Geotechnical Investigation

GEOTECHNICAL INVESTIGATION

RESTORE ERODED AND DIKED MARSH
TISCORNIA MARSH HABITAT RESTORATION
SAN RAFAEL, CALIFORNIA

Project No. 923.01
January 14, 2021

Prepared by

Hultgren – Tillis Engineers

A California Corporation
Specializing in Geotechnical Engineering

Hultgren-Tillis Engineers

January 14, 2021
Project No. 923.01

Environmental Science Associates
180 Grand Avenue, Suite 1050
Oakland, California 94612

Attention: Mr. Dane Behrens

Geotechnical Investigation
Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Dear Mr. Behrens:

We performed a geotechnical investigation for the proposed Restore Eroded and Diked Marsh alternative as part of the Tiscornia Marsh Habitat Restoration and Sea Level Rise Adaptation project in San Rafael, California in accordance with the Subcontractor Agreement dated October 28, 2019. The results of the investigation are presented in the attached report.

It was a pleasure working with you on this project. If you have any questions, please call.

Sincerely,

Hultgren – Tillis Engineers

Callan J. Yu
Geotechnical Engineer

R. Kevin Tillis
Geotechnical Engineer

CJY:RKT:lm:la

cc: Ann Borgonovo, Environmental Science Associates (via email)

File Name. 92301R01 Levee

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I. INTRODUCTION

This report presents the results of our geotechnical investigation for the proposed Restore Eroded and Diked Marsh alternative as part of the Tiscornia Marsh Habitat Restoration and Sea Level Rise Adaptation project in San Rafael, California. The project is located on the south bank of the San Rafael Creek adjacent to Pickleweed Park. A vicinity map showing the location of the site is presented on Plate 1. The site is shown on the Site Plan, Plate 2.

The project elements consist of tidal restoration of existing upland landside areas and redeveloping former tidal bayside marsh areas.

The upland landside area habitat improvements include constructing a new setback ecotone levee within the existing 4 to 8 acres diked marsh and rehabilitating the existing levees with habitat transition slopes. The new setback levee is approximately 600-feet-long and located near the northern edge of the soccer field. The new setback levee will be about 7 feet tall and include an ecotone slope. The existing levee rehabilitation includes raising and offsetting the levee crest. The existing levee raising extents are about 550 feet long and located east of the soccer field. The offset levee alignment extents are about 450 feet long and adjacent to Canal Street. Borrow material for levee fill will be imported to the site.

The existing tidal habitat marsh has experienced considerable erosion along its bayward edge, retreating as much as 200 feet and losing approximately 3 acres over the past 30 years. The tidal bayside marsh area habitat improvements include expanding the previously eroded tidal marsh and constructing a coarse beach and rock jetty. The project will restore approximately 10 to 15 acres of tidal marsh habitat to historic conditions. The eroded tidal marsh area will be restored to previous elevations by placing dredged fill. The coarse beach and rock jetty will protect the dredged fill from erosion.

Topographic data provided by Environmental Science Associates (ESA) is based on the North American Vertical Datum of 1988 (NAVD88). Unless otherwise specifically noted, all elevations in this report refer to the NAVD88.

Our scope of services was outlined in the Subcontractor Agreement dated October 28, 2019. Our services consisted of conducting a geotechnical investigation that included subsurface exploration for the proposed levee alignment, laboratory testing, and developing conclusions and recommendations regarding geotechnical aspects of the project. The results of our geotechnical investigation are presented in this report. The tidal marsh restoration and dredged containment was initially proposed as a design-build project. The project is currently considering additional design for plans and specifications for contractor bid. We performed geotechnical engineering analyses using presumptive soil parameters and developed preliminary design and construction configurations. Additional geotechnical exploration will be needed for final design.

II. FIELD EXPLORATION AND LABORATORY TESTING

A. Field Exploration

We explored subsurface conditions along the existing levee and proposed new setback ecotone levee alignment by advancing Cone Penetration Tests (CPTs) and drilling borings. The approximate locations of the CPTs and borings are shown on the Site Plan, Plate 2.

1. Cone Penetration Tests

We explored subsurface conditions on November 1 and 4, 2019 by pushing five CPTs to depths of about 51.5 to 87.5 feet below existing grade. The CPTs were performed by our subcontractor with a 25-ton truck-mounted CPT rig. After pushing each CPT, the holes were backfilled with grout. The CPT logs are presented in Appendix A, Plates A-1 through A-5. Soil descriptions on the CPT logs are in general accordance with the CPT Soil Behavior Type Legend presented on Plate A-6. Pore pressure dissipation test results are presented in Plates A-7 and A-8.

2. Borings

We explored subsurface conditions on November 7 and November 8, 2019 by drilling six borings to depths of 17.5 to 51.5 feet below existing grade. Our subcontractor drilled the borings with truck-mounted hollow stem auger drilling equipment. We collected samples with a 2.5-inch outside diameter (OD), 1.9-inch inside diameter (ID) split barrel sampler or 3.0-inch OD, 2.87-inch ID Shelby tubes. The split barrel sampler was driven with a 140-pound hammer dropping approximately 30-inches for a penetration depth of up to 18-inches. The hammer utilized an automatic trip system. The Shelby tubes were advanced into the ground by hydraulic pressure.

We performed additional subsurface conditions on February 28, 2020 by conducting four hand auger borings to depths of 11 to 12.5 feet below existing grade. The hand auger borings were performed with a 3-inch diameter hydraulic powered hand auger tool. Our subcontractor collected samples with 3.0-inch OD, 2.87-inch ID Shelby tubes.

Our engineer logged the borings and recorded blow counts from driving the samplers. We recovered samples from the borings for further visual classification and for selecting materials for laboratory testing. Our engineer used a pocket penetrometer to evaluate unconfined compressive strength or a torvane to evaluate the soil shear strength. The drilled borings were backfilled with neat cement grout upon completion. The hand auger borings were backfilled with tamped spoils.

We converted the field penetration resistance obtained while driving the 2.5-inch O.D. sampler to equivalent SPT N-value blow counts by multiplying by 0.8 to account for sampler size and 1.25 to account for the hammer energy. The two corrections were offsetting, resulting in a 1.0 correction factor. Soil descriptions and equivalent SPT N-value blow counts are shown on the Logs of Borings, Appendix B, Plates B-1 through B-13.

The soil descriptions on the logs of boring are presented in general accordance with the Soil Classification System presented on Plate B-14, and laboratory test results are presented in the manner described by the Key to Test Data.

B. Laboratory Testing

The laboratory test results are presented in Appendix C. The laboratory tests consisted of moisture content, dry density, and organic content measurements, Atterberg limits, sieve analysis, unconsolidated-undrained triaxial shear strength (TxUU) tests, and consolidation tests. The moisture content, dry density and organic content measurements are presented on the individual boring logs. Atterberg limits test results are shown on Plate C-1. Sieve analysis test results are shown on Plate C-2. TxUU test results are presented on Plates C-3 through C-9. The consolidation and associated time-rate plots are presented on Plates C-10 through C-21.

A hand-held vane shear (Geonor Model H-60), commonly used to measure shear strength in situ, was used to measure shear strength within select Shelby tube samples. The vane shear data was modified by using a Bjerrum's vane correction factor (μ) of 0.85 in correlation with the plasticity index. The vane shear measurements are presented on the individual boring logs.

III. SITE CONDITIONS

A. Geologic Setting

The present configuration of the greater San Francisco Bay area, including the site, began to form after the last ice age when the sea level rose, flooding the valleys. Eroded fine-grained silt and clay particles were carried down streams to the bay, where they met the salty and relatively quiet bay waters. There they settled to form the highly plastic clay and silt estuary deposit known as San Francisco Bay Mud (Bay Mud). The accretion of Bay Mud formed mudflats and marshlands. The marshlands were diked and reclaimed in the early- to mid-1900s.

Blake, Graymer, Jones, and Soule published a geologic map for parts of Marin County in 2000. Selected portions of their geologic map and the descriptions of map units are presented on Plate 3. The geology map indicates artificial fill over marine and marsh deposits (Qmf) within the study area boundaries. The study area is mapped as artificial fill because it has been diked and reclaimed.

The geologic map by Goldman in 1969, presented on Plate 4, indicates that the site is underlain by Bay Mud extending to between Elevation -20 feet to Elevation -60 feet (Mean Lower Low Water (MLLW) datum). On Plate 4, we also presented our estimated contours of the bottom of Bay Mud within our project site. The map indicates that the Bay Mud is shallower to the north and becomes deeper to the south. Bay Mud is typically normally-consolidated to slightly over-consolidated, weak and highly compressible soil. Bay Mud typically exhibits low permeability and low shear strength. Bay Mud is typically underlain by stronger and less compressible alluvial soils.

The predominant seismic hazard for this site is strong groundshaking resulting from earthquakes. The improvements should be designed to accommodate such groundshaking in accordance with existing codes. No known active faults pass through the site and we conclude that the risk of fault rupture is low. The nearest active faults are the Hayward fault located about 7.2 miles east of the site and the San Andreas fault located approximately 10.5 miles west of the site.

Soil liquefaction is the phenomenon in which a loose to medium dense saturated granular soil undergoes reduction of internal strength as a result of increased pore water pressure generated by shear strains within the soil mass. This behavior is most commonly induced by strong ground shaking associated with earthquakes. Soil conditions consist predominately of medium dense to dense sand fill underlain by Bay Mud. We judge that the potential for liquefaction and/or loss of strength is low.

B. Site History

We reviewed available historic shoreline surveys (t-sheets) by NOAA published in 1853, 1943, and 1979. The historic shoreline surveys are presented on Plates 5 through 7. We also reviewed available historic topographic maps published by USGS. The existing perimeter levees around the diked marsh and soccer field were likely built in the early- to mid-1900s. The perimeter levee was then extended along the shoreline of San Rafael Creek to San Pablo Bay in the 1960s to accommodate further development. The levees were likely constructed by excavating Bay Mud from the adjacent land, waterways or ditches. The tidal marshplain located east of the soccer field has been eroding at a rate up to 4 to 5 feet per year for the last several decades.

C. Surface Conditions

1. Upland Landside Area

a. New Setback Ecotone Levee

The setback ecotone levee alignment will extend along the approximate 600-foot-long northern edge of the soccer field and within the existing diked marsh. The LIDAR topographic survey data from 2019 indicates that the ground surface of the soccer field is relatively flat and generally varies from Elevation +7 feet to Elevation +8 feet. A small berm is located along the northern edge of the soccer field. The ground surface along the northern edge of the soccer field and berm varies from Elevation +8 feet to Elevation +10 feet. The diked marsh, north of the soccer field, is relatively flat, generally at Elevation +7 feet. The soccer field is covered predominately by grass. The diked marsh is covered predominately by low brush or other vegetation.

b. Existing Perimeter Levee

The rehabilitation of the existing levee includes the approximate 550-foot long levee located adjacent and east of the soccer field and the 450-foot-long levee located adjacent and north of Canal Street. The LIDAR topographic survey indicates that the top of the existing levee crest east of the soccer field varies from Elevation +11 feet to Elevation +12 feet. The top of the existing levee crest north of Canal Street varies from Elevation +10 feet to Elevation +11 feet. The levee crest generally ranges from about 10 to 15 feet wide. The height of the levee crest ranges from one to 3 feet above the landside interior. The levee landside toe is near Elevation +8 feet. The levee slopes are generally inclined 2.5H:1V (horizontal to vertical) or flatter on both the landside and waterside. The levee waterside toe adjacent to the tidal marsh is generally at Elevation +6 feet.

The levee crest is covered with asphalt concrete pavement where the levee is adjacent to the soccer field. The levee crest adjacent to Canal Street is covered with gravel. The levee landside toe adjacent to Canal Street was previously a playground area and is currently covered with sand. Some trees and brush exist along the landside toe of the levee.

2. Tidal Marsh Area

The topographic and bathymetric data indicate that the tidal marshplain ranges from about 150 to 500 feet wide and varies from Elevation +5.5 feet to Elevation +6.5 feet. Brush and low-lying vegetation typically covers the marshplain areas. The marshplain areas are generally near or above daily tide water but can be inundated during high tides and wind generated waves. The typical outboard edge of the marshplain has a steep, nearly vertical scarp about 3 to 4 feet in height. The scarp is the result of the active erosion of the marsh. The edge of the marshplain transitions to the mudflat. The mudflat is generally at Elevation +2 feet and slopes down gently to Elevation +1 foot toward the east. The mudflat areas are generally inundated with bay water at tide levels higher than mean sea level.

D. Subsurface Conditions

1. Upland Landside Area

We subdivided the subsurface conditions encountered during our field exploration into three strata based on their engineering properties: Existing Fill, Bay Mud, and Alluvium. These layers are described further below.

a. Existing Fill

The existing fill is present along the planned levee alignment and generally consists of mixtures of silts and sands with occasional gravels. The silt fill is generally stiff and the sand fill is generally medium dense to dense. The fill was encountered in our borings and CPTs to depths of 2 to 9 feet below existing grade. Boring 5 encountered gravelly clay fill beneath the silt and sand fill. The fill extended to the depth explored of 17.5 feet.

b. Bay Mud

Bay Mud underlies the fill along the planned levee alignment. The upper portions of Bay Mud underlying existing fill is likely fill placed during initial construction of the levee but is indistinct from the native Bay Mud. Bay Mud also blankets the diked marsh interior. Within the diked marsh interior, the upper several feet is dryer due to desiccation, creating a medium stiff to stiff surficial layer. Beneath the crust, the Bay Mud is typically normally-consolidated to slightly over-consolidated, weak and highly compressible fat clay. The Bay Mud typically ranges from very soft to medium stiff. The strength of Bay Mud generally increases with depth. Atterberg limits performed within the Bay Mud indicate the soil has liquid limits ranging between 56 to 95 and plasticity indices between 28 to 56. The base of the Bay Mud extends to depths ranging from 44 to 64 feet below grade at the borings and CPTs locations. The depths correspond to Elevation -35 feet to Elevation -53 feet. The base of the Bay Mud is typically shallower to the northwest and deeper to the southeast. The base of the Bay Mud at the exploration locations appear to be consistent with the geologic mapping (Goldman 1969) shown on Plate 4.

c. Alluvium

Alluvium underlies Bay Mud. The alluvial soils generally consist of silts and clays. The alluvial silt and clays are stiff to very stiff. The alluvium extends to the maximum depth explored of about 87 feet.

2. Tidal Marsh Area

We did not perform geotechnical exploration within the tidal marsh areas. Review of geologic maps indicate that Bay Mud blankets the tidal marsh area. The base of the Bay Mud likely varies to depths ranging from 20 to 60 feet below existing grade. The base of the Bay Mud is likely shallower to the north and deeper to the south. The strength of the Bay Mud likely increases with depth. Alluvial soils are expected to underly the Bay Mud.

We subdivided the footprint of the tidal marsh into two areas based on their engineering properties: Eroded Marsh Area and Virgin Marsh Area. These areas are described further below.

a. Eroded Marsh Area

The eroded marsh areas are underlain by Bay Mud. The ground surface was previously about 4 feet higher than existing grade, resulting in a slightly over-consolidated, but still weak and highly compressible clay.

b. Virgin Marsh Area

The virgin marsh areas are mudflat areas that have not been previously loaded and are located beyond the historic limits of the marsh. The Bay Mud is likely normally-consolidated, and very weak and highly compressible. The surface of the Bay Mud will be composed of recent sediments that are also very weak and very compressible.

E. Groundwater

1. Upland Landside Area

The groundwater levels within the site are primarily controlled by evapo-transpiration and drainage. During exploration, water was noted at 12 feet below ground surface in Boring 3. Water was encountered in Hand Auger Borings 7 through 10 at depths of 4- to 6-inches below existing grade. Water was not measured in Borings 1, 2, 4, 5, and 6 because they were obscured due to hollow stem auger drilling. The borings were backfilled immediately, and stabilized water levels were not obtained.

The above descriptions of soil conditions summarize observations at the time of the investigations. Conditions are expected to vary across the site, with time, and depend on several factors including changes in moisture content resulting from seasonal precipitation, drainage operations, and tides.

2. Tidal Marsh Area

Within mudflat areas, daily water depths can vary from about 0 to 4 feet. The typical daily tidal range at the site varies from about Elevation +0.2 feet to Elevation +6.1

feet. The mean tide level at the site is at about Elevation +3.3 feet. The FEMA 100-year base flood elevation along the San Rafael shoreline is at about Elevation +9.5 feet.

IV. DISCUSSION AND CONCLUSIONS

A. General

Geotechnical concerns for this project include the presence of Bay Mud, the presence of sand fill along the proposed levee alignment, and potential impacts from fill placement. Bay Mud blankets the entire project area. The Bay Mud is weak and highly compressible. Considerable settlement will occur under the weight of new fills. In addition, Bay Mud is weak and has limited capacity to support new loads. The issues described above and other considerations for design and construction of the project are discussed further below.

B. Upland Landside Area

1. Levee Design

The new and rehabilitated levees will retain flood water and protect the urban areas from inundation. The levee should be designed to prevent overtopping during flood stages. Levee overtopping could cause erosion damage and increases the risk of breach. The levee will include 3 feet of freeboard above the design water surface and be further raised to accommodate future estimated settlement.

The levee crest design elevation was provided by ESA. The design water surface is at Elevation +10 feet (the approximate 100-year flood). The levee crest includes 3 feet of freeboard above the design water surface corresponding to a minimum levee crest height of Elevation +13 feet. The levee crest will have a 12-foot wide crest with side slopes inclined at 3H:1V. The new setback levee and offset levee adjacent to Canal Street will include a waterside ecotone slope inclined at 10H:1V or flatter. The ecotone slope will extend up to at least Elevation +9 feet or at least 3 feet above Mean Higher High Water (MHHW).

We evaluated the levees for settlement, slope stability, seismic vulnerability, and seepage. We chose two cross sections for analysis. One cross section is located within the setback ecotone levee and the second cross section is located within the offset levee. An overview of the analysis for the levee is presented in the report body with more details on the design parameters, sections and analyses provided in the appendices.

2. Settlement Analyses

The new fills will cause the Bay Mud to consolidate and the levees will settle. Considerable settlement will occur under the loading of the new levee embankment fill and the settlement will continue for the next several decades. The levee will need to be constructed higher than the minimum grade initially to accommodate settlement. The intent is to raise the levee to a sufficient height initially to accommodate the estimated settlement.

The actual settlement will vary from our estimates both in magnitude and in the time for settlement to occur. The process of soil consolidation occurs over time as water is pushed out of the Bay Mud. The method to estimate settlement and the rate that the water flows from the soil are not precise. If the levee settles more than the overbuild provision it will need to be raised in the future to maintain the 3 feet of freeboard.

We performed consolidation analyses to estimate the magnitude of settlement due to the weight of new fill along several different levee reaches. We used data obtained from the borings and laboratory testing to develop material properties. A more detailed discussion and details of the settlement analyses and soil parameters are presented in Appendix D. The results of the settlement estimates at the centerline, levee toe, and at 25 feet from the levee toe are shown in Tables 1 and 2, below.

Table 1: Settlement Estimates for Setback Ecotone Levee

Thickness of New Fill (feet)	Settlement at Centerline (feet)	Settlement at Levee Toe (feet)	Settlement 25 feet from Levee Toe (feet)
2	0.9	0.6	<0.10
4	1.6	0.8	0.15
6	2.2	1.0	0.20
8	2.5	1.1	0.23
10	2.8	1.2	0.25

Table 2: Settlement Estimates for Offset Levee

Thickness of New Fill (feet)	Settlement at Centerline (feet)	Settlement at Levee Toe (feet)	Settlement 25 feet from Levee Toe (feet)
2	0.8	0.4	<0.10
4	1.4	0.6	0.15
6	1.8	0.7	0.18
8	2.1	0.8	0.20

For the levee raising adjacent to the soccer field, where approximately 2 to 3 feet thick of fill is anticipated to raise the crest, we estimate that placement of every 1-foot of fill will cause about 3-inches of settlement.

For the new setback and offset levees, the rate of settlement is expected to continue for about 20 years assuming double drainage conditions. We estimate that about half the settlement will occur over the next 2 to 5 years. The rate of settlement is dependent on several factors including the permeability, compressibility and thickness of the Bay Mud soils. The magnitude and time for settlement to occur can vary from our estimates.

3. Slope Stability Analyses

We performed slope stability analyses for the levee configurations. We developed soil parameters using data from borings and laboratory test results, along with our assessment of undrained shear strengths and effective stress. A more detailed discussion and details of the slope stability analysis and results are presented in Appendix E.

The results indicate that the factors of safety for the end of construction configurations are at least 1.5 for the landside and waterside slopes. The results indicate that the levee configurations can be constructed in one stage according to the typical details provided on Plates 8 and 9.

4. Seismic Deformation

We used a simplified procedure to evaluate seismic deformations of the levee embankment. The analysis suggests that these earthquake scenarios will result in small vertical deformations for the levee crest generally less than 4-inches. Some regrading of the levee embankment may be needed following a large earthquake. Further details and discussions of the seismic vulnerability analyses and results are presented in Appendix F.

5. Seepage Considerations

The levee embankment will be constructed using import materials predominately consisting of fine-grained, low permeability silt and clay. The levee foundation consists of variable fill including clay and sand over Bay Mud. Borings 3, 4, and 6 encountered surficial layers of sand to depths of 3 to 6 feet below existing grade. The sand may be deeper in some areas. The existing sand fill is a concern for seepage beneath the levee (underseepage).

We judge that along the footprint of the setback ecotone levee and offset levee, the underlying sand fill should be overexcavated and backfilled with compacted, low permeable clay.

In addition, the footprint of new setback ecotone levee will extend onto the existing diked marsh. The interface between the new levee fill and the foundation soils are a preferential seepage path. To disrupt preferential seepage paths, we conclude that the subgrade preparation should include a keyway constructed below the levee crest.

6. Levee Abutments

The new setback levee will tie into existing levees on the east and west. Seepage is a concern at the abutments. Where the new setback levee abuts the existing levees, the existing levees will have already settled under the weight of the existing levee fill. The new levee section will settle as new fill loads are placed. Differential settlement will occur due to unequal consolidation of Bay Mud in the abutment areas. Differential settlement can cause cracks to form within the compressing layer and the fill above. To reduce the risk of settlement-induced cracking and the associated seepage risk, flatter levee embankment slopes can be used in these transition areas. We understand that the abutment areas may be limited. Other alternatives include installing sheetpiles or cutoffs. The levee abutments will need to be monitored and if cracking or seepage develops, then remedial work will be needed. In addition, the new fill should be benched into the existing levee.

7. Erosion Protection

The project does not plan to initially armor the waterside slopes with riprap. The design of the erosion protection is not within our scope. The waterside of the setback levee will consist of clay. The existing perimeter levee waterside slopes are not armored. Riprap facing is a traditional scheme for erosion protection when erosion is a concern. Riprap can be added in the future if needed. As an alternative, riprap can be buried within the ecotone slope. The buried riprap would provide a redundancy for erosion protection in the design.

8. Interior Drainage

The drainage pattern changes due to the new setback levee should be assessed. The current drainage typically flows off from the soccer field property to the low-lying marsh to the north. We understand that gravity drainage structures are not anticipated.

C. Tidal Marsh Area

1. Function and Design

The existing tidal habitat marsh has experienced considerable erosion along its bayward edge, resulting in significant loss of habitat. ESA developed conceptual alternatives for marsh restoration. The selected project elements include an expanded tidal marsh through placement of dredge materials to raise site grades, a coarse beach along the eastern marsh edge, and a rock jetty along the San Rafael Canal to the north. The function of the expanded marsh is to increase and enhance tidal marsh habitat at a marshplain height of about Elevation +6 feet. The intent of the coarse beach is to protect the expanded marsh from erosion. The purpose of the rock jetty is to trap and accumulate sediment within the proposed expanded tidal marsh and to reduce erosion of the coarse beach.

The footprint for the tidal marsh restoration, including the location of the coarse beach and rock jetty, have not been determined. The preliminary plan is to restore to at least the historic footprint of the eroded marsh with dredged fill. We understand the design team is also evaluating alternatives for an expanded marsh into the virgin mudflat areas.

Design criteria for the coarse beach and rock jetty was provided by ESA. The coarse beach includes an 8-foot wide crest at Elevation +8 feet with a landside slope inclined 2H:1V and a waterside slope inclined 8H:1V. The rock jetty includes an 8-foot wide crest at Elevation +9 feet with both slopes inclined at 2H:1V. The landside of the coarse beach and rock jetty will be buttressed and partially buried by the dredge material.

We performed preliminary settlement and slope stability analyses for the construction of the coarse beach and rock jetty using presumptive soil parameters. The results should be considered preliminary. During final design, additional subsurface exploration and laboratory testing should be performed to characterize the subsurface conditions and engineering properties within the footprint of the expanded marsh.

2. Settlement Analyses

The marsh will settle as the Bay Mud consolidates from the weight of new fills. The minimum design coarse beach and rock jetty elevations can be maintained by overbuilding to accommodate the estimated consolidation settlement. We evaluated alternatives for restoring the marsh to the historic footprint (eroded marsh area) and restoring the marsh beyond the historic footprint (virgin marsh area). We performed consolidation analyses to estimate the magnitude of settlement due to the weight of new fill, including rock and dredged fill materials. The estimated settlement results for the thicknesses of new rock and new dredged fill materials are shown in Tables 3 and 4, below. As discussed previously, the actual settlement will vary from our estimates both in magnitude and in the time for settlement to occur. Further discussion and details of the settlement analyses are presented in Appendix D. While the coarse beach and rock jetty need to maintain a minimum height to limit overtopping, the elevation of the marsh and tolerances for settlement should be determined by the elevation range that is desirable for the type of vegetation.

Table 3: Settlement Estimates Within Eroded Marsh Areas

Thickness of New Fill (feet)	Rock Fill, 135 pcf* (feet)	Dredged Fill, 100 pcf (feet)
2	0.1	0.1
4	0.7	0.2
6	1.5	0.9
8	2.3	1.5
10	3.0	2.1
12	3.6	2.7

Table 4: Settlement Estimates Within Virgin Marsh Areas

Thickness of New Fill (feet)	Rock Fill, 135 pcf (feet)	Dredged Fill, 100 pcf (feet)
2	1.0	0.8
4	2.0	1.5
6	2.8	2.2
8	3.5	2.8
10	4.1	3.3
12	4.7	3.8

*pcf: pounds per cubic foot

The rate of settlement for the coarse beach and rock jetty is expected to continue for about 20 years assuming double drainage conditions. We estimate that about half the settlement will occur over the next 2 to 5 years. The rate of settlement is dependent on several factors including the permeability, compressibility and thickness of the Bay Mud soils. The magnitude and time for settlement to occur can vary from our estimates.

3. Slope Stability Analyses

We performed slope stability analyses for the coarse beach constructed on eroded marsh areas or on virgin marsh areas as well as the rock jetty constructed on the eroded marsh areas. We used presumptive soil parameters for slope stability analyses. Discussion and details of the slope stability analysis and results are presented in Appendix E.

The results indicate that the fill for the coarse beach and rock jetty will need to be placed in stages. We concluded that the coarse beach constructed on the eroded marsh areas will require two stages of rock placement. The coarse beach constructed on the virgin marsh areas will require at least three stages of placement. The third stage would require a waiting period of 10 years or more. The timing and sequencing for the third stage can be completed in final design if the project decides to construct over the virgin marsh. The rock jetty on the eroded marsh areas will require two stages of rock placement and stability berms will be needed to buttress the side slopes between stages of rock placement. We conclude that berms are needed to support the crest levels and provide a more reliable level of safety.

4. Seismic Deformation

A discussion of seismic vulnerability analyses and results are presented in Appendix F. The analysis suggests that these earthquake scenarios will result in small vertical deformations of about 3-inches or less for the rock berms on eroded marsh areas and about 8-inches or less for rock berms on virgin marsh areas. Some regrading of the rock berms may be needed following a large earthquake.

5. Mudwaves

The expanded marsh, rock berms, coarse beach, and rock jetty will be constructed on weak recent Bay Mud sediments in tidal areas. It is not unusual for the weight of the new fill to create a “mudwave” as the displaced sediments are heaved up in front of and/or to the sides of advancing fill. We anticipate that there is a high risk of creating mudwaves during fill placement in the tidal marsh area even where the factor of safety suggests that fill can be safely loaded on the Bay Mud. Thin lifts should be placed to reduce the risk of mudwaves.

6. Overtopping, Inundation and Erosion

The eastern shoreline has experienced considerable historic erosion. The expanded marshplain will also be inundated during high tides. The project aims to expand the marshplain and reduce this ongoing erosion and loss of tidal marsh by placing a coarse beach and rock jetty. The coarse beach and rock jetty will be constructed to stabilize the shoreline and reduce the effects of waves on the marsh. The coarse beach and rock jetty is less susceptible to erosion than the dredged fill material. The protection of the expanded tidal marsh depends on the coarse beach materials preventing additional erosion. As an additional protection, we suggest that the protection include a zone of larger rock riprap buried beneath the upstream edge of the coarse beach.

7. Staged Construction

We conclude that the restored marsh fills need to be placed in stages to limit stress on the Bay Mud. We have developed preliminary construction sequences for the coarse beach and rock jetty. The construction sequence for the coarse beach on the eroded marsh areas is presented on Plate 11. The construction sequence for the coarse beach on the virgin marsh areas is presented on Plate 12. The construction sequence for the rock jetty on eroded marsh areas is presented on Plate 13. The sequences are also described below.

a. Coarse Beach on the Eroded Marsh Areas

1. Place first stage of rock materials consisting of 5 feet maximum thickness of fill with side slopes inclined at 2H:1V or flatter on the landside and 8H:1V on the waterside.
2. Place landside buttress consisting of a 4.5 feet thickness of dredged fill materials (assumed 100 pcf) at least 50 feet wide with side slope inclined at 2H:1V or flatter.
3. Place second stage of rock materials consisting of 3 feet thickness of fill with side slopes inclined at 2H:1V or flatter on the landside and 8H:1V on the waterside.

b. Coarse Beach on the Virgin Marsh Areas

1. Place first stage of rock materials consisting of 3.5 feet maximum thickness of fill with side slopes inclined at 2H:1V or flatter on the landside and 8H:1V on the waterside.

2. Place landside buttress consisting of 6 feet thickness of dredged fill materials (assumed 100 pcf) at least 50 feet wide with side slope inclined at 10H:1V or flatter.
3. Place second stage of rock materials consisting of 5 feet thickness of fill with side slopes inclined at 2H:1V or flatter on the landside and 8H:1V on the waterside.
4. After a waiting period (10 years or more), place third stage of rock materials consisting of 2 feet thickness of fill with side slopes inclined at 2H:1V or flatter on the landside and 8H:1V on the waterside.

c. Rock Jetty on Eroded Marsh Areas

1. Place first stage of rock materials consisting of 5 feet maximum thickness of fill with side slopes inclined at 2H:1V or flatter on both the landside and waterside.

2a. Place landside buttress consisting of 4.5 feet thickness of dredged fill materials (assumed 100 pcf) at least 50 feet wide with side slopes inclined at 2H:1V or flatter.

2b. Place waterside rock berm buttress consisting of 3 feet thickness of fill (assumed 135 pcf) at least 30 feet wide with side slopes inclined at 2H:1V or flatter on the waterside.

3. Place second stage of rock materials consisting of 5 feet thickness of fill with side slopes inclined at 2H:1V or flatter.

8. Temporary Water Retention Structures

To place dredged fill, the marsh needs to be isolated from the bay. The design team is considering using bladder dams for retaining tidal water for isolating the marsh. Bladder dams are flexible water-filled, watertight tubes for temporary water barrier and dewatering purposes. The bladder dam should be designed for the lateral water forces and for uplift.

Sheetpiles could be used as an alternative to bladder dams for retaining water. The sheetpiles would likely require placement of rock as a buttress to retain the differential water head during high tides. To reduce the deformations due to induced settlement from placement of rock, the sheetpiles may need to penetrate the full thickness of the Bay Mud. For cost estimating purposes, average sheetpiles lengths of about 60 feet can be used.

9. Temporary Access Roads

Equipment will need to cross marsh areas for construction of the tidal marsh restoration. Temporary access roads are proposed for the project and will include crossing the existing vegetated marshplain areas and the eroded marsh areas in an east-west direction toward the coarse beach.

The subgrade may become unstable and subject to pumping under heavy equipment loads. The contractor should be prepared to stabilize the subgrade bottom and construct temporary haul roads. The actual design of the temporary haul road should come from the contractor as one of their submittals. We have developed a typical detail to assist during the design and to help with permitting. The typical detail includes geogrid and compacting a nominally 2 feet thick layer of fill over the geogrid. Typical details of the temporary access roads are presented on Plate 10.

D. General Grading Considerations

The project requires cuts and fills to create the various habitat zones and channels within the proposed expanded tidal marsh. The main near surface soil material present across the site is Bay Mud. Much of the grading will create habitat zones where engineered compacted fills are not required and criteria for placement is not provided in this report.

The groundwater is located at shallow depths and excavating within the site should consider the presence of groundwater. The near surface soils are relatively wet and moisture processing will be required prior to use of these materials as compacted fill.

E. Impacts on Utilities and Setback Distance

1. Upland Landside Area

In general, the further away from the new levee embankment or new fills, the less ground settlement will occur. As currently planned, the toe of the levee slopes will be at least 25 feet from the nearest overhead utility. At that distance, we estimate that the levee embankment will cause less than 3-inches total ground settlement.

The design team is evaluating alternatives for the western abutment of the setback levee. We understand that two sanitary sewer force mains and a storm drain are located within the vicinity of the western abutment. The force mains consist of a 16-inch and a 26-inch diameter HDPE pipelines. The storm drain consists of a 54-inch diameter corrugated metal pipe.

The weight of the new levee fill may cause settlement to the existing pipelines, depending on the depths of the pipeline. We performed consolidation analyses to estimate the magnitude of pipe settlement due to the weight of new fill. A more detailed discussion and details of the settlement analyses and soil parameters are presented in Appendix D.

The force mains are relatively deep and range from 30 to 45 feet below existing grade near the western abutment. For the level marsh area and a force main depth of 30 feet below existing grade, we estimate that new fill will cause the force main pipe to settle about 0.25 feet. For a force main depth of 40 feet below existing grade, we estimate that new fill will cause negligible settlement of the pipe. We judge that at these fill thickness and depths, the settlement impacts can be considered minor.

The storm drain is shallower and ranges from about 5 feet below existing grade along the level marsh area to about 8 feet below existing grade near the existing levee. The shallow storm drain could undergo significant settlement from the weight of the new fill if the levee is constructed directly over the pipe. For the level marsh area and a storm drain depth of 5 feet below existing grade, we estimate that 7 feet of new fill will cause the pipe to settle about 2.1 feet. At the existing levee, with the storm drain at a depth of 8 feet below existing grade, we estimate that 4 feet of new fill will cause about 0.9 feet of settlement. For other thicknesses of fill, these values can change in proportion to the fill thicknesses.

To reduce settlement impacts, the western levee abutment alignment can be setback from the storm drain and/or force main. The settlement estimates shown in Table 1 can be used to evaluate settlement based on offset distances. We judge that the toe of the new levee should be at least 25 feet from the storm drain if a minimal impact is required. The floodwall will nominally be about 3 feet tall.

2. Western Abutment

To avoid the storm drain, the levee needs to tie into the existing levee north of the setback levee. The existing levee is lower than the setback levee and needs to be raised about 3 feet. As an alternative to raising the levee, a short floodwall could be constructed. The floodwall could be construed with driven sheetpiles (possibly capped with concrete). For planning purposes, the sheetpiles should extend at least 15 feet below the existing levee crest. The design of the floodwall will need to consider overtopping. Water should not be allowed to flow over the floodwall to avoid erosion and loss of support.

3. Tidal Marsh Area

Two PG&E overhead electrical transmission towers are located within the footprint of the proposed expanded tidal marsh area. One tower is within the existing marshplain and we anticipate minor grading is needed within the vicinity. The other tower is within the footprint of the previously eroded marshplain. Within the footprint of the previously eroded marsh plain, we estimate that 4 feet of new dredged fill will cause about 3-inches of settlement. Survey hubs can be installed and monitored during and after construction to check horizontal or vertical movement during and after placing fill. During final design, we should review project plans to check the fill thicknesses adjacent to utilities.

F. Borrow Materials

1. Levee Fill

We understand that borrow materials will be imported for levee fill. The levee should be constructed using low permeability, fine-grained soils. The U.S. Army Corps of Engineers (USACE) has fill specifications for levees that require use of fill that is typically lean clays or plastic clayey sand. Typically, fill materials require at least 20 percent fines (passing the No. 200 sieve), a plasticity index of 8 or more and a liquid limit of no more than 50.

2. Tidal Marsh Area

Borrow materials for the tidal marsh area will consist of various materials including dredged fill material for the expanded marsh, mixtures of sand, gravel, cobbles, and rock for the coarse beach, and various rock sizes for the rock jetty. During final design, we should review the sources of import borrow materials.

V. RECOMMENDATIONS

A. Upland Landside Area

1. Typical Levee Design Configuration

The levee crest should be designed and maintained at or above the minimum design elevation (Elevation +13 feet). The new levees should consist of at least a 12-foot wide crest with side slopes inclined at 3H:1V or flatter.

The existing sand fill beneath the footprint of the levee embankment along the new setback and offset levees should be overexcavated and removed. The new setback ecotone levee should also include a keyway. The levee keyway should be centered on the levee centerline and should be 3 feet deep and 12 feet wide at the base. The existing sand fill and keyway should be replaced with low-permeable material meeting the requirements below for fill. The slopes should extend up the ground surface at 2H:1V. We recommend that the levee geometry for the new setback ecotone levee and new offset levee conform to the details and configuration presented on Plates 8 and 9, respectively. We recommend that the crest height for the levee segment east of the soccer field be constructed initially to Elevation +14 feet to accommodate some future settlement.

2. Earthwork

a. Site Preparation

The footprint of the levee should be cleared and grubbed of surface and subsurface deleterious matter including trees, brush, and other vegetation and debris designated for removal. The site should be stripped to sufficient depth to remove vegetation and soil containing roots. Tree roots greater than 1-inch in diameter should be removed. Stripped and grubbed materials should be removed from the site and should not be used as fill. The existing asphalt or gravel base trail should be removed from the existing levee crest prior to reworking the levee surface and placing fill.

If loose or soft materials are encountered, they should be excavated to expose firm soil and placed in accordance with the recommendations presented below. Debris and deleterious materials encountered during grading should be removed from the site.

b. Fill Materials

Fill for the levee should be a soil or soil/rock mixture free of deleterious matter and have no rocks or hard fragments greater than 6-inches in maximum dimension with less than 15 percent larger than 1-inch in maximum dimension. Fill material should have at least 20 percent fines passing the No. 200 sieve. Fill should have a plasticity index of 8 or more and a liquid limit below 50.

Aggregate base should meet the requirements for Caltrans Class 2 aggregate base.

Samples of fill material should be submitted to us for approval before importing to the site.

c. Compaction

Surfaces in areas to be filled should be scarified to a depth of at least 8-inches or the full depth of shrinkage cracks, whichever is deeper. Although not anticipated, if shrinkage cracks extend below 12-inches, some excavation in addition to scarifying will be required to adequately moisture condition and compact soils. The scarified soil should be moisture conditioned at least 3 percent over optimum moisture content and compacted to at least 90 percent relative compaction. ASTM test D-1557 should be used to establish the reference values for computing optimum moisture content and relative compaction.

Fill should be placed in lifts 8-inches or less in loose thickness and moisture conditioned to at least 3 percent above the optimum. Moisture conditioning should be performed prior to compacting. Each lift should be methodically compacted to at least 90 percent relative compaction. A sheepsfoot compactor or equivalent kneading compaction equipment should be used for compacting clay soils. Material that fails to meet the moisture or compaction criteria should be loosened by ripping or scarifying, moisture conditioned, and then recompacted. After compaction, fills should not be allowed to dry out. This may require periodic sprinkling. Compacted fill that has dried should be scarified, remoisture conditioned and recompacted prior to receiving additional fill. Fill should be placed on horizontal surfaces. The fill should be benched into existing fill to allow recompaction of some of the existing soil. The horizontal bench width into the existing slopes should not exceed 5 feet.

On the levee crest and ramps, the upper 6-inches of subgrade should be compacted to at least 95 percent relative compaction and rolled to provide a smooth, non-yielding surface. Subgrade soils should be proof-rolled before placing aggregate base. Proof-rolling should be performed with the heaviest available rubber-tired construction equipment and should be observed by the geotechnical engineer. Soft or pumping areas should be aerated or excavated and recompacted.

Aggregate base should be placed in thin lifts no greater than 6-inches in loose thickness and in a manner that avoids segregation, moisture conditioned as necessary, and compacted to at least 95 percent relative compaction. A smooth drum roller compactor or equivalent compaction equipment should be used to compact aggregate base.

d. Slopes

Fill slopes should be inclined at 3H:1V or flatter except as noted. Fill slopes should be constructed fat and trimmed back to expose well-compacted fill. Finished slopes should be trackwalked perpendicular to the slope face with a bulldozer after completion. The slopes should be hydroseeded to promote vegetation. Vegetation should be limited to grasses or other vegetation that can be mowed or disced to allow inspection of levee slopes. Trees, bushes, and brush should not be allowed within the footprint of the levee slopes.

e. Surface Drainage and Maintenance

Drainage off the levee should be by sheetflow. Ground surfaces should slope away from the levee crest and toe. Irregularities that may tend to concentrate drainage should be corrected to re-establish sheetflow. Ponding of surface water should not be allowed on the levee crest or toe.

B. Tidal Marsh Area

1. Typical Configuration Details

We have developed preliminary construction sequences for the dredged containment including for the coarse beach on eroded marsh areas, the coarse beach on virgin marsh areas, and the rock jetty on eroded marsh areas. The preliminary construction sequence for the coarse beach on eroded marsh areas is presented on Plate 11, the coarse beach on virgin marsh areas is presented on Plate 12, and the rock jetty on eroded marsh areas is presented on Plate 13. The construction sequences are based on limited geotechnical data and presumptive soil conditions. We recommend that additional geotechnical exploration and laboratory testing be performed to characterize the subsurface conditions. During final design, we should review the preliminary analysis results and revise the preliminary construction sequences, as necessary.

2. Earthwork

Coarse beach fill material should be placed in lifts 24-inches or less in loose thickness and trackwalked perpendicular to the slope face with a bulldozer or similar equipment.

Rock fill should be inclined 2H:1V or flatter. All large rocks should be placed to achieve 3-point bearing on the underlying rock layer. Rock fill should be locked into place by systemically tamping with the bucket of an excavator or similar equipment. Rearranging of individual pieces of rock may be needed. Rock placement should meet the criteria presented in Caltrans specifications.

SELECTED REFERENCES

SELECTED REFERENCES

Blake, M.C., Graymer, R.W., Jones, D.L., and Soule, Adam, 2000, Geologic map and map database of parts of Marin, San Francisco, Alameda, Contra Costa, and Sonoma Counties, California: U.S. Geological Survey, Miscellaneous Field Studies Map MF-2337, scale 1:75,000.

California Department of Water Resources, 2012. Urban Levee Design Criteria, May 2012.

Environmental Science Associates, 2018. Tiscornia Marsh Habitat Restoration and Sea Level Rise Adaptation Project, dated July 2018.

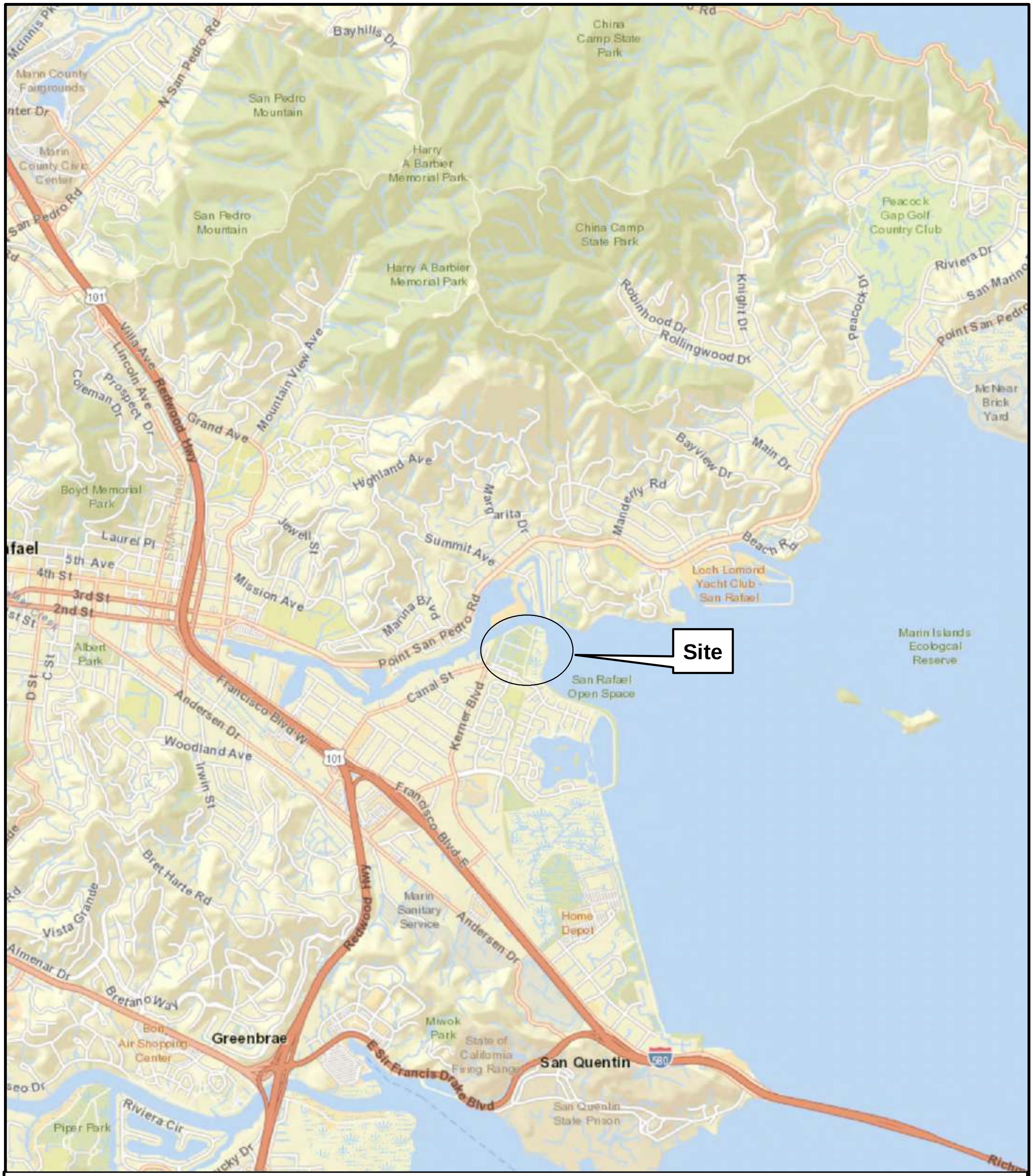
Goldman, H. B., 1969. Geologic and Engineering Aspects of San Francisco Bay Fill: California Division of Mines and Geology Special Report 97.

U.S. Geological Survey, 2020, The National Geologic Map Database available online at https://ngmdb.usgs.gov/. (Accessed April 1, 2020)

URS, 2015. Guidance Document for Geotechnical Analyses, Urban Levee Evaluations Project, Prepared for Department of Water Resources, Division of Flood Management, April 2015.

U.S. Army Corps of Engineers, 2000. Design and Construction of Levees, Engineer Manual No. 1110-2-1913, Department of the Army, U.S. Army Corps of Engineers, Washington D.C., dated April 30, 2000.

