A California Corporation
Specializing in Geotechnical Engineering

Hultgren-Tillis Engineers

CONCEPTUAL DESIGN

STATEN ISLAND DAM
SAN JOAQUIN COUNTY, CALIFORNIA

Project No. 516.02
July 16, 2004

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July 16, 2004
Project No. 516.02

Jones & Stokes
2600 V Street, Suite 100
Sacramento, California 95818

Attention: Mr. Sam Garcia

Conceptual Design
Staten Island Dam
San Joaquin County, California

Dear Mr. Garcia:

We performed conceptual design for the proposed new dam locations on Staten Island, California in accordance with Subconsultant Consulting Services Task Order Master Agreement dated April 17, 2002 and Task Order 2. The results of our conceptual design are presented in the attached report.

We enjoyed working on this project and look forward to working with you during completion of the environmental documents. If you have any questions, please call.

Sincerely,

Hultgren – Tillis Engineers

R. Kevin Tillis
Geotechnical Engineer

REGISTERED PROFESSIONAL ENGINEER
R. KEVIN TILLIS
No. GE 2160
Exp. 3/31/07
GEOTECHNICAL
STATE OF CALIFORNIA

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I. INTRODUCTION

This report presents the results of our conceptual design of proposed new embankments on Staten Island, in San Joaquin County, California. The location of Staten Island is shown on the Vicinity Map, Plate 1. Reclamation District No. 38 stationing of Staten Island's perimeter levee is shown on the Site Plan, Plate 2. Staten Island is surrounded by the South Mokelumne River to the south and east and the North Mokelumne River to the north and west.

As part of the North Delta Flood Control and Ecosystem Restoration project, a portion of Staten Island will be used to temporarily store floodwaters. We understand that the island will store water no more frequently than once every 10 years, on average. Only a portion of the island will be used for temporary storage. To create water storage, one or more new embankment(s) are planned to partition the island and create a reservoir. The exact locations of embankments have not been finalized. Existing plans indicate that embankments will be constructed on the central to north end of the island. Embankments may be used to protect an existing grain silo and several existing residences.

The island is below sea level and would be filled through flood control weirs or other inflow structures. The site cannot drain by gravity since the island ground surface is well below the water levels in the surrounding channels. Pumps will be required to empty the reservoir. We understand that the current plan is to have the capability of removing half the water from the reservoir in approximately 26 days.

The new embankments may be classified as dams and fall under the jurisdiction of State of California, Department of Water Resources (DWR), Division of Safety of Dams (DSOD). For this reason, we have referred to the embankments as dams throughout this report, which will be provided to DSOD staff to help make a final determination. The existing levees would not be under DSOD jurisdiction.

Our scope of services was outlined in the Subconsultant Consulting Services Task Order Master Agreement dated April 17, 2002 and Task Order 2. This study is intended to evaluate the feasibility of constructing one or more dams on Staten Island. We used existing subsurface and topographic data. We did not collect additional data for this study. A comprehensive geotechnical exploration program and a detailed analysis will be needed for final design of the selected alignment.

II. SITE CONDITIONS

A. Surface Conditions

The ground surface within the interior of Staten Island varies from about Elevation –2 feet (NGVD, 1929) on the north side of the island to about Elevation –20 feet on the south side. The island is surrounded by water and levees protect the island from flooding. The 100-year flood level[1] varies from about Elevation 14 feet on the north side of Staten Island to about Elevation 7.5 feet on the southwest side. The crest of the existing levee varies in elevation around the island perimeter to roughly match the variation in the 100-year flood. Within the central to northern portion of the island where one of the new dams is being considered, the ground surface within the island is at about Elevation –12 feet and the existing levee crest is at about Elevation 12 feet.

B. Subsurface Data

We reviewed existing subsurface data consisting mainly of borings by DWR for the Salinity Control Barrier investigation from the 1950's and monitoring wells installed as part of a seepage study from 1994. We understand that the data has been previously submitted to DSOD by DWR. The existing data is limited to borings and monitoring wells near or in the existing levees. We did not find subsurface data within the island interior. The existing data suggests that the peat is relatively thin in the central and northern portion of the island and appears to be 5 feet thick or less in most of these areas. The peat is thicker on the southern end of the island and probably extends 10 to 15 feet below the existing ground surface. Sands and clay underlie the peat. The continuity of these sand and clay layers is not well defined from the existing data.

The groundwater level within delta islands is typically within a few feet of the ground surface and the depth varies from winter to summer. The existing water levels in the levees vary. Close to the levees, the groundwater within the peat and sand is strongly influenced by tides, with the tidal influence becoming less pronounced at increasing distance from the levees.

[1] Source: Sacramento-San Joaquin Delta Atlas, August 1987, State of California, The Resources Agency, Department of Water Resources.

The above descriptions of soil and groundwater conditions summarize conditions from widely spaced borings located on the perimeter of the island. The actual site conditions should be expected to vary. The description is intended to provide a basis for conceptual design of a dam.

III. DISCUSSION AND CONCLUSIONS

A. Basis of Design

To provide an evaluation of the safety of a dam on Staten Island, we used the following assumptions as the basis for conceptual design:

1. The dam will be constructed with low permeability materials (lean clay or clayey sand to sandy clay);
2. The water within the reservoir will be removed before full saturation of the dam embankment and the phreatic line will not develop to the downstream face. Interior drains will not be needed;
3. The existing levees will be the dam abutments;
4. The existing levees will be used as the spillway;
5. The reservoir will be drained by pumping or outlet structures through the existing levee. Outlet works through the dam will not be constructed;
6. Seismic analysis will not be required by DSOD for this level of design;
7. To meet DSOD criteria, the dam crest should be at least 1.5 feet above the maximum water level that develops when water flows over the spillway. To achieve this, we have set the dam crest at 2 feet above the crest of the existing levee;
8. The operating freeboard will be 5 feet. The provisions to control the water level to 5 feet below the dam crest (3 feet below the existing levee) will be provided by DWR or others.

The design of the spillway over the existing levee has not been completed. The plan to lower the reservoir level by pumping has also not been completed. We have assumed that the reservoir will be lowered to at least 3 feet below the existing levee crest relatively quickly to protect the dam and existing levee from excessive erosion and overtopping from wind-generated waves. If this criteria cannot be met, the alternative is to raise the dam to 5 feet above the existing levee to provide 5 feet of freeboard. We did not analyze a dam to this height although the basis analysis indicates that a dam is feasible on Staten Island. We believe raising the dam crest an additional 3 feet to 5 feet above the levee will be feasible with little modification to the basic cross-sections.

