SOUTH SHORE OF STATEN ISLAND, NY
COASTAL RISK MANAGEMENT

INTERIM FEASIBILITY STUDY
FOR
FORT WADSWORTH TO OAKWOOD BEACH

Interim Geotechnical Evaluation Appendix

US Army Corps of Engineers
New York District

June 2016

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF ATTACHMENTS

1.0 INTRODUCTION

1. This report presents the results of geotechnical evaluations performed by the Joint Venture of Moffatt & Nichol and URS as part of geotechnical and structural design tasks in support of the Interim Feasibility Study for Coastal Risk Management along the South Shore of Staten Island (SSSI) located in Staten Island, New York (see Figure 1).

1.1 Project Overview

2. The SSSI Coastal Risk Management Interim Feasibility Study project area is located between Fort Wadsworth and Oakwood Beach in Staten Island, New York (see Figure 2). The Interim Feasibility Study primarily includes three types of coastal risk management measures along the approximately 5 mile project reach. These measures consist of a buried seawall/armored levee, earth embankment levee, and floodwall (T-Wall). These primary measures make up the Line of Protection (LOP) for the Tentatively Selected Plan (TSP). The LOP is intended to act as the first line of defense against tidal and storm surges into the study area and provide coastal risk management to commercial and residential property during periods of hurricanes and other severe storms. The entire LOP is divided into 4 reaches designated as A-1 through A-4 (see Figure 3) based on the physical conditions of the shoreline, existing coastal and stormwater outfall structures, and LOP structure type. A depiction of these reaches and the corresponding LOP measures are presented in Figures 4 through 6.

3. For this study, LOP alternatives were considered for a 13.3, 14.3 and 15.6 ft NAVD 1929 design stillwater elevation (SWEL). Typical sections of each measure type for the TSP (15.6 NGVD 1929 stillwater design level) are presented in Figures 7 through 9.

1.2 Interim Geotechnical Evaluations

4. The geotechnical evaluation appendix for the Interim Feasibility Study consisted of the following:

1) Reviewed the existing subsurface investigation data provided by the USACE and NYCDEP and utilized it for the geotechnical evaluations;
2) Prepared plan drawings showing the approximate locations of test borings;
3) Prepared generalized soil profiles along the alignment of the line of protection;
4) Conducted an engineering evaluation and prepared this report that includes the following:
    a) An overview of the general site and geologic conditions.

b) A description of the previous subsurface investigation program and laboratory testing conducted.

c) A description of the generalized soil conditions throughout the project site.

d) A description of the seismic considerations including seismic site classification and liquefaction potential.

e) A description of the seepage and slope stability analyses performed and a summary of the results.

f) Appendices including boring logs, laboratory test results and calculation details.

2.0 SUBSURFACE INVESTIGATIONS AND SITE CONDITIONS

5. The subsurface investigation consisted of a field investigation and laboratory testing. The field investigation included a test boring program to identify soil and rock conditions for the project area. Details of the subsurface investigation and generalized subsurface conditions are presented in the subsequent sub-sections.

2.1 Local Geology

6. The south shore area of Staten Island is in a geological, structural, and topographic province known as the Atlantic Coastal Plain. In this area, the Coastal Plain consists of unconsolidated deposits of sands, silts, and clays that gently dip seaward. The coastal plain deposits are overlain with younger glacial deposits of till, outwash material, and moraine deposits. More recent deposits of fill, stream material, and reworked sediments overlie the glacial deposits. In general, the surficial sediments of Staten Island, from top to bottom, consist of artificial fill, outwash, terminal moraine, till, and marine and lacustrine sediments.

7. In the project area, the Coastal Plain deposits consist of the Raritan Formation, a thick sand unit, and the overlying Magothy Formation, which consists of silts and clays with some sand layers. In the southern portion of Staten Island, the glacial deposits are over 50 ft thick and the underlying Coastal Plain sediments are over 100 ft thick (Merguerian, 2008). In the immediate site area, borings advanced to a depth of 30 ft encountered only glacial deposits.

2.2 Test Boring Program

8. A total of fourteen (14) test borings (designated as SS02-4 through SS02-17) were performed along the alignment of the tentatively selected LOP between Fort Wadsworth and Oakwood Beach. The subsurface exploration was conducted by Matrix Environmental Services of Florham Park, NJ in October 2002 for US Army Corps of Engineers (USACE).

9. All borings were advanced using mud rotary drilling techniques. Soil samples were obtained using techniques and equipment in general accordance with the American Society for Testing and Materials (ASTM) Standard Specification D1586-Standard Penetration Test (SPT). The SPT consists of driving a 2 inch O.D. split spoon sampler for a distance of 24 inches, with repeated blows of a 140 lb. hammer free falling a distance of 30 inches. The standard penetration, or N-value, is determined as the number of blows required to advance the sampler 12 inches after the initial 6 inches of penetration. Soils were classified using the Unified Soil Classification System (USCS) method and one to two samples per boring were chosen for laboratory analysis. Undisturbed Shelby tube samples were also obtained from relatively soft or organic fine-grained soils for laboratory testing. All test borings were advanced to final depths ranging from 24 to 30 ft below ground surface (bgs). Bedrock was

not encountered in any of the test borings. The USACE (2002) test boring logs are provided in Attachment A.

10. A portion of the line of line of protection (LOP) between stations 30+00 and 85+00 (which also includes the Oakwood Beach Waste Water Treatment Plant) is located within a wetland area. Since vast majority of the test borings performed by USACE were outside the wetland area, additional soil test boring records of test borings performed within the wetland area were provided by New York City Department of Environmental Protection (NYCDEP). These test borings were performed by various New York City agencies in between 1949 and 1966. A total of 20 soil test borings were selected from the test boring records provided by NYCDEP. These selected test borings are included in Sheet 1 of the boring location plan (see Figure 4). The NYCDEP test boring records are provided in Attachment B.

2.3 Laboratory Testing Program

11. The laboratory testing program consisted of a variety of tests performed on selected soil samples obtained from the borings to verify the field classifications and to provide additional information for engineering evaluations. The tests included grain size, specific gravity, unit weight, Atterberg Liquid and Plastic Limits, and consolidated undrained triaxial compression. The triaxial compression strength, grain size, unit weight, and Atterberg limits tests were performed on undisturbed Shelby Tube samples. All tests were performed by SOR Testing Laboratories, Inc. of Cedar Grove, NJ. These laboratory test results are provided in Attachment C of this Appendix.

2.4 Generalized Subsurface Conditions

12. A generalized subsurface profile was developed along the line of protection and is presented in Figures 10 through 13. The generalized descriptions of the subsurface conditions at the site given below are primarily based on our interpretation of the results of the 2002 field investigation and laboratory test results.

Stratum 1: SAND

13. The primary soil type encountered within the project area was coarse to fine sand with varying amounts of silt and gravel. The laboratory tests show that the majority of the sands consist of trace to some amounts of silt and gravel. The borings also indicate the presence of some clay and silt lenses within this stratum that ranged from 1 to 9 ft in thickness, at various depths ranging from the ground surface to approximately 25 feet below ground surface. These lenses were encountered in borings SS02-5, SS02-7, SS02-13, SS02-14, and SS02-15. Boring SS02-8 indicated an approximately 2ft thick organic clay and silt lens at a depth of about 6.5 ft. Generally, the SPT N-values within this stratum ranged from 10 blows per foot (bpf) to 30 bpf with an average of about 18 bpf, indicative of a medium dense material. However, it should be noted that as mentioned above isolated pockets of soft

silty/clayey soils and loose sandy soils were also encountered within the project limits. Since all borings were terminated within this stratum, the thickness of this stratum is not defined at present.

Stratum 2: ORGANICS

14. The NYCDEP soil test borings records indicated approximately 6 ft thick soft organic soils within the wetland area (Sta. 30+00 to 85+00). These organic soils were generally encountered immediately below the ground surface and overlying the sand layer (Stratum 1).

2.5 Groundwater Conditions

15. Considering the proximity of the site to the Lower New York Bay and the topography of the site it is anticipated that the groundwater is likely to be encountered at about +2 ft (NGVD 29).

3.0 ENGINEERING EVALUATIONS

16. As per the project requirements, engineering evaluations were primarily performed using the USACE design manuals, EM 1110-2-1913 “Design and Construction of Levees” (2000), EM 1110-2-1902 “Slope Stability” (2003), EM 1110-2-2502 “Retaining and Flood Walls” (1989), and EM 1110-1-1904 “Settlement Analysis” (1990).

17. The subsequent sub-sections provide descriptions and results of analysis performed to evaluate soil behavior under seismic conditions, seepage conditions, and slope stability.

3.1. Seismic Considerations

18. In accordance with EM 1110-2-1913, slope stability analyses should also be performed for the seismic loading case as presented in Section 3.5. At present there is no USACE Engineering Manual for seismic analysis. Therefore, seismic analyses were performed herein based on the National Earthquake Hazards Reduction Program (NEHRP, 2009) seismic provisions.

19. The seismic loading condition was evaluated using the pseudo-static method of analysis. The effects of the seismic motion were simulated by applying a pseudo-static coefficient in the horizontal direction. The pseudo-static coefficient was assumed 2/3 of the peak ground acceleration (PGA) at the foundation (ground surface) level for the 2,500-year seismic event. Considering that the depth to bedrock at the project area appears to be greater than 100 ft, and the soils within the top 100 ft are likely to be generally medium dense to dense in compactness, the soil profile type is seismic site class ‘D’ (SD). Based on 2008 Probabilistic Hazard Curves from the U.S. Geological Survey (USGS, 2008), the PGA at the bedrock level is approximately 0.16g for a 2,500-year seismic event at the project site. Therefore, as per NEHRP (2009) provisions, the PGA at the ground surface for seismic site class D (SD) soil profile was estimated to be about 0.24g. Hence, the pseudo-static coefficient of 0.16g (i.e., 0.67 × 0.24) was assumed for the seismic loading case.

20. The phenomenon of soil liquefaction, or significant reduction in soil strength and stiffness as a result of shear-induced increased pore-water pressure, is a major cause of seismic damage to embankments and slopes. Since the sandy soils below the groundwater level at the project site are generally medium dense to dense in compactness, it appears that seismic induced liquefaction at the project site will not likely occur and therefore should not be a concern. Therefore, sophisticated dynamic analyses of stability and deformations under seismic loadings are not warranted. However, it should be noted that at a few isolated locations pockets of loose sandy soils were

encountered and additional investigations will be required at these locations to verify the extent of such loose sandy soils.

3.2. Representative Sections for Analyses

21. Seepage and stability analyses were performed for each type of structure using representative sections. The sections were selected so as to represent a maximum height of the measure above grade along the project reach. A summary of the selected representative sections are presented below in Table 3-1.

Table 3-1: Summary of Representative Sections

Structure Type	Figure No.	Reach Nos.	Maximum Height (ft)	Total Length (ft)
Levee	7	A-1 and A-2	20	3,430
Floodwall	8	A-3	17.5	1,826
Buried Seawall/Armored Levee	9	A-4	19.5	22,705

3.3. Seepage Analyses

22. Seepage analyses for the three types of coastal risk management measures were performed in order to estimate the seepage quantity through and/or underneath the structures, exit hydraulic gradients on the land upside of the structures and the pore pressures within the embankments. The results of these analyses were used to perform the slope stability analyses described in Section 3.5.

23. Typically, a fully developed phreatic surface obtained from a steady-state seepage analysis to perform the slope stability analysis under a long-term condition is used when it is expected that the water remains at or near flood stage for a sufficient period of time to result in full embankment saturation and a condition of steady seepage. However, considering the relatively short duration (about 6 hours to 24 hours) of anticipated storms, this condition will most likely not occur during the anticipated storms. Therefore, as presented in URS memorandum dated July 22, 2011 (see Attachment D), both transient and steady seepage analyses were performed for the buried seawall/armored levee. For all other structures, only steady seepage analyses were performed because steady-state seepage analyses are conservative compared to the transient analyses.

24. The design SWEL of 15.6 ft (NGVD 29) was used in the seepage analyses. The storm hydrographs used in the transient seepage analyses are presented in Figures 14 and

15. In addition, the hypothetical storm hydrograph used to determine the duration of the storm to develop a steady-state seepage condition is presented in Figure 16.

25. The seepage analyses were performed using the commercially available finite element method (FEM) software program SEEP/W©. In order to perform the seepage analyses, a representative cross section was selected for each type of structure. As indicated in Section 3.3, these representative sections were conservatively selected at maximum height locations. One of the important parameters required to perform the seepage analyses is the hydraulic conductivity of storm damage reduction structure materials and foundation materials. The hydraulic conductivity values of various materials and the results of the seepage analyses using these values are presented in Section 3.3.1 and Section 3.3.2, respectively.

3.3.1. Selection of Hydraulic Conductivity Values for Analyses

26. The saturated hydraulic conductivity of porous materials varies typically by one or two orders of magnitude (e.g. silty sand, 10^{-3} to 10^{-5} cm/sec). Therefore, seepage analyses were performed for a range of hydraulic conductivity values. Based on the results of these analyses, conservative values were selected and are presented in this section.

27. The phreatic surfaces for the stability analyses were developed from the seepage analyses. In order to develop the phreatic surfaces, the materials within the embankments were modeled as saturated / unsaturated materials with hydraulic conductivity as function of the pore pressure. However, considering that the results of the seepage analyses are not sensitive to hydraulic conductivity as function of the pore pressure, only saturated hydraulic conductivity values are presented. They are:

1) The foundation soils generally consist of coarse to fine sands with varying amounts of clay, silt and gravel. Considering this, the hydraulic conductivity (k) for the foundation soils was assumed to be 1×10^{-4} cm/sec. Typical hydraulic conductivity values were obtained from Electric Power Research Institute (EPRI) report EL-6800 (after Terzaghi and Peck, 1967), Page 7-1 and Table 7-1.
2) Compacted fill will be used for core and shell material for levee structures, and as earth cover material on the water side and impervious fill on the landside for the buried seawall/armored levee. Considering that the compacted fill should be relatively impervious, it is anticipated that silty sand (SM) and/or clay sand (SC) with a hydraulic conductivity less than 1×10^{-5} cm/sec will be used as compacted fill. Therefore, for the compacted fill, a hydraulic conductivity (k) of 1×10^{-5} cm/sec was assumed.
3) Armor and bedding stones will be used for the construction of the buried seawalls/armored levee. Considering that these materials will have a significant

amount of voids, a hydraulic conductivity (k) of 10 cm/sec was assumed for these materials.

4) Steel sheet piles, concrete fascia and concrete caps will be used for the construction of sheet pile walls and Floodwalls. Considering that any water seepage through the joints of the sheet piles walls and concrete cracking will be relatively small, a hydraulic conductivity (k) of 1×10^{-6} cm/sec was assumed for these materials.

3.3.2. Results of Analyses

28. The seepage analyses results are presented in this section for three types of LOP measures. The analyses were performed using the representative sections presented in Table 3-1 and for a SWEL of 15.6 ft (NGVD 29) as described previously.

29. The results of both transient and steady-state seepage analyses were presented in URS memorandum dated July 22, 2011 (URS, 2011), for Buried Seawalls (see Attachment D). Based on those analyses, steady-state seepage conditions are not expected to develop during the anticipated storms. Therefore, for Buried Seawalls, the results of transient seepage analyses are presented in Table 3-2. However, for all other structures, the steady-state seepage (conservative) analyses results are presented in Table 3-2.

Table 3-2: Summary of Seepage Analyses Results

Reach No.	Type of Structure	Length (ft)	Total Seepage Quantity		Exit Hydraulic Gradient
			ft^3/sec (cfs)	Gallons/min (gpm)	
A-1 and A-2	Levee	3,430	<1	20	0.25
A-3	Flood wall	1,826	< 1	20	0.05
A-4	Buried Seawall/Armored Levee	22,705	< 1	95	0.01

30. The results of the seepage analyses are graphically presented in Figures 17 through 19 for all three types of structures. In addition, the exit corresponding hydraulic gradient graphs are presented in Figures 20 through 22. It should be noted that the pore pressures obtained from the seepage analyses were used for the Case II slope stability analyses as described in the next section.

3.4. Slope Stability Analyses

31. In accordance with USACE design manuals EM 1110-2-1913 and EM 1110-2-1902, slope stability analyses were performed for Levee and Buried Seawall sections, along the line of protection. As per EM 1110-2-1913, slope stability analyses were performed for four loading conditions as follows:

- Case I, end of construction (land side slope);
- Case II, steady-state seepage from full flood stage (land side slope);
- Case III, sudden drawdown (water side slope);
- Case IV, earthquake (land side slope).

32. A commercially available computer program, SLOPE/W©, was used to perform the slope stability analyses. SLOPE/W© is a general purpose slope stability program that uses limit equilibrium methods to compute the factor of safety (FOS) for a given slope geometry and loading conditions. Spencer's Procedure for the method of slices for circular failure was used to evaluate the slope stability as this procedure satisfies the complete static equilibrium for each slice. SLOPE/W© automatically searches for the circular shear surface associated with the minimum FOS, which is considered the critical or controlling shear surface. As mentioned in Section 3.4, the pore pressures within the embankments for the Case II loading condition were obtained from the phreatic surfaces developed using the transient and/or steady state seepage analyses using SEEP/W©. Since SEEP/W© and SLOPE/W© are companion programs, pore pressures obtained from the SEEP/W© analysis can be automatically transferred to the corresponding SLOPE/W© stability analysis. For Case III (sudden drawdown) loading condition, because of the instantaneous drawdown, it was assumed that pore pressures within the embankment remain the same before and after the drawdown.

33. Because of the low probability of earthquakes coinciding with severe storm events, stability analyses for the Case IV (earthquake) loading condition was performed assuming no water above the ground surface. As described in Section 3.2, pseudo-static coefficient of 0.16g was assumed for the earthquake loading case.

34. Besides knowledge of the pore pressure distribution within the embankment, the shear strength parameter values of the embankment materials and foundation soils are important for the slope stability analyses. Section 3.4.1 the assumed shear strength parameter values are presented.

3.4.1. Selection of Material Parameter Values for Stability Analyses

35. The material parameters required for the stability analyses are the shear strength and unit weight properties of the embankment fill and foundation soils. Considering that sandy soil and stones will be used as embankment fill materials, and since the

foundations soils generally consist of sandy materials, effective stress shear strength parameter values were used in the stability analyses for all conditions as follows:

1) Foundation soils are generally medium dense to dense sandy soils. Based on the SPT N-values obtained within the foundation soils and widely used empirical correlations, a conservative effective stress friction angle of 30 degrees was used in the current analysis for the foundation soils. However, as mentioned previously in Section 2.5, pockets of clayey/silty soils and loose sandy soils were encountered at isolated locations. But, currently it was assumed that there are no continuous layers of soft clayey/silty soils and/or loose sandy soils within the project limits. However, we have conservatively included a loose sand layer in the slope stability analyses above the medium dense sand layer.
2) Sandy fill will be compacted to a density corresponding to 95% of the maximum dry density. Therefore, a conservative effective stress friction angle of 32 degrees was used in the current analysis for the compacted fill.
3) Bedding stone and armor stone friction angle values are typically greater than 36 degrees. Therefore, conservative effective stress friction angle values of 36 degrees and 38 degrees were used in the current analyses for bedding stone and armor stone, respectively. Quality requirements for the armor stone and bedding stone are discussed in the Engineering and Design Appendix, Section 4.3.2.

36. Table 3-3 below summarizes the material shear strength and unit weight parameter values used in the stability analyses.

Table 3-3: Summary of Material Parameters for Stability Analyses

Materials	**Unit Weight (pcf)**	**Friction Angle (degrees)**	**Cohesion (psf)**
Foundation Soils (upper stratum – loose)	120	26	0
Foundation Soils (lower stratum – medium dense)	120	30	0
Compacted Fill	125	32	0
Bedding Stone	140	36	0
Armor Stone	145	38	0

37. As mentioned in Section 2.5, soft compressible soils were encountered within the wetland area (Sta. 30+00 to 85+00). Therefore, the end-of-construction (Case I) slope stability analysis will need to be performed using the undrained shear strength of the

organic soils (Stratum 2). At present undrained shear strength of 200 psf was assumed for the organic soils. However, during the design stage undisturbed tube samples of organic soils should be obtained and triaxial undrained shear strength tests should be performed.

3.4.2. Results of Analyses

38. The slope stability analyses results are presented in this section for Buried Seawall/Armored Levee and Earthen Levee. As presented in URS (2011), the slope stability analyses of buried seawalls for the Case II loading condition was performed using pore pressures obtained from transient seepage analyses. However, for the earth embankment levees the slope stability analyses for the Case II loading condition were performed using conservative pore pressures obtained from the steady-state seepage analyses. As per EM 1110-2-1913, slope stability analyses were performed for all four loading conditions. The results are presented in Table 3-4, along with the corresponding minimum acceptable factors of safety.

Table 3-4: Summary of Slope Stability Analyses Results

Slope	**Design Condition**	**Minimum Acceptable Factor of Safety**	**Buried Seawall**	**Levee**
Land Side	Case I: End of Construction	1.3	1.4	1.7
Lind Side	Case II: Seepage from maximum flood level	1.4	1.4	1.5
Water Side	Case III: Sudden drawdown	1.0	1.2	1.2
Land Side	Case IV: Earthquake	1.0	1.0	1.2

39. The results of the stability analyses are graphically presented in Figures 23 through 33 for the above mentioned structures. The stability analyses results of buried seawalls for the Case II loading condition, based on both transient and steady-state seepage analyses was previously summarized in URS (2011) and is provided in Attachment D.

Remarks:

40. Table 3-4 presents the factors of safety after the soft organic soils have been excavated and the compact fill added. Figures 23 and 28 depict that that the end-of-construction (Case 1) factor of safety values were originally 0.9 and 1.1 for a Levee and Buried Seawall/Armored Levee founded on soft organic soils, respectively. It should be noted that these factor of safety values are less than the minimum acceptable value of 1.3. Therefore, wherever encountered the soft organic soils should be removed and replaced with compacted sandy fill. It is recommended to remove soft organic soils and/or portions of soils with lumps of soft organics to a depth at least 6-inches deeper than bottom surface of soft organic soils. Also, the removal should be extended to at least 10 feet beyond the toe of the levee slopes or beyond the structure.

41. As shown in Figure 30, Case II factor of safety value is 0.8 for sacrificial cover layer of the buried seawall under steady seepage condition. However, as mentioned in Section 3.4.1 and URS (2011), steady seepage condition will most likely not occur during the anticipated storms. Further, considering that shear surface corresponding to factor of safety of 0.8 is within the sacrificial cover, even if steady seepage condition develops only sacrificial cover layer will likely to be impacted.

42. Additional test borings should be performed within the wetland area and within the reminder of the alignment during the design stage to completely characterize the subsurface conditions along the LOP. These borings should be drilled to a depth that can be used to confirm the pile design capacities and drivability.

3.5. Settlement Analyses

43. As stated under the stability analyses remarks (Para 40), in order to have satisfactory slope stability for the levee sections, soft organic soils wherever encountered should be removed and replaced with compacted sandy fill. Thus, the existence of soft organic soils was not considered in the settlement analyses. Potential immediate settlement values were estimated as per EM 1110-1-1904. Accordingly, the estimated immediate settlement values approximately ranges from ½ inch to 1½ inches. Since most of the estimated immediate settlement will likely to occur during construction, it should not be a concern. Details of the immediate settlement analyses are provided in Attachment E. Long term consolidation settlement should not be a concern because after removing any soft organic soil layer that could be present near the ground surface the subsurface soils are generally sandy soils as indicated in Section 2.4 (Para 13).

3.6. Floodwall Pile Recommendations

44. It is our understanding that the floodwall is to be supported on pile foundation. Based on the subsurface conditions and DRIVEN pile capacity analyses, we recommend HP14x89 friction piles driven to sandy stratum for this purpose. Refer to Attachment F

for the DRIVEN analysis results and additional details. The recommended pile lengths and corresponding estimated pile capacities are as follows:

Allowable Compression and Uplift Capacity (tons)	Estimated Length for Compression Capacity (ft)	Estimated Length for Uplift Capacity (ft)
35	70	80
50	80	95
70	95	115

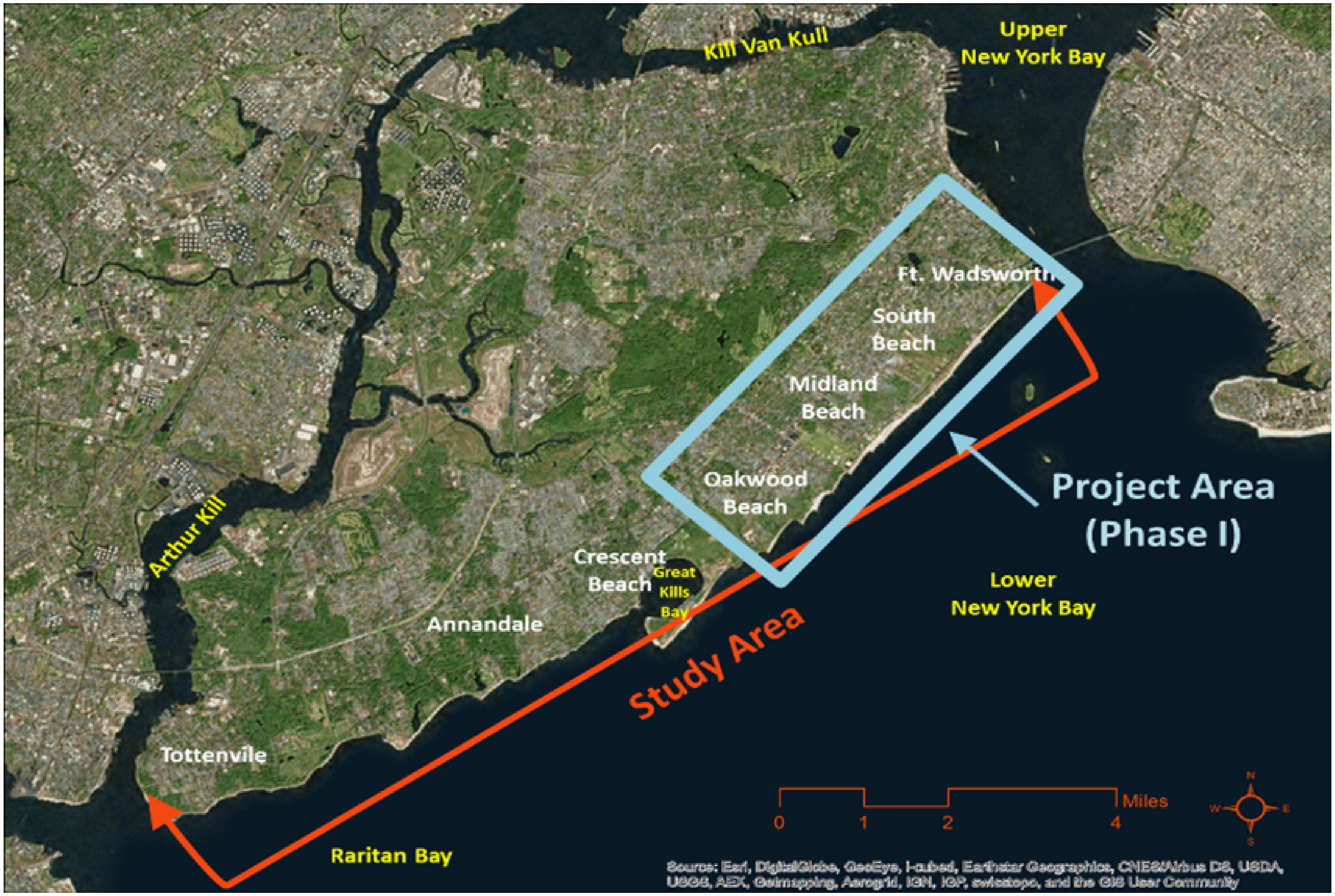
FIGURES

Vicinity Map
Storm Damage Reduction Feasibility Study
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: NTS	PROJ: 11020302
	DATE: June, 2012	FIG NO: 1

I:\Projects\11020302(South Shore of Staten Island)\Report\Figures\Figure 1



Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Study Area
Storm Damage Reduction Feasibility Study
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: NTS	PROJ: 11020302
	DATE: September, 2014	FIG NO: 2

I:\Projects\11020302(South Shore of Staten Island)\Report\Figures\Figure 2

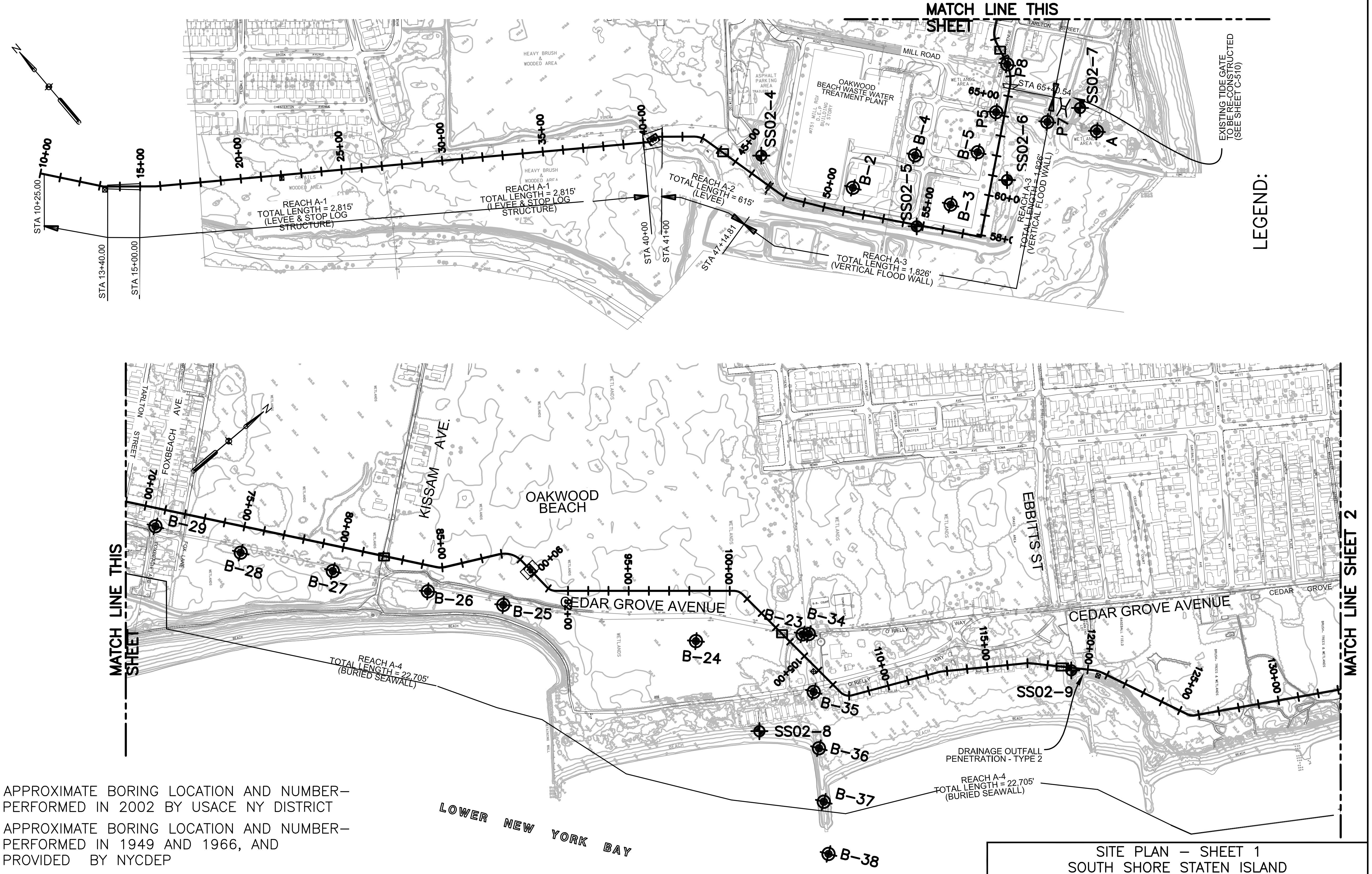
Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Project Area
Storm Damage Reduction Feasibility Study
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: NTS	PROJ: 11020302
	DATE: September, 2014	FIG NO: 3

I:\Projects\11020302(South Shore of Staten Island)\Report\Figures\Figure 3



LEGEND:

SS02-5 ⊕ APPROXIMATE BORING LOCATION AND NUMBER–PERFORMED IN 2002 BY USACE NY DISTRICT

B-5, P5 ⊕ APPROXIMATE BORING LOCATION AND NUMBER–PERFORMED IN 1949 AND 1966, AND PROVIDED BY NYCDEP

150+00 ALIGNMENT OF PROTECTION STRUCTURES (LINE OF PROTECTION)