PLATES



N

0 3,000 feet

1 inch = 3,000 feet

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Vicinity Map

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. 1

Approximate Location of Boring

Approximate Location of CPT

N

SCALE

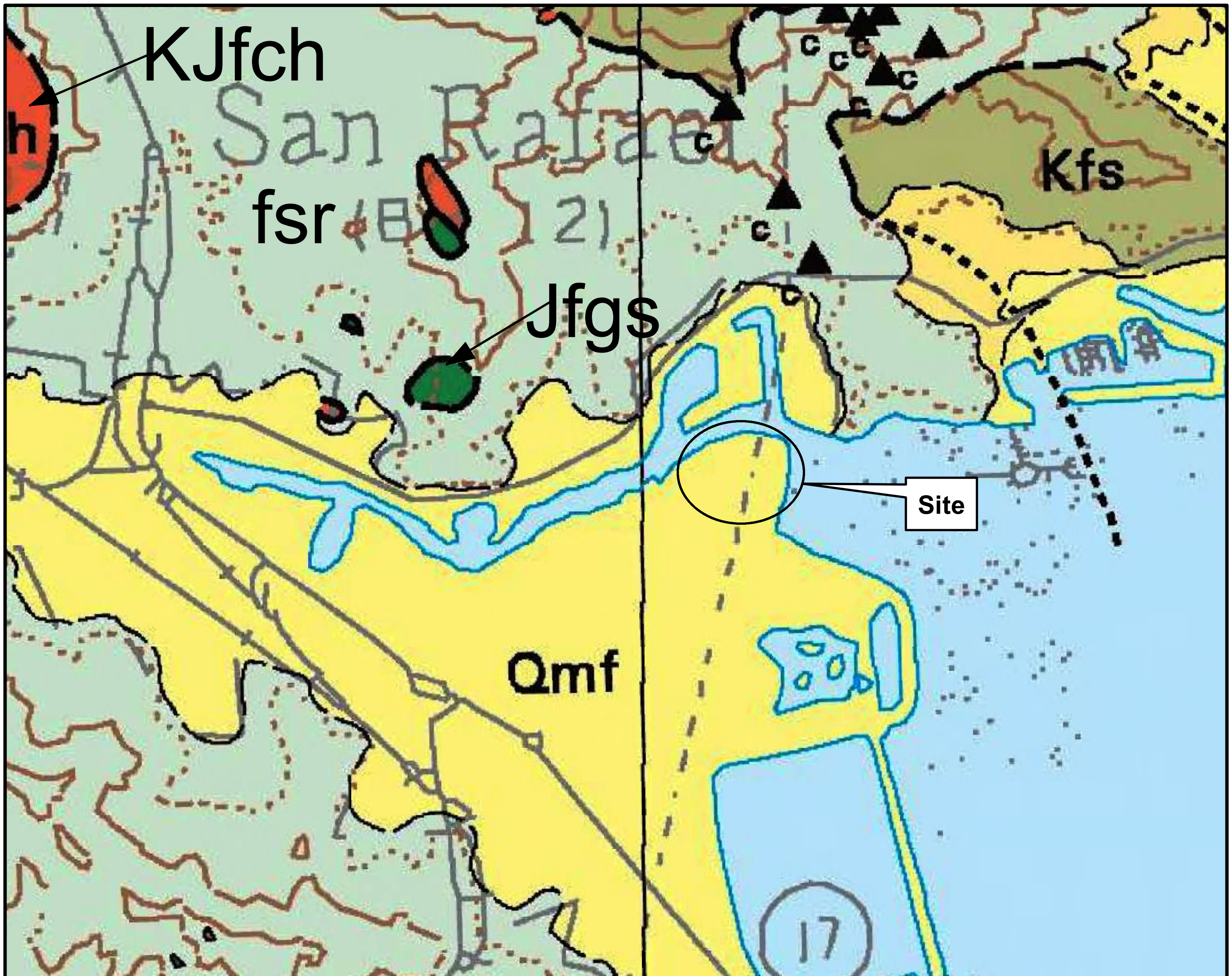
0 200 feet

1 inch = 200 feet

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Site Plan

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. 2



Legend

Qmf	Artificial fill over marine and marsh deposits (Quaternary)
Kfs	Sandstone and shale (Cretaceous)
fsr	Melange
KJfch	Chert (Createaceous and Jurassic)
Jfgs	Greenstone (Jurassic)

SCALE 0 2,000 feet

1 inch = 2,000 feet

N

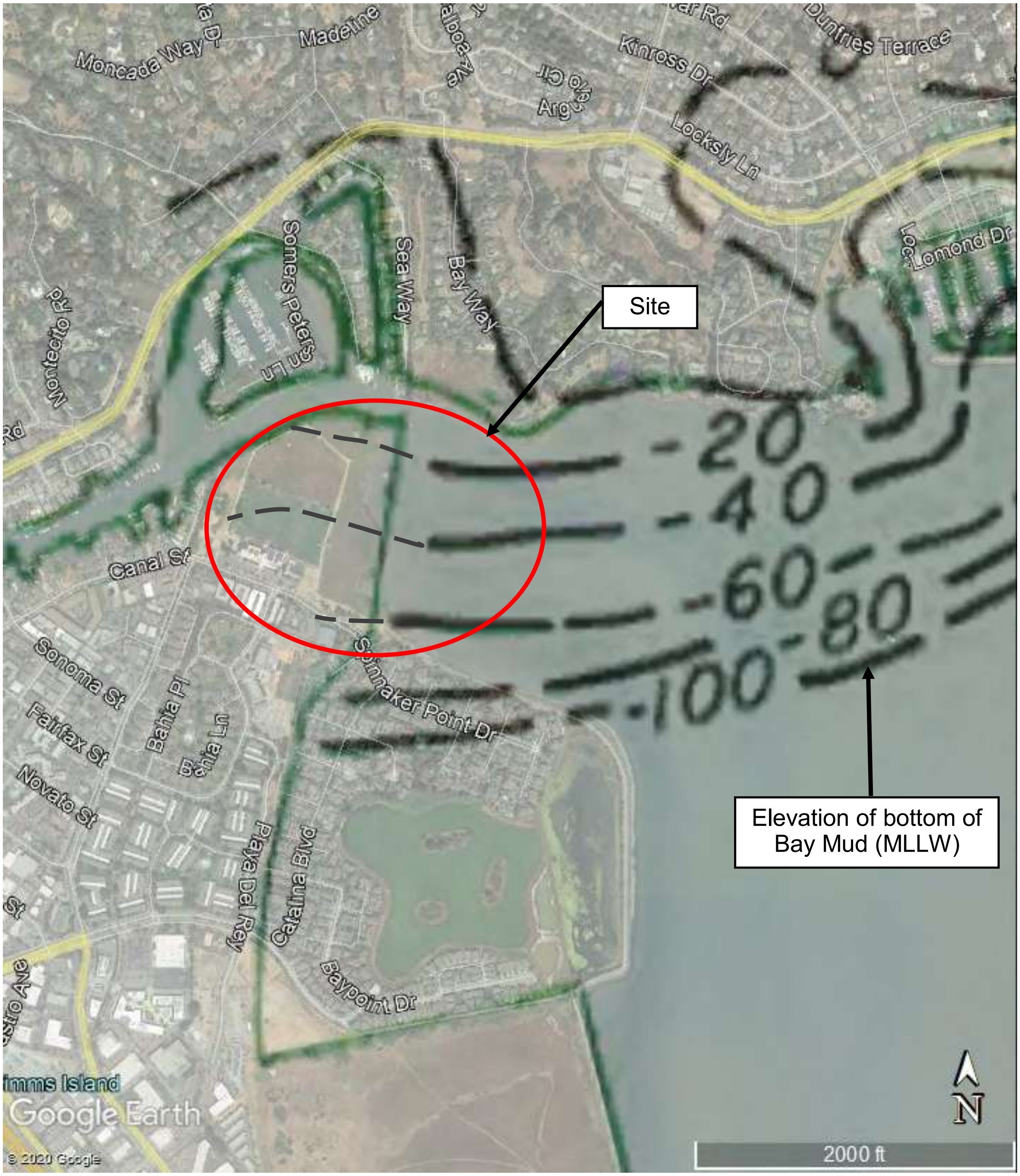
Fault - Dashed where approximately located, small dashed where inferred, dotted where concealed, queried where location is uncertain, inferred, dotted where concealed

Source: Geologic Map and Map Database of Parts of Marin, San Francisco, Alameda, Contra Costa, and Sonoma Counties, California, by M.C. Blake Jr., R.W. Graymer, D.L. Jones, and A. Soule, 2000

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Geologic Map

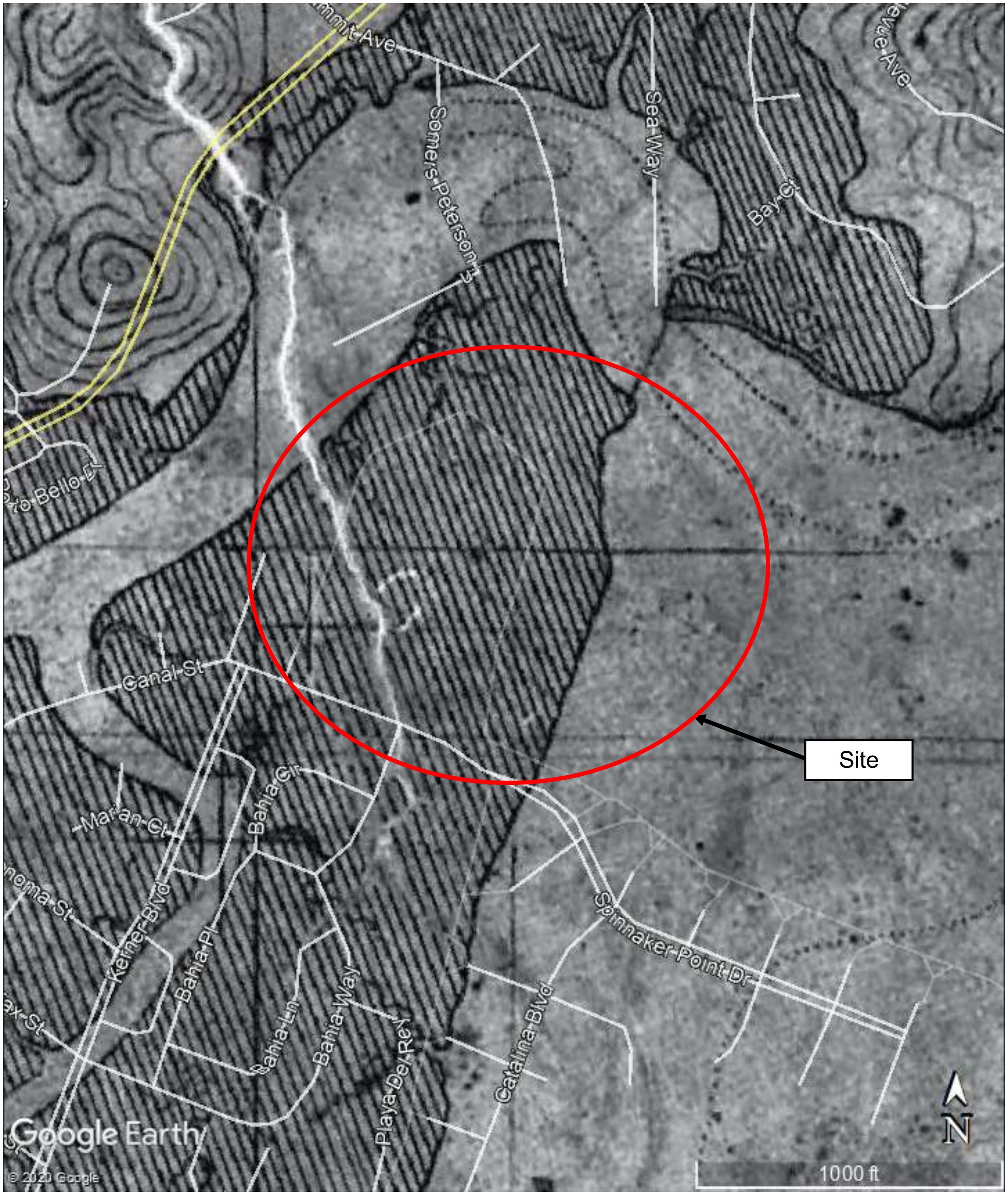
Hultgren - Tillis Engineers	Project No. 923.01	Plate No. 3



Source: Goldman, H. B., 1969. Geologic and Engineering Aspects of San Francisco Bay Fill: California Division of Mines and Geology Special Report 97 *(modified with dashed contours through site interpreted by HT)*.

Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Contours of the Bottom of Bay Mud**

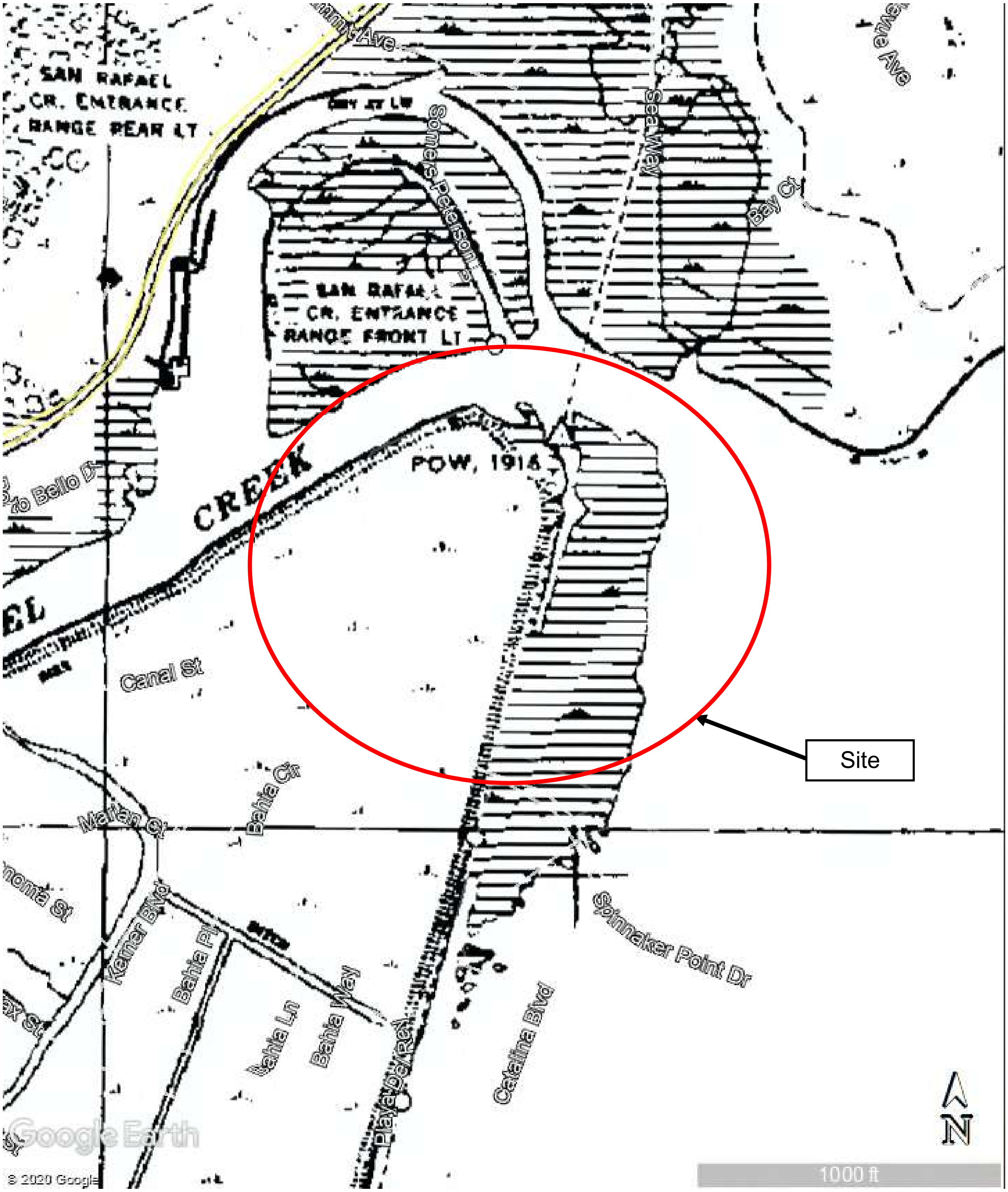
Hultgren - Tillis Engineers	Project No. 923.01	Plate No. 4



Source: U.S. Coast Survey, San Francisco, California, Plane Table Sheet No. IV, 1853.

Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Historic Shoreline Survey Map** **1853**

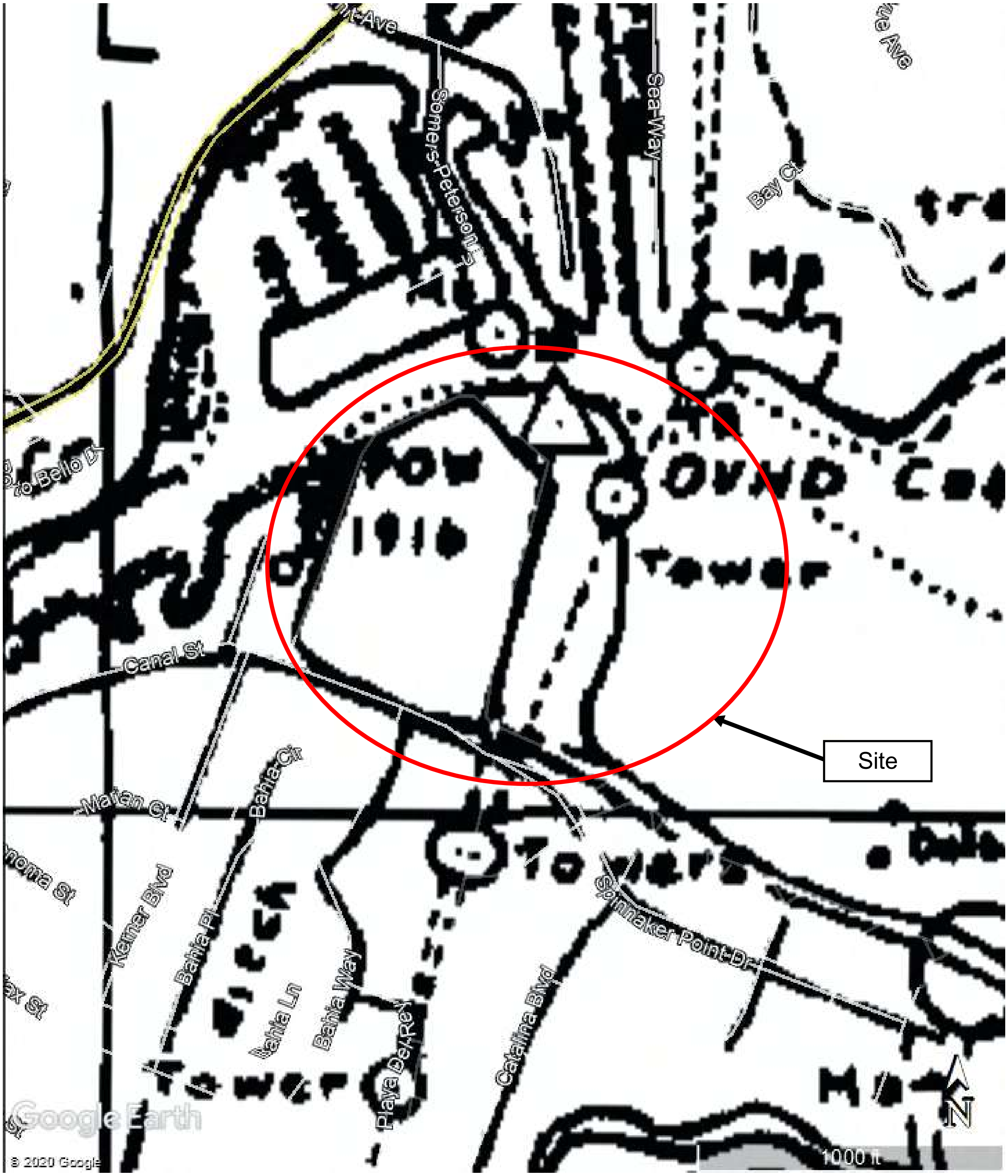
Hultgren - Tillis Engineers	Project No. 923.01	Plate No. 5



Source: U.S. Coast and Geodetic Survey, Planimetric Map, T-5930, California, San Pablo Strait, San Rafael and Vicinity, 1943

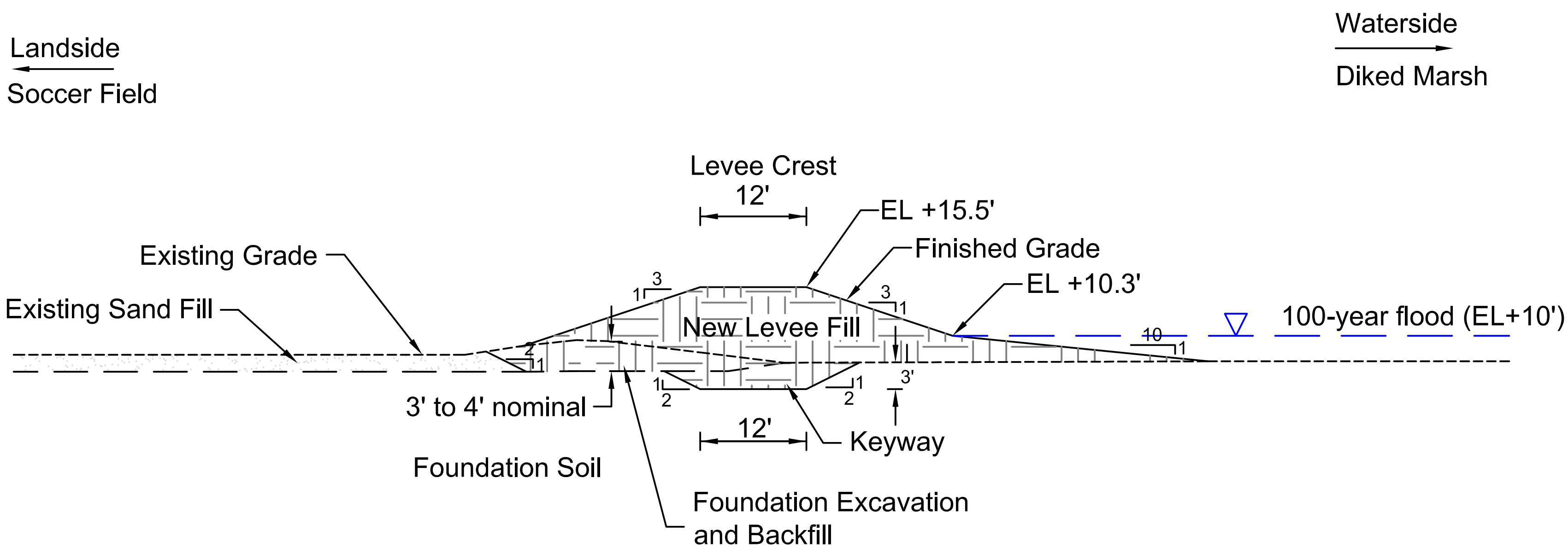
Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Historic Shoreline Survey Map** **1943**

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. 6



Source: National Ocean Survey, Shoreline Manuscript, TP-00526, California, San Rafael Bay, San Francisco and San Pablo Bays, 1979.

Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Historic Shoreline Survey Map 1979**	
Hultgren - Tillis Engineers	Project No. 923.01	Plate No. 7



Notes:

(1) Foundation excavation should extend through the existing sand fill, nominally 3 to 4 feet below existing grade.
(2) Base of keyway should be at least 12 feet wide and at least 3 feet below existing grade.
(3) Foundation and keyway excavation should have side slopes inclined at 2H:1V or flatter.
(4) New levee fill should meet criteria per report.
(5) Levee crest fill thickness of 8.5 feet will cause estimated settlement of about 2.5 feet.
(6) Levee crest as shown includes 2.5 feet of overbuild to accommodate settlement.
(7) Ecotone slope fill thickness of 3 feet will cause estimated settlement of about 1.3 feet.
(8) Ecotone slope should include overbuild to accommodate settlement.

SCALE
0 20 feet
1 inch = 20 feet

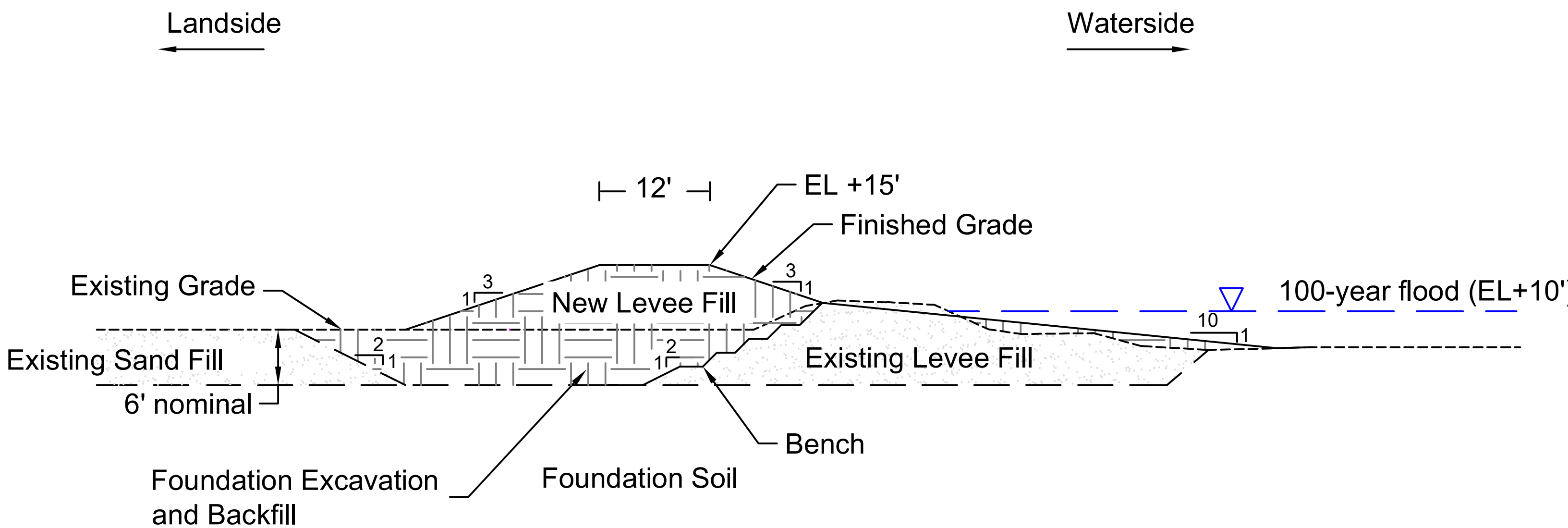
Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Typical Configuration Details
Upland Landside Area
Setback Ecotone Levee

Hultgren - Tillis Engineers

Project No. 923.01

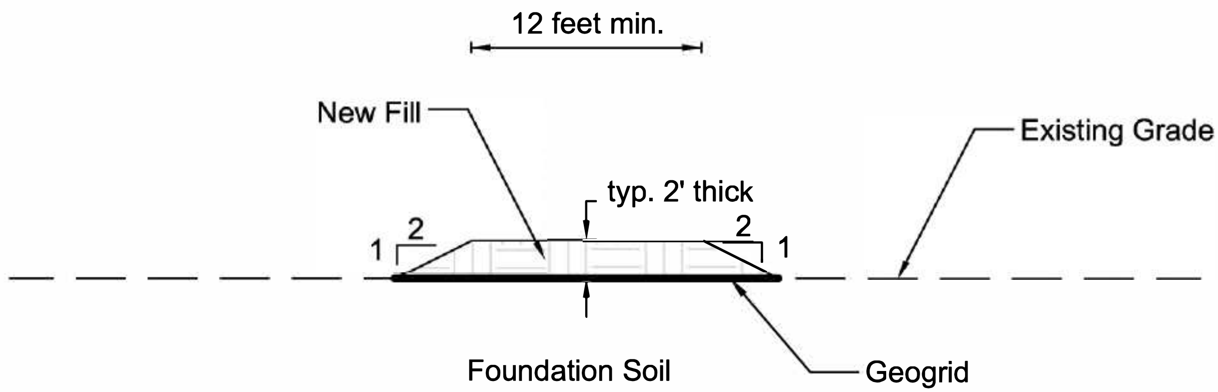
Plate No. 8



Notes:

(1) Foundation excavation should extend through the existing sand fill, nominally 6 feet below existing grade.
(2) Foundation excavation should have side slopes inclined at 2H:1V or flatter.
(3) New levee fill should meet criteria per report.
(4) Levee crest fill thickness of 7 feet will cause an estimated settlement of about 2 feet.
(5) Levee crest as shown includes two feet of overbuild to accommodate settlement.
(6) New fill should be benched into existing levee fill. Horizontal bench width should not exceed 5 feet.

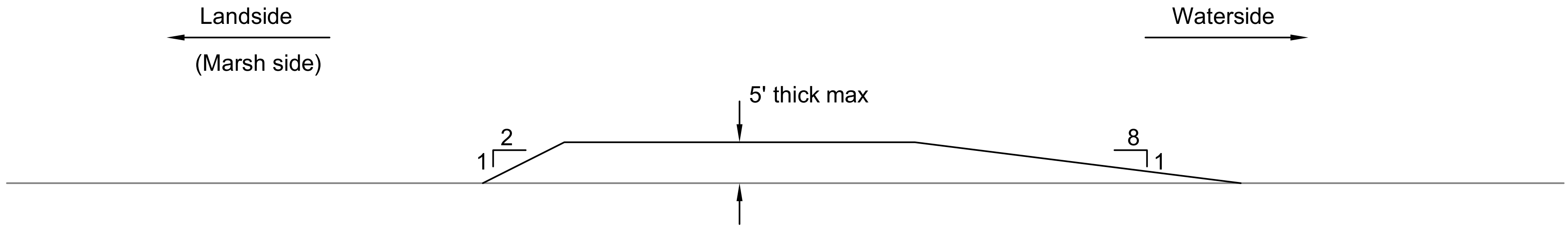
SCALE 0 — 20 feet 1 inch = 20 feet	Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Typical Configuration Details** **Upland Landside Area** **Offset Levee Along Canal Street**	
	Hultgren - Tillis Engineers	Project No. 923.01	Plate No. 9



Notes:

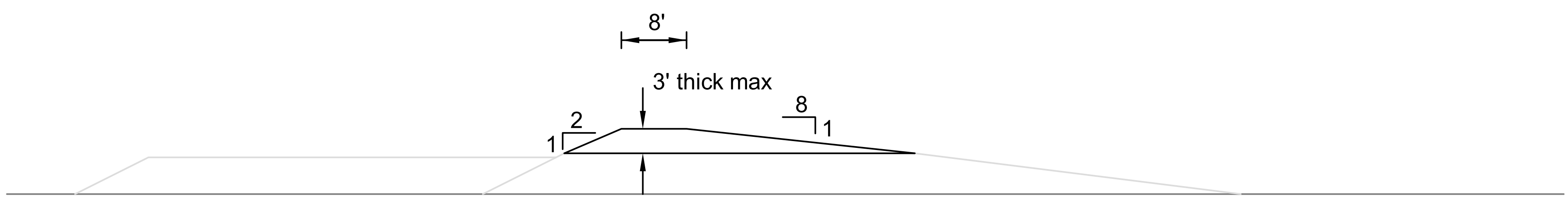
1. Geogrid should be placed underneath new fill.
2. Geogrid should consist of Tensar BX1100 or equal.

NOT TO SCALE	Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Typical Detail** **Temporary Access Road**	
	Hultgren - Tillis Engineers	Project No. 923.01	Plate No. 10



Step 1: Place 5' thick rock fill, 2:1 slope or flatter on landside, 8:1 on waterside.

Step 2: Place 4.5' thick dredge fill (weighs 100 pcf) and at least 50' wide for buttress

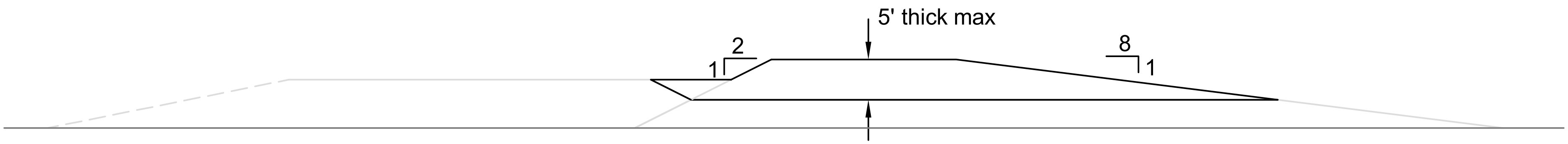


Step 3: Place 3' rock fill on coarse beach for total of 8' fill.

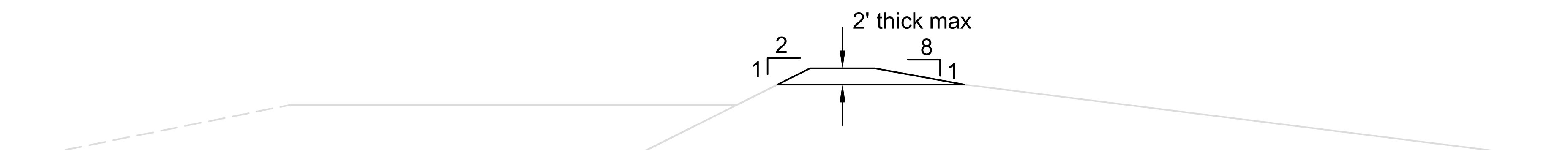
NOT TO SCALE	Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Preliminary Typical Configuration Details** **Tidal Marsh Area** **Coarse Beach Section on Eroded Marsh Areas**	
	Hultgren - Tillis Engineers	Project No. 923.01	Plate No. 11

Step 1: Place 3.5' thick rock fill, 2:1 slope or flatter on landside, 8:1 on waterside.

Step 2: Place 6' thick dredged fill (weighs 100 pcf) and at least 50' wide for buttress.

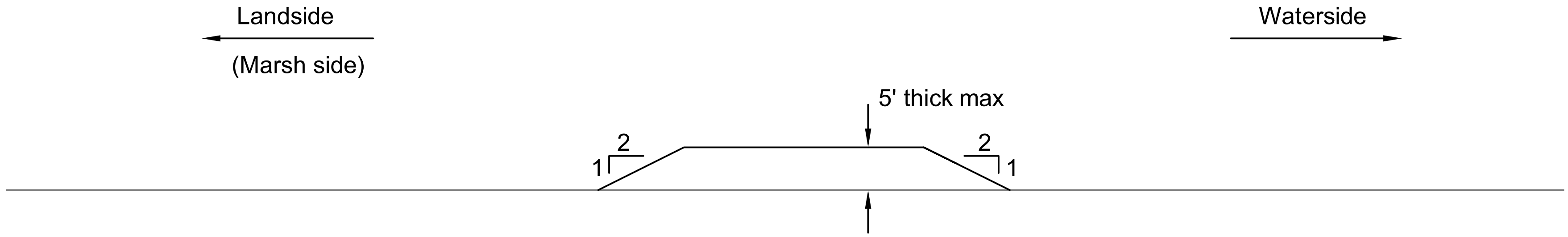


Step 3: Place 5' rock fill on coarse beach for total of 8.5' fill.

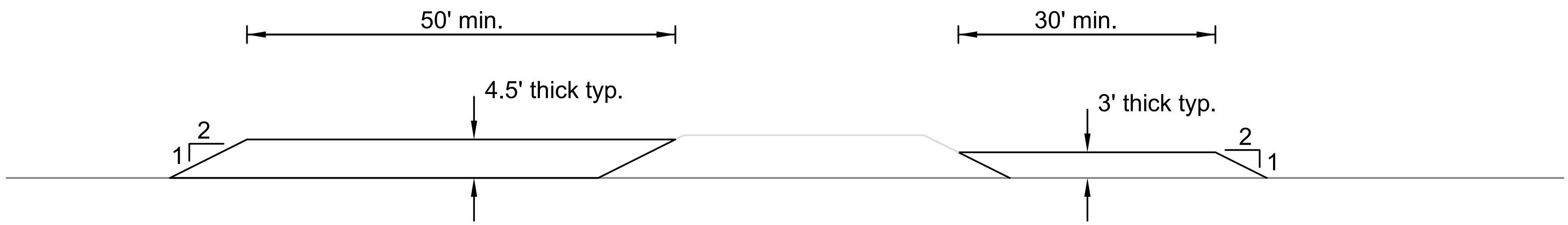


Step 4: Need third stage of rock fill on coarse beach placement, but need waiting period.

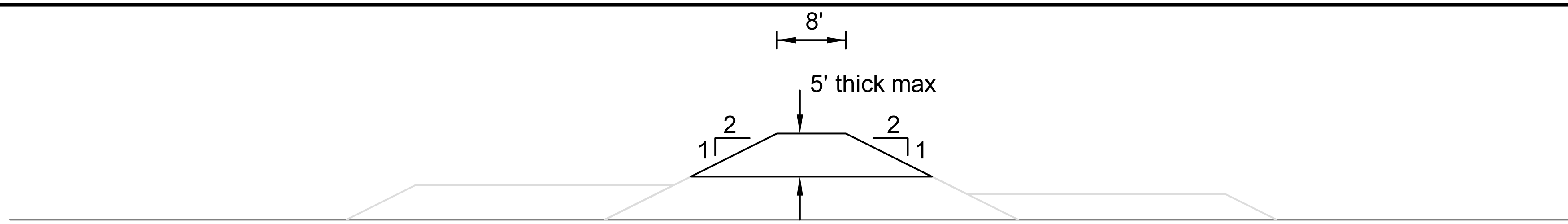
NOT TO SCALE	Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Preliminary Typical Configuration Details** **Tidal Marsh Area** **Coarse Beach Section on Virgin Marsh Areas**	
	Hultgren - Tillis Engineers	Project No. 923.01	Plate No. 12



Step 1: Place 5' thick rock fill, 2:1 slope or flatter.



Step 2A: Place dredge fill (weights 100 pcf) to 4.5' thick and at least 50' wide for buttress.
Step 2B: Place rock berm fill (weights 135 pcf) 3' thick and at least 30' wide on waterside for buttress.

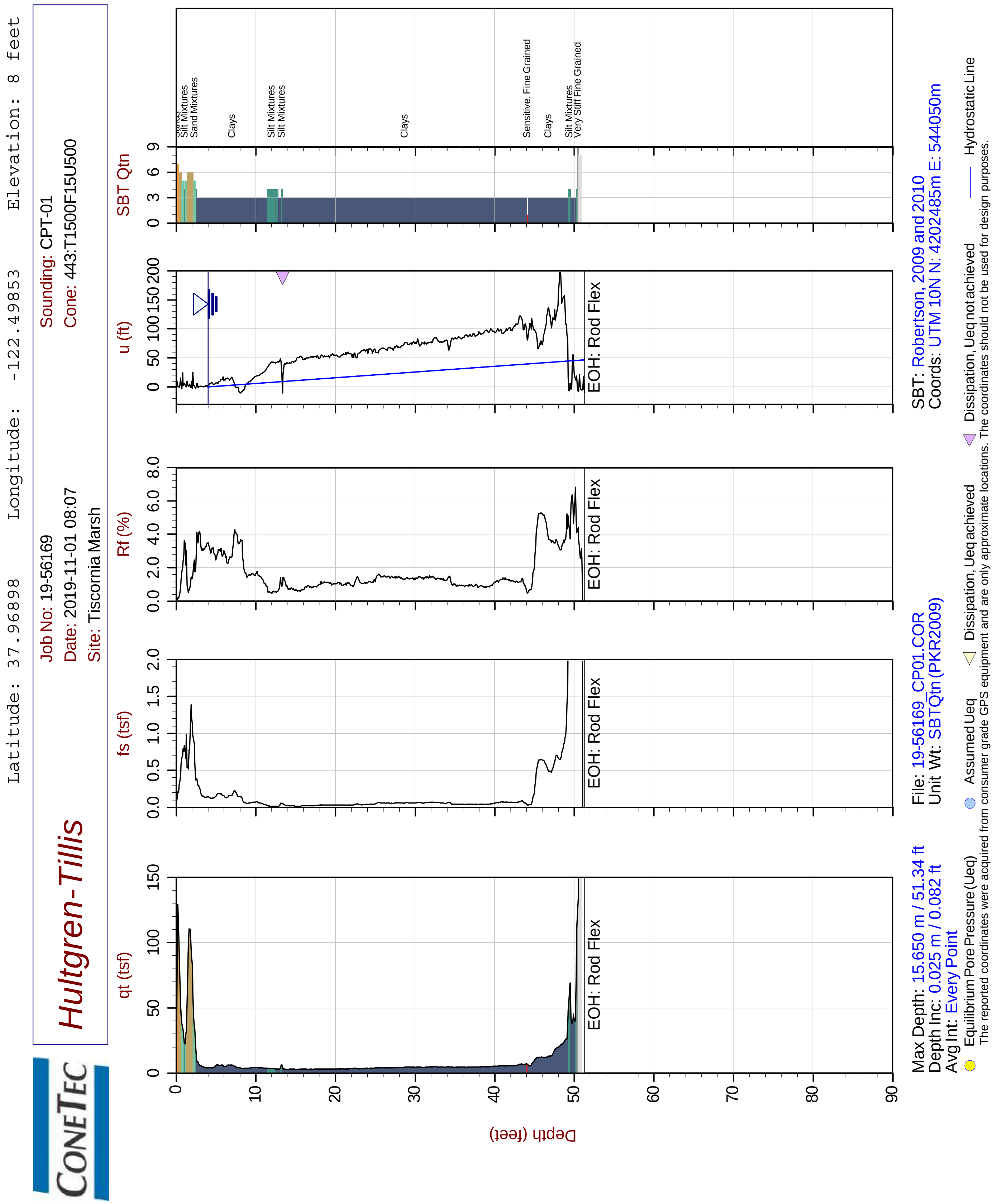


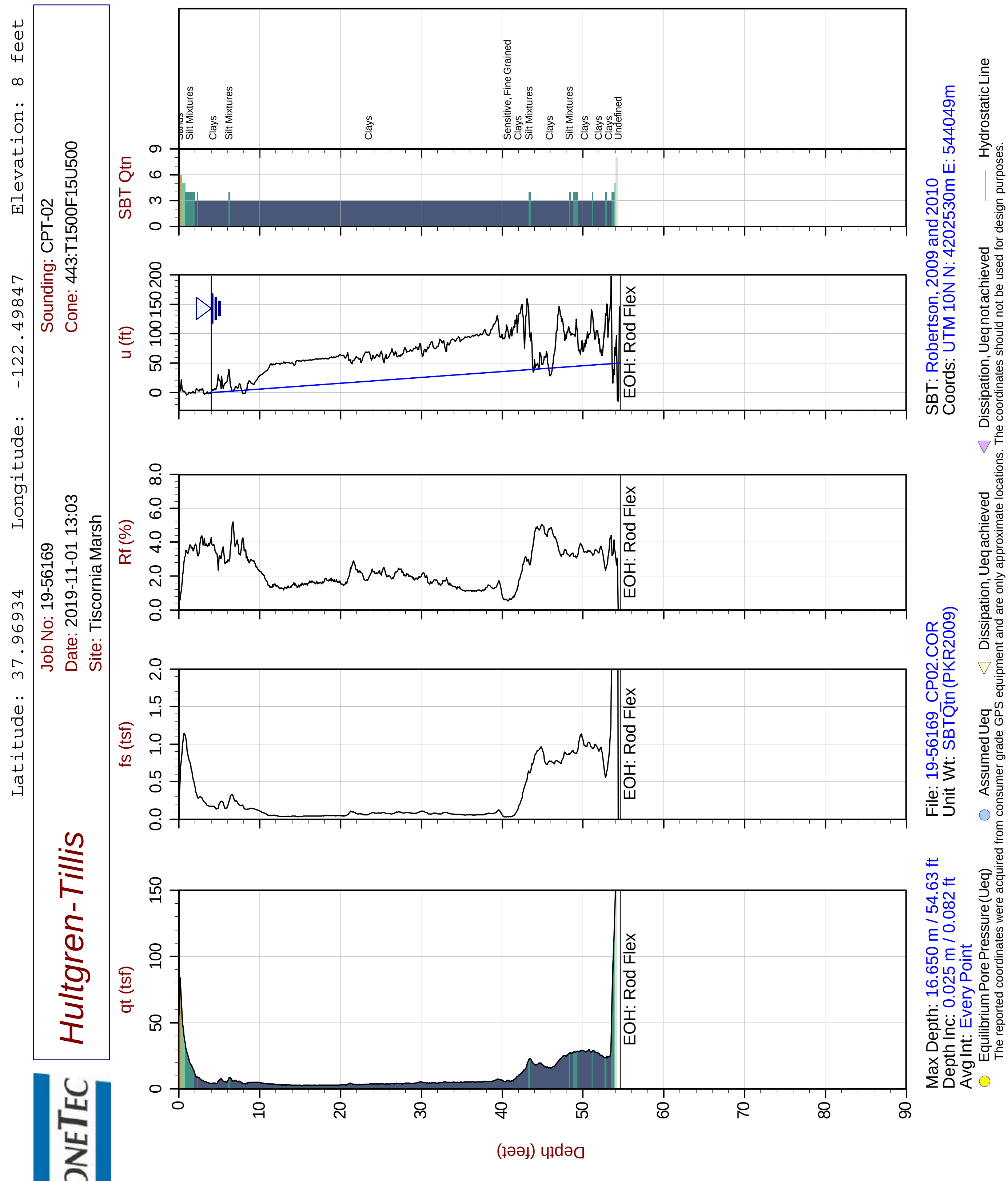
Step 3: Place 5' rock fill for a total of 10' fill.

NOT TO SCALE	Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Preliminary Typical Configuration Details** **Tidal Marsh Area** **Rock Jetty Section on Eroded Marsh Areas**	
	Hultgren - Tillis Engineers	Project No. 923.01	Plate No. 13

APPENDIX A

Logs of Cone Penetration Tests


Latitude: 37.96898 Longitude: -122.49853 Elevation: 8 feet
Hultgren-Tillis
Job No: 19-56169
Date: 2019-11-01 08:07
Site: Tiscornia Marsh
Sounding: CPT-01
Cone: 443:T1500F15U500
CONETEC
qt (tsf)
fs (tsf)
Rf (%)
u (ft)
SBT Qtn
Depth (feet)
EOH: Rod Flex
Sands
Silt Mixtures
Sand Mixtures
Clays
Sensitive, Fine Grained
Very Stiff Fine Grained
Max Depth: 15.650 m / 51.34 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point
File: 19-56169_CP01.COR
Unit Wt: SBTQtn (PKR2009)
SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4202485m E: 544050m
Equilibrium Pore Pressure (Ueq)
Assumed Ueq
Dissipation, Ueq achieved
Dissipation, Ueq not achieved
Hydrostatic Line
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.