B. Typical Dam Profiles

The final alignment(s) of the dam or dams has not been determined. To allow flexibility in future siting of the dams, we have evaluated two potential dam profiles.

Profile 1: This profile assumes that the peat is shallow enough (about 5 feet thick or less) to fully remove it below the footprint of the dam. We have assumed that the peat would be replaced with the same fill material used for the embankment materials. We have assumed that the peat would be removed to a distance of 20 feet beyond the downstream and upstream toes. The dam would then be constructed on the underlying stiffer sands and clay. A typical detail is presented on Plate 3.

Profile 2: This profile assumes that the peat is too thick to effectively remove. The island is well below sea level and dewatering to remove the peat may not be practical. For conceptual design on Profile 2, we have assumed that the dam would be constructed on 10 feet of peat. A typical detail is shown on Plate 4.

C. Seismic Design

Although, DSOD has indicated that seismic design would not be required at this stage of design, we considered the potential effects of liquefaction on the two dam profiles. The existing data is not sufficient to evaluate whether materials exist below the site that are susceptible to liquefaction. The intent of our evaluation is to check the impacts to dam safety should liquefaction occur.

For Profile 1 we conclude that potentially liquefiable sand can be densified with conventional earthwork equipment or other techniques such as deep dynamic compaction. The liquefaction hazard can be reduced to a level that will keep deformation sufficiently small to maintain the integrity of the dam under operating conditions.

For Profile 2 we assumed that if the material below the peat is potentially liquefiable, that there is no cost effective method to densify the underlying sand and eliminate the liquefaction hazard. We used the residual strength in the sand in computing the factor of safety for slope stability.

During final design, a thorough seismic analysis of the dam will be needed. The deformation of the dam from seismic shaking needs to be checked. Some modification to the basic cross-section may be needed to limit deformation and provide a safe, reliable dam.

D. Design Parameters and Analysis

The design parameters used for slope stability analysis are shown in Table 1, below. The design values are based on typical published values for fill and stiff soil and on data collected by our firm on the strength of peat in the delta.

We used the computer program U-Texas 3 for slope stability analysis. For purposes of the stability analysis, we assumed that a phreatic line develops through the dam as shown on Plates 6 and 9. Although the basic design concept is to remove the water quickly enough to limit saturation of the dam and the need for an internal drain, we made a conservative assumption on the phreatic line for the stability analysis.

For the dam on stiff ground, we used effective stress parameters to check the factor of safety for the downstream slope. For rapid drawdown we used both undrained and effective stress for fill and the two-stage analysis. We used an initial phreatic line that is high in the dam, then lowered the reservoir level but left the phreatic level constant.

For the dam on peat, we used the two-stage analysis to assess the undrained strength of the peat for landside (downstream) slope stability. We also checked the factor of safety using an existing undrained shear strength of 200 psf. We did not check the effective stress condition since the effective stress strength is higher. We conclude that the peat will fail undrained and believe that is the appropriate analysis for peat. For rapid drawdown we used two-stage strength for peat and fill assuming the peat had fully consolidated under fill loads.

For liquefaction, we used a residual strength of 200 psf for sand. We calculated the factor of safety assuming 5 feet and 10 feet thicknesses of liquefied sand and full consolidation of the peat.

Table 1. Soil Parameters

Soil Type	Unit Weight (pcf)	Undrained Strength		Effective Strength	
		Cohesion (psf)	Friction Angle (°)	Cohesion (psf)	Friction Angle (°)
Fill	125	300	18	200	25
Peat	70	150	20	100	40
Native Soil	125	-	-	200	25
Sand-Residual	125	200	0	-	-

E. Dam on Stiff Ground

For a dam on Profile 1, we assumed that the peat was excavated and replaced with compacted fill. We analyzed the stability of an earth embankment with a 16-feet wide crest located at Elevation 14 feet (2 feet above the perimeter flood control levee), with a 3:1 upstream slope and 2.5:1 downstream slope. We assumed that the ground surface is at Elevation –12 feet and the dam height is 26 feet. A typical section is presented on Plate 3. We checked the embankment for "long-term" steady state conditions and rapid drawdown on the upstream face.

Table 2. Safety Factors for Dam on Stiff Soil

Case	Factor of Safety
Steady State – Downstream Slope	1.54
Rapid Drawdown - Halfway Upstream	1.78
Rapid Drawdown – Complete	1.45

We calculated a factor of safety of 1.54 for steady state conditions for the downstream slope and a factor of safety of 1.78 for drawdown of half the reservoir and 1.45 for drawdown of all of the reservoir. The results are presented on Plates 6 through 8.

We conclude that this dam cross-section is feasible and appropriate for conceptual design. During final design some changes in the cross-section may be needed depending on the type and strength of materials chosen to construct the dam.

F. Dam on Peat

We assumed that the peat is 10 feet thick below the embankment for Profile 2. We analyzed the stability of a dam with a final crest width of 16 feet after full consolidation of the peat, an upstream slope of 3:1 buttressed with a toe berm inclined at 10:1 and a downstream

slope of 2.5:1 buttressed by a 10:1 toe berm. For the immediately-after-construction condition, we used an initial crest width of 30 feet at Elevation 14 feet to allow for raising of the dam as it settles. We assumed that the toe berm started at one-half the height of the dam. We assumed that the ground surface is at Elevation –12 feet and the dam height is 26 feet. A typical section is shown on Plate 4.

For the analysis, we assumed that the dam would be constructed quickly and used the existing undrained shear strength of the peat to evaluate the factor of safety. We also checked the factor of safety after complete consolidation and strength gain within the peat. We do not believe that the dam should be constructed in one sequence, rather, it should be constructed in stages that allow strength gain in the peat. However, we wanted to check the factor of safety assuming single stage construction and then compare it to the factor of safety after full consolidation. We also checked the factor of safety for rapid drawdown after full consolidation and for liquefaction of the sand below the peat. The factor of safety for these cases is presented in Table 3 below. The results are also presented on Plates 9 through 14.

Table 3. Safety Factors for Dam on Peat

Case	Factor of Safety	Comments
Single Stage of Fill	1.22	2-stage strength peat
Single Stage of Fill	1.28	C=200 psf for peat
After Consolidation	2.13	
Rapid Drawdown - half-way	1.95	
Rapid Drawdown – complete	1.78	
Liquefaction - 5’ of sand	1.56	
Liquefaction – 10’ of sand	1.27	
Liquefaction – 10’ of sand with 12:1 berm	1.38	Flatten berm to 12:1

The analysis indicates that it is not safe to rapidly construct the embankment to its full height. Stages of filling with time between stages will be needed to safely construct the embankment. The factor of safety after full consolidation is 2.13. The factor of safety assuming liquefaction and a residual strength of 200 psf in the sand is 1.56 for a 5-foot thickness of liquefied material. The factor of safety is 1.27 for a 10-foot thick liquefied layer. If the toe berm is flattened to 12:1, the factor of safety increases to 1.38 for a 10-foot thick liquefied layer.

