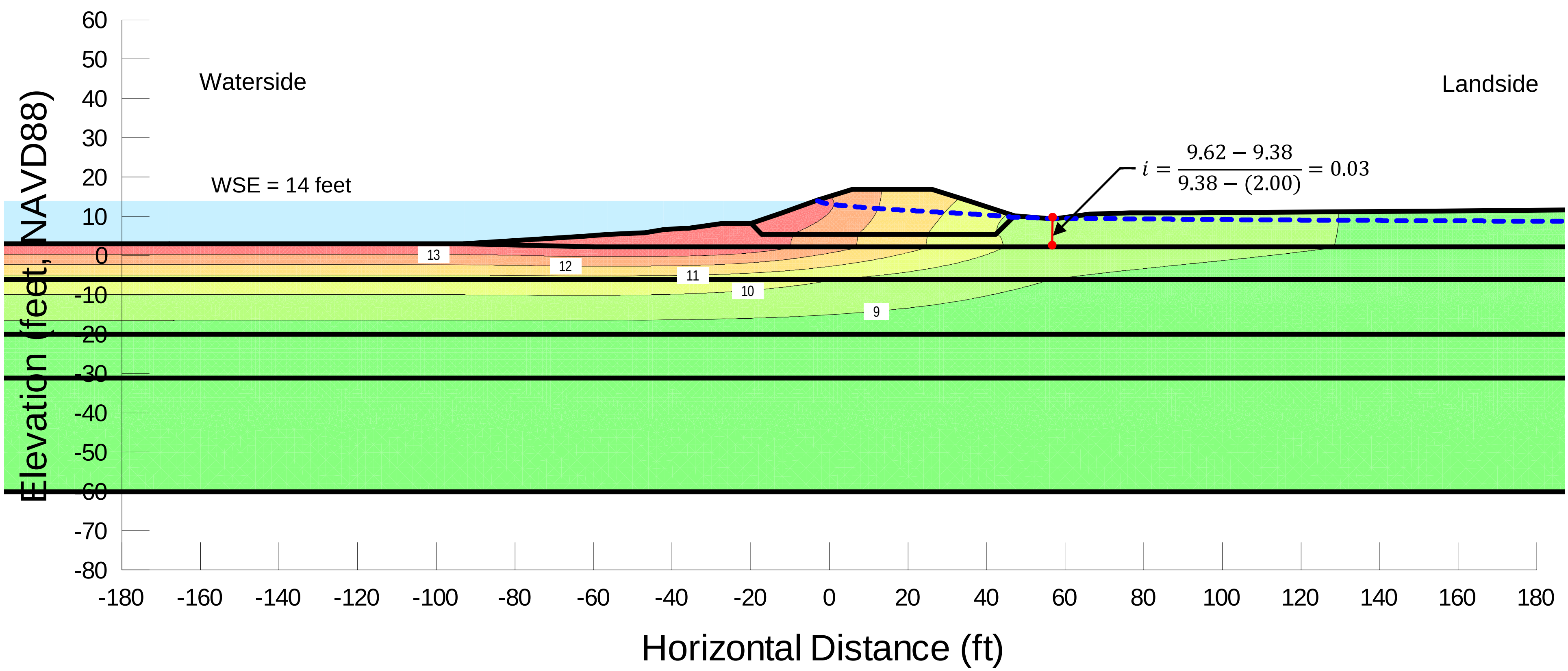
May 2016

Figure D-2

Layer Number	Layer Name	k_h (cm/sec)	k_v (cm/sec)	k_h/k_v (-)
1	CL - Levee Fill	1.0E-06	2.5E-07	4
2	SC/CL - Fill	1.0E-05	2.5E-06	4
3	CH – YBM	4.0E-07	1.0E-07	4
4	CL - Alluvium	1.0E-06	2.5E-07	4
5	SP-SM - Alluvium	1.0E-02	2.5E-03	4
6	CL - Alluvium	1.0E-06	2.5E-07	4



SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G2** Steady-State Seepage Model
Menlo Park and East Palo Alto, California		May 2016 — Figure D-3



SAFER Bay Project, Task Order No. 1

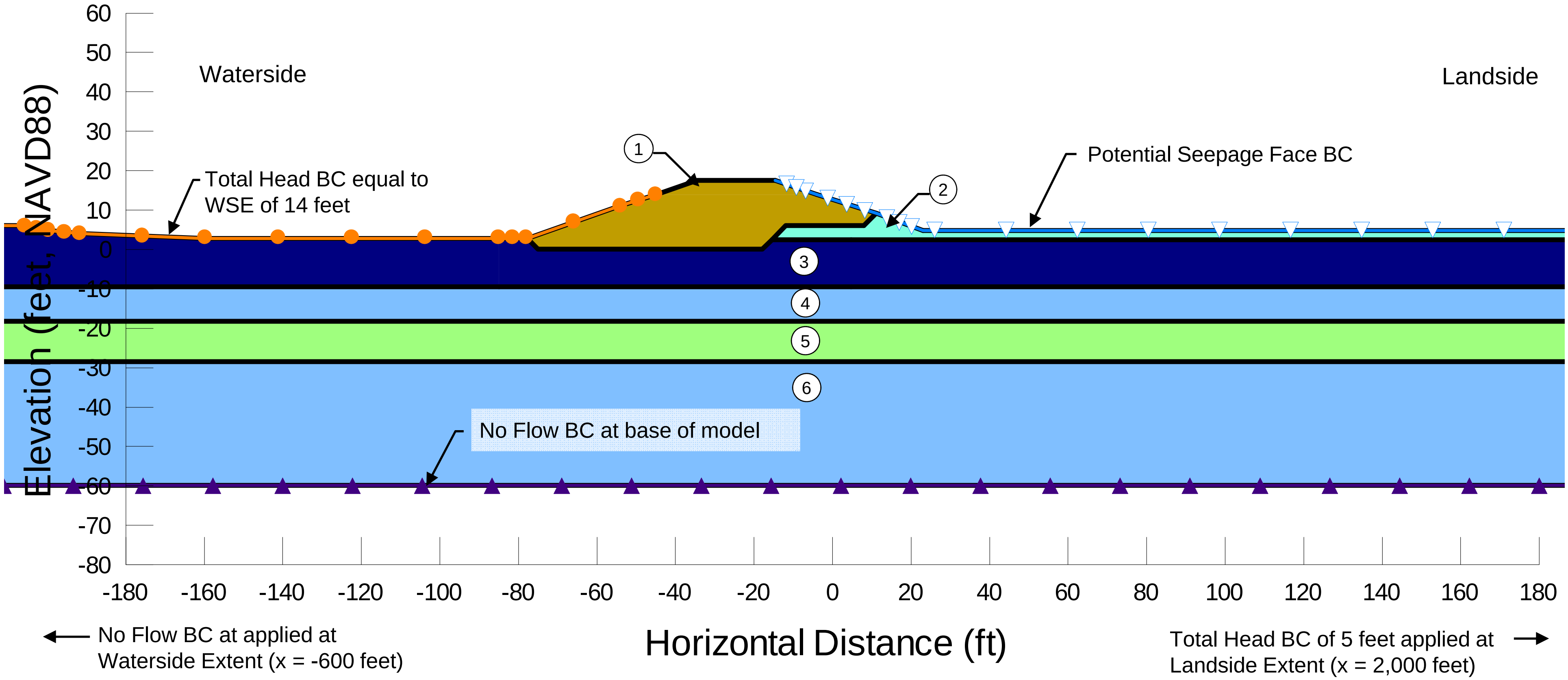
Menlo Park and East Palo Alto, California

Cross Section G2

Steady-State Seepage Results

May 2016 Figure D-4

Layer Number	Layer Name	k_h (cm/sec)	k_v (cm/sec)	k_h/k_v (-)
1	CL – Levee Fill	1.0E-06	2.5E-07	4
2	SC/CL - Fill	1.0E-05	2.5E-06	4
3	CH/MH - YBM	4.0E-07	1.0E-07	4
4	CL - Alluvium	1.0E-06	2.5E-07	4
5	SW-SC - Alluvium	1.0E-03	2.5E-04	4
6	CL - Alluvium	1.0E-06	2.5E-07	4



SAFER Bay Project, Task Order No. 1

Menlo Park and East Palo Alto, California

Cross Section G3

Steady-State Seepage Model

May 2016

Figure D-5

Calculate Transformed Blanket Thickness

Layer 2 Thickness: $Z_2 = 5.00 - 2.50 = 2.50$ feet

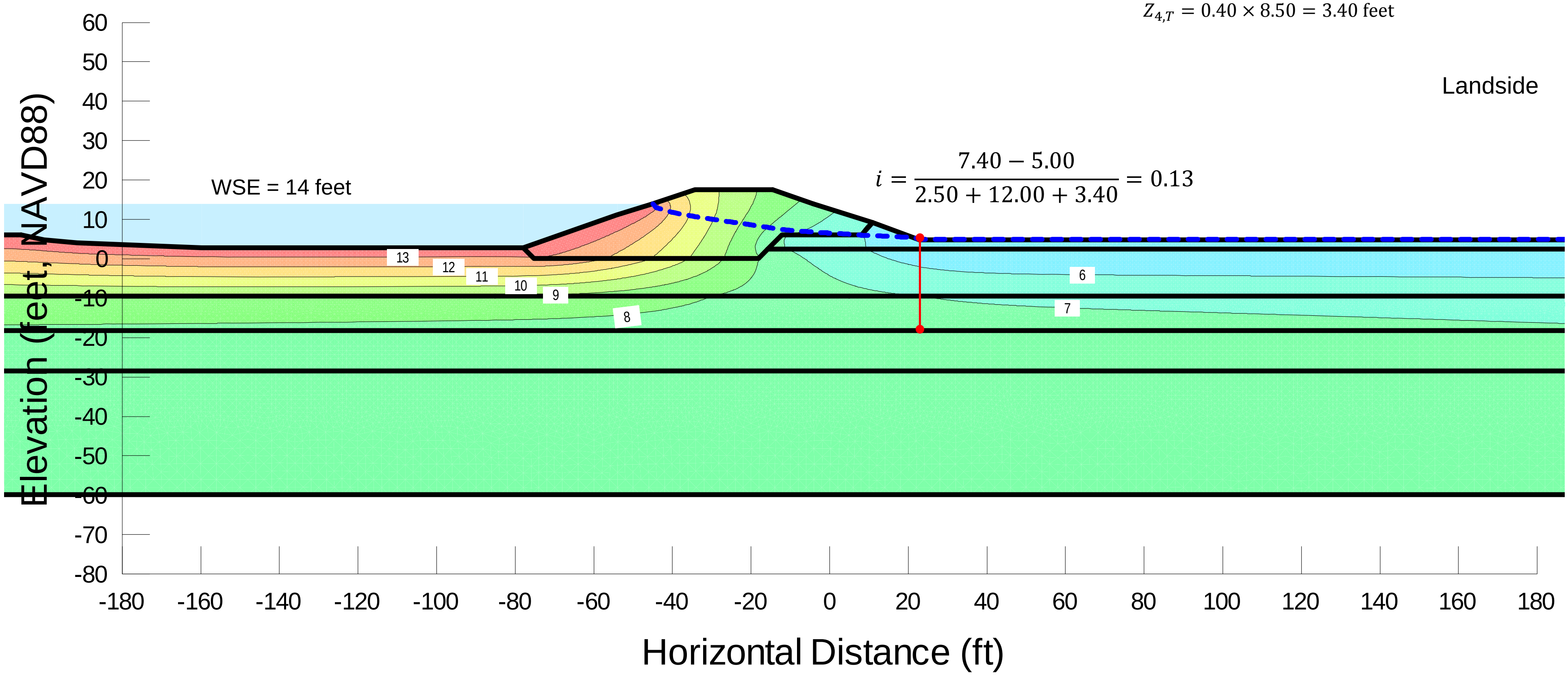
Layer 3 Thickness: $Z_3 = 2.50 - (-9.50) = 12.00$ feet