DTP COMBINED TRUCK & PEDESTRIAN ACCESS RAMP

MVA MAINTENANCE VEHICLE ACCESS RAMP

SITE PLAN – SHEET 1
SOUTH SHORE STATEN ISLAND
NEW YORK

URS
CLIFTON, NEW JERSEY

DR. BY	ET	SCALE	AS SHOWN	DWG. NO.	01–PLAN	PROJ. NO.	11020302
CK'D. BY	NV	DATE	AUGUST, 2012			FIG. NO.	4

K:\CADD\11020302(SOUTH SHORE STATEN ISLAND)\01-PLAN.DWG(SHEET-1)

LEGEND:

SS02-5 ⊕	APPROXIMATE BORING LOCATION AND NUMBER–PERFORMED IN 2002 BY USACE NY DISTRICT
B-5, P5 ⊕	APPROXIMATE BORING LOCATION AND NUMBER–PERFORMED IN 1949 AND 1966, AND PROVIDED BY NYCDEP
150+00	ALIGNMENT OF PROTECTION STRUCTURES (LINE OF PROTECTION)
DTP	COMBINED TRUCK & PEDESTRIAN ACCESS RAMP
MVA	MAINTENANCE VEHICLE ACCESS RAMP

0 250 500 1000

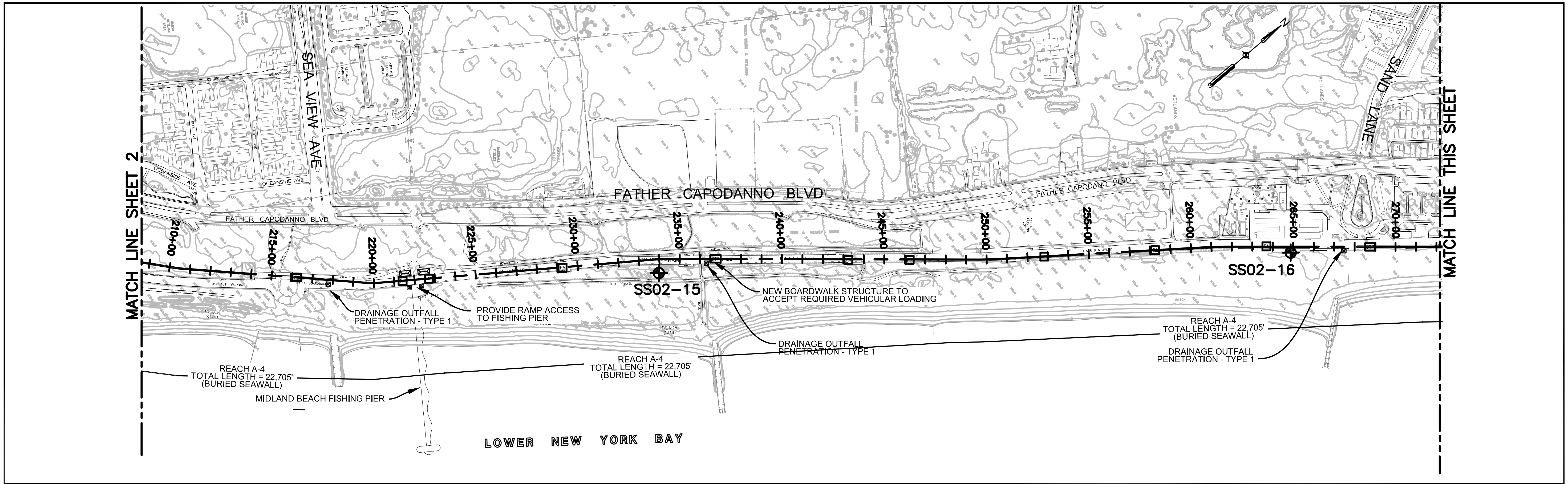
SCALE (FEET)

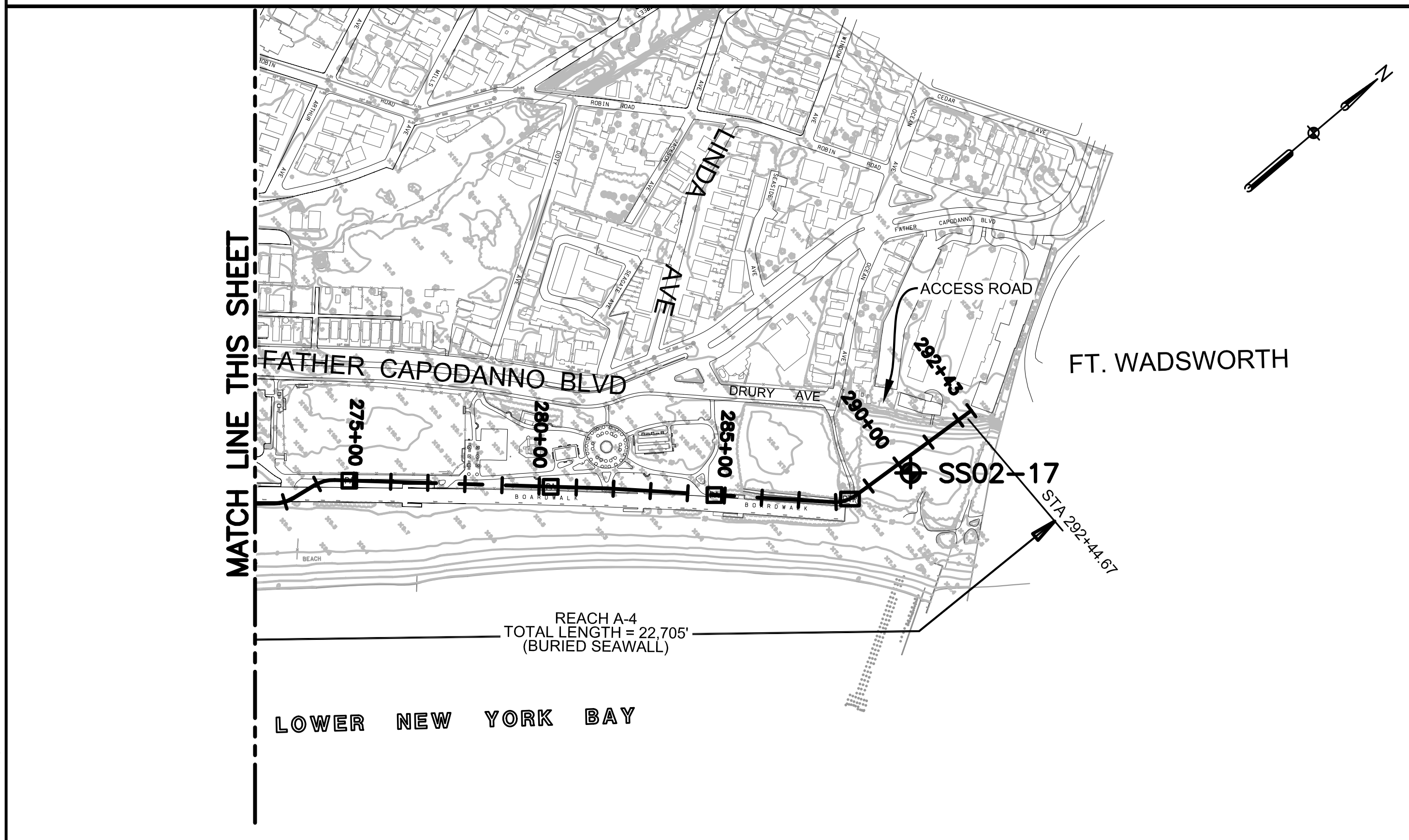
SITE PLAN – SHEET 2
SOUTH SHORE STATEN ISLAND
NEW YORK

URS
CLIFTON, NEW JERSEY

DR. BY	ET	SCALE	AS SHOWN	DWG. NO.	01–PLAN	PROJ. NO.	11020302
CK'D. BY	NV	DATE	AUGUST, 2012	FIG. NO.	5		

K:\CADD\11020302(SOUTH SHORE STATEN ISLAND)\01-PLAN.DWG(SHEET-2)





LEGEND:

SS02-5 ⊕	APPROXIMATE BORING LOCATION AND NUMBER– PERFORMED IN 2002 BY USACE NY DISTRICT
B-5, P5 ⊕	APPROXIMATE BORING LOCATION AND NUMBER– PERFORMED IN 1949 AND 1966, AND PROVIDED BY NYCDEP
150+00 ┼┼┼┼┼┼	ALIGNMENT OF PROTECTION STRUCTURES (LINE OF PROTECTION)
DTP	COMBINED TRUCK & PEDESTRIAN ACCESS RAMP
MVA	MAINTENANCE VEHICLE ACCESS RAMP

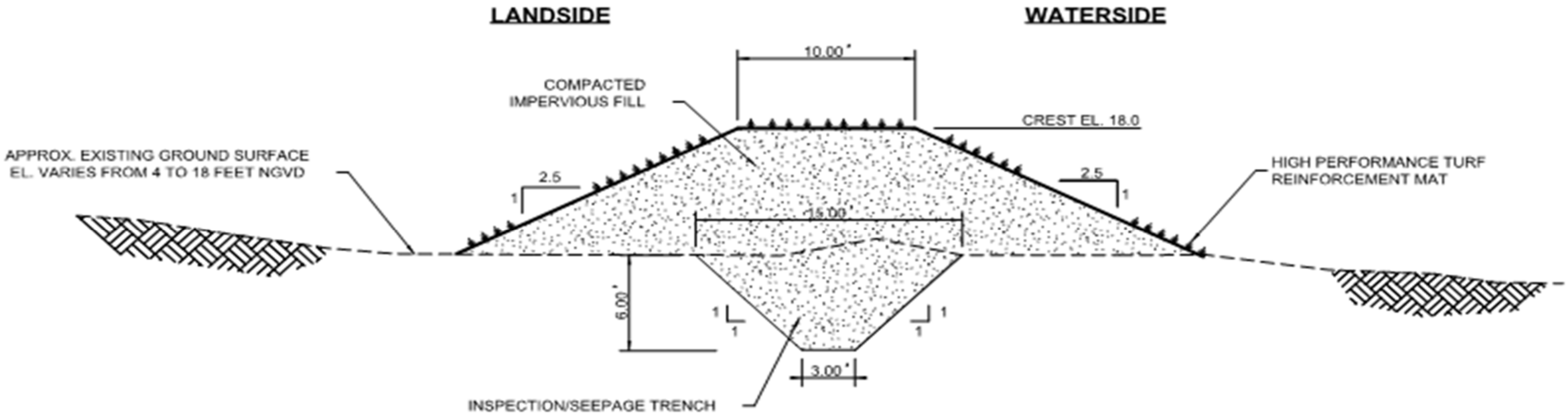
0 250 500 1000
SCALE (FEET)

SITE PLAN – SHEET 3
SOUTH SHORE STATEN ISLAND
NEW YORK

URS
CLIFTON, NEW JERSEY

DR. BY	ET	SCALE	AS SHOWN	DWG. NO.	01–PLAN	PROJ. NO.	11020302
CK'D. BY	NV	DATE	AUGUST, 2012			FIG. NO.	6

K:\CADD\11020302(SOUTH SHORE STATEN ISLAND)\01-PLAN.DWG(SHEET-3)



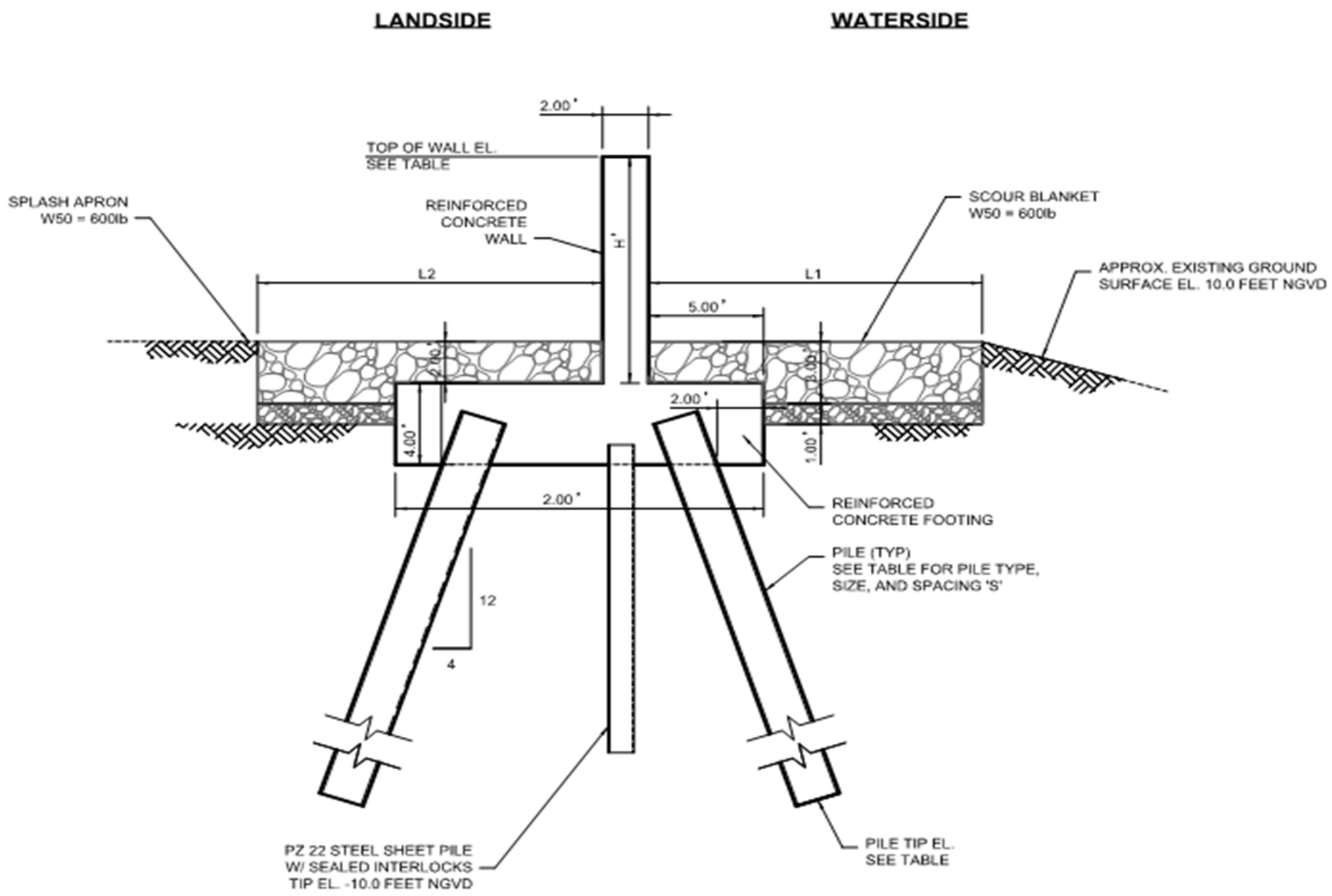
C2
C-501
LEVEE SECTION (15.6 FT SWL)

SCALE: 3/16"=1'-0"

Levee (Reach A-2)
Storm Damage Reduction Feasibility Study
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: NTS	PROJ: 11020302
	DATE: September, 2014	FIG NO: 7



B2
C-503

FLOOD WALL SECTION

SCALE: 1/4"=1'-0"

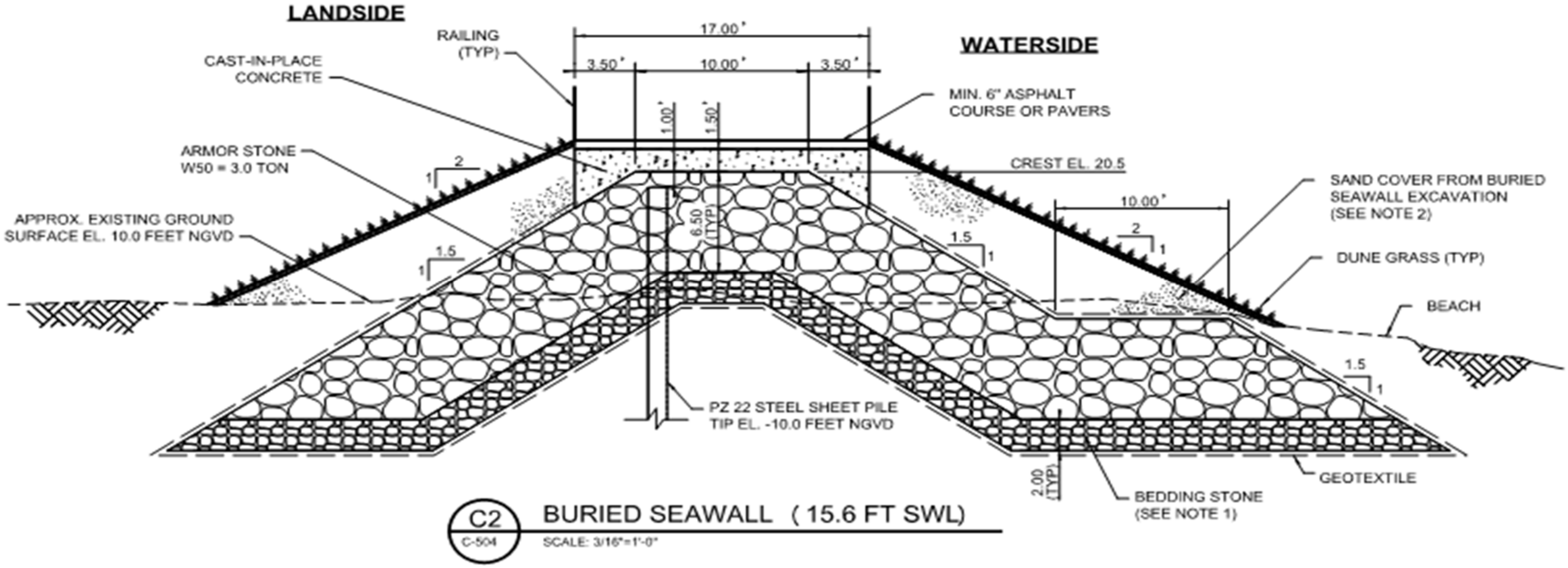
ELEVATIONS (FT, NGVD)			PILE DATA		DIMENSIONS					
SWL (FT)	TOP OF WALL	PILE TIP	TYPE	SIZE	H (FT)	B (FT)	T (FT)	L1 (FT)	L2 (FT)	S (FT)
13.3	16.0	-75.0	H-PILE	HP14 X 89	8.0	12.0	1.5	15.0	10.0	12.0
14.3	18.0	-75.0	H-PILE	HP14 X 89	10.0	15.0	1.5	15.0	12.0	12.0
15.6	20.5	-90.0	H-PILE	HP14 X 89	12.5	16.0	2.0	15.0	15.0	12.0
16.6	22.5	-90.0	H-PILE	HP14 X 90	14.5	18.0	2.5	15.0	16.0	10.0

Floodwall (Reach A-3)
Storm Damage Reduction Feasibility Study
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: NTS	PROJ: 11020302
	DATE: September, 2014	FIG NO: 8

I:\Projects\11020302(South Shore of Staten Island)\Report\Figures\Figure 8



BURIED SEAWALL (15.6 FT SWL)

SCALE: 3/16"=1'-0"

NOTES

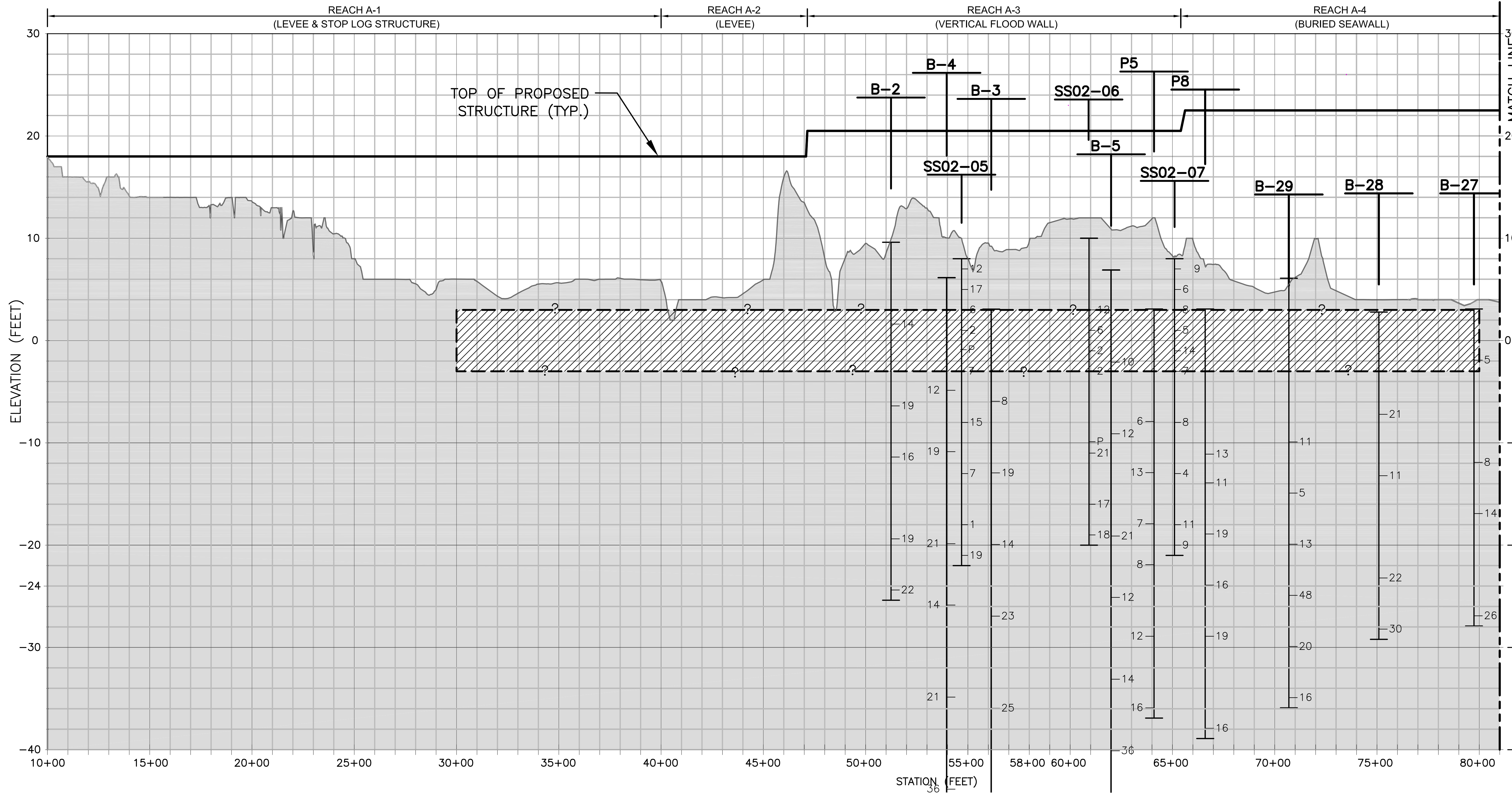
1. MIN. 2.0' THICKNESS OF BEDDING STONE LAYER IN CORE AREA. THICKNESS WILL VARY WITH EXISTING GROUND ELEVATION.
2. NO SAND COVER FROM STA 65+40 TO STA 102+00. SAND COVER FROM STA 102+00 TO STA 139+00, AND STA 289+00 TO STA 292+44.67.

Buried Seawall (Reach A-4)
Storm Damage Reduction Feasibility Study
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: NTS	PROJ: 11020302
	DATE: September, 2014	FIG NO: 9

I:\Projects\11020302(South Shore of Staten Island)\Report\Figures\Figure 9



LEGEND

SS02-05 GEOTECHNICAL BORING CONDUCTED BY MATRIX ENVIRONMENTAL SERVICES OF FLORHAM PARK, NJ.

−19 N–VALUE, DEFINED AS NUMBER OF BLOWS OF A 140–LB HAMMER FREE FALLING FOR 30 INCHES REQUIRED TO ADVANCE A STANDARD SPLIT SPOON SAMPLER 12 INCHES AFTER INITIAL 6 INCH PENETRATION

−P PUSHED SHELBY TUBE

— —?— — APPROXIMATE STRATA BOUNDARY

GENERALIZED SOIL DESCRIPTIONS:

░	COARSE TO FINE SAND WITH SILT AND GRAVEL
▨	INORGANIC CLAY/INORGANIC SILTY CLAY
▨	ORGANIC CLAYEY SILT
▩	INORGANIC SILT/INORGANIC CLAYEY SILT

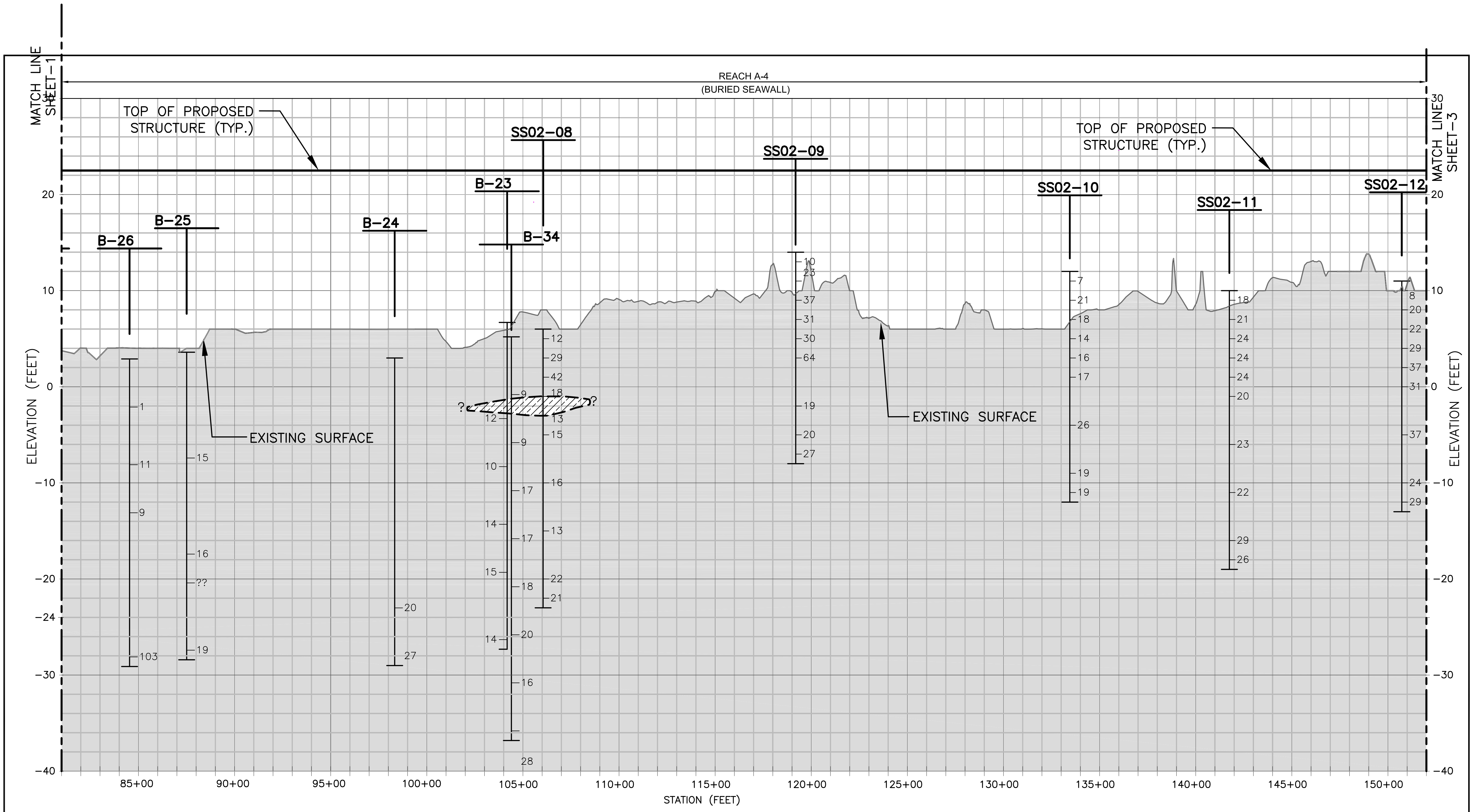
0 250 500 1000
HORIZONTAL SCALE (FEET)

0 5 10 20
VERTICAL SCALE (FEET)

CROSS–SECTION – SHEET 1
SOUTH SHORE STATEN ISLAND
NEW YORK

URS
CLIFTON, NEW JERSEY

DR. BY	ET	SCALE AS SHOWN		DWG. NO. 02–SECTIONS	PROJ. NO. 11020302
CK'D. BY	NV	DATE	AUGUST, 2012	FIG. NO.	10



LEGEND

SS02-05 GEOTECHNICAL BORING CONDUCTED BY MATRIX ENVIRONMENTAL SERVICES OF FLORHAM PARK, NJ.

-19 N-VALUE, DEFINED AS NUMBER OF BLOWS OF A 140-LB HAMMER FREE FALLING FOR 30 INCHES REQUIRED TO ADVANCE A STANDARD SPLIT SPOON SAMPLER 12 INCHES AFTER INITIAL 6 INCH PENETRATION

-P PUSHED SHELBY TUBE

— —?— — APPROXIMATE STRATA BOUNDARY

GENERALIZED SOIL DESCRIPTIONS:

▒	COARSE TO FINE SAND WITH SILT AND GRAVEL
▨	INORGANIC CLAY/INORGANIC SILTY CLAY
▨	ORGANIC CLAYEY SILT
▩	INORGANIC SILT/INORGANIC CLAYEY SILT

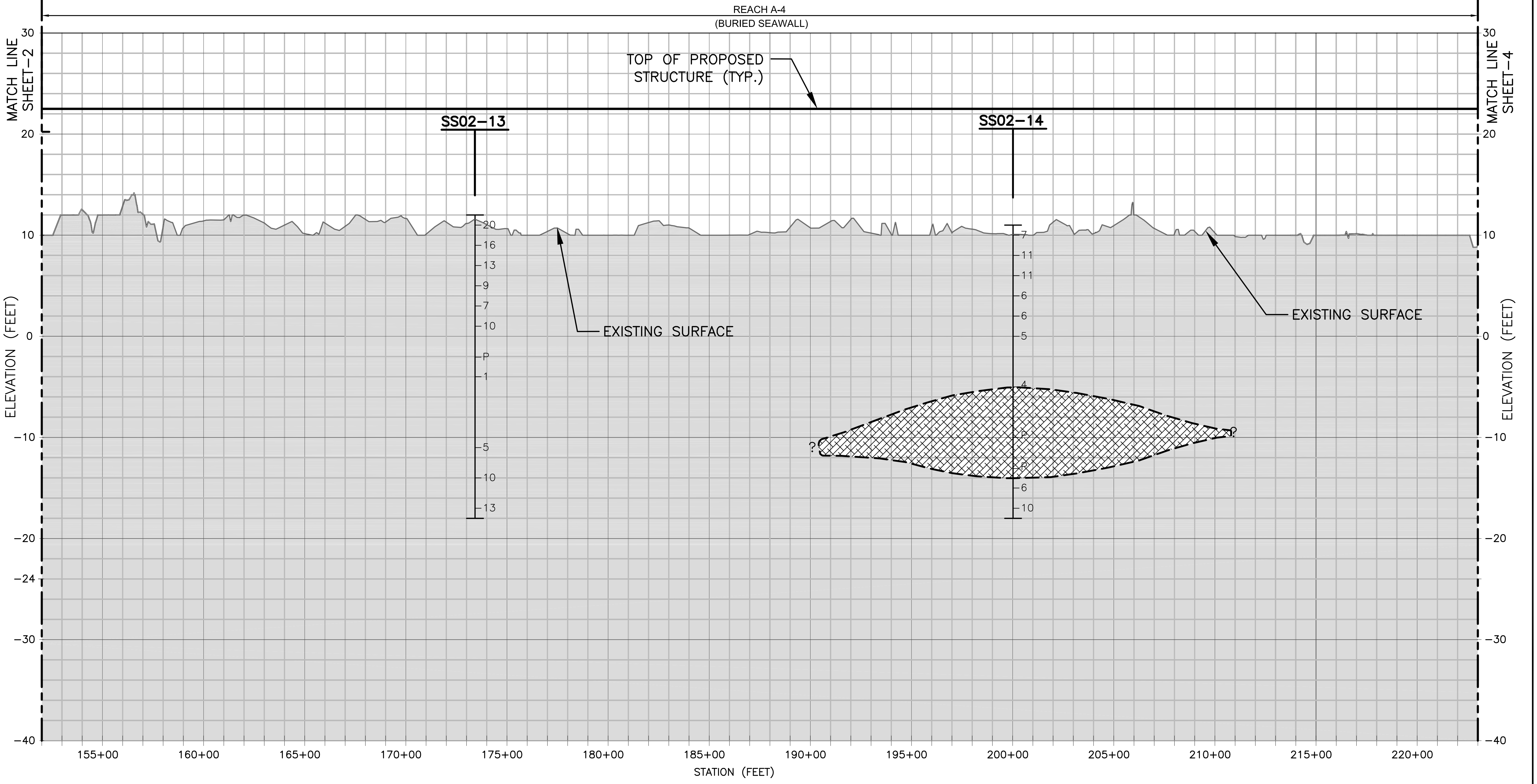
0 250 500 1000
HORIZONTAL SCALE (FEET)

0 5 10 20
VERTICAL SCALE (FEET)

CROSS-SECTION – SHEET 2
SOUTH SHORE STATEN ISLAND
NEW YORK

URS
CLIFTON, NEW JERSEY

DR. BY	ET	SCALE	AS SHOWN	DWG. NO. 02-SECTIONS	PROJ. NO. 11020302
CK'D. BY	NV	DATE	AUGUST, 2012	FIG. NO.	11



LEGEND

SS02–05 — GEOTECHNICAL BORING CONDUCTED BY MATRIX ENVIRONMENTAL SERVICES OF FLORHAM PARK, NJ.