We conclude that the dam is feasible to construct over peat. The analysis indicates that the risk of liquefaction induced slope failure can be reduced to a safe level with wide toe berms. The safety of the dam is enhanced by the fact that the reservoir will only store water for short periods and the probability that the reservoir will store water during the design earthquake is very low. The impacts of liquefaction will need further consideration during final design.

We estimate that the peat will compress about 4 to 5 feet under the crest of the dam. The settlement of the dam may introduce tensile stresses within the fill which may cause cracking. There may be a benefit to placing plastic geogrids within the core of the embankment. Geogrids will stiffen the embankment and tend to reduce differential settlement and cracking within the core area. The geogrid needs to be able to accommodate settlement of the embankment without rupturing. The need for geogrid and its compatibility with dam settlement should be evaluated during final design.

G. Abutments

The existing perimeter levee will be the abutment for new dams. The existing levee consists of fill over peat. A typical abutment cross-section is shown on Plate 5. The fills were not placed under engineering observations. Options to improve the existing levees are limited since the levees continuously retain water. The peat can be removed to near the toe of the existing levee for the dam cross-section where peat is removed. The remainder of the peat will need to remain below the abutment.

Seepage through the abutment is a concern because placing the embankment against the existing levee will cause the levee to settle and may cause differential settlement with adjacent sections of the levee. To provide protection against settlement induced cracking and seepage, we conclude that a cutoff should be placed through the existing levee fill and peat. The cutoff should consist of a low permeability material to reduce seepage yet still be flexible enough to resist cracking from differential settlement. A soil bentonite slurry cutoff trench would meet this criteria.

For conceptual design and cost estimating, the cutoff should extend along the axis of the existing levee to at least 20 feet beyond the new dam toe. The cutoff should also extend along the axis of the dam and extend about 20 feet beyond the toe of the existing levee.

We estimate that the total length of cutoff at each abutment will be 340 feet for a dam on stiff ground and 480 feet for a dam constructed on peat.

H. Spillway

Others will perform the spillway design. We have assumed that the spillway will be located at or below the crest of the existing levee. For conceptual design, we have set the dam crest two feet above the existing levee to provide residual freeboard during spilling. We conclude that the dam should have a freeboard of at least 5 feet soon after spilling to provide protection against runup and overtopping from wind generated waves. The perimeter levees will also need protection. The additional freeboard could be obtained through a low level weir or outlet works through the existing levee. Pumping from the reservoir may also be used to drawdown the reservoir and create more freeboard.

I. Outlet Works

We conclude that having a low level outlet to the downstream side of the dam is not practical for this project. The downstream side of the dam will be below sea level. Discharging water through the dam would cause buildup of water downstream of the dam on the southern side of Staten Island. The downstream side of the dam would store water until it was pumped out. For conceptual design, we assume that no pipes will extend through the dam. For a dam constructed on peat, this eliminates the concern of settlement damaging the outlet works.

J. Erosion Protection

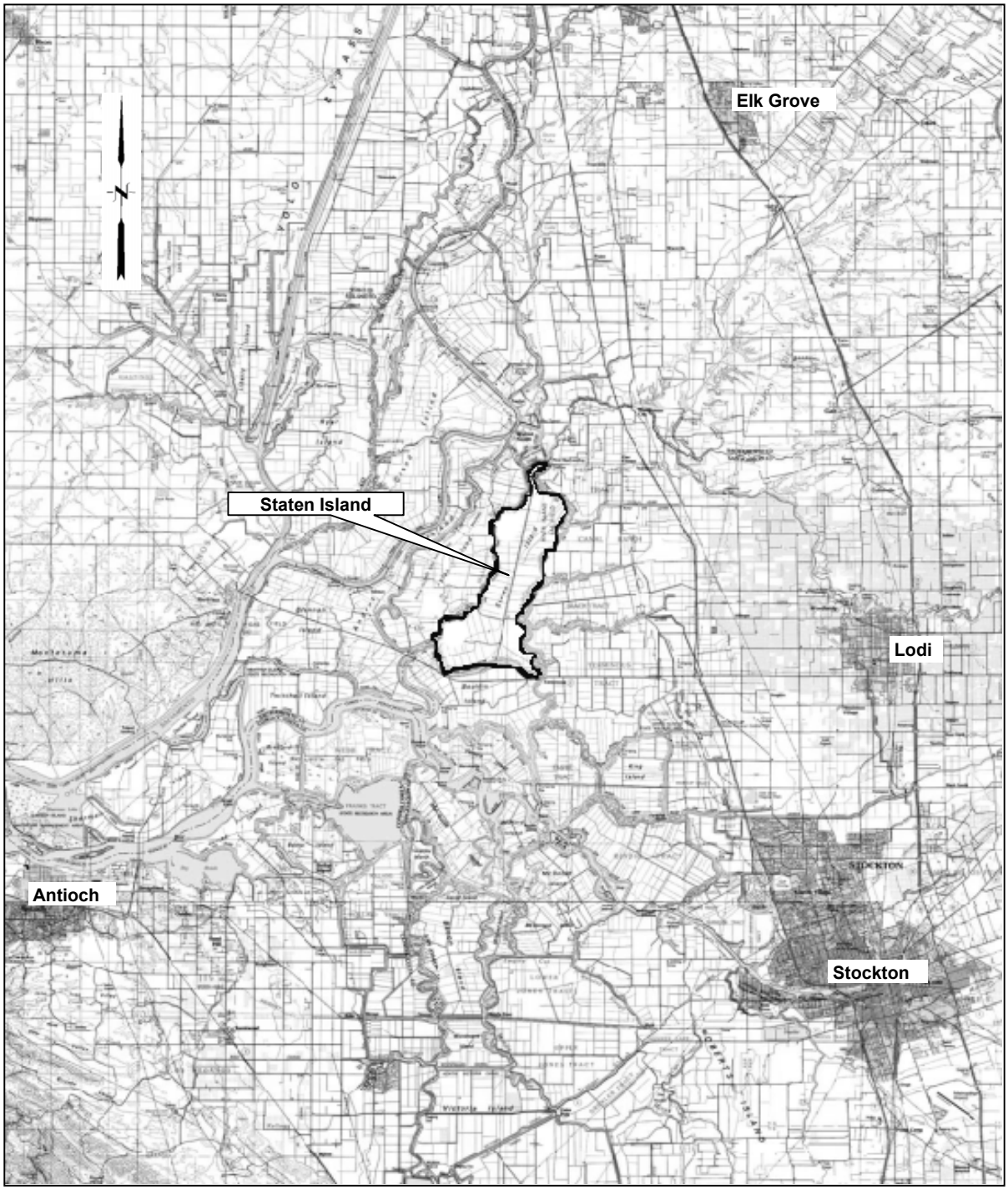
The upstream face of the dam will need to be protected from erosion. Conventional riprap is appropriate to protect the embankment. Where peat is removed, soil treated with cement or lime and placed as a facing material may provide adequate protection. This can be considered during final design along with riprap. The freeboard requirements may be higher for a soil-cement facing since wave runoff tends to be higher for smoother slopes. We conclude that a treated soil facing material is not compatible with the large settlements associated with construction on peat and should not be used for a dam constructed on peat.