Layer 4 Thickness: $Z_4 = -9.50 - (-18.00) = 8.50$ feet

Layer 4 Transformed Thickness $Z_{4,T} = F_t \times Z_4$

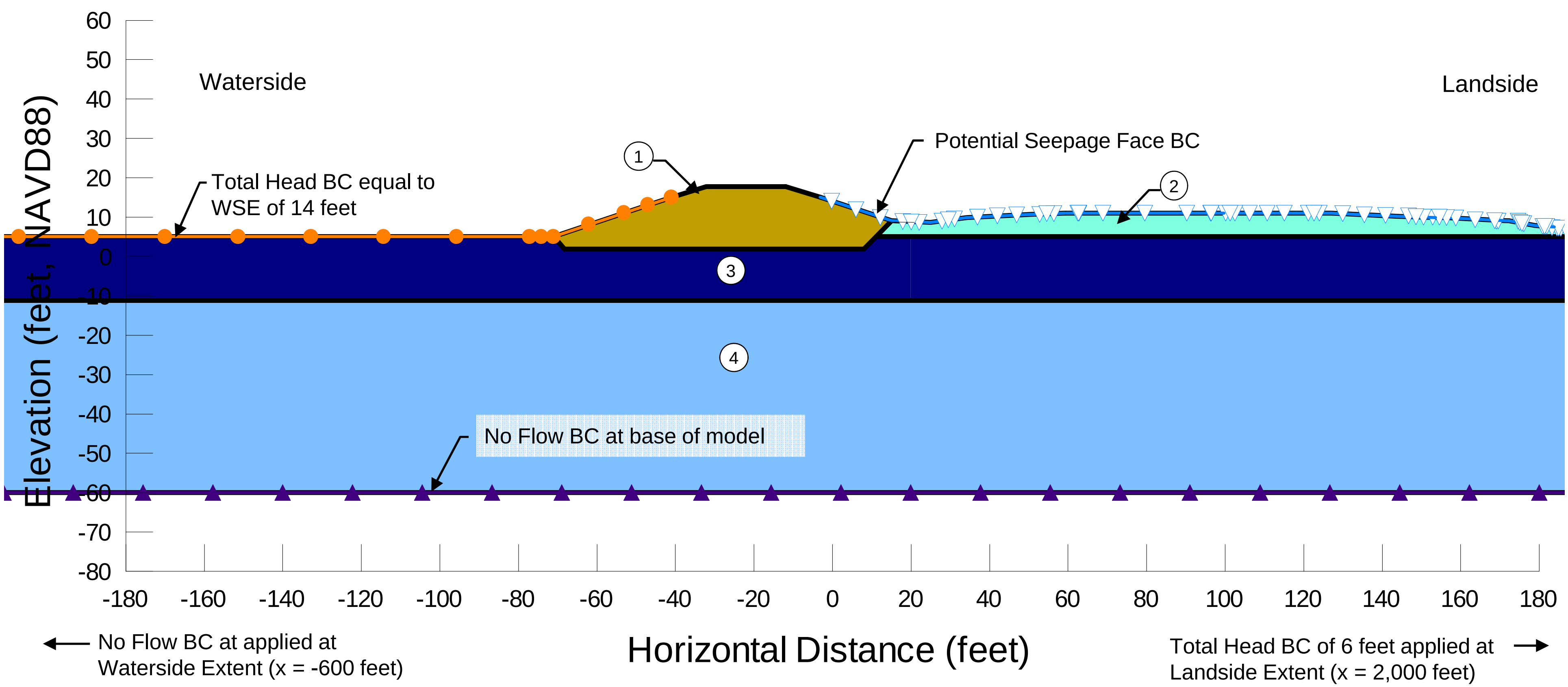
Where: $F_t = \frac{\text{Layer 3 K}_\text{v}}{\text{Layer 4 K}_\text{v}} = \frac{1.0\times10^{-7}}{2.5\times10^{-7}} = 0.40$

$Z_{4,T} = 0.40 \times 8.50 = 3.40$ feet



SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G3** Steady-State Seepage Results
Menlo Park and East Palo Alto, California		May 2016 Figure D-6

Layer Number	Layer Name	k_h (cm/sec)	k_v (cm/sec)	k_h/k_v (-)
1	CL – Levee Fill	1.0E-06	2.5E-07	4
2	SC/CL - Fill	1.0E-05	2.5E-06	4
3	CH/MH - YBM	4.0E-07	1.0E-07	4
4	CL - Alluvium	1.0E-06	2.5E-07	4



SAFER Bay Project, Task Order No. 1

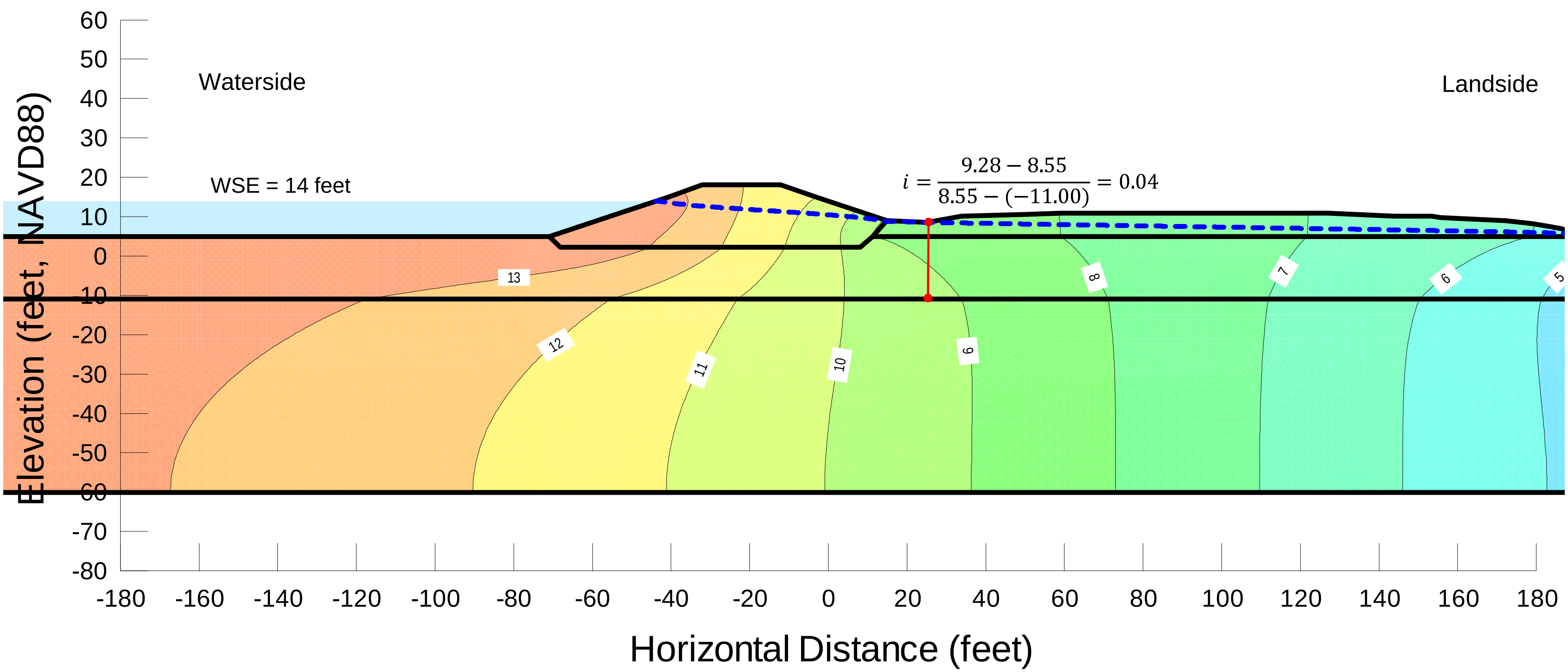
Menlo Park and East Palo Alto, California

Cross Section G4

Steady-State Seepage Model

May 2016

Figure D-7



SAFER Bay Project, Task Order No. 1

Menlo Park and East Palo Alto, California

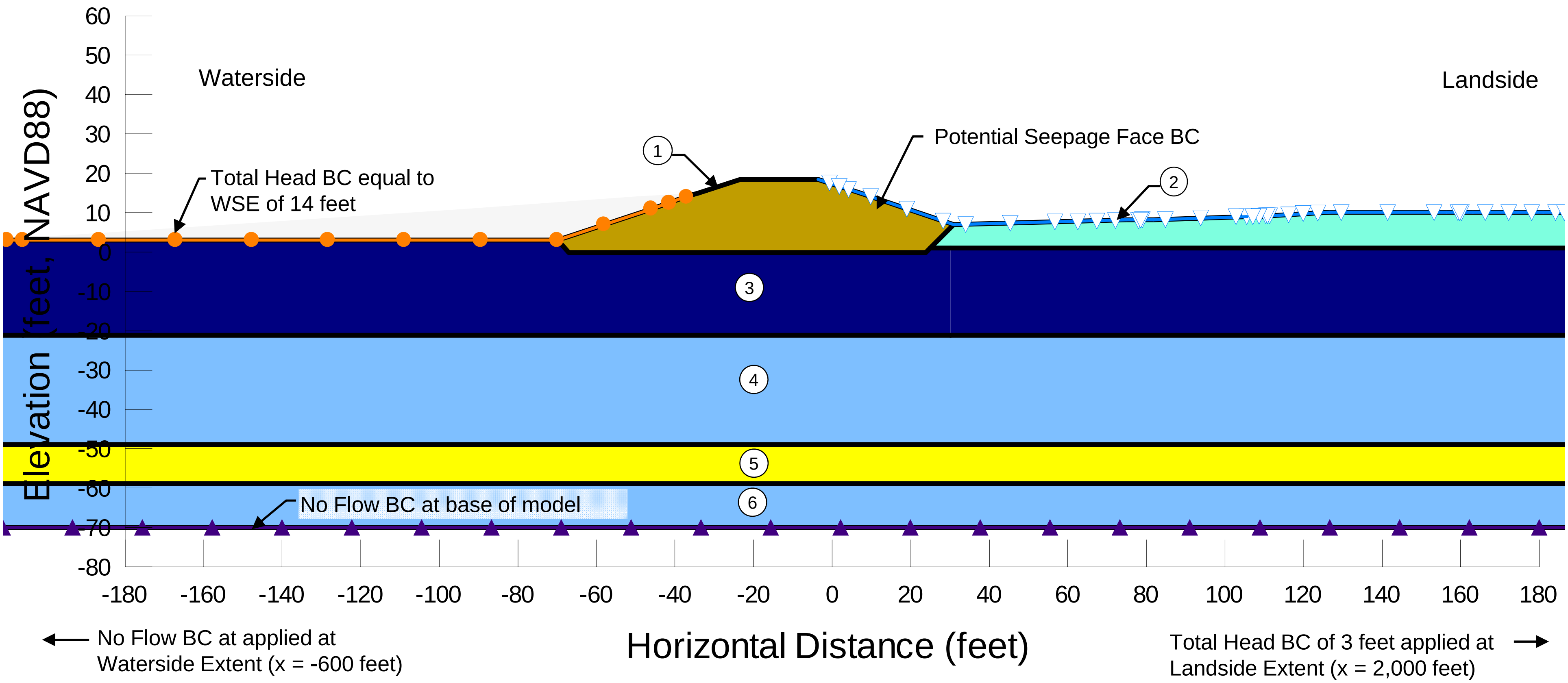
Cross Section G4

Steady-State Seepage Results

May 2016

Figure D-8

Layer Number	Layer Name	k_h (cm/sec)	k_v (cm/sec)	k_h/k_v (-)
1	CL - Levee Fill	1.0E-06	2.5E-07	4
2	SC/CL - Fill	1.0E-05	2.5E-06	4
3	MH/CH - YBM	4.0E-07	1.0E-07	4
4	CL - Alluvium	1.0E-06	2.5E-07	4
5	SP-SM - Alluvium	1.0E-02	2.5E-03	4
6	CL - Alluvium	1.0E-06	2.5E-07	4