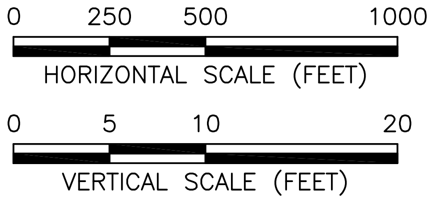
–19 — N–VALUE, DEFINED AS NUMBER OF BLOWS OF A 140–LB HAMMER FREE FALLING FOR 30 INCHES REQUIRED TO ADVANCE A STANDARD SPLIT SPOON SAMPLER 12 INCHES AFTER INITIAL 6 INCH PENETRATION

–P — PUSHED SHELBY TUBE

— —?— — APPROXIMATE STRATA BOUNDARY

GENERALIZED SOIL DESCRIPTIONS:

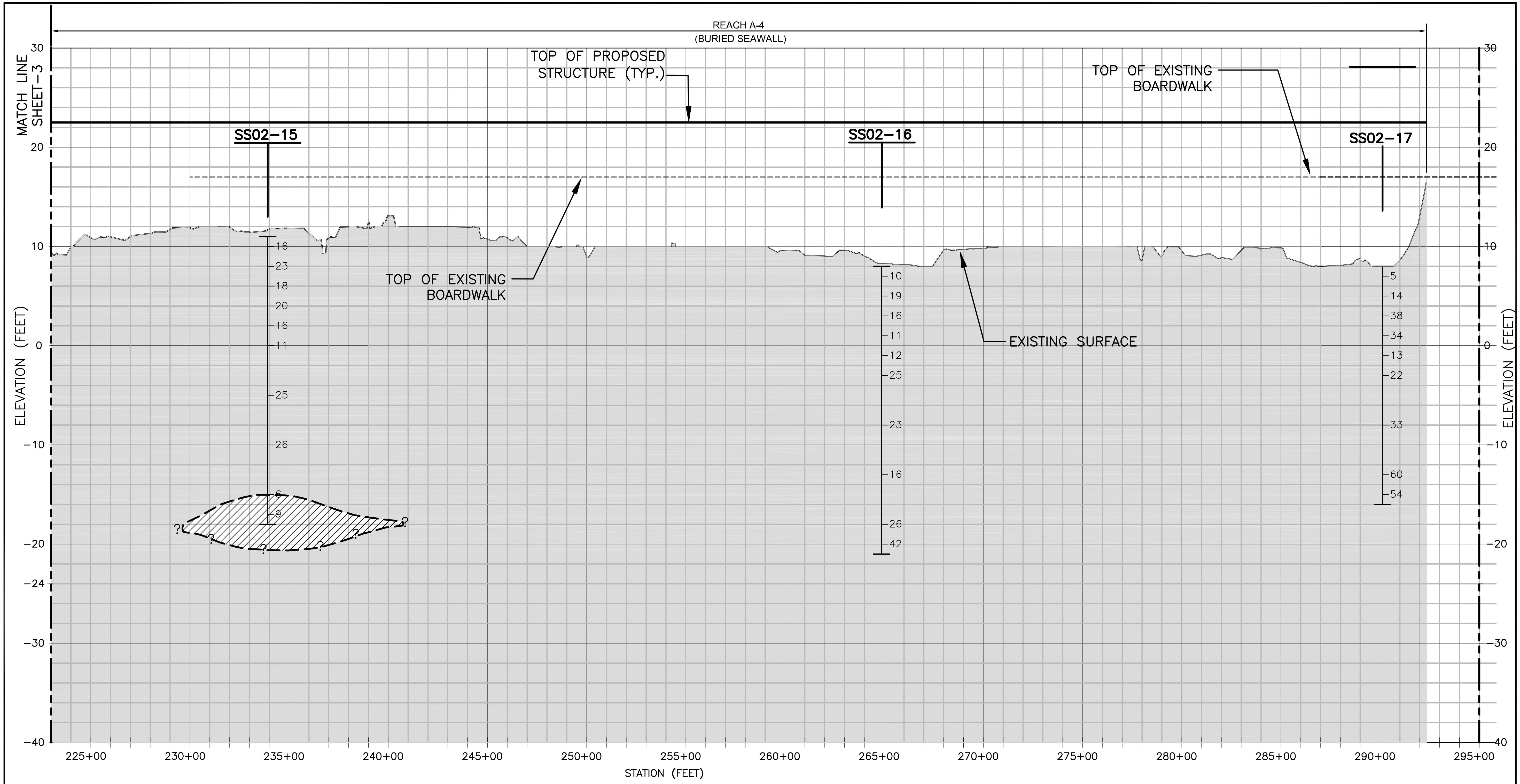
▒	COARSE TO FINE SAND WITH SILT AND GRAVEL
▨	INORGANIC CLAY/INORGANIC SILTY CLAY
▨	ORGANIC CLAYEY SILT
▩	INORGANIC SILT/INORGANIC CLAYEY SILT



CROSS–SECTION – SHEET 3
SOUTH SHORE STATEN ISLAND
NEW YORK

URS
CLIFTON, NEW JERSEY

DR. BY	ET	SCALE	AS SHOWN	DWG. NO.	02–SECTIONS	PROJ. NO.	11020302
CK'D. BY	NV	DATE	AUGUST, 2012			FIG. NO.	12

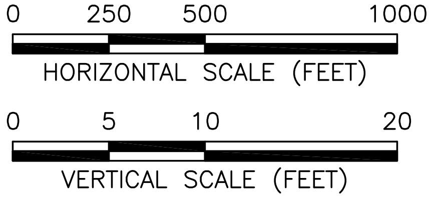


LEGEND

SS02-05	GEOTECHNICAL BORING CONDUCTED BY MATRIX ENVIRONMENTAL SERVICES OF FLORHAM PARK, NJ.
−19	N-VALUE, DEFINED AS NUMBER OF BLOWS OF A 140-LB HAMMER FREE FALLING FOR 30 INCHES REQUIRED TO ADVANCE A STANDARD SPLIT SPOON SAMPLER 12 INCHES AFTER INITIAL 6 INCH PENETRATION
−P	PUSHED SHELBY TUBE
— —?— —	APPROXIMATE STRATA BOUNDARY

GENERALIZED SOIL DESCRIPTIONS:

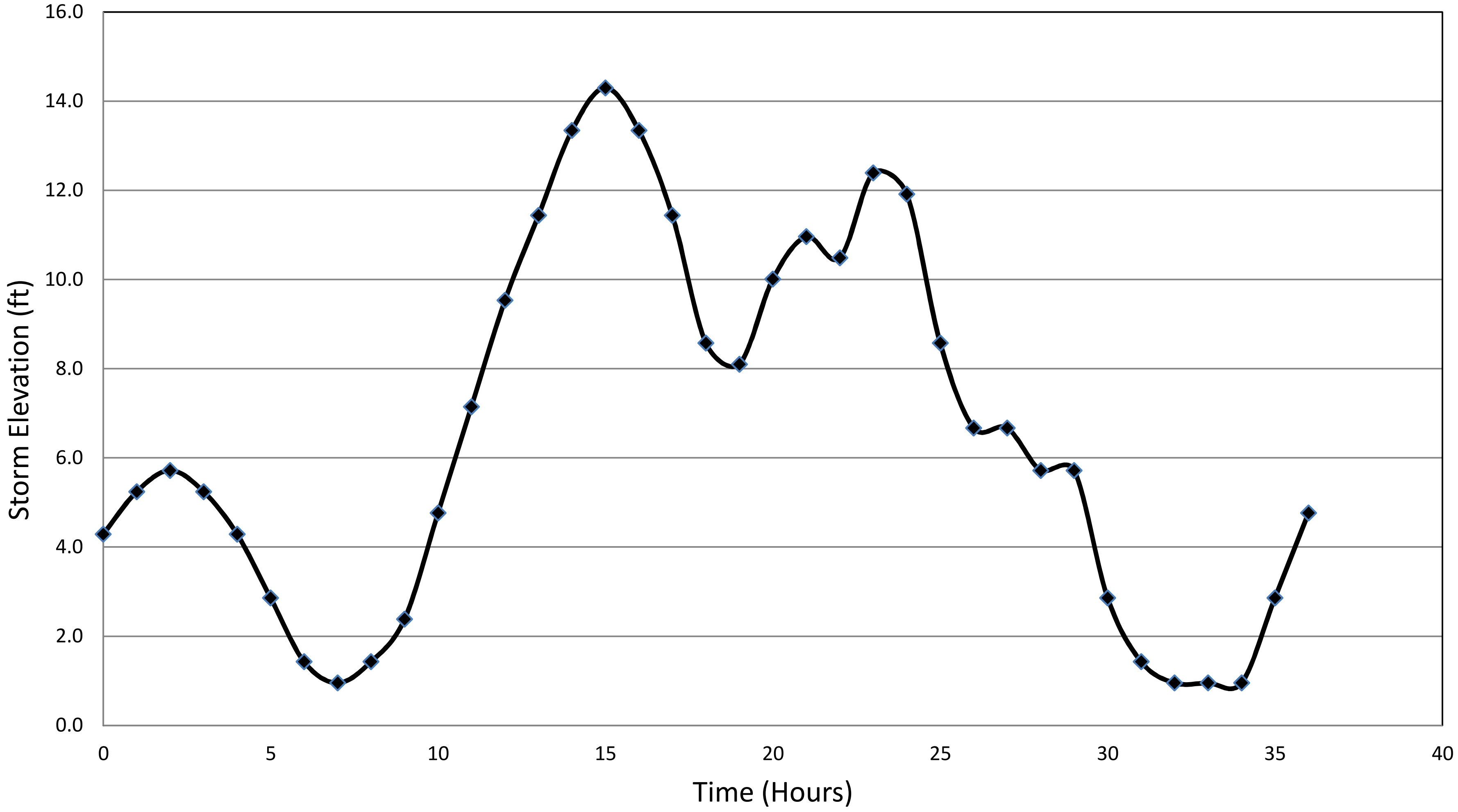
▒	COARSE TO FINE SAND WITH SILT AND GRAVEL
▨	INORGANIC CLAY/INORGANIC SILTY CLAY
▨	ORGANIC CLAYEY SILT
▩	INORGANIC SILT/INORGANIC CLAYEY SILT



CROSS–SECTION – SHEET 4
SOUTH SHORE STATEN ISLAND
NEW YORK

URS
CLIFTON, NEW JERSEY

DR. BY	ET	SCALE	AS SHOWN	DWG. NO. 02-SECTIONS	PROJ. NO. 11020302	
CK'D. BY	NV	DATE	AUGUST, 2012	FIG. NO.	13	



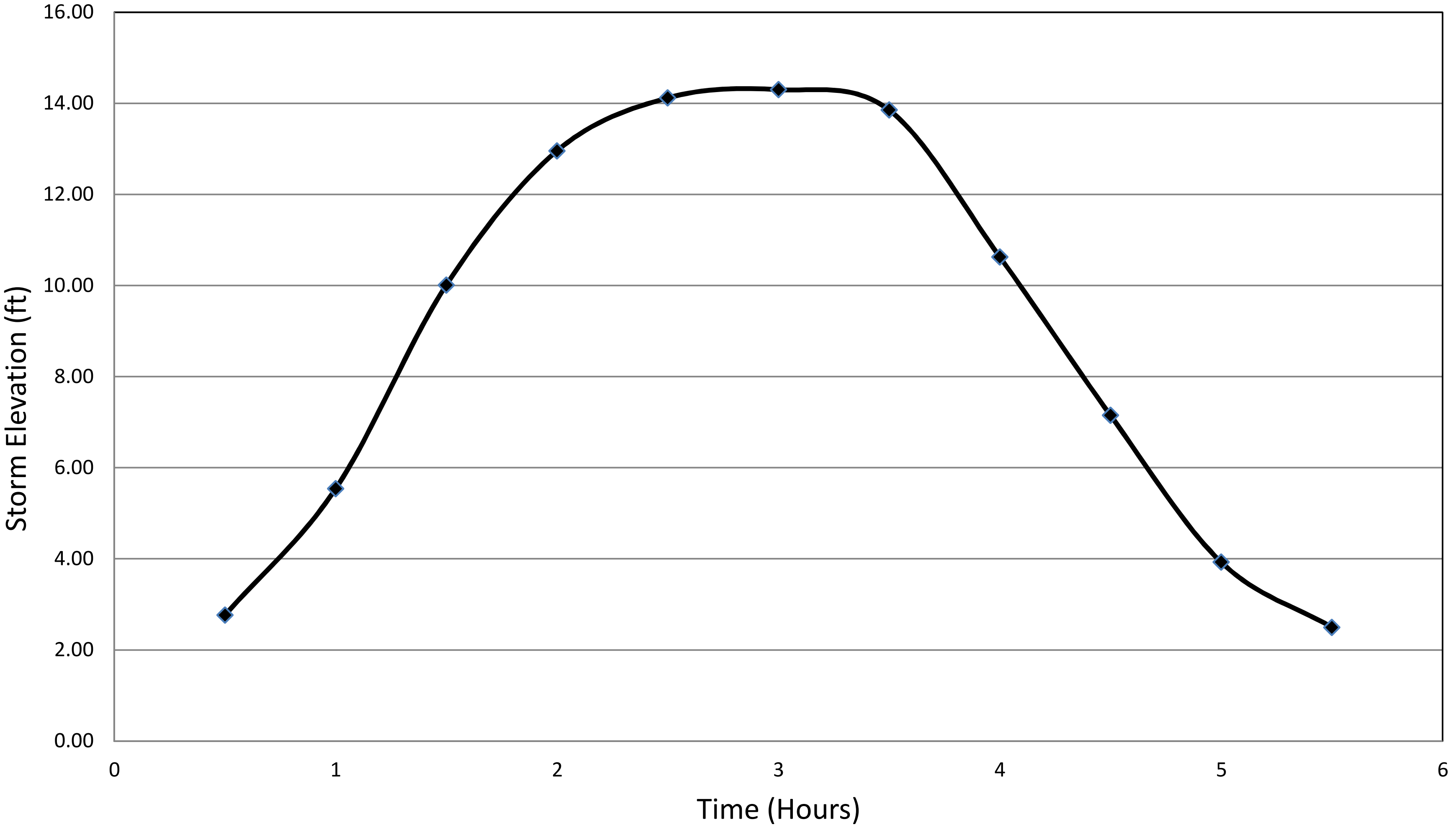
Source:
November 1950 nor'easter in NYC, peak water elevation
modified to match the design storm elevation

Storm (Nor'Easter) Hydrograph
Storm Damage Reduction Feasibility Study
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: VN	SCALE: As Shown	PROJ: 11020302
	DATE: July, 2011	FIG NO: 14

I:\Projects\11020302(South Shore of Staten Island)\Report\Figures\Figure 14-16 Figure15



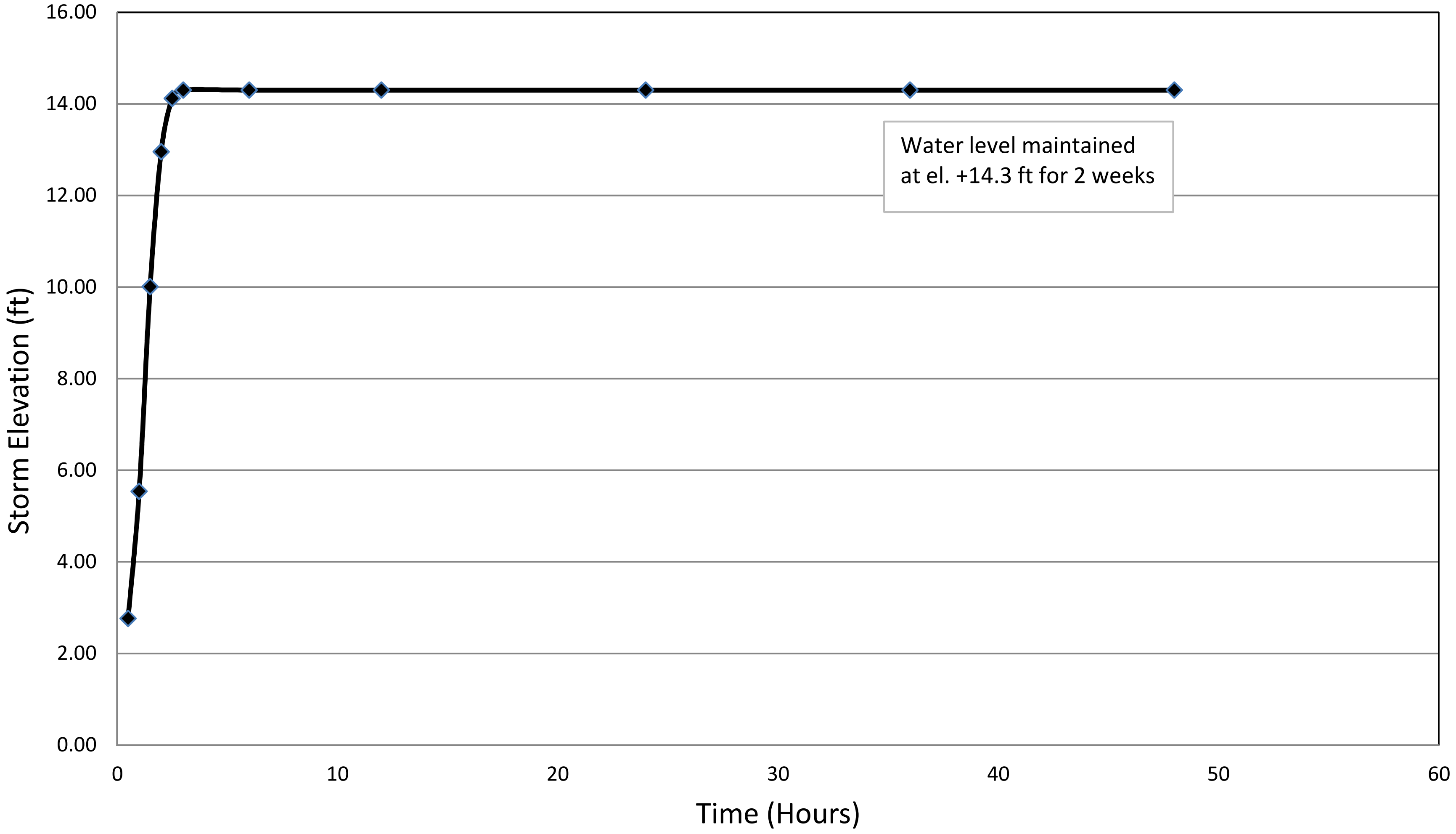
Source:
Huricane hydrograph from another location, peak water elevation
modified to match the design storm elevation

Hurricane Hydrograph
Storm Damage Reduction Feasibility Study
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: VN	SCALE: NTS	PROJ: 11020302
	DATE: July, 2011	FIG NO: 15

I:\Projects\11020302(South Shore of Staten Island)\Report\Figures\Figure 14-16 Figure16



NOTE:
Maximum still water level hypothetically maintained
for about 2 weeks

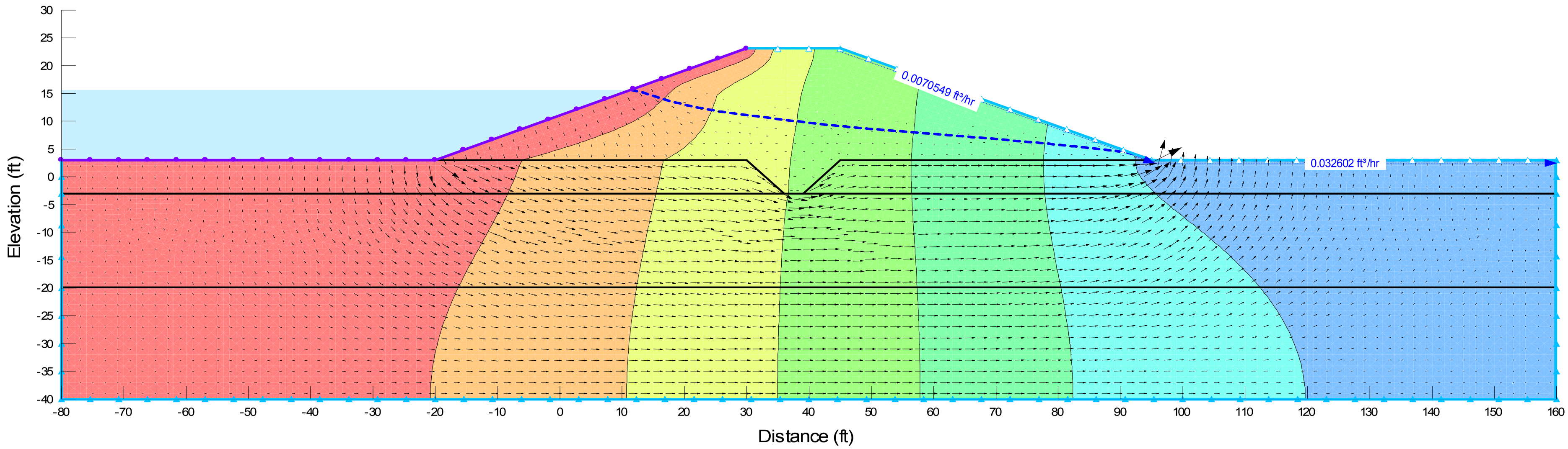
Hypothetical Hurricane Hydrograph
Storm Damage Reduction Feasibility Study
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: VN	SCALE: NTS	PROJ: 11020302
	DATE: JAN., 2012	FIG NO: 16

I:\Projects\11020302(South Shore of Staten Island)\Report\Figures\Figure 14-16 Figure17

Name: Medium Dense Sand (k=1x10-4cm/s)   Model: Saturated Only   K-Sat: 0.0118 ft/hr   Volumetric Water Content: 0 ft³/ft³
Name: Compacted Impervious Fill   Model: Saturated / Unsaturated   K-Function: k=1x10-5cm/s   Vol. WC. Function: Silty Sand
Name: Loose Sand (k=1x10-4cm/s)   Model: Saturated Only   K-Sat: 0.0118 ft/hr   Volumetric Water Content: 0 ft³/ft³
Name: Common Fill   Model: Saturated / Unsaturated   K-Function: k=1x10-4cm/s   Vol. WC. Function: Silty Sand



File: C2-Levee_ExGradeEl+3'.gsz   Analysis: Steady Seepage
Directory: I:\Projects\11020302(South Shore of Staten Island)\Slope Stability Analysis\Analyses_withNewAlignment\

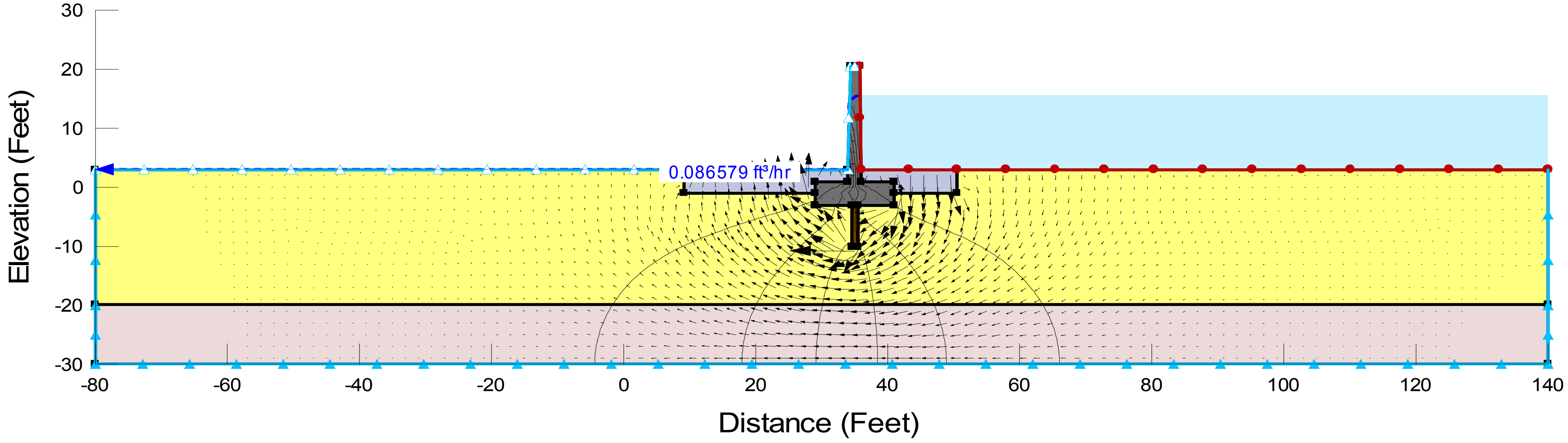
Levee (Reach A-2)
Seepage Analysis Results
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: As Shown	PROJ: 11020302
	DATE: September, 2014	FIG NO: 17

I:\Projects\11020302(South Shore of Staten Island)\Report\Figures\Figure 17

Name: Loose Sand Model: Saturated Only K-Sat: 0.0118 ft/hr Volumetric Water Content: 0 ft³/ft³
Name: Med Dense Sand Model: Saturated Only K-Sat: 0.0118 ft/hr Volumetric Water Content: 0 ft³/ft³
Name: Porous Materials Model: Saturated / Unsaturated K-Function: k=1x10-2cm/s Vol. WC. Function: Silty Sand
Name: Concrete Model: Saturated / Unsaturated K-Function: k=1x10-6cm/s Vol. WC. Function: Silty Sand
Name: sheet pile Model: Saturated / Unsaturated K-Function: k=1x10-6cm/s Vol. WC. Function: Silty Sand



Directory: I:\Projects\11020302(South Shore of Staten Island)\Slope Stability Analysis\Analyses_withNewAlignment\B2_Floodwall_SWL15-6ft_ExGradeEl-3'.gsz

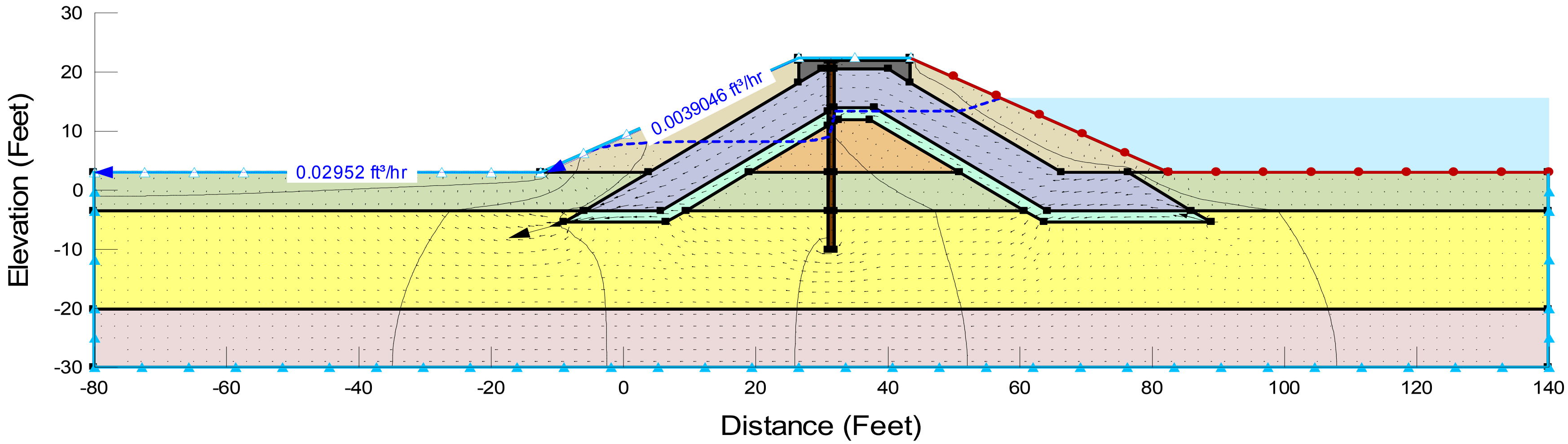
Floodwall (Reach A-3)
Seepage Analysis Results
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: As Shown	PROJ: 11020302
	DATE: September, 2014	FIG NO: 18

Steady-State Seepage

Name: Loose Sand Model: Saturated Only K-Sat: 0.0118 ft/hr Volumetric Water Content: 0 ft³/ft³
Name: Med Dense Sand Model: Saturated Only K-Sat: 0.0118 ft/hr Volumetric Water Content: 0 ft³/ft³
Name: Armor Stone Model: Saturated / Unsaturated K-Function: k=10cm/s Vol. WC. Function: Silty Sand
Name: Bedding Stone Model: Saturated / Unsaturated K-Function: k=10cm/s Vol. WC. Function: Silty Sand
Name: Embankment Model: Saturated / Unsaturated K-Function: Embankment Vol. WC. Function: Silty Sand
Name: Organic Silt Model: Saturated Only K-Sat: 0.00118 ft/hr Volumetric Water Content: 0 ft³/ft³
Name: RCC Model: Saturated / Unsaturated K-Function: k=1x10-6cm/s Vol. WC. Function: Silty Sand
Name: sheet pile Model: Saturated / Unsaturated K-Function: k=1x10-6cm/s Vol. WC. Function: Silty Sand
Name: Fill Model: Saturated / Unsaturated K-Function: Embankment Vol. WC. Function: Silty Sand



Directory: I:\Projects\11020302(South Shore of Staten Island)\Slope Stability Analysis\Analyses_withNewAlignment\C2_BuriedSeawall_SWL15-6ft_ExGradeEl-3'.gsz

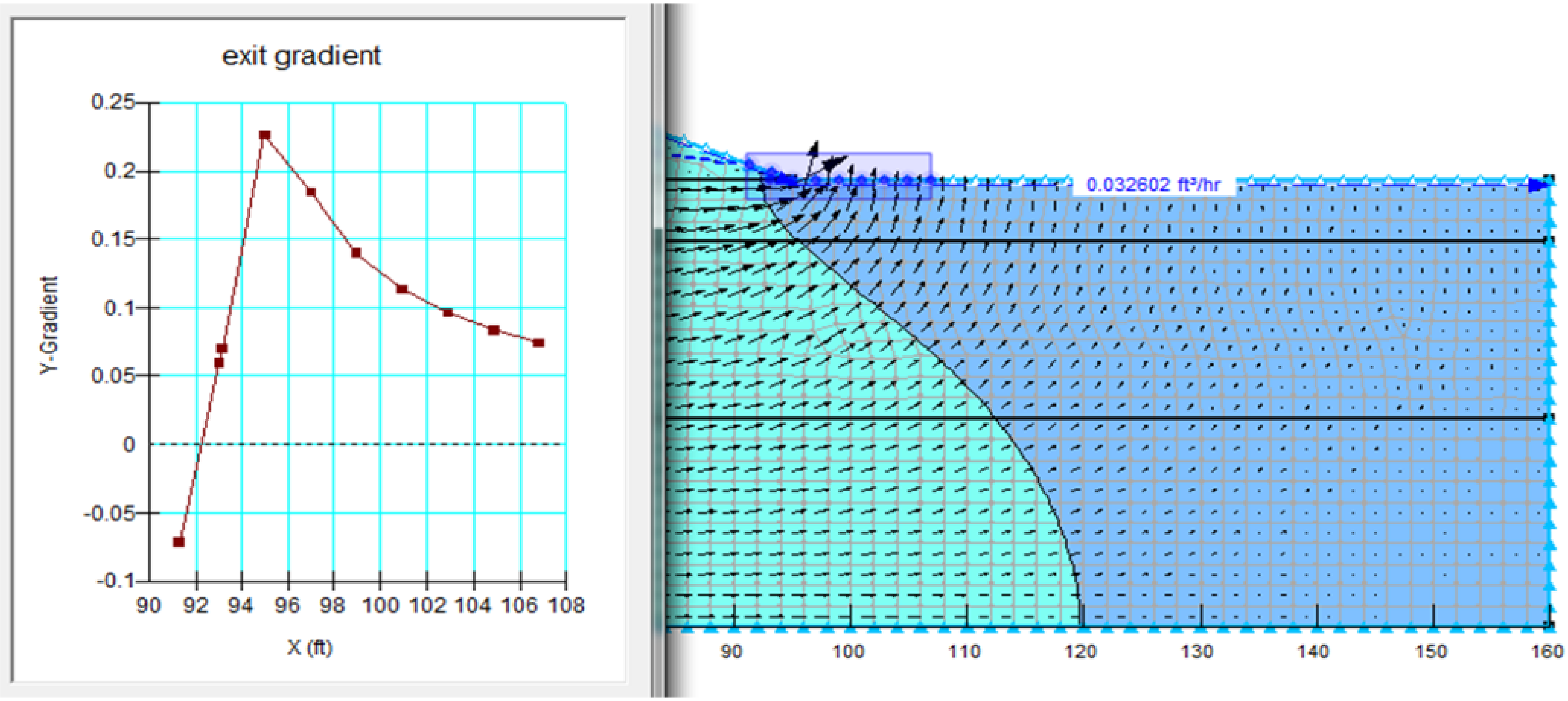
Buried Seawall (Reach A-4)
Seepage Analysis Results
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: As Shown	PROJ: 11020302
	DATE: September, 2014	FIG NO: 19