K. Earthwork

The embankment should be constructed with low permeability materials. The moisture content and compaction criteria should be developed based on the material type. The toe berm materials could be higher permeability materials since their main function is to provide

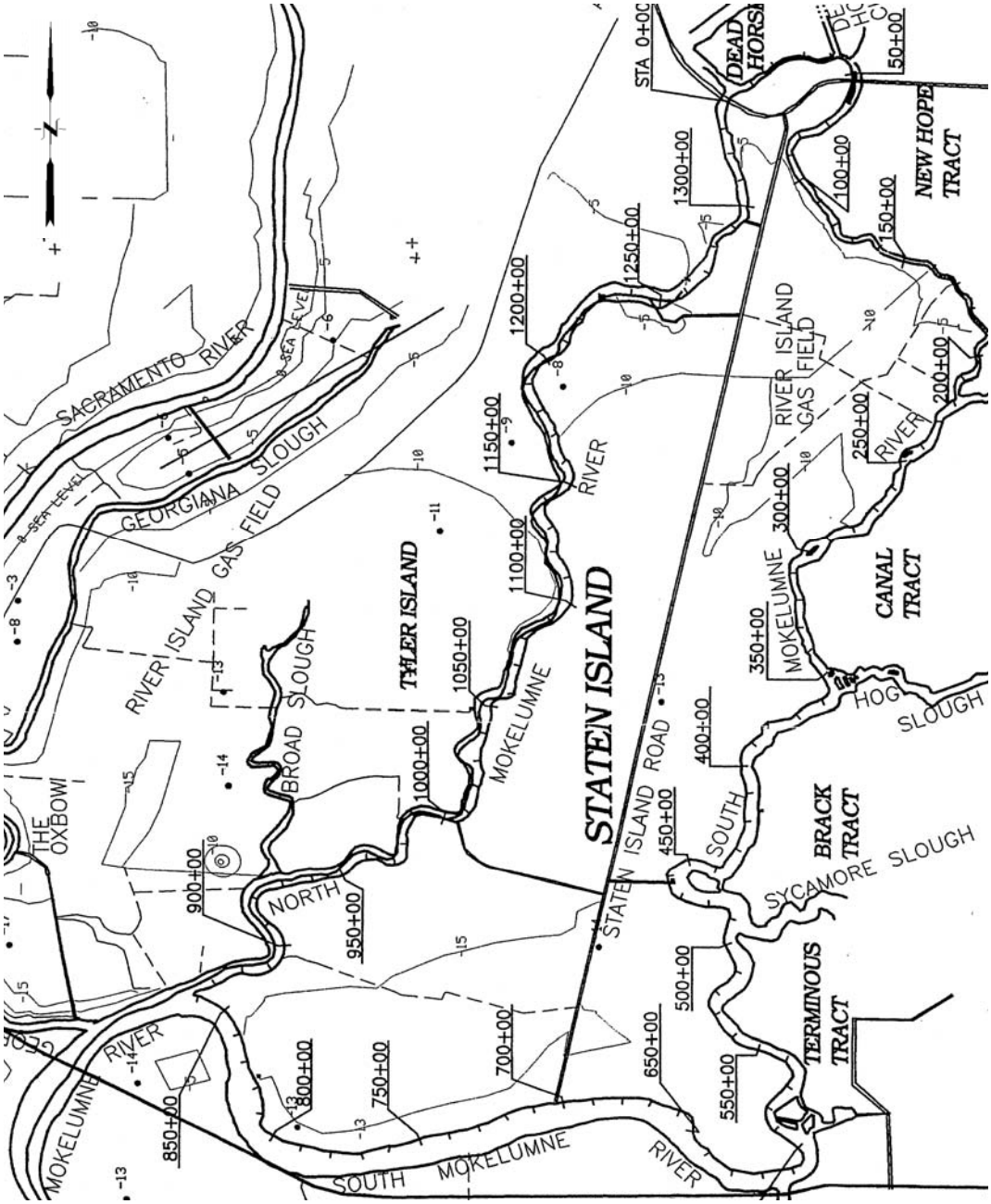
mass to resist slope movements. A higher permeability downstream toe may also provide more protection from seepage. The downstream slope should be covered with vegetation that will provide erosion protection and allow ready examination of the downstream slope. The crest should be covered with at least 6 inches of aggregate base to provide an all-weather road surface.

PLATES



Not to Scale

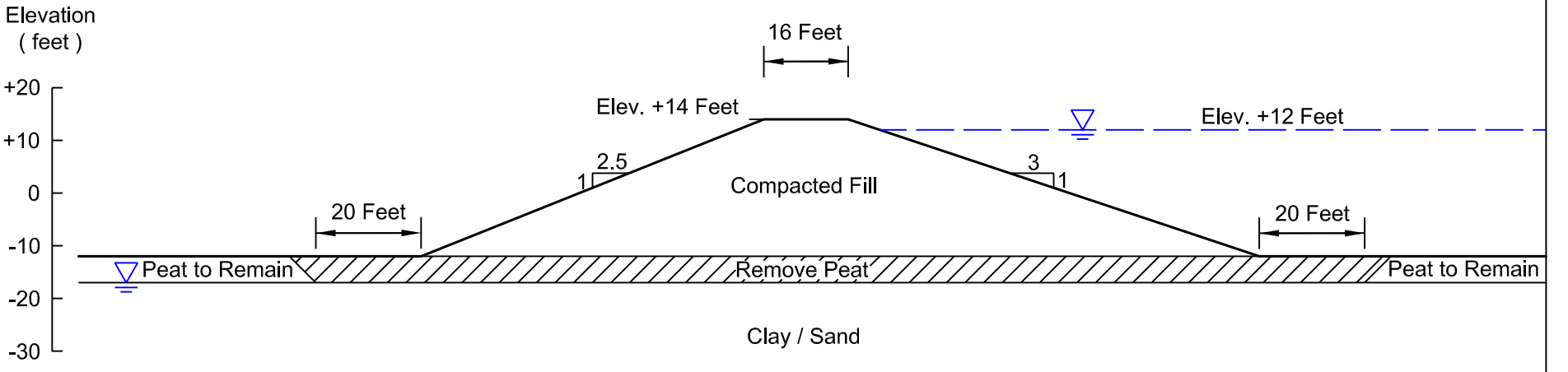
Staten Island Dam San Joaquin County, California	**Vicinity Map**	
Hultgren - Tillis Engineers	Project No. 516.02	Plate No. 1