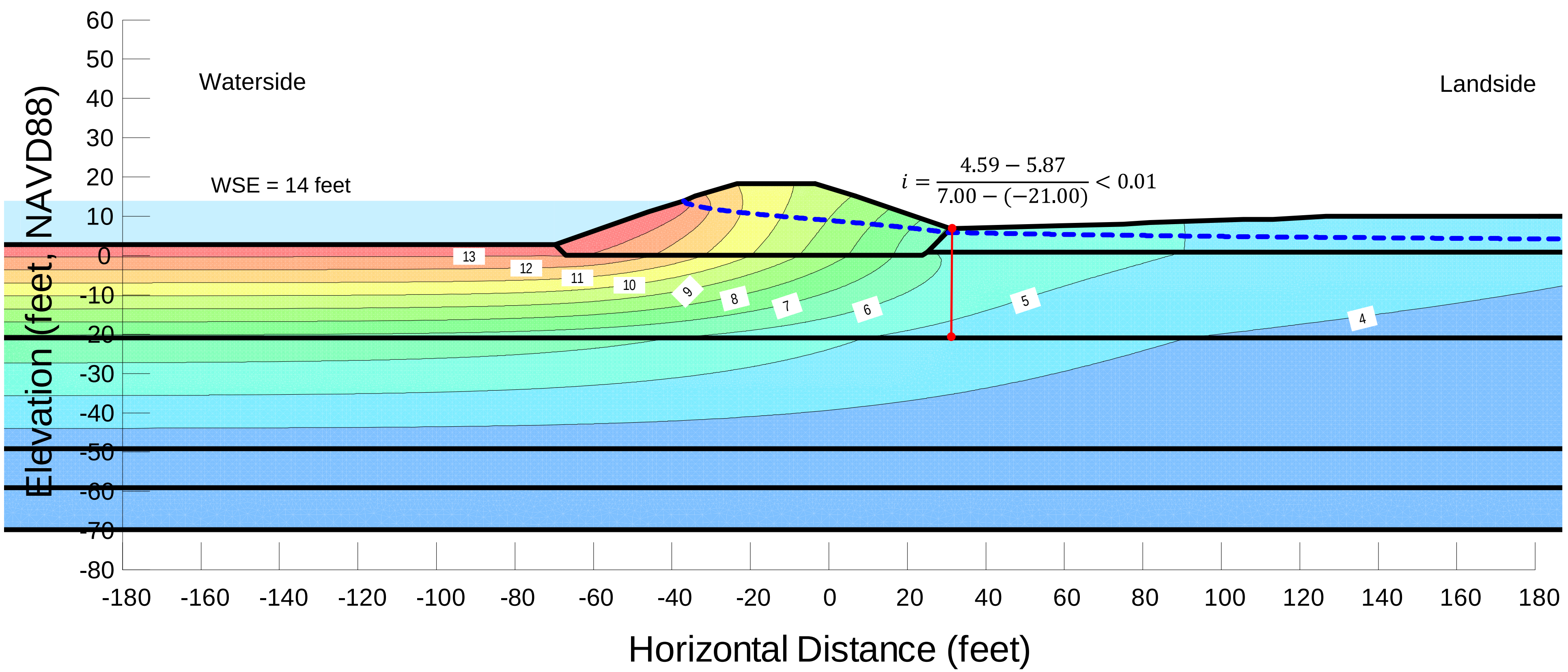
SAFER Bay Project, Task Order No. 1

Menlo Park and East Palo Alto, California

Cross Section G5

Steady-State Seepage Model

May 2016 Figure D-9



SAFER Bay Project, Task Order No. 1

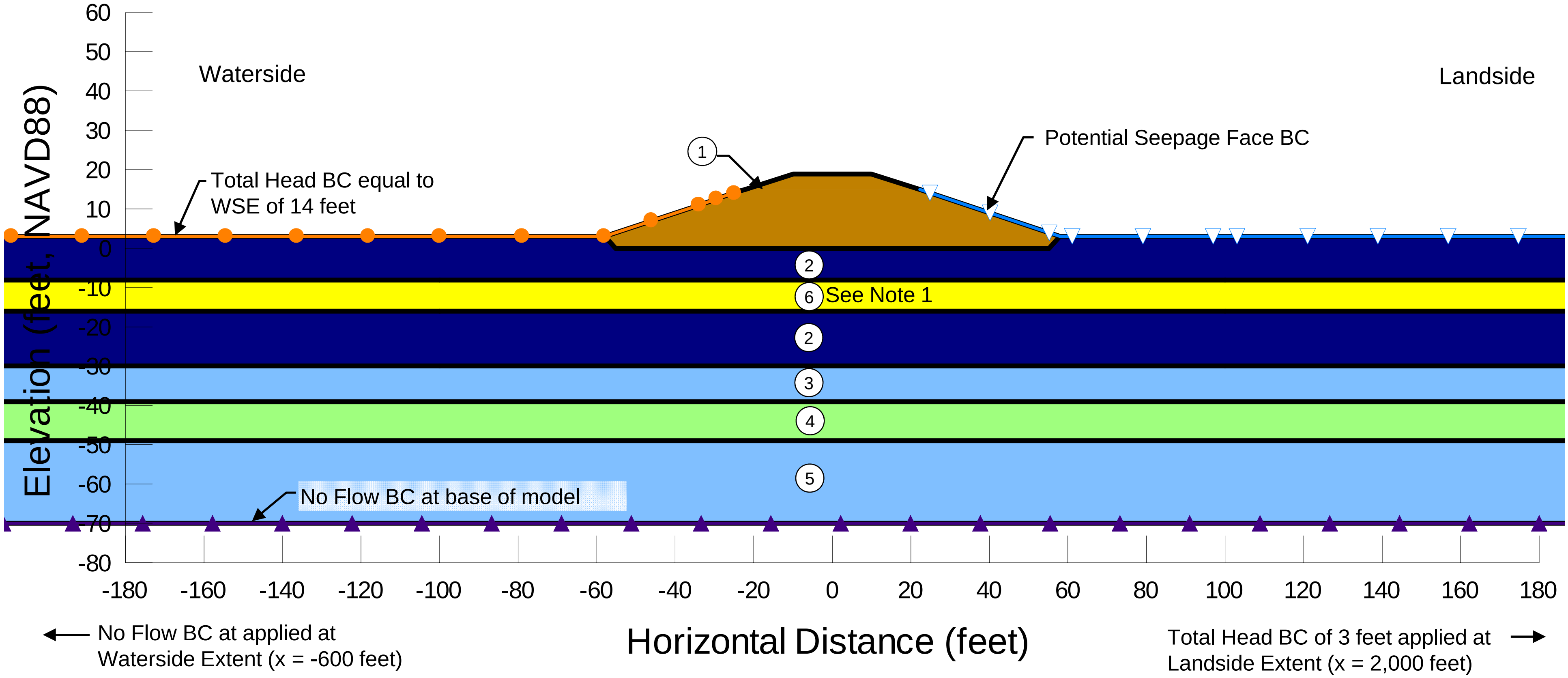
Menlo Park and East Palo Alto, California

Cross Section G5

Steady-State Seepage Results

May 2016 Figure D-10

Layer Number	Layer Name	k_h (cm/sec)	k_v (cm/sec)	k_h/k_v (-)
1	CL - Levee Fill	1.0E-06	2.5E-07	4
2	MH/CH - YBM	4.0E-07	1.0E-07	4
3	CL - Alluvium	1.0E-06	2.5E-07	4
4	SM - Alluvium	1.0E-03	2.5E-04	4
5	CL - Alluvium	1.0E-06	2.5E-07	4
6 (Note 1)	SP-SM - Sand	1.0E-02	2.5E-03	4



Notes:

1. Layer 6 (SP-SM Sand) is only included for steady-state seepage and stability analyses. Layer 6 is omitted for end-of-construction and waterside rapid drawdown stability analyses for conservativeness.

SAFER Bay Project, Task Order No. 1

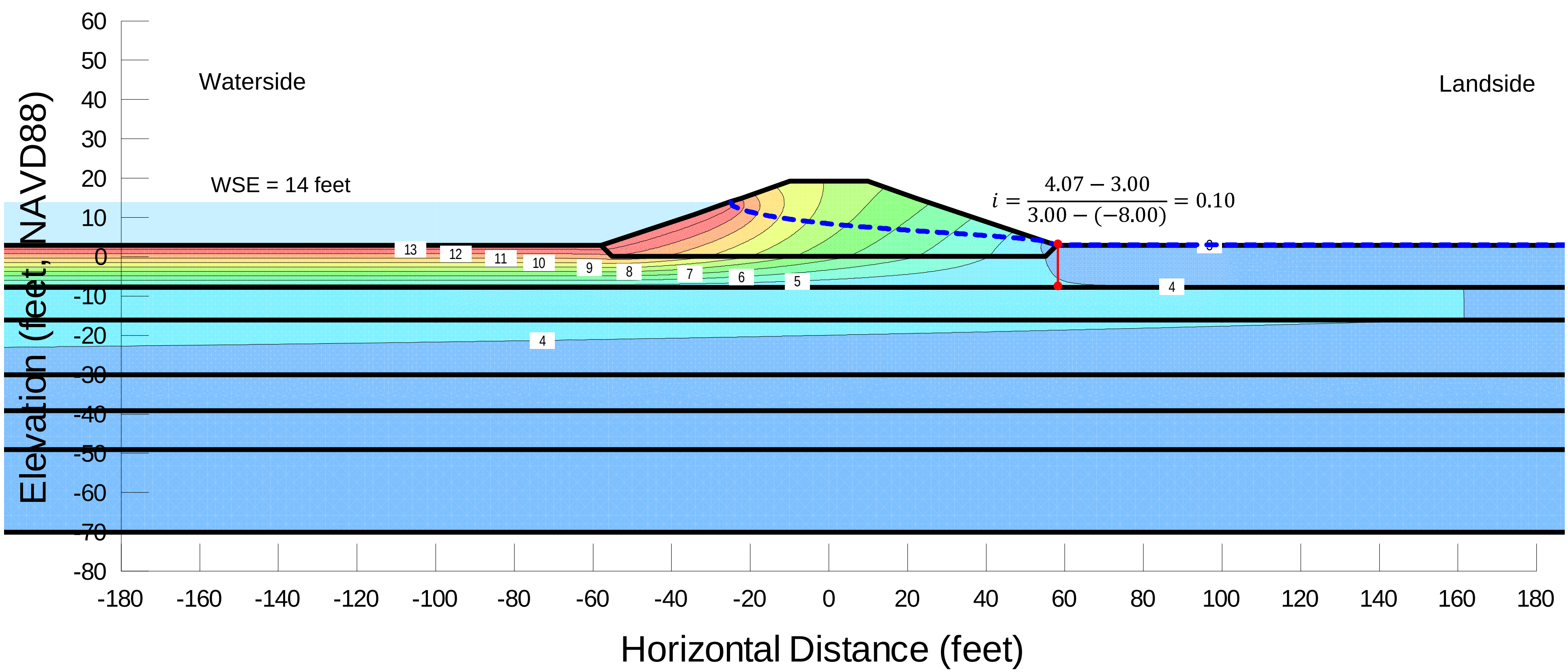
Menlo Park and East Palo Alto, California