I:\Projects\11020302(South Shore of Staten Island)\Report\Figures\Figure 19

Exit Hydraulic Gradient

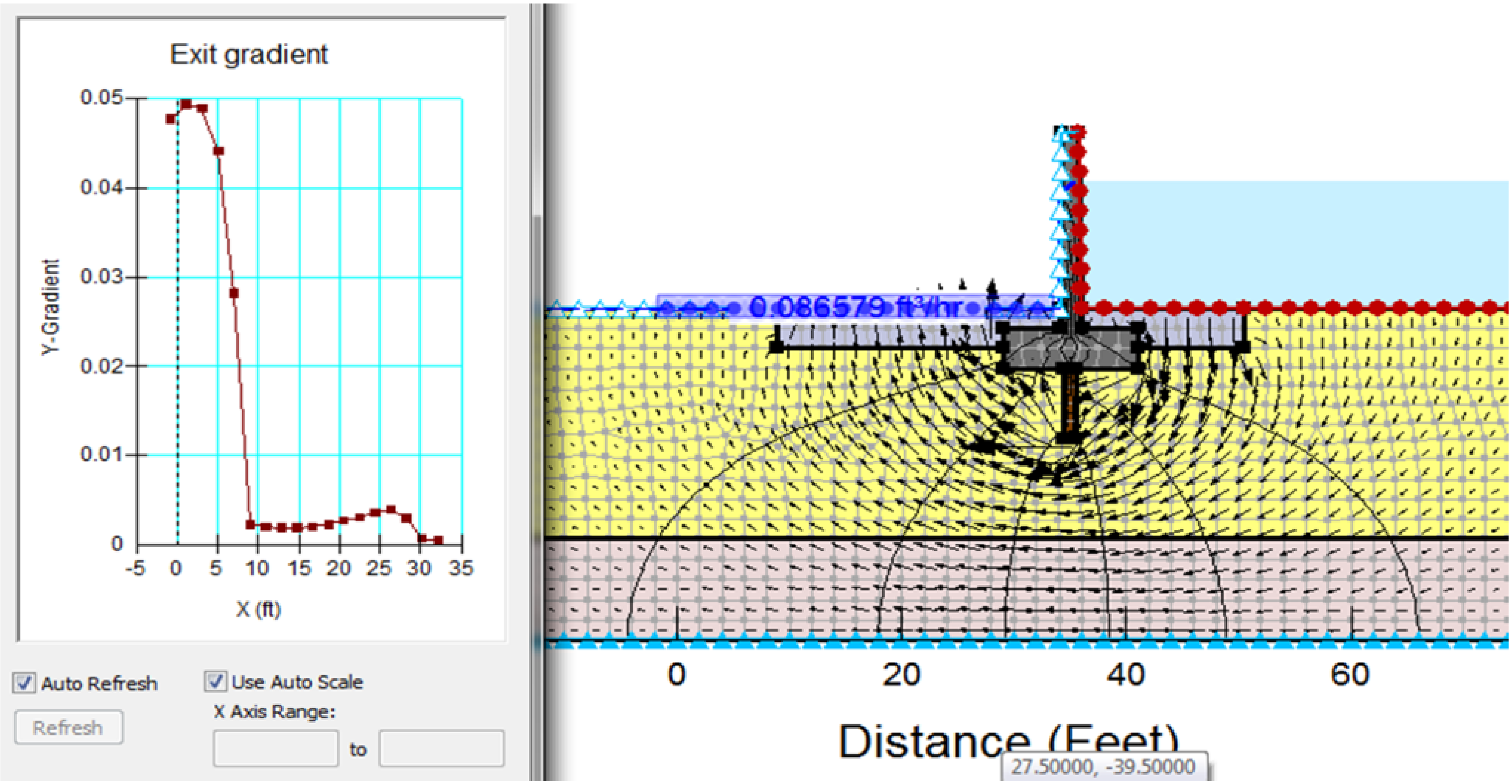


Levee (Reach A-2)
Exit Hydraulic Gradient
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: As Shown	PROJ: 11020302
	DATE: September, 2014	FIG NO: 20

Exit Hydraulic Gradient

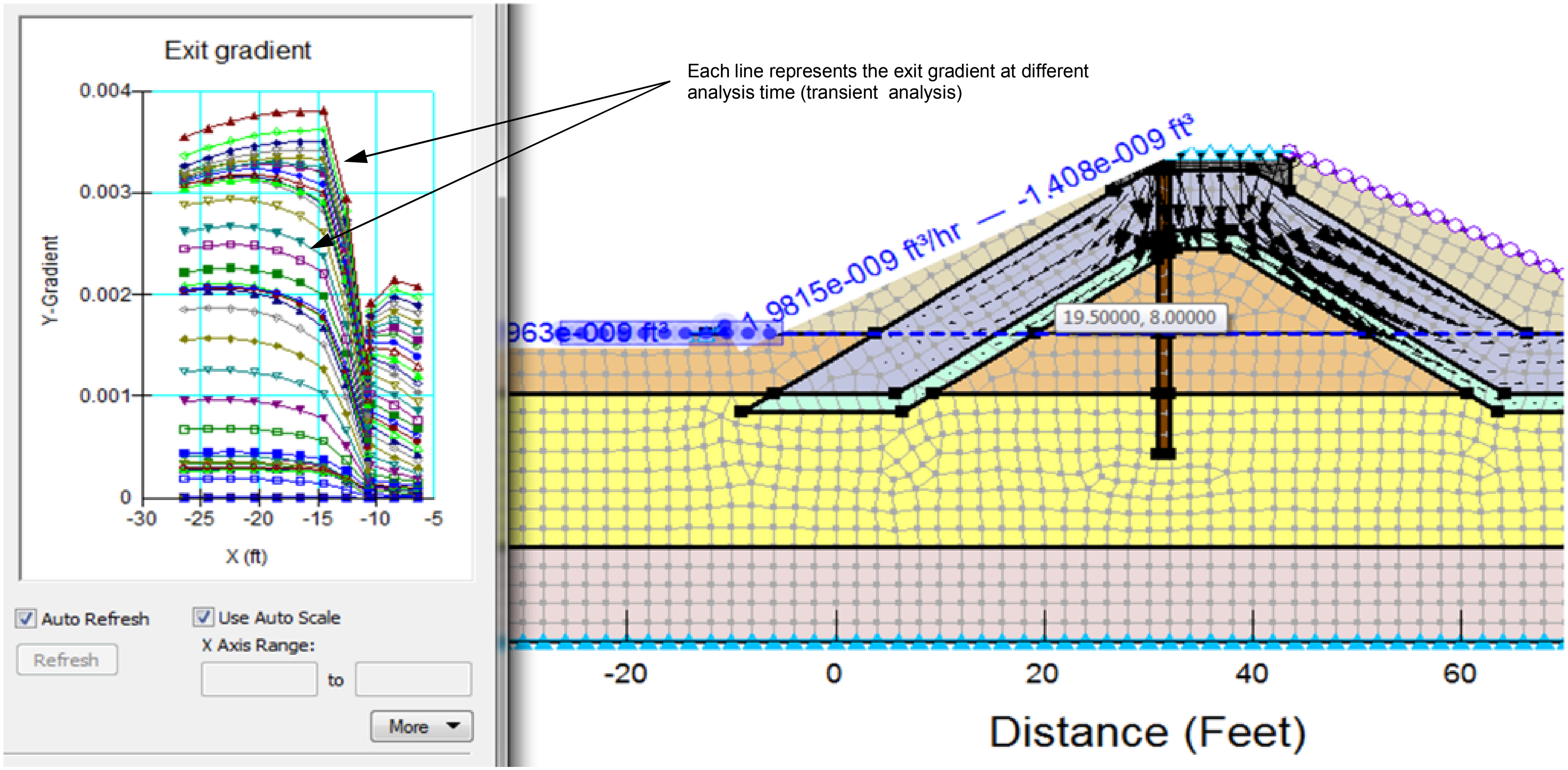


Floodwall (Reach A-3)
Exit Hydraulic Gradient
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: As Shown	PROJ: 11020302
	DATE: September, 2014	FIG NO: 21

Exit Hydraulic Gradient



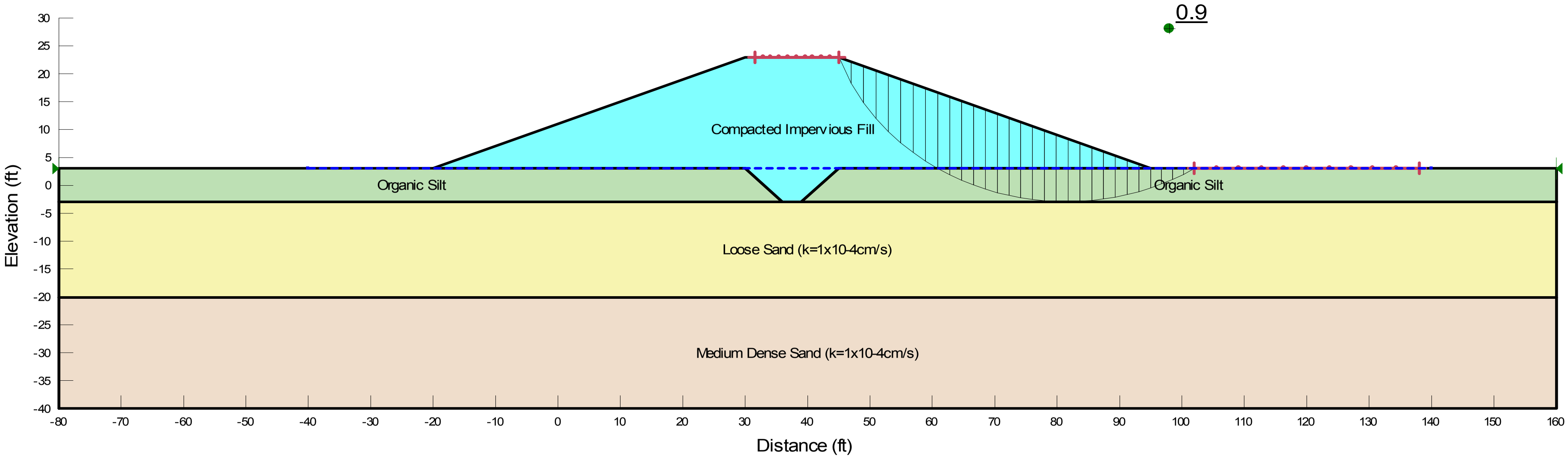
Each line represents the exit gradient at different analysis time (transient analysis)

Buried Seawall (Reach A-4)
Exit Hydraulic Gradient
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: As Shown	PROJ: 11020302
	DATE: September, 2014	FIG NO: 22

Name: Medium Dense Sand (k=1x10-4cm/s) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf Phi: 30 ° Piezometric Line: 1
Name: Compacted Impervious Fill Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 0 psf Phi: 32 ° Piezometric Line: 1
Name: Loose Sand (k=1x10-4cm/s) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf Phi: 26 ° Piezometric Line: 1
Name: Organic Silt Model: Mohr-Coulomb Unit Weight: 100 pcf Cohesion: 200 psf Phi: 0 ° Piezometric Line: 1



File: C2-Levee_ExGradeEl+3'.gsz Analysis: End of Construction (with Organics)
Directory: I:\Projects\11020302(South Shore of Staten Island)\Slope Stability Analysis\Analyses_withNewAlignment\

Note:

1. The above results are for End of Construction analysis **with** Organic soil layer
2. Analysis on the Upstream Stability yielded same Factor of Safety (FOS).

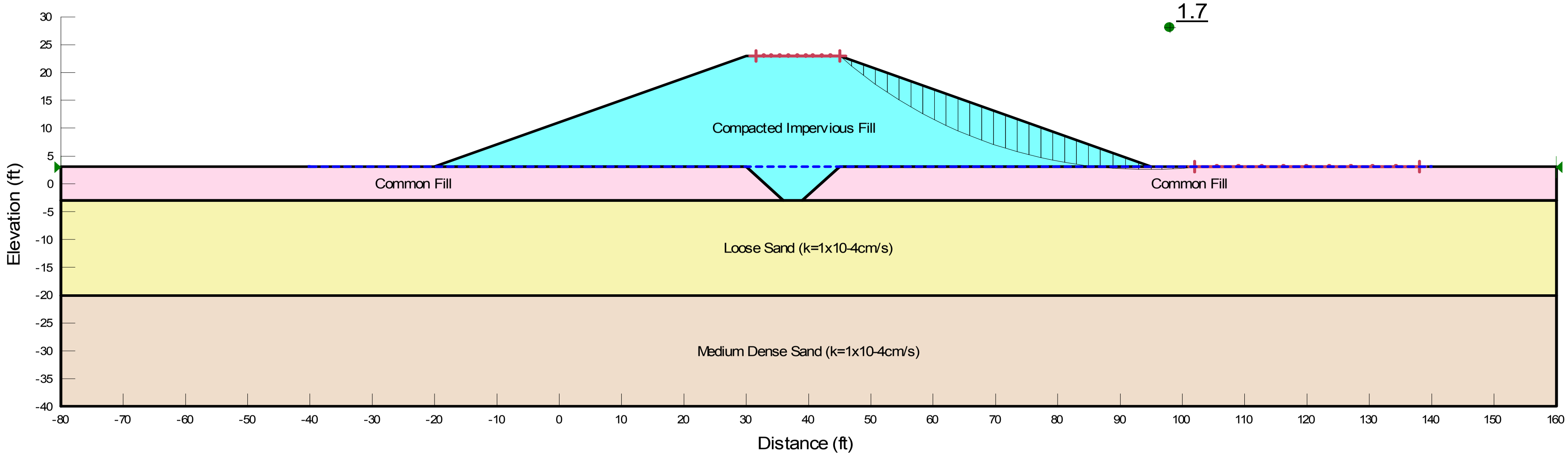
Levee (Reach A-2)
Slope Stability Case I Results
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: As Shown	PROJ: 11020302
	DATE: September, 2014	FIG NO: 23

I:\Projects\11020302(South Shore of Staten Island)\Report\Figures\Figure 23

Name: Medium Dense Sand (k=1x10-4cm/s)   Model: Mohr-Coulomb   Unit Weight: 120 pcf   Cohesion: 0 psf   Phi: 30 °   Piezometric Line: 1
Name: Compacted Impervious Fill   Model: Mohr-Coulomb   Unit Weight: 125 pcf   Cohesion: 0 psf   Phi: 32 °   Piezometric Line: 1
Name: Loose Sand (k=1x10-4cm/s)   Model: Mohr-Coulomb   Unit Weight: 120 pcf   Cohesion: 0 psf   Phi: 26 °   Piezometric Line: 1
Name: Common Fill   Model: Mohr-Coulomb   Unit Weight: 125 pcf   Cohesion: 0 psf   Phi: 32 °   Piezometric Line: 1



File: C2-Levee_ExGradeEl+3'.gsz   Analysis: End of Construction (Downstream Slope)
Directory: I:\Projects\11020302(South Shore of Staten Island)\Slope Stability Analysis\Analyses_withNewAlignment\

Note:

1. The above results are for End of Construction analysis **without** the Organic soil layer
2. Analysis on the Upstream Stability yielded same Factor of Safety (FOS).

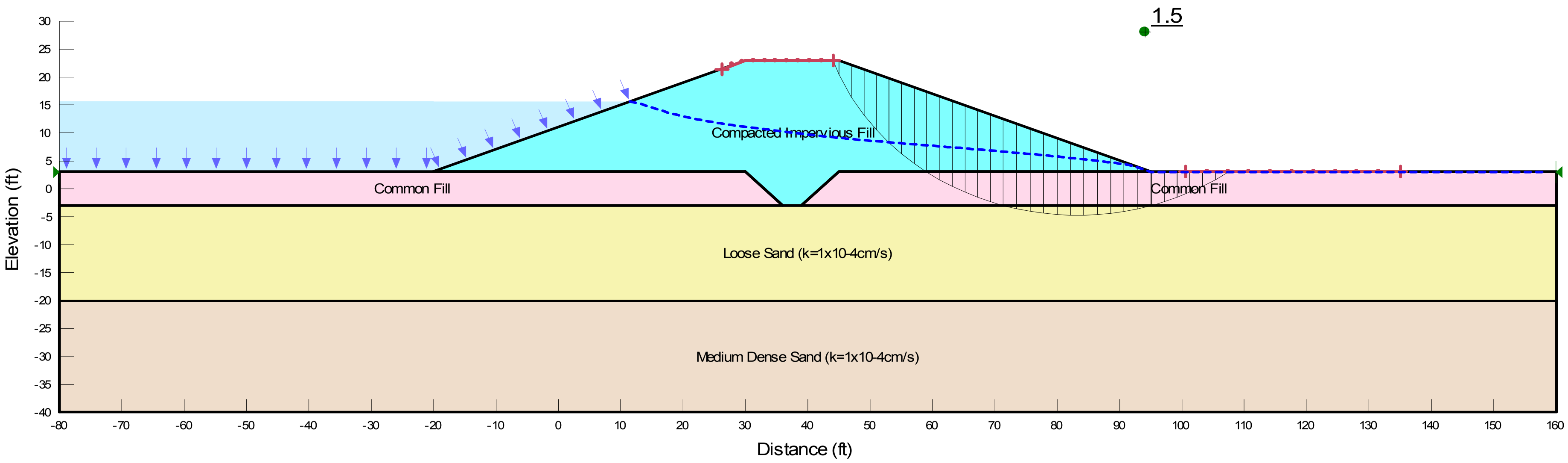
Levee (Reach A-2)
Slope Stability Case I Results
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: As Shown	PROJ: 11020302
	DATE: September, 2014	FIG NO: 24

I:\Projects\11020302(South Shore of Staten Island)\Report\Figures\Figure 24

Name: Medium Dense Sand (k=1x10-4cm/s)   Model: Mohr-Coulomb   Unit Weight: 120 pcf   Cohesion: 0 psf   Phi: 30 °
Name: Compacted Impervious Fill   Model: Mohr-Coulomb   Unit Weight: 125 pcf   Cohesion: 0 psf   Phi: 32 °
Name: Loose Sand (k=1x10-4cm/s)   Model: Mohr-Coulomb   Unit Weight: 120 pcf   Cohesion: 0 psf   Phi: 26 °
Name: Common Fill   Model: Mohr-Coulomb   Unit Weight: 125 pcf   Cohesion: 0 psf   Phi: 32 °



File: C2-Levee_ExGradeEl+3'.gsz   Analysis: Long Term
Directory: I:\Projects\11020302(South Shore of Staten Island)\Slope Stability Analysis\Analyses_withNewAlignment\

Note:

1. The above results are for Steady Seepage analysis **without** the Organic soil layer

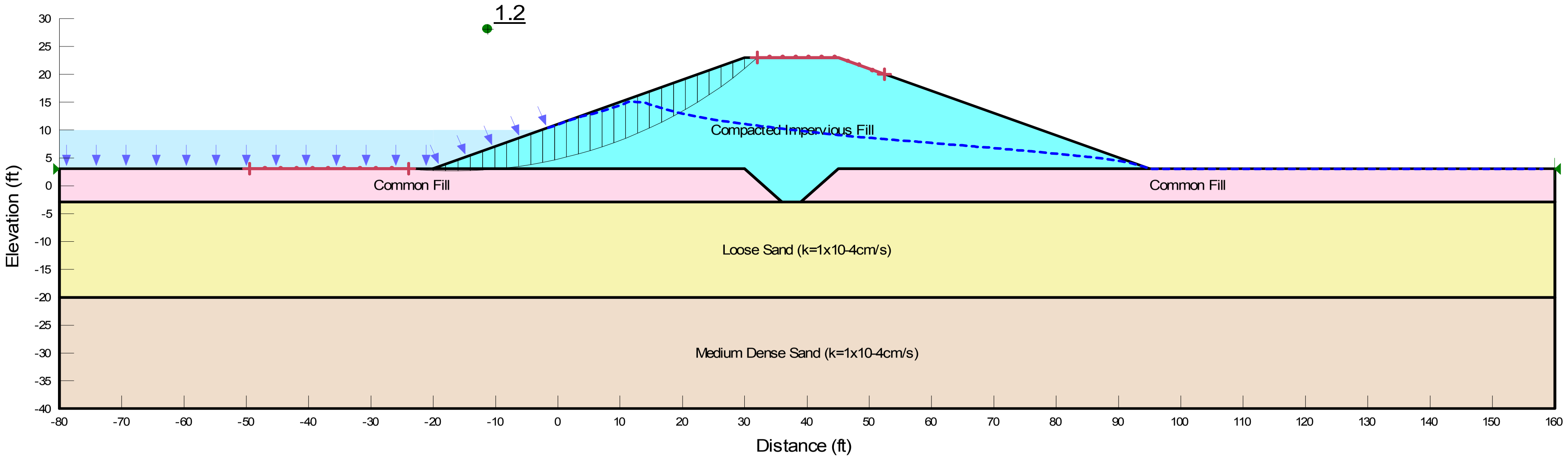
Levee (Reach A-2)
Slope Stability Case 2 Results
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: As Shown	PROJ: 11020302
	DATE: September, 2014	FIG NO: 25

I:\Projects\11020302(South Shore of Staten Island)\Report\Figures\Figure 25

Name: Medium Dense Sand (k=1x10-4cm/s) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf Phi: 30 °
Name: Compacted Impervious Fill Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 0 psf Phi: 32 °
Name: Loose Sand (k=1x10-4cm/s) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf Phi: 26 °
Name: Common Fill Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 0 psf Phi: 32 °



File: C2-Levee_ExGradeEl+3'.gsz Analysis: Slope Stability
Directory: I:\Projects\11020302(South Shore of Staten Island)\Slope Stability Analysis\Analyses_withNewAlignment\

Note:

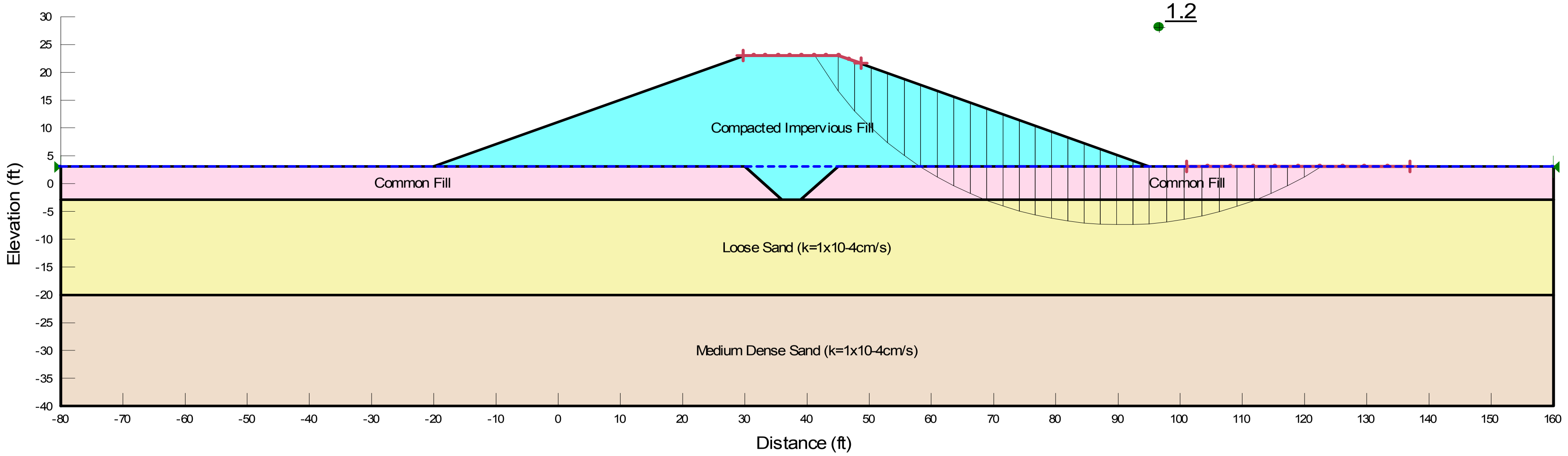
1. The above results are for Rapid Drawdown Analysis **without** the Organic soil layer

Levee (Reach A-2)
Slope Stability Case 3 Results
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: As Shown	PROJ: 11020302
	DATE: September, 2014	FIG NO: 26

Name: Medium Dense Sand (k=1x10-4cm/s)   Model: Mohr-Coulomb   Unit Weight: 120 pcf   Cohesion: 0 psf   Phi: 30 °   Piezometric Line: 1
Name: Compacted Impervious Fill   Model: Mohr-Coulomb   Unit Weight: 125 pcf   Cohesion: 0 psf   Phi: 32 °   Piezometric Line: 1
Name: Loose Sand (k=1x10-4cm/s)   Model: Mohr-Coulomb   Unit Weight: 120 pcf   Cohesion: 0 psf   Phi: 26 °   Piezometric Line: 1
Name: Common Fill   Model: Mohr-Coulomb   Unit Weight: 125 pcf   Cohesion: 0 psf   Phi: 32 °   Piezometric Line: 1



File: C2-Levee_ExGradeEl+3'.gsz   Analysis: Seismic Case 2
Directory: I:\Projects\11020302(South Shore of Staten Island)\Slope Stability Analysis\Analyses_withNewAlignment\

Note:

1. The above results are for Seismic Stability Analysis **without** the Organic soil layer

Levee (Reach A-2)
Slope Stability Case 4 Results
Staten Island, New York

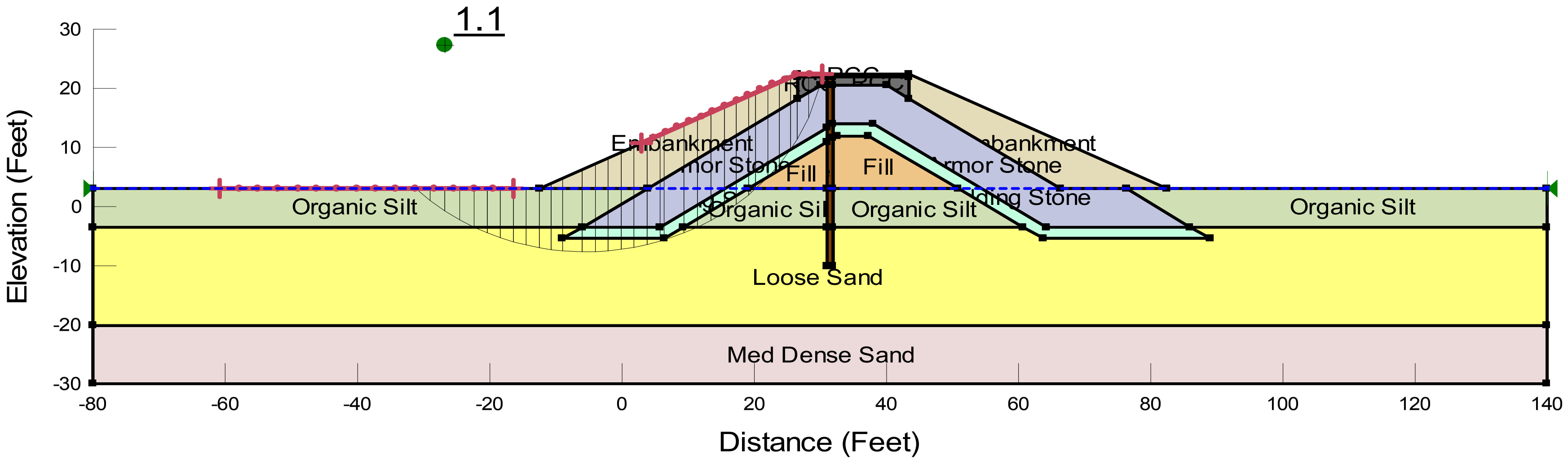
URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: As Shown	PROJ: 11020302
	DATE: September, 2014	FIG NO: 27

I:\Projects\11020302(South Shore of Staten Island)\Report\Figures\Figure 27

Stability: End of Construction (Downstream Slope)

Name: Loose Sand Unit Weight: 120 pcf Cohesion: 0 psf Phi: 26 ° Piezometric Line: 1
Name: Med Dense Sand Unit Weight: 120 pcf Cohesion: 0 psf Phi: 30 ° Piezometric Line: 1
Name: Armor Stone Unit Weight: 145 pcf Cohesion: 0 psf Phi: 38 ° Piezometric Line: 1
Name: Bedding Stone Unit Weight: 140 pcf Cohesion: 0 psf Phi: 36 ° Piezometric Line: 1
Name: Embankment Unit Weight: 125 pcf Cohesion: 0 psf Phi: 32 ° Piezometric Line: 1
Name: Organic Silt Unit Weight: 100 pcf Cohesion: 200 psf Phi: 0 ° Piezometric Line: 1
Name: RCC Unit Weight: 150 pcf Cohesion: 0 psf Phi: 35 ° Piezometric Line: 1
Name: sheet pile Unit Weight: 150 pcf Cohesion: 1000 psf Phi: 0 ° Piezometric Line: 1
Name: Fill Unit Weight: 120 pcf Cohesion: 0 psf Phi: 32 ° Piezometric Line: 1



Directory: I:\Projects\11020302(South Shore of Staten Island)\Slope Stability Analysis\Analyses_withNewAlignment\C2_BuriedSeawall_SWL15-6ft_ExGradeEl-3'.gsz

Note:

1. The above results are for End of Construction analysis **with** Organic soil layer
2. Analysis on the Upstream Stability yielded same Factor of Safety (FOS).

Buried Seawall (Reach A-4)
Slope Stability Case I Results
Staten Island, New York

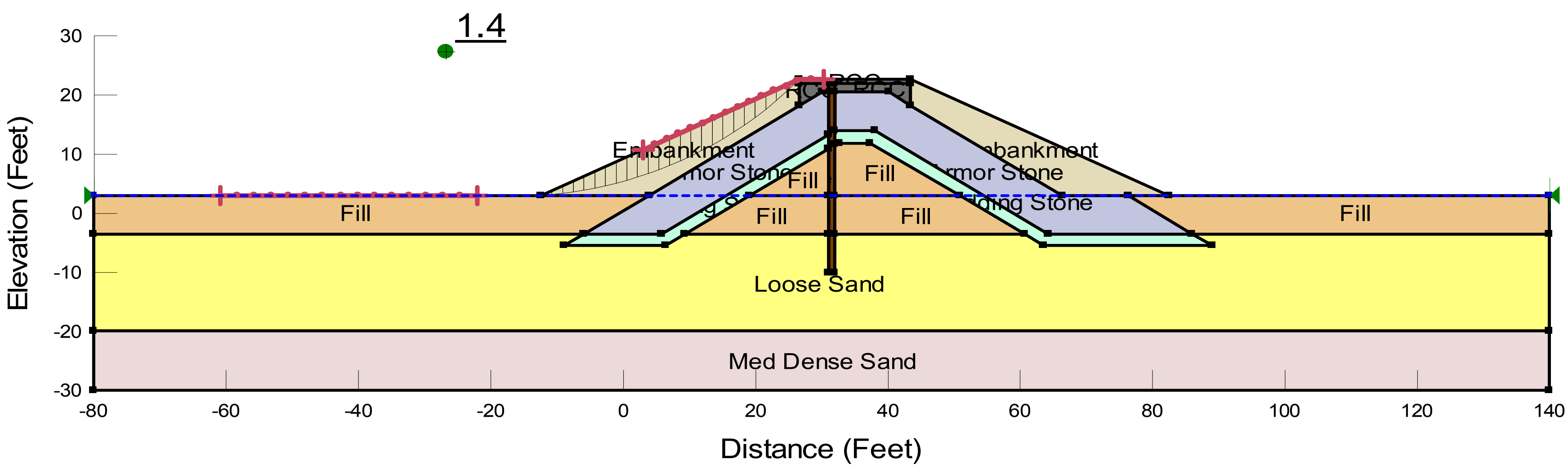
URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: As Shown	PROJ: 11020302
	DATE: September, 2014	FIG NO: 28

I:\Projects\11020302(South Shore of Staten Island)\Report\Figures\Figure 28

Stability: End of Construction (Downstream Slope, No Organics)

Name: Loose Sand Unit Weight: 120 pcf Cohesion: 0 psf Phi: 26 ° Piezometric Line: 1
Name: Med Dense Sand Unit Weight: 120 pcf Cohesion: 0 psf Phi: 30 ° Piezometric Line: 1
Name: Armor Stone Unit Weight: 145 pcf Cohesion: 0 psf Phi: 38 ° Piezometric Line: 1
Name: Bedding Stone Unit Weight: 140 pcf Cohesion: 0 psf Phi: 36 ° Piezometric Line: 1
Name: Embankment Unit Weight: 125 pcf Cohesion: 0 psf Phi: 32 ° Piezometric Line: 1
Name: RCC Unit Weight: 150 pcf Cohesion: 0 psf Phi: 35 ° Piezometric Line: 1
Name: sheet pile Unit Weight: 150 pcf Cohesion: 1000 psf Phi: 0 ° Piezometric Line: 1
Name: Fill Unit Weight: 120 pcf Cohesion: 0 psf Phi: 32 ° Piezometric Line: 1



Directory: I:\Projects\11020302(South Shore of Staten Island)\Slope Stability Analysis\Analyses_withNewAlignment\C2_BuriedSeawall_SWL15-6ft_ExGradeEl-3'.gsz

Note:

1. The above results are for End of Construction analysis **without** the Organic soil layer
2. Analysis on the Upstream Stability yielded same Factor of Safety (FOS).