Latitude: 37.96934 Longitude: -122.49847 Elevation: 8 feet
Hultgren-Tillis
Job No: 19-56169
Date: 2019-11-01 13:03
Site: Tiscornia Marsh
Sounding: CPT-02
Cone: 443:T1500F15U500
qt (tsf)
fs (tsf)
Rf (%)
u (ft)
SBT Qtn
EOH: Rod Flex
Sands
Silt Mixtures
Clays
Silt Mixtures
Clays
Sensitive, Fine Grained
Clays
Silt Mixtures
Clays
Silt Mixtures
Clays
Clays
Clays
Undefined
Depth (feet)
Max Depth: 16.650 m / 54.63 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point
File: 19-56169_CP02.COR
Unit Wt: SBTQtn (PKR2009)
SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4202530m E: 544049m
Equilibrium Pore Pressure (Ueq)
Assumed Ueq
Dissipation, Ueq achieved
Dissipation, Ueq not achieved
Hydrostatic Line
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

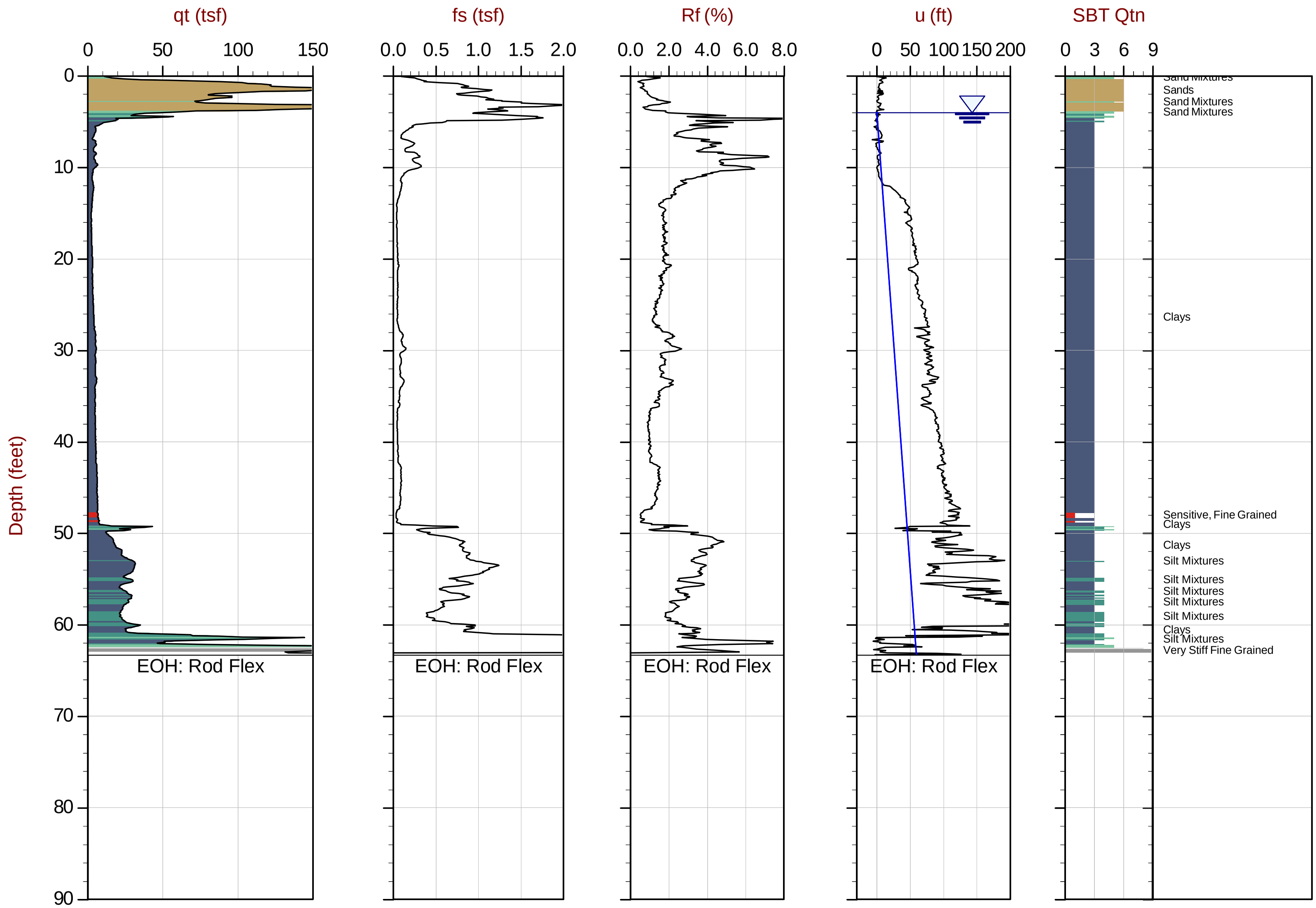
Latitude: 37.96901 Longitude: -122.49709 Elevation: 10 feet

CONETEC

Hultgren-Tillis

Job No: 19-56169
Date: 2019-11-01 10:28
Site: Tiscornia Marsh

Sounding: CPT-03
Cone: 443:T1500F15U500



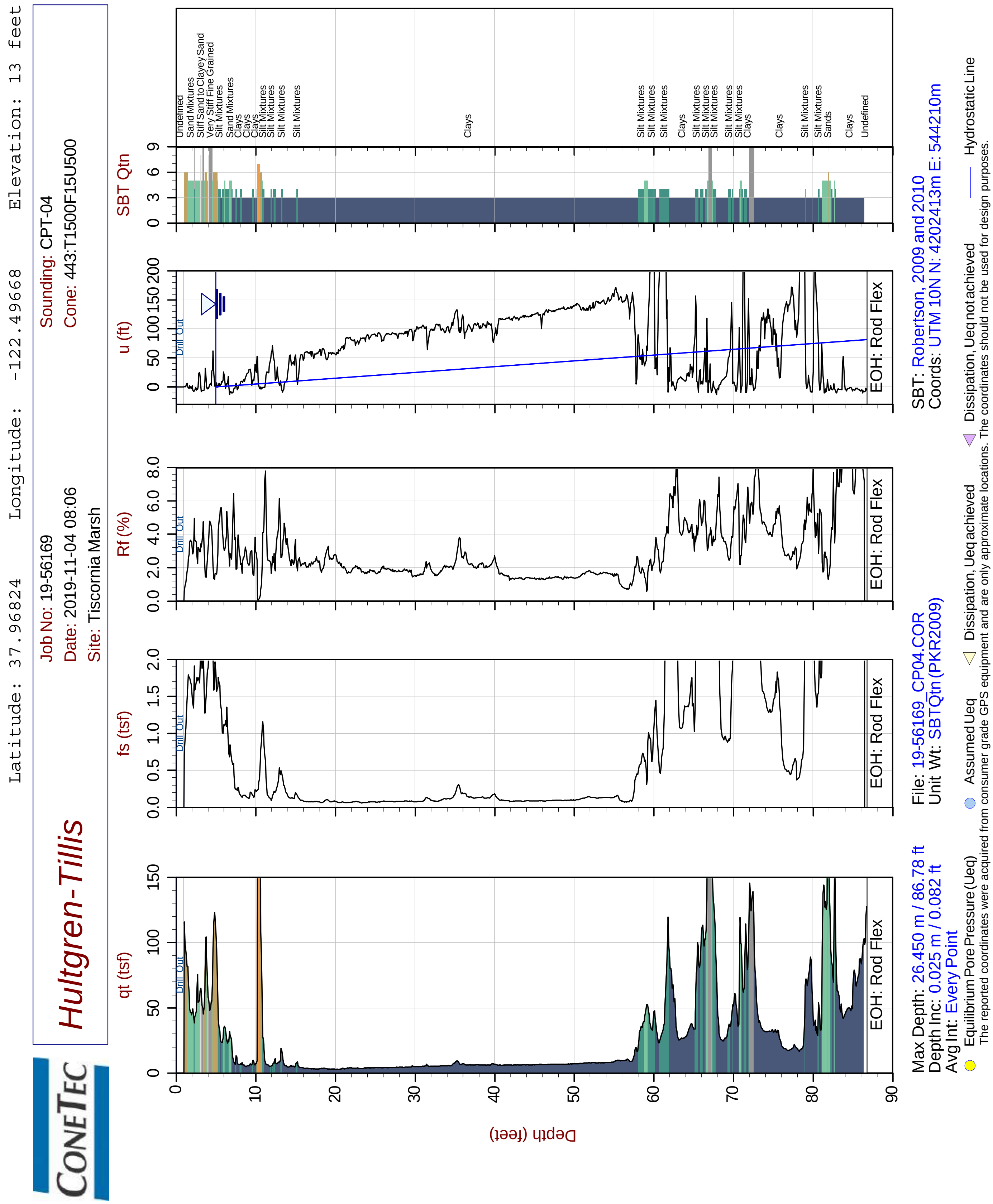
Max Depth: 19.300 m / 63.32 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

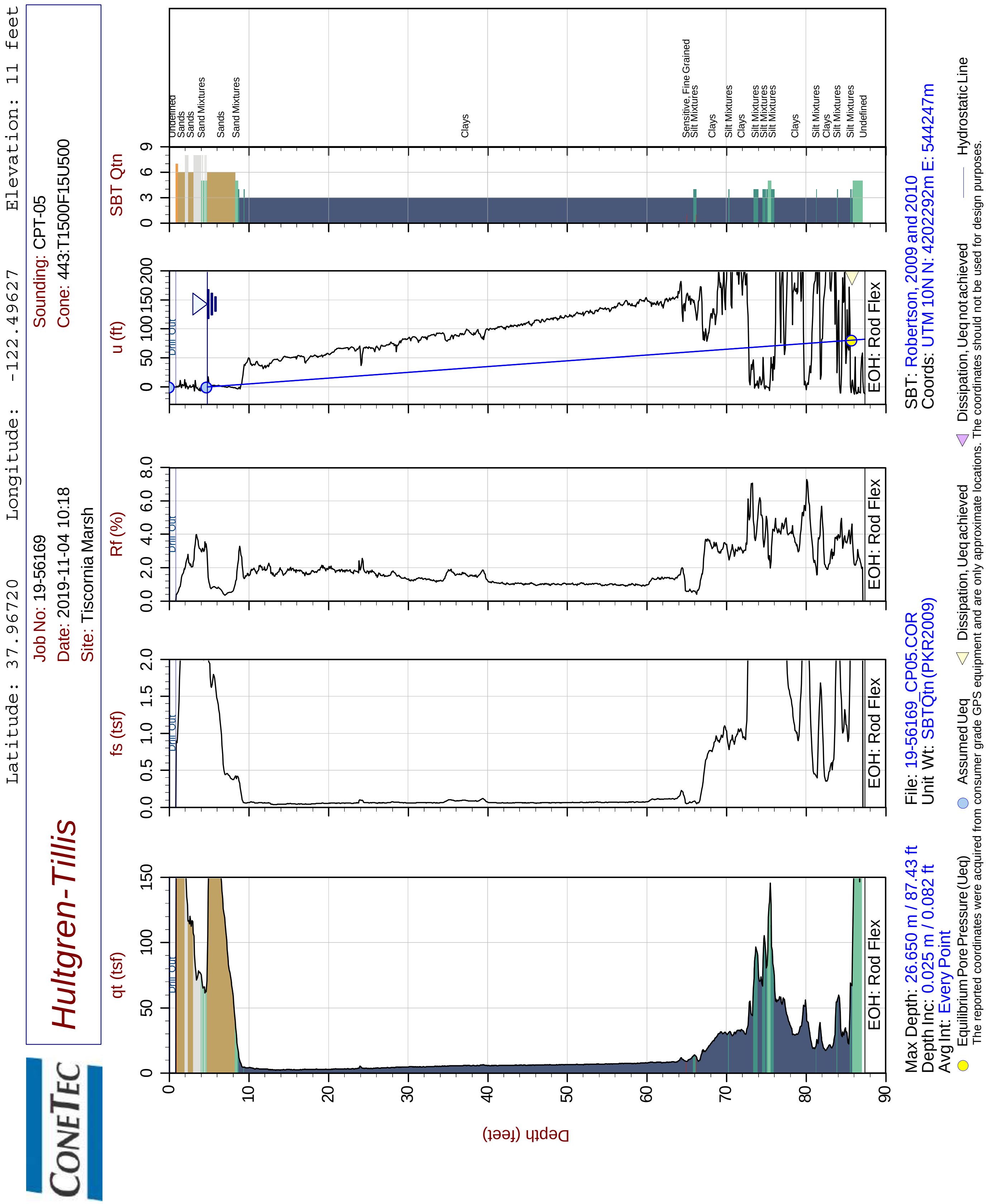
File: 19-56169_CP03.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4202494m E: 544169m

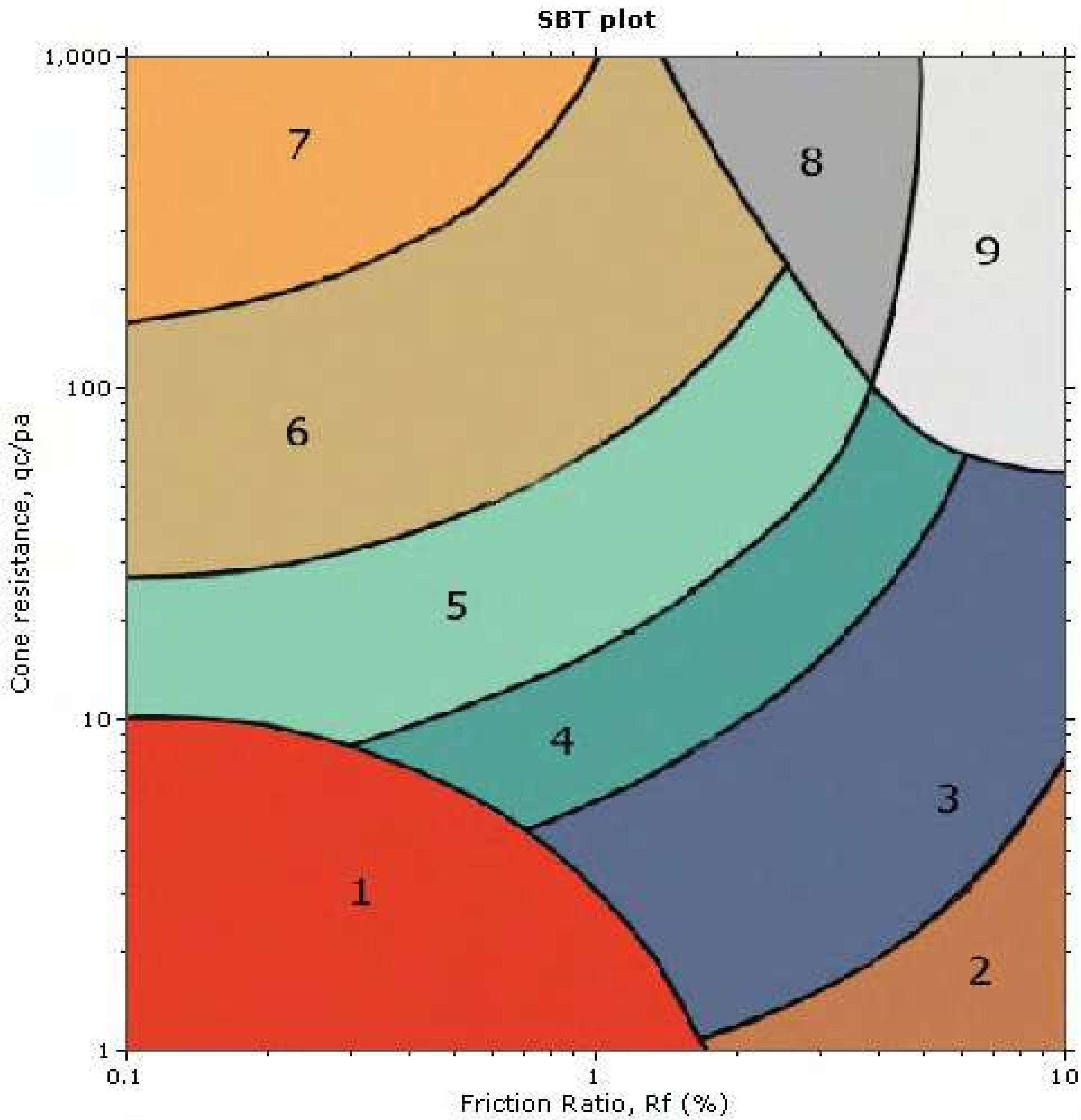
Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.


Latitude: 37.96824 Longitude: -122.49668 Elevation: 13 feet
Hultgren-Tillis
Job No: 19-56169
Date: 2019-11-04 08:06
Site: Tiscornia Marsh
Sounding: CPT-04
Cone: 443:T1500F15U500
ConeTec
qt (tsf)
fs (tsf)
Rf (%)
u (ft)
SBT Qtn
Depth (feet)
Drill Out
EOH: Rod Flex
Max Depth: 26.450 m / 86.78 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point
File: 19-56169_CP04.COR
Unit Wt: SBTQtn (PKR2009)
SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4202413m E: 544210m
Equilibrium Pore Pressure (Ueq)
Assumed Ueq
Dissipation, Ueq achieved
Dissipation, Ueq not achieved
Hydrostatic Line
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.



Latitude: 37.96720 Longitude: -122.49627 Elevation: 11 feet
Hultgren-Tillis
Job No: 19-56169
Date: 2019-11-04 10:18
Site: Tiscornia Marsh
Sounding: CPT-05
Cone: 443:T1500F15U500
CONETEC
qt (tsf)
fs (tsf)
Rf (%)
u (ft)
SBT Qtn
Depth (feet)
EOH: Rod Flex
Drill Out
Undefined
Sands
Sand Mixtures
Clays
Sensitive, Fine Grained
Silt Mixtures
Max Depth: 26.650 m / 87.43 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point
File: 19-56169_CP05.COR
Unit Wt: SBTQtn (PKR2009)
SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4202292m E: 544247m
Equilibrium Pore Pressure (Ueq)
Assumed Ueq
Dissipation, Ueq achieved
Dissipation, Ueq not achieved
Hydrostatic Line
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

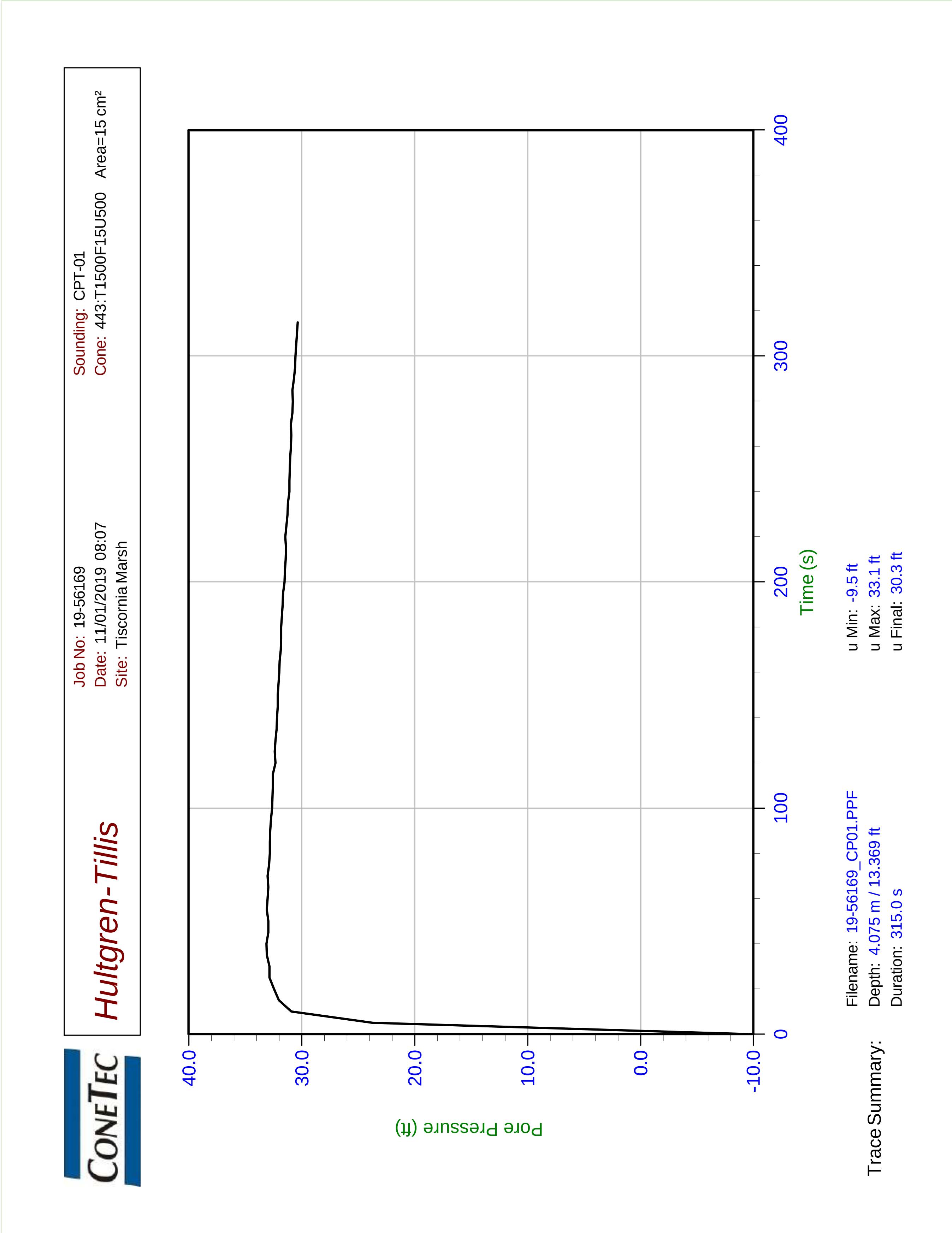


SBT zone	Proposed common SBT description
1	*Sensitive fine-grained*
2	*Clay - organic soil*
3	*Clays: clay to silty clay*
4	*Silt mixtures: clayey silt & silty clay*
5	*Sand mixtures: silty sand to sandy silt*
6	*Sands: clean sands to silty sands*
7	*Dense sand to gravelly sand*
8	*Stiff sand to clayey sand**
9	*Stiff fine-grained**

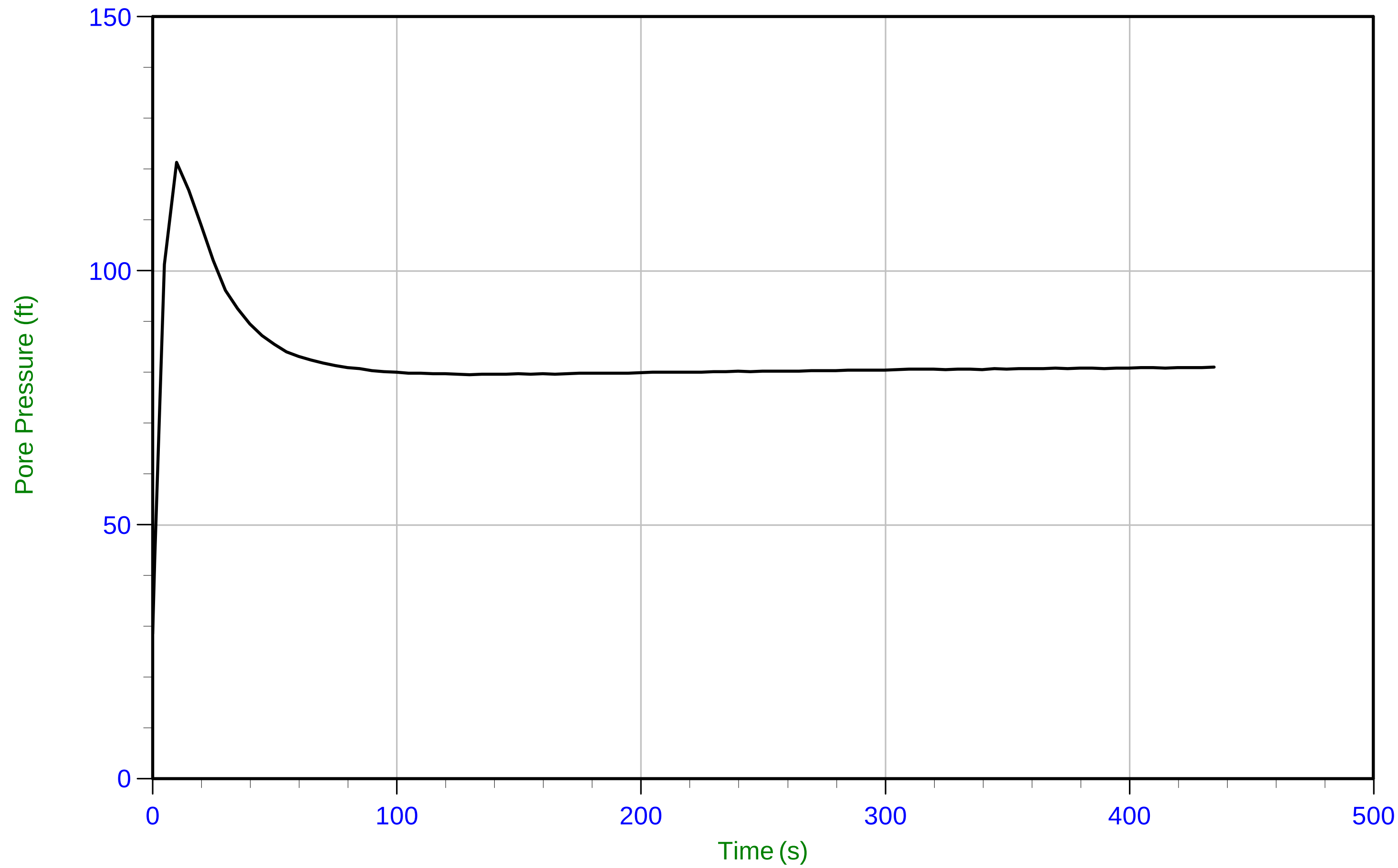
** Overconsolidated or cemented*

Note: Updated Soil Behavior Type (SBT) chart based on non-normalized CPT (after Robertson 2010a).

Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**CPT Soil Behavior Type Legend**	
Hultgren - Tillis Engineers	Project No. 923.01	Plate No. A-6


ConeTec
Hultgren-Tillis
Job No: 19-56169
Date: 11/01/2019 08:07
Site: Tiscornia Marsh
Sounding: CPT-01
Cone: 443:T1500F15U500 Area=15 cm²
Pore Pressure (ft)
40.0
30.0
20.0
10.0
0.0
-10.0
Time (s)
0
100
200
300
400
Trace Summary:
Filename: 19-56169_CP01.PPF
Depth: 4.075 m / 13.369 ft
Duration: 315.0 s
u Min: -9.5 ft
u Max: 33.1 ft
u Final: 30.3 ft

Hultgren-Tillis	Job No: 19-56169 Date: 11/04/2019 10:18 Site: Tiscornia Marsh	Sounding: CPT-05 Cone: 443:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 19-56169_CP05.PPF	u Min: 28.6 ft	WT: 1.449 m / 4.754 ft
Depth: 26.150 m / 85.793 ft	u Max: 121.3 ft	Ueq: 81.0 ft
Duration: 435.0 s	u Final: 81.0 ft	

APPENDIX B

Logs of Borings

Date : 11/7/2019
Drilling Method : Hollow-Stem Auger
Elevation (Feet) : 8
Latitude : 37.96903
Longitude : -122.49851

Depth in Feet	Samples Type/ Recovery	Blow Count	Graphic	USCS	Water Levels	Material Description	Torvane (tsf)	Pocket Pen (tsf)	Moisture Content (%)	Dry Density (pcf)	Other Laboratory Tests
				SM		Silty Sand (SM), yellowish brown, fine grained sand, dry, dense, some gravel, (fill)					
	M	7		CH		Fat Clay (CH), brown, moist, firm, high plasticity, no dilatancy, high toughness, high dry strength, (Bay Mud Crust)	0.25		63	61	
5	M	6		CH		Fat Clay (CH), dark olive gray, wet, stiff, high plasticity, no dilatancy, high toughness, high dry strength, trace organics, (Bay Mud)	0.57	1.3	60	66	
	M	6				Firm	0.41 0.25	0.8	65	56	
10	M	5		CH		Fat Clay (CH), dark olive gray, wet, firm, high plasticity, no dilatancy, high toughness, high dry strength, (Bay Mud)					
15	T	P				Soft	0.13				VS=340

Bottom of boring at 17.5 feet
Groundwater obscured due to hollow-stem augers
The laboratory vane shear strength shown was computed by mutiplying the data by an estimated Bjerrum's correction factor of 0.85

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Log of Boring 1
(Page 1 of 1)

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. B-1

Date : 11/7/2019
Drilling Method : Hollow-Stem Auger
Elevation (Feet) : 8
Latitude : 37.96930
Longitude : -122.49849

Depth in Feet	Samples Type/ Recovery	Blow Count	Graphic	USCS	Water Levels	Material Description	Torvane (tsf)	Pocket Pen (tsf)	Moisture Content (%)	Dry Density (pcf)	Other Laboratory Tests
				SM		Silty Sand (SM), yellowish brown, fine grained sand, dry, dense, some gravel, (fill)					
	M	8		CH		Fat Clay (CH), brown, moist, stiff, high plasticity, no dilatancy, high toughness, high dry strength, (Bay Mud Crust)	0.53	2.5	49	66	
5	M	6		CH		Fat Clay (CH), dark olive gray, wet, stiff, high plasticity, no dilatancy, high toughness, high dry strength, trace organics, (Bay Mud)	0.52		55	67	
	M	5					0.35	0.8	61	65	
						Fat Clay (CH), dark olive gray, wet, soft, high plasticity, no dilatancy, high toughness, high dry strength, (Bay Mud)	0.50				
10	M	6					0.25	0.5	61	62	LL=56 PI=28
				CH		Becoming soft					
15	T	P				Very Soft	0.09				VS=180

Bottom of boring at 17.5 feet
Groundwater obscured due to hollow-stem augers
The laboratory vane shear strength shown was computed by mutiplying the data by an estimated Bjerrum's correction factor of 0.85

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Log of Boring 2
(Page 1 of 1)

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. B-2

Depth in Feet	Samples Type/ Recovery	Blow Count	USCS	Water Levels	Material Description	Torvane (tsf)	Pocket Pen (tsf)	Moisture Content (%)	Dry Density (pcf)	Other Laboratory Tests
					Date : 11/8/2019 Drilling Method : Hollow-Stem Auger Elevation (Feet) : 9 Latitude : 37.96918 Longitude : -122.49769					
			SM		Silty Sand (SM), dark yellowish brown, fine grained sand, moist, dense, (fill)					
			SM		Silty Sand (SM), light yellowish brown, fine grained sand, dry, medium dense, some gravel, (fill)					
	M	17					2.5	42	71	
			CH		Fat Clay (CH), olive brown, moist, medium stiff, low plasticity, no dilatancy, medium toughness, medium dry strength, oxidation marks, (Bay Mud Crust)					
5						0.32		55	65	
	M	5								
			CH		Fat Clay (CH), dark olive gray, wet, firm, high plasticity, no dilatancy, high toughness, high dry strength, with organics, (Bay Mud)					
	T	P								
10						0.18		69	58	TxUU=290 VS=460
	T	P						75	55	TxUU=220
				∇	Fat Clay (CH), dark olive gray, wet, soft, high plasticity, no dilatancy, high toughness, high dry strength, (Bay Mud) 11/8/2019					VS=340
15						0.20				
	M	4				0.17		86		Organic=4%
20										LL=68
	T	P						81 83	52 52	PI=38 Consol TxUU=330
						0.09				VS=380
25	M	4	CH			0.20 0.25				
30										
	T	P						67	59	TxUU=380
					Firm					VS=535
35	M	4				0.22 0.24				
40										
	T	P				0.28		95	47	TxUU=560 VS=750
			CL		Lean Clay (CL), greenish gray, wet, stiff, low					

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
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Log of Boring 3
(Page 1 of 2)

Depth in Feet	Samples Type/ Recovery	Blow Count	Graphic	USCS	Water Levels	Date : 11/8/2019 Drilling Method : Hollow-Stem Auger Elevation (Feet) : 9 Latitude : 37.96918 Longitude : -122.49769 Material Description	Torvane (tsf)	Pocket Pen (tsf)	Moisture Content (%)	Dry Density (pcf)	Other Laboratory Tests
	M	20		CL		plasticity, slow dilatancy, medium toughness, medium dry strength	0.26	1.0	19	103	
50								1.7			
	M	51					0.85	1.8	29	90	

Bottom of boring at 51.5 feet
Groundwater encountered at 12 feet during drilling
The laboratory vane shear strength shown was computed by mutiplying the data by an estimated Bjerrum's correction factor of 0.85

Date : 11/7/2019
Drilling Method : Hollow-Stem Auger
Elevation (Feet) : 10
Latitude : 37.96903
Longitude : -122.49717

Depth in Feet	Samples Type/ Recovery	Blow Count	Graphic	USCS	Water Levels	Material Description	Torvane (tsf)	Pocket Pen (tsf)	Moisture Content (%)	Dry Density (pcf)	Other Laboratory Tests
				SM		Silty Sand (SM), dark yellowish brown, fine grained sand, moist, dense, (fill)					
	M	83 11"		SM		Silty Sand with Gravel (SM), light yellowish brown, dry, very dense, some gravel, (fill)		4.5+	7	125	-200=32
5	M	10		CH		Fat Clay (CH), olive brown, wet, stiff, high plasticity, no dilatancy, high toughness, high dry strength, trace organics, (Bay Mud Crust)	0.53	1.0	20	83	
	M	6				Fat Clay (CH), dark olive gray, wet, firm to stiff, high plasticity, no dilatancy, high toughness, high dry strength, trace organics, (Bay Mud)	0.39	1.3	44	70	
10	M	4		CH			0.22 0.17	0.8	84 63	59	Organic=6%
						Fat Clay (CH), dark olive gray, wet, soft, high plasticity, no dilatancy, high toughness, high dry strength, (Bay Mud)					
15	T	P					0.15		79	54	TxUU=290 VS=410
20	M	4					0.20 0.17				
25	T	P					0.25		85 82	51 52	LL=72 PI=40 Consol TxUU=360 VS=410
				CH							
30	M	6					0.22 0.26	0.5			
35	T	P				Firm	0.17		73	57	TxUU=400 VS=460
40	M	5					0.19				

Restore Eroded and Diked Marsh
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San Rafael, California

Log of Boring 4
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Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. B-5

Date	: 11/7/2019
Drilling Method	: Hollow-Stem Auger
Elevation (Feet)	: 10
Latitude	: 37.96903
Longitude	: -122.49717

Depth in Feet	Samples Type/ Recovery	Blow Count	Graphic	USCS	Water Levels	Material Description	Torvane (tsf)	Pocket Pen (tsf)	Moisture Content (%)	Dry Density (pcf)	Other Laboratory Tests
	T	P		CH			0.32		73	56	TxUU=540 VS=620
50	M	24		CL		Lean Clay (CL), bluish green, wet, stiff, low plasticity, slow dilatancy, medium toughness, medium dry strength	0.45 0.67	1.0 1.4	23	103	

Bottom of boring at 51.5 feet
Groundwater obscured due to hollow-stem augers
The laboratory vane shear strength shown was computed by mutiplying the data by an estimated Bjerrum's correction factor of 0.85

Date : 11/7/2019
Drilling Method : Hollow-Stem Auger
Elevation (Feet) : 13
Latitude : 37.96821
Longitude : -122.49669

Depth in Feet	Samples Type/ Recovery	Blow Count	USCS	Material Description	Torvane (tsf)	Pocket Pen (tsf)	Moisture Content (%)	Dry Density (pcf)	Other Laboratory Tests
				Asphalt (3- to 4- inches)					
			SM	Silty Sand with Gravel (SM), light yellowish brown, dry, dense, (fill)					
	M	38	ML			4.5+	8	123	
				Silt (ML), brown, moist, very stiff, some gravel and sand, (fill)					
5	M	22	SM			4.5+	11	116	-200=25
				Silty Sand with Gravel (SM), yellowish brown and olive, moist, medium dense, (fill)					
	M	11		Gravelly Fat Clay with Sand (CH), olive gray, wet, stiff, high plasticity, no dilatancy, high toughness, high dry strength, trace organics, 1/4-inch size angular gravel, (fill)	0.56	1.4	52	69	
10	M	14			0.30		20	102	
			CH						
15									
	T	P			0.55		20	104	VS=1060

Bottom of boring at 17.5 feet
Groundwater obscured due to hollow-stem augers
The laboratory vane shear strength shown was computed by mutiplying the data by an estimated Bjerrum's correction factor of 0.85

Date	:	11/8/2019
Drilling Method	:	Hollow-Stem Auger
Elevation (Feet)	:	8
Latitude	:	37.96717
Longitude	:	-122.49644

Depth in Feet	Samples Type/ Recovery	Blow Count	Graphic	USCS	Water Levels	Material Description	Torvane (tsf)	Pocket Pen (tsf)	Moisture Content (%)	Dry Density (pcf)	Other Laboratory Tests
				SP		Poorly-Graded Sand (SP), light yellowish brown, fine grained sand, dry, medium dense, (fill)					
	M	23							25	98	-200=4
5				SP		Poorly-Graded Sand (SP), dark gray, medium grained sand, wet, medium dense, (fill)					
	M	4					0.25		38	84	
				CH		Fat Clay (CH), olive brown, wet, soft, high plasticity, no dilatancy, high toughness, high dry strength, with organics. (Bay Mud crust)	0.15				
	M	4							90	48	LL=69 PI=30
10						Fat Clay (CH), dark olive gray, wet, very soft, high plasticity, no dilatancy, high toughness, high dry strength, with organics, (Bay Mud) With sea shells					
	T	P							80	53	TxUU=130
							0.09				VS=180
15	T	P					0.15				LL=68 PI=38 Consol
									74 78	56 54	TxUU=340 VS=340
20	M	6					0.17				
25	T	P		CH			0.17		79	54	TxUU=360 VS=440
30	M	6					0.19 0.15				
35	T	P							72	57	TxUU=370
							0.25				VS=485
40	M	6				Soft	0.22		49	69	

Restore Eroded and Diked Marsh
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Log of Boring 6
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Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. B-8

Depth in Feet	Samples Type/ Recovery	Blow Count	Graphic	USCS	Water Levels	Date : 11/8/2019 Drilling Method : Hollow-Stem Auger Elevation (Feet) : 8 Latitude : 37.96717 Longitude : -122.49644 Material Description	Torvane (tsf)	Pocket Pen (tsf)	Moisture Content (%)	Dry Density (pcf)	Other Laboratory Tests
	T	P		CH			0.22		64	61	TxUU=350 VS=490
50	M	4					0.20		57	62	

Bottom of boring at 51.5 feet
Groundwater obscured due to hollow-stem augers
The laboratory vane shear strength shown was computed by mutiplying the data by an estimated Bjerrum's correction factor of 0.85

Date : 2/28/2020
Drilling Method : Hand Auger
Elevation (Feet) : 7
Latitude : 37.96940
Longitude : -122.49777

Depth in Feet	Samples Type/ Recovery	Blow Count	Graphic	USCS	Water Levels	Material Description	Torvane (tsf)	Pocket Pen (tsf)	Moisture Content (%)	Dry Density (pcf)	Other Laboratory Tests
					▽	Fat Clay with Sand (CH), brown, wet, stiff, high plasticity, no dilatancy, high toughness, high dry strength, with organics, occasional gravel, (Bay Mud crust)					
	T	P		CH					53	67	TxUU=420
							0.31				VS=850
5	T	P				Olive brown, medium stiff			60	62	TxUU=390
						Fat Clay (CH), gray, wet, soft, high plasticity, no dilatancy, high toughness, high dry strength, (Bay Mud)	0.38				VS=675
	T	P							63	59	LL=92
							0.25				PI=53
	T	P		CH					71	56	VS=570
10							0.26				TxUU=365
	T	P							70	52	VS=425
							0.19				VS=250

Bottom of boring at 12.5 feet
Groundwater encountered at 6-inches during hand augering

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

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Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. B-10

Date : 2/28/2020
Drilling Method : Hand Auger
Elevation (Feet) : 7
Latitude : 37.96930
Longitude : -122.49751

Depth in Feet	Samples Type/ Recovery	Blow Count	Graphic	USCS	Water Levels	Material Description	Torvane (tsf)	Pocket Pen (tsf)	Moisture Content (%)	Dry Density (pcf)	Other Laboratory Tests
	T	P		CH	▽	Fat Clay with Sand (CH), brown, wet, stiff, high plasticity, no dilatancy, high toughness, high dry strength, with organics, occasional gravel, (Bay Mud crust)			64	60	TxUU=425
							0.25				VS=425
	T	P							58	63	TxUU=290
							0.35				VS=675
5	T	P				Gray, medium stiff			36	78	TxUU=480
				CH		Fat Clay (CH), gray, wet, soft, high plasticity, no dilatancy, high toughness, high dry strength, (Bay Mud)	0.38				VS=710
	T	P							86	51	TxUU=370
							0.18				VS=445
10	T	P							60	63	
							0.26				VS=460

Bottom of boring at 11.5 feet
Groundwater encountered at 6-inches during hand augering

Restore Eroded and Diked Marsh
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Log of Boring 8
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Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. B-11

Date : 2/28/2020
Drilling Method : Hand Auger
Elevation (Feet) : 7
Latitude : 37.96920
Longitude : -122.49712

Depth in Feet	Samples Type/ Recovery	Blow Count	Graphic	USCS	Water Levels	Material Description	Torvane (tsf)	Pocket Pen (tsf)	Moisture Content (%)	Dry Density (pcf)	Other Laboratory Tests
	T	P		CH	▽	Fat Clay with Sand (CH), brown, wet, stiff, high plasticity, no dilatancy, high toughness, high dry strength, with organics, occasional gravel, (Bay Mud crust)			65	59	TxUU=315
							0.40				VS=850
5	T	P				Gray			56	64	TxUU=285
						Fat Clay (CH), gray, wet, medium stiff, high plasticity, no dilatancy, high toughness, high dry strength, (Bay Mud)	0.46				VS=675
	T	P		CH					74	54	
							0.43				VS=515
10	T	P							53	69	TxUU=415
						Soft	0.21				VS=390

Bottom of boring at 11 feet
Groundwater encountered at 4-inches during hand augering

Depth in Feet	Samples Type/ Recovery	Blow Count	Graphic	USCS	Water Levels	Date : 2/28/2020 Drilling Method : Hand Auger Elevation (Feet) : 7 Latitude : 37.96910 Longitude : -122.49686 Material Description	Torvane (tsf)	Pocket Pen (tsf)	Moisture Content (%)	Dry Density (pcf)	Other Laboratory Tests
	T	P		CH		Fat Clay with Sand (CH), brown, wet, stiff, high plasticity, no dilatancy, high toughness, high dry strength, occasional gravel, (Bay Mud crust)	0.39		77	52	TxUU=305 VS=320
5	T	P		CH		Fat Clay (CH), gray, wet, medium stiff, high plasticity, no dilatancy, high toughness, high dry strength, (Bay Mud)	0.24		74	55	TxUU=285 VS=390
	T	P					0.11		82	50	LL=95 PI=56 VS=180
10	T	P					0.15		81	51	VS=180

Bottom of boring at 12 feet
Groundwater encountered at 4-inches during hand augering

Restore Eroded and Diked Marsh
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Hultgren - Tillis Engineers

Project No. 923.01

Plate No. B-13

MAJOR DIVISIONS				GROUP NAMES
COARSE GRAINED SOILS MORE THAN 50% RETAINED ON NO. 200 SIEVE	GRAVELS MORE THAN 50% OF COARSE FRACTION IS RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS WITH LESS THAN 5% FINES	GW	WELL GRADED GRAVEL
			GP	POORLY GRADED GRAVEL
		GRAVELS WITH OVER 12% FINES	GM	SILTY GRAVEL
			GC	CLAYEY GRAVEL
	SANDS 50% OR MORE OF COARSE FRACTION PASSES NO. 4 SIEVE	CLEAN SANDS WITH LESS THAN 5% FINES	SW	WELL GRADED SAND
			SP	POORLY GRADED SAND
		SANDS WITH OVER 12% FINES	SM	SILTY SAND
			SC	CLAYEY SAND
FINE GRAINED SOILS 50% OR MORE PASSES NO. 200 SIEVE	SILTS AND CLAYS LIQUID LIMIT LESS THAN 50		ML	SILT
			CL	LEAN CLAY
			OL	ORGANIC CLAY, ORGANIC SILT
	SILTS AND CLAYS LIQUID LIMIT 50 OR MORE		MH	ELASTIC SILT
			CH	FAT CLAY
			OH	ORGANIC CLAY, ORGANIC SILT
HIGHLY ORGANIC SOILS			Pt	PEAT

UNIFIED SOIL CLASSIFICATION SYSTEM- ASTM D 2487

S	- SPT	▽	- Water Level at Time of Drilling	P	- Push
		▼	- Water Level after Drilling (with date measured)	Perm	- Permeability
M	- 2.5 inch	Consol	- Consolidation	Sieve	- Particle Size Analysis
		Gs	- Specific Gravity	VS	- Laboratory Vane Shear (psf)
C	- 3.0 inch	LL	- Liquid Limit (%)	-200	- % Passing No. 200 Sieve
		PI	- Plasticity Index (%)		
T	- Shelby Tube	TxUU	- Shear Strength (psf) - Unconsolidated Undrained Triaxial Shear		
		TxCU	- Shear Strength (psf) - Consolidated Undrained Triaxial Shear		
B	- Bag	UC	- Compressive Strength (psf) - Unconfined Compression		

KEY TO TEST DATA

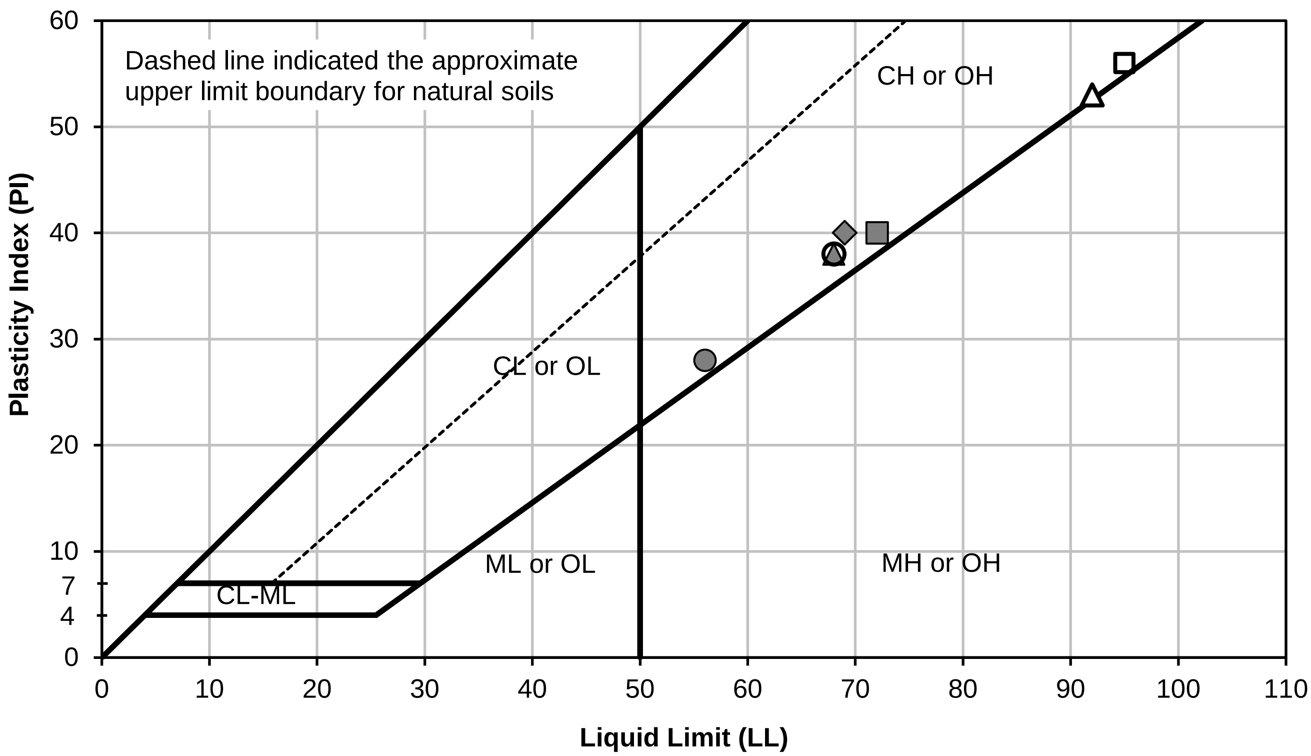
Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Soil Classification Chart