Cross Section G6

Steady-State Seepage Model

May 2016

Figure D-11



SAFER Bay Project, Task Order No. 1

Menlo Park and East Palo Alto, California

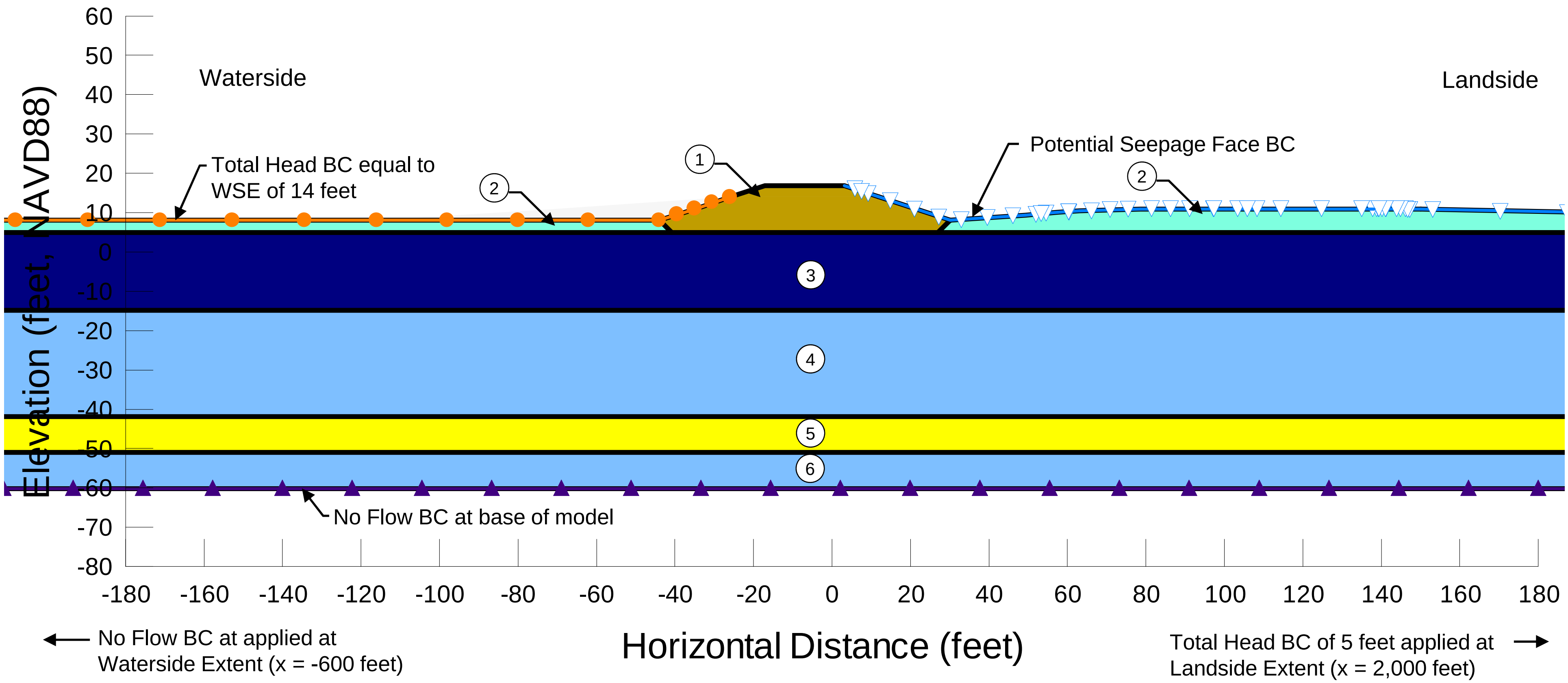
Cross Section G6

Steady-State Seepage Results

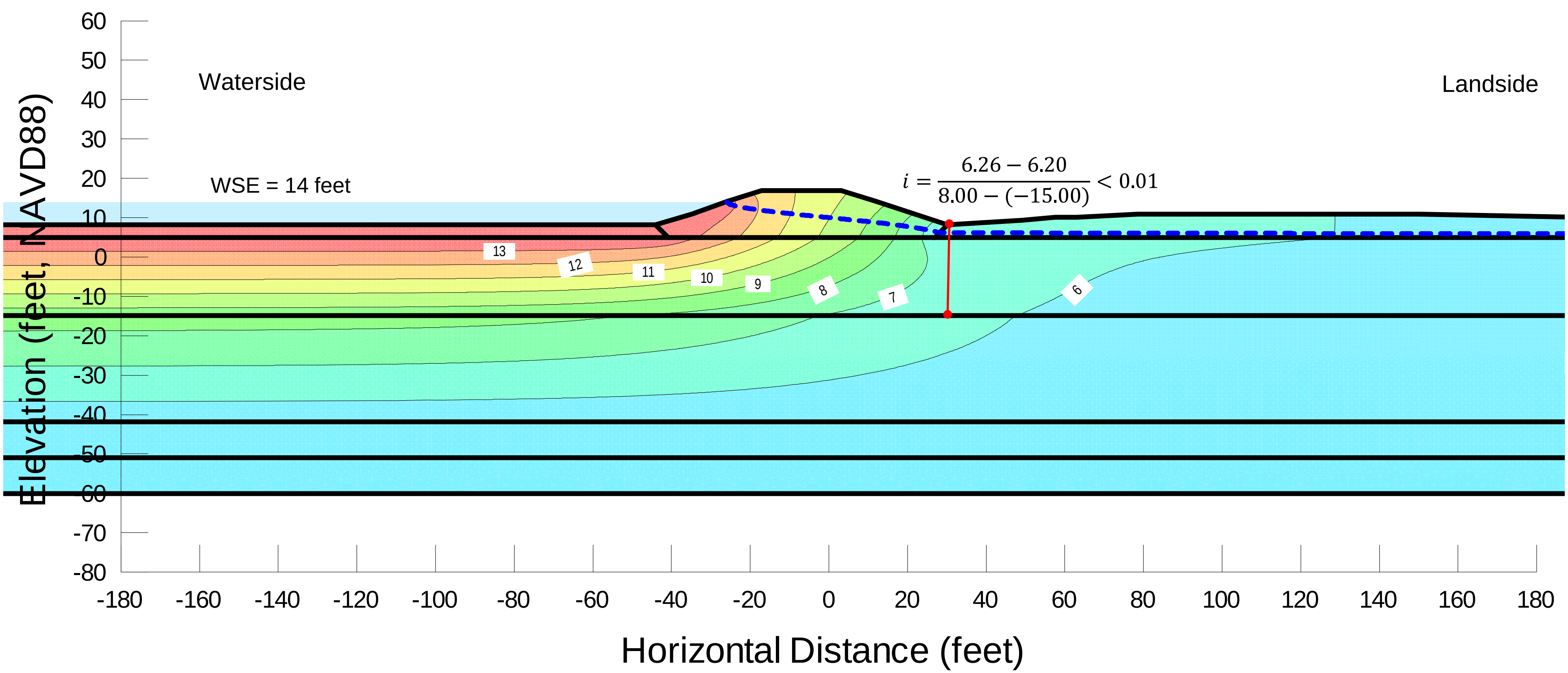
May 2016

Figure D-12

Layer Number	Layer Name	k_h (cm/sec)	k_v (cm/sec)	k_h/k_v (-)
1	CL - Levee Fill	1.0E-06	2.5E-07	4
2	ML - Fill	1.0E-04	2.5E-05	4
3	CH - YBM	4.0E-07	1.0E-07	4
4	CL - Alluvium	1.0E-06	2.5E-07	4
5	SP-SM - Alluvium	1.0E-02	2.5E-03	4
6	CL - Alluvium	1.0E-06	2.5E-07	4



SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G7** Steady-State Seepage Model
Menlo Park and East Palo Alto, California		May 2016 Figure D-13