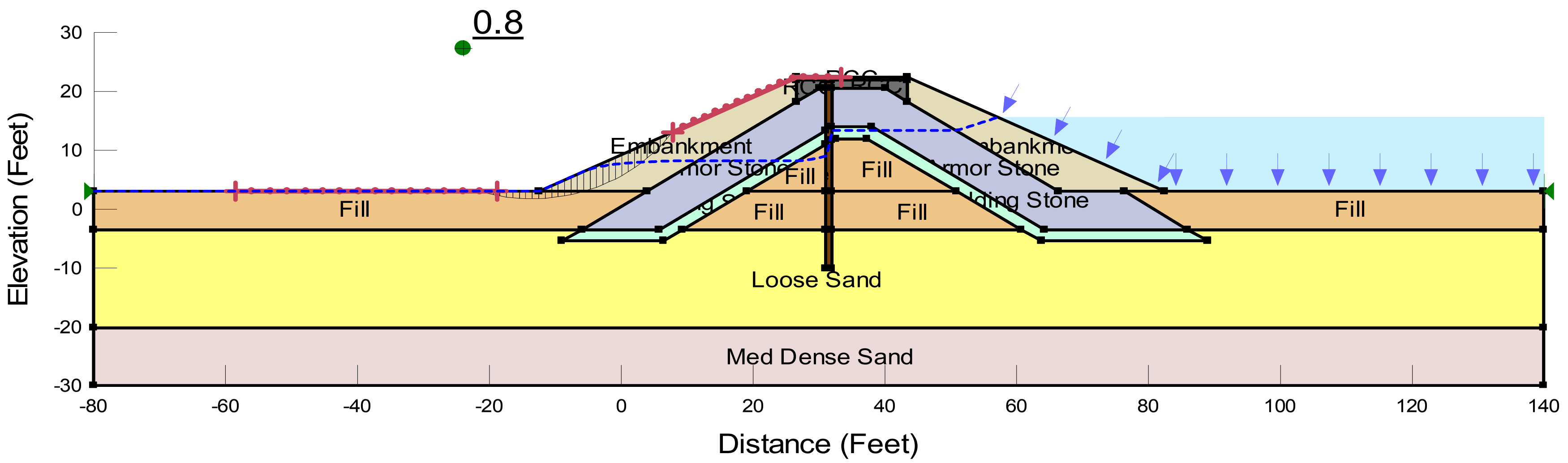
Buried Seawall (Reach A-4)
Slope Stability Case I Results
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: As Shown	PROJ: 11020302
	DATE: September, 2014	FIG NO: 29

Stability: Long Term (No Organics)

Name: Loose Sand Unit Weight: 120 pcf Cohesion: 0 psf Phi: 26 °
Name: Med Dense Sand Unit Weight: 120 pcf Cohesion: 0 psf Phi: 30 °
Name: Armor Stone Unit Weight: 145 pcf Cohesion: 0 psf Phi: 38 °
Name: Bedding Stone Unit Weight: 140 pcf Cohesion: 0 psf Phi: 36 °
Name: Embankment Unit Weight: 125 pcf Cohesion: 0 psf Phi: 32 °
Name: RCC Unit Weight: 150 pcf Cohesion: 0 psf Phi: 35 °
Name: sheet pile Unit Weight: 150 pcf Cohesion: 1000 psf Phi: 0 °
Name: Fill Unit Weight: 120 pcf Cohesion: 0 psf Phi: 32 °



Directory: I:\Projects\11020302(South Shore of Staten Island)\Slope Stability Analysis\Analyses_withNewAlignment\C2_BuriedSeawall_SWL15-6ft_ExGradeEl-3'.gsz

Note:

1. The above results are for Steady Seepage analysis **without** the Organic soil layer

Buried Seawall (Reach A-4)
Slope Stability Case 2 Results
Staten Island, New York

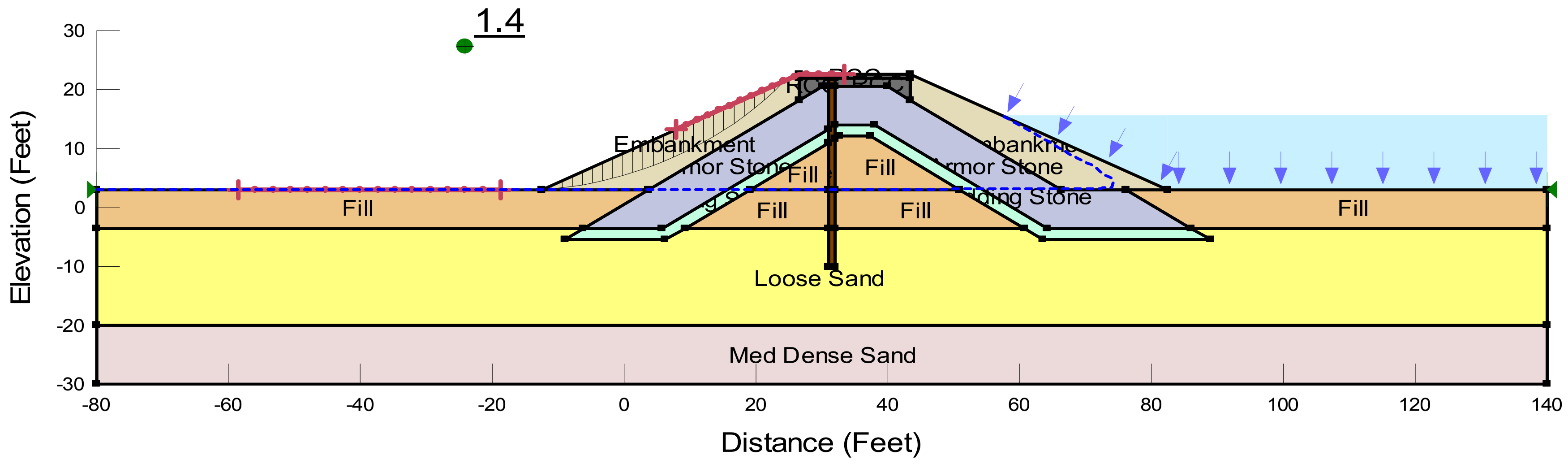
URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: As Shown	PROJ: 11020302
	DATE: September, 2014	FIG NO: 30

I:\Projects\11020302(South Shore of Staten Island)\Report\Figures\Figure 30

Stability: Long Term (Transient Seepage)

Name: Loose Sand Unit Weight: 120 pcf Cohesion: 0 psf Phi: 26 °
Name: Med Dense Sand Unit Weight: 120 pcf Cohesion: 0 psf Phi: 30 °
Name: Armor Stone Unit Weight: 145 pcf Cohesion: 0 psf Phi: 38 °
Name: Bedding Stone Unit Weight: 140 pcf Cohesion: 0 psf Phi: 36 °
Name: Embankment Unit Weight: 125 pcf Cohesion: 0 psf Phi: 32 °
Name: RCC Unit Weight: 150 pcf Cohesion: 0 psf Phi: 35 °
Name: sheet pile Unit Weight: 150 pcf Cohesion: 1000 psf Phi: 0 °
Name: Fill Unit Weight: 120 pcf Cohesion: 0 psf Phi: 32 °



Directory: I:\Projects\11020302(South Shore of Staten Island)\Slope Stability Analysis\Analyses_withNewAlignment\C2_BuriedSeawall_SWL15-6ft_ExGradeEl-3'.gsz

Note:

1. The above results are for Transient Seepage analysis **without** the Organic soil layer

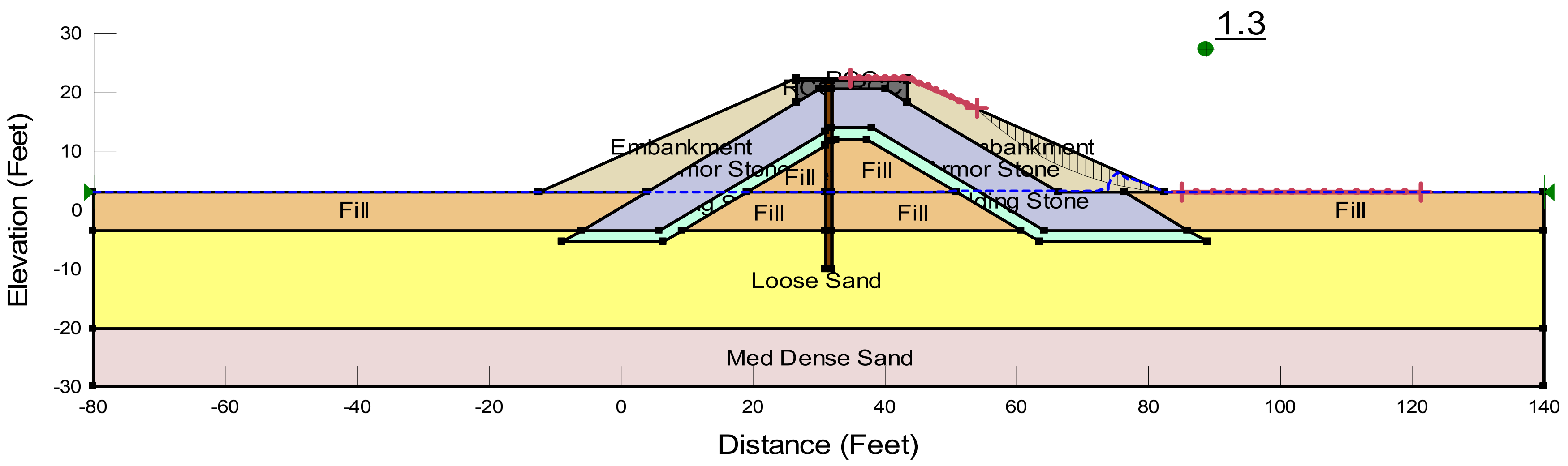
Buried Seawall (Reach A-4)
Slope Stability Case 2 Results
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: As Shown	PROJ: 11020302
	DATE: September, 2014	FIG NO: 31

Stability: Rapid Drawdown

Name: Loose Sand   Unit Weight: 120 pcf   Cohesion: 0 psf   Phi: 26 °
Name: Med Dense Sand   Unit Weight: 120 pcf   Cohesion: 0 psf   Phi: 30 °
Name: Armor Stone   Unit Weight: 145 pcf   Cohesion: 0 psf   Phi: 38 °
Name: Bedding Stone   Unit Weight: 140 pcf   Cohesion: 0 psf   Phi: 36 °
Name: Embankment   Unit Weight: 125 pcf   Cohesion: 0 psf   Phi: 32 °
Name: RCC   Unit Weight: 150 pcf   Cohesion: 0 psf   Phi: 35 °
Name: sheet pile   Unit Weight: 150 pcf   Cohesion: 1000 psf   Phi: 0 °
Name: Fill   Unit Weight: 120 pcf   Cohesion: 0 psf   Phi: 32 °



Directory: I:\Projects\11020302(South Shore of Staten Island)\Slope Stability Analysis\Analyses_withNewAlignment\C2_BuriedSeawall_SWL15-6ft_ExGradeEl-3'.gsz

Note:

1. The above results are for Rapid Drawdown analysis **without** the Organic soil layer

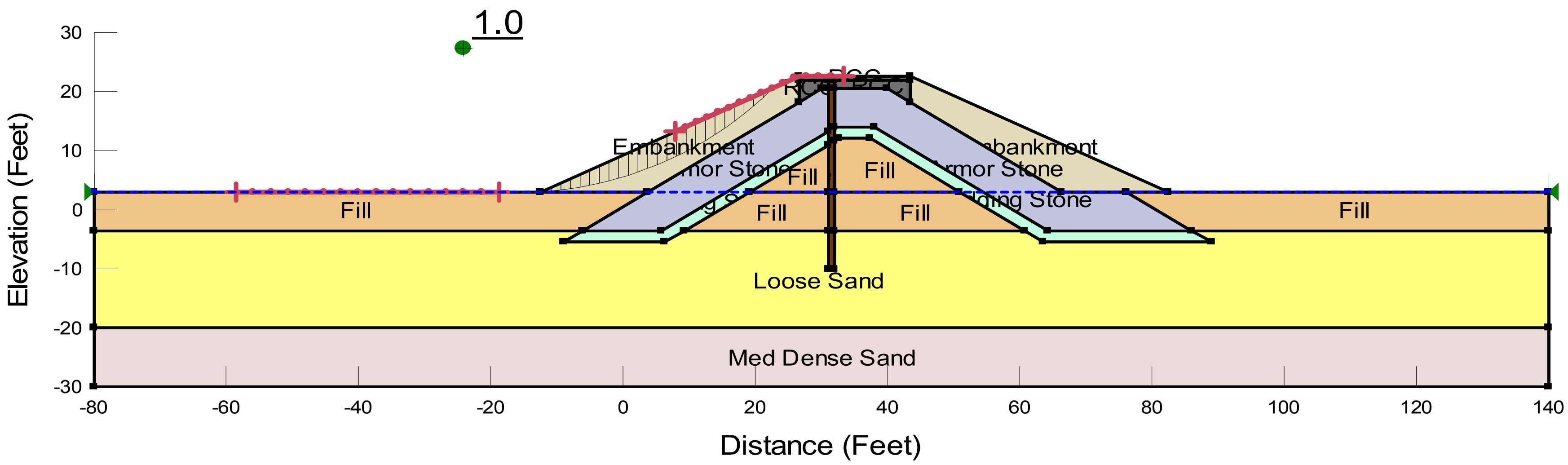
Buried Seawall (Reach A-4)
Slope Stability Case 3 Results
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: As Shown	PROJ: 11020302
	DATE: September, 2014	FIG NO: 32

Stability: Seismic Loading

Name: Loose Sand Unit Weight: 120 pcf Cohesion: 0 psf Phi: 26 ° Piezometric Line: 1
Name: Med Dense Sand Unit Weight: 120 pcf Cohesion: 0 psf Phi: 30 ° Piezometric Line: 1
Name: Armor Stone Unit Weight: 145 pcf Cohesion: 0 psf Phi: 38 ° Piezometric Line: 1
Name: Bedding Stone Unit Weight: 140 pcf Cohesion: 0 psf Phi: 36 ° Piezometric Line: 1
Name: Embankment Unit Weight: 125 pcf Cohesion: 0 psf Phi: 32 ° Piezometric Line: 1
Name: RCC Unit Weight: 150 pcf Cohesion: 0 psf Phi: 35 ° Piezometric Line: 1
Name: sheet pile Unit Weight: 150 pcf Cohesion: 1000 psf Phi: 0 ° Piezometric Line: 1
Name: Fill Unit Weight: 120 pcf Cohesion: 0 psf Phi: 32 ° Piezometric Line: 1



Directory: I:\Projects\11020302(South Shore of Staten Island)\Slope Stability Analysis\Analyses_withNewAlignment\C2_BuriedSeawall_SWL15-6ft_ExGradeEl-3'.gsz

Note:

1. The above results are for Seismic Stability analysis **without** the Organic soil layer

Buried Seawall (Reach A-4)
Slope Stability Case 4 Results
Staten Island, New York

URS
CLIFTON, NEW JERSEY

DR. BY: SK	SCALE: As Shown	PROJ: 11020302
	DATE: September, 2014	FIG NO: 33

ATTACHMENT A – TEST BORING LOGS (USACE)

SS02-4		140339
20.0'	South Shore SI	951280

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS	REMARKS
	1 2	5 7 10 10	S1		Brown, fine to coarse SAND, some fine to coarse Gravel, little Silt (SM)	
	3 4	6 4 3 7	S2		Black-brown, fine to coarse SAND, some fine to coarse Gravel, little Silt (SM)	Debris (glass)
15	5 6	5 5 4 3	S3		Brown, fine to coarse SAND, some Silt, little fine to medium Gravel (SM)	
	7 8	2 2 6 7	S4		Black, fine to coarse SAND, some fine to coarse Gravel, little Silt (SP)	
10	9 10	4 3 2 2	S5		Brown, fine-coarse SAND, some Clayey Silt, little fine to medium Gravel (SM)	
	11 12	2 3 5 4	S6		Brown, fine to coarse SAND, some Silt, little fine to medium Gravel (SP-SW)	
	13 14					
5	15 16	6 6 6 8	S7		Brown, Clayey SILT, little fine Sand, little fine Gravel (CL)	
	17 18 19					
0	20 21	3 5 6 2	S8		Red-brown, fine to coarse SAND, some fine to coarse Gravel, trace Silt (SP-GP)	
	22 23 24					
-5	25 26	8 6 7 8	S9		Red-brown, fine to coarse SAND, little fine to coarse Gravel, trace Silt (SP)	
	27 28	8 7 8 10	S10			TD = -29'
	29					
-10	30 31 32 33					

DEPTH	USCS	%G	%S	%F	LL	PL	PI	%H2O	SG	UnitWt
4-6'	SM	28	53	19				4.6	2.64	89.6
15-17'	SM	19	51	30				23.7		63.8

SS02-5		139575
8.0'	South Shore SI	951641

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS	REMARKS
	1	2 4	S1		Brown, fine to coarse SAND, some Silt, trace fine Gravel (SM)	
	2	8 10				
5	3	9 11	ⓈS2		Red-brown, fine-coarse SAND, some fine-med Gravel, little Silt (SM)	
	4	8 7				
	5	4 3	S3		Brown, fine to coarse SAND, some fine-med Gravel, little Silt (SW-SM)	
	6	3 3				
	7	1 1	S4		Black, Silty CLAY (CL)	Roots
0	8	1 1				
	9		U			
	10		T			
	11	3 3	S5		Red-brown, fine to coarse SAND, some fine to coarse Gravel, little Silt (SP)	
	12	4 3				
-5	13					
	14					
	15					
	16	4 5	S6			
	17	10 9				
-10	18					
	19					
	20					
	21	2 4	S7		Red-brown, fine to coarse SAND, some Silt, trace fine Gravel (SM)	
	22	3 3				
-15	23					
	24					
	25					
	26	3 3	S8			
	27	8 7				
-20	28					
	29	5 8	S9			
	30	11 16				TD = -22'
	31					
	32					
-25	33					

DEPTH	USCS	%G	%S	%F	LL	PL	PI	%H2O	SG	UnitWt
2-4'	SW-SM	33	59	8				6.5		
8-10'	CL-ML				23	18	5			108.1

SS02-6	139461

10.0'	South Shore SI	952130

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	CLASSIFICATION OF MATERIALS	REMARKS
	1	5 5 8 13	S1	Brown, fine to coarse SAND, some Silt (SM)	Top Soil
	2				
	3	25 19 14 8	S2		
	4				No Recovery
5	5	5 3 3 4	S3		
	6				
	7	13 7 5 4	S4	Brown, fine to coarse SAND, some Clayey Silt, trace fine Gravel (SM)	
	8				
	9	4 3 3 4	S5		
0	10				
	11	WOH 1 1 1	S6	Brown, fine to coarse SAND, little Silt, trace fine Gravel (SM)	
	12				
	13	1 1 1	S7		Peat on rotor bit
	14				
-5	15				
	16				
	17				
	18		U		
	19		T		Shelby Tube (No Recovery)
-10	20				
	21	2 10 11 12	⑧ S8	Brown, fine to coarse SAND, little fine Gravel, little Silt (SP-SM)	
	22				
	23				
	24				
-15	25				
	26	5 8 9 7	S9		
	27				
	28				
	29	3 9 9 11	S10		
-20	30				TD --30'
	31				
	32				

DEPTH	USCS	%G	%S	%F	LL	PL	PI	%H2O	SG	UnitWt
20-22'	SP-SM	11	83	6				18.0		

SS02-7

139500

8.0'

South Shore SI

952636

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS	REMARKS
	1	3 4	S1		Brown, Clayey SILT, some fine to medium Sand (CL-ML)	Roots
	2	5 3				
5	3	7 3	S2		Brown, Clayey SILT, some fine to med Sand, little fine Gravel (SM)	
	4	3 2				
	5	3 4	S3		Brown, fine to coarse SAND, some Silt, little fine-med Gravel (SM)	
	6	4 5				
	7	3 3	S4		Gray-brown, fine to coarse SAND, some Silt, trace fine Gravel (SM)	
0	8	2 4				
	9	5 7	S5		Red-brown, fine to coarse SAND, little Silt, little fine to medium Gravel (SM-SP)	
	10	7 8				
	11	2 4	S6			
	12	3 4				
-5	13					
	14					
	15					
	16	3 3	S7			
	17	5 5				
-10	18					
	19					
	20					
	21	1 2	ⓈS8			
	22	2 3				
-15	23					
	24					
	25					
	26	3 5	S9		Red-brown, fine to coarse SAND, little Silt (SM-SP)	
	27	6 7				
-20	28	4 4	S10			
	29	5 4				TD - -21'
	30					
	31					
	32					
-25	33					

DEPTH	USCS	%G	%S	%F	LL	PL	PI	%H2O	SG	UnitWt
20-22'	SP-SM	3	92	5				4.2		

SS02-8		141760
6.0'	South Shore SI	955498

ELEVATION	DEPTH	BLOWS/6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS	REMARKS
5	1	1 4 8 12	S1	⁘	Brown, fine to medium SAND, trace Silt (SP)	
	2			⁘		
	3	11 12 17 17	ⓈS2	⁘		
	4			⁘	Brown, fine to coarse SAND, little fine Gravel, trace Silt (SP)	
	5	15 19 23 22	S3	⁘		
0	6			⁘		
	7	12 9 9 10	S4	▥	Gray-black Clayey SILT (OL)	
	8			▥		
	9	4 5 8 10	(S5)	⁘	Gray, fine to coarse SAND, some fine to coarse Gravel, trace Silt (SP-GP)	
	10			⁘		
-5	11	4 6 9 11	S6	⁘	Red-brown, fine to coarse SAND, some fine to medium Gravel, trace Silt (SP-GP)	
	12			⁘		
	13			⁘		
	14			⁘		
	15			⁘	Red-brown, fine to coarse SAND, trace fine Gravel, trace Silt (SP)	
-10	16	5 7 9 10	S7	⁘		
	17			⁘		
	18			⁘		
	19			⁘		
	20			⁘	Brown, fine to medium SAND, trace Silt (SP)	
-15	21	5 6 7 8	S8	⁘		
	22			⁘		
	23			⁘		
	24			⁘		
	25			⁘	Red-brown, fine to medium SAND, little fine Gravel, trace Silt (SP)	
-20	26	5 9 13 13	S9	⁘		
	27			⁘		
	28	3 9 12 16	S10	⁘		TD = -23'
	29					
	30					
-25	31					
	32					

DEPTH	USCS	%G	%S	%F	LL	PL	PI	%H2O	SG	UnitWt
2-4'	SW	26	69	5				2.3		
8-10'	SM	45	41	14				15.7		109.8

SS02-9	143132
14.0' South Shore SI	956265

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS	REMARKS
	1	2 3 7 8	S1		Brown, fine to medium SAND, trace Silt (SP)	
	2					
	3	8 10 13 13	S2			
10	4					
	5	15 18 19 26	S3			
	6					
	7	20 23 18 18	S4			
	8					
5	9	7 12 18 15	S5			
	10				Gray-brown, fine to coarse SAND, some fine to coarse Gravel, trace Silt (SP-GP)	
	11	10 32 32 20	S6			
	12					
	13					
0	14					
	15				Red-brown, fine to coarse SAND, some fine to medium Gravel, trace Silt (SP-GP)	
	16	6 8 11 11	⑦ S7			
	17					
	18					
-5	19					
	20				Red-brown, fine SAND, trace Silt (SP)	
	21	6 10 10 12	S8			
	22				Red-brown, fine to medium SAND, trace fine Gravel, trace Silt (SP)	
	23	12 13 14 18	S9			
-10	24					TD - -10'
	25					
	26					
	27					

DEPTH	USCS	%G	%S	%F	LL	PL	PI	%H2O	SG	UnitWt
15-17'	SP-SM	12	82	6				20.4	2.68	102.1

SS02-10		144078
12.0'	South Shore SI	957301

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS	REMARKS
	1	1 3 4 4	S1	∴	Brown, fine to medium SAND, trace Silt (SP)	
10	2	7 10 11 13	S2	∴	Red-brown, fine to coarse SAND, little fine Gravel,trace Silt (SP)	
	3					
	4	8 10 8 10	S3			
	5					
	6	6 6 8 8	S4			
5	7					
	8	6 8 8 12	S5			
	9					
	10	5 8 9 12	S6	∴	Red-brown, fine to medium SAND, trace Silt (SP)	
	11					
0	12					
	13					
	14					
	15	9 11 15 15	S7	∴	Red-brown, fine to coarse SAND, some fine Gravel, trace Silt (SP)	
	16					
-5	17					
	18					
	19					
	20	6 9 10 11	S8	∴	Red-brown, fine to medium SAND, trace Silt (SP)	
	21					
-10	22	7 9 10 10	S9			
	23					
	24					TD = -12'
	25					
	26					
-15	27					
	28					

DEPTH	USCS	%G	%S	%F	LL	PL	PI	%H2O	SG	UnitWt
2-4'	SM	24	62	14				9.7		

SS02-11		144545
10.0'	South Shore SI	957784

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS	REMARKS
	1	2 6	S1	⁘	Brown, fine to medium SAND, trace Silt (SP)	
	2	12 12		⁘		
	3	9 9	ⓈS2	⁘		
	4	12 13		⁘		
5	5	9 12	S3	⁘		
	6	12 12		⁘		
	7	11 12	S4	⁘	Brown, fine to coarse SAND, trace Silt (SP)	
	8	12 15		⁘		
	9	10 12	S5	⁘	Brown, fine to coarse SAND, little fine Gravel, trace Silt (SP)	
0	10	12 13		⁘		
	11	9 10	S6	⁘		
	12	10 12		⁘		
	13			⁘		
	14			⁘		
-5	15			⁘		
	16	7 10	S7	⁘	Brown, fine SAND, trace Silt (SP)	
	17	13 15		⁘		
	18			⁘		
	19			⁘		
-10	20			⁘		
	21	10 11	S8	⁘		
	22	11 14		⁘		
	23			⁘		
	24			⁘		
-15	25			⁘		
	26	8 12	Ⓢ9	⁘	Brown, fine to coarse SAND, little fine to medium Gravel, trace Silt (SP)	
	27	17 17		⁘		
	28	8 11	S10	⁘		
	29	15 15		⁘		TD = -19'
-20	30					
	31					
	32					

DEPTH	USCS	%G	%S	%F	LL	PL	PI	%H2O	SG	UnitWt
2-4'	SP-SW	6	85	9				49.8	2.70	93.3
25-27'	SP-SM	19	74	7				17.1		

SS02-12		145244
11.0'	South Shore SI	958431

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS	REMARKS
10	1	2 2 6 8	S1	∴	Brown, fine to medium SAND, trace Silt (SP)	
	2			∴		
	3	6 8 12 16	S2	∴		
	4			∴		
	5	9 11 11 12	S3	∴		
5	6			∴		
	7	8 12 17 21	ⓢ S4	∴		
	8			∴		
	9	14 17 20 20	S5	∴		
	10			∴		
0	11	5 12 19 20	S6	∴		
	12			∴		
	13			∴		
	14			∴		
	15	10 19 18 18	S7	∴	Brown, fine SAND, trace fine Gravel, trace Silt (SP)	
-5	16			∴		
	17			∴		
	18			∴		
	19			∴		
	20	8 12 12 13	S8	∴	Brown, fine to medium SAND, trace fine Gravel, trace Silt (SP)	
-10	21			∴		
	22	11 14	S9A	∴		
	23	15 17	S9B	∴		
	24					TD = -14'
	25					
-15	26					
	27					
	28					
	29					
	30					

DEPTH	USCS	%G	%S	%F	LL	PL	PI	%H2O	SG	UnitWt
6-8'	SP		98	2				5.8	2.68	104.1

SS02-13

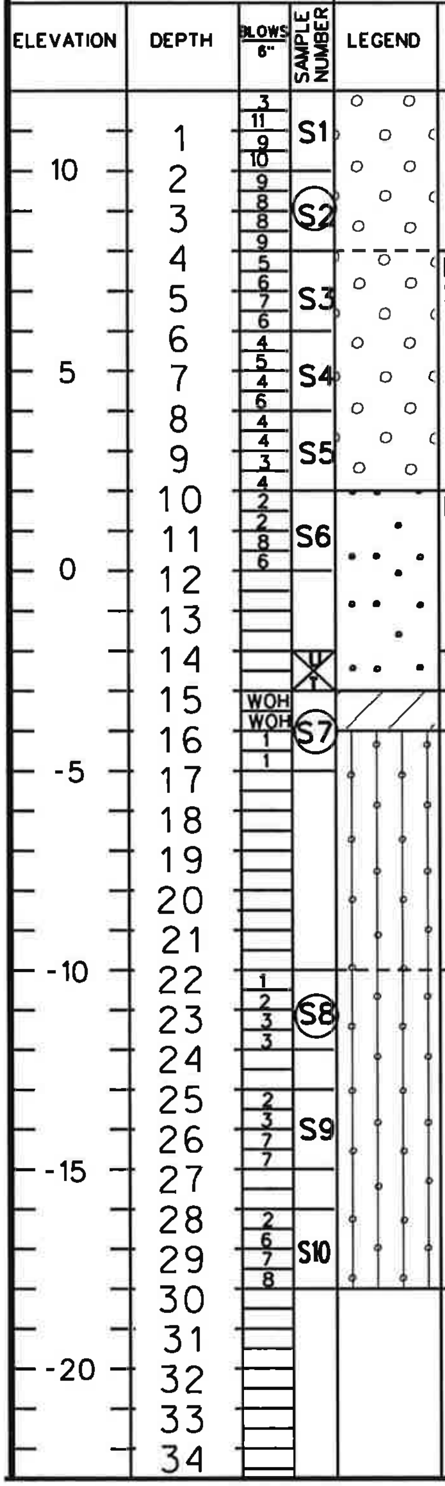
147153

12.0'

South Shore SI

959647

ELEVATION | DEPTH | BLOWS/6" | SAMPLE NUMBER | LEGEND | CLASSIFICATION OF MATERIALS | REMARKS



Red, fine to coarse SAND, little fine Gravel, trace Silt (SW)

Top Soil & Fill

Brown, fine to coarse SAND, trace Silt (SW)

Red-brown, fine to coarse SAND, some fine to medium Gravel, trace Silt (SP-GP)

No Recovery

Silty CLAY, some fine to coarse Sand (CL-SC)

Fine to coarse SAND, some Silt, little fine Gravel (SM)

Brown, fine to coarse SAND, little Silt, trace fine Gravel (SM)

TD = -18'

DEPTH	USCS	%G	%S	%F	LL	PL	PI	%H20	SG	UnitWt
2-4'	SP	2	95	3				5.0		
15-17'	SW-SM	26	62	12	25	21	4	24.7		92.9
22-24'	SP-SM	1	89	10				25.5	2.68	97.4