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. B-14

APPENDIX C

Laboratory Test Results

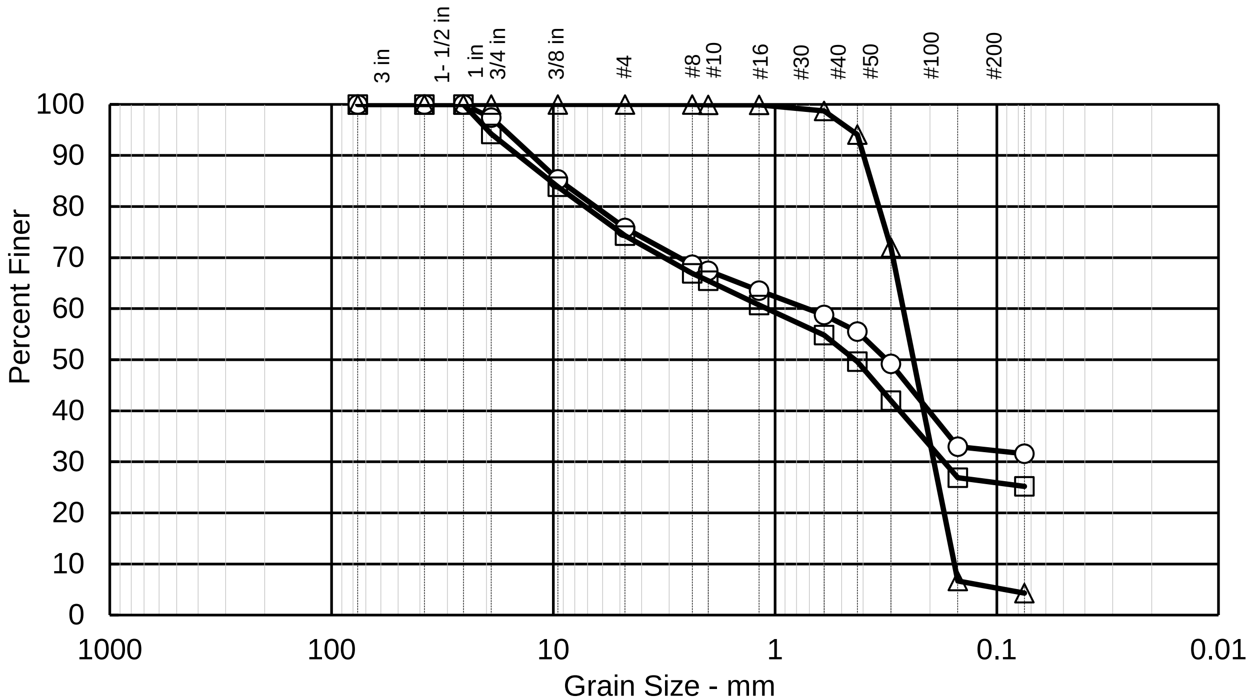


Symbol	Boring Number	Depth (feet)	Soil Description	LL (%)	PL (%)	PI (%)	Moisture Content (%)
● (shaded circle)	2	11	Dark Olive Gray Fat CLAY	56	28	28	61
▲ (shaded triangle)	3	20	Dark Olive Gray Fat CLAY	68	30	38	81
■ (shaded square)	4	25	Dark Olive Gray Fat CLAY	72	32	40	85
◆ (shaded diamond)	6	8.5	Dark Olive Brown Fat CLAY	69	29	40	90
○	6	15	Dark Olive Gray Fat CLAY	68	30	38	74
△	7	7	Gray Fat CLAY	92	39	53	63
□	10	8.5	Gray Fat CLAY	95	39	56	82

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Atterberg Limits

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. C-1



Sieve Size	○	□	△
	Percent Finer		
3 in	100.0	100.0	100.0
1-1/2 in	100.0	100.0	100.0
1 in	100.0	100.0	100.0
3/4 in	97.4	94.2	100.0
3/8 in	85.3	83.9	100.0
#4	75.8	74.3	100.0
#8	68.6	66.9	100.0
#10	67.4	65.5	99.9
#16	63.5	60.7	99.9
#30	58.8	54.8	98.7
#40	55.5	49.6	94.1
#50	49.2	42.0	72.0
#100	33.0	26.9	6.7
#200	31.6	25.2	4.3
	Grain Size		
D60	0.711	1.086	0.265
D30	-	0.181	0.199
D10	-	-	0.158
	Coefficients		
Cc	-	-	0.95
Cu	-	-	1.68

Soil Description	
○	Light yellowish brown silty SAND with gravel (SM)
□	Yellowish brown and olive silty SAND with gravel (SM)
△	Dark gray poorly graded SAND (SP)

Sample Key	
○	Boring 4 at 3.0 ft
□	Boring 5 at 6.0 ft
△	Boring 6 at 3.5 ft

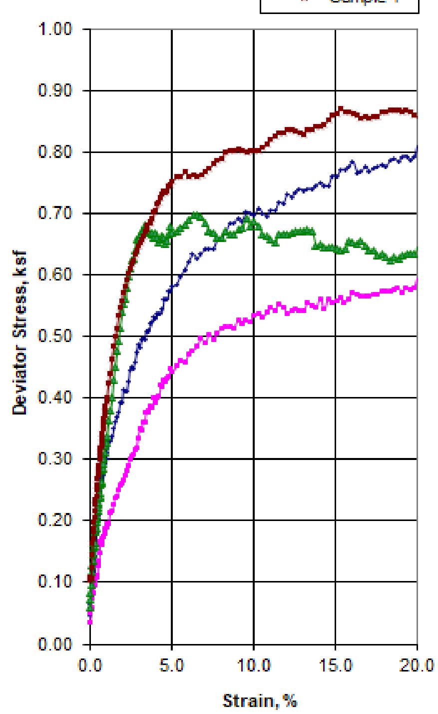
Testing performed by
B. Hillebrandt Soils Testing Inc.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Sieve Analysis Results

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. C-2

Unconsolidated-Undrained Triaxial Test
ASTM D2850



Sample Data	1	2	3	4
Moisture %	69.1	75.1	82.5	67.4
Dry Den,pcf	58.3	55.4	52.0	59.0
Void Ratio	1.891	2.043	2.239	1.857
Saturation %	98.6	99.2	99.5	98.0
Height in	5.97	5.96	5.96	5.97
Diameter in	2.85	2.86	2.87	2.85
Cell psi	2.4	3.5	5.1	6.5
Strain %	15.00	15.00	6.56	15.00
Deviator, ksf	0.761	0.554	0.698	0.860
Rate %/min	1.00	1.00	1.00	1.00
in/min	0.060	0.059	0.060	0.060
Job No.:	212-180a			
Client:	Hultgren-Tillis Engineers			
Project:	923.01			
Boring:	B3	B3	B3	B3
Sample:				
Depth ft:	7.5	10-12.5	20(Tip-4")	30(Tip-3")

Visual Soil Description

Sample #	
1	Dark olive gray fat CLAY
2	Dark olive gray fat CLAY
3	Dark olive gray fat CLAY
4	Dark olive gray fat CLAY

Remarks:

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

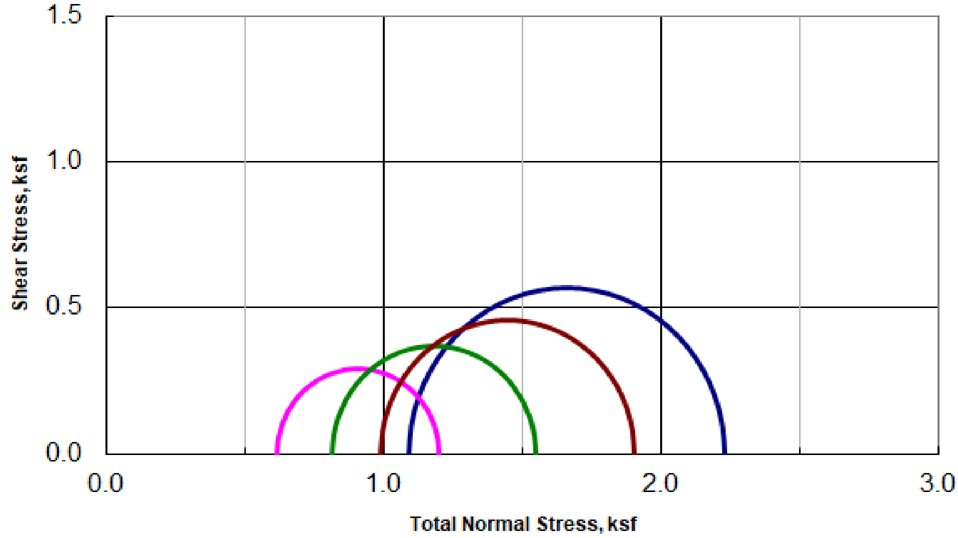
Testing performed by Cooper Testing Laboratory

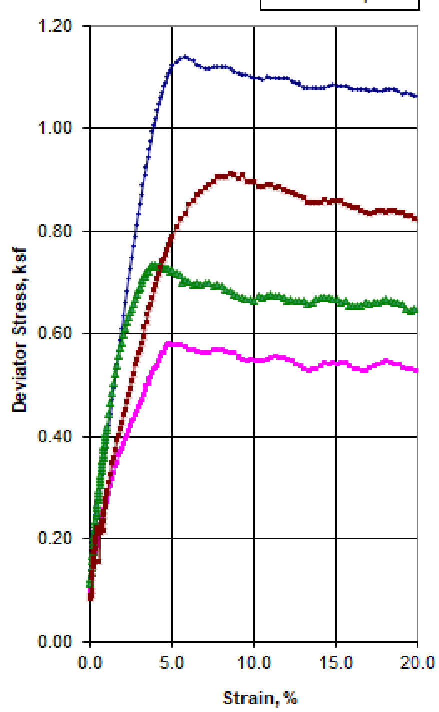
Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Triaxial (UU) Test Results

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. C-3

Unconsolidated-Undrained Triaxial Test
ASTM D2850





Sample Data	1	2	3	4
Moisture %	94.6	79.2	81.9	72.7
Dry Den,pcf	46.6	53.6	52.2	56.7
Void Ratio	2.613	2.145	2.229	1.971
Saturation %	97.7	99.7	99.2	99.6
Height in	5.91	5.97	5.98	5.95
Diameter in	2.85	2.87	2.85	2.87
Cell psi	7.6	4.3	5.7	6.9
Strain %	5.80	4.84	4.34	8.55
Deviator, ksf	1.139	0.581	0.731	0.912
Rate %/min	1.00	1.00	1.00	1.00
in/min	0.059	0.060	0.060	0.059
Job No.:	212-180b			
Client:	Hultgren-Tillis Engineers			
Project:	923.01			
Boring:	B3	B4	B4	B4
Sample:				
Depth ft:	40	15	25(Tip-4")	35

Visual Soil Description

Sample #	
1	Dark olive gray fat CLAY
2	Dark olive gray fat CLAY
3	Dark olive gray fat CLAY
4	Dark olive gray fat CLAY

Remarks:

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

Testing performed by Cooper Testing Laboratory

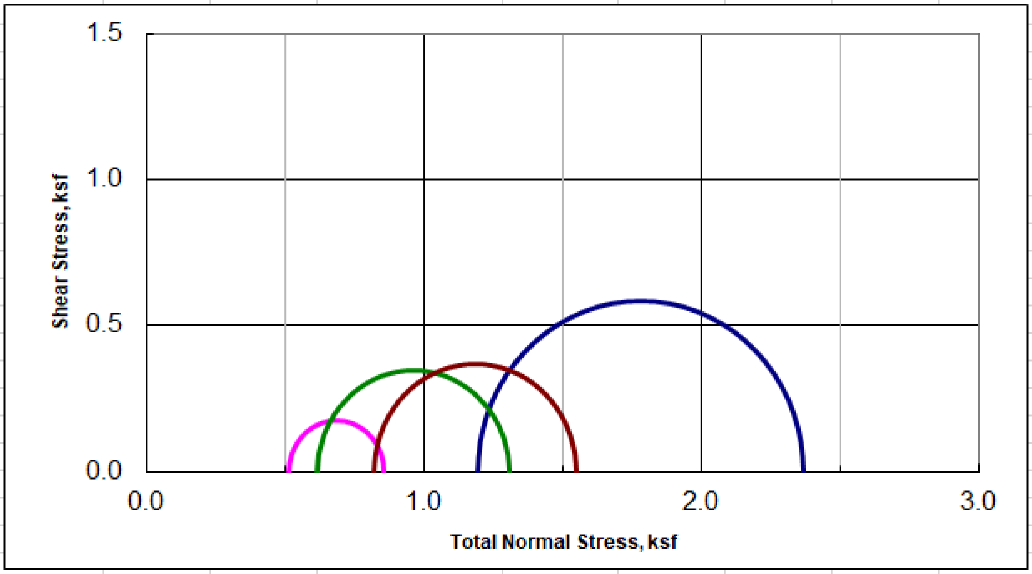
Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

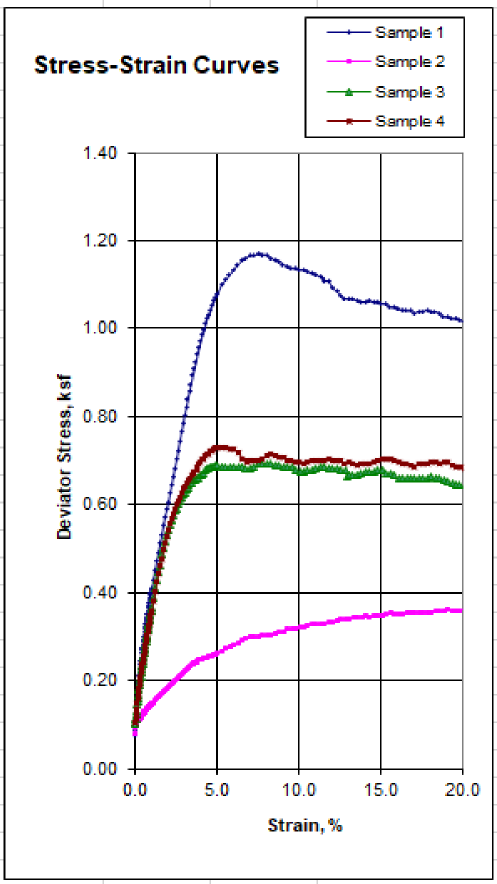
Triaxial (UU) Test Results

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. C-4

COOPER TESTING LABORATORY

Unconsolidated-Undrained Triaxial Test
ASTM D2850





Sample Data				
	1	2	3	4
Moisture %	73.4	79.6	77.9	78.8
Dry Den,pcf	56.4	53.2	54.0	53.6
Void Ratio	1.987	2.169	2.120	2.145
Saturation %	99.7	99.1	99.2	99.2
Height in	5.96	5.91	5.94	5.96
Diameter in	2.84	2.85	2.87	2.85
Cell psi	8.3	3.6	4.3	5.7
Strain %	7.55	15.00	8.30	5.30
Deviator, ksf	1.170	0.348	0.694	0.731
Rate %/min	1.00	1.00	1.00	1.00
in/min	0.060	0.059	0.059	0.060
Job No.:	212-180c			
Client:	Hultgren-Tillis Engineers			
Project:	923.01			
Boring:	B4	B6	B6	B6
Sample:				
Depth ft:	45(Tip-7")	10	15(Tip-4")	25

Visual Soil Description	
Sample #	
1	Dark olive gray fat CLAY
2	Dark olive gray fat CLAY
3	Dark olive gray fat CLAY
4	Dark olive gray fat CLAY

Remarks:

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

Testing performed by Cooper Testing Laboratory

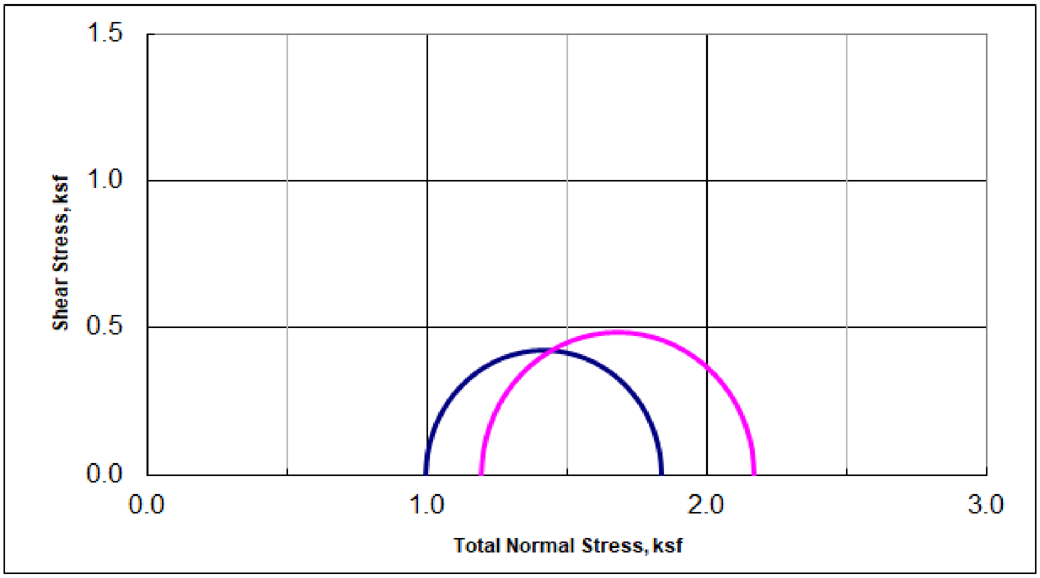
Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

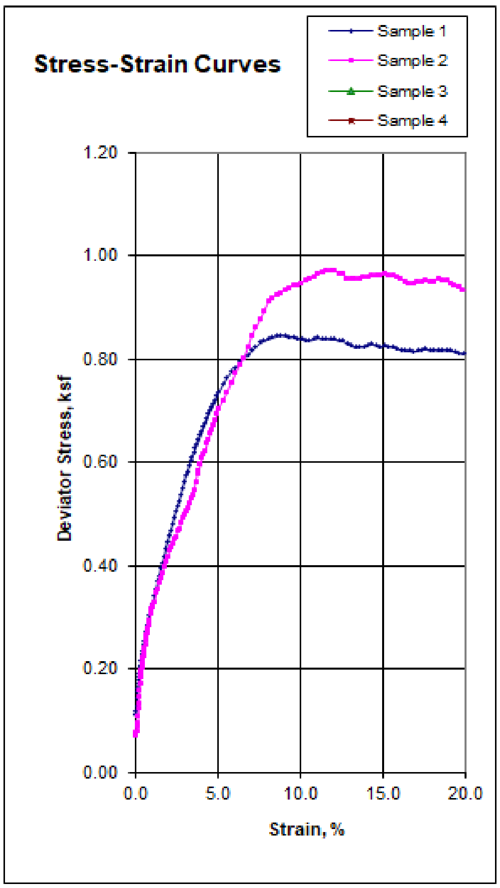
Triaxial (UU) Test Results

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. C-5

COOPER TESTING LABORATORY

Unconsolidated-Undrained Triaxial Test
ASTM D2850





Sample Data	1	2	3	4
Moisture %	72.3	64.0		
Dry Den,pcf	56.9	61.4		
Void Ratio	1.960	1.743		
Saturation %	99.5	99.1		
Height in	5.93	5.95		
Diameter in	2.87	2.85		
Cell psi	6.9	8.3		
Strain %	8.82	12.08		
Deviator, ksf	0.847	0.971		
Rate %/min	1.00	1.00		
in/min	0.059	0.060		
Job No.:	212-180d			
Client:	Hultgren-Tillis Engineers			
Project:	923			
Boring:	B6	B6		
Sample:				
Depth ft:	35	45		

Visual Soil Description

Sample #	
1	Dark olive gray fat CLAY
2	Dark olive gray fat CLAY
3	
4	

Remarks:

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

Testing performed by Cooper Testing Laboratory

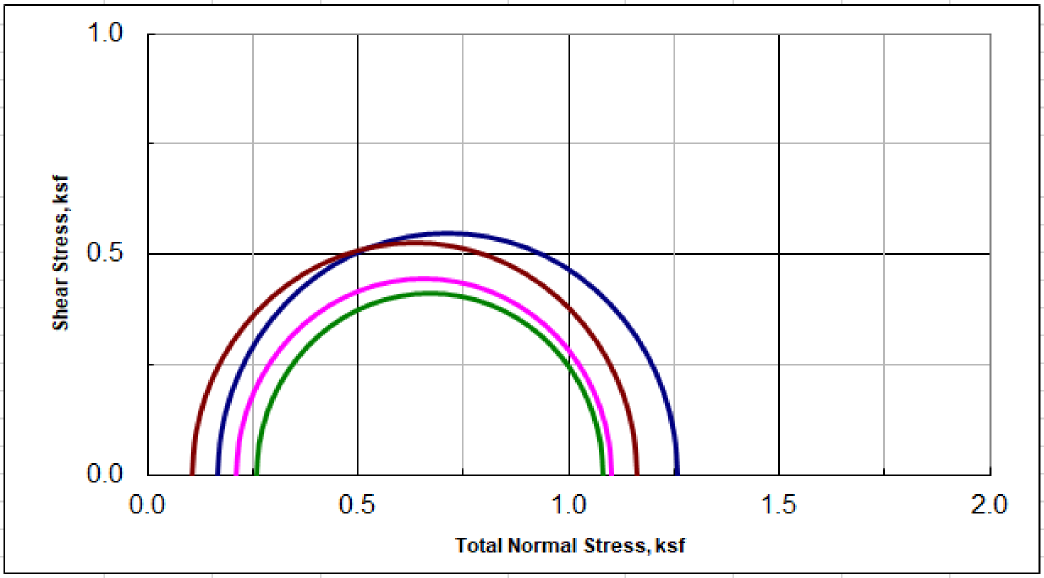
Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

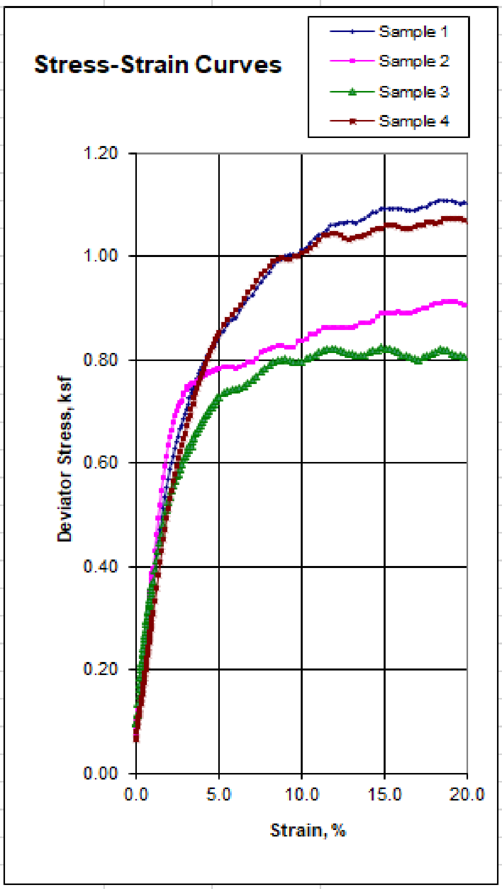
Triaxial (UU) Test Results

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. C-6

COOPER TESTING LABORATORY

Unconsolidated-Undrained Triaxial Test
ASTM D2850





Sample Data	1	2	3	4
Moisture %	53.0	60.1	74.1	64.2
Dry Den,pcf	67.0	62.0	56.0	60.4
Void Ratio	1.517	1.720	2.010	1.789
Saturation %	94.4	94.4	99.5	96.8
Height in	5.92	5.97	5.98	5.99
Diameter in	2.86	2.85	2.86	2.85
Cell psi	1.2	1.5	1.8	0.8
Strain %	15.00	15.00	14.84	15.00
Deviator, ksf	1.093	0.890	0.823	1.053
Rate %/min	1.00	1.00	1.00	1.00
in/min	0.059	0.060	0.060	0.060
Job No.:	212-182a			
Client:	Hultgren-Tillis Engineers			
Project:	923.01			
Boring:	B7	B7	B7	B8
Sample:				
Depth ft:	1-3.5	3.5-6(Tip-3")	7.5-10	0-2(Tip-3")

Visual Soil Description

Sample #	
1	Brown Fat CLAY w/ Sand
2	Olive Brown Fat CLAY /w Sand
3	Gray Fat CLAY
4	Brown Fat CLAY w/ Sand

Remarks:

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

Testing performed by Cooper Testing Laboratory

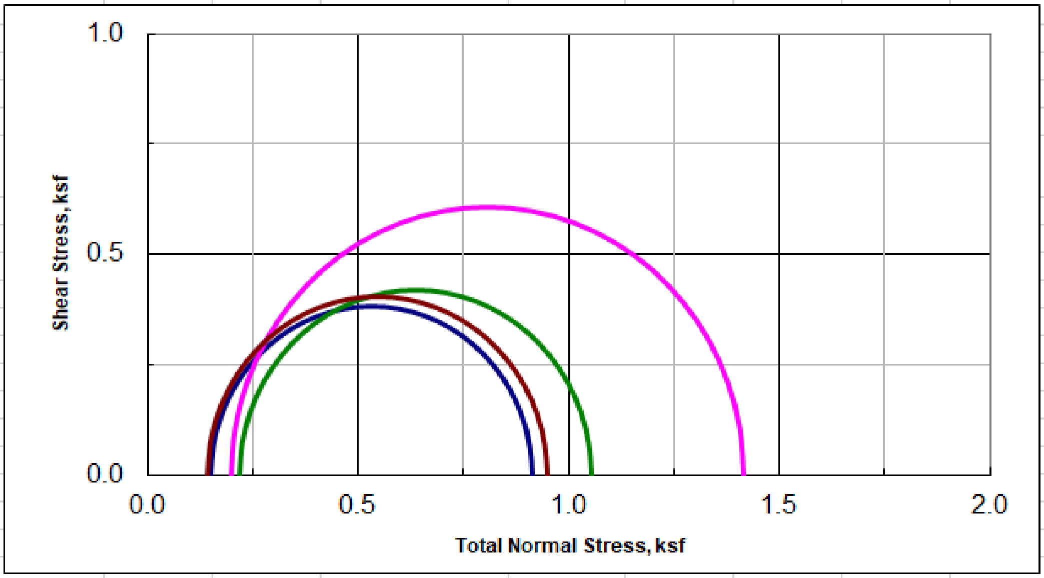
Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

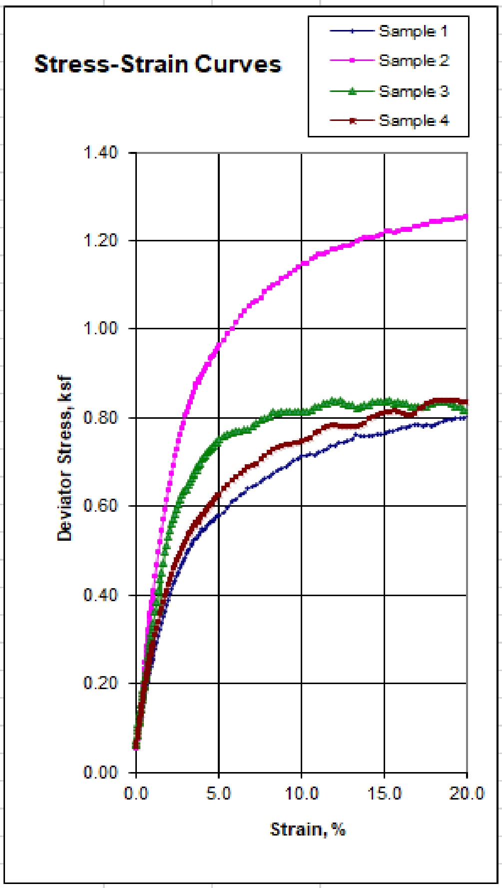
Triaxial (UU) Test Results

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. C-7

COOPER TESTING LABORATORY

Unconsolidated-Undrained Triaxial Test
ASTM D2850





Sample Data	1	2	3	4
Moisture %	57.6	36.1	85.8	65.1
Dry Den,pcf	63.4	77.7	50.7	59.1
Void Ratio	1.658	1.168	2.326	1.853
Saturation %	93.8	83.5	99.6	94.9
Height in	6.00	5.96	5.96	6.00
Diameter in	2.85	2.84	2.85	2.87
Cell psi	1.0	1.4	1.5	1.0
Strain %	15.00	15.00	15.00	15.00
Deviator, ksf	0.762	1.216	0.837	0.811
Rate %/min	1.00	1.00	1.00	1.00
in/min	0.060	0.060	0.060	0.060
Job No.:	212-182b			
Client:	Hultgren-Tillis Engineers			
Project:	923.01			
Boring:	B8	B8	B8	B9
Sample:				
Depth ft:	2-4.5(Tip-2")	4.5-6.5(Tip-2")	6.5-9	1-3.5(Tip-2")

Visual Soil Description

Sample #	
1	Brown Fat CLAY w/ Sand
2	Gray Fat CLAY w/ Sand
3	Gray Fat CLAY
4	Brown Fat CLAY w/ Sand

Remarks:

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

Testing performed by Cooper Testing Laboratory

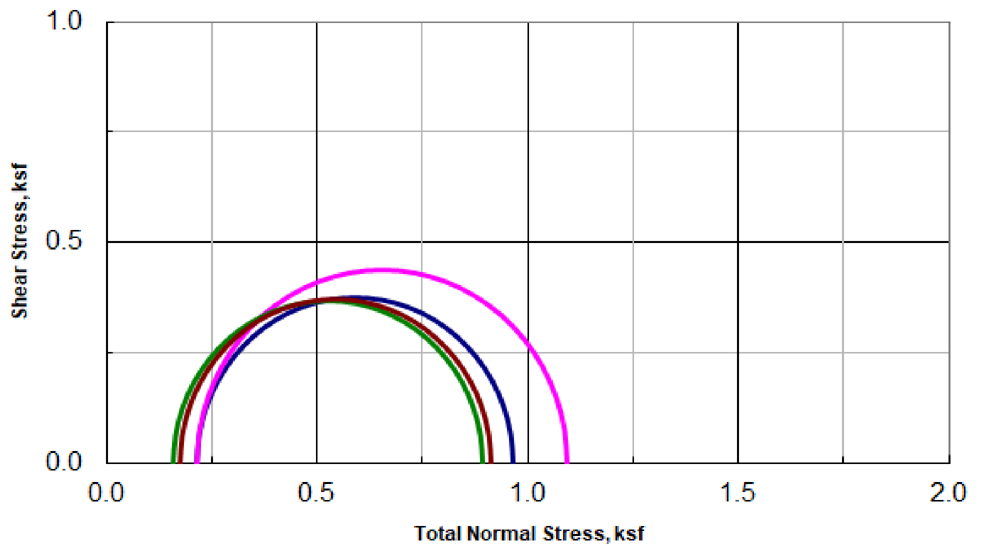
Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

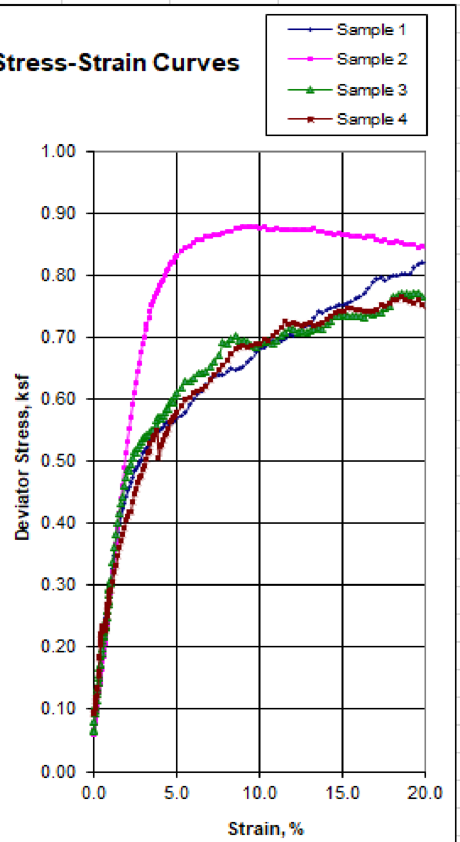
Triaxial (UU) Test Results

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. C-8

COOPER TESTING LABORATORY

Unconsolidated-Undrained Triaxial Test
ASTM D2850





Sample Data	1	2	3	4
Moisture %	55.6	53.4	76.5	73.9
Dry Den,pcf	63.9	69.0	51.9	55.3
Void Ratio	1.636	1.443	2.245	2.047
Saturation %	91.8	99.9	92.0	97.5
Height in	6.00	5.96	6.00	6.00
Diameter in	2.86	2.86	2.85	2.85
Cell psi	1.5	1.5	1.1	1.2
Strain %	15.00	10.30	15.00	15.00
Deviator, ksf	0.751	0.878	0.735	0.742
Rate %/min	1.00	1.00	1.00	1.00
in/min	0.060	0.060	0.060	0.060
Job No.:	212-182c			
Client:	Hultgren-Tillis Engineers			
Project:	923.01			
Boring:	B9	B9	B10	B10
Sample:				
Depth ft:	3.5-6(Tip-2")	8.5-11(Tip-3")	1-3.5(Tip-5")	5-7

Visual Soil Description	
Sample #	
1	Gray Fat CLAY w/ Sand
2	Gray Fat CLAY
3	Brown Fat CLAY w/ Sand
4	Gray Fat CLAY

Remarks:

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

Testing performed by Cooper Testing Laboratory

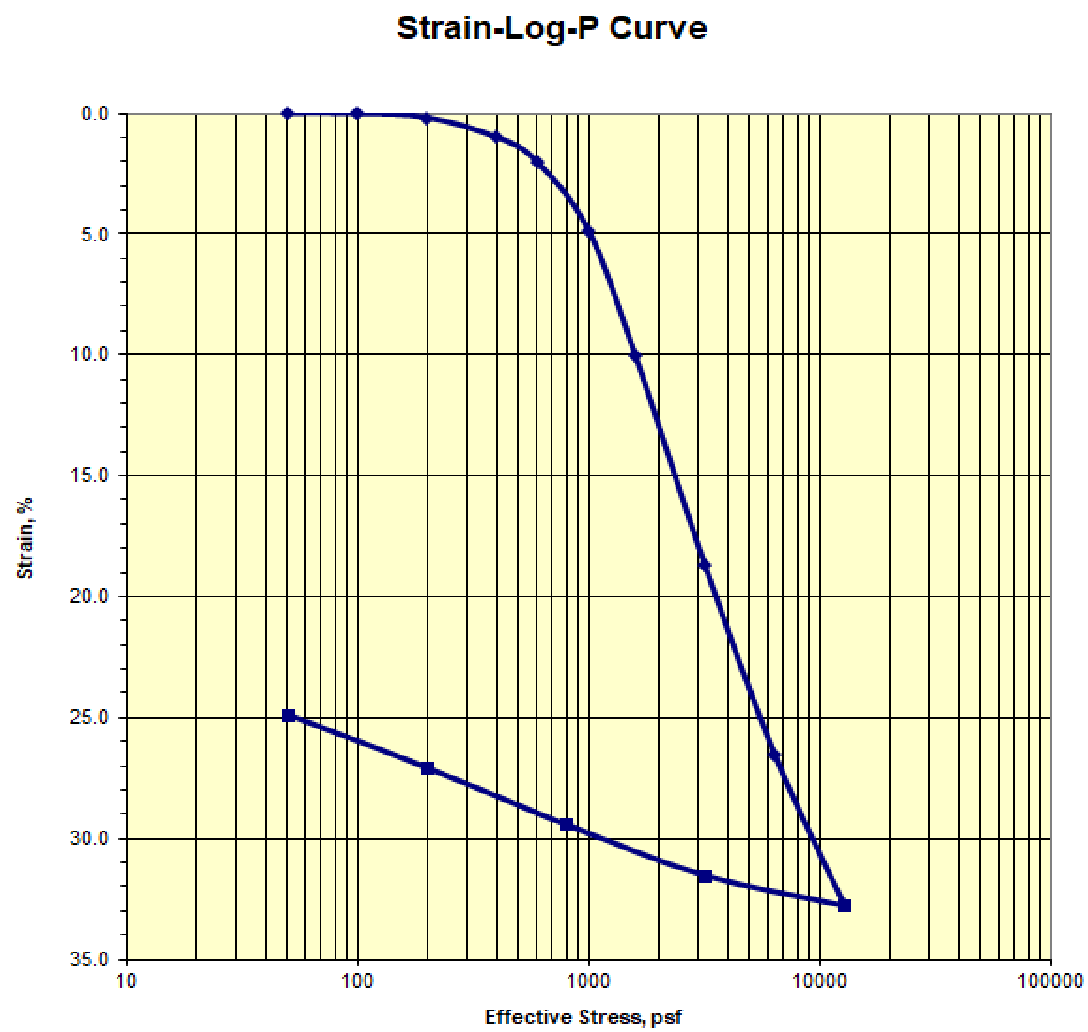
Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Triaxial (UU) Test Results

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. C-9

Consolidation Test
ASTM D2435

Job No.:	212-180	**Boring:**	B3	**Run By:**	MD
Client:	Hultgren-Tillis Engineers	**Sample:**		**Reduced:**	PJ
Project:	923-01	**Depth, ft.:**	20(Tip-3")	**Checked:**	PJ/DC
Soil Type:				**Date:**	12/19/2019



Assumed Gs 2.6	**Initial**	**Final**
Moisture %:	80.5	50.9
Dry Density, pcf:	52.3	69.8
Void Ratio:	2.101	1.325
% Saturation:	99.7	100.0

Remarks:

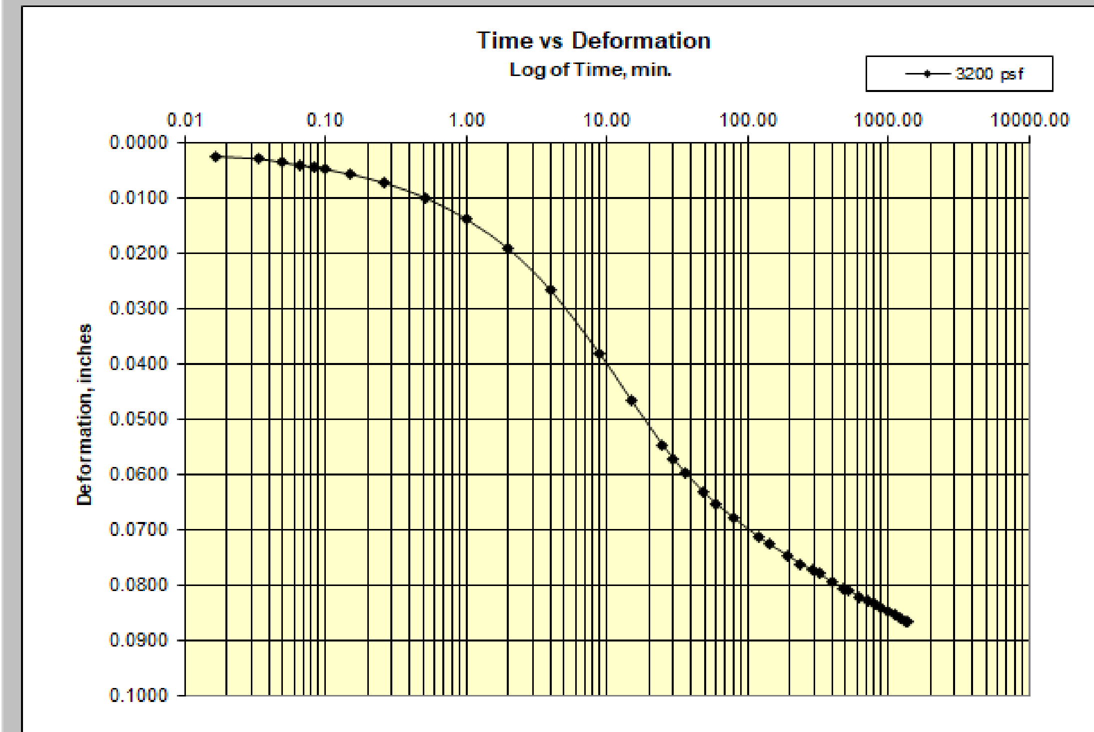
Testing performed by Cooper Testing Laboratory

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

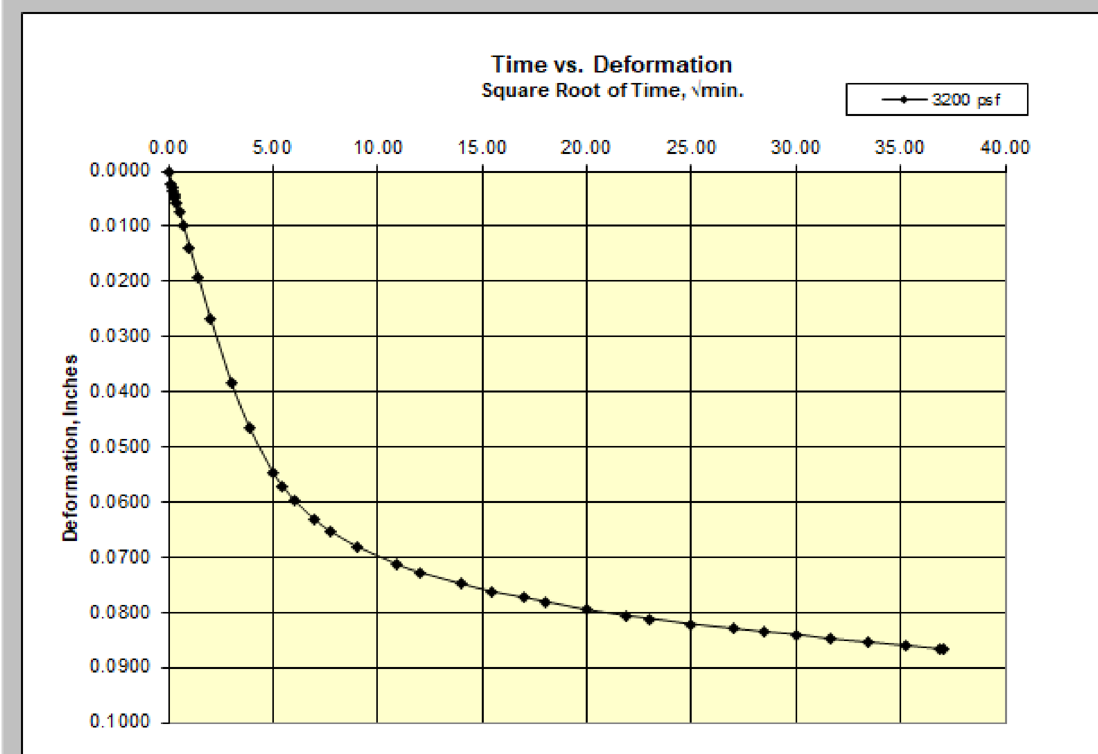
Consolidation Test Results

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. C-10

Load 8 3200 psf



3200 psf



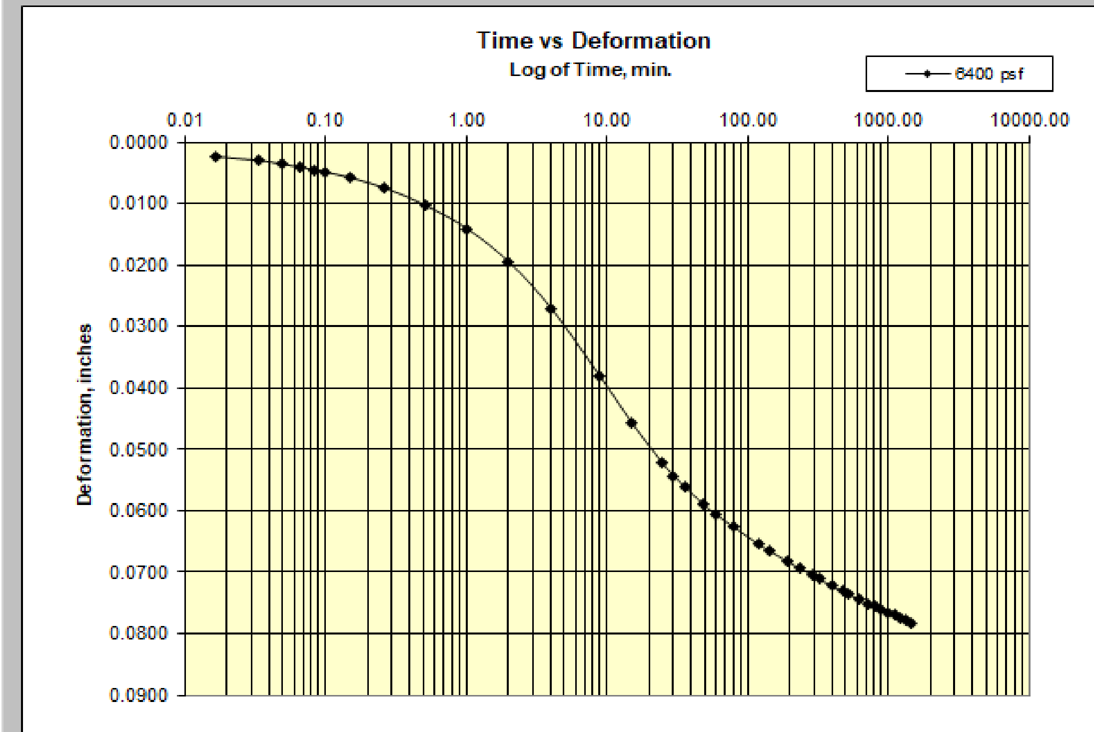
Testing performed by Cooper Testing Laboratory

Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Consolidation Time-Rate Plots**

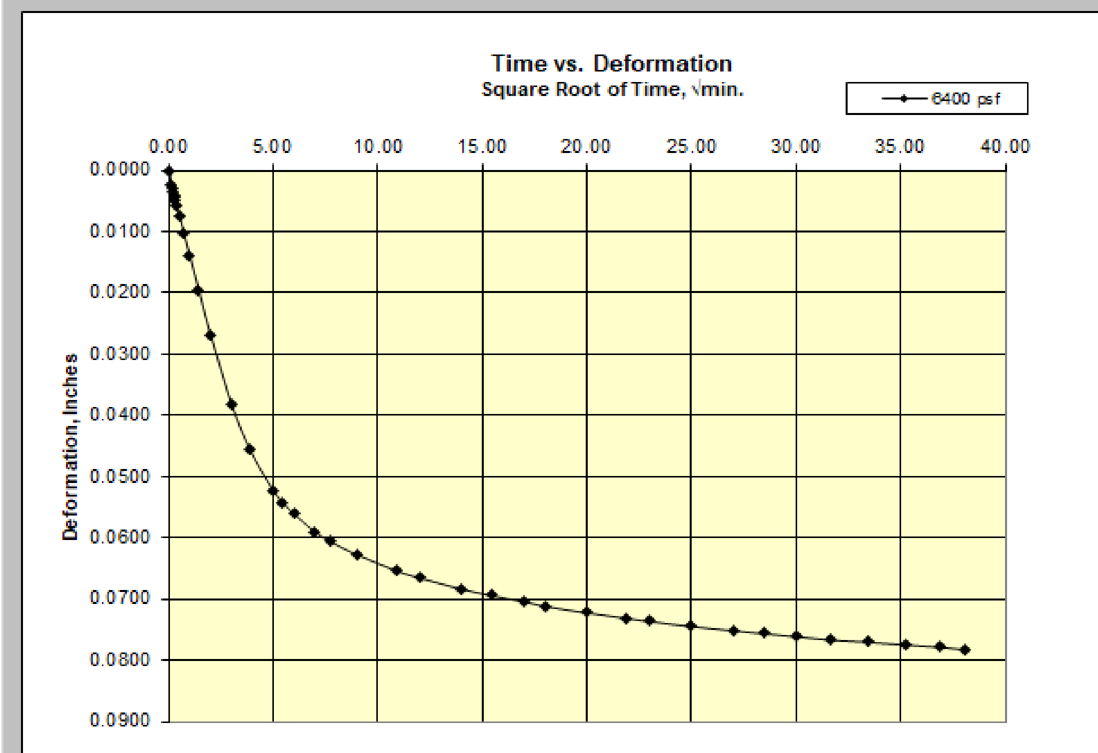
Hultgren - Tillis Engineers	Project No. 923.01	Plate No. C-11