SAFER Bay Project, Task Order No. 1

Menlo Park and East Palo Alto, California

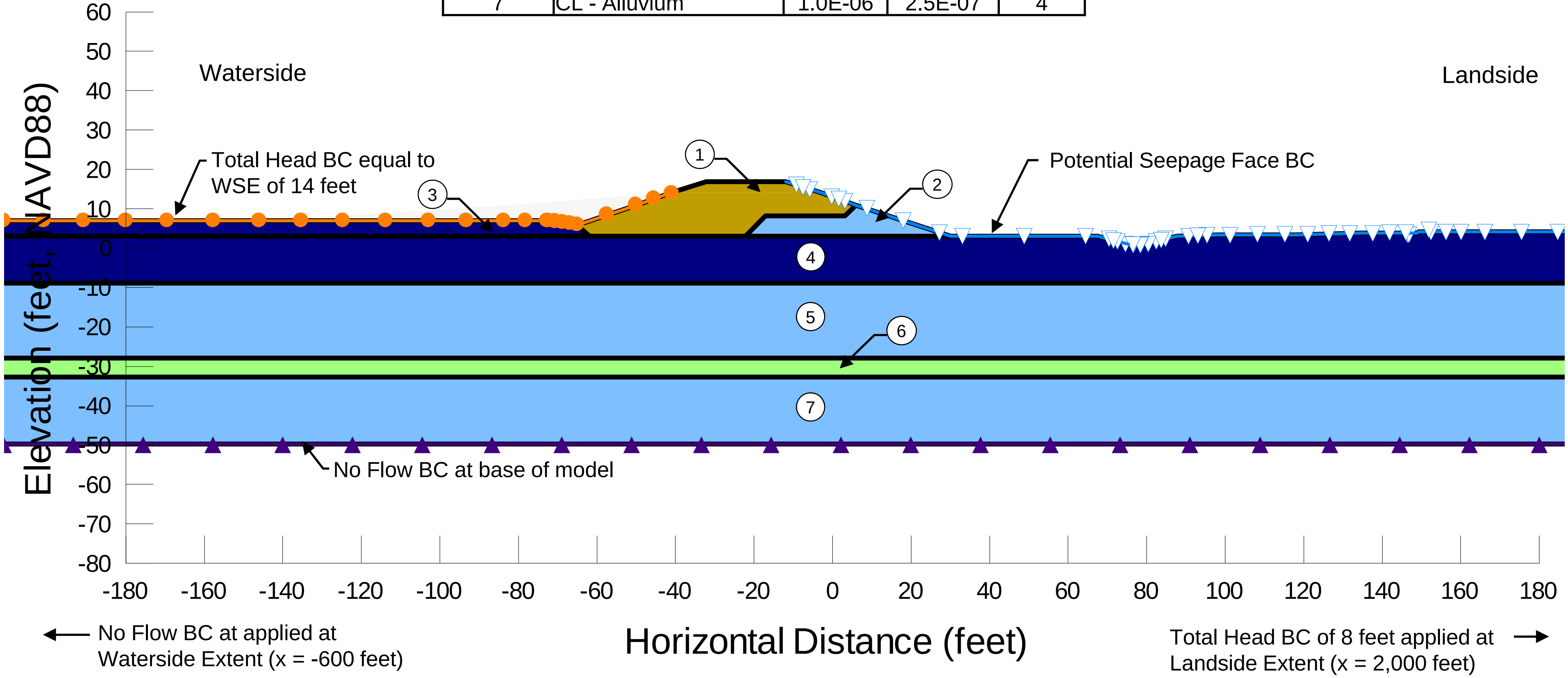
Cross Section G7

Steady-State Seepage Results

May 2016

Figure D-14

Layer Number	Layer Name	k_h (cm/sec)	k_v (cm/sec)	k_h/k_v (-)
1	CL - Levee Fill	1.0E-06	2.5E-07	4
2	CH - Existing Levee	1.0E-06	2.5E-07	4
3	CH - YBM Fill	4.0E-06	1.0E-06	4
4	CH - YBM	4.0E-07	1.0E-07	4
5	CL - Alluvium	1.0E-06	2.5E-07	4
6	SW-SC - Alluvium	1.0E-03	2.5E-04	4
7	CL - Alluvium	1.0E-06	2.5E-07	4



SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G8** Steady-State Seepage Model
Menlo Park and East Palo Alto, California		May 2016 Figure D-15

Calculate Transformed Blanket Thickness

Layer 4 Thickness (at toe): $Z_{4,toe} = 3.00 - (-9.00) = 12.00$ feet

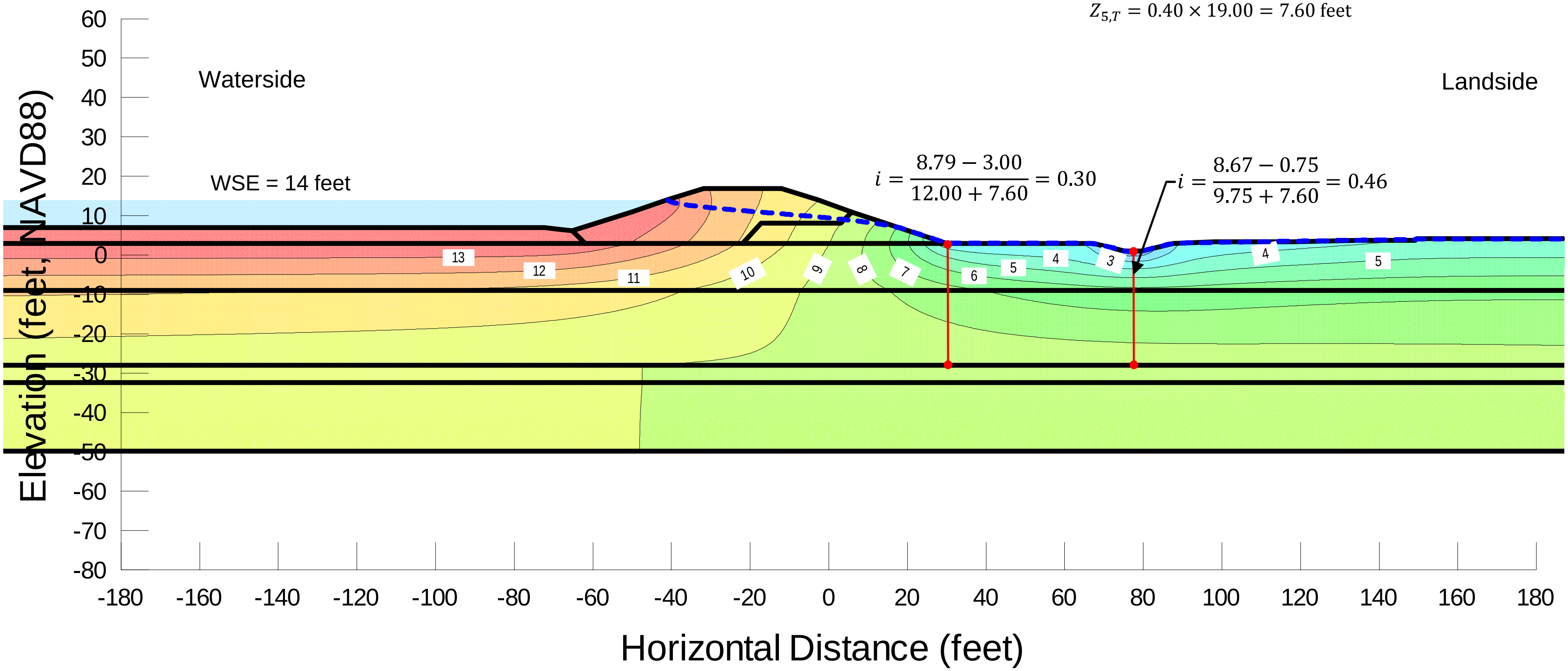
Layer 4 Thickness (at ditch): $Z_{4,ditch} = 0.75 - (-9.00) = 9.75$ feet

Layer 5 Thickness: $Z_5 = -9.00 - (-28.00) = 19.00$

Layer 5 Transformed Thickness $Z_{5,T} = F_t \times Z_5$

Where: $F_t = \frac{\text{Layer 3 K}_v}{\text{Layer 4 K}_v} = \frac{1.0\times10^{-7}}{2.5\times10^{-7}} = 0.40$

$Z_{5,T} = 0.40 \times 19.00 = 7.60$ feet



SAFER Bay Project, Task Order No. 1	HDR	**Cross Section G8** Steady-State Seepage Results
Menlo Park and East Palo Alto, California		May 2016 — Figure D-16

Appendix B - Individual Reach Feasibility Evaluation Factors and Consideration Scoring Metrics

2365 Iron Point Road, Suite 300, Folsom, CA **hdrinc.com**
P 916-817-4700

Construction Cost and Constructability

Reaches	Option 1	Points	Option 2	Points	Option 3	Points	Option 4	Points
Reach 1	$ 1,840,000	5	$ 12,770,000	1				
Reach 2	$ 11,878,000	1						
Reach 3	$ 5,210,000	3						
Reach 4	$ 6,891,000	3	$ 7,808,000	2				
Reach 5	$ 39,559,000	1					$ 53,755,000	1
Reach 7			$ 15,636,000	1				
Reach 8			$ 5,298,000	3				
Reach 9	$ 3,435,000	4						

	Average		Sum
1, Low Cost Alternative	**2.6**	**$ 89,747,000**	**21**
2, Restoration Alternative	**2.0**	**$ 115,790,000**	**16**
3, Recreation Alternative	**2.0**	**$ 115,790,000**	**16**
4, Optimized Alternative	**2.5**	**$ 104,860,000**	**20**

Lifecycle Cost

Reaches	Option 1	Points	Option 2	Points	Option 3	Points	Option 4	Points
Reach 1	Easiest	5	Some Difficulty	2				
Reach 2	Some Difficulty	2						
Reach 3	Easiest	5						
Reach 4	Minor Difficulty	4	Easiest	5				
Reach 5	Minor Difficulty	4					Some Difficulty	2
Reach 7			Easiest	5				
Reach 8			Easiest	5				
Reach 9	Easiest	5						

	Average	Sum
1, Low Cost Alternative	**4.4**	**35**
2, Restoration Alternative	**3.9**	**31**
3, Recreation Alternative	**3.9**	**31**
4, Optimized Alternative	**4.3**	**34**

Construction Schedule

Reaches	Option 1	Points	Option 2	Points	Option 3	Points	Option 4	Points
Reach 1	< 1 Season	4	1 Season	3				
Reach 2	1 Season	3						
Reach 3	1 Season	3						
Reach 4	1 Season	3	1 Season	3				
Reach 5	2 Seasons	2					3 Seasons	1
Reach 7			1 Season	3				
Reach 8			1 Season	3				
Reach 9	1 Season	3						

	Average	Sum
1, Low Cost Alternative	**3.0**	**24**
2, Restoration Alternative	**2.8**	**22**
3, Recreation Alternative	**2.8**	**22**
4, Optimized Alternative	**2.9**	**23**

Construction Considerations

Reaches	Option 1	Points	Option 2	Points	Option 3	Points	Option 4	Points
Reach 1	Moderate Difficulty	3	Minor Difficulty	4				
Reach 2	Minor Difficulty	4						
Reach 3	Easiest	5						
Reach 4	Moderate Difficulty	3	Minor Difficulty	4				
Reach 5	Some Difficulty	2					Most Difficult	1
Reach 7			Minor Difficulty	4				
Reach 8			Moderate Difficulty	3				
Reach 9	Easiest	5						

	Average	Sum
1, Low Cost Alternative	**3.6**	**29**
2, Restoration Alternative	**3.8**	**30**
3, Recreation Alternative	**3.8**	**30**
4, Optimized Alternative	**3.6**	**29**

Real Estate and Access

Reaches	Option 1	Points	Option 2	Points	Option 3	Points	Option 4	Points
Reach 1	Modest Impacts; 0.1 ac	4	Modest Impacts; 9 ac	4				
Reach 2	Modest Impacts; 8 ac	4						
Reach 3	Severe Impacts; 23 ac	2						
Reach 4	Modest Impacts; 0.1 ac	4	Modest Impacts; 0.1 ac	4				
Reach 5	Most Impacts; 50 ac	1					Most Impacts; 50 ac	1
Reach 7			Moderate Impacts; 16 ac	3				
Reach 8			Moderate Impacts; 10 ac	3				
Reach 9	Moderate Impacts; 13 ac	3						

	Average	Sum
1, Low Cost Alternative	**3.0**	**24**
2, Restoration Alternative	**3.0**	**24**
3, Recreation Alternative	**3.0**	**24**
4, Optimized Alternative	**3.0**	**24**

Operation and Maintenance

Reaches	Option 1	Points	Option 2	Points	Option 3	Points	Option 4	Points
Reach 1	Easiest	5	Some Difficulty	2				
Reach 2	Some Difficulty	2						
Reach 3	Easiest	5						
Reach 4	Minor Difficulty	4	Easiest	5				
Reach 5	Minor Difficulty	4					Some Difficulty	2
Reach 7			Easiest	5				
Reach 8			Easiest	5				
Reach 9	Easiest	5						

	Average	Sum
1, Low Cost Alternative	**4.4**	**35**
2, Restoration Alternative	**3.9**	**31**
3, Recreation Alternative	**3.9**	**31**
4, Optimized Alternative	**4.3**	**34**