Scale: 1 " = 6000'

Staten Island Dam San Joaquin County, California	**Site Plan**	
Hultgren - Tillis Engineers	Project No. 516.02	Plate No. 2

Typical Dam - Peat Removed



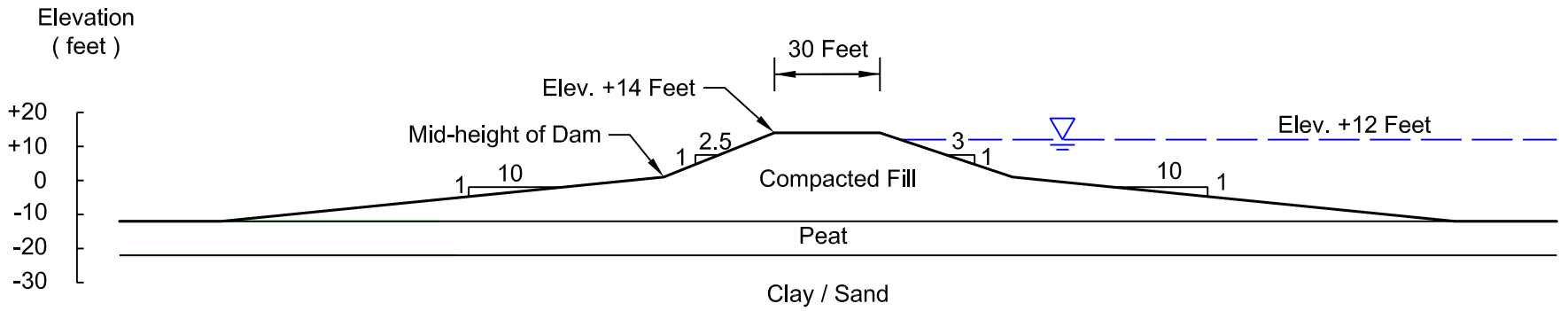
SCALE

0 30 feet

1 inch = 30 feet

Staten Island Dam San Joaquin, California	Typical Dam After Peat Removed	
Hultgren - Tillis Engineers	Project 516.02	Plate 3

Typical Dam Constructed Over Peat



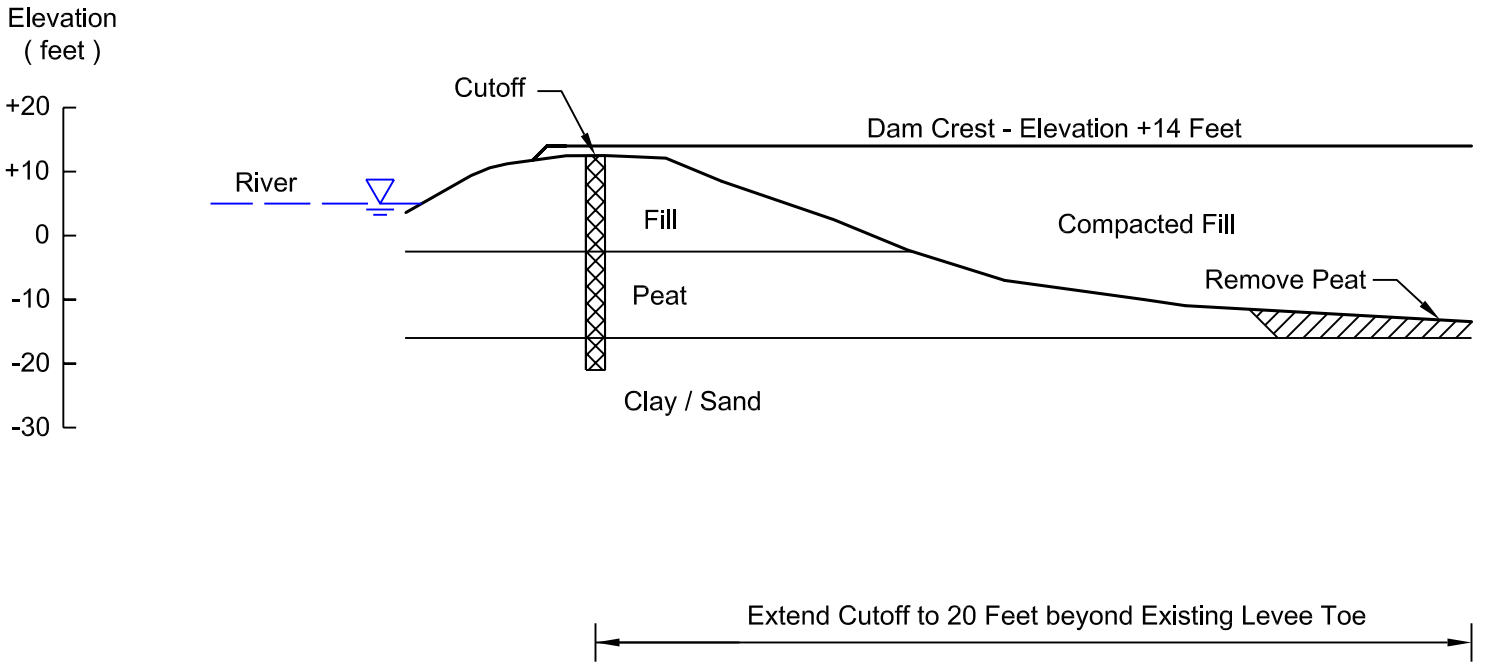
SCALE

0 50 feet

1 inch = 50 feet

Staten Island Dam San Joaquin County, California	Typical Dam Constructed Over Peat	
Hultgren - Tillis Engineers	Project 516.02	Plate 4