Load 9

6400 psf



6400 psf

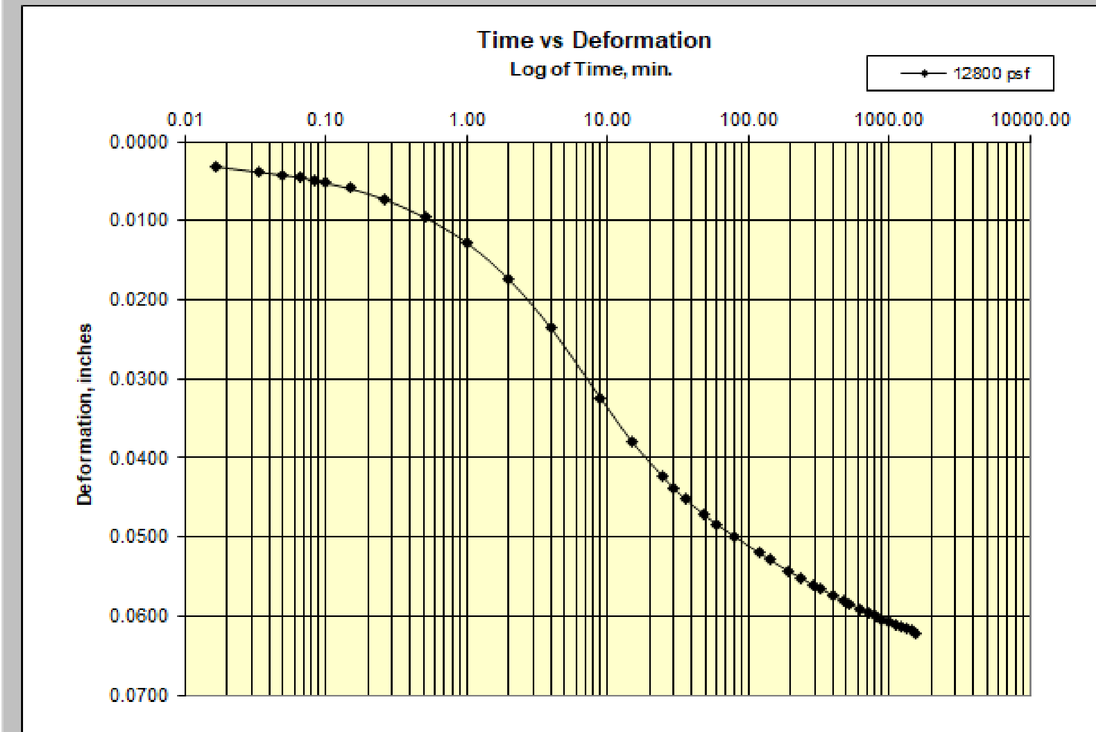


Testing performed by Cooper Testing Laboratory

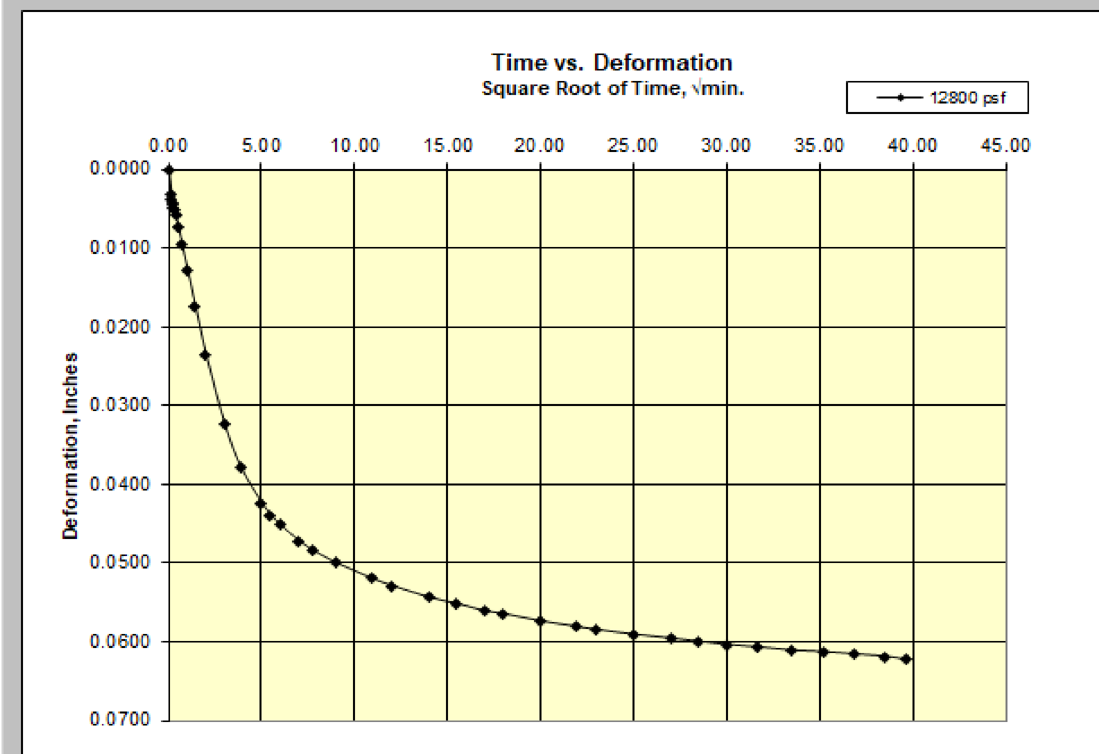
Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Consolidation Time-Rate Plots**

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. C-12

Load 10 | 12800 psf



12800 psf



Testing performed by Cooper Testing Laboratory

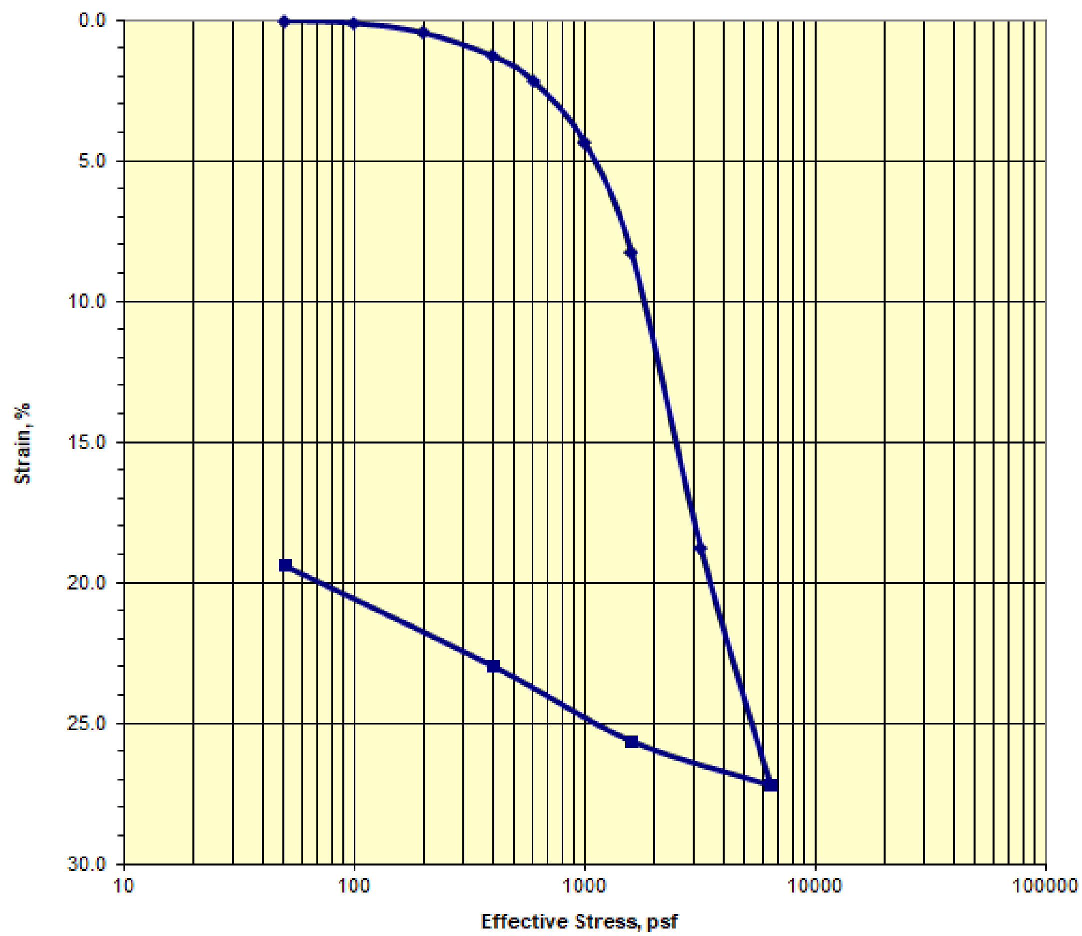
Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Consolidation Time-Rate Plots**

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. C-13

Consolidation Test
ASTM D2435

Job No.:	212-180	Boring:	B4	Run By:	MD
Client:	Hultgren-Tillis Engineers	Sample:		Reduced:	PJ
Project:	923-01	Depth, ft.:	25(Tip-3")	Checked:	PJ/DC
Soil Type:				Date:	12/19/2019

Strain-Log-P Curve



Assumed Gs	2.75	Initial	Final
Moisture %:		85.2	61.6
Dry Density, pcf:		51.4	63.7
Void Ratio:		2.343	1.694
% Saturation:		99.9	100.0

Remarks:

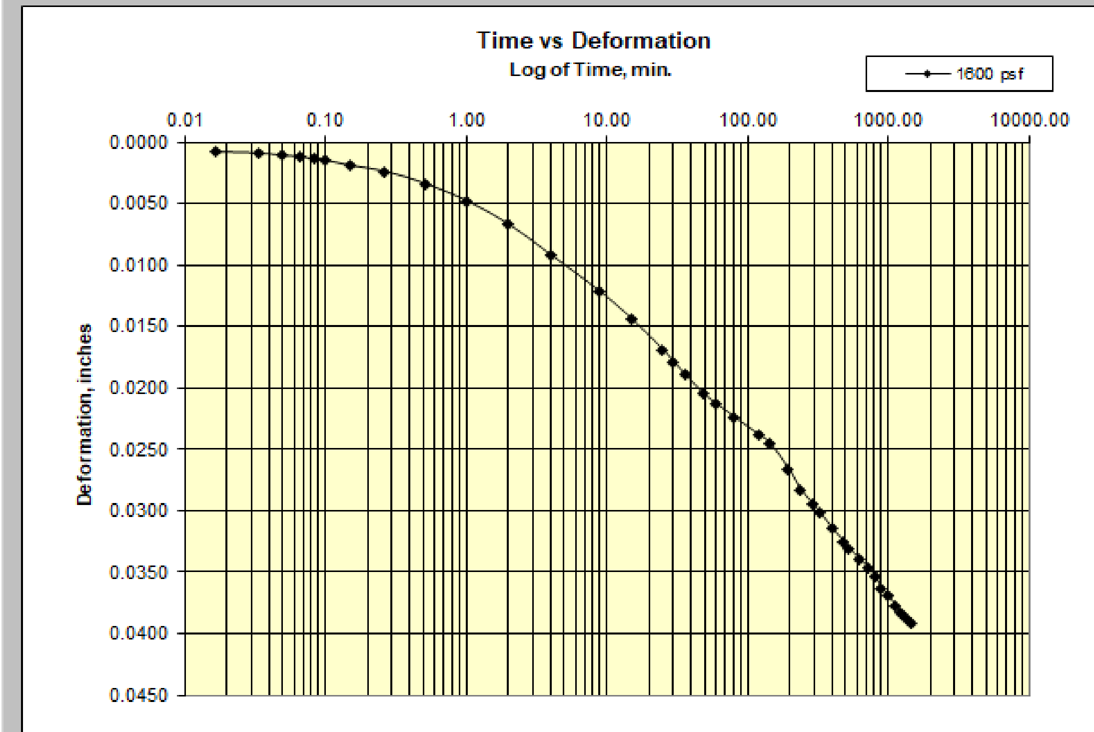
Testing performed by Cooper Testing Laboratory

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

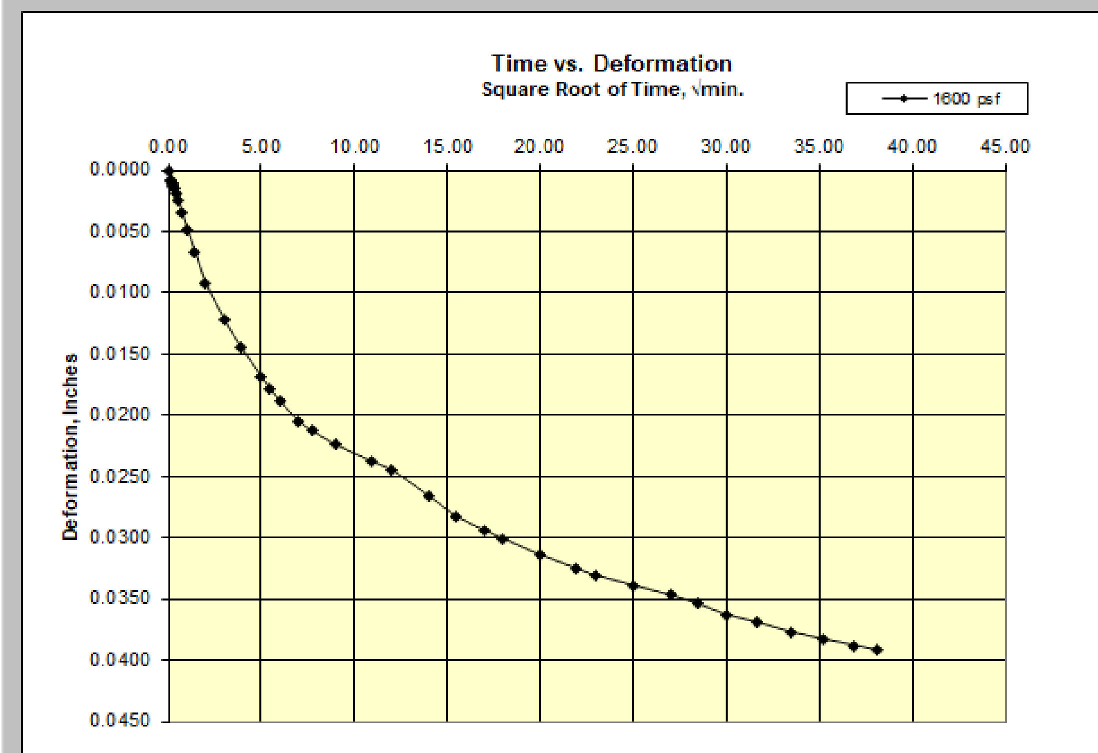
Consolidation Test Results

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. C-14

Load 7 1600 psf



1600 psf

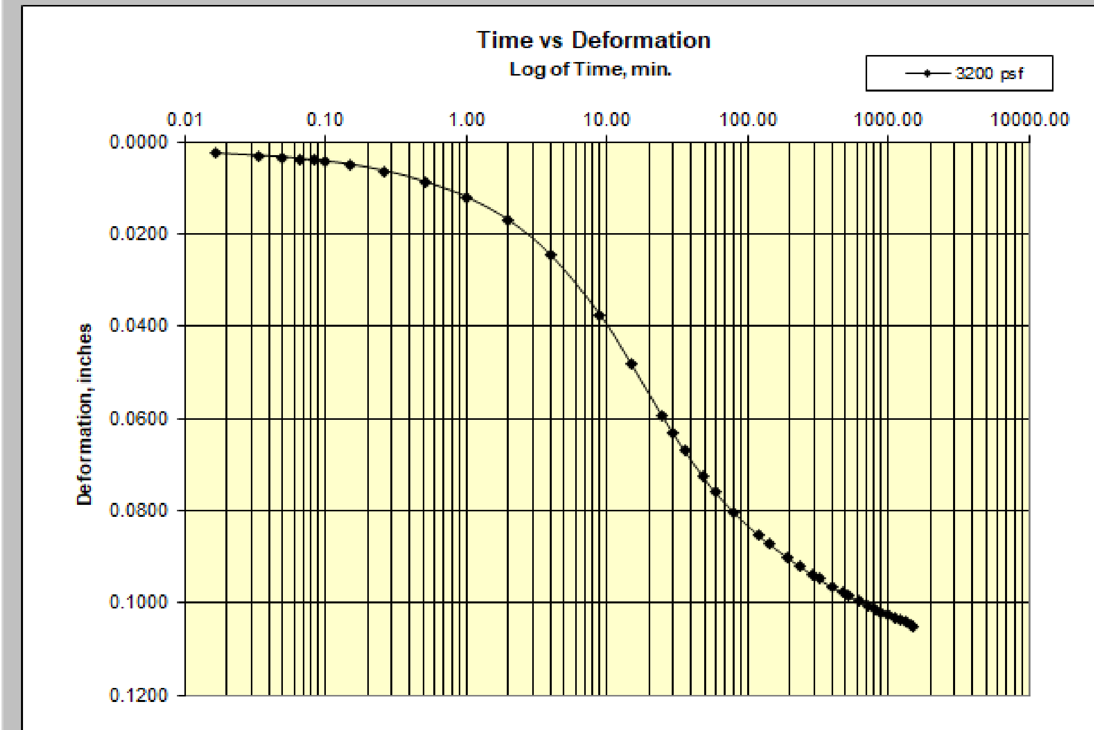


Testing performed by Cooper Testing Laboratory

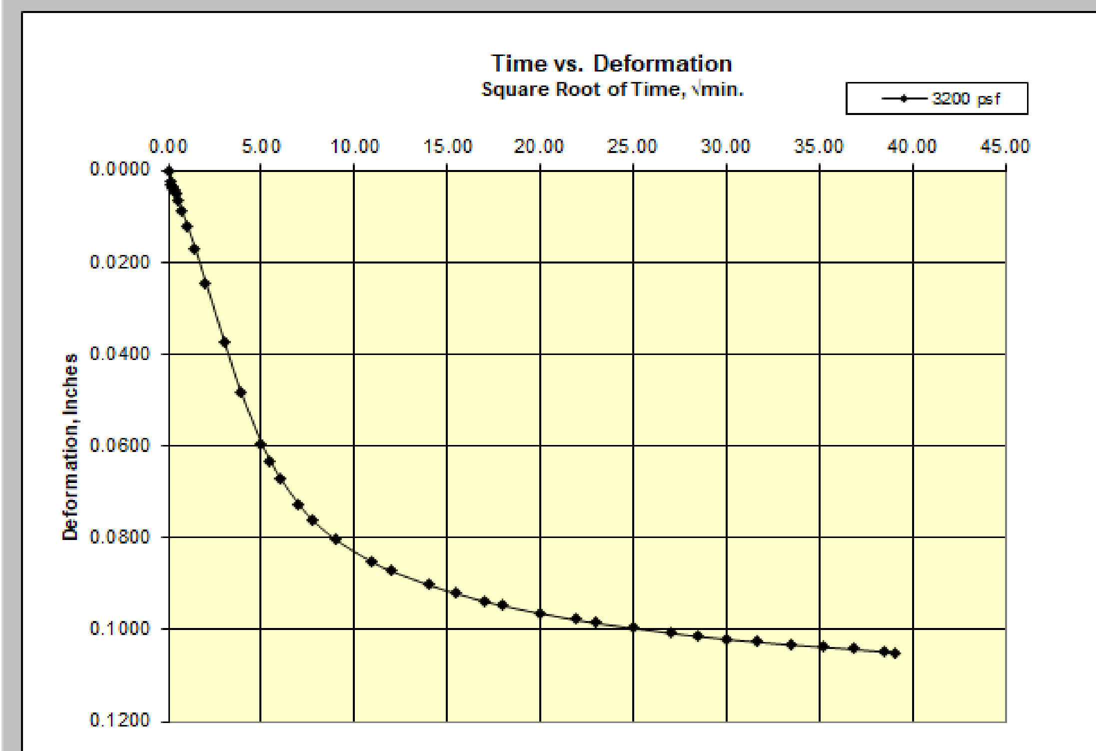
Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Consolidation Time-Rate Plots**

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. C-15

Load 8 3200 psf



3200 psf



Testing performed by Cooper Testing Laboratory

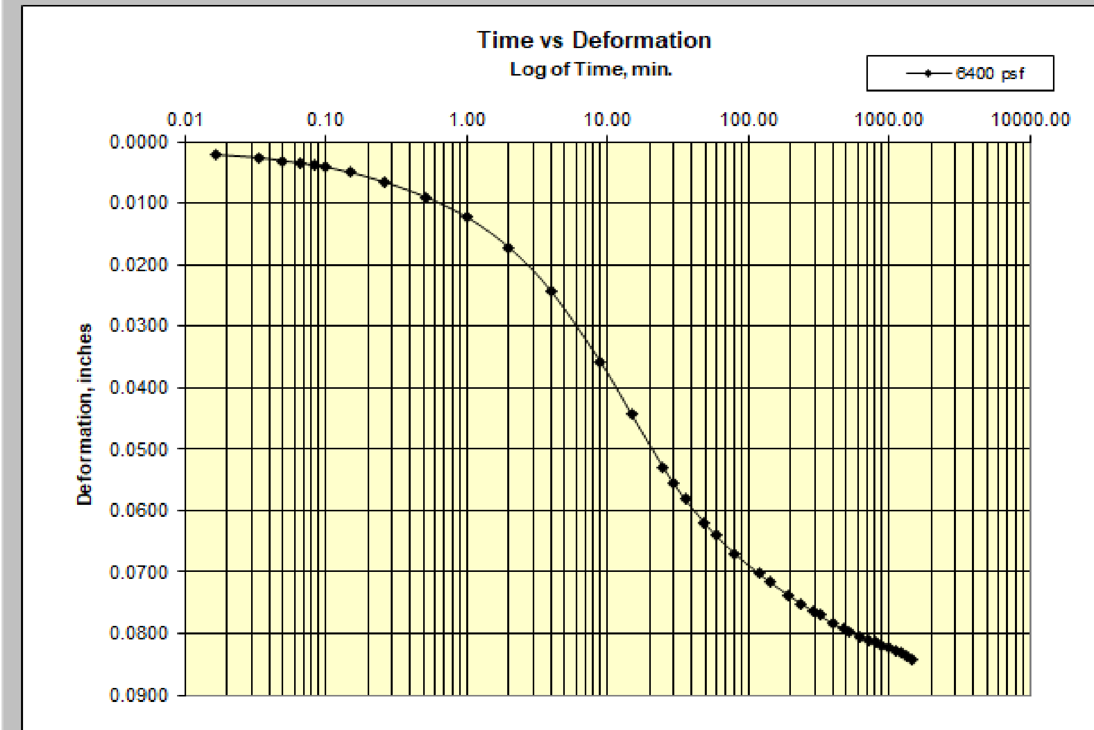
Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Consolidation Time-Rate Plots

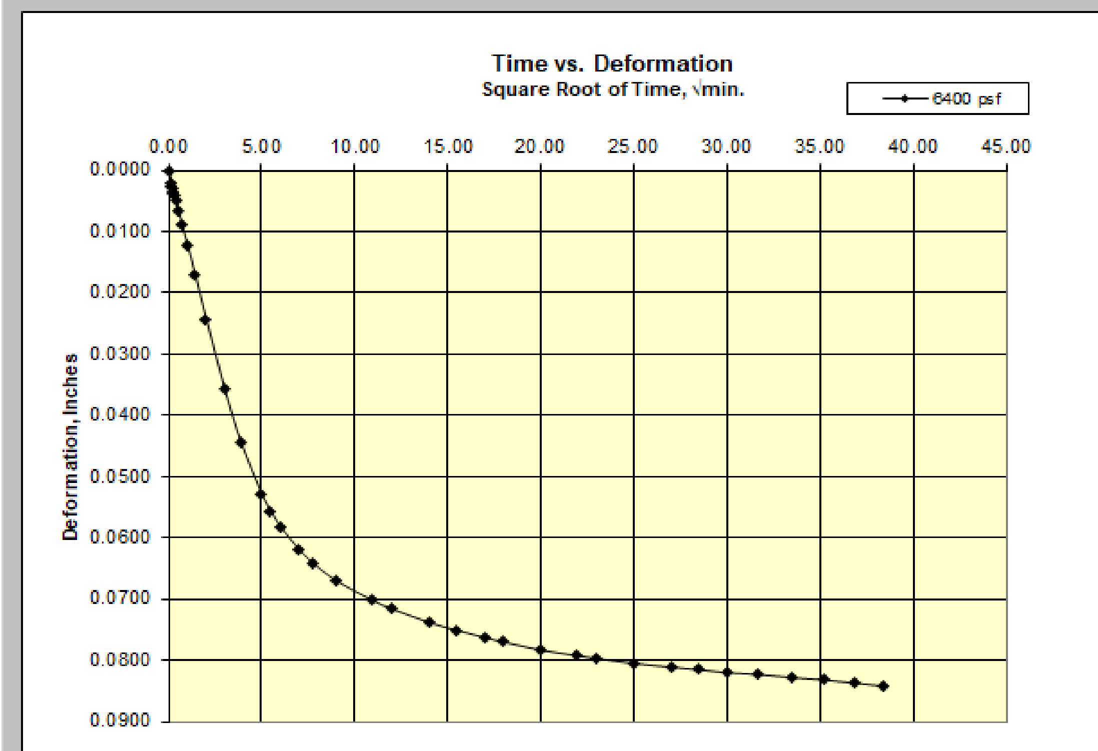
Hultgren - Tillis Engineers	Project No. 923.01	Plate No. C-16

Load 9

6400 psf



6400 psf



Testing performed by Cooper Testing Laboratory

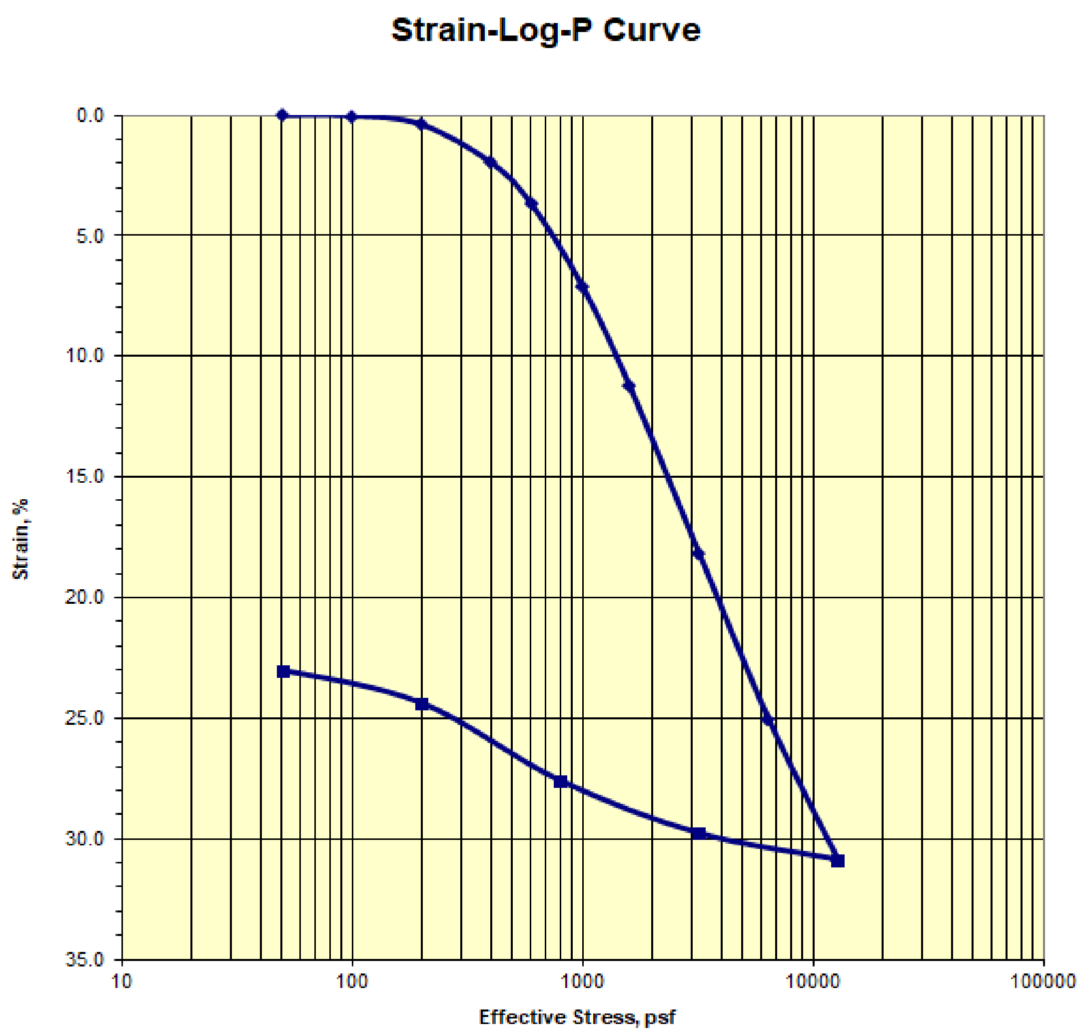
Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Consolidation Time-Rate Plots

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. C-17

Consolidation Test
ASTM D2435

Job No.:	212-180	Boring:	B6	Run By:	MD
Client:	Hultgren-Tillis Engineers	Sample:		Reduced:	PJ
Project:	923-01	Depth, ft.:	15(Tip-3")	Checked:	PJ/DC
Soil Type:				Date:	12/19/2019



Assumed Gs	2.65	Initial	Final
Moisture %:		74.0	48.6
Dry Density, pcf:		55.7	72.3
Void Ratio:		1.968	1.288
% Saturation:		99.6	100.0

Remarks:

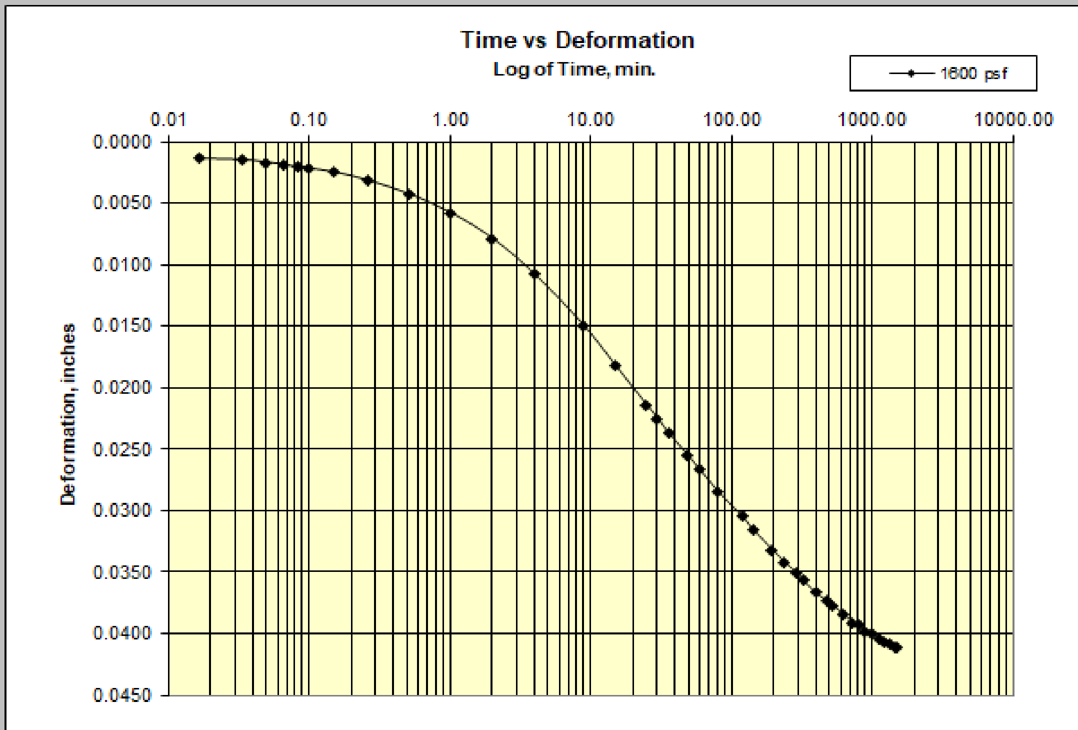
Testing performed by Cooper Testing Laboratory

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

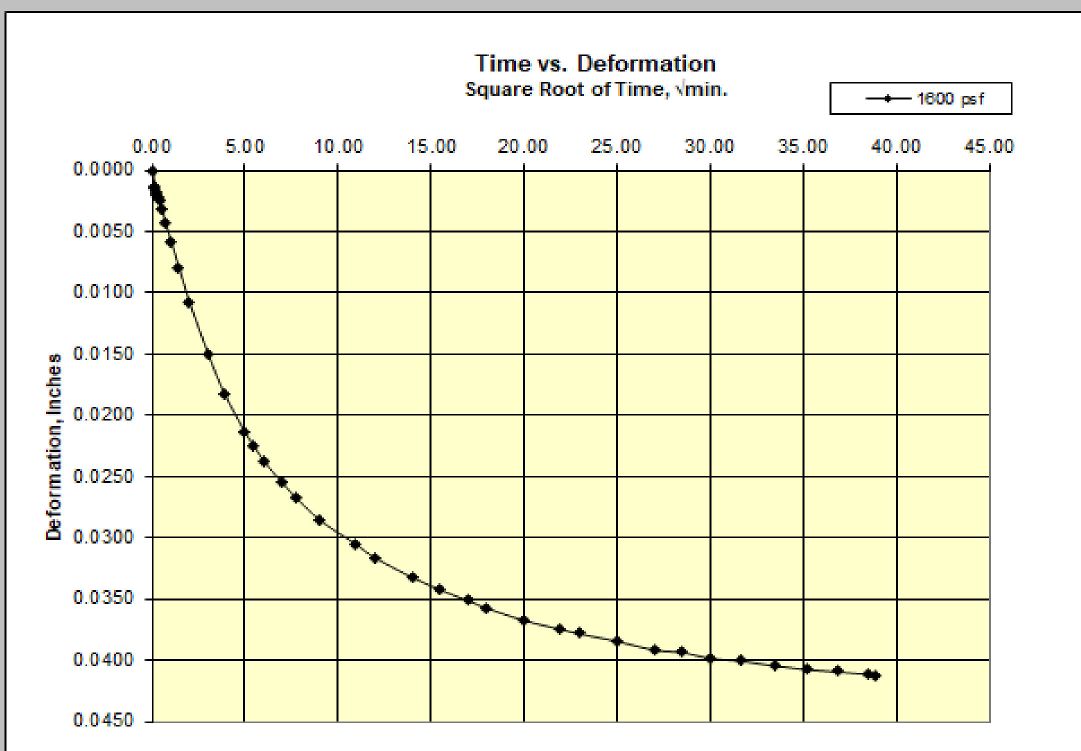
Consolidation Test Results

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. C-18

Load 7 1600 psf



1600 psf



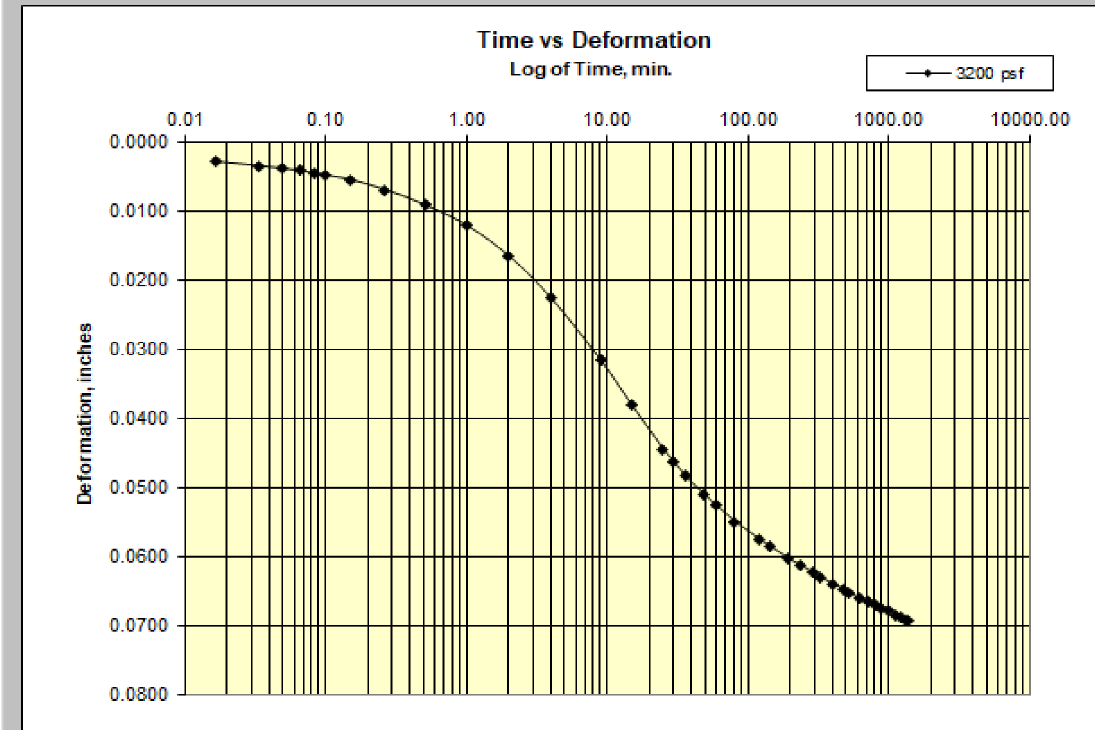
Testing performed by Cooper Testing Laboratory

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

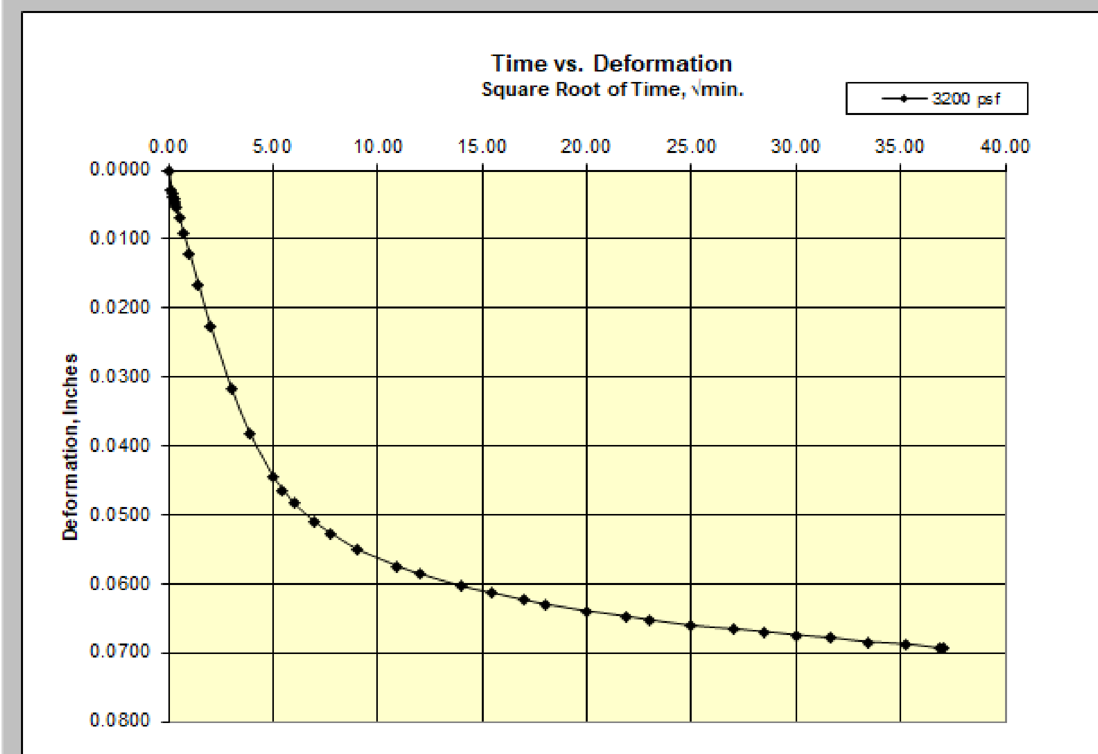
Consolidation Time-Rate Plots

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. C-19

Load 8 3200 psf



3200 psf

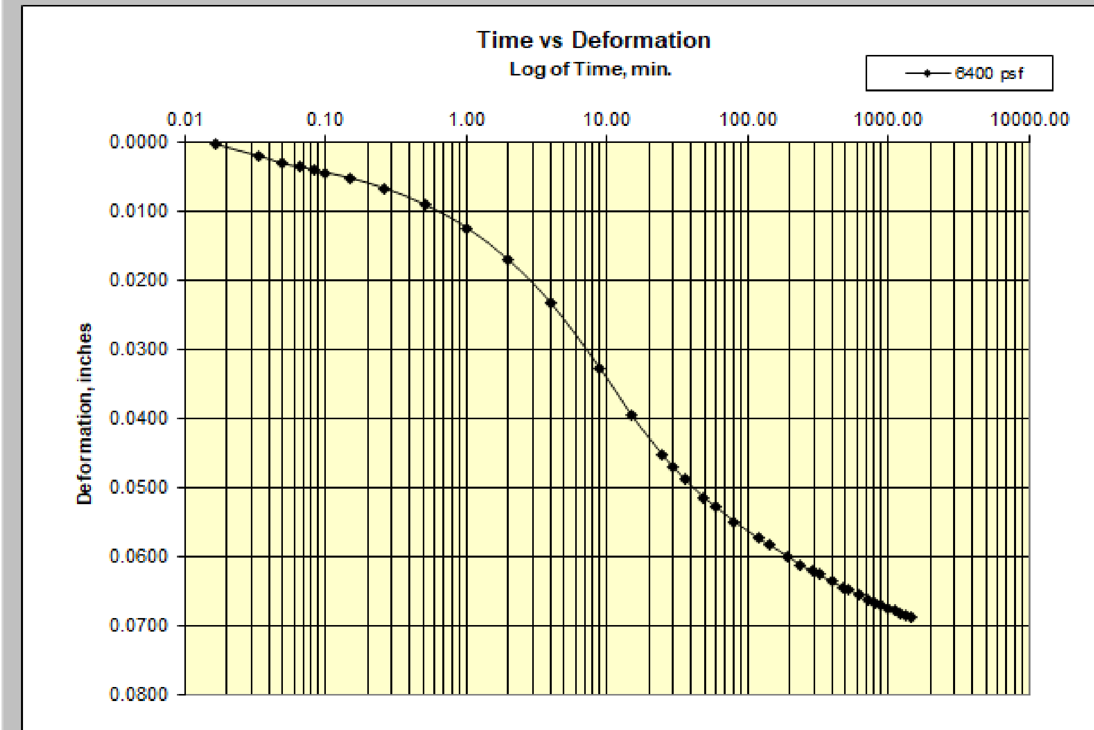


Testing performed by Cooper Testing Laboratory

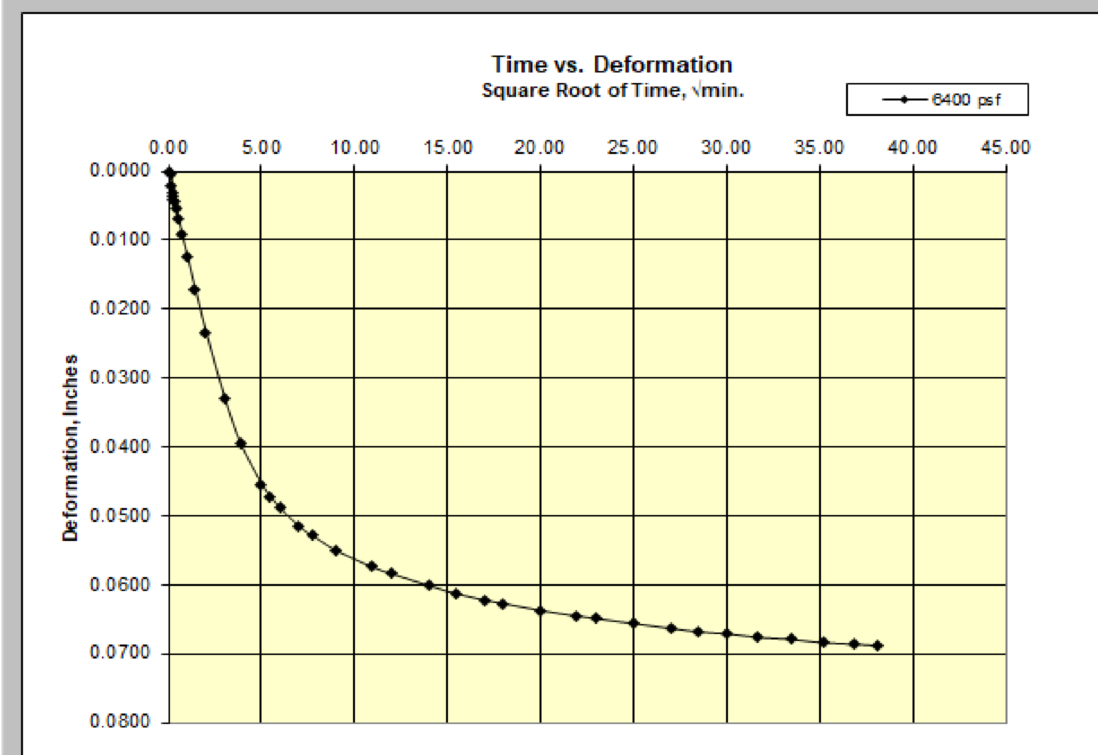
Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Consolidation Time-Rate Plots**

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. C-20

Load 9 6400 psf



6400 psf



Testing performed by Cooper Testing Laboratory

Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Consolidation Time-Rate Plots**

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. C-21

APPENDIX D

Settlement Analyses

D-1. SETTLEMENT ANALYSES

A. Levee Embankment

We performed consolidation analyses to estimate the magnitude of settlement due to the weight of new fill. We used data obtained from the borings and laboratory testing to develop material properties. To estimate the magnitude and time rate of settlement, we used the parameters in Table D-1, below.

Table D-1: Soil Properties Used for Settlement Analyses

New Fill Unit Weight	135 pcf*
Existing Fill Unit Weight	115 pcf
Bay Mud Crust	100 pcf
Bay Mud Unit Weight	97 pcf
Bay Mud Void Ratio, e_0	2.14
Bay Mud Compression Index, Cc	0.9
Bay Mud Recompression Index, Cr	0.1
Bay Mud Compression Ratio, Cc / (1+ e_0)	0.29
Bay Mud Recompression Ratio, Cr / (1+ e_0)	0.03
Bay Mud Coefficient of Consolidation, c_v	10 to 20 ft^2/year
Groundwater Elevation	+2 to +3 feet

*pcf: pounds per cubic foot

The settlement analyses was performed using the computer program CONSOL version 3.0. To characterize the stress distribution beneath the new levee fill, we modeled the load of the new fill as a series of superimposed infinite strip fills of varying widths to account for the trapezoidal cross section of the levee embankment. We assumed that the underlying Bay Mud is normally consolidated. We judge that the time rate of settlement can be reasonably characterized by assuming double drainage for the Bay Mud thicknesses.

Minimum levee crest design elevations were provided by ESA. The approximate 100-year flood elevation is at Elevation +10 feet. The levee includes 3 feet of freeboard and a minimum levee crest above Elevation +13 feet.

For the new setback ecotone levee alignment along the north edge of the soccer field, we analyzed a Bay Mud Crust thickness of 4 feet and a Bay Mud thickness of 43 feet. We assumed the ground surface is at Elevation +7 feet and the groundwater is at Elevation +3 feet. We analyzed varying new fill thicknesses and the results of the settlement estimates at the centerline of the levee, the levee toe, and at 25 feet from the levee toe are shown in Table D-2. To maintain a crest elevation of +13 feet, the total fill thickness is 8.5 feet (Elevation +15.5 feet initially) and causing about 2.5 feet of settlement.

Table D-2: Settlement Estimates for Setback Ecotone Levee

Thickness of New Fill (feet)	Settlement at Centerline (feet)	Settlement at Levee Toe (feet)	Settlement 25 feet from Levee Toe (feet)
2	0.9	0.6	<0.10
4	1.6	0.8	0.15
6	2.2	1.0	0.20
8	2.5	1.1	0.23
10	2.8	1.2	0.25

At the western setback levee abutment area, the force mains are relatively deep, ranging from 30 to 45 feet below existing grade. The Bay Mud is nominally 40 feet deep. The force mains, at a depth of 30 feet, are near the bottom of Bay Mud. The force mains, at a depth of 45 feet, are below the bottom of Bay Mud.