SS02-14		148917
11.0'	South Shore SI	961615

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS	REMARKS
10	1 2	2 2 5 7	S1		Clayey SILT (ML) Red-brown, fine to coarse SAND, little Silt, little fine Gravel (SM)	Top Soil
	3 4	8 8 3 5	S2		Red-brown, fine to coarse SAND, little fine to medium Gravel, trace Silt (SP)	
5	5 6	3 6 5 4	S3			
	7 8	4 3 3 4	S4			
	9 10	3 2 4 3	S5			
0	11 12	2 2 3 4	S6			
	13 14					
-5	15 16 17	1 2 2 4	S7		Gray SILT (ML)	
	18 19					
-10	20 21 22		U T		No Recovery	
	23 24		U T			
-15	25 26	1 3 3 4	S8		Red-brown, fine to medium SAND, some Silt, little fine to medium Gravel (SM)	
	27 28	3 4 6 5	S9			
	29					TD = -18'
-20	30 31 32 33 34 35					

DEPTH	USCS	%G	%S	%F	LL	PL	PI	%H2O	SG	UnitWt
15-17'	SM		79	21				25.1		

SS02-15		151395
11.0'	South Shore SI	963919

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS	REMARKS
10	1	3 7	S1	○	Brown, fine to coarse SAND, trace Silt (SW)	
	2	9 11		○		
	3	11 11	S2	○	Brown, fine to coarse SAND, little fine Gravel, trace Silt(SW)	
	4	12 13		○		
	5	10 9	ⓈS3	○	Brown, fine to coarse SAND, little fine-medium Gravel, trace Silt (SW)	
5	6	9 10		○		
	7	9 10	S4	○	Brown, fine to medium SAND, trace fine Gravel, trace Silt (SW)	
	8	10 12		○		
	9	6 8	S5	○	Brown, fine to medium SAND, little fine Gravel, trace Silt (SW)	
	10	8 9		○		
0	11	5 5	S6	○	Brown, fine to medium SAND, trace Silt (SW)	
	12	6 8		○		
	13			○		
	14			○		
	15			○		
-5	16	2 10	S7	•	Gray, fine SAND, trace fine Gravel, trace Silt (SP)	
	17	15 16		•		
	18			•		
	19			•		
	20			•		
-10	21	15 11	S8	•	Gray, fine SAND, trace Silt (SP)	
	22	15 16		•		
	23			•		
	24			•		
	25			•		
-15	26	5 3	S9	▨	Gray, Silty CLAY (CL)	
	27	3 5		▨		
	28	3 4	S10	▨		
	29	5 6		▨		TD= -18'
	30					
-20	31					
	32					

DEPTH	USCS	%G	%S	%F	LL	PL	PI	%H20	SG	UnitWt
4-6'	SW	40	56	4				3.8	2.64	79.5
25-27'	CL		35	65	25			36.0		107.4

SS02-16	153816
8.0' South Shore SI	965838

ELEVATION	DEPTH	BLOWS/6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS	REMARKS
	1	1 3	Ⓢ1		Brown, fine to medium SAND, trace Silt (SP)	
	2	7 12				
5	3	9 8	S2			
	4	11 12				
	5	8 8	S3			
	6	8 9				
	7	7 6	S4			
0	8	5 5				
	9	5 6	S5			
	10	6 8				
	11	3 8	S6		Gray-brown, fine to coarse SAND, trace Silt (SP)	
	12	17 26				
-5	13					
	14					
	15					
	16	9 12	S7		Gray-brown, fine to medium SAND, trace Silt (SP)	
	17	11 13				
-10	18					
	19					
	20					
	21	10 10	Ⓢ8		Gray-brown, fine to coarse SAND and fine to coarse GRAVEL, trace Silt (GW)	
	22	6 20				
-15	23					
	24					
	25					
	26	13 13	S9		Red-brown, fine SAND, trace Silt (SP)	
	27	13 16				
-20	28	15 20	S10			
	29	22 25				TD - -21'
	30					
	31					
	32					

DEPTH	USCS	%G	%S	%F	LL	PL	PI	%H2O	SG	UnitWt
0-2'	SW	3	93	4				4.2	2.68	104.5
20-22'	GW	67	32	1				13.5		

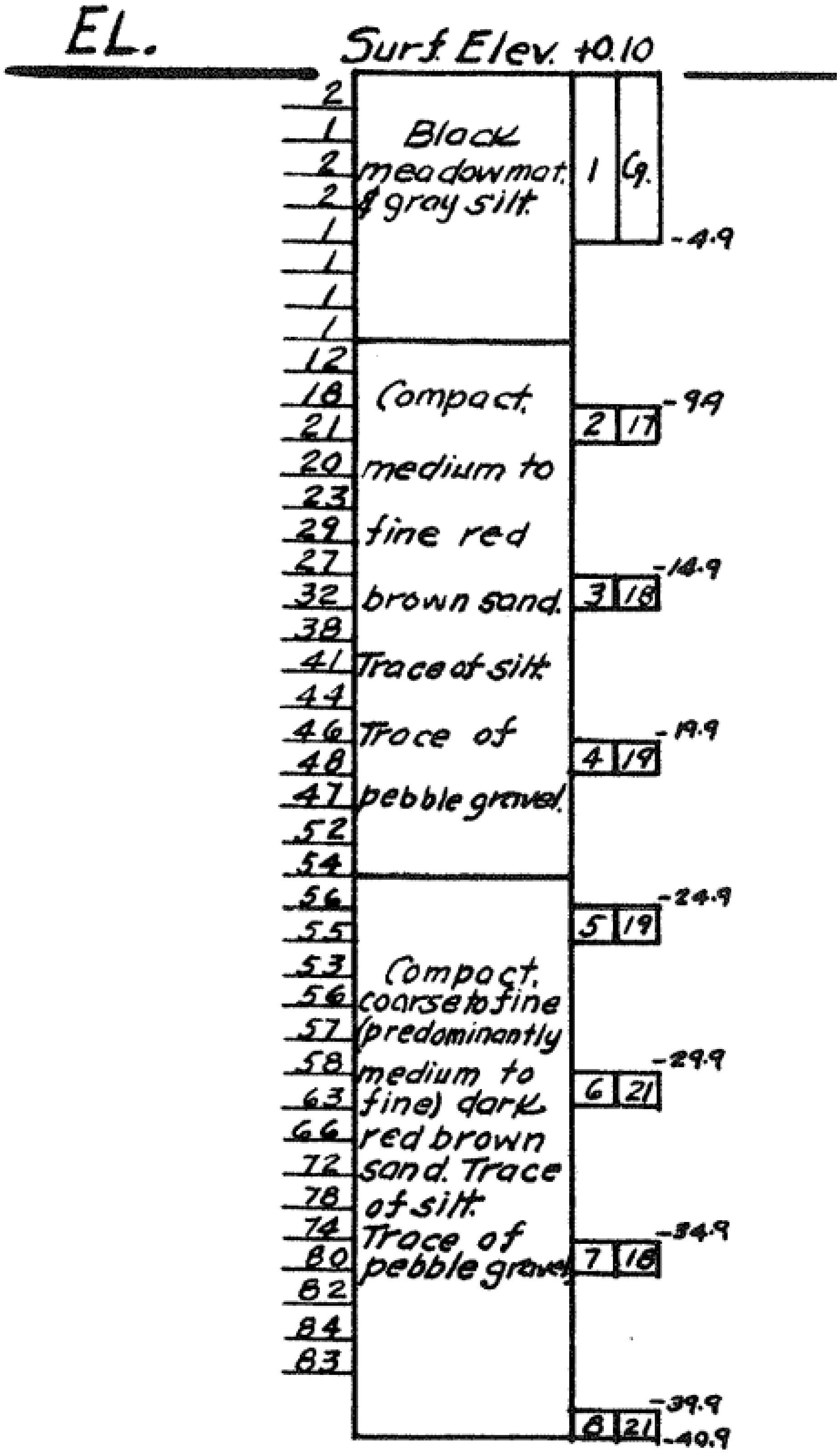
SS02-17		155794
8.0'	South Shore SI	967367

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS	REMARKS
	1	1 2 3 6	S1		Brown, fine to medium SAND, little Clayey Silt (SP-SM)	Roots
	2					
5	3	4 5 9 14	S2		Brown, fine to medium SAND, trace Silt (SP)	
	4					
	5	15 18 20 28	S3			
	6					
	7	10 14 20 20	S4			
0	8					
	9	7 9 4 3	S5		Red-brown, fine to coarse SAND, little f. Gravel, trace Silt (SW)	
	10					
	11	5 8 14 18	⑥ S6		Gray, fine to coarse SAND, little fine Gravel, trace Silt (SW)	
	12					
-5	13					
	14					
	15					
	16	10 20 13 13	S7		Red-brown, fine SAND, little Silt (SP-SM)	
	17					
-10	18					
	19					
	20					
	21	15 28 32 32	S8		Red-brown, fine to medium SAND, trace Silt (SP)	
	22					
-15	23	20 25 29 34	S9		Red-brown, fine to coarse SAND, trace Silt (SP)	
	24					TD = -16'
	25					
	26					
	27					

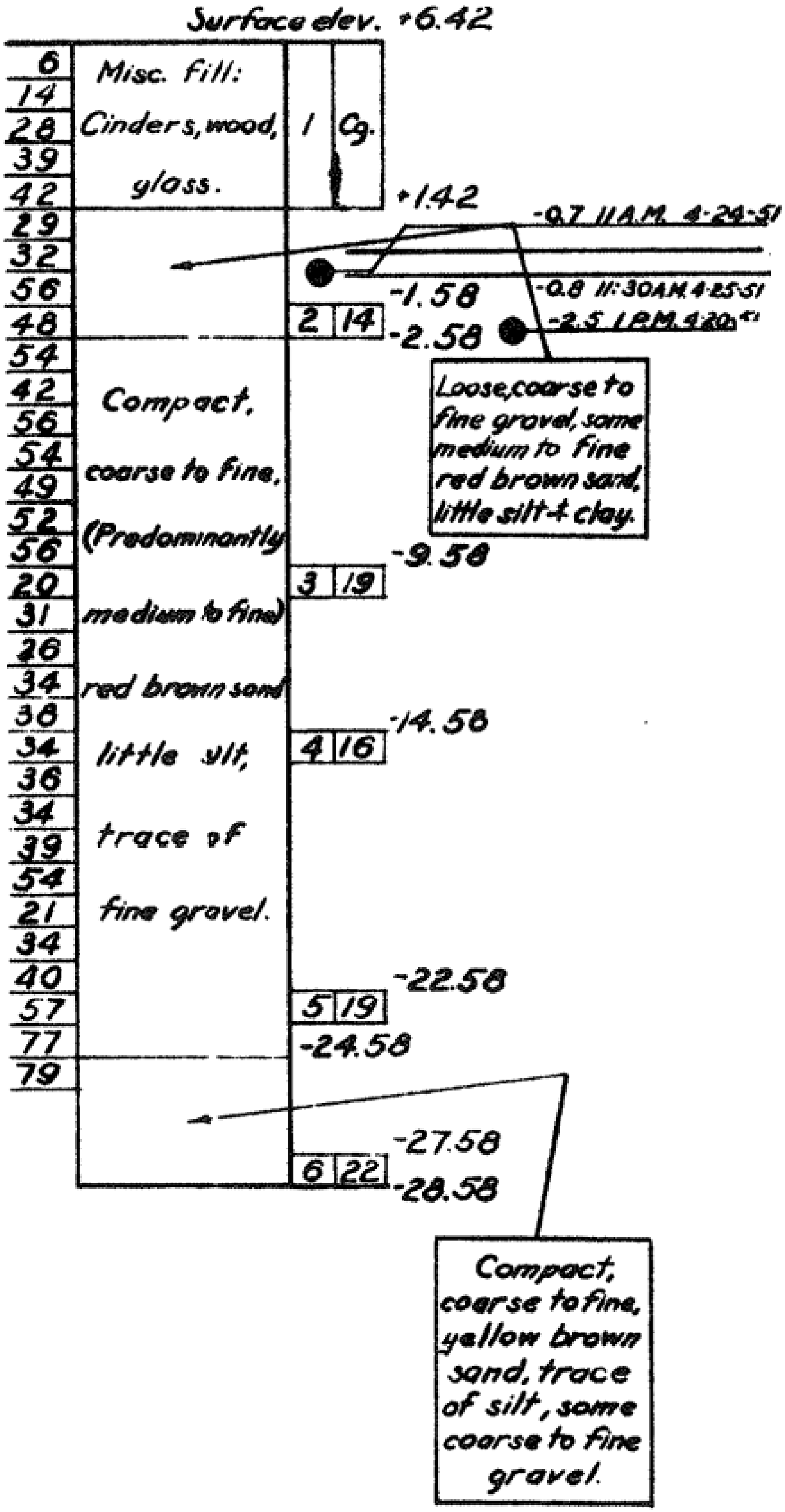
DEPTH	USCS	%G	%S	%F	LL	PL	PI	%H2O	SG	UnitWt
10-12'	SP-SM	2	92	6				20.2	2.69	100.2

ATTACHMENT B – TEST BORING LOGS (NYCDEP)

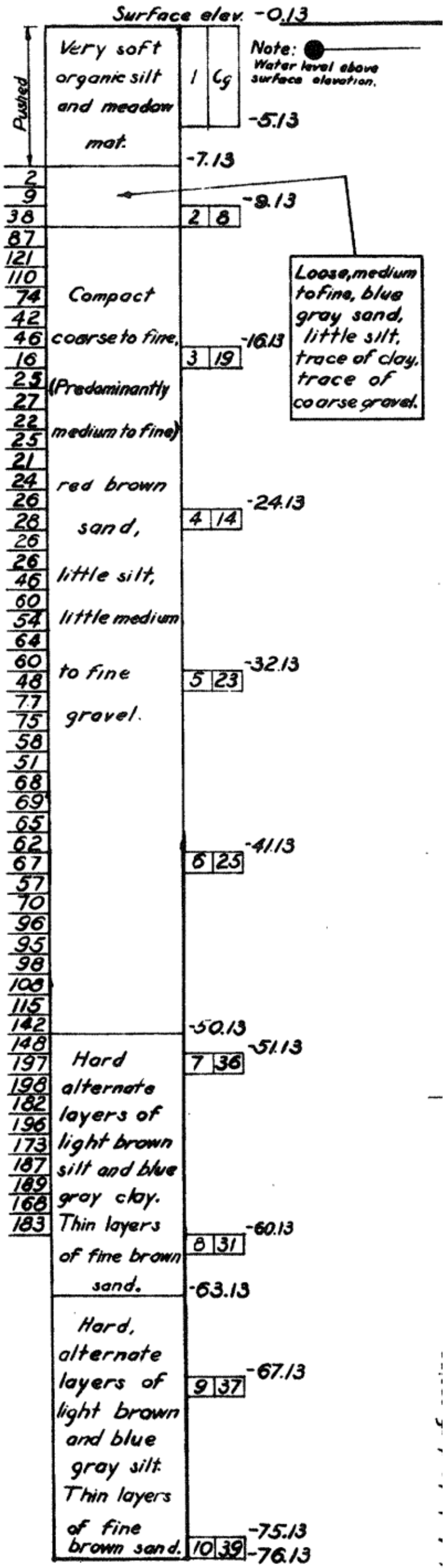
Boring A


EL.
Surf. Elev. +0.10
2
1
2
2
1
1
1
1
Black meadowmat. & gray silt.
1
Cg.
-4.9
12
18
21
20
23
29
27
32
38
41
44
46
48
47
52
54
Compact. medium to fine red brown sand. Trace of silt. Trace of pebble gravel.
2
17
-9.9
3
18
-14.9
4
19
-19.9
56
55
53
56
57
58
63
66
72
78
74
80
82
84
83
Compact. coarse to fine (predominantly medium to fine) dark red brown sand. Trace of silt. Trace of pebble gravel.
5
19
-24.9
6
21
-29.9
7
18
-34.9
8
21
-39.9
-40.9

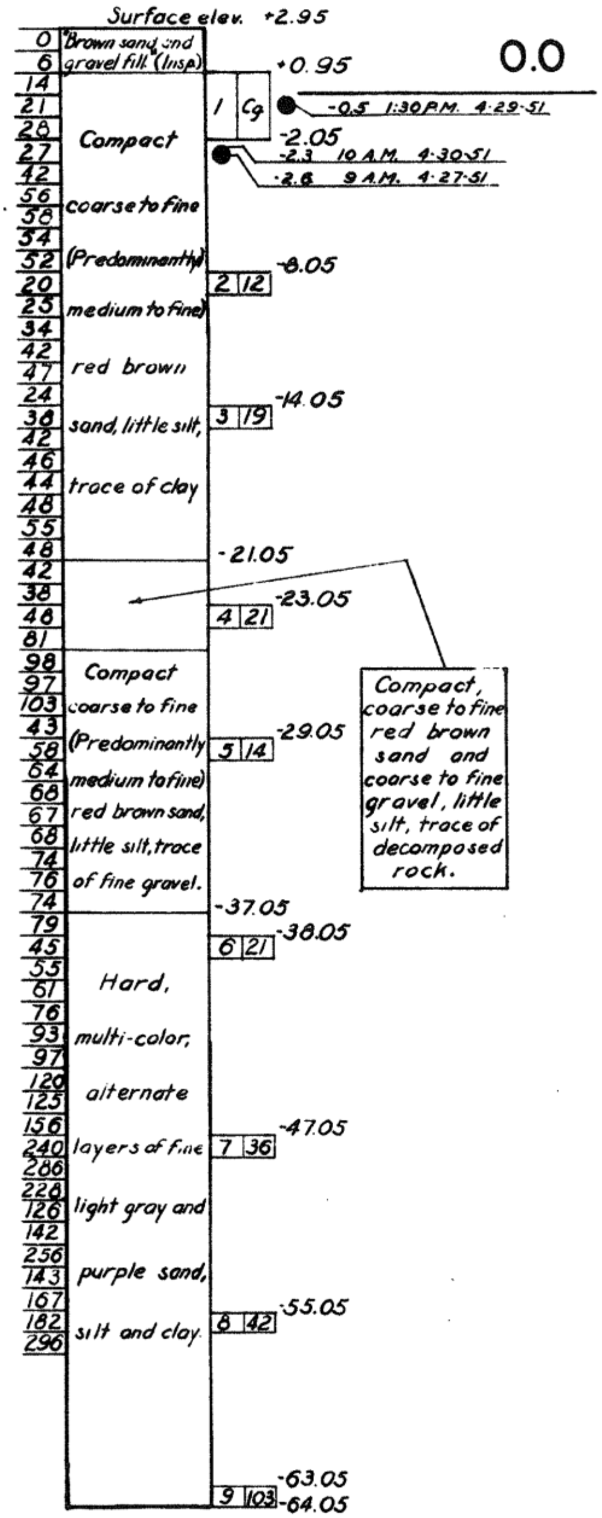
Boring B-2


Surface elev. +6.42
6
14
28
39
42
29
32
56
48
54
42
56
54
49
52
56
20
31
26
34
38
34
36
34
39
54
21
34
40
57
77
79
Misc. fill: Cinders, wood, glass.
1
Cg.
+1.42
-0.7 11 A.M. 4-24-51
-0.8 11:30 A.M. 4-25-51
-2.5 1 P.M. 4-20-51
-1.58
2
14
-2.58
Loose, coarse to fine gravel, some medium to fine red brown sand, little silt + clay.
Compact, coarse to fine, (Predominantly medium to fine) red brown sand little silt, trace of fine gravel.
-9.58
3
19
-14.58
4
16
-22.58
5
19
-24.58
-27.58
6
22
-28.58
Compact, coarse to fine, yellow brown sand, trace of silt, some coarse to fine gravel.

Boring B-3

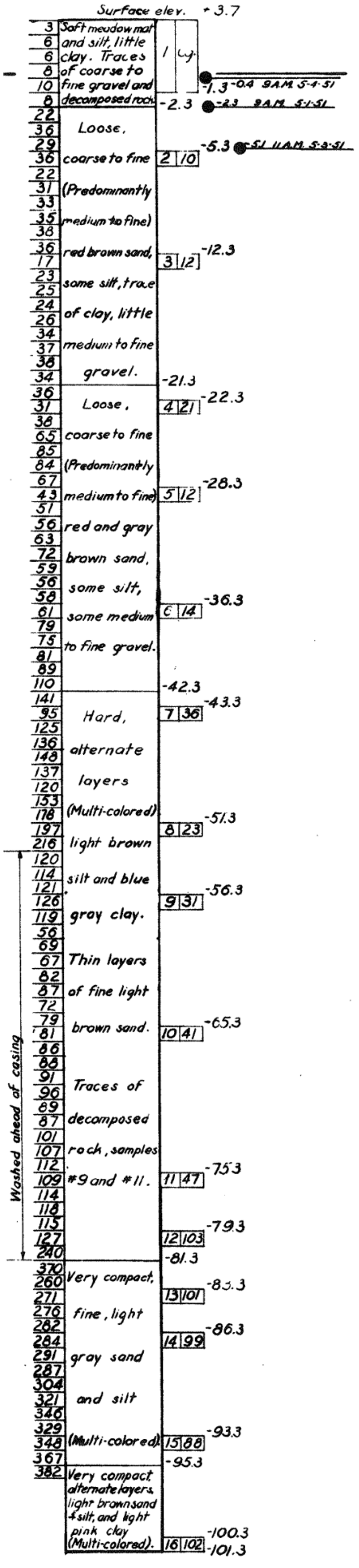

Surface elev. -0.13
Note: ● Water level above surface elevation.
Pushed
Very soft organic silt and meadow mat.
1 Cg
-5.13
-7.13
2
9
38
2 8
-9.13
Loose, medium to fine, blue gray sand, little silt, trace of clay, trace of coarse gravel.
87
121
110
74
42
46
16
23
27
22
25
21
24
26
28
26
26
46
60
54
64
60
48
77
75
58
51
68
69
65
62
67
57
70
96
95
98
108
115
142
Compact coarse to fine, (Predominantly medium to fine) red brown sand, little silt, little medium to fine gravel.
3 19
-16.13
4 14
-24.13
5 23
-32.13
6 25
-41.13
-50.13
148
197
198
182
196
173
187
189
168
183
Hard alternate layers of light brown silt and blue gray clay. Thin layers of fine brown sand.
7 36
-51.13
8 31
-60.13
-63.13
Hard, alternate layers of light brown and blue gray silt. Thin layers of fine brown sand.
9 37
-67.13
10 39
-75.13
-76.13

Boring B-4

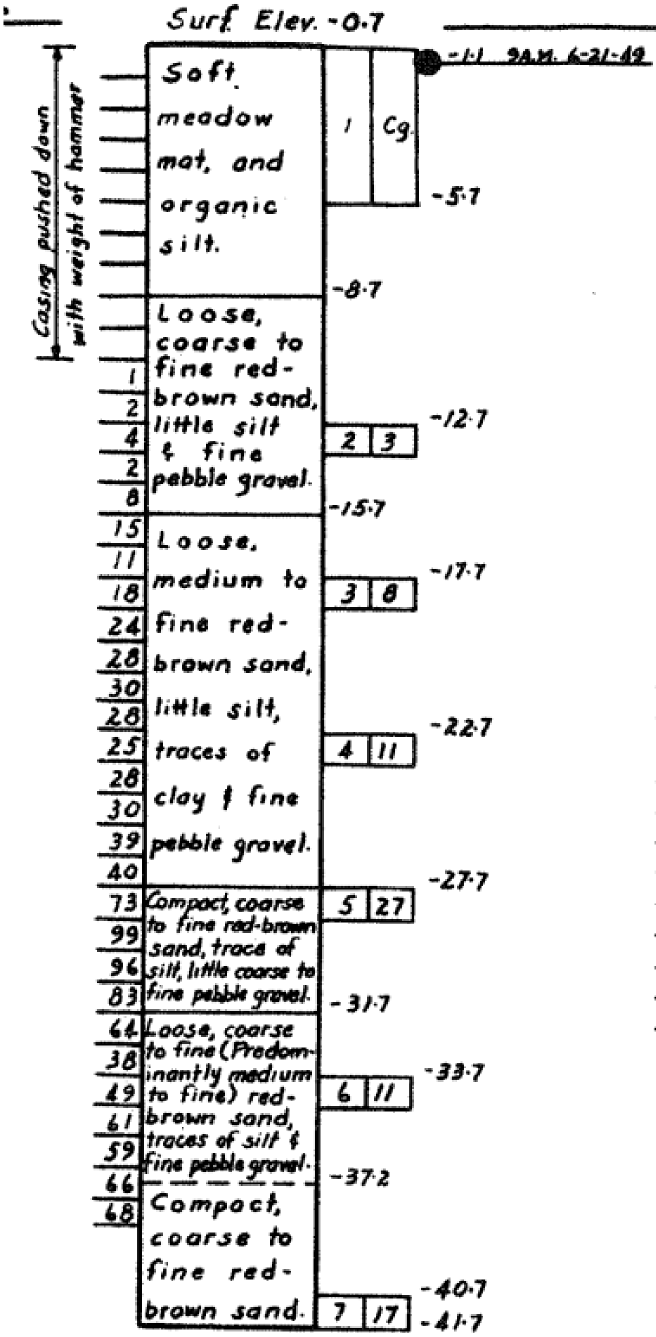


Surface elev. +2.95
0.0
+0.95
-0.5 1:30 P.M. 4-29-51
-2.05
-2.3 10 A.M. 4-30-51
-2.6 9 A.M. 4-27-51
Brown sand and gravel fill (Insp)
1 Cg
Compact coarse to fine (Predominantly medium to fine) red brown sand, little silt, trace of clay
2 12
-8.05
3 19
-14.05
-21.05
4 21
-23.05
Compact, coarse to fine red brown sand and coarse to fine gravel, little silt, trace of decomposed rock.
Compact coarse to fine (Predominantly medium to fine) red brown sand, little silt, trace of fine gravel.
5 14
-29.05
-37.05
6 21
-38.05
Hard, multi-color, alternate layers of fine light gray and purple sand, silt and clay.
7 36
-47.05
8 42
-55.05
-63.05
9 103
-64.05
0
6
14
21
28
27
42
56
58
54
52
20
25
34
42
47
24
38
42
46
44
48
55
48
42
38
48
81
98
97
103
43
58
64
68
67
68
74
76
74
79
45
55
61
76
93
97
120
125
156
240
286
228
126
142
256
143
167
182
296

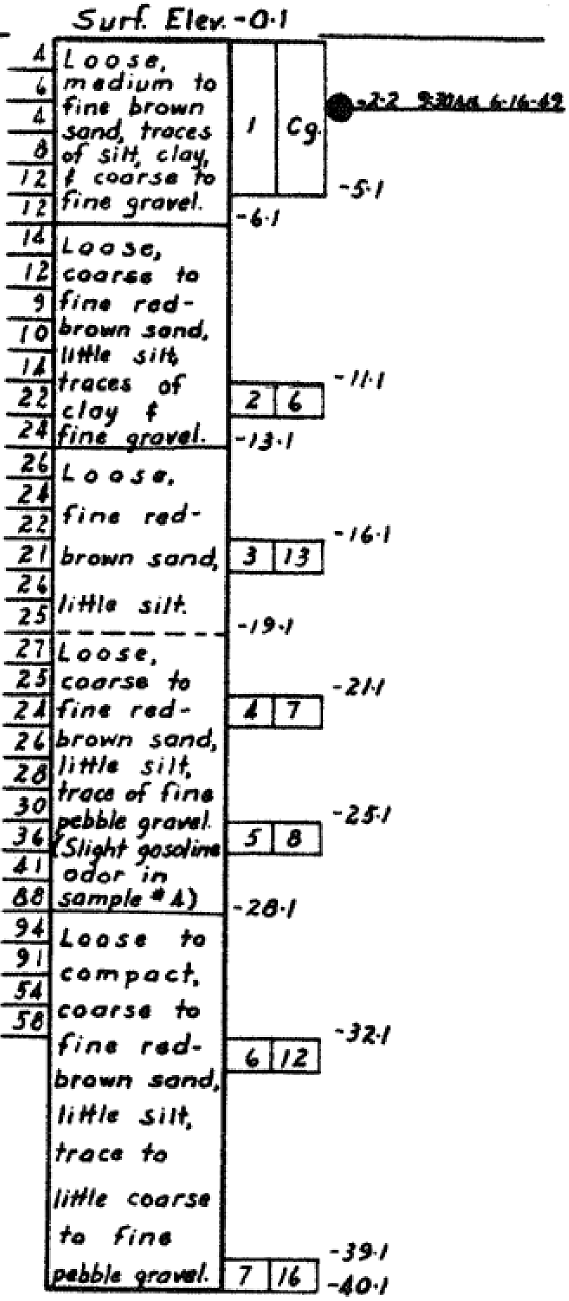
Boring B-5


Surface elev. + 3.7
3
6
6
8
10
8
22
36
29
36
22
31
33
35
38
36
17
23
25
24
26
34
37
38
34
36
31
38
65
85
84
67
43
51
56
63
72
59
56
58
61
79
75
81
89
110
141
95
125
136
148
137
120
153
178
197
216
120
114
121
126
119
56
69
67
82
87
72
79
81
86
88
91
96
89
87
101
107
112
109
114
118
115
127
240
370
260
271
276
282
284
291
287
304
321
346
329
348
367
382
Soft meadow mat and silt, little clay. Traces of coarse to fine gravel and decomposed rock.
1
cy.
-1.3
-0.4 9 A.M. 5-4-51
-2.3
-2.3 9 A.M. 5-1-51
-5.3
-5.1 11 A.M. 5-3-51
Loose, coarse to fine (Predominantly medium to fine) red brown sand, some silt, trace of clay, little medium to fine gravel.
2
10
3
12
-12.3
-21.3
Loose, coarse to fine (Predominantly medium to fine) red and gray brown sand, some silt, some medium to fine gravel.
4
21
-22.3
5
12
-28.3
6
14
-36.3
-42.3
Hard, alternate layers (Multi-colored) light brown silt and blue gray clay. Thin layers of fine light brown sand. Traces of decomposed rock, samples #9 and #11.
7
36
-43.3
8
23
-51.3
9
31
-56.3
10
41
-65.3
11
47
-75.3
12
103
-79.3
-81.3
Washed ahead of casing
Very compact, fine, light gray sand and silt (Multi-colored).
13
101
-83.3
14
99
-86.3
15
88
-93.3
-95.3
Very compact alternate layers, light brown sand & silt, and light pink clay (Multi-colored).
16
102
-100.3
-101.3