Typical Dam Abutment at Levee
Cross-Section - Staten Island Station 1115 + 00



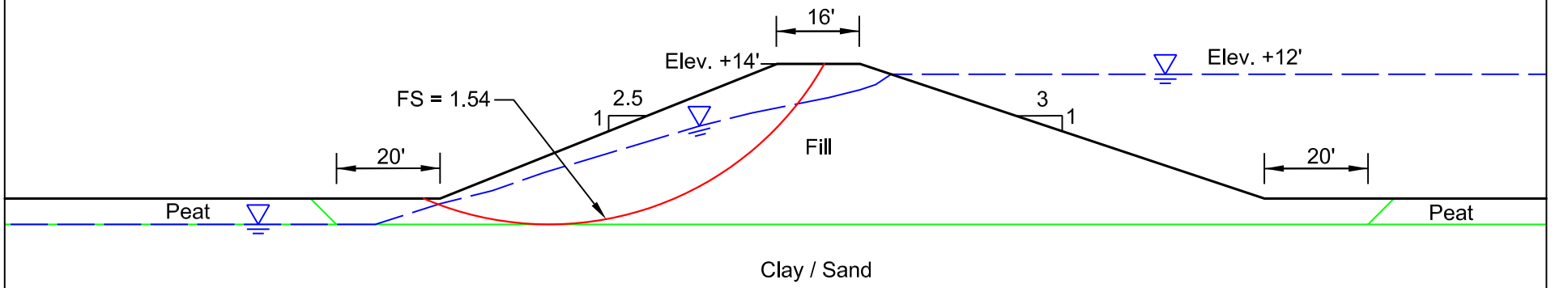
SCALE

0 30 feet

1 inch = 30 feet

Staten Island Dam San Joaquin County, California	Typical Dam Abutment	
Hultgren - Tillis Engineers	Project 516.02	Plate 5

Typical Dam - Peat Removed
Full Reservior



SOIL PARAMETERS

Soil Type	Unit Weight (pcf)	Undrained Strength		Effective Strength	
		Cohesion (psf)	Friction Angle (°)	Cohesion (psf)	Friction Angle (°)
Fill	125	300	18	200	25
Peat	70	150	20	100	40
Native Soil	125	-	-	200	25

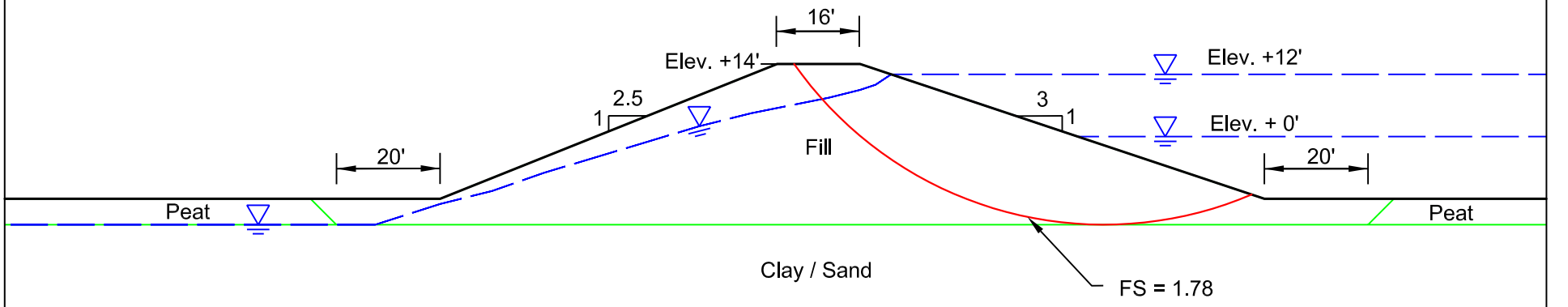
SCALE

0 30 feet

1 inch = 30 feet

Staten Island Dam San Joaquin County, California	Typical Dam - Peat Removed Full Reservior	
Hultgren - Tillis Engineers	Project 516.02	Plate 6

Typical Dam - Peat Removed
Rapid Drawdown - One-Half of Reservior



SOIL PARAMETERS

Soil Type	Unit Weight (pcf)	Undrained Strength		Effective Strength	
		Cohesion (psf)	Friction Angle (°)	Cohesion (psf)	Friction Angle (°)
Fill	125	300	18	200	25
Peat	70	150	20	100	40
Native Soil	125	-	-	200	25

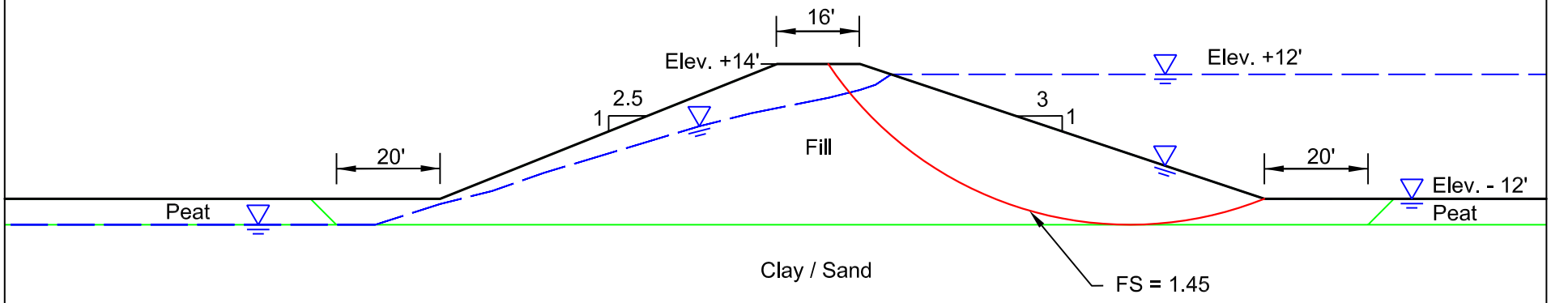
SCALE

0 30 feet

1 inch = 30 feet

Staten Island Dam San Joaquin County, California	Typical Dam - Peat Removed Rapid Drawdown - One-Half of Reservior	
Hultgren - Tillis Engineers	Project 516.02	Plate 7

Typical Dam - Peat Removed
Rapid Drawdown - Empty Reservior



SOIL PARAMETERS

Soil Type	Unit Weight (pcf)	Undrained Strength		Effective Strength	
		Cohesion (psf)	Friction Angle (°)	Cohesion (psf)	Friction Angle (°)
Fill	125	300	18	200	25
Peat	70	150	20	100	40
Native Soil	125	-	-	200	25