For the level marsh area and a force main depth of 30 feet below existing grade, we estimate that new fill will cause the force main pipe to settle about 0.25 feet. For a force main depth of 40 feet or deeper below existing grade, we estimate that new fill will cause negligible settlement of the pipe. We judge that at these fill thicknesses and depths, the settlement impacts can be consider minor.

The storm drain is shallower and ranges from about 5 feet below existing grade along the level marsh area and to about 8 feet below existing grade near the existing levee. The shallow storm drains could undergo significant settlement from the weight of the new fill if the levee is constructed directly over the pipe. For the level marsh area and a storm drain depth of 5 feet below existing grade, we estimate that 7 feet of new fill will cause the pipe to settle about 2.1 feet. At the existing levee, with the storm drain at a depth of 8 feet below existing grade, we estimate that 4 feet of new fill will cause about 0.9 feet of settlement. For other thicknesses of fill, these values can change in proportion to the fill thicknesses.

For the levee located east of the soccer field, the existing levee crest is near Elevation +11 feet to Elevation +12 feet. We judge that the levee crest should be constructed initially to Elevation +14 feet to accommodate 1-foot of settlement. Approximately 2 to 3 feet thick of new fill is anticipated. The settlement results indicate that placement of every 1-foot of fill will cause about 3-inches of settlement.

For the offset levee embankment alignment adjacent to Canal Street, we analyzed an existing fill thickness of 7 feet and a Bay Mud thickness of 55 feet. We assumed the ground surface is at Elevation +8 feet and the groundwater is at Elevation +2 feet. We analyzed varying new fill thicknesses and the resulting settlement estimates at the centerline of the levee, the levee toe, and at 25 feet from the levee toe are shown in Table D-3. For a long-term crest elevation of +13 feet, the total fill thickness is estimated to be 7 feet and causing about 2 feet of settlement.

Table D-3: Settlement Estimates for Offset Levee

Thickness of New Fill (feet)	Settlement at Centerline (feet)	Settlement at Levee Toe (feet)	Settlement 25 feet from Levee Toe (feet)
2	0.8	0.4	<0.10
4	1.4	0.6	0.15
6	1.8	0.7	0.18
8	2.1	0.8	0.20

B. Tidal Marsh Area

Various fill materials including dredged fill, rock berms, coarse beach, and rock jetty will be placed within the footprint of the tidal marsh area. For the purposes of analyses, we assumed that rock berms, coarse beach and rock jetty fill materials are similar in weight. We considered fill placement along two subsurface soil conditions: (1) eroded marsh areas, and (2) virgin marsh areas. We understand that the marshplain was likely near Elevation +6 feet prior to erosion. The bathymetric data indicates that the mudflat is near Elevation +2 feet.

We performed consolidation analyses to estimate the magnitude of settlement due to the weight of new fill within the eroded marsh areas and virgin marsh areas. We used presumptive soil parameters for analyses as shown in Table D-4. We assumed that the bottom of Bay Mud is at Elevation -40 feet.

Table D-4: Presumptive Soil Properties Used for Settlement Analyses

New Rock Fill Unit Weight	135 pcf*
New Dredged Fill Unit Weight	100 pcf
Bay Mud Unit Weight	97 pcf
Bay Mud Void Ratio, e_0	2.14
Bay Mud Compression Index, Cc	0.9
Bay Mud Recompression Index, Cr	0.1
Bay Mud Compression Ratio, Cc / (1+ e_0)	0.29
Bay Mud Recompression Ratio, Cr / (1+ e_0)	0.03
Groundwater Elevation	- 1 to +2 feet

*pcf: pounds per cubic foot

We computed the total settlement for varying thickness of areal fill for rock and dredged materials. We assumed that the underlying Bay Mud is slightly over-consolidated. The estimated settlement results for the thicknesses of new rock and new dredged fill materials are shown in Tables D-5 and D-6, below.

Table D-5: Settlement Estimates at Eroded Marsh Areas

Thickness of New Fill (feet)	Rock Fill, 135 pcf (feet)	Dredged Fill, 100 pcf (feet)
2	0.1	0.1
4	0.7	0.2
6	1.5	0.9
8	2.3	1.5
10	3.0	2.1
12	3.6	2.7

Table D-6: Settlement Estimates at Virgin Marsh Areas

Thickness of New Fill (feet)	Rock Fill, 135 pcf (feet)	Dredged Fill, 100 pcf (feet)
2	1.0	0.8
4	2.0	1.5
6	2.8	2.2
8	3.5	2.8
10	4.1	3.3
12	4.7	3.8

For the coarse beach on eroded marsh areas, total fill thickness is estimated to be 8 feet of fill causing about 2.3 feet of settlement. For the rock jetty on eroded marsh areas, total fill thickness is estimated to be 10 feet of fill causing about 3 feet of settlement. For the coarse beach on virgin marsh areas, fill thickness of 8.5 feet will cause about 3.6 feet of settlement.

APPENDIX E

Slope Stability Analyses

E-1. SLOPE STABILITY ANALYSES

A. Levee Embankment

1. Static

We performed analysis to check the factors of safety of the new levee slopes for static loading conditions. We used the computer program SLOPE/W and Spencer's method of analysis. We used data obtained from the borings and CPTs along with our assessment of effective stress and undrained shear strengths to develop material properties. Values from TxUU shear strength mobilized at 5 percent axial strain and vane shear strength data were plotted to develop undrained strength parameters within the Bay Mud. The TxUU and vane shear strength data within the Bay Mud are presented on Plate E-1. The soil parameters used in our analysis are presented on Table E-1 below.

Table E-1: Material Properties Used for Slope Stability Analyses

Material Type	Unit Weight (pcf)	Undrained Strength		Effective Strength	
		Cohesion (psf*)	Friction Angle (deg)	Cohesion (psf)	Friction Angle (deg)
New Levee Fill	135	-	-	50	32
Existing Fill	115	-	-	50	32
Bay Mud Crust	100	See Plates	0	-	-
Bay Mud	97	See Plates	0	-	-
Stiff Clay	115	1,000	-	-	-

psf: pounds per square foot

We reviewed topography and selected two cross sections to represent the new setback ecotone levee and new offset levee. For the new setback ecotone levee, the cross section used for analysis consists of a 12-foot wide levee crest at Elevation +15.5 feet with side slopes inclined at 3H:1V. The ecotone slope is inclined at 10H:1V below Elevation +10.3 feet. The ecotone slope includes an overbuild of 1.3 feet to accommodate settlement. The levee crest height included an overbuild of 2.5-feet to accommodate settlement. For the new offset levee, the cross section used for analysis consists of a 12-foot wide levee crest at Elevation +15 feet with side slopes inclined 3H:1V. The levee crest height included an overbuild of 2-feet to accommodate settlement.

We checked that cross section configurations for both the landside and waterside slopes have a minimum factor of safety of at least 1.5 for the end of construction condition. With time, the Bay Mud will gain strength as it consolidates and the long-term factors of safety will increase. The results of the slope stability factors of safety for the end of construction configurations are presented in Table E-2. We have presented the results of the slope stability cases and the soil properties used in our analysis on Plates E-2 through E-5.

Table E-2: Factors of Safety for the End-of-Construction Condition

	Factor of Safety	
Segment	**Landside**	**Waterside**
Setback Ecotone Levee	1.6	1.5
Offset Levee	1.7	1.5

2. Pseudo-Static

We performed a pseudo-static slope stability analysis for the levee configurations for the landside and waterside slopes. The pseudo-static analysis applies a horizontal force at the center of gravity to model an earthquake force. The yield coefficient is the value of the force resulting in a factor of safety of 1.0. The analysis assumes that materials do not lose strength during earthquake shaking.

For pseudo-static loading conditions, we analyzed the new levee configurations using undrained strengths and the parameters presented in Table E-1. We used an approximate average tide level at Elevation +3 feet for the analyses. Table E-3 presents the results. We have presented the results of the pseudo-static slope stability cases and the soil properties used in our analysis on Plates E-6 through E-9.

Table E-3: Yield Coefficients (K_y) from Pseudo-Static Loading

	Yield Coefficient	
Segment	**Landside**	**Waterside**
Setback Ecotone Levee	0.13	0.10
Offset Levee	0.14	0.08

The results can be used to determine the level of seismic vulnerability and to estimate seismic deformations.

B. Tidal Marsh Area

1. Static

We performed slope stability analyses to determine the factors of safety for the end of construction condition to evaluate the safe rate of fill placement. We used the computer program SLOPE/W and Spencer's method of analysis. We used presumptive undrained shear strengths for the underlying Bay Mud. In eroded marsh areas, we used an undrained strength of 140 psf at the ground surface and increasing 10 psf for each additional foot of depth. In virgin marsh areas, we used an undrained strength of 100 psf at the ground surface and increasing 10 psf for each additional foot of depth. The soil parameters used in our analysis are presented on Table E-4 below.

Table E-4: Presumptive Material Properties Used for Slope Stability Analyses

Material Type	Unit Weight (pcf)	Undrained Strength		Effective Strength	
		Cohesion (psf)	Friction Angle (deg)	Cohesion (psf)	Friction Angle (deg)
New Rock Fill	135	-	-	50	38
New Dredged Fill	100	-	-	50	30
Bay Mud in Eroded Marsh Areas	97	140 psf + 10 psf/ft	0	-	-
Bay Mud in Virgin Marsh Areas	97	100 psf + 10 psf/ft	0	-	-
Stiff Clay	115	1,000	-	-	-

The coarse beach consists of an 8-foot wide levee crest at Elevation +8 feet with side slopes inclined 2H:1V on the landside and 8H:1V on the waterside. The rock jetty consists of an 8-foot wide levee crest at Elevation +9 feet with side slopes inclined 2H:1V.

a. Coarse Beach on Eroded Marsh Areas

We performed slope stability analyses to assess the end of construction factor of safety for the coarse beach on the eroded marsh areas assuming one stage filling. The results as shown on Plates E-10 and E-11 indicate factors of safety of 1.1 and 1.7 on the landside (toward expanded marsh) and waterside, respectively. The results indicate that the fill cannot be placed in one stage and that a landside buttress and staged construction would be necessary to provide an acceptable level of safety.

A combination of landside stability berm widths and thicknesses were analyzed to develop a configuration to maintain for a minimum end-of-construction slope stability factor of safety of 1.5. We developed a sequence of construction to achieve the design elevation. The first step consists of a maximum rock fill thickness of 5 feet with side slopes inclined at 2H:1V or flatter on the landside and 8H:1V on the waterside. The second step is a landside buttress consisting of 4.5 feet thickness of dredged fill materials (assumes 100 pcf) at least 20 feet wide with side slope inclined at 2H:1V or flatter. The third step is to place a second stage of rock materials consisting of 3 feet thickness of fill with side slopes inclined at 2H:1V or flatter on the landside and 8H:1V on the waterside. The end of construction factors of safety are shown in Table E-5 and on Plates E-12 through E-17. We assumed no strength gain between stages in the underlying soils.

Table E-5: Factors of Safety for the End-of-Construction Condition

	Factor of Safety	
Stages	**Landside**	**Waterside**
Step 1	1.5	2.2
Step 2	2.2	2.2
Step 3	1.5	1.7

b. Coarse Beach on Virgin Marsh Areas

We performed slope stability analyses to assess the end of construction factor of safety for the coarse beach on virgin marsh areas assuming one stage filling. The results as shown on Plates E-18 and E-19 indicate factors of safety of 0.7 and 1.3 on the landside (toward expanded marsh) and waterside, respectively. The results indicate that the fill cannot be placed in one stage and that a landside buttress and staged construction would be necessary to provide an acceptable level of safety.

A combination of landside stability berm widths and thicknesses were analyzed to develop a configuration to achieve minimum end-of-construction slope stability factor of safety of 1.5. We developed a sequence of construction to achieve the design elevation. The first step consists of a maximum rock fill thickness of 3.5 feet with side slopes inclined at 2H:1V or flatter on the landside and 8H:1V on the waterside. The second step is a landside buttress consisting of 6 feet thickness of dredged fill materials (assumes 100 pcf) at least 45 feet wide with side slope inclined at 10H:1V or flatter. The third step is to place a second stage of rock materials consisting of 5 feet thickness of fill with side slopes inclined at

2H:1V or flatter on the landside and 8H:1V on the waterside. The end of construction factors of safety are shown in Table E-6 and on Plates E-20 through E-25.

Table E-6: Factors of Safety for the End-of-Construction Condition

	Factor of Safety	
Stages	**Landside**	**Waterside**
Step 1	1.5	2.3
Step 2	1.5	1.9
Step 3	1.7	1.5

We assumed no strength gain between stages in the underlying soils. A third stage of rock materials (Step 4) consisting of 2 feet thickness of fill with side slopes inclined at 2H:1V or flatter on the landside and 8H:1V on the waterside would be needed to maintain the design elevation. The third stage of rock materials would require a waiting period and strength gain of the underlying soils. We did not evaluate the potential strength gain required for the third stage of rock materials. We anticipate that the waiting period between stages would be about 10 years or more. The timing and sequencing for the third stage can be completed in final design.

c. Rock Jetty on Eroded Marsh Areas

We performed slope stability analyses to assess the end of construction factor of safety for the rock jetty on eroded marsh areas assuming one stage filling. The results as shown on Plate E-26 and E-27 indicate factors of safety of 0.9 for both the landside (toward expanded marsh) and waterside. The results indicate that more than one stage of fill placement is needed and that both landside and waterside buttresses and staged construction would be necessary to provide an acceptable level of safety.

A combination of landside stability berm widths and thicknesses were analyzed to develop a configuration to achieve for a minimum end-of-construction slope stability factor of safety of 1.5. We developed a sequence of construction to achieve the design elevation. The first step consists of a maximum rock fill thickness of 5 feet with side slopes inclined at 2H:1V or flatter on both the landside and waterside. The second step is a landside buttress consisting of 4.5 feet thickness of dredged fill materials (assumes 100 pcf) at least 30 feet wide with side slope inclined at 2H:1V or flatter and a waterside buttress consisting of 3 feet thickness of rock fill materials (assumes 135 pcf) at least 30 feet wide with side slope inclined at 2H:1V or flatter. The third step is to place a second stage of rock materials consisting of 5 feet thickness of fill with side slopes inclined at 2H:1V or flatter. The end of construction factors of safety are shown in Table E-7 and on Plates E-28 through E-33. We assumed that the waterside buttress is at least 10 feet from the top of the creek slope. We assumed no strength gain between stages in the underlying soils.

Table E-7: Factors of Safety for the End-of-Construction Condition

	Factor of Safety	
Stages	**Landside**	**Waterside**
Step 1	1.5	1.5
Step 2	2.3	2.5
Step 3	1.5	1.6

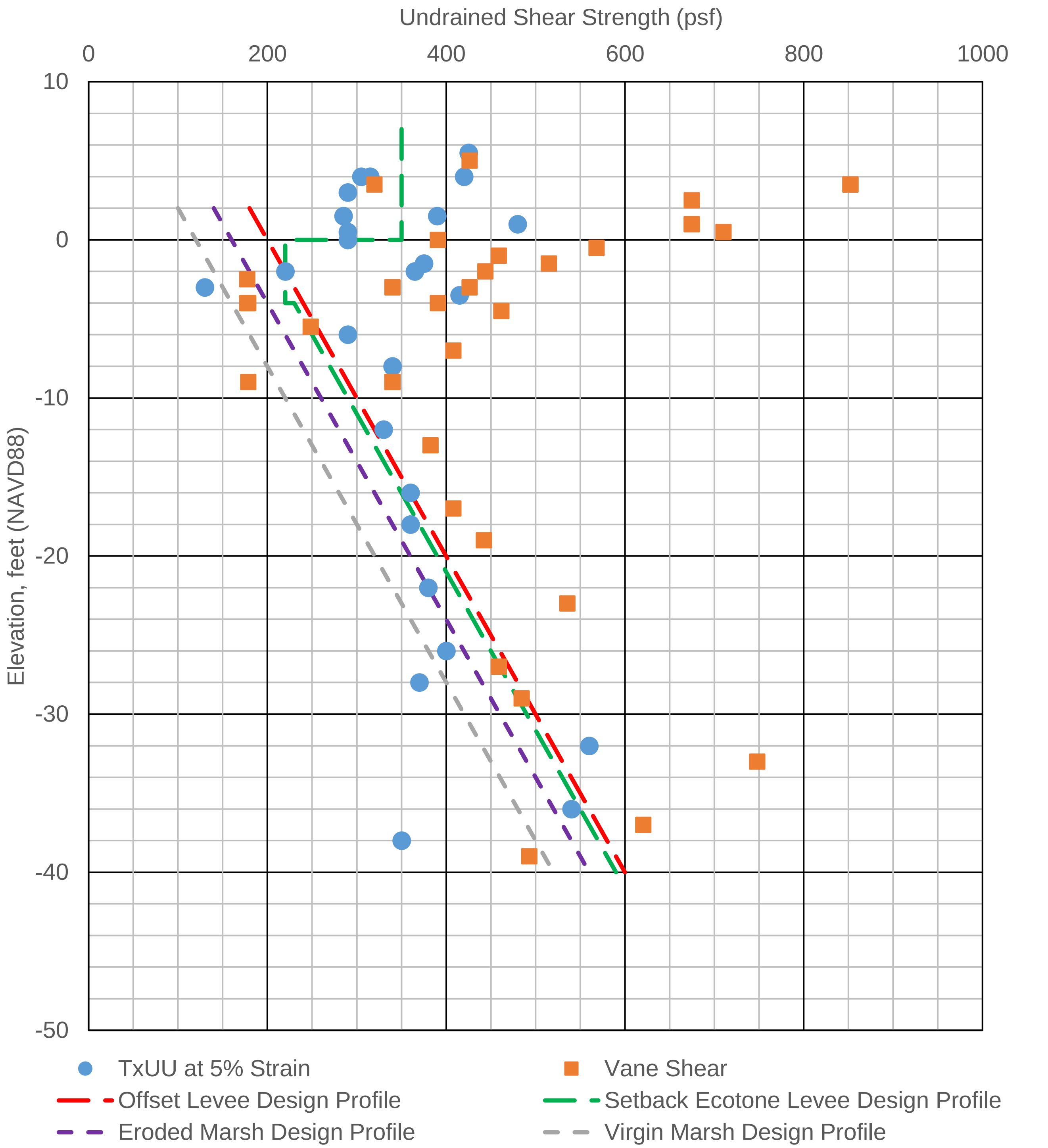
2. Pseudo-Static

For pseudo-static loading conditions, we analyzed the coarse beach on eroded marsh areas and virgin marsh areas and the rock jetty on eroded marsh areas. We used an approximate average tide level at Elevation +3 feet for analyses. Table E-8 presents the results of the yield coefficients (K_y). We have presented the results of the pseudo-static slope stability cases and the soil properties used in our analysis on Plates E-34 through E-39.

Table E-8: Yield Coefficients (K_y) from Pseudo-Static Loading

	Yield Coefficient	
Section	**Landside**	**Waterside**
Coarse Beach on Eroded Marsh Areas	0.16	0.10
Coarse Beach on Virgin Marsh Areas	0.12	0.06
Rock Jetty on Eroded Marsh Areas	0.15	0.09

The results can be used to determine the level of seismic vulnerability and to estimate seismic deformations.

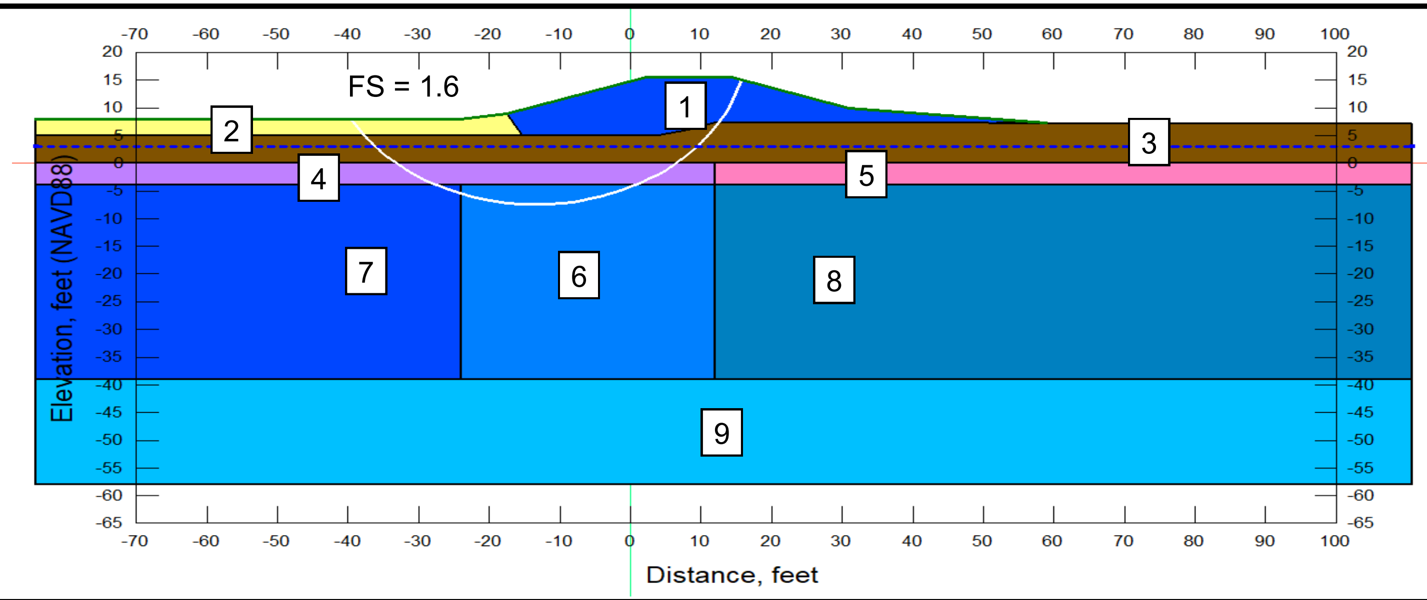


Notes:

1. Setback and offset levee design profiles at center of the existing levees.
2. Setback and offset levee design profiles at the landside and waterside of the existing levee are not shown.

Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Shear Strength Data in Bay Mud and Design Profiles**

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. E-1

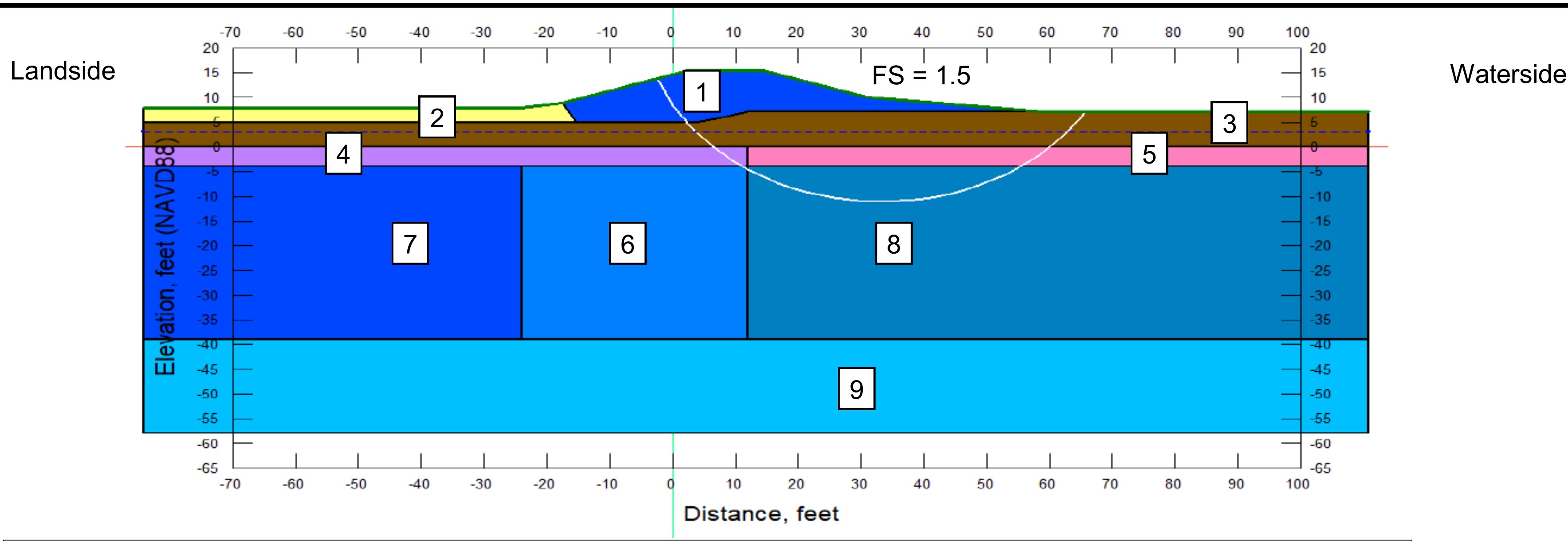


STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Fill	135	-	-	50	32
2		Existing Fill	115	-	-	50	32
3		Bay Mud Crust 1	100	350	-	-	-
4		Bay Mud Crust 2	100	220	-	-	-
5		Bay Mud Crust 3	100	200	-	-	-
6		Bay Mud 1	97	230 + 10H	-	-	-
7		Bay Mud 2	97	220 + 10H	-	-	-
8		Bay Mud 3	97	210 + 10H	-	-	-
9		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Slope Stability Analyses Results** **Setback Ecotone Levee** **End of Construction (LS)**

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. E-2



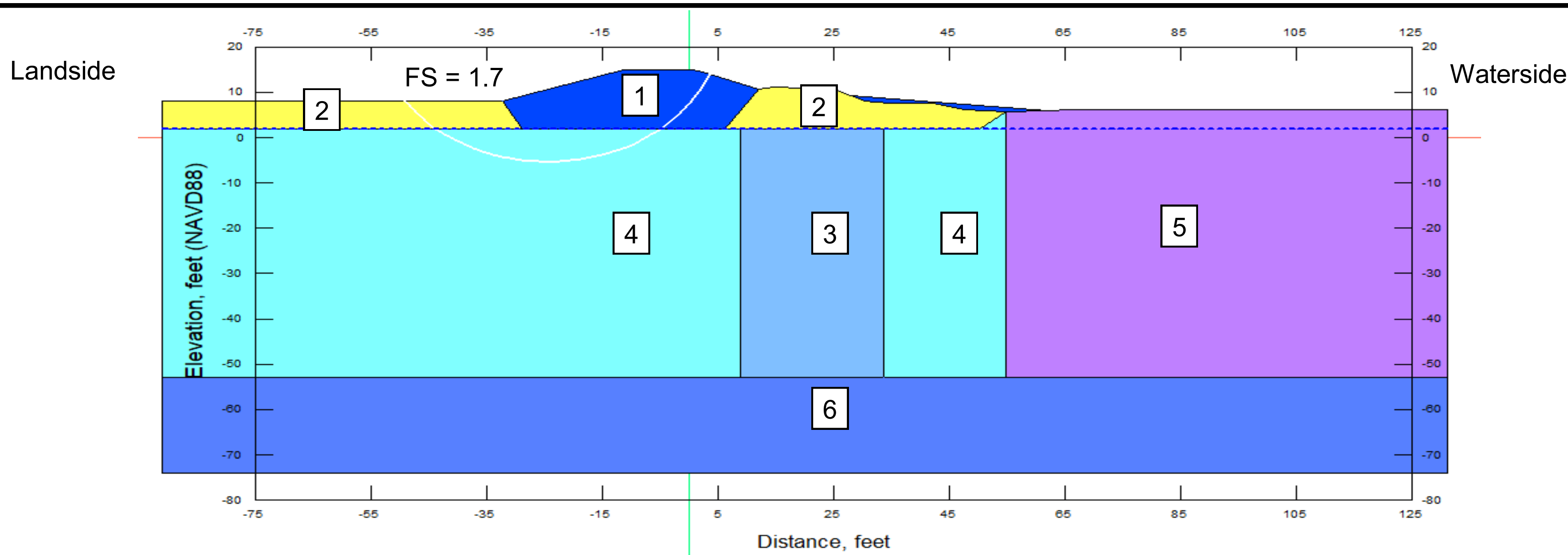
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Fill	135	-	-	50	32
2		Existing Fill	115	-	-	50	32
3		Bay Mud Crust 1	100	350	-	-	-
4		Bay Mud Crust 2	100	220	-	-	-
5		Bay Mud Crust 3	100	200	-	-	-
6		Bay Mud 1	97	230 + 10H	-	-	-
7		Bay Mud 2	97	220 + 10H	-	-	-
8		Bay Mud 3	97	210 + 10H	-	-	-
9		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Setback Ecotone Levee
End of Construction (WS)

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-3



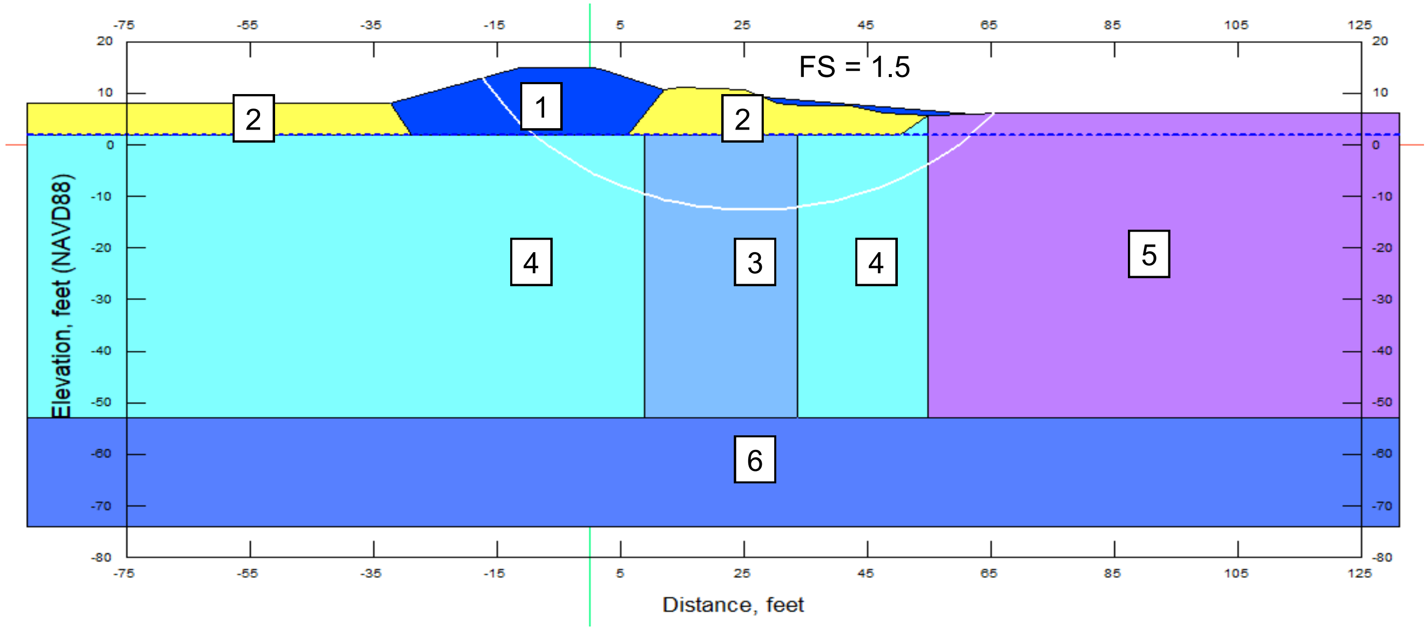
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Fill	135	-	-	50	32
2		Existing Fill	115	-	-	50	32
3		Bay Mud 1	97	180 + 10H	-	-	-
4		Bay Mud 2	97	160 + 10H	-	-	-
5		Bay Mud 3	97	100 + 10H	-	-	-
6		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Offset Levee
End of Construction (LS)

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-4



STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Fill	135	-	-	50	32
2		Existing Fill	115	-	-	50	32
3		Bay Mud 1	97	180 + 10H	-	-	-
4		Bay Mud 2	97	160 + 10H	-	-	-
5		Bay Mud 3	97	100 + 10H	-	-	-
6		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

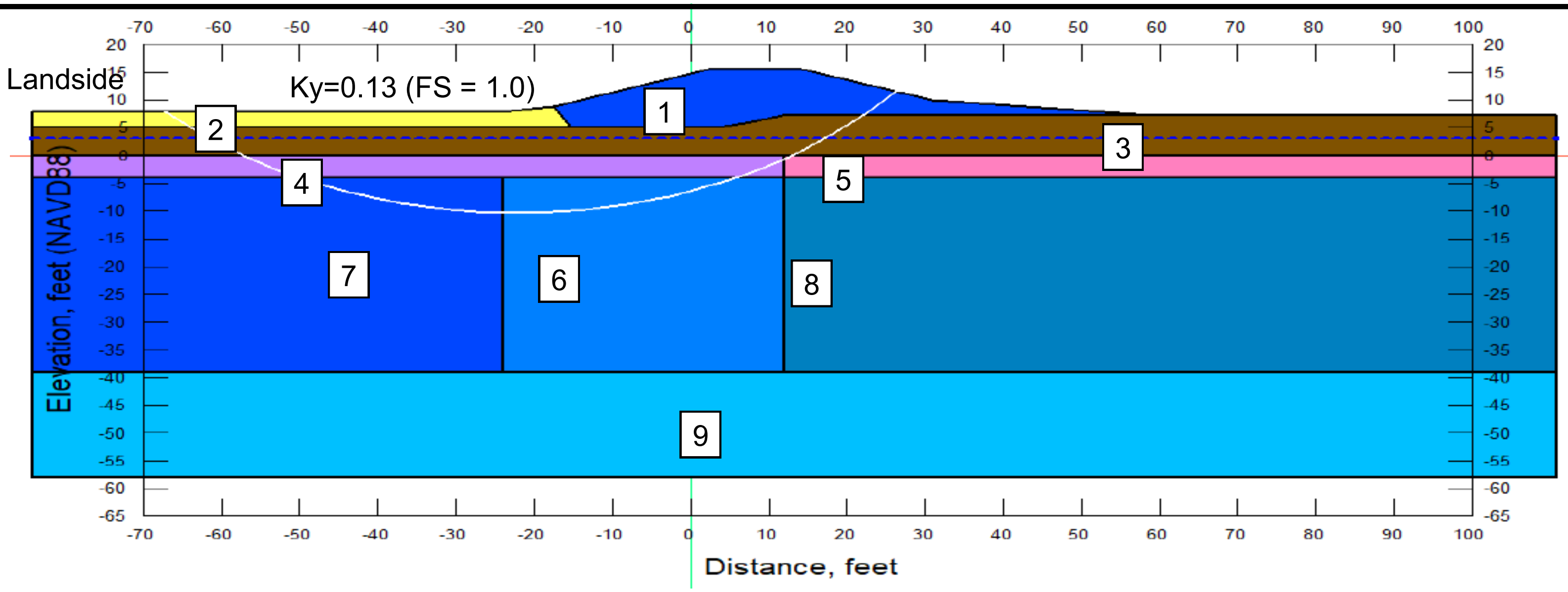
Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Offset Levee
End of Construction (WS)

Hultgren - Tillis Engineers

Project No. 923.01

Plate No. E-5



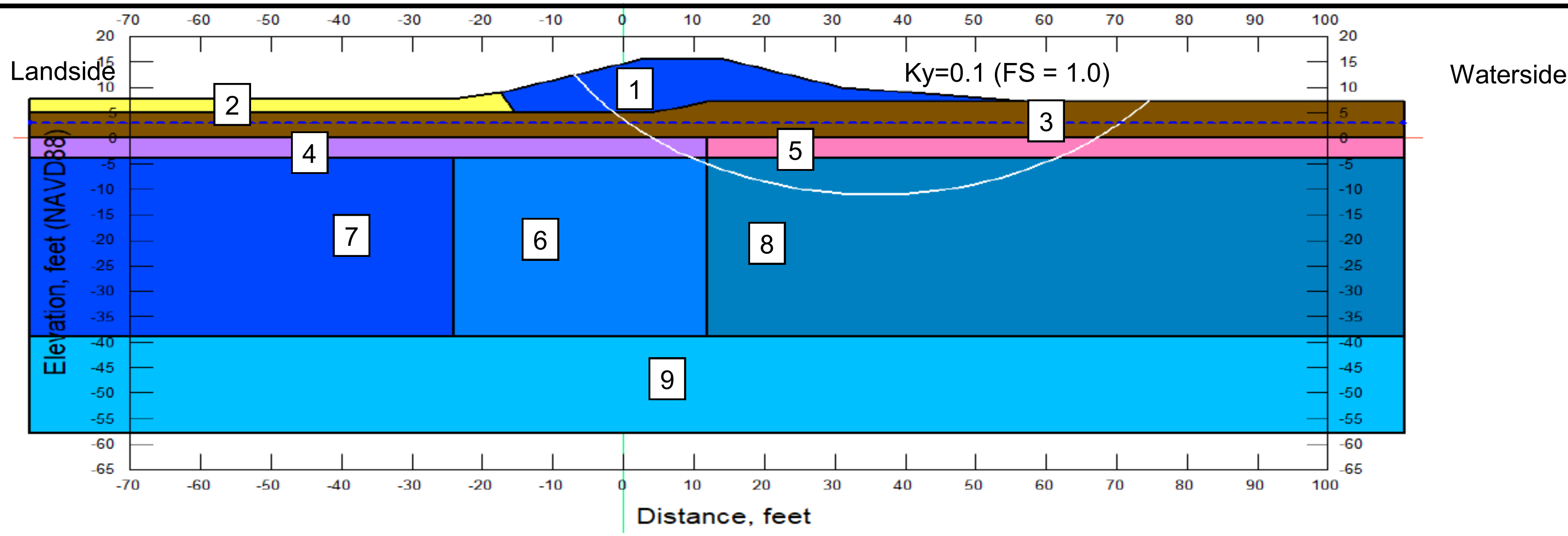
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Fill	135	-	-	50	32
2		Existing Fill	115	-	-	50	32
3		Bay Mud Crust 1	100	350	-	-	-
4		Bay Mud Crust 2	100	220	-	-	-
5		Bay Mud Crust 3	100	200	-	-	-
6		Bay Mud 1	97	230 + 10H	-	-	-
7		Bay Mud 2	97	220 + 10H	-	-	-
8		Bay Mud 3	97	210 + 10H	-	-	-
9		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Setback Ecotone Levee
Pseudo Static (LS)

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-6



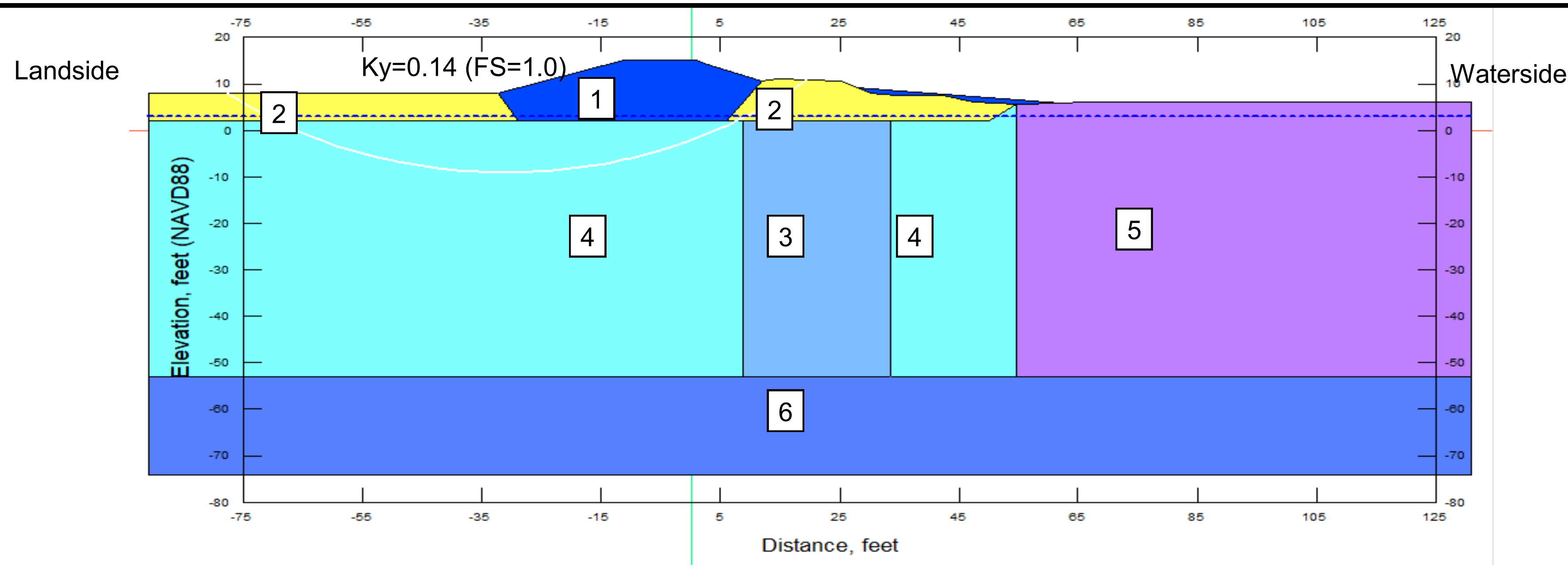
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Fill	135	-	-	50	32
2		Existing Fill	115	-	-	50	32
3		Bay Mud Crust 1	100	350	-	-	-
4		Bay Mud Crust 2	100	220	-	-	-
5		Bay Mud Crust 3	100	200	-	-	-
6		Bay Mud 1	97	230 + 10H	-	-	-
7		Bay Mud 2	97	220 + 10H	-	-	-
8		Bay Mud 3	97	210 + 10H	-	-	-
9		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Setback Ecotone Levee
Pseudo Static (WS)

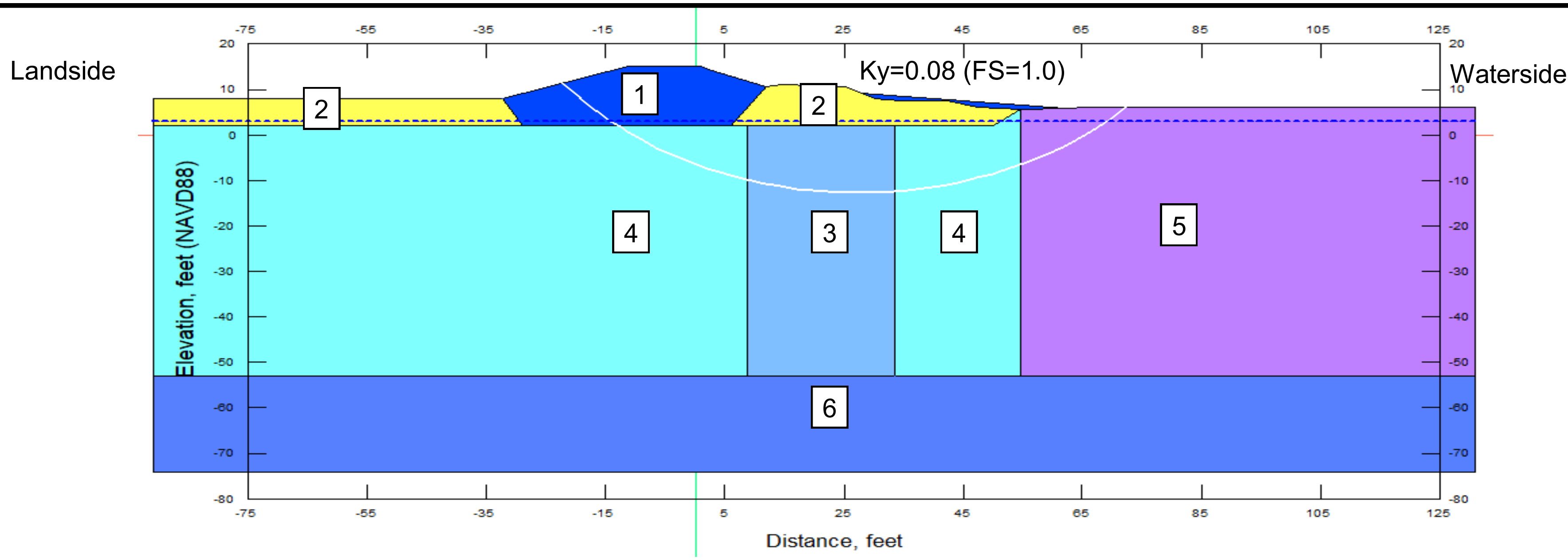
Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-7



STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Fill	135	-	-	50	32
2		Existing Fill	115	-	-	50	32
3		Bay Mud 1	97	180 + 10H	-	-	-
4		Bay Mud 2	97	160 + 10H	-	-	-
5		Bay Mud 3	97	100 + 10H	-	-	-
6		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California		**Slope Stability Analyses Results Offset Levee Pseudo Static (LS)**
Hultgren - Tillis Engineers	Project No. 923.01	Plate No. E-8



STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Fill	135	-	-	50	32
2		Existing Fill	115	-	-	50	32
3		Bay Mud 1	97	180 + 10H	-	-	-
4		Bay Mud 2	97	160 + 10H	-	-	-
5		Bay Mud 3	97	100 + 10H	-	-	-
6		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

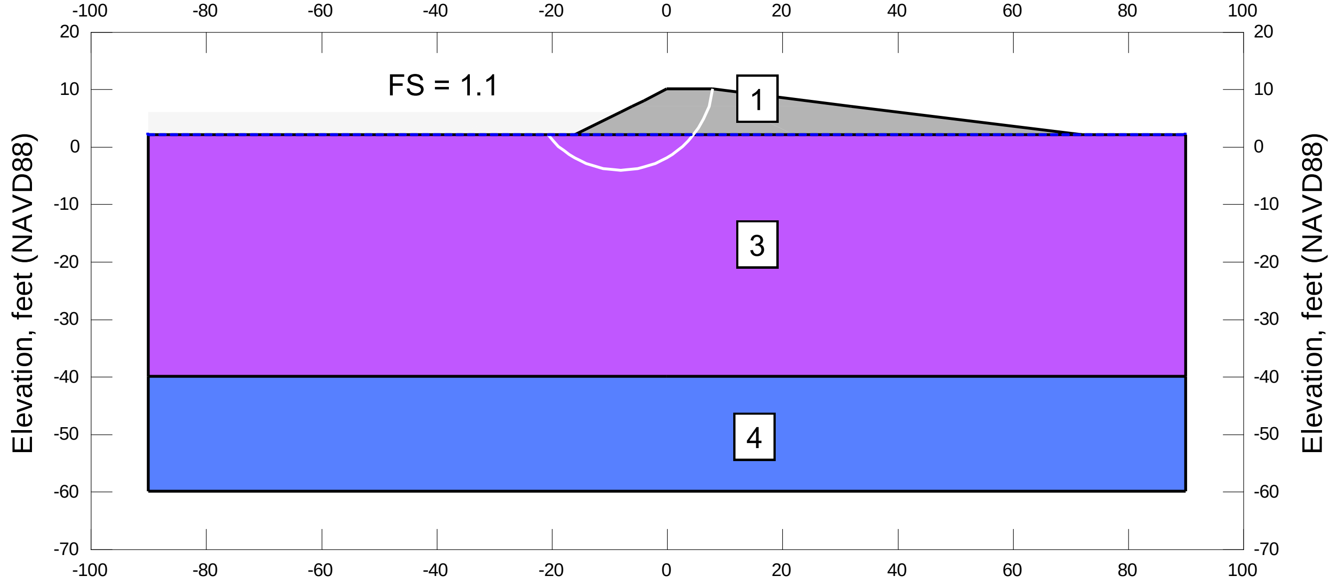
Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Offset Levee
Pseudo Static (WS)