Debris and Sediment Management

Reaches	Option 1	Points	Option 2	Points	Option 3	Points	Option 4	Points
Reach 1	Easiest	5	Some Difficulty	2				
Reach 2	Some Difficulty	2						
Reach 3	Easiest	5						
Reach 4	Easiest	5	Easiest	5				
Reach 5	Some Difficulty	2					Most Difficult	1
Reach 7			Easiest	5				
Reach 8			Easiest	5				
Reach 9	Easiest	5						

	Average	Sum
1, Low Cost Alternative	**4.3**	**34**
2, Restoration Alternative	**3.8**	**30**
3, Recreation Alternative	**3.8**	**30**
4, Optimized Alternative	**4.1**	**33**

Passive / Active

Reaches	Option 1	Points	Option 2	Points	Option 3	Points	Option 4	Points
Reach 1	Active	1	Active	1				
Reach 2	Passive/Active	3						
Reach 3	Passive	5						
Reach 4	Passive	5	Passive	5				
Reach 5	Active	1					Active	1
Reach 7			Passive/Active	3				
Reach 8			Passive/Active	3				
Reach 9	Passive	5						

	Average	Sum
1, Low Cost Alternative	**3.3**	**26**
2, Restoration Alternative	**3.3**	**26**
3, Recreation Alternative	**3.3**	**26**
4, Optimized Alternative	**3.3**	**26**

Flood Fighting Accessability

Reaches	Option 1	Points	Option 2	Points	Option 3	Points	Option 4	Points
Reach 1	Good	4	Poor	2				
Reach 2	Very Poor	1						
Reach 3	Moderate	3						
Reach 4	Good	4	Good	4				
Reach 5	Moderate	3					Very Poor	1
Reach 7			Good	4				
Reach 8			Good	4				
Reach 9	Poor	2						

	Average	Sum
1, Low Cost Alternative	**3.1**	**25**
2, Restoration Alternative	**2.6**	**21**
3, Recreation Alternative	**2.6**	**21**
4, Optimized Alternative	**2.9**	**23**

Restoration

Reaches	Option 1	Points	Option 2	Points	Option 3	Points	Option 4	Points
Reach 1	0 acres	0	0 acres	0				
Reach 2	0 acres	0						
Reach 3	0 acres	0						
Reach 4	0 acres	0	0 acres	0				
Reach 5	600 acres	3					720 acres	5
Reach 7			170 acres	3				
Reach 8			100 acres	3				
Reach 9	110 acres	3						

	Average	Sum
1, Low Cost Alternative	**1.5**	**12**
2, Restoration Alternative	**1.8**	**14**
3, Recreation Alternative	**1.8**	**14**
4, Optimized Alternative	**1.8**	**14**

Interagency Coordination

Reaches	Option 1	Points	Option 2	Points	Option 3	Points	Option 4	Points
Reach 1	Poor	2	Good	4				
Reach 2	Good	4						
Reach 3	Good	4						
Reach 4	Good	4						
Reach 5	Moderate	3					Excellent	5
Reach 7			Poor	2				
Reach 8			Moderate	3				
Reach 9	Poor	2						

	Average	Sum
1, Low Cost Alternative	**3.0**	**24**
2, Restoration Alternative	**3.4**	**24**
3, Recreation Alternative	**3.4**	**24**
4, Optimized Alternative	**3.1**	**22**

Environmental - Potential Impacts / Migitation Requirements

Reaches	Option 1	Points	Option 2	Points	Option 3	Points	Option 4	Points
Reach 1	No Impacts	5	Modest Impacts	4				
Reach 2	Modest Impacts	4						
Reach 3	Moderate Impacts	4						
Reach 4	Moderate Impacts	4	Self-mitigating	5				
Reach 5	Severe Impacts	2					Self-mitigating	5
Reach 7			Self-mitigating	5				
Reach 8			Self-mitigating	5				
Reach 9	Modest Impacts	4						

	Average	Sum
1, Low Cost Alternative	**4.1**	**33**
2, Restoration Alternative	**4.5**	**36**
3, Recreation Alternative	**4.5**	**36**
4, Optimized Alternative	**4.6**	**37**

Recreation, Bay Trail

Reaches	Option 1	Points	Option 2	Points	Option 3	Points	Option 4	Points
Reach 1	3,120 ft	2	No Trail	1				
Reach 2	2,560 ft	1						
Reach 3	4,200 ft	1						
Reach 4	4,240 ft	4	4,240 ft	4				
Reach 5	11,590 ft = 2.2mi	4					14,538 ft = 2.7 mi	5
Reach 7			4270 ft	2				
Reach 8			2,160 ft	2				
Reach 9	2,800 ft	2						

	Average	Sum
1, Low Cost Alternative	**2.3**	**18**
2, Restoration Alternative	**2.3**	**18**
3, Recreation Alternative	**2.3**	**18**
4, Optimized Alternative	**2.4**	**19**

Interpretive / Viewing

Reaches	Option 1	Points	Option 2	Points	Option 3	Points	Option 4	Points
Reach 1	Moderate Impacts	3	No Impacts	5				
Reach 2	No Impacts	5						
Reach 3	Severe Impacts	2						
Reach 4	Moderate Impacts	3	Severe Impacts	2				
Reach 5	Most Impacts	1					Moderate Impacts	3
Reach 7			Modest Impacts	4				
Reach 8			Modest Impacts	4				
Reach 9	Modest Impacts	4						

	Average	Sum
1, Low Cost Alternative	**3.3**	**26**
2, Restoration Alternative	**3.6**	**29**
3, Recreation Alternative	**3.6**	**29**
4, Optimized Alternative	**3.4**	**27**

Appendix C - Individual Reach Feasibility Level Cost Estimates

Job No.	222952 - 28	No.

HDR Engineering, Inc.

Project	SAFER BAY	Computed	LJ	September-16
Subject	SAFER BAY Feasibilty Cost Analysis	Checked	RET	September-16

REACH 1

OPTION 1

Line Item	Bid Item	Length (ft)	Width (ft)	Depth (ft)	X-SEC AREA (ft^2)	Quantity	Unit	Unit Price	Subtotal Price	Contingency (30%)	Total Price
A1	Mobilization/Demobilization	-	-	-	-	1	LS	$66,500	$66,500	$20,000	**$86,500**
A2	Erosion Control	-	-	-	-	1	LS	$13,300	$13,300	$4,000	**$17,300**
A3	Tree Removal	-	-	-	-	6	EA	$1,200	$7,200	$2,200	**$9,400**
A4	Demolition - Asphalt	100	20			222	SY	$12	$2,700	$900	**$3,600**
A5	Excavation - Trench for Floodwall	700			85	2,204	CY	$30.00	$66,200	$19,900	**$86,100**
A6	Concrete Floodwall	700	-	-	30	778	CY	$800	$622,300	$186,700	**$809,000**
A7	Retractable Flood Gate - Haven Ave	100	-	-	-	1	LS	$630,000	$630,000	$189,000	**$819,000**
A8	Property Acquisition	700	10			0.2	AC	$0.00	$0	$0	**$0**
								TOTAL =	**$1,408,200**	**$422,700**	**$1,840,000**

OPTION 2

Line Item	Bid Item	Length (ft)	Width (ft)	Depth (ft)	X-SEC AREA (ft^2)	Quantity	Unit	Unit Price	Subtotal Price	Contingency (30%)	Total Price
A1	Mobilization/Demobilization	-	-	-	-	1	LS	$463,100	$463,100	$139,000	**$602,100**
A2	Erosion Control	-	-	-	-	1	LS	$92,700	$92,700	$27,900	**$120,600**
A3	Tree Removal	-	-	-	-	5	EA	$1,200	$6,000	$1,800	**$7,800**
A4	Clearing and Grubbing	3,080	125	-	-	8.8	AC	$5,000	$44,200	$13,300	**$57,500**
A5	Stripping	3,120	105	0.5	53	6,066.7	CY	$20	$121,400	$36,500	**$157,900**
A6	Demolition - Existing Bike Path	3,120	10	-	-	3,466.7	SY	$12	$41,600	$12,500	**$54,100**
A7	Excavation	3,120	-	-	473	54,658	CY	$20	$1,093,200	$328,000	**$1,421,200**
A8	Levee Embankment Fill	3,120	-	-	1,171	135,316	CY	$25	$3,382,900	$1,014,900	**$4,397,800**
A9	Geogrid Reinforcement	3,120	98	-	-	33,973	SY	$6	$203,900	$61,200	**$265,100**
A10	Asphalt Concrete Pavement	3,120	20	0.5	10	1,156	CY	$266	$307,000	$92,100	**$399,100**
A11	Concrete Floodwall	920	-	-	30	1,022	CY	$800	$817,800	$245,400	**$1,063,200**
A12	Retractable Flood Gate	30	-	-	-	1	LS	$220,500	$220,500	$66,200	**$286,700**
A13	Water Control Structure - 1 Gate	-	-	-	-	3	EA	$1,000,000	$3,000,000	$900,000	**$3,900,000**
A14	Hydroseeding	3,120	106	-	-	8	AC	$3,000	$22,800	$6,900	**$29,700**
A15	Property Acquisition	4,040	135 & 10			9.9	AC	$0.00	$0	$0	**$0**
								Total	**$9,817,100**	**$2,945,700**	**$12,770,000**

Job No.	222952 - 28	No.

HDR Engineering, Inc.

Project	SAFER BAY	Computed	LJ	September-16
Subject	SAFER BAY Feasibilty Cost Analysis	Checked	RET	September-16

REACH 2

OPTION 1

Line Item	Bid Item	Length (ft)	Width (ft)	Depth (ft)	X-SEC AREA (ft^2)	Quantity	Unit	Unit Price	Subtotal Price	Contingency (30%)	Total Price
A1	Mobilization/Demobilization	-	-	-	-	1	LS	$431,000	$431,000	$129,300	$560,300
A2	Erosion Control	-	-	-	-	1	LS	$86,200	$86,200	$25,900	$112,100
A3	Tree Removal	-	-	-	-	2	EA	$1,200	$2,400	$800	$3,200
A4	Clearing and Grubbing - West Levee	800	102	-	-	2	AC	$5,000	$9,400	$2,900	$12,300
A5	Clearing and Grubbing - East Levee	2,560	110	-	-	6	AC	$5,000	$32,400	$9,800	$42,200
A6	Stripping - West Levee	800	82	0.5	41.0	1,215	CY	$20	$24,300	$7,300	$31,600
A7	Stripping - East Levee	2,560	90	0.5	45.0	4,267	CY	$20	$85,400	$25,700	$111,100
A8	Demolition - Asphalt West Levee	800	25	-	-	2,222.2	SY	$12	$26,700	$8,100	$34,800
A9	Excavation - West Levee	800	-	-	268	7,941	CY	$20	$158,900	$47,700	$206,600
A10	Excavation - East Levee	2,560	-	-	430	40,770	CY	$20	$815,500	$244,700	$1,060,200
A11	Import Fill - West Levee	800	-	-	613.0	18,163	CY	$25	$454,100	$136,300	$590,400
A12	Import Fill - East Levee	2,560	-	-	916.0	86,850	CY	$25	$2,171,300	$651,400	$2,822,700
A13	Geogrid Reinforcement	2,560	80	-	-	22,756	SY	$6	$136,600	$41,000	$177,600
A14	Water Control Structure - 2 Gates	-	-	-	-	3	EA	$1,500,000	$4,500,000	$1,350,000	$5,850,000
A15	Bike Path - AC Pavement - West Levee	800	25	0.5	12.5	370	CY	$266	$98,400	$29,600	$128,000
A16	Aggregate Surface - East Levee	2,560	20	0.5	10.0	948	CY	$82	$77,800	$23,400	$101,200
A17	Hydroseeding - West Levee	800	104	-	-	2	AC	$3,000	$5,800	$1,800	$7,600
A18	Hydroseeding - East Levee	2,560	110	-	-	6	AC	$3,000	$19,400	$5,900	$25,300
A19	Property Acquisition	3,360				8	AC	$0	$0	$0	$0
								Total	**$9,135,600**	**$2,741,600**	**$11,877,200**

Job No. 222952 - 28	No.