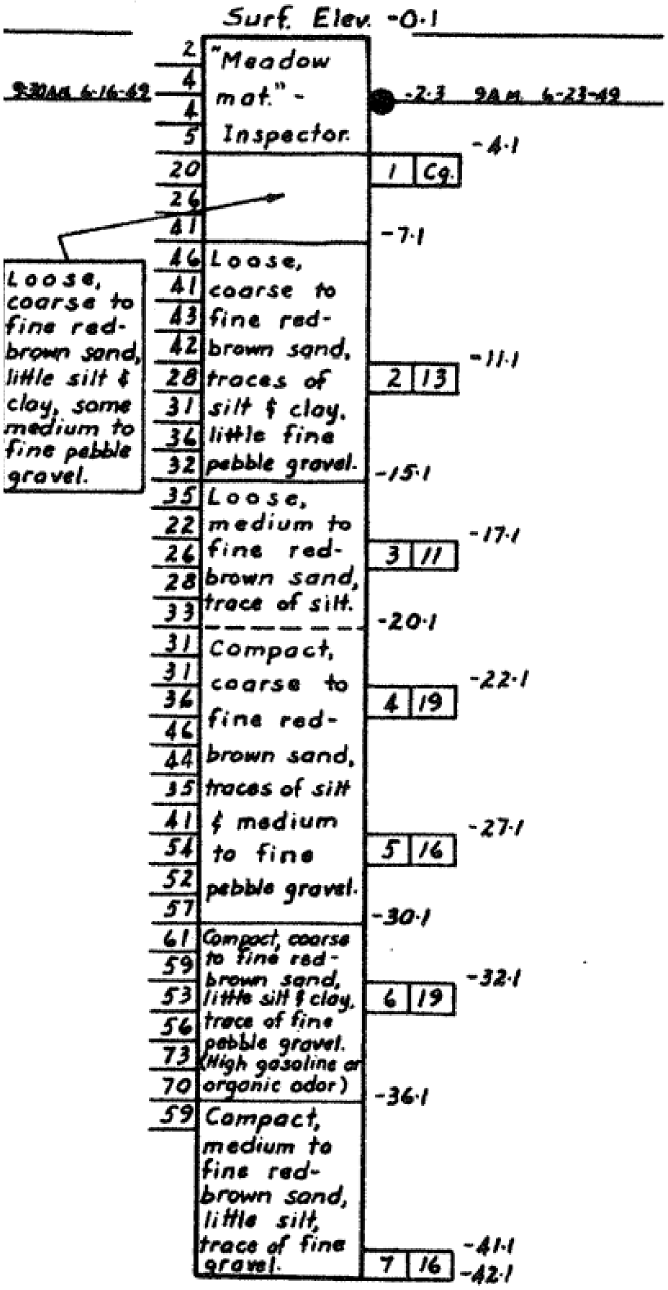
Boring P7



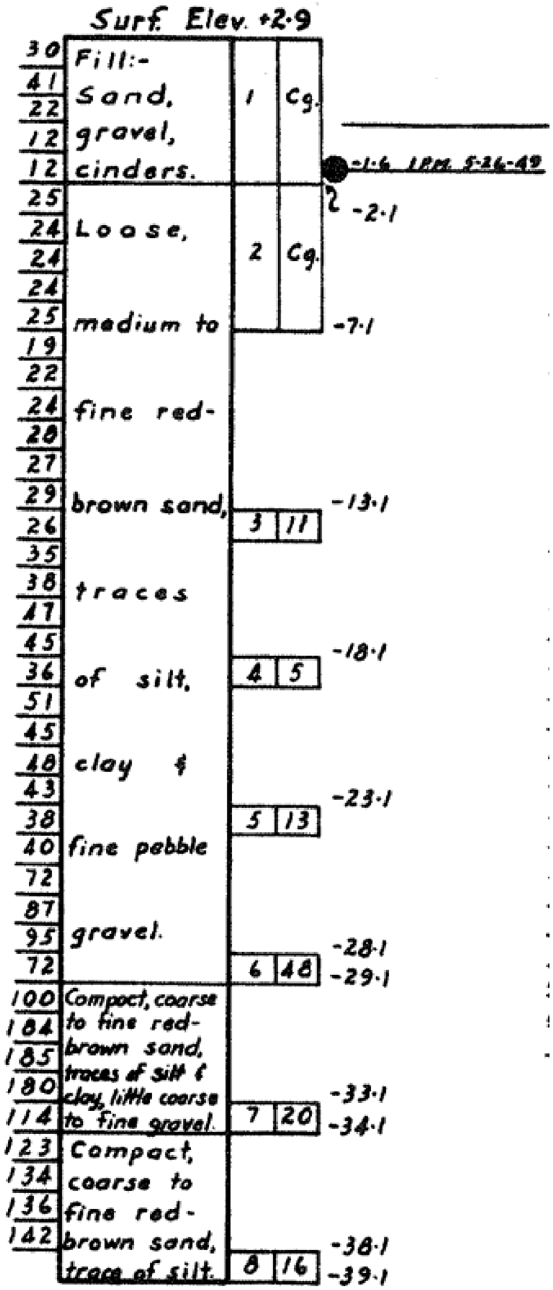
Boring P5



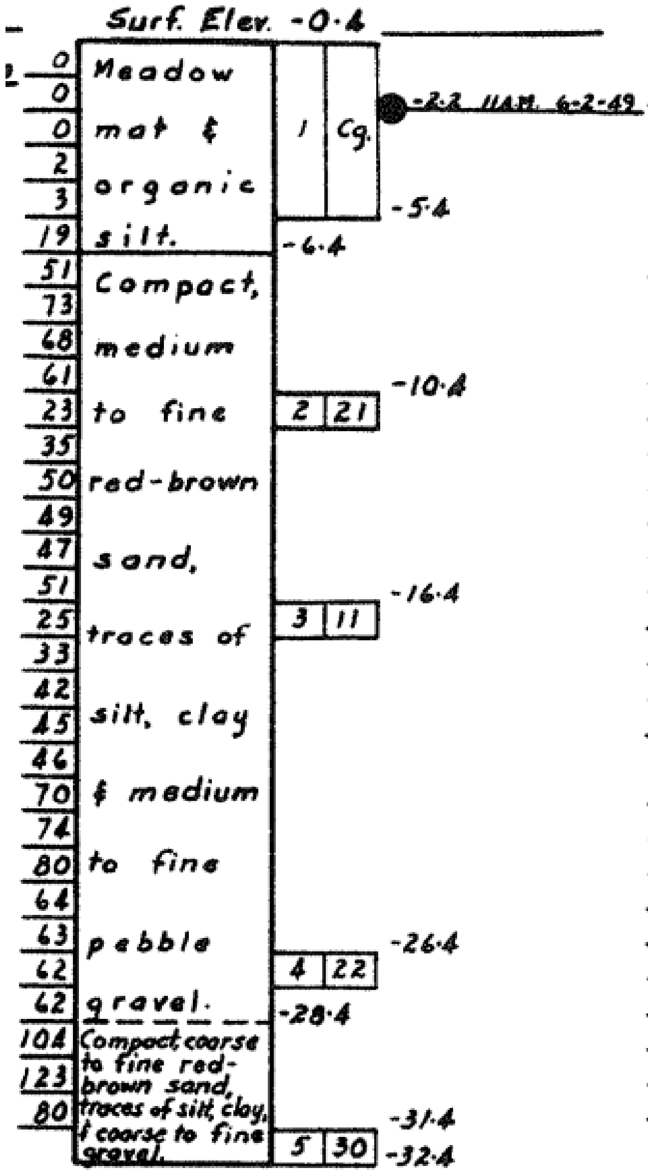
Boring P8



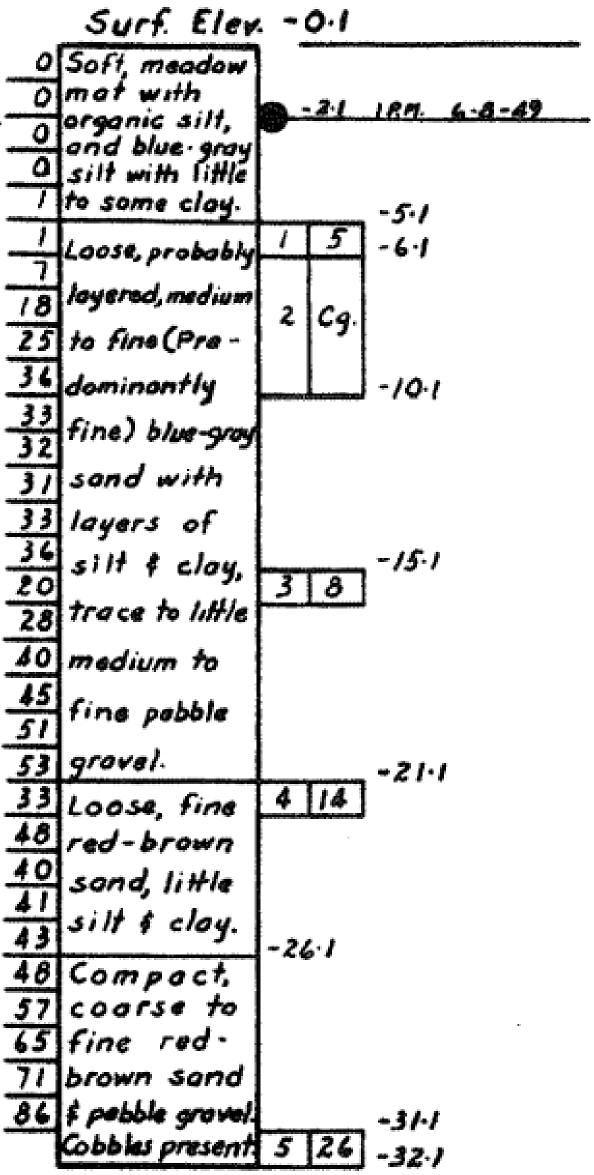
Boring B-29



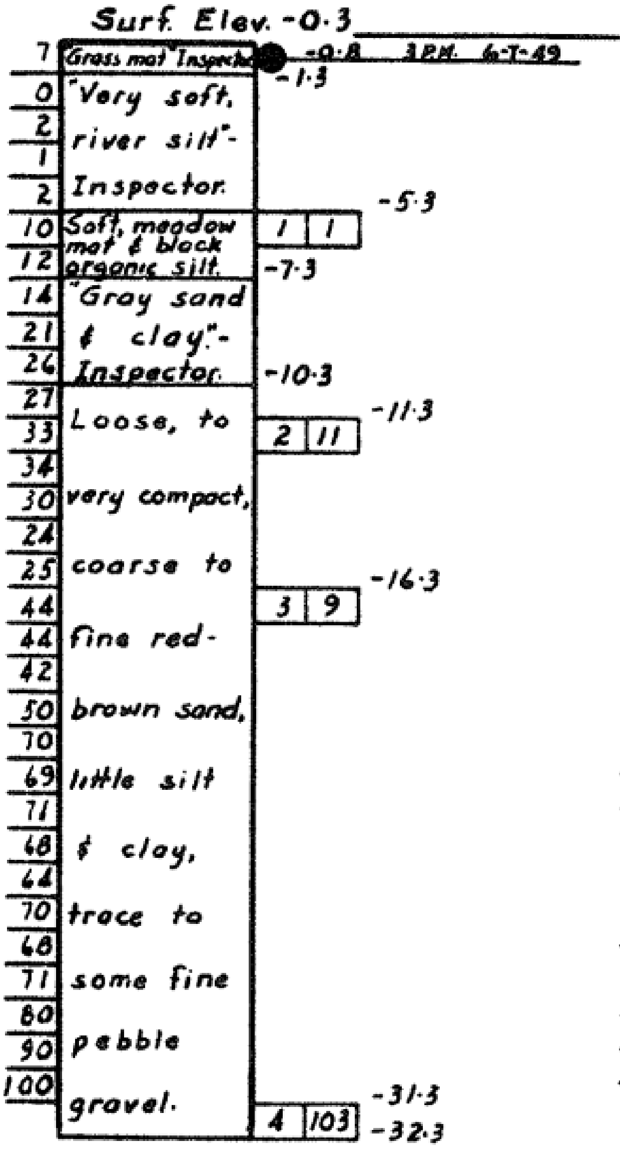
Boring B-28



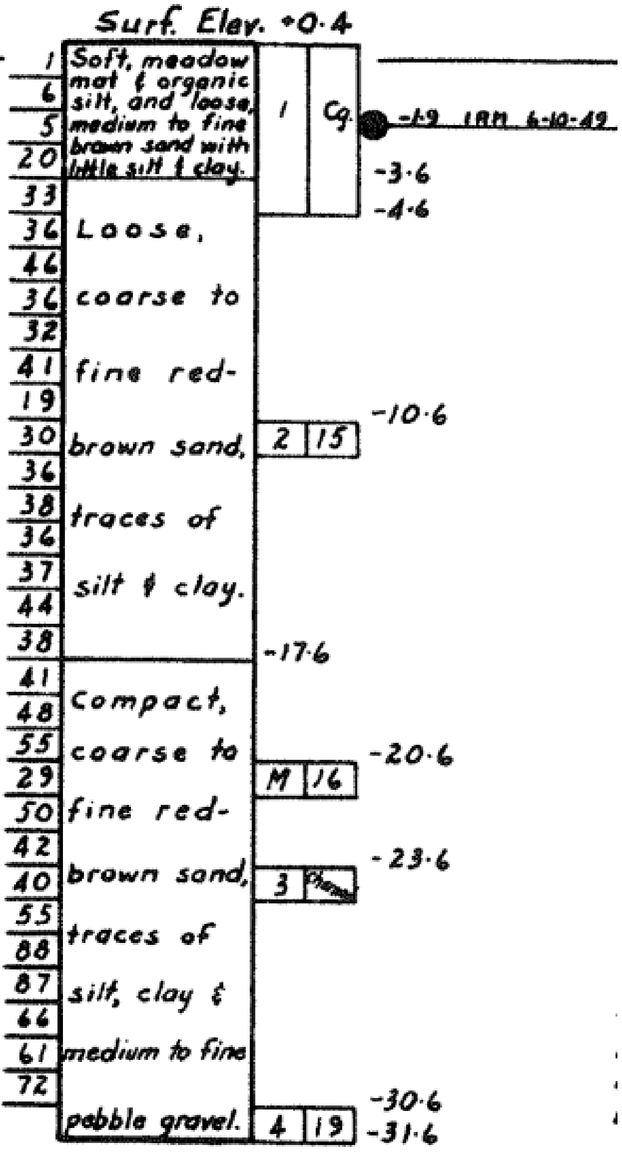
Boring B-27



Boring B-26

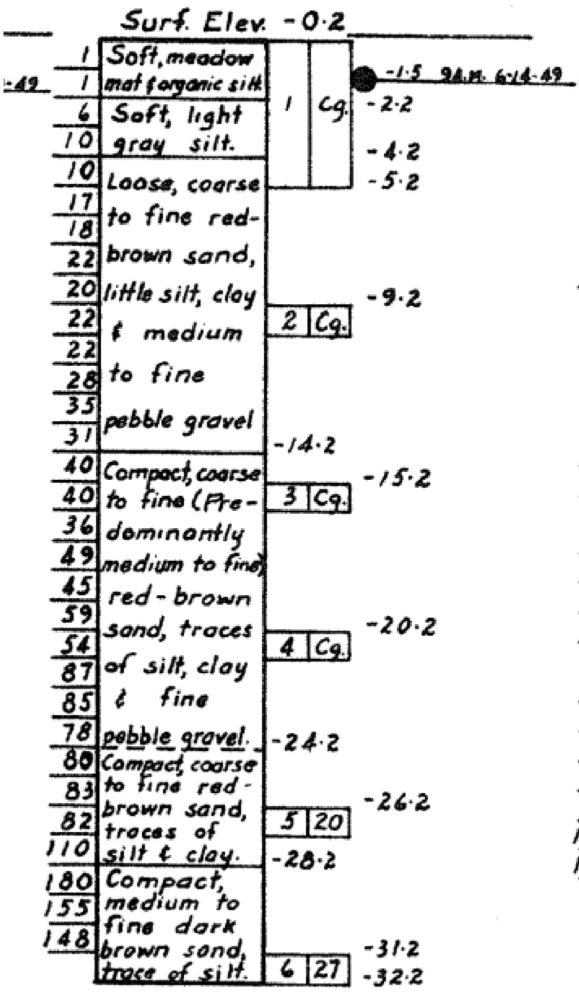


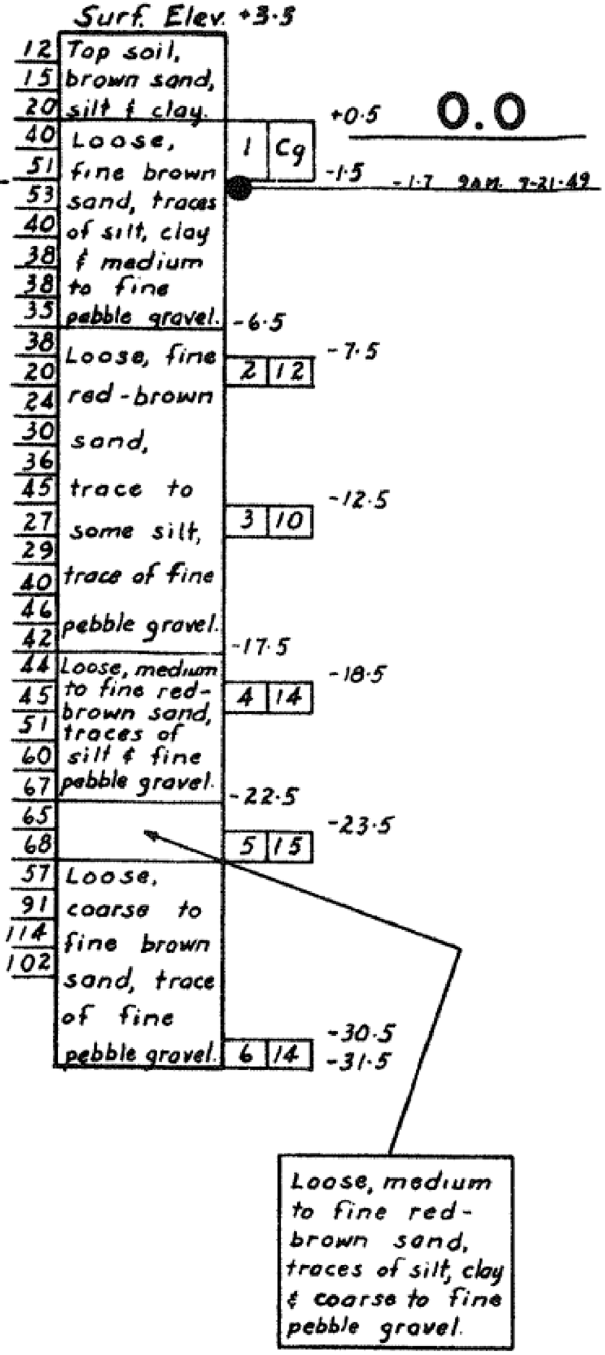
Boring B-25

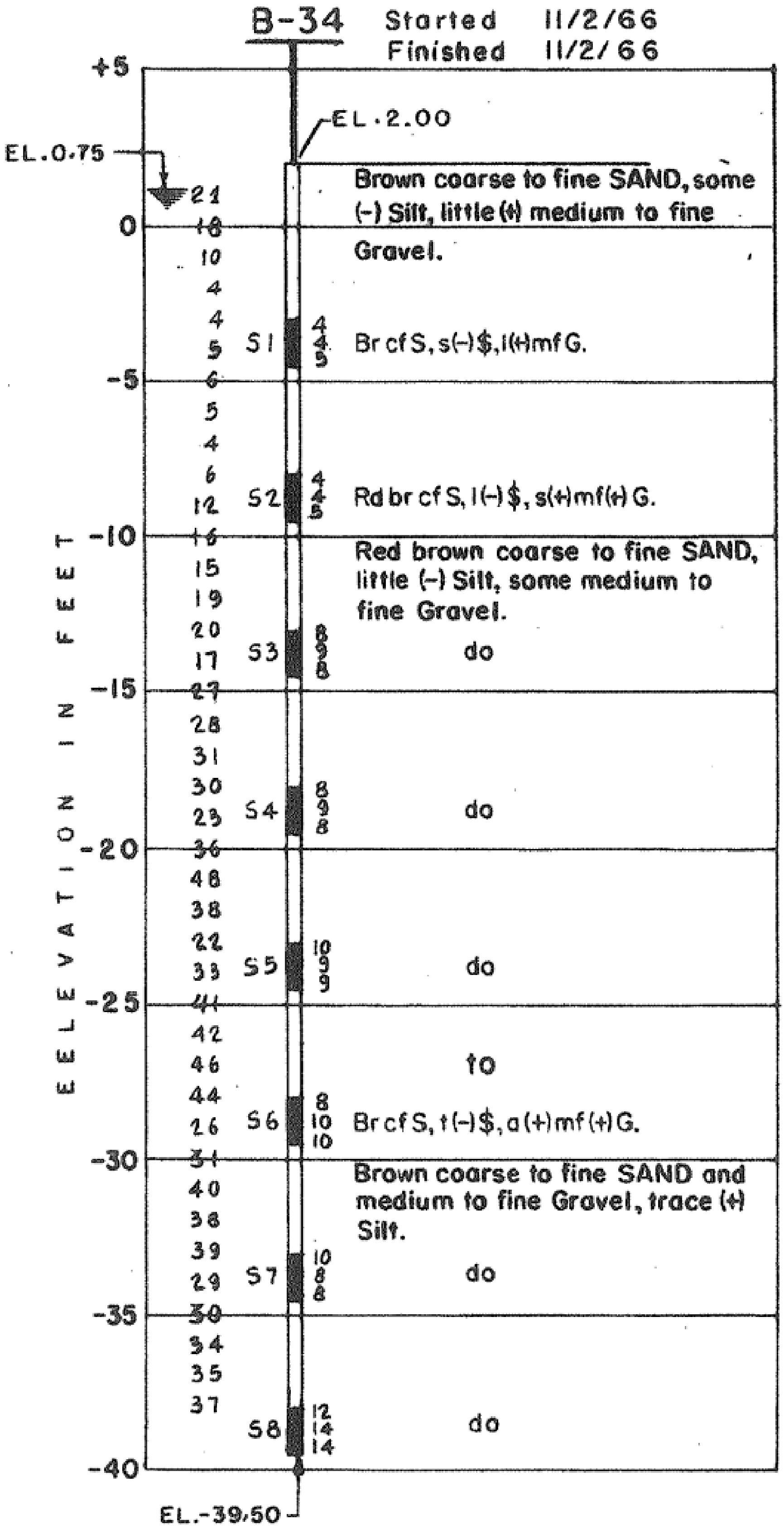


Boring B-24

Boring B-23







Brown coarse to fine SAND, some (-) Silt, little (+) medium to fine Gravel.

Br cf S, s(-)$, l(+)mf G.

Rd br cf S, l(-)$, s(+)mf(+) G.

Red brown coarse to fine SAND, little (-) Silt, some medium to fine Gravel.

do

do

do

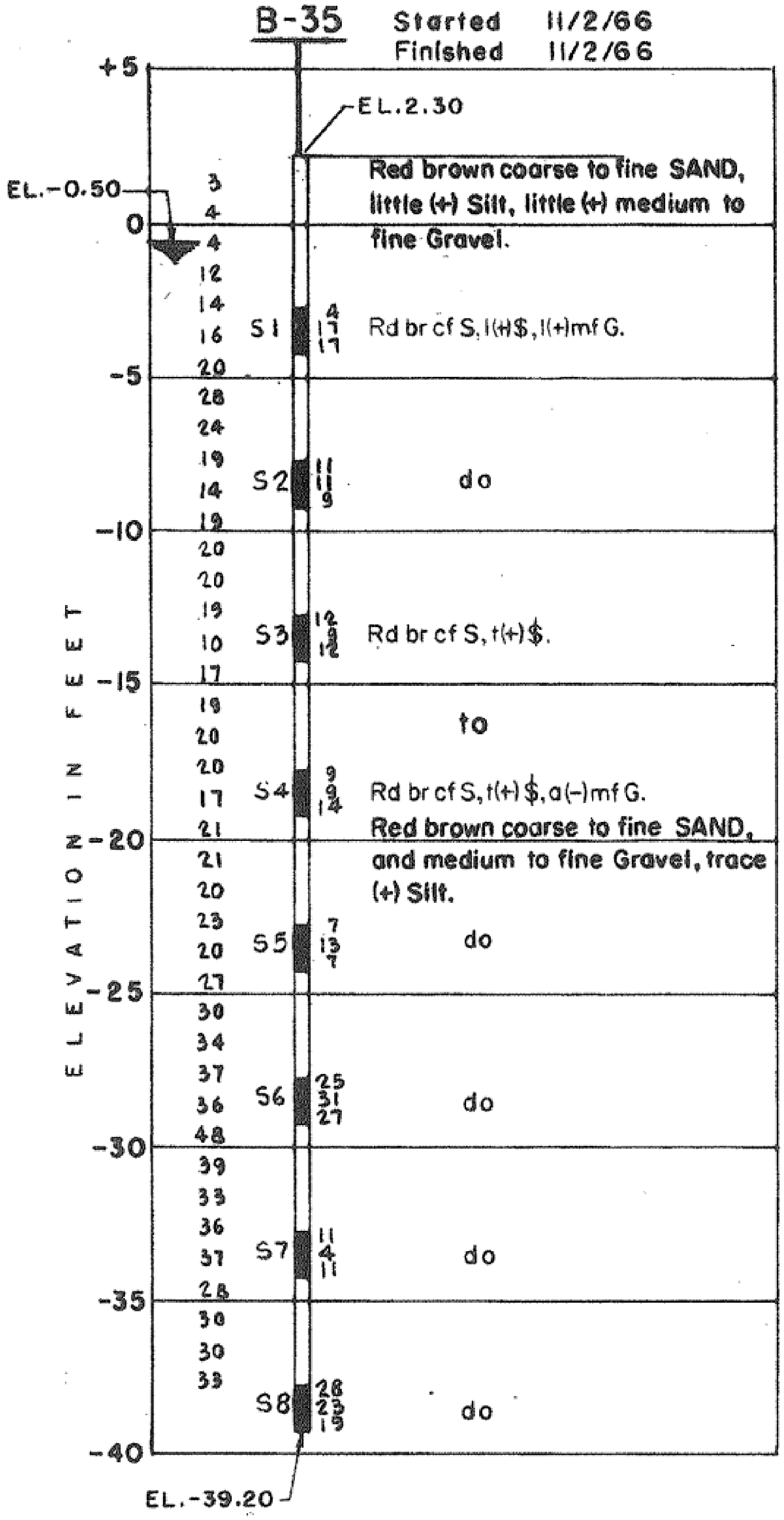
to

Br cf S, t(-)$, a(+)mf(+)G.

Brown coarse to fine SAND and medium to fine Gravel, trace (+) Silt.

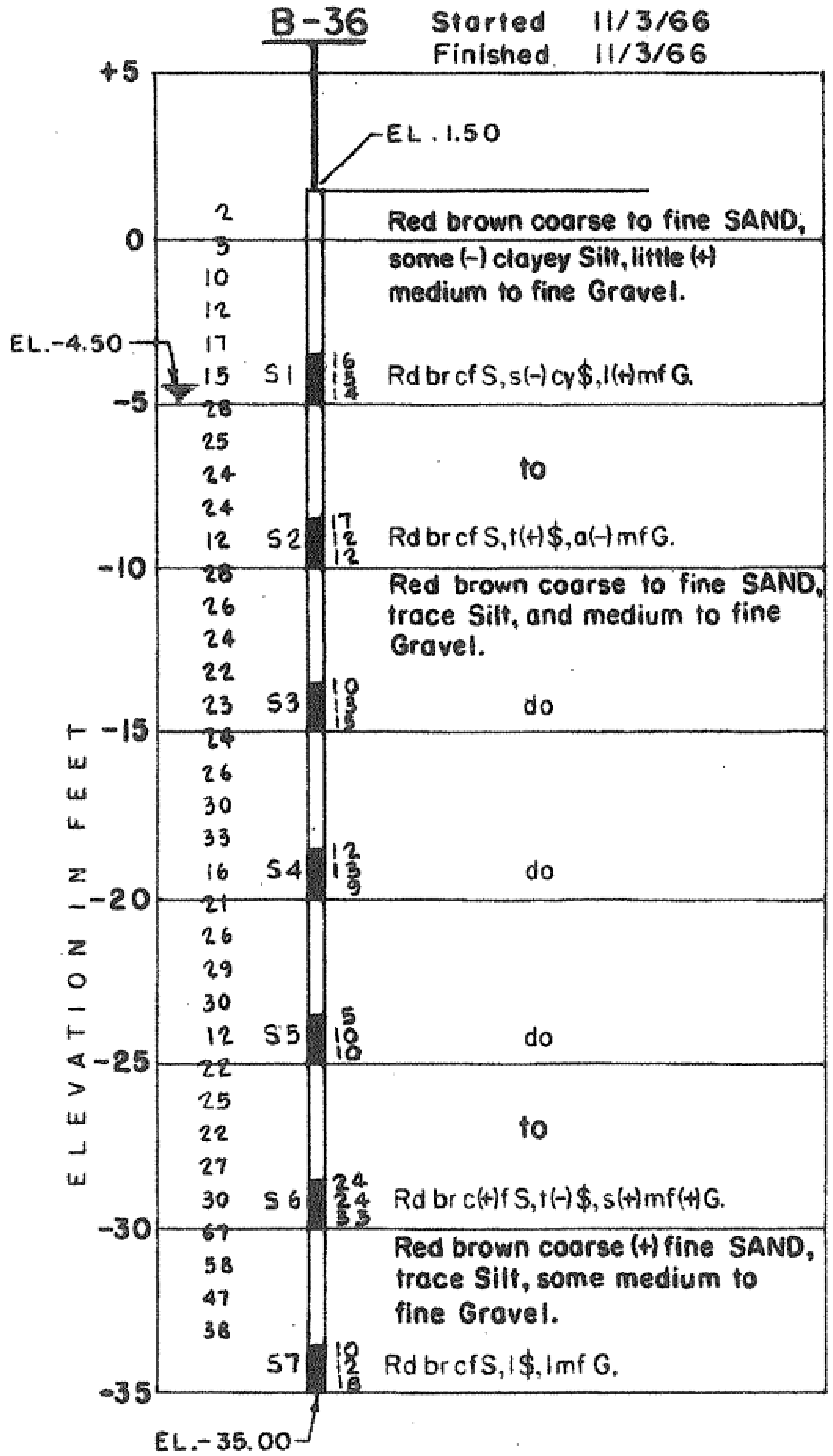
do

do


B-35
Started 11/2/66
Finished 11/2/66
EL.2.30
EL.-0.50
ELEVATION IN FEET
+5
0
-5
-10
-15
-20
-25
-30
-35
-40
3
4
4
12
14
16
20
28
24
19
14
19
20
20
19
10
17
19
20
20
17
21
21
20
23
20
27
30
34
37
36
48
39
33
36
37
28
30
30
33
S1
4
17
17
S2
11
11
9
S3
12
9
12
S4
9
9
14
S5
7
13
7
S6
25
31
27
S7
11
4
11
S8
28
23
19
Red brown coarse to fine SAND, little (+) Silt, little (+) medium to fine Gravel.
Rd br cf S, l(+)$, l(+)mf G.
do
Rd br cf S, t(+)$.
to
Rd br cf S, t(+) $, a(-)mf G.
Red brown coarse to fine SAND, and medium to fine Gravel, trace (+) Silt.
do
do
do
do
EL.-39.20

B-36

Started 11/3/66
Finished 11/3/66



Red brown coarse to fine SAND, some (-) clayey Silt, little (+) medium to fine Gravel.

Rd br cf S, s(-) cy $, l(+) mf G.

to

Rd br cf S, t(+) $, a(-) mf G.

Red brown coarse to fine SAND, trace Silt, and medium to fine Gravel.

do

do

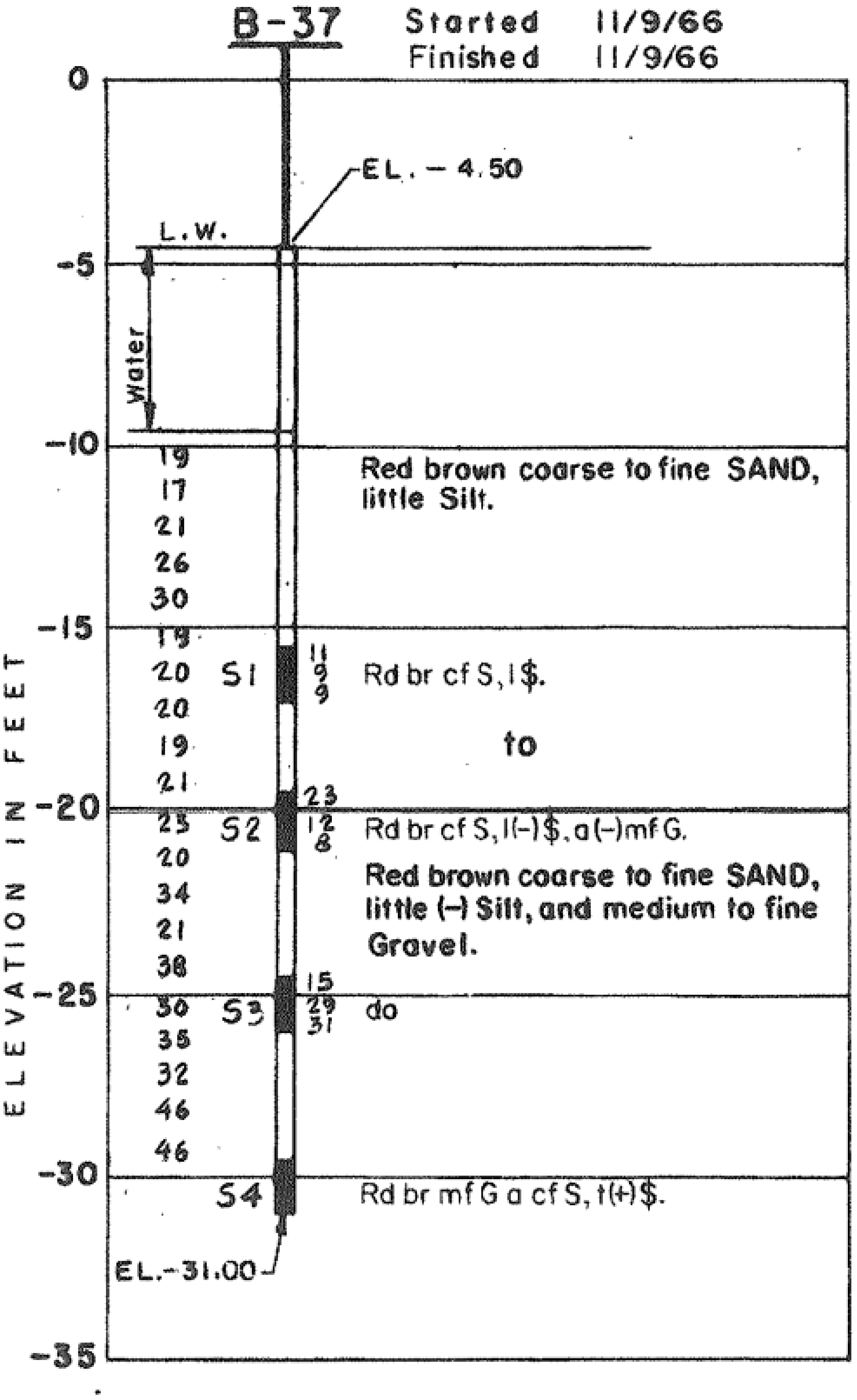
do

to

Rd br c(+) f S, t(-) $, s(+) mf(+) G.