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-9

Landside

Waterside



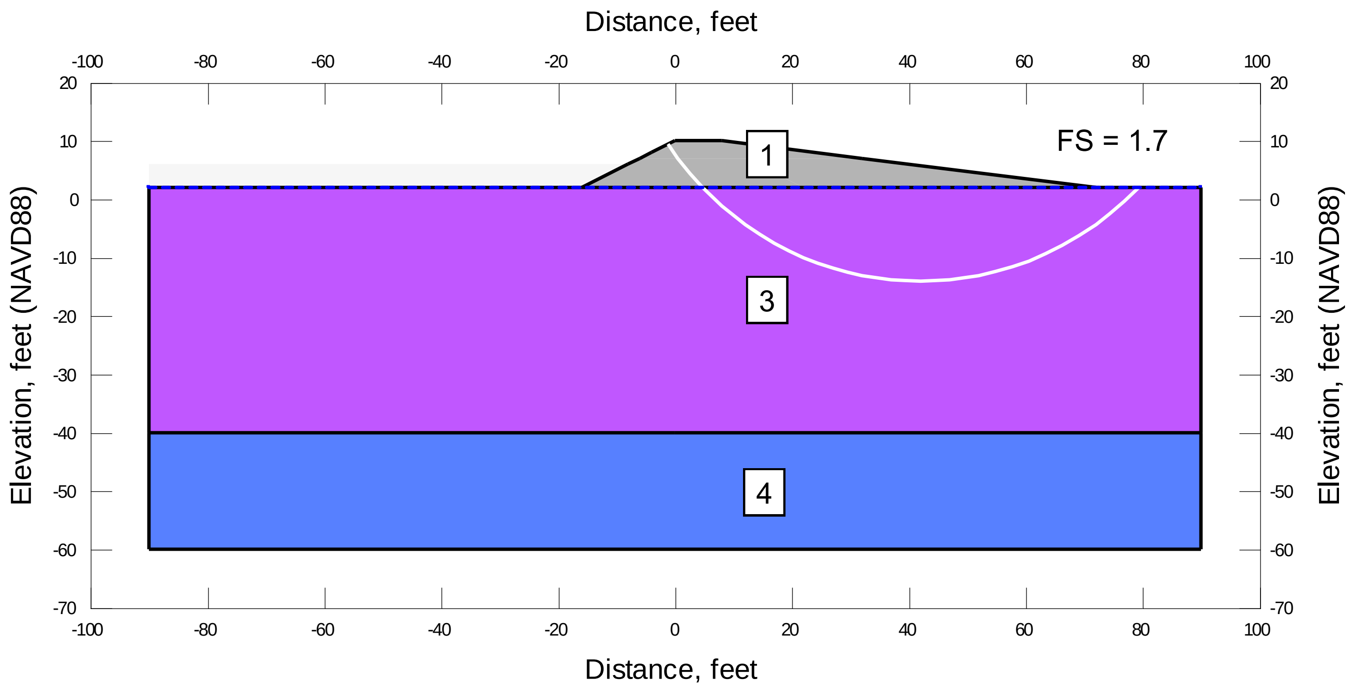
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Eroded Bay Mud	97	140 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Slope Stability Analyses Results** **Coarse Beach on Eroded Marsh** **Full Section (LS)**	
Hultgren - Tillis Engineers	Project No. 923.01	Plate No. E-10

Landside

Waterside



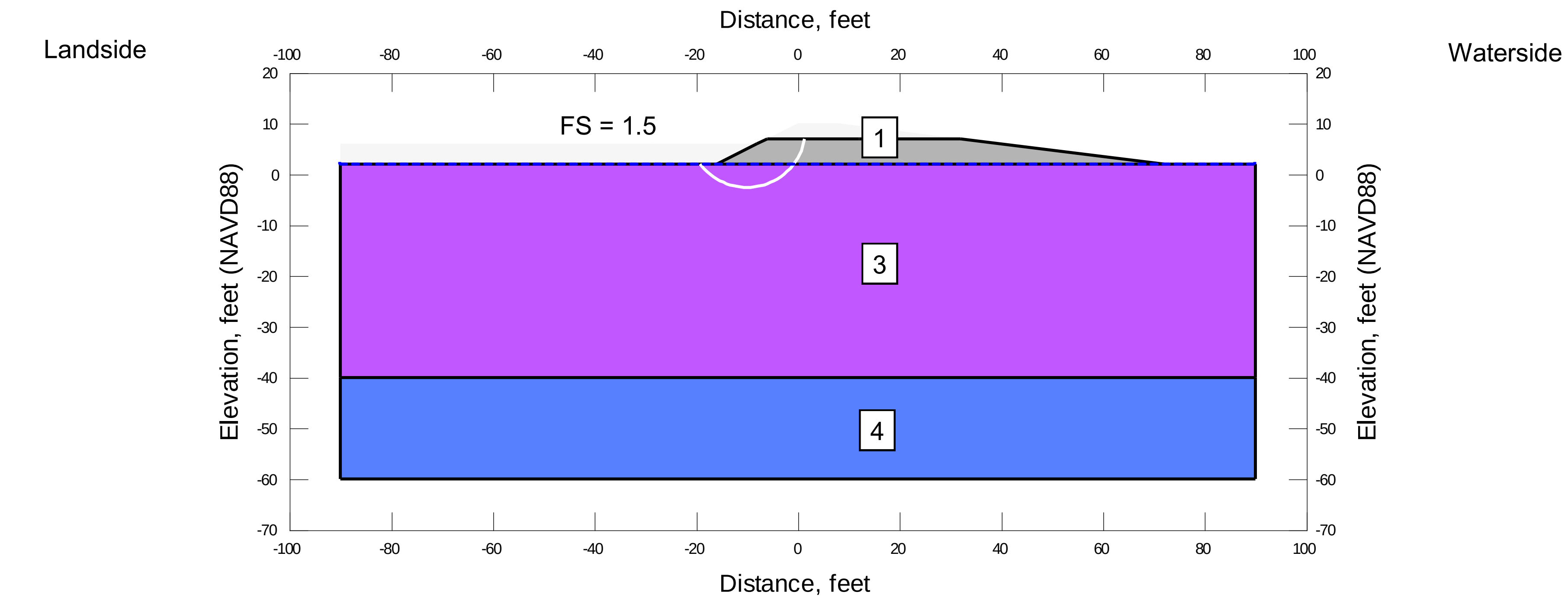
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Eroded Bay Mud	97	140 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Coarse Beach on Eroded Marsh
Full Section (WS)

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-11



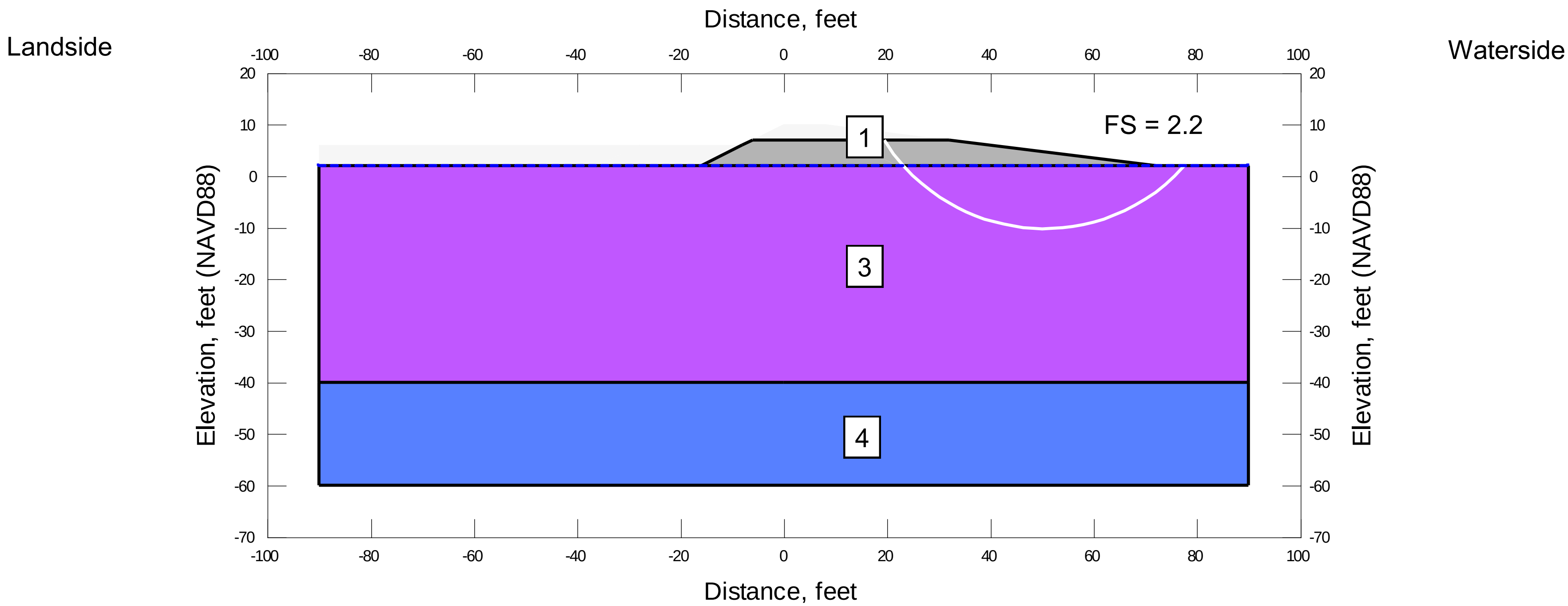
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Eroded Bay Mud	97	140 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Coarse Beach on Eroded Marsh
Step 1: First Lift Rock Fill (LS)

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. E-12



STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Eroded Bay Mud	97	140 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

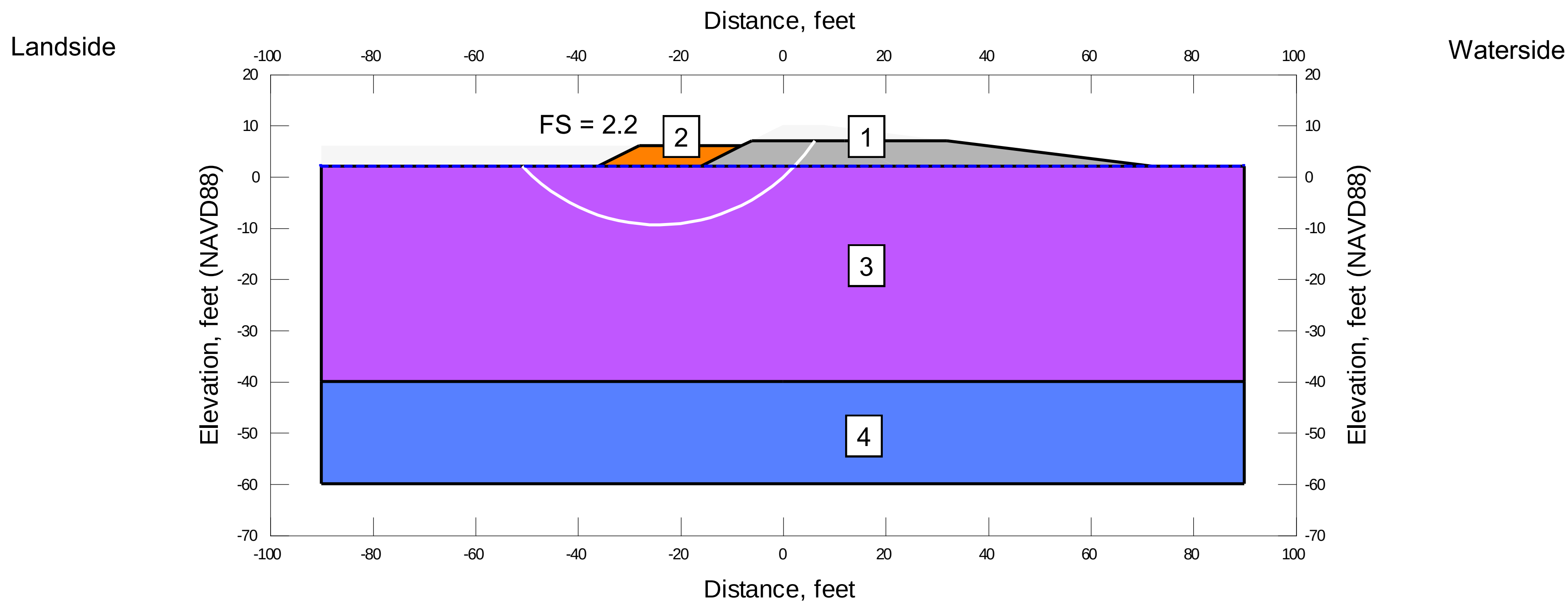
Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Coarse Beach on Eroded Marsh
Step 1: First Lift Rock Fill (WS)

Hultgren - Tillis Engineers

Project No. 923.01

Plate No. E-13



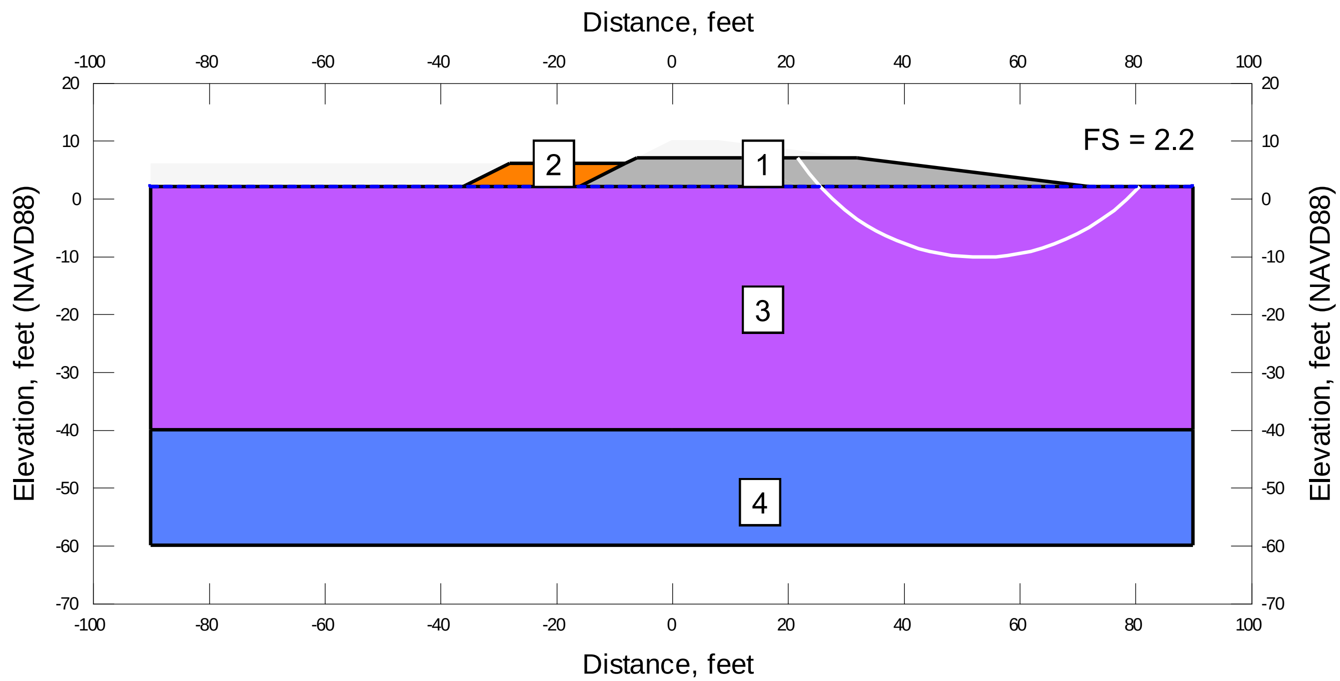
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Eroded Bay Mud	97	140 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Slope Stability Analyses Results** **Coarse Beach on Eroded Marsh** **Step 2: Buttress Landside Slope (LS)**
Hultgren - Tillis Engineers	Project No. 923.01 — Plate No. E-14

Landside

Waterside



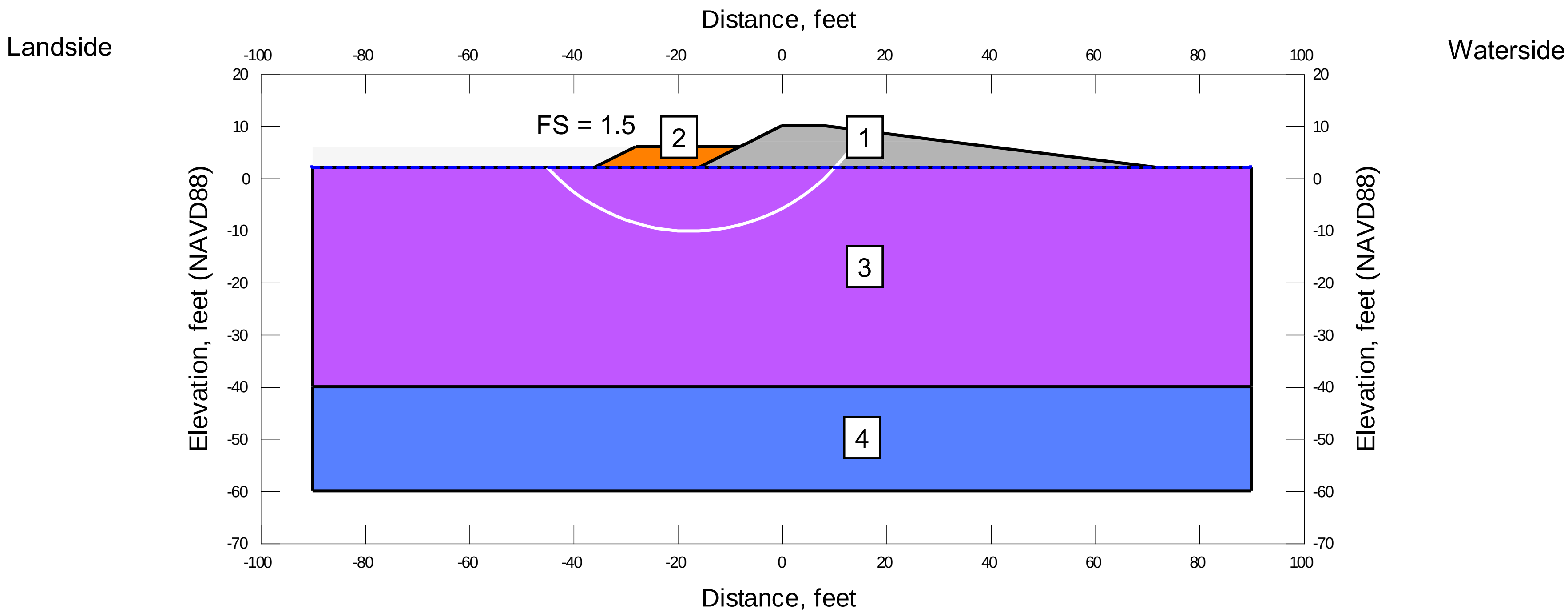
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Eroded Bay Mud	97	140 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Coarse Beach on Eroded Marsh
Step 2: Buttress Landside Slope (WS)

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. E-15



STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Eroded Bay Mud	97	140 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

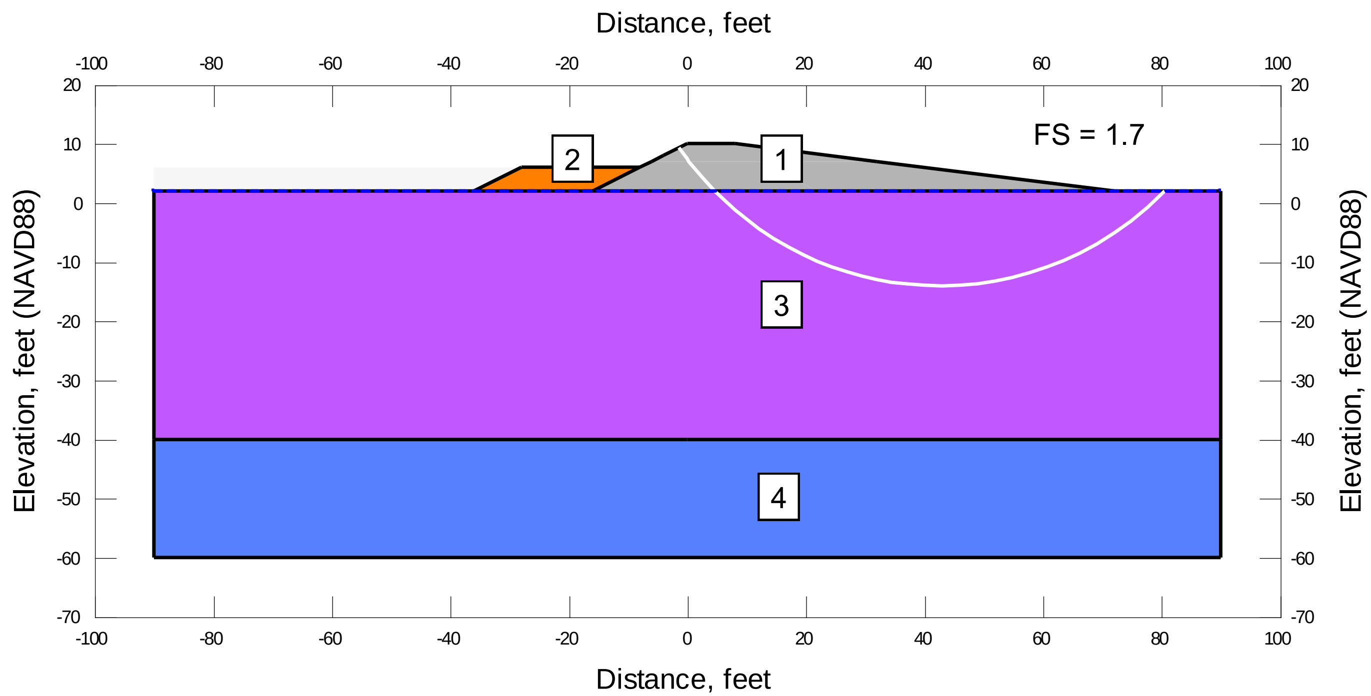
Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Coarse Beach on Eroded Marsh
Step 3: Second Lift Rock Fill (LS)

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-16

Landside

Waterside



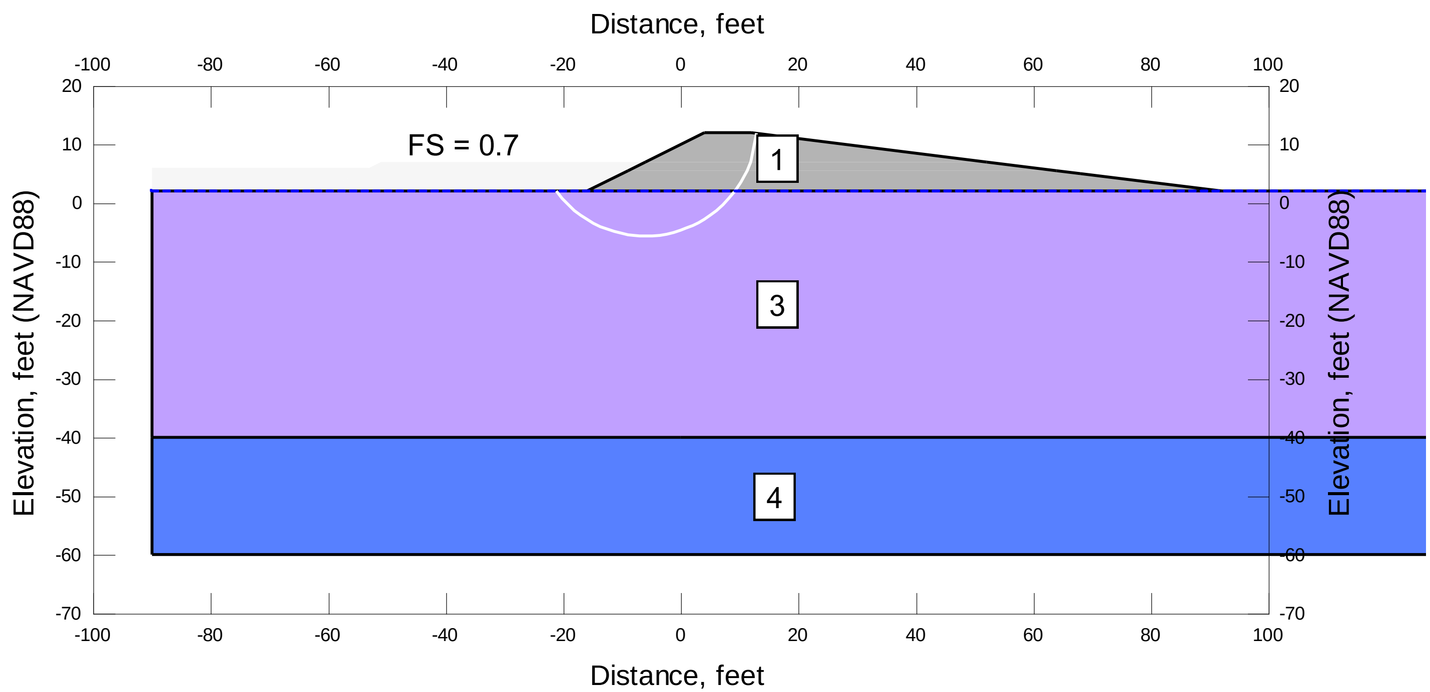
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Eroded Bay Mud	97	140 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Coarse Beach on Eroded Marsh
Step 3: Second Lift Rock Fill (WS)

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-17



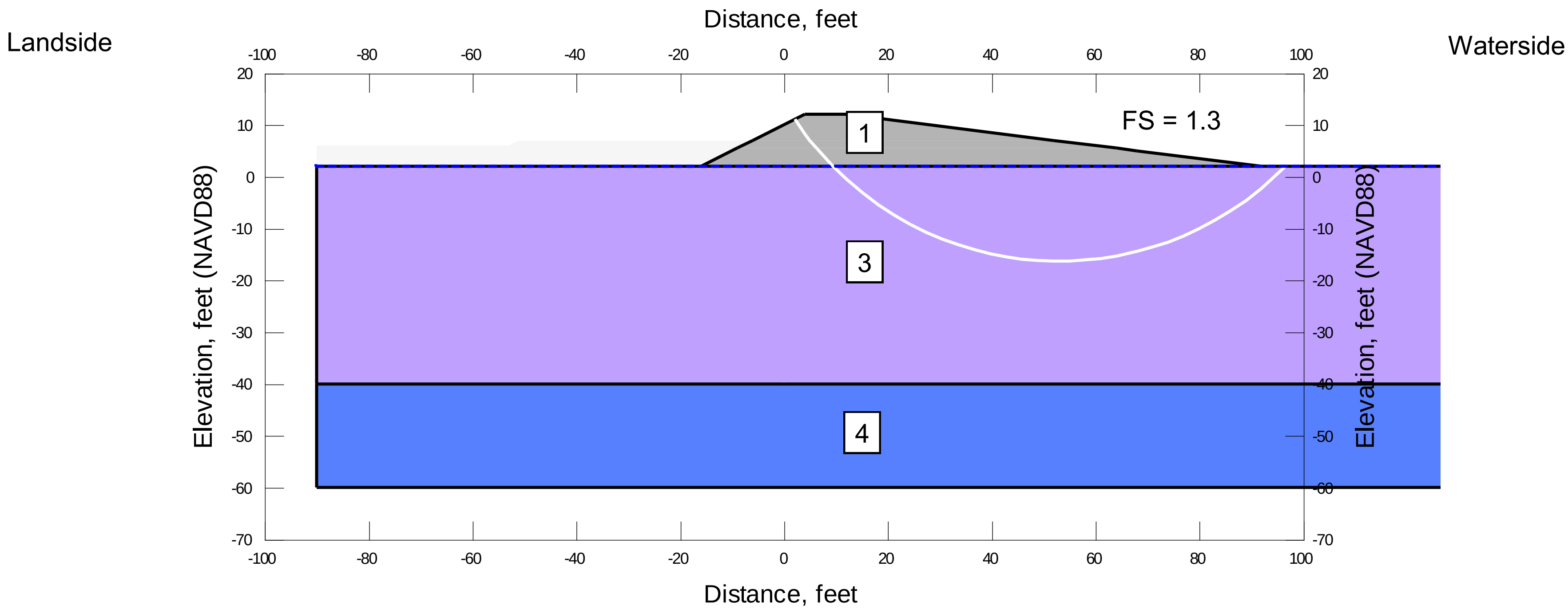
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1	(gray)	New Rock Fill	135	-	-	50	38
2	(orange)	New Dredged Fill	100	-	-	50	30
3	(lavender)	Virgin Bay Mud	97	100 + 10H	-	-	-
4	(blue)	Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Coarse Beach on Virgin Marsh
Full Section (LS)

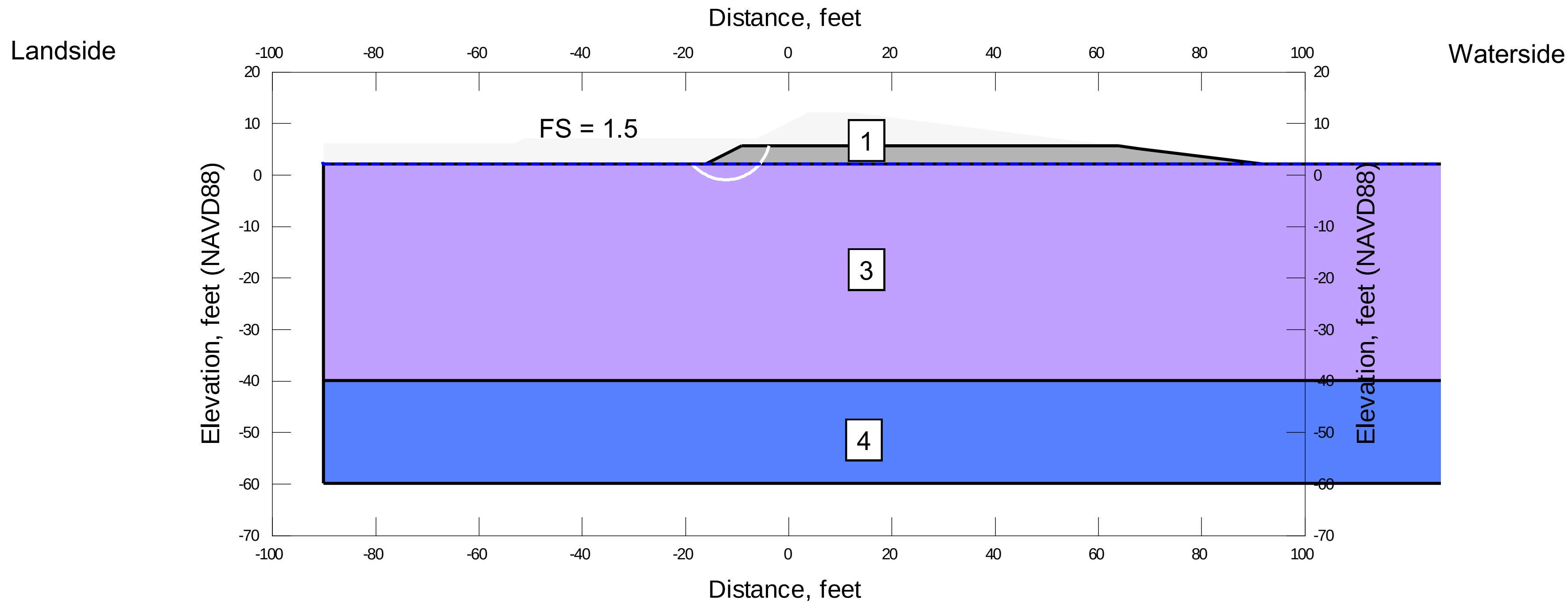
Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-18



STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Virgin Bay Mud	97	100 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Slope Stability Analyses Results Coarse Beach on Virgin Marsh Full Section (WS)**
Hultgren - Tillis Engineers	Project No. 923.01 — Plate No. E-19



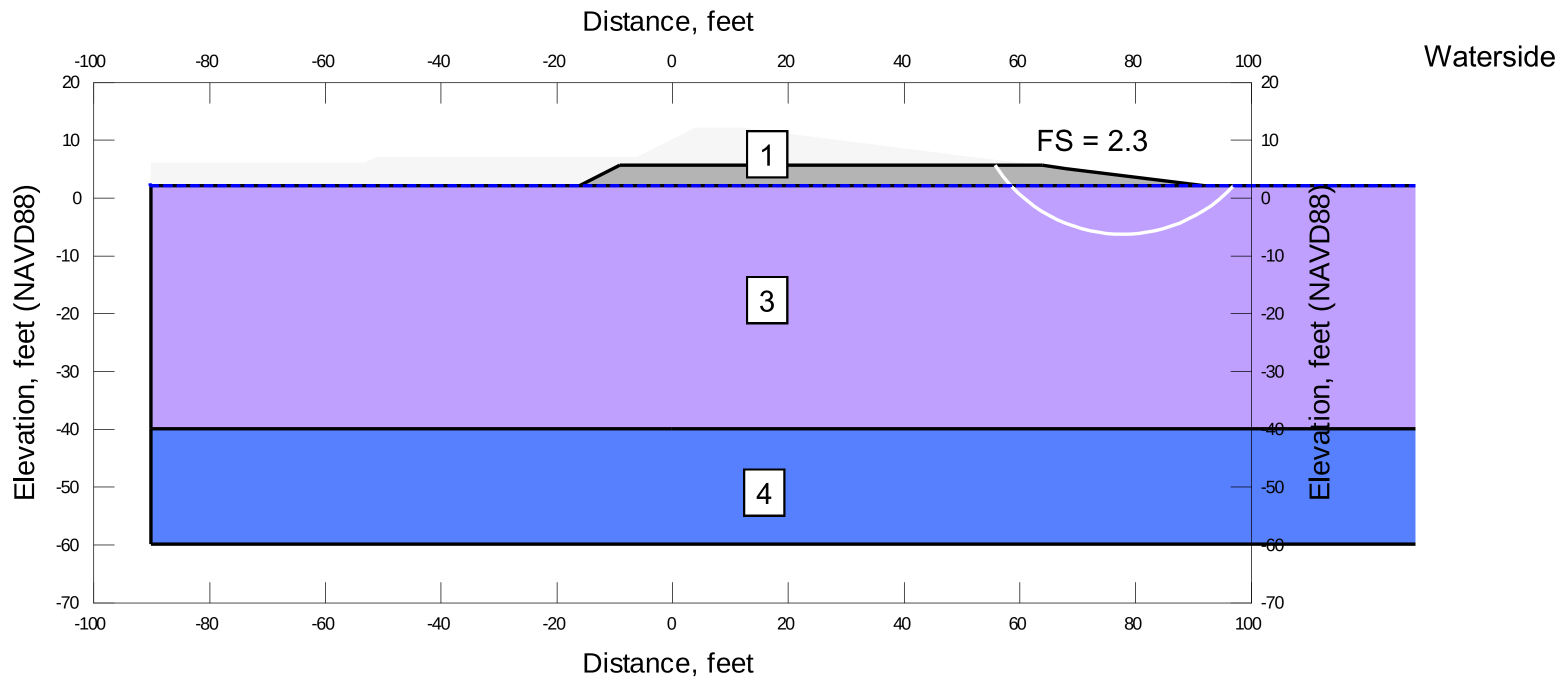
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Virgin Bay Mud	97	100 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Coarse Beach on Virgin Marsh
Step 1: First Lift Rock Fill (LS)

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-20



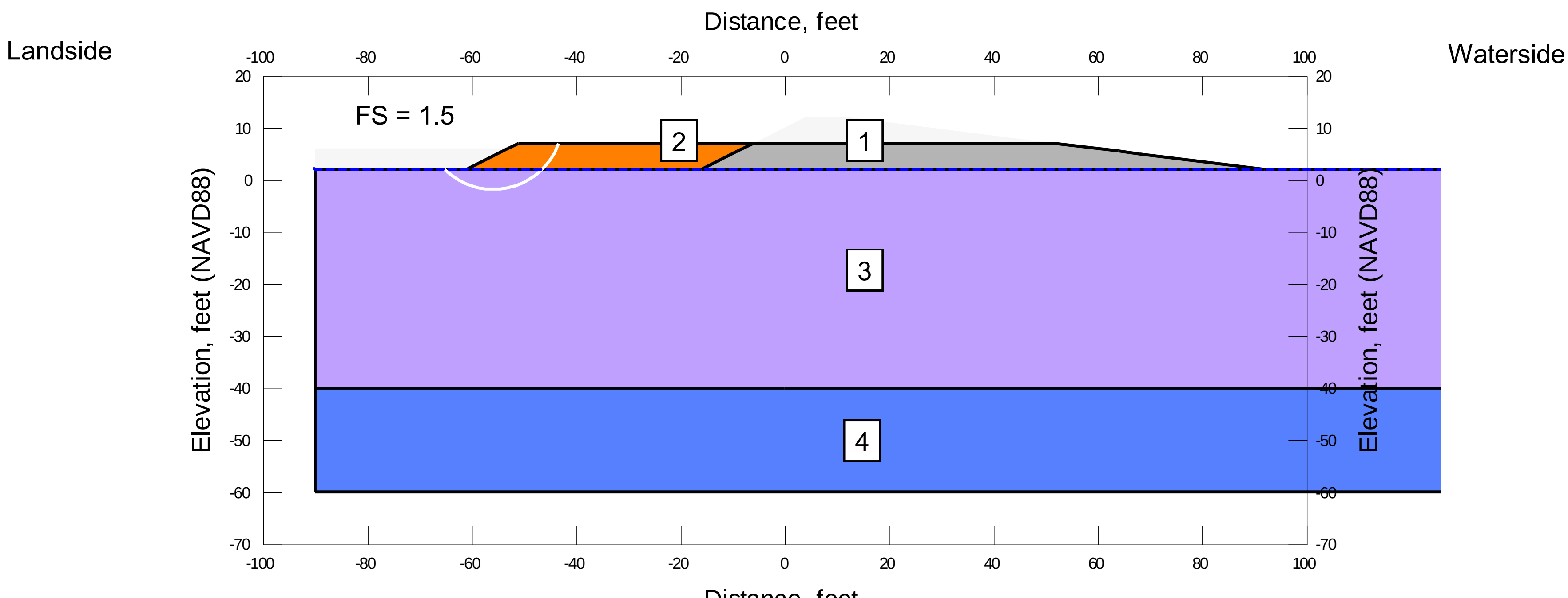
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Virgin Bay Mud	97	100 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Coarse Beach on Virgin Marsh
Step 1: First Lift Rock Fill (WS)

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-21



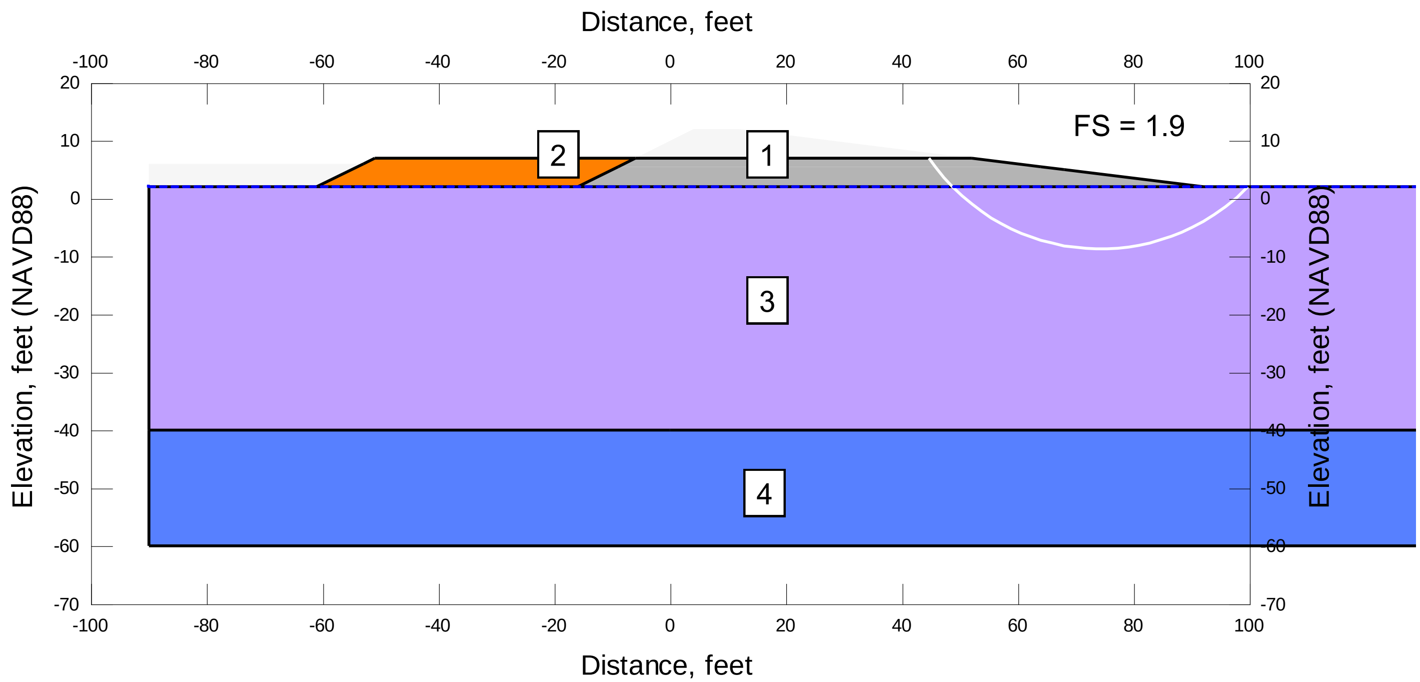
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Virgin Bay Mud	97	100 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Slope Stability Analyses Results** **Coarse Beach on Virgin Marsh** **Step 2: Buttress Landside Slope (LS)**
Hultgren - Tillis Engineers	Project No. 923.01 / Plate No. E-22

Landside

Waterside



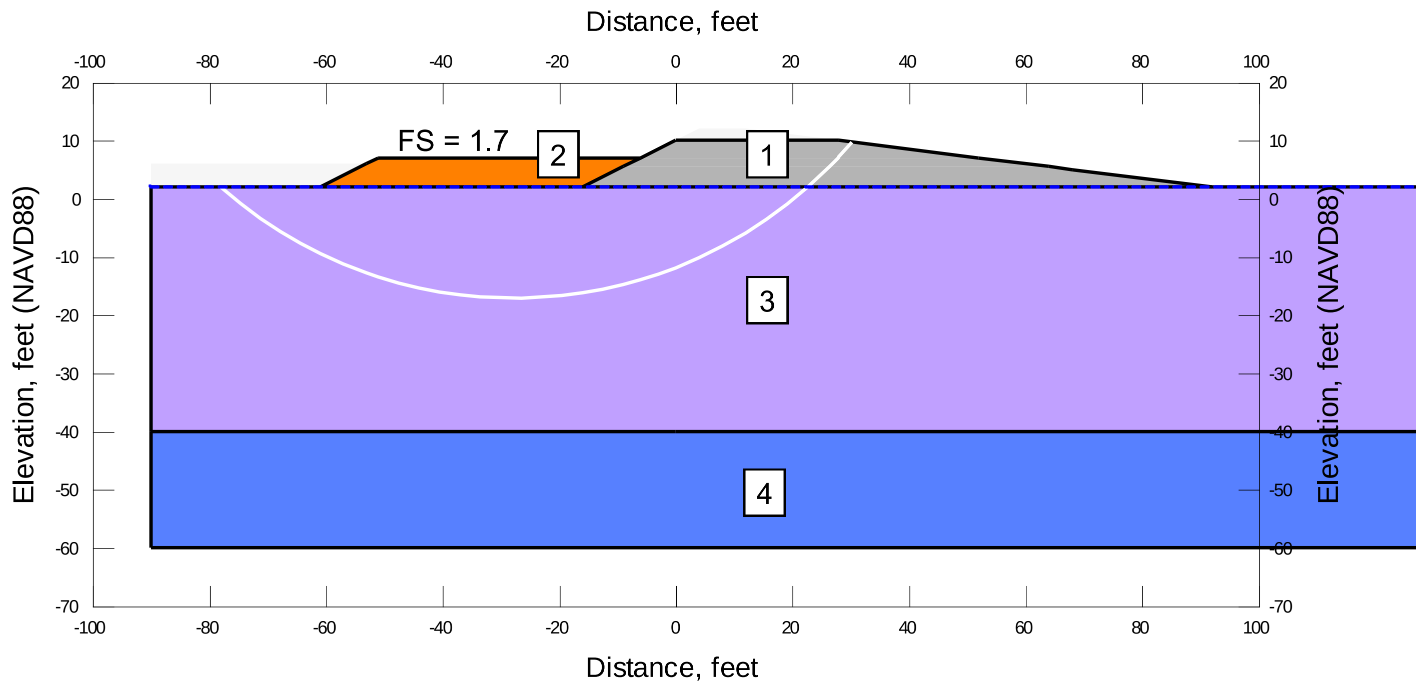
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Virgin Bay Mud	97	100 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Coarse Beach on Virgin Marsh
Step 2: Buttress Landside Slope (WS)

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-23



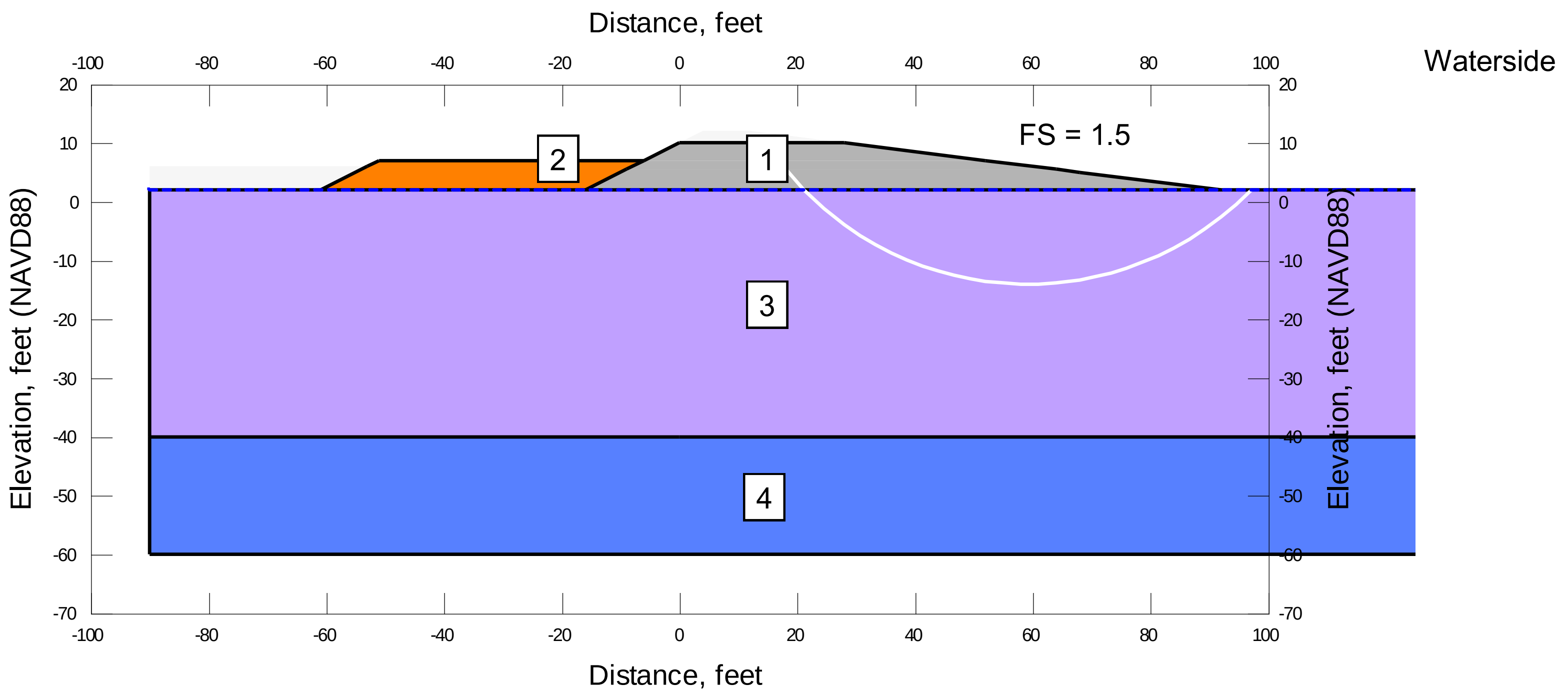
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Virgin Bay Mud	97	100 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Coarse Beach on Virgin Marsh
Step 3: Second Lift Rock Fill (LS)