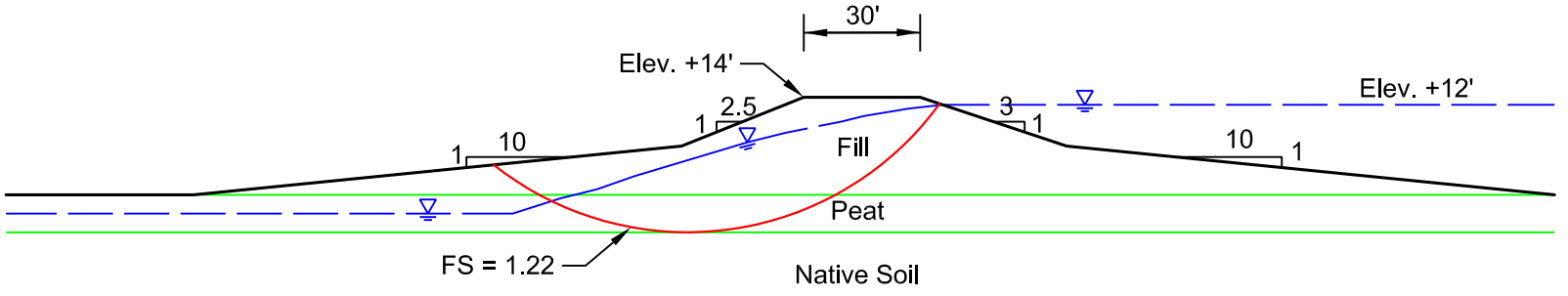
SCALE

0 30 feet

1 inch = 30 feet

Staten Island Dam San Joaquin County, California	Typical Dam - Peat Removed Rapid Drawdown - Empty Reservior	
Hultgren - Tillis Engineers	Project 516.02	Plate 8

Typical Dam - Constructed on Peat
Single Stage of Construction
Two-Stage Undrained Strengths



SOIL PARAMETERS

Soil Type	Unit Weight (pcf)	Undrained Strength		Effective Strength	
		Cohesion (psf)	Friction Angle (°)	Cohesion (psf)	Friction Angle (°)
Fill	125	300	18	200	25
Peat	70	150	20	100	40
Native Soil	125	-	-	200	25

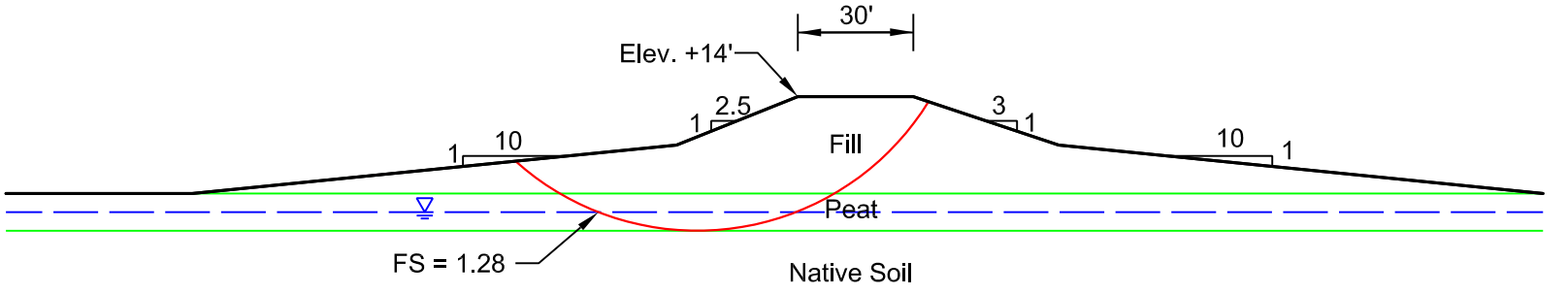
SCALE

0 50 feet

1 inch = 50 feet

Staten Island Dam San Joaquin County, California	Typical Dam - Constructed on Peat Single Stage of Construction	
Hultgren - Tillis Engineers	Project 516.02	Plate 9

Typical Dam - Constructed on Peat
Single Stage of Construction
Undrained Strength



SOIL PARAMETERS

Soil Type	Unit Weight (pcf)	Undrained Strength		Effective Strength	
		Cohesion (psf)	Friction Angle (°)	Cohesion (psf)	Friction Angle (°)
Fill	125	300	18	200	25
Peat	70	200	0	-	-
Native Soil	125	-	-	200	25

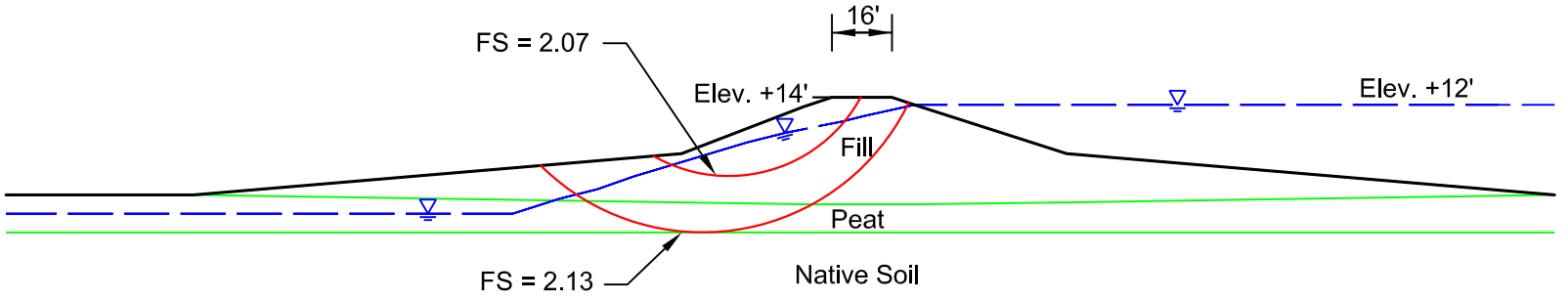
SCALE

0 50 feet

1 inch = 50 feet

Staten Island Dam San Joaquin County, California	Typical Dam - Constructed on Peat Single Stage of Construction	
Hultgren - Tillis Engineers	Project 516.02	Plate 10

Typical Dam - Constructed on Peat
Full Reservior
After Peat Consolidation
Two-Stage Undrained Strengths



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Soil Type	Unit Weight (pcf)	Undrained Strength		Effective Strength	
		Cohesion (psf)	Friction Angle (°)	Cohesion (psf)	Friction Angle (°)
Fill	125	300	18	200	25
Peat	70	150	20	100	40
Native Soil	125	-	-	200	25