HDR Engineering, Inc.

Project	SAFER BAY	Computed	LJ	September-16
Subject	SAFER BAY Feasibilty Cost Analysis	Checked	RET	September-16

REACH 3

OPTION 1

Line Item	Bid Item	Length (ft)	Width (ft)	Depth (ft)	X-SEC AREA (ft^2)	Quantity	Unit	Unit Price	Subtotal Price	Contingency (30%)	Total Price
A1	Mobilization/Demobilization	-	-	-	-	1	LS	$189,000	$189,000	$56,700	**$245,700**
A2	Erosion Control	-	-	-	-	1	LS	$37,800	$37,800	$11,400	**$49,200**
A3	Clearing and Grubbing	4,200	87	-	-	8	AC	$5,000	$42,000	$12,600	**$54,600**
A4	Stripping	4,200	67	0.5	34	5,211	CY	$20	$104,300	$31,300	**$135,600**
A5	Demolition - Asphalt West Levee	4,200	10	-	-	4,666.7	SY	$12	$56,000	$16,800	**$72,800**
A6	Excavation	4,200	-	-	242	37,644	CY	$20	$752,900	$225,900	**$978,800**
A7	Geogrid Reinforcement	4,200	60	-	-	28,000	SY	$6	$168,000	$50,400	$218,400
A8	Levee Embankment Fill	4,200	-	-	570	88,667	CY	$25	$2,216,700	$665,100	**$2,881,800**
A9	Asphalt Concrete Pavement	4,200	20	0.5	10	1,556	CY	$266	$413,300	$124,000	**$537,300**
A10	Hydroseeding	4,200	90	-	-	9	AC	$3,000	$26,100	$7,900	**$34,000**
A11	Property Acquisition	4,200	87			8	AC	$0	$0	$0	**$0**
								Total	**$4,006,100**	**$1,202,100**	**$5,208,200**

HDR Engineering, Inc.

Project	SAFER BAY	Computed	LJ	March-16
Subject	SAFER BAY Feasibilty Cost Analysis	Checked	RET	September-16

REACH 4

Option 1- FLOODWALL

Line Item	Bid Item	Length (ft)	Width (ft)	Depth (ft)	X-SEC AREA (ft^2)	Quantity	Unit	Unit Price	Subtotal Price	Contingency (30%)	Total Price
A1	Mobilization/Demobilization	-	-	-	-	1	LS	$250,000	$250,000	$75,000	**$325,000**
A2	Erosion Control	4,240	-	-	-	1	LS	$50,000	$50,000	$15,000	**$65,000**
A3	Clearing and Grubbing	4,240	59	-	-	5.7	AC	$5,000	$28,800	$8,700	**$37,500**
A4	Stripping	4,240	39	0.5	20	3,062	CY	$20	$61,300	$18,400	**$79,700**
A5	Tree Removal					100	EA	$1,200	$120,000	$36,000	**$156,000**
A6	Demolition - Remove AC Bike Path	4,240	10	-	-	4,711	SY	$12	$56,600	$17,000	**$73,600**
A7	Excavation for Floodwall	4,240			70	10,993	CY	$20	$219,900	$66,000	**$285,900**
A8	Bike Path Embankment Fill	4,240	-	-	120	18,844	CY	$25	$471,200	$141,400	**$612,600**
A9	Floodwall	4,240			30	4,711	CY	$800	$3,768,900	$1,130,700	**$4,899,600**
A10	Bike Path - AC Pavement	4,240	10	0.5	5	785	CY	$266	$208,600	$62,600	**$271,200**
A11	Traffic Control	-	-	-	-	1	LS	$50,000	$50,000	$15,000	**$65,000**
A12	Hydroseed	4,240	50	-	-	5	AC	$3,000	$14,700	$4,500	**$19,200**
A13	Property Acquisition	4,240	59			5.7	AC	$0	$0	$0	**$0**
								Total	**$5,300,000**	**$1,590,300**	**$6,890,300**

Option 2 - Levee

Line Item	Bid Item	Length (ft)	Width (ft)	Depth (ft)	X-SEC AREA (ft^2)	Quantity	Unit	Unit Price	Subtotal Price	Contingency (30%)	Total Price
A1	Mobilization/Demobilization	-	-	-	-	1	LS	$283,300	$283,300	$85,000	**$368,300**
A2	Erosion Control	4,240		-	-	1	LS	$56,700	$56,700	$17,100	**$73,800**
A3	Clearing and Grubbing	4,240	115			11	AC	$5,000	$56,000	$16,800	**$72,800**
A4	Stripping	4,240	95	0.5	48	7,459	CY	$20	$149,200	$44,800	**$194,000**
A5	Tree Removal					100	EA	$1,200	$120,000	$36,000	**$156,000**
A6	Demolition - Remove AC Bike Path	4,240	10	-	-	4,711	SY	$12	$56,600	$17,000	**$73,600**
A7	Excavation	4,240			260	40,830	CY	$20	$816,600	$245,000	**$1,061,600**
A8	Levee Embankment Fill	4,240	-	-	969	152,169	CY	$25	$3,804,300	$1,141,300	**$4,945,600**
A9	Geogrid Reinforcement	4,240	57			26,853	SY	$6	$161,200	$48,400	$209,600
A10	Bike Path - AC Pavement	4,240	20	0.5	10	1,570	CY	$266	$417,200	$125,200	**$542,400**
A11	Traffic Control	-	-	-	-	1	LS	$50,000	$50,000	$15,000	**$65,000**
A12	Hydroseed	4,240	118	-	-	11	AC	$3,000	$34,500	$10,400	**$44,900**
A13	Property Acquisition	4,240	115			11	AC	$0	$0	$0	**$0**
								Total	**$6,005,600**	**$1,802,000**	**$7,807,600**

Job No.	222952 - 28	No.

HDR Engineering, Inc.

Project	SAFER BAY	Computed	LJ	September-16
Subject	SAFER BAY Feasibilty Cost Analysis	Checked	RET	September-16

REACH 5

Option 1 - Levees and Flood Gates

Line Item	Bid Item	Length (ft)	Width (ft)	Depth (ft)	X-SEC AREA (ft^2)	Quantity	Unit	Unit Price	Subtotal Price	Contingency (30%)	Total Price
A1	Mobilization/Demobilization	-	-	-	-	1	LS	$1,435,400	$1,435,400	$430,700	**$1,866,100**
A2	Erosion Control	15,950		-	-	1	LS	$287,100	$287,100	$86,200	**$373,300**
A3	Clearing and Grubbing - Section A	1,700	106	-	-	4	AC	$5,000	$20,700	$6,300	**$27,000**
A4	Clearing and Grubbing - Section B North	5,590	121	-	-	16	AC	$5,000	$77,700	$23,400	**$101,100**
A5	Clearing and Grubbing - Section B South	4,300	128	-	-	13	AC	$5,000	$63,200	$19,000	**$82,200**
A6	Clearing and Grubbing - Section D	3,960	94	-	-	9	AC	$5,000	$42,800	$12,900	**$55,700**
A7	Demolition - Remove AC Bike Path	7,150	10	-	-	7,944	SY	$12	$95,400	$28,700	**$124,100**
A8	Stripping - Section A	1,700	86	0.5	43	2,707	CY	$20	$54,200	$16,300	**$70,500**
A9	Stripping - Section B North	5,590	101	0.5	51	10,455	CY	$20	$209,200	$62,800	**$272,000**
A10	Stripping - Section B South	4,300	108	0.5	54	8,600	CY	$20	$172,000	$51,600	**$223,600**
A11	Stripping - Section D	3,960	74	0.5	37	5,427	CY	$20	$108,600	$32,600	**$141,200**
A12	Excavation for Floodwall	400	-	-	40	593	CY	$30	$17,800	$5,400	**$23,200**
A13	Excavation - Section A	1,700	-	-	381	23,989	CY	$20	$479,800	$144,000	**$623,800**
A14	Excavation - Section B North	5,590	-	-	454	93,995	CY	$20	$1,879,900	$564,000	**$2,443,900**
A15	Excavation - Section B South	4,300	-	-	362	57,652	CY	$20	$1,153,100	$346,000	**$1,499,100**
A16	Excavation - Section D	3,960			229	33,587	CY	$20	$671,800	$201,600	**$873,400**
A17	Geogrid Reinforcement - Section A	1,700	86	-	-	16,244	SY	$6	$97,500	$29,300	**$126,800**
A18	Geogrid Reinforcement - Section B North	5,590	100	-	-	62,111	SY	$6	$372,700	$111,900	**$484,600**
A19	Geogrid Reinforcement - Section B South	4,300	108	-	-	51,600	SY	$6	$309,600	$92,900	**$402,500**
A20	Geogrid Reinforcement - Section D	3,960	73	-	-	32,120	SY	$6	$192,800	$57,900	**$250,700**
A21	Levee Embankment Fill - Section A	1,700	-	-	1,151	72,470	CY	$25	$1,811,800	$543,600	**$2,355,400**
A22	Levee Embankment Fill - Section B North	5,590	-	-	1,488	308,071	CY	$25	$7,701,800	$2,310,600	**$10,012,400**
A23	Levee Embankment Fill - Section B South	4,300	-	-	1,532	243,985	CY	$25	$6,099,700	$1,830,000	**$7,929,700**
A24	Levee Embankment Fill - Section D	3,960	-	-	728	106,773	CY	$25	$2,669,400	$800,900	**$3,470,300**
A25	Bike Path - AC Pavement	7,150	20	0.5	10	2,648	CY	$266	$703,500	$211,100	**$914,600**
A26	Aggregate Surface	8,800	20	0.5	10	3,259	CY	$82	$267,300	$80,200	**$347,500**
A27	Retractable Flood Gate - Frontage Road	-	30	-	-	1	LS	$270,000	$270,000	$81,000	**$351,000**
A28	Retractable Flood Gate - Hwy 84	-	120	-	-	1	LS	$756,000	$756,000	$226,800	**$982,800**
A29	Concrete Flood Wall	400	-	-	30	444	CY	$800	$355,600	$106,700	**$462,300**
A30	Railroad Flood Gate	-	-	-	-	1	EA	$93,150	$93,200	$28,000	**$121,200**
A31	Traffic Control	-	-	-	-	1	LS	$50,000	$50,000	$15,000	**$65,000**
A32	Hydroseed - Section A	1,700	110	-	-	4	AC	$3,000	$12,900	$3,900	**$16,800**
A33	Hydroseed - Section B North	5,590	134	-	-	17	AC	$3,000	$51,600	$15,500	**$67,100**
A34	Hydroseed - Section B South	4,300	136	-	-	13	AC	$3,000	$40,300	$12,100	**$52,400**
A35	Hydroseed - Section D	3,960	97	-	-	9	AC	$3,000	$26,500	$8,000	**$34,500**
A36	Extend Ravenswood Pump Station	100	100	6	600	2,222	CY	$800	$1,777,800	$533,400	**$2,311,200**
A37	Property Acquisition	13,760	130			41.1	AC	$0	$0	$0	**$0**
								Total	**$30,428,700**	**$9,130,300**	**$39,559,000**