Red brown coarse (+) fine SAND, trace Silt, some medium to fine Gravel.

Rd br cf S, l $, l mf G.



Red brown coarse to fine SAND, little Silt.

Rd br cf S, l $.

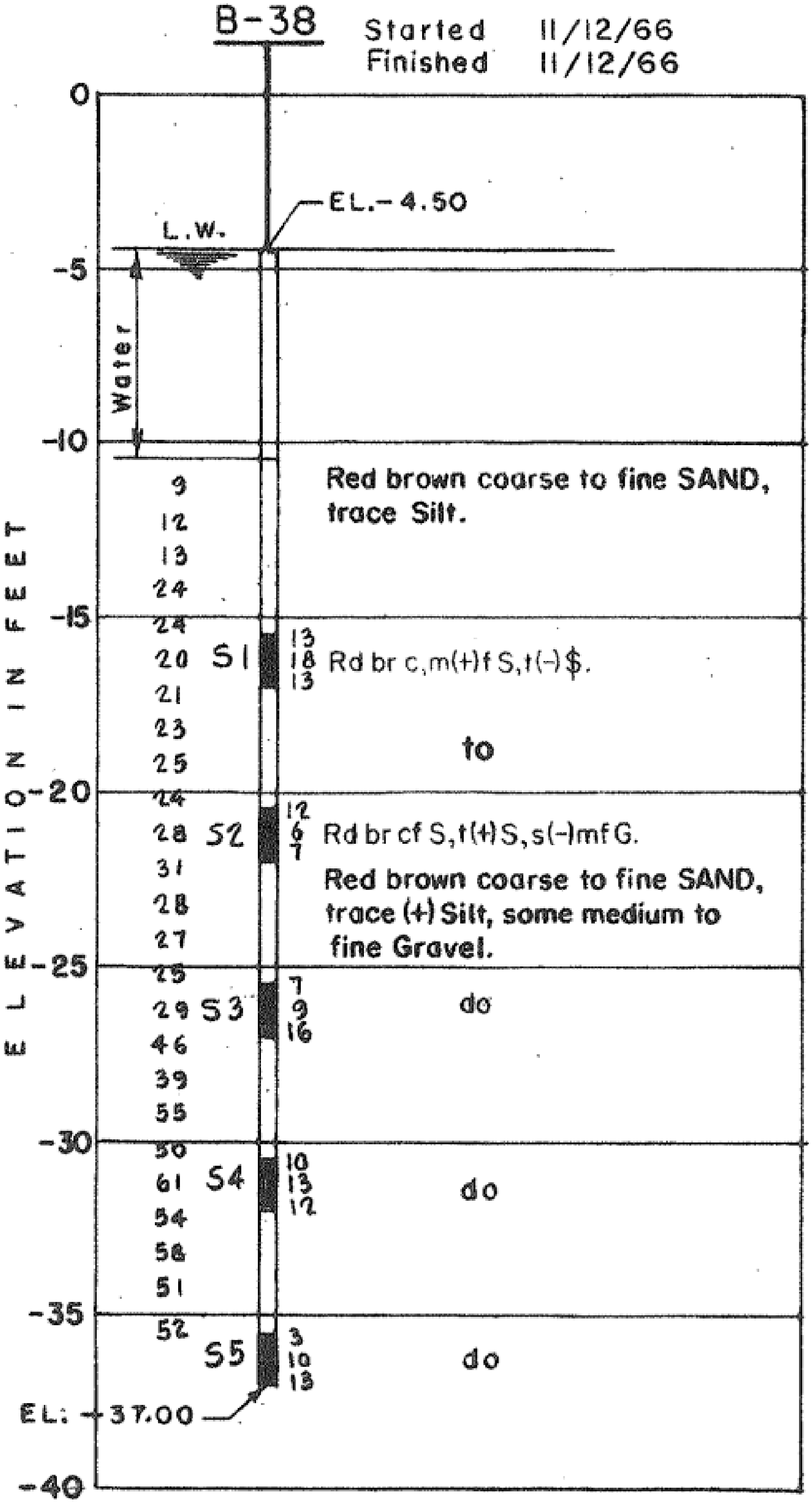
to

Rd br cf S, l(−)$, a(−)mf G.

Red brown coarse to fine SAND, little (−) Silt, and medium to fine Gravel.

do

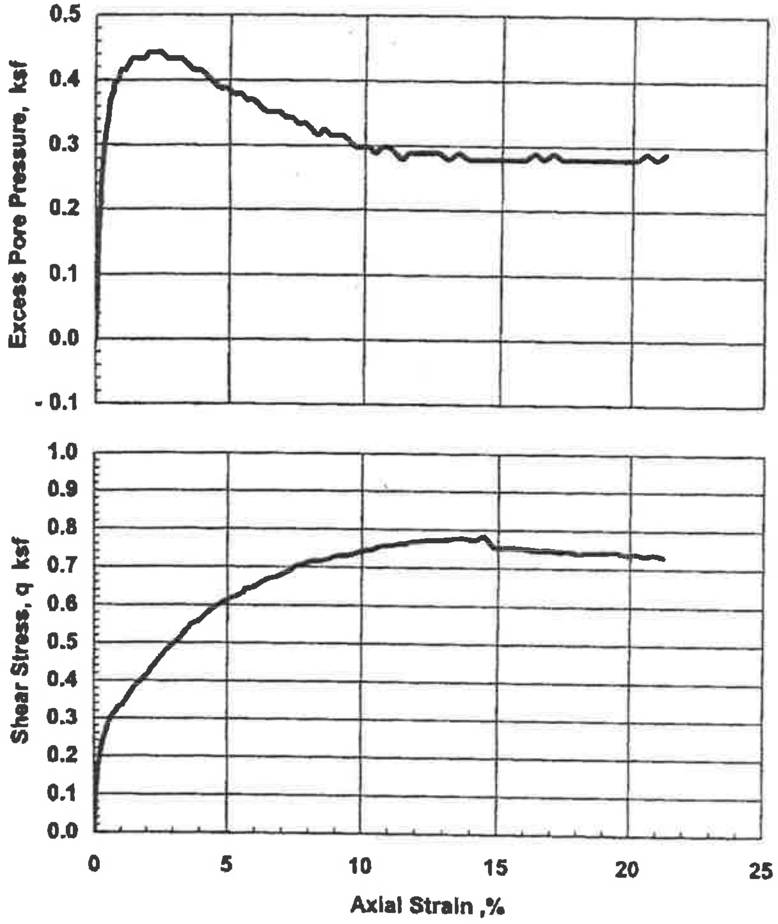
Rd br mf G a cf S, t(+)$.


B-38
Started 11/12/66
Finished 11/12/66
0
EL.-4.50
L.W.
-5
Water
-10
ELEVATION IN FEET
9
12
13
24
Red brown coarse to fine SAND, trace Silt.
-15
24
20
S1
13
18
13
Rd br c,m(+)f S,t(-)$.
21
23
25
to
-20
24
28
S2
12
6
7
Rd br cf S,t(+)S,s(-)mf G.
31
28
27
Red brown coarse to fine SAND, trace (+) Silt, some medium to fine Gravel.
-25
25
29
S3
7
9
16
do
46
39
55
-30
50
61
S4
10
13
12
do
54
58
51
-35
52
S5
3
10
13
do
EL: -37.00
-40

ATTACHMENT C – LABORATORY TEST RESULTS

Table showing laboratory results from soil samples

Boring	Depth (feet)	USCS	% Gravel	% Sand	% Fines	Moisture Content (%)	Specific Gravity	Unit Weight (p.c.f)	LL	PL	PI
CB02-1	10-12	SM	28.3	42.2	29.5	16.1					
	25-27	SM	0.0	81.2	18.8	24.0	2.71	72.1			
CB02-2	2-4	SW	32.2	66.1	1.7	8.0					
CB02-3	10-12	GW-GM	78.2	15.4	6.4	13.8	2.70	78.9			
CB02-4	4-6	CL-ML						76.0	24	19	5
	15-17	SM/CL-ML	0.0	31.2	68.8	20.7		78.3	23	18	5
CB02-5	4-6	SM/CL	0.0	47.6	52.4	22.5		76.5	25	17	8
CB02-6	2-4	SM	17.6	55.3	27.1	44.4	2.71				
	4-6	SM/CL	0.0	38.4	61.6	5.6	2.53	77.4	30	21	9
CB02-7	20-22	SP-SM	9.7	84.0	6.3	19.8	2.67	103.0			
CB02-8	10-12	SM	0.0	85.6	14.4	15.2	2.67				
CB02-9	6-8	SM/ML	0.0	32.7	67.3	25.5		88.0	19	17	2
CB02-11	2-4	SP	1.2	97.7	1.1	4.4	2.84	97.2			
CB02-12	4-6	SP	2.9	93.2	3.9	5.4					
	8-10	SW-SM	26.2	66.1	7.7	24.6	2.67	106.2			
SS02-3	2-4	SM	10.7	36.8	52.5	31.4	2.52	71.1			
	8-10	SM	41.6	40.5	17.9	30.8					
SS02-4	4-6	SM	27.6	53.0	19.4	4.6	2.64	89.6			
	15-17	SM	19.3	51.3	29.4	23.7		63.8			
SS02-5	2-4	SW-SM	32.8	59.4	7.8	6.5					
(UT)	8-10	CL-ML						108.1	23	18	5
SS02-6	20-22	SP-SM	11.4	83.0	5.6	18.0					
SS02-7	20-22	SP-SM	3.2	91.5	5.3	4.2					
SS02-8	2-4	SW	26.3	68.9	4.8	2.3					
	8-10	SM	45.2	40.9	13.9	15.7		109.8			
SS02-9	15-17	SP-SM	11.9	82.5	5.6	20.4	2.68	102.1			
SS02-10	2-4	SM	23.9	62.4	13.7	9.7					
(UT)	5-7	ML						98.4	22	19	3
SS02-11	2-4	SW-SM	5.7	84.8	9.5	49.8	2.70	93.3			
	25-27	SP-SM	19.1	74.4	6.5	17.1					
SS02-12	6-8	SP	0.0	97.8	2.2	5.8	2.68	104.1			
SS02-13	2-4	SP	2.3	94.9	2.8	5.0					
	15-17	SW-SM/ CL-ML	25.6	62.6	11.8	24.7		92.9	25	21	4
	22-24	SP-SM	0.7	89.4	9.9	25.5	2.68	97.4			
SS02-14	15-17	SM	0.0	78.9	21.1	25.1					
(UT)	23-25	SW-SM/ML	50.2	40.7	9.1	20.5		107.5	26	22	4
SS02-15	4-6	SW	40.3	56.1	3.6	3.8	2.64	79.5			
	25-27	SM	0.0	34.9	65.1	36.0		107.4	25		
SS02-16	0-2	SW-SP	3.1	93.1	3.8	4.2	2.68	104.5			
	20-22	GW	66.9	32.6	0.5	13.5					
SS02-17	10-12	SP-SM	2.4	91.4	6.2	20.2	2.69	100.2			



SPECIMEN INFORMATION (Initial)

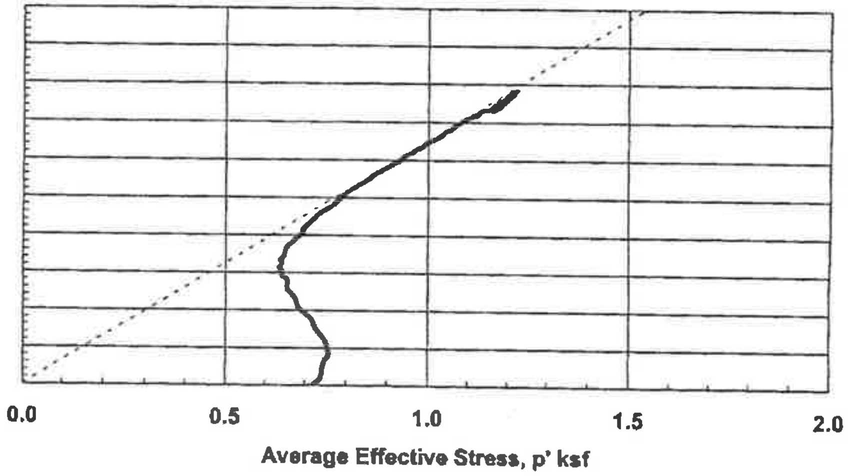
Height: 6.02 inch Diameter: 2.81 inch Area: 6.21 in²
Water Content: 28.0 % Total Unit Weight: 126.0 pcf

TEST SUMMARY

Consolidation Stresses: 0.72 ksf vertical, 0.72 ksf lateral
Water Content: 25.4 % Total Unit Weight: 128.4 pcf
B Coefficient: 99.4 Strain Rate: 0.020 %/min
Peak Shear Strength: 0.78 ksf @ 14.5 % Strain
Peak Effective Friction Angle: 40.4°

REMARKS:


Failure Sketch

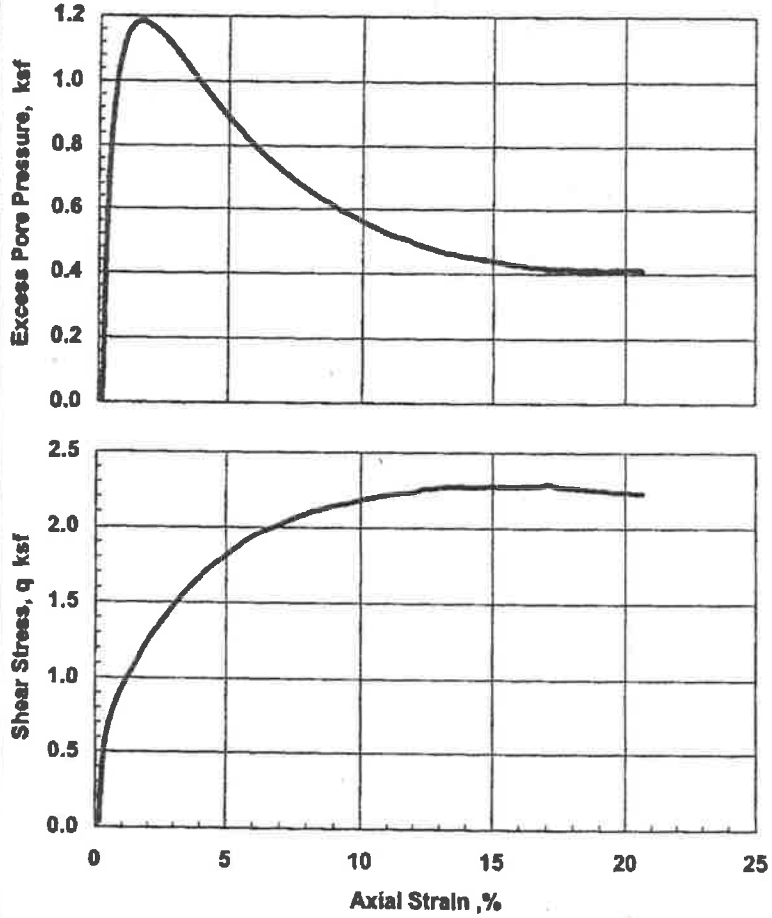


SOR TESTING LABORATORIES, INC.

98 Sand Park Road - Cedar Grove, NJ 07009
(973) 239-6001

CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION

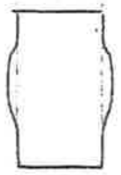
PROJECT	Crescent Beach & South Shore ACOE Project	JOB NO.	02-481
SAMPLE NO.	CB 02-10 U1 (5'-7') SOIL : ML (Sandy Silt)	DATE	11/19/02

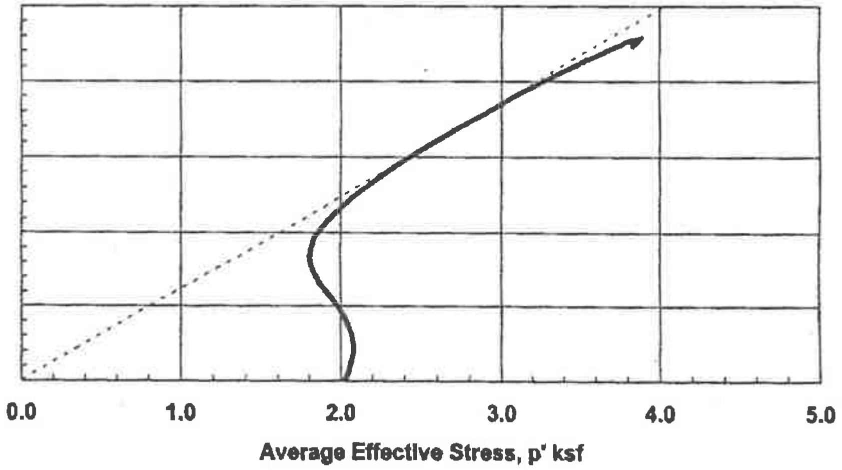


SPECIMEN INFORMATION (Initial)
Height: 6.02 inch Diameter: 2.83 Inch Area: 6.30 in²
Water Content: 20.5 % Total Unit Weight: 129.5 pcf

TEST SUMMARY
Consolidation Stresses: 2.02 ksf vertical, 2.02 ksf lateral
Water Content: 18.8 % Total Unit Weight: 134.1 pcf
B Coefficient: 100.2 Strain Rate: 0.020 %/min
Peak Shear Strength: 2.29 ksf @ 17.1 % Strain
Peak Effective Friction Angle: 38.3°

REMARKS:


Failure
Sketch

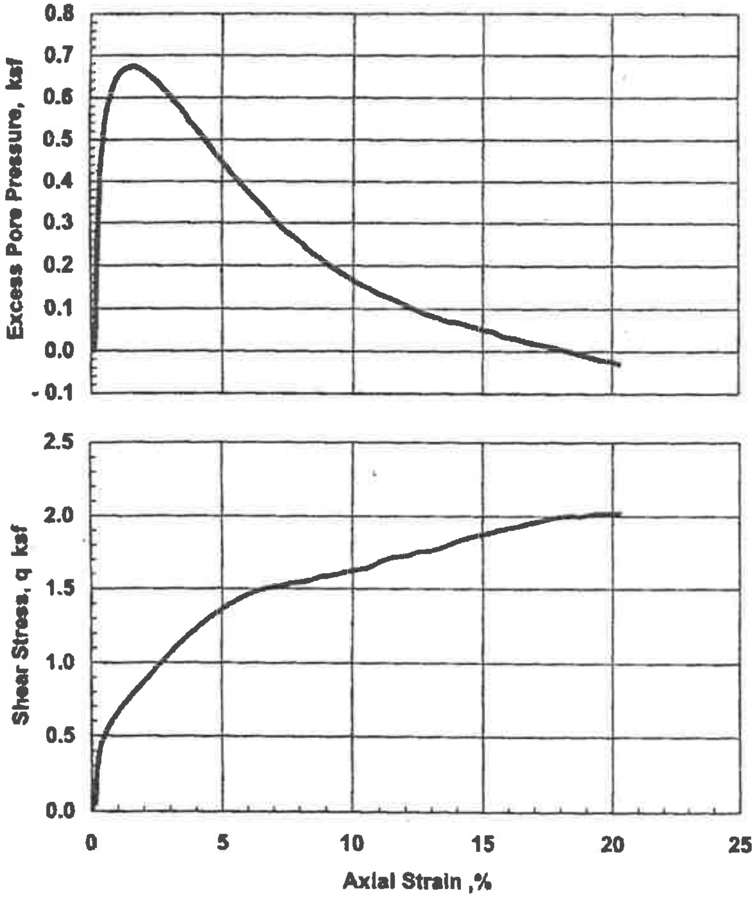


SOR TESTING LABORATORIES, INC.

98 Sand Park Road - Cedar Grove, NJ 07009
(973) 239-6001

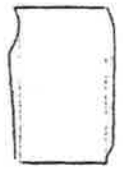
CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION

PROJECT	Crescent Beach & South Shore ACOE Project	JOB NO.	02-481
SAMPLE NO.	SS 02-14 U2 (23'-25') SOIL : SM (Silty Sand)	DATE	11/19/02



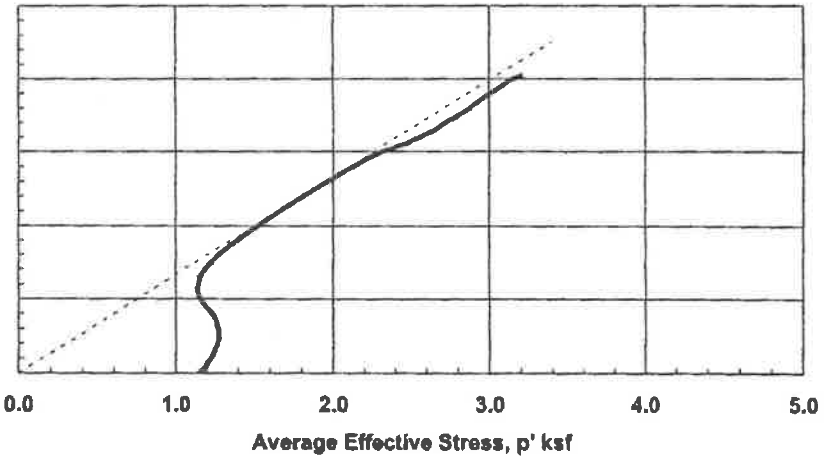
SPECIMEN INFORMATION (Initial)
Height: 6.02 inch Diameter: 2.82 inch Area: 6.26 in²
Water Content: 20.8 % Total Unit Weight: 130.6 pcf

TEST SUMMARY
Consolidation Stresses: 1.15 ksf vertical, 1.15 ksf lateral
Water Content: 18.9 % Total Unit Weight: 134.3 pcf
B Coefficient: 99.9 Strain Rate: 0.031 %/min
Peak Shear Strength: 2.02 ksf @ 20.3 % Strain
Peak Effective Friction Angle: 41.6°



Failure
Sketch

REMARKS:



SOR TESTING LABORATORIES, INC.

98 Sand Park Road - Cedar Grove, NJ 07009
(973) 239-6001

CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION

PROJECT	Crescent Beach & South Shore ACOE Project	JOB NO.	02-481
SAMPLE NO.	SS 02-5 U1 (8'-10') **SOIL** : SC (Clayey Sand)	DATE	11/19/02

ATTACHMENT D – URS MEMORANDUM

MEMORANDUM

To: Michael G. Cannon

From: Vai Navaratnam

Date: July 22, 2011

Subject: **Preliminary - Seepage / Slope Stability Analyses Hurricane and Storm Damage Reduction Feasibility Study for the South Shore of Staten Island, NY**

The purpose of this memorandum is to summarize preliminary seepage and slope stability analyses results for selected cases performed for the referenced project.

BACKGROUND

There are primarily five types of hurricane and storm damage reduction structures along the line of protection (approximately 4.75 miles long). These structures consist of a buried seawall, stone seawall, earth embankment levee, single sheetpile wall and a double sheetpile wall. In accordance with USACE design manuals EM 1110-2-1913 and EM 1110-2-2502, seepage and stability analyses have been performed for all structures along the line of protection. The details and results of these analyses will be reported in the draft report to be submitted to the USACE. As per EM 1110-2-1913 (Design and Construction of Levees), slope stability analyses need to be performed for four loading conditions as follows: Case I, end of construction; Case II, sudden drawdown; Case III, steady-state seepage from full flood stage; and Case IV, earthquake.

Typically, it is our standard practice to conservatively use the fully developed phreatic surface obtained from a steady-state seepage analysis to perform the slope stability analysis under Case III loading condition. This condition occurs when the water remains at or near flood stage for a sufficient period of time to result in full embankment saturation and a condition of steady seepage. However, considering the relatively short duration (less than 6 hours) of the design storm, this condition will most likely not occur during the design storm. Therefore, the results of transient and steady seepage analyses along with corresponding results of Case III slope stability analyses are presented below for Buried Seawalls and Stone Seawalls. It should be noted that analyses of the other slope stability loading conditions, and other wall types are not presented here because they are not relevant considering the purpose of this memorandum.

BURIED SEAWALL

The total length of the buried seawall is approximately 2 miles (10, 655 ft) and the height of the wall varies from approximately 10 ft to 11.5 ft for a 500 year design storm. The representative cross section selected for the buried seawall analyses is shown in Figure 1. The 500 year storm still water elevation of 14.3 ft (NGVD 29) was used in the seepage analyses. The storm hydrographs used in the transient seepage analyses are presented in Figures 2 and 3. In addition, the storm hydrograph used to determine the duration of the storm to develop a steady-state seepage condition is presented in Figure 4. The seepage and slope stability analyses were performed using the commercially available software programs SEEP/W and SLOPE/W, respectively. In SLOPE/W, the pore pressures obtained from the results of the SEEP/W analyses were used to simulate the pore pressures within the embankment.

Transient Analyses

Based on the transient analyses performed using the storm hydrograph shown in Figure 2, the maximum phreatic surface was obtained at the end of 15 hours. The slope stability analysis performed using pore pressures obtained for this case (see Figure 5) resulted in an estimated factor of safety (FOS) of 1.7 during the flood (Case III). This is greater than the acceptable FOS of 1.4 (EM 1110-2-1913). In addition, as shown in Figure 6 the total seepage flow for an approximately 5,200 ft long Reach A3 is estimated to be about 0.1 cfs (45 gpm for 5200 ft), with a corresponding maximum exit hydraulic gradient of 0.25 (Figure 7).

In order to determine the duration of the storm required to develop a steady-state condition, a hypothetical hydrograph (see Figure 4) was developed assuming that after reaching the maximum water level of el. +14.3 ft it will remain constant for about two weeks. Based on the transient seepage analyses performed using this hydrograph, it will take more than a week (about 192 hrs) to fully develop the steady-state seepage condition (see Figure 8). Slope stability FOS values corresponding to times ranging from 15 hrs to 192 hrs were computed as follows: 15 hrs, FOS = 1.7; 48 hrs, FOS = 1.4; 60 hrs, FOS = 1.3; 192 hrs, FOS = 1.1 (see Figures 9 to 12). Therefore, if the flood level remains at an elevation of approximately 14.3 ft for about 48 hours, the slope stability FOS value will become less than 1.4. Since the design storm duration of 6 hours is much shorter than 48 hrs, based on the results of the transient analyses, the slope stability FOS value for Case III loading condition will be greater than the acceptable value of 1.4.

Steady-State Analysis

Steady-state seepage analyses were performed independently and the results were compared with transient (hypothetical hydrograph in Figure 4) analyses results after 192 hrs (8 days). As expected, the results were comparable. As shown in Figure 13, the FOS is 1.1 and the exit hydraulic gradient is about 0.6 (Figure 14). Although this FOS value is less than 1.4, the steady-state seepage condition is not expected to develop during the design storm. Therefore, steady-state seepage analyses are not appropriate for this design storm.

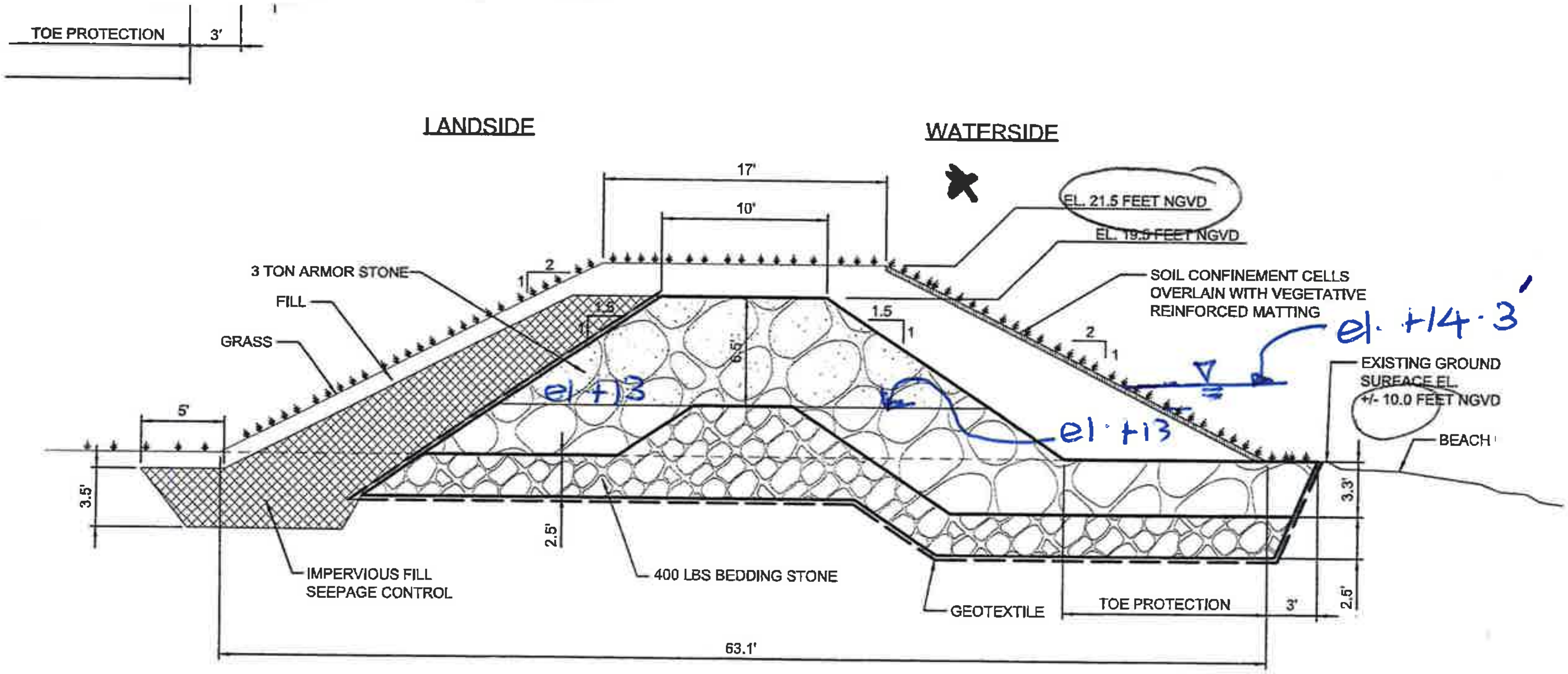
STONE SEAWALL

The total length of the stone seawall is about 4,765 ft and the maximum height is about 23 ft (see Figure 15). As shown in Figure 15, the bottom of the grouted armor stone will be at approximately el. +16 ft. The 500 year storm still water elevation is 14.3 ft (NGVD 29). Therefore, armor stone below the design storm elevation will not be grouted. Based on our analyses the slope stability FOS of the stone wall is about 1.4 for both the steady-state and transient seepage conditions. The estimated seepage flow using the transient seepage analyses is about 0.1 cfs/ft (45 gpm/ft); and using the steady state seepage analyses is about 0.13 cfs/ft (60 gpm/ft). The stone seawall in Reach A-8 is about 3,165 ft long. Therefore, as an example, the estimated seepage flow for Reach A-8 will be about 320 cfs and 410 cfs based on the transient and steady-state seepage analyses, respectively. In addition, the exit hydraulic gradients are estimated to be less than 0.2 for both transient and steady-state seepage analyses.

CONCLUSION:

Typically, for the earth embankment levees and seawalls with relatively impermeable cores which are constructed on suitable foundation, the estimated slope stability FOS values are greater or equal to 1.4 as per EM 1110-2-1913 under Case III (steady-state seepage from full flood stage) loading condition. However, in this project since the buried seawalls does not have relatively impermeable core, the estimated FOS value under steady seepage for Case III loading condition is 1.1. Based on the results of transient seepage analyses, the estimated FOS for Case III loading condition is 1.7 for the 6 hrs design storm and the duration of a hypothetical storm to develop steady-seepage is about 192 hours (8 days). Therefore, considering that the design storm is only about 6 hrs, it very unlikely that stead-seepage condition will develop. Hence, slope-stability analyses based on the fully developed phreatic surface is not warranted. If USACE also agrees with this conclusion, URS will use phreatic surfaces obtained from transient seepage analyses to estimate the slope stability FOS values for buried seawalls and stonewalls.

Enclosures



A2 C-108 **SECTION (500 YR)**
SCALE: 3/16"=1'-0"

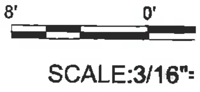