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-24



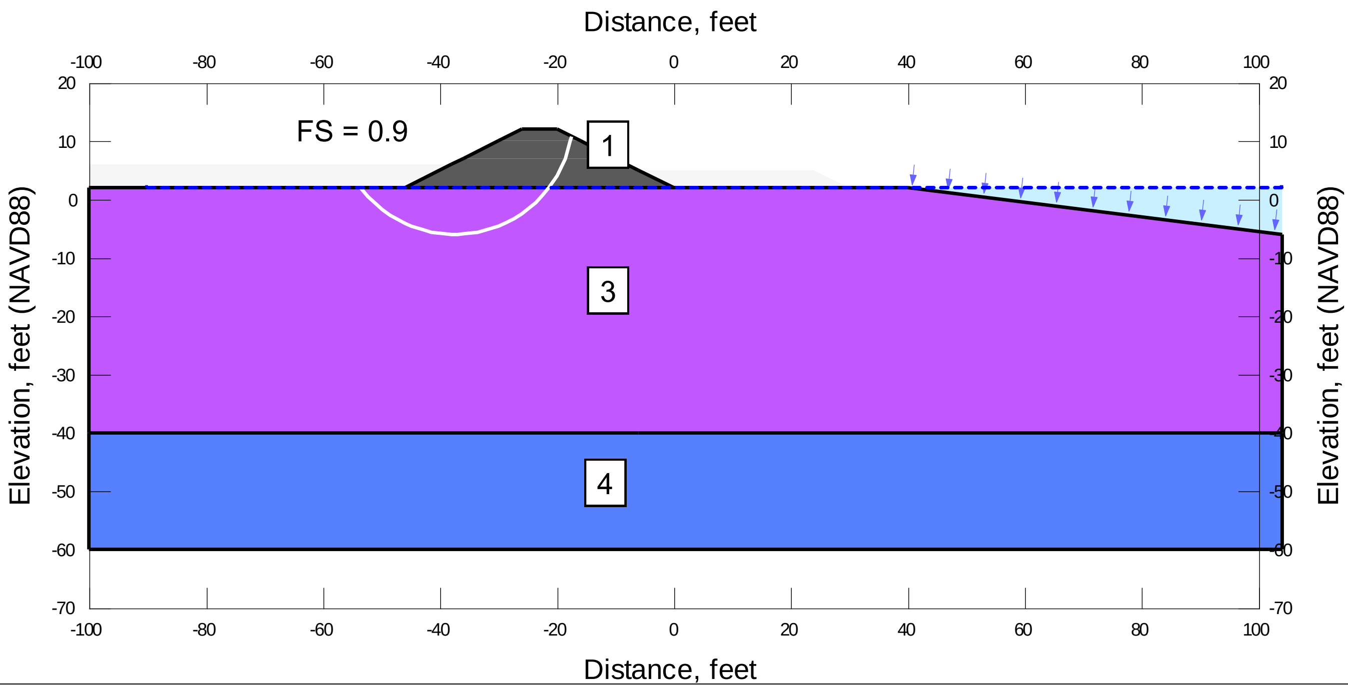
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Virgin Bay Mud	97	100 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Coarse Beach on Virgin Marsh
Step 3: Second Lift Rock Fill (WS)

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-25



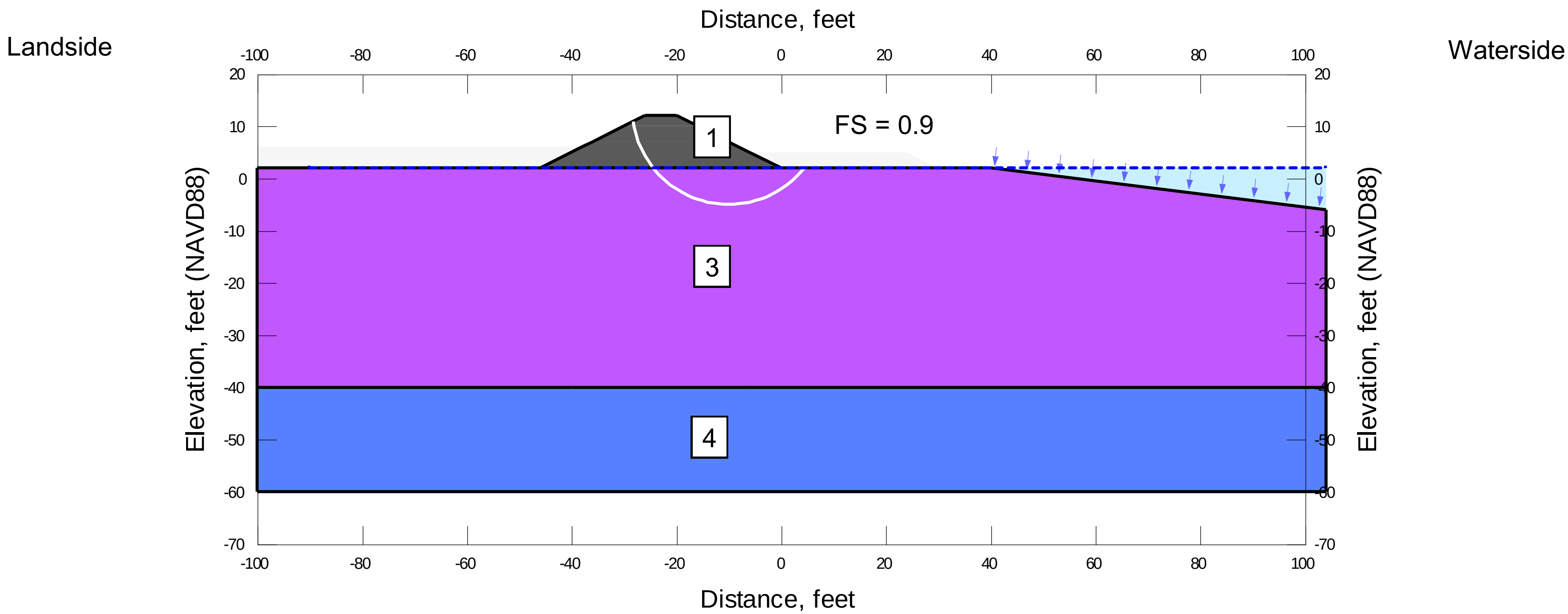
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Eroded Bay Mud	97	140 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Rock Jetty on Eroded Marsh
Full Section (LS)

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-26



STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Eroded Bay Mud	97	140 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Rock Jetty on Eroded Marsh
Full Section (WS)

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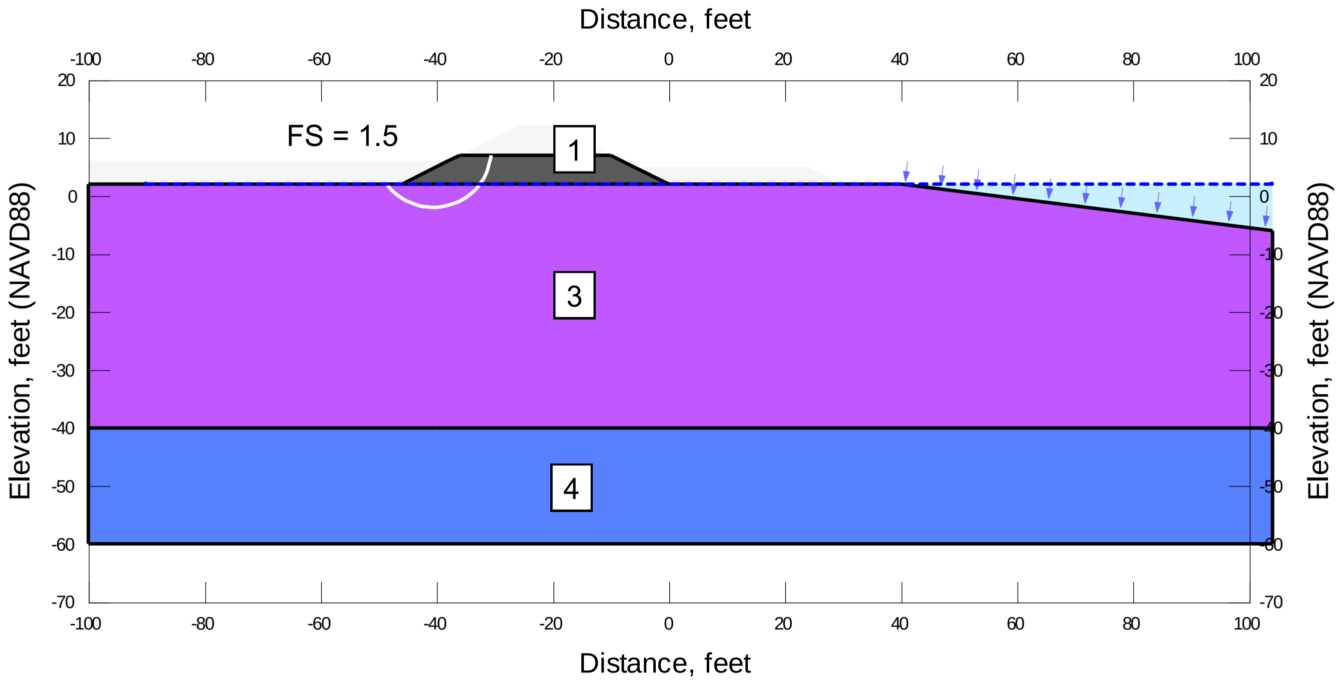
Landside

Waterside



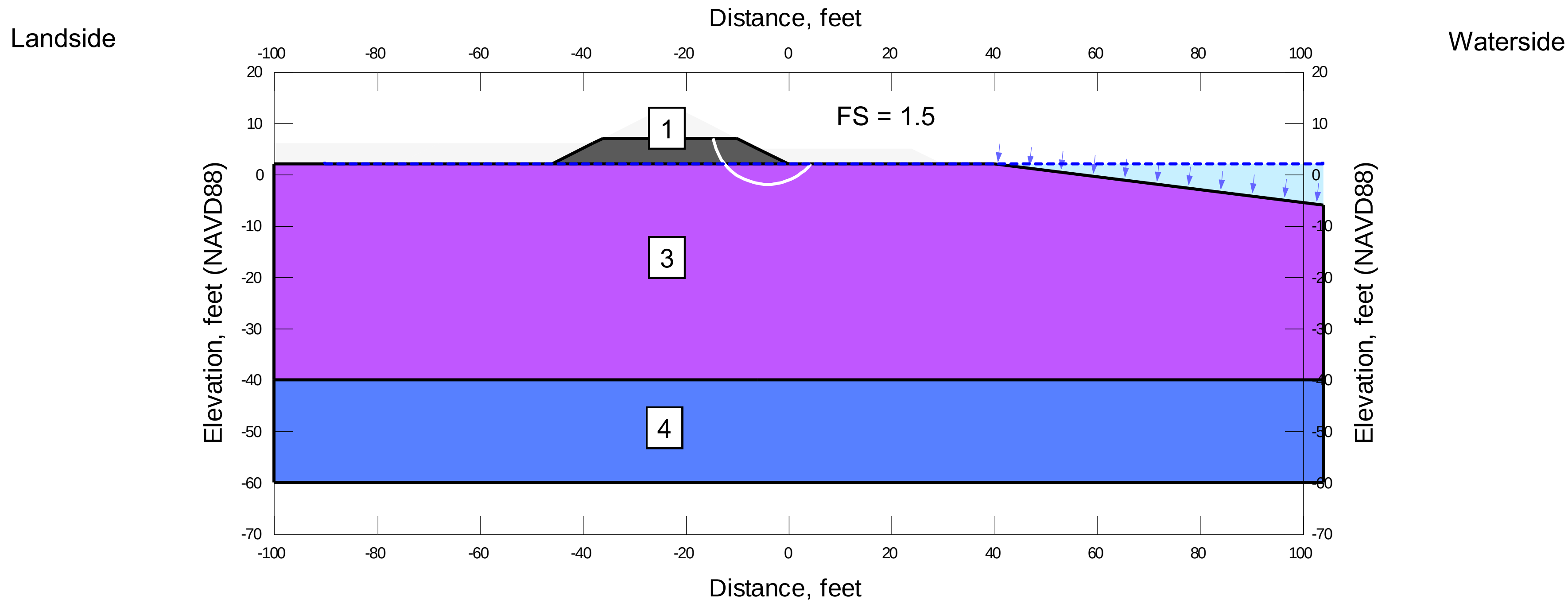
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Eroded Bay Mud	97	140 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Rock Jetty on Eroded Marsh
Step 1: First Lift Rock Fill (LS)

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-28



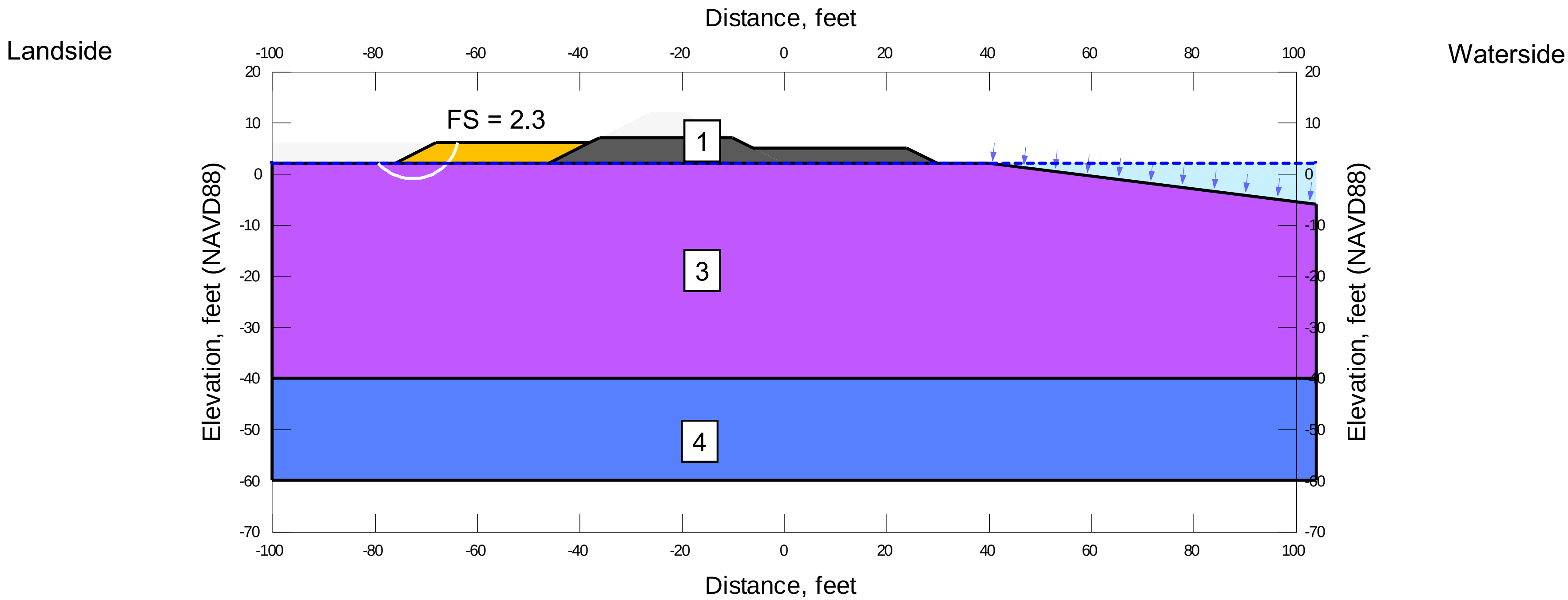
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Eroded Bay Mud	97	140 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Rock Jetty on Eroded Marsh
Step 1: First Lift Rock Fill (WS)

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-29



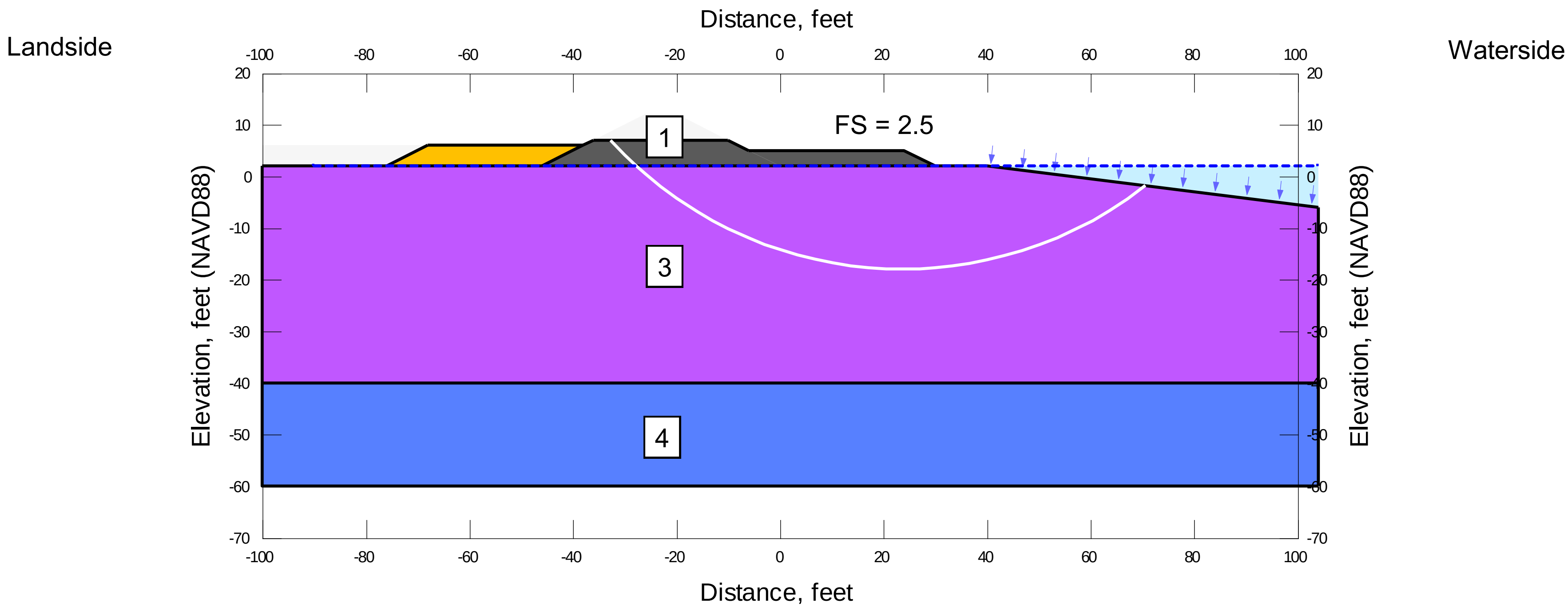
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Eroded Bay Mud	97	140 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Rock Jetty on Eroded Marsh
Step 2: Buttress Slopes (LS)

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-30



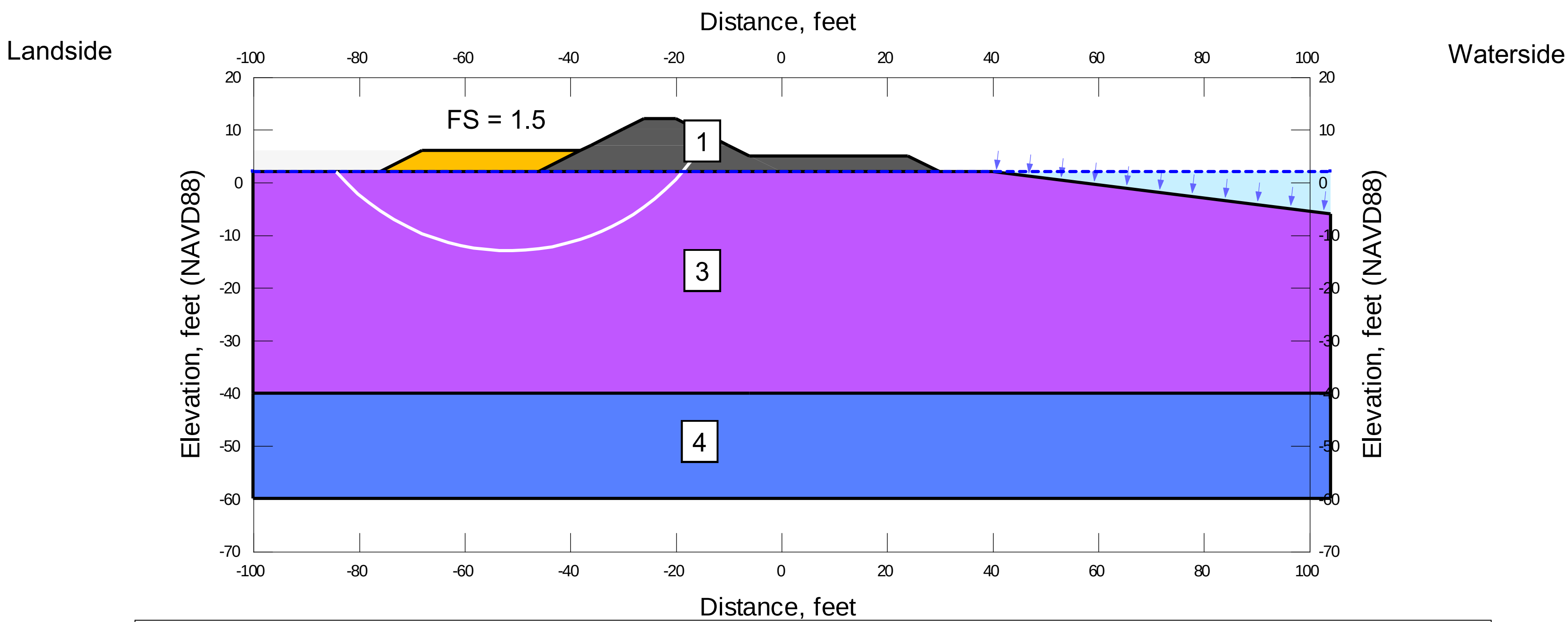
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Eroded Bay Mud	97	140 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Rock Jetty on Eroded Marsh
Step 2: Buttress Slopes (WS)

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-31



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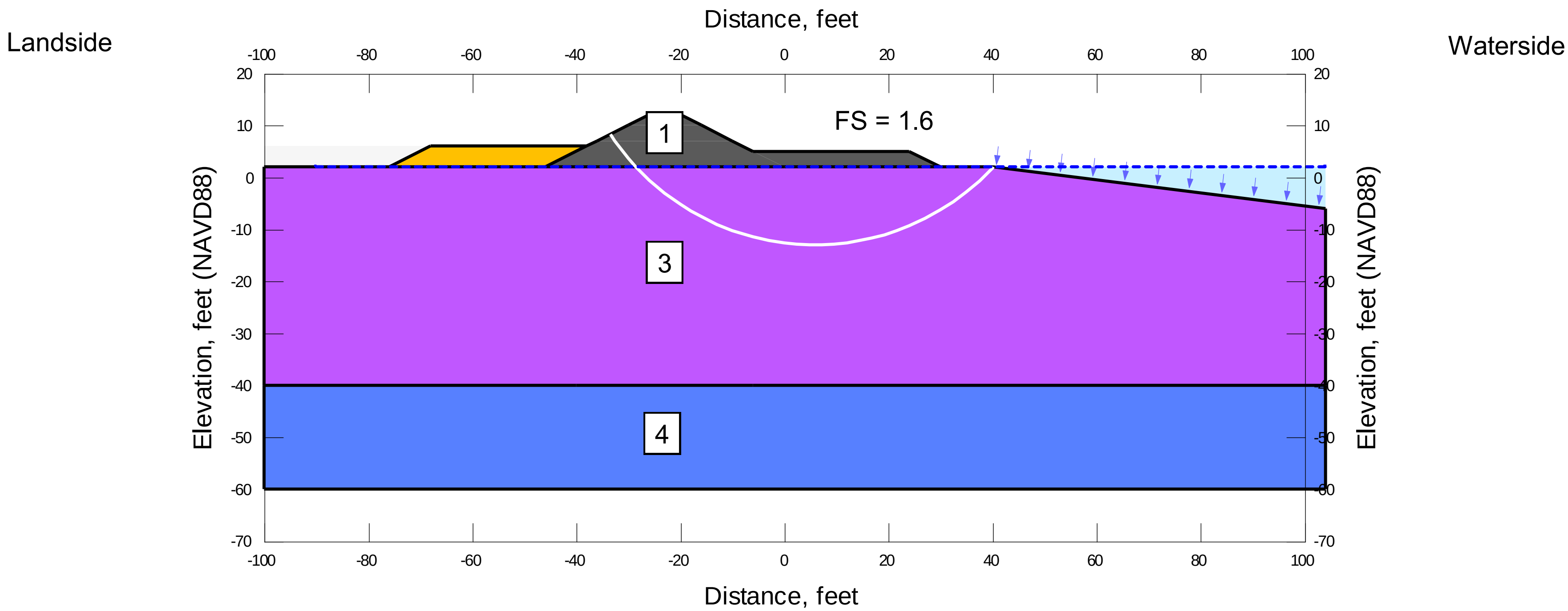
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Eroded Bay Mud	97	140 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Rock Jetty on Eroded Marsh
Step 3: Second Lift Rock Fill (LS)

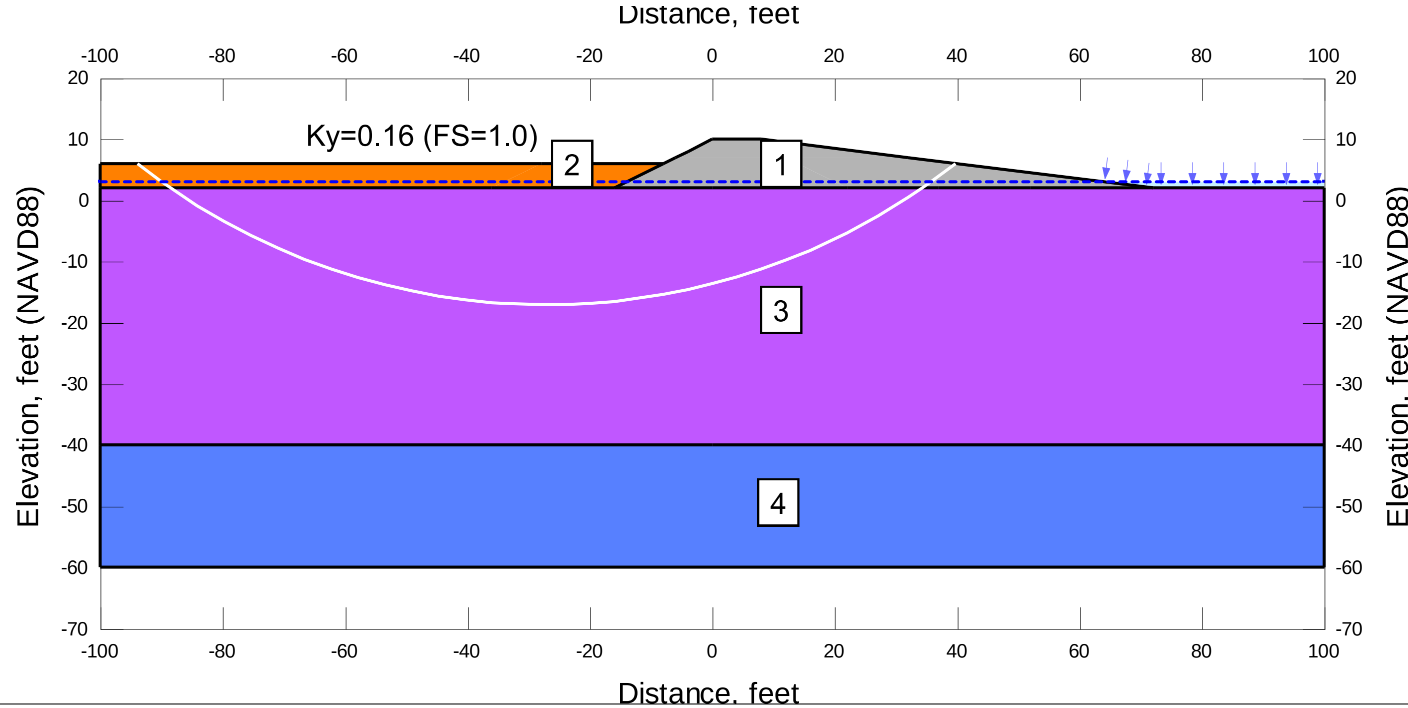
Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-32



STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Eroded Bay Mud	97	140 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Slope Stability Analyses Results Rock Jetty on Eroded Marsh Step 3: Second Lift Rock Fill (WS)**	
Hultgren - Tillis Engineers	Project No. 923.01	Plate No. E-33



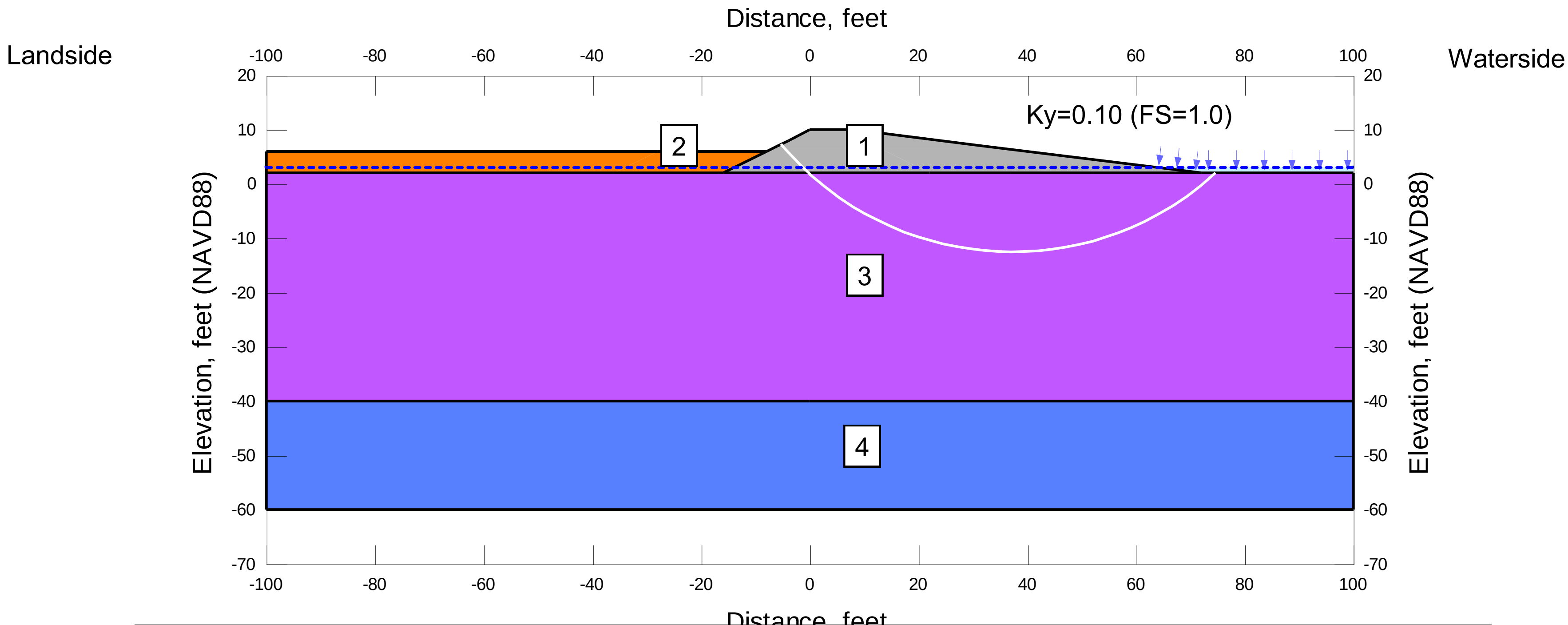
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Eroded Bay Mud	97	140 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Coarse Beach on Eroded Marsh
Pseudo-Static (LS)

Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-34



STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Eroded Bay Mud	97	140 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

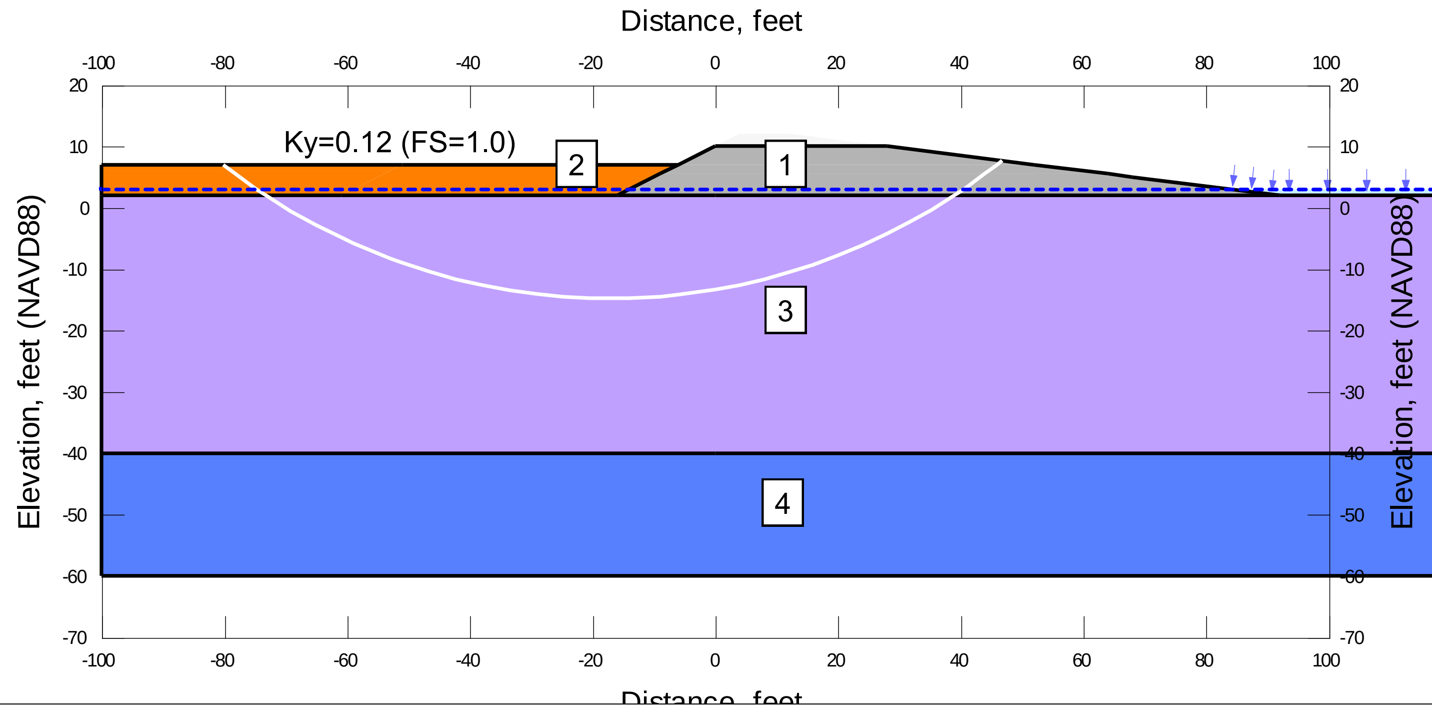
Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Coarse Beach on Eroded Marsh
Pseudo-Static (WS)

Hultgren - Tillis Engineers

Project No. 923.01

Plate No. E-35



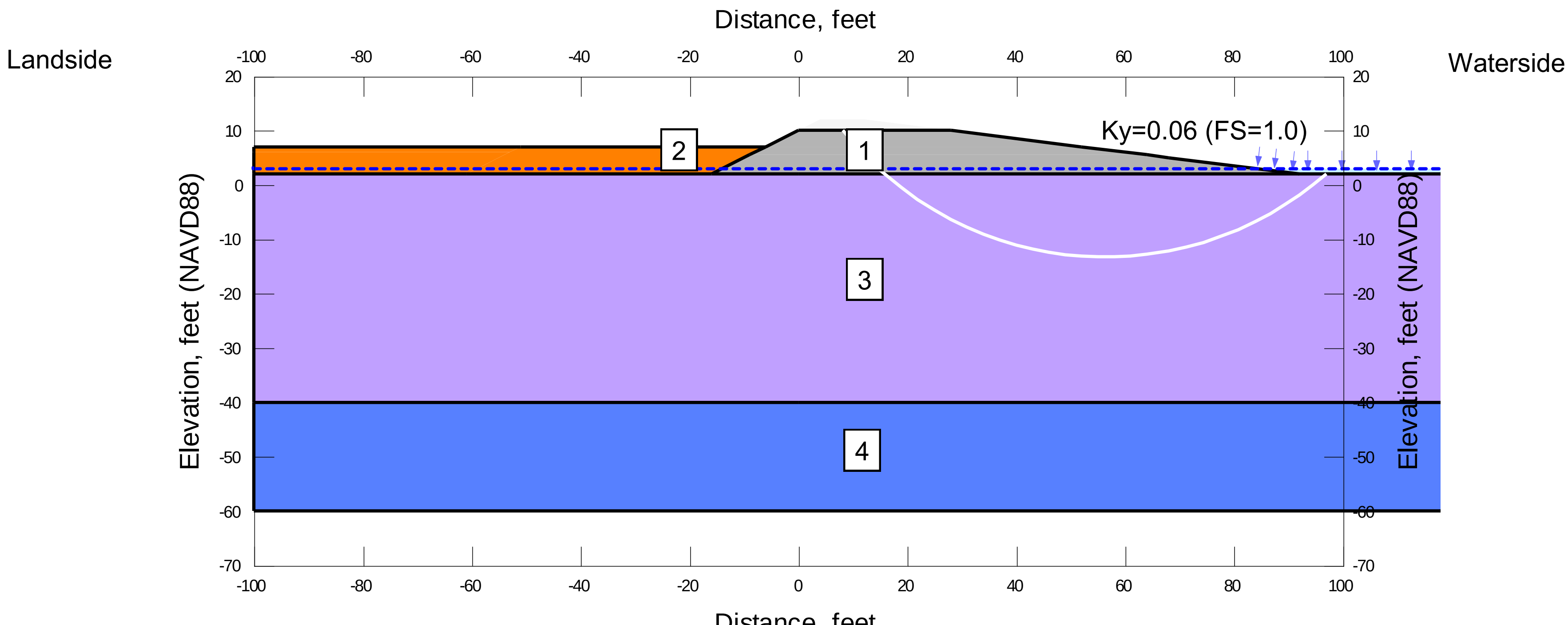
STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Virgin Bay Mud	97	100 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Coarse Beach on Virgin Marsh
Pseudo-Static (LS)

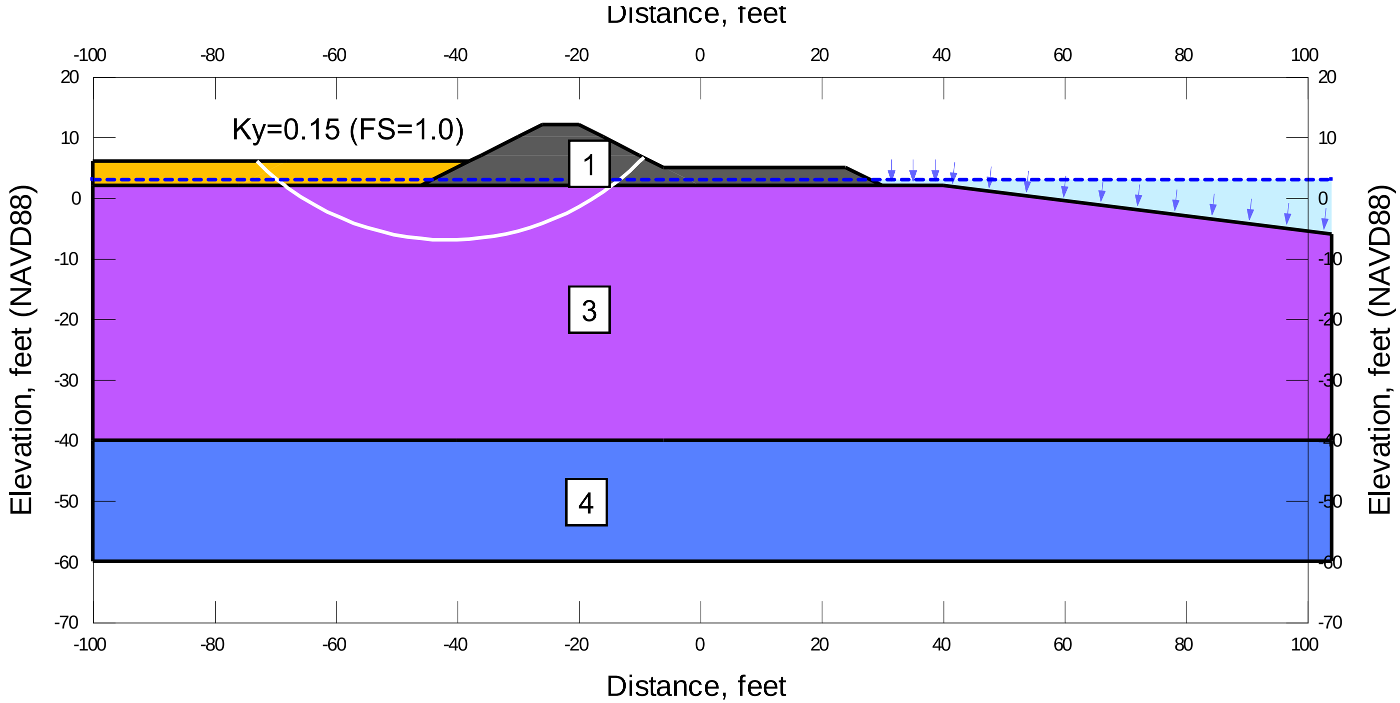
Hultgren - Tillis Engineers | Project No. 923.01 | Plate No. E-36



STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Virgin Bay Mud	97	100 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Slope Stability Analyses Results** **Coarse Beach on Virgin Marsh** **Pseudo-Static (WS)**
Hultgren - Tillis Engineers	Project No. 923.01 — Plate No. E-37



STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Eroded Bay Mud	97	140 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

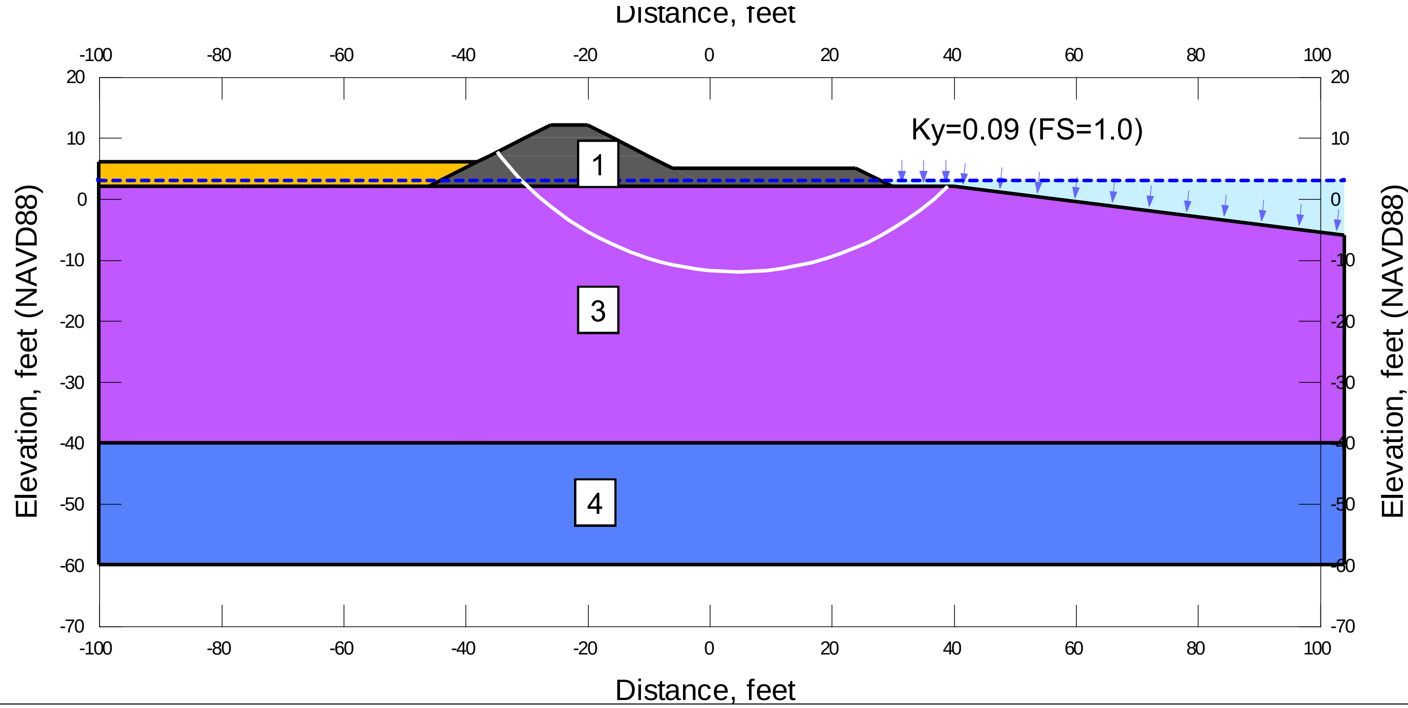
Restore Eroded and Diked Marsh
Tiscornia Marsh Habitat Restoration
San Rafael, California

Slope Stability Analyses Results
Rock Jetty on Eroded Marsh
Pseudo-Static (LS)

Hultgren - Tillis Engineers

Project No. 923.01

Plate No. E-38



STABILITY MODEL MATERIAL PROPERTIES							
UNIT NO.	LAYER COLOR	MATERIAL TYPE	UNIT WEIGHT (pcf)	UNDRAINED STRENGTH		EFFECTIVE STRENGTH	
				COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
1		New Rock Fill	135	-	-	50	38
2		New Dredged Fill	100	-	-	50	30
3		Eroded Bay Mud	97	140 + 10H	-	-	-
4		Stiff Clay	120	1,000	-	-	-

Note:
H is depth below top of unit layer.

Restore Eroded and Diked Marsh Tiscornia Marsh Habitat Restoration San Rafael, California	**Slope Stability Analyses Results Rock Jetty on Eroded Marsh Pseudo-Static (WS)**

Hultgren - Tillis Engineers	Project No. 923.01	Plate No. E-39

APPENDIX F

Seismic Deformation

F-1. SEISMIC DEFORMATION

A. Levee Embankment

We analyzed seismic deformation using the simplified procedure presented in URS Guidance Document (2015) for Urban Levee Evaluations. The analysis is based on an earthquake with a 200-year return period and a moment magnitude of 7.0. The estimated peak horizontal acceleration (PHA) from the USGS Unified Hazard Tool calculator at the site is about 0.34g. Deformations can be estimated based on the ratio of the yield acceleration (k_y) to the maximum seismic coefficient (k_{max}). Using a symmetric levee geometry and assuming a potential deep shear surface, we estimate that k_{max} is 0.22g. For a k_y of 0.08, the analysis suggests that the calculated k_y to k_{max} ratio will result in horizontal deformations of 0.5 feet or less for the offset and setback levee. As a qualitative estimate of loss of freeboard, the vertical deformation of the levee crest is estimated as 0.7 times the total deformations. The resulting estimated vertical deformations is about 4-inches or less for the new levee crest. Some regrading of the levee embankment may be needed following a large earthquake.

B. Tidal Marsh Area

We also analyzed seismic deformation for the coarse beach and rock jetty using the simplified procedure presented in URS Guidance Document (2015) for Urban Levee Evaluations. Using a symmetric berm geometry and assuming a potential deep shear surface, we estimate that k_{max} is 0.22g. For a k_y of 0.09, the analysis suggests that the calculated k_y to k_{max} ratio will result in horizontal deformations of 0.4 feet or less. As a qualitative estimate of loss of freeboard, the vertical deformation of the berm crest is estimated as 0.7 times the total deformations. The resulting estimated vertical deformations is about 3-inches or less for the new coarse beach and rock jetty berm crest on eroded marsh areas. For a k_y of 0.09, the resulting estimated vertical deformations is about 8-inches or less for the new coarse beach or virgin marsh areas. Some regrading of the berms may be needed following a large earthquake.