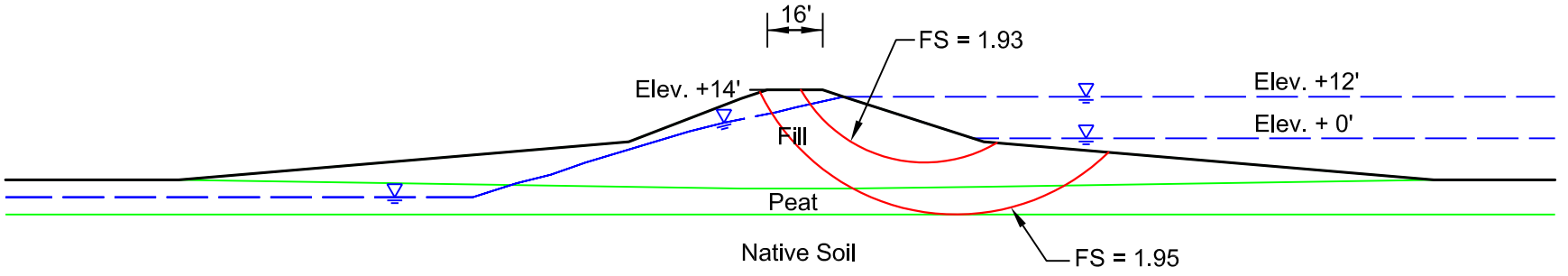
SCALE

0 50 feet

1 inch = 50 feet

Staten Island Dam San Joaquin County, California	Typical Dam - Constructed on Peat Full Reservior	
Hultgren - Tillis Engineers	Project 516.02	Plate 11

Typical Dam - Constructed on Peat
Rapid Drawdown - One-Half of Reservior
After Peat Consolidation



SOIL PARAMETERS

Soil Type	Unit Weight (pcf)	Undrained Strength		Effective Strength	
		Cohesion (psf)	Friction Angle (°)	Cohesion (psf)	Friction Angle (°)
Fill	125	300	18	200	25
Peat	70	150	20	100	40
Native Soil	125	-	-	200	25

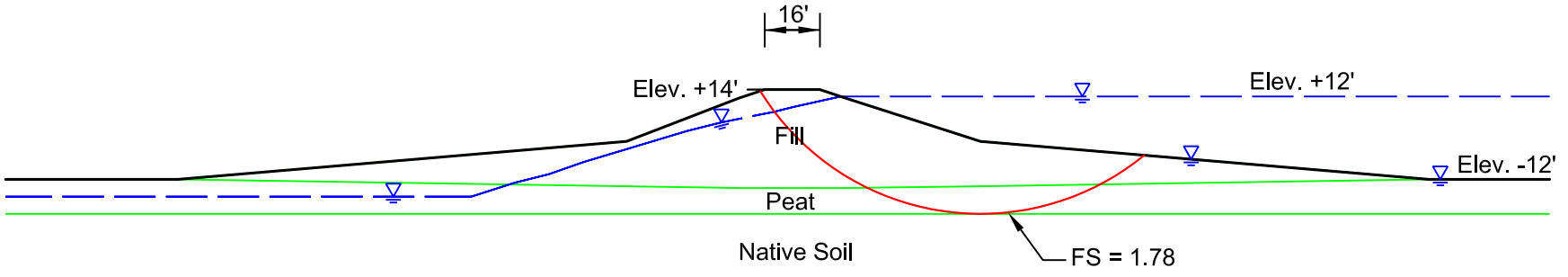
SCALE

0 50 feet

1 inch = 50 feet

Staten Island Dam San Joaquin County, California	Typical Dam - Constructed on Peat Rapid Drawdown - One-Half of Reservior	
Hultgren - Tillis Engineers	Project 516.02	Plate 12

Typical Dam - Constructed on Peat
Rapid Drawdown - Empty Reservior
After Peat Consolidation



SOIL PARAMETERS

Soil Type	Unit Weight (pcf)	Undrained Strength		Effective Strength	
		Cohesion (psf)	Friction Angle (°)	Cohesion (psf)	Friction Angle (°)
Fill	125	300	18	200	25
Peat	70	150	20	100	40
Native Soil	125	-	-	200	25

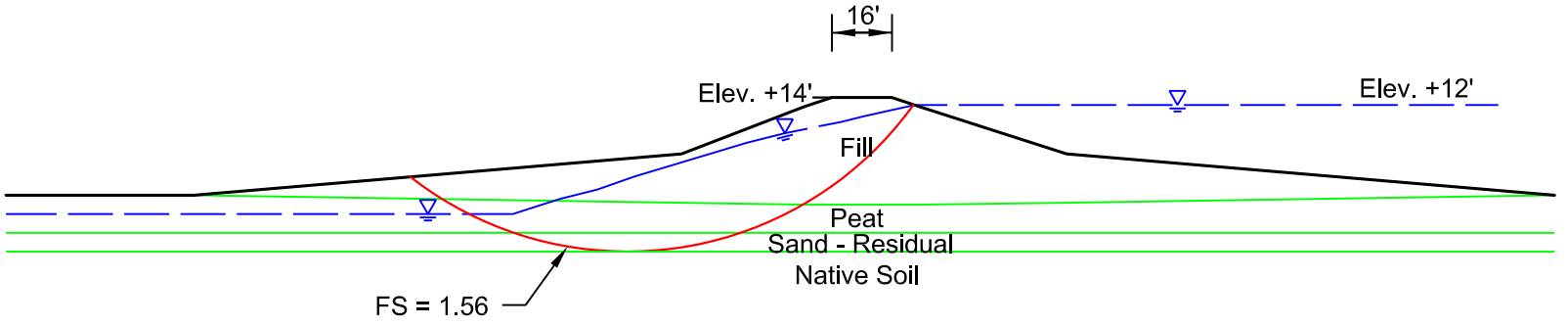
SCALE

0 50 feet

1 inch = 50 feet

Staten Island Dam San Joaquin County, California	Typical Dam - Constructed on Peat Rapid Drawdown - Empty Reservior	
Hultgren - Tillis Engineers	Project 516.02	Plate 13

Typical Dam - Constructed on Peat
Liquefaction of Sand to 5 Feet Depth
After Peat Consolidation



SOIL PARAMETERS

Soil Type	Unit Weight (pcf)	Undrained Strength		Effective Strength	
		Cohesion (psf)	Friction Angle (°)	Cohesion (psf)	Friction Angle (°)
Fill	125	300	18	200	25
Peat	70	150	20	100	40
Native Soil	125	-	-	200	25
Sand - Residual	125	200	0	-	-

SCALE

0 50 feet

1 inch = 50 feet

Staten Island Dam San Joaquin County, California	Typical Dam - Constructed on Peat Liquefaction of Sand to 5 Feet Depth	
Hultgren - Tillis Engineers	Project 516.02	Plate 14