Option 4 - Levee Around Highway 84 and Pond SF2 w/ Floodgate

Line Item	Bid Item	Length (ft)	Width (ft)	Depth (ft)	X-SEC AREA (ft^2)	Quantity	Unit	Unit Price	Subtotal Price	Contingency (30%)	Total Price
A1	Mobilization/Demobilization	-	-	-	-	1	LS	$1,534,100	$1,534,100	$460,300	**$1,994,400**
A2	Erosion Control	-	-	-	-	1	LS	$391,900	$391,900	$117,600	**$509,500**
A3	Clearing and Grubbing - Section A	1,700	106	-	-	4	AC	$5,000	$20,700	$6,300	**$27,000**
A4	Clearing and Grubbing - Section B North	7,370	121	-	-	20	AC	$5,000	$102,400	$30,800	**$133,200**
A5	Clearing and Grubbing - Section B South	1,910	128	-	-	6	AC	$5,000	$28,100	$8,500	**$36,600**
A6	Clearing and Grubbing - Section C	5,088	138	-	-	16	AC	$5,000	$80,600	$24,200	**$104,800**
A7	Stripping - Section A	1,700	86	0.5	43	2,707	CY	$20	$54,200	$16,300	**$70,500**
A8	Stripping - Section B North	7,370	101	0.5	51	13,785	CY	$20	$275,700	$82,800	**$358,500**
A9	Stripping - Section B South	1,910	108	0.5	54	3,820	CY	$20	$76,400	$23,000	**$99,400**
A10	Stripping - Section C	5,088	118	0.5	59	11,118	CY	$20	$222,400	$66,800	**$289,200**
A11	Demolition - Remove AC Bike Path	1,050	10	-	-	1,167	SY	$12	$14,000	$4,200	**$18,200**
A12	Excavation for Floodwall	760	-	-	40	1,126	CY	$30	$33,800	$10,200	**$44,000**
A13	Excavation - Section A	1,700	-	-	381	23,989	CY	$20	$479,800	$144,000	**$623,800**
A14	Excavation - Section B North	7,370	-	-	454	123,925	CY	$20	$2,478,600	$743,600	**$3,222,200**
A15	Excavation - Section B South	1,910	-	-	362	25,608	CY	$20	$512,200	$153,700	**$665,900**
A16	Excavation - Section C	5,088	-	-	473	89,134	CY	$20	$1,782,700	$534,900	**$2,317,600**
A17	Geogrid Reinforcement - Section A	1,700	86	-	-	16,244	SY	$6	$97,500	$29,300	**$126,800**
A18	Geogrid Reinforcement - Section B North	7,370	100	-	-	81,889	SY	$6	$491,400	$147,500	**$638,900**
A19	Geogrid Reinforcement - Section B South	1,910	108	-	-	22,920	SY	$6	$137,600	$41,300	**$178,900**
A20	Geogrid Reinforcement - Section C	5,088	116	-	-	65,579	SY	$6	$393,500	$118,100	**$511,600**
A21	Levee Embankment Fill - Section A	1,700	-	-	1,151	72,470	CY	$25	$1,811,800	$543,600	**$2,355,400**
A22	Levee Embankment Fill - Section B North	7,370	-	-	1,488	406,169	CY	$25	$10,154,300	$3,046,300	**$13,200,600**
A23	Levee Embankment Fill - Section B South	1,910	-	-	1,532	108,375	CY	$25	$2,709,400	$812,900	**$3,522,300**
A24	Levee Embankment Fill - Section C	5,088	-	-	1,563	294,539	CY	$25	$7,363,500	$2,209,100	**$9,572,600**
A25	Aggregate Surface	17,475	20	0.5	10	6,472	CY	$82	$530,800	$159,300	**$690,100**
A26	Floodwall	760			30	844	CY	$800	$675,600	$202,700	**$878,300**
A27	Bike Path - AC Pavement	1,050	20	0.5	10	389	CY	$266	$103,400	$31,100	**$134,500**
A28	Traffic Control	-	-	-	-	1	LS	$50,000	$50,000	$15,000	**$65,000**
A29	Northern Tide Gate - 5 Gates	-	-	-	-	1	EA	$3,000,000	$3,000,000	$900,000	**$3,900,000**
A30	Southern Tide Gate - 6 Gates	-	-	-	-	1	EA	$4,000,000	$4,000,000	$1,200,000	**$5,200,000**
A31	Ravenswood Pump Station Outfall	-	-	-	-	1	EA	$1,500,000	$1,500,000	$450,000	**$1,950,000**
A32	Railroad Flood Gate	-	-	-	-	1	EA	$93,150	$93,200	$28,000	**$121,200**
A33	Hydroseed - Section A	1,700	110			4	AC	$3,000	$12,900	$3,900	**$16,800**
A34	Hydroseed - Section B North	7,370	134			23	AC	$3,000	$68,100	$20,500	**$88,600**
A35	Hydroseed - Section B South	1,910	136			6	AC	$3,000	$17,900	$5,400	**$23,300**
A36	Hydroseed - Section C	5,088	142	-	-	17	AC	$3,000	$49,800	$15,000	**$64,800**
A37	Property Acquisition	#REF!	123			#REF!	AC	$0	#REF!	#REF!	**#REF!**
								Total	**#REF!**	**#REF!**	**#REF!**

Job No.	222952 - 28	No.

HDR Engineering, Inc.

Project	SAFER BAY	Computed	LJ	September-16
Subject	SAFER BAY Feasibilty Cost Analysis	Checked	RET	September-16

REACH 7

Option 2

Line Item	Bid Item	Length (ft)	Width (ft)	Depth (ft)	X-SEC AREA (ft^2)	Quantity	Unit	Unit Price	Subtotal Price	Contingency (30%)	Total Price
A1	Mobilization/Demobilization	-	-	-	-	1	LS	$567,400	$567,400	$170,300	**$737,700**
A2	Erosion Control	-	-	-	-	1	LS	$113,500	$113,500	$34,100	**$147,600**
A3	Clearing and Grubbing	4,270	94	-	-	9.2	AC	$5,000	$46,100	$13,900	**$60,000**
A4	Stripping	4,270	74	0.5	37	5,851	CY	$20	$117,100	$35,200	**$152,300**
A5	Excavation	4,270			213	33,686	CY	$20	$673,800	$202,200	**$876,000**
A6	Demolition - Remove AC Bike Path	1,240	10	-	-	1,378	SY	$12	$16,600	$5,000	**$21,600**
A7	Levee Embankment Fill	4,270	-	-	636	100,582	CY	$25	$2,514,600	$754,400	**$3,269,000**
A8	AB Surface Course	4,270	20	0.5	10	1,581	CY	$82	$129,700	$39,000	**$168,700**
A9	Water Control Structure - 4 Gates	-	-	-	-	3	EA	$2,500,000	$7,500,000	$2,250,000	**$9,750,000**
A10	Retractable Flood Gate - Bay Road	-	-	-	-	1	EA	$270,000	$270,000	$81,000	**$351,000**
A11	Traffic Control	-	-	-	-	1	LS	$50,000	$50,000	$15,000	**$65,000**
A12	Hydroseed	4,270	96	-	-	9	AC	$3,000	$28,300	$8,500	**$36,800**
A13	Property Acquisition	4,270	94			9.2	AC	$0	$0	$0	**$0**
								Total	**$12,027,100**	**$3,608,600**	**$15,635,700**

Job No.	222952 - 28	No.

HDR Engineering, Inc.

Project	SAFER BAY	Computed	LJ	September-16
Subject	SAFER BAY Feasibilty Cost Analysis	Checked	RET	September-16
REACH 8				

OPTION 2

Line Item	Bid Item	Length (ft)	Width (ft)	Depth (ft)	X-SEC AREA (ft^2)	Quantity	Unit	Unit Price	Subtotal Price	Contingency (30%)	Total Price
A1	Mobilization/Demobilization	-	-	-	-	1	LS	$192,300	$192,300	$57,700	**$250,000**
A2	Erosion Control	-	-	-	-	1	LS	$38,500	$38,500	$11,600	**$50,100**
A3	Tree Removal	-	-	-	-	3	EA	$1,200	$3,600	$1,100	**$4,700**
A4	Clearing and Grubbing	2,160	96	-	-	5	AC	$5,000	$23,900	$7,200	**$31,100**
A5	Stripping	2,160	76	0.5	38.0	3,040	CY	$20	$60,800	$18,300	**$79,100**
A6	Demolition - Remove AC Bike Path	280	10	-	-	311	SY	$12	$3,800	$1,200	**$5,000**
A7	Excavation	2,160			378	30,240	CY	$20	$604,800	$181,500	**$786,300**
A8	Levee Embankment Fill	2,160	-	-	710.0	56,800	CY	$25	$1,420,000	$426,000	**$1,846,000**
A9	Asphalt Concrete Pavement	2,160	20	0.5	10.0	800	CY	$266	$212,600	$63,800	**$276,400**
A10	Water Control Structure - 2 Gates	-	-	-	-	1	EA	$1,500,000	$1,500,000	$450,000	**$1,950,000**
A11	Hydroseeding	2,160	99	-	-	5	AC	$3,000	$14,800	$4,500	**$19,300**
A12	Property Acquistion	2,160	96	-	-	5	AC	$0	$0	$0	**$0**

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HDR Engineering, Inc.

Project	SAFER BAY	Computed	LJ	September-16
Subject	SAFER BAY Feasibilty Cost Analysis	Checked	RET	September-16

REACH 9

OPTION 1

Line Item	Bid Item	Length (ft)	Width (ft)	Depth (ft)	X-SEC AREA (ft^2)	Quantity	Unit	Unit Price	Subtotal Price	Contingency (30%)	Total Price
A1	Mobilization/Demobilization	-	-	-	-	1	LS	$124,600	$124,600	$37,400	**$162,000**
A2	Erosion Control	-	-	-	-	1	LS	$25,000	$25,000	$7,500	**$32,500**
A3	Clearing and Grubbing	2,800	117	-	-	8	AC	$5,000	$37,700	$11,400	**$49,100**
A4	Stripping	2,800	97	0.5	48.5	5,030	CY	$20	$100,600	$30,200	**$130,800**
A5	Demolition - AC Bike Path	2,800	10	-	-	3,111.1	SY	$12	$37,400	$11,300	**$48,700**
A6	Excavation	2,800			199	20,637	CY	$20	$412,800	$123,900	**$536,700**
A7	Levee Embankment Fill	2,800	-	-	619.0	64,193	CY	$25	$1,604,900	$481,500	**$2,086,400**
A8	Asphalt Concrete Pavement	2,800	20	0.5	10.0	1,037	CY	$266	$275,500	$82,700	**$358,200**
A9	Hydroseeding	2,800	119	-	-	8	AC	$3,000	$23,000	$6,900	**$29,900**
A10	Property Acquisition	2,800	117	-	-	8	AC	$0	$0	$0	**$0**
								Total	**$2,641,500**	**$792,800**	**$3,434,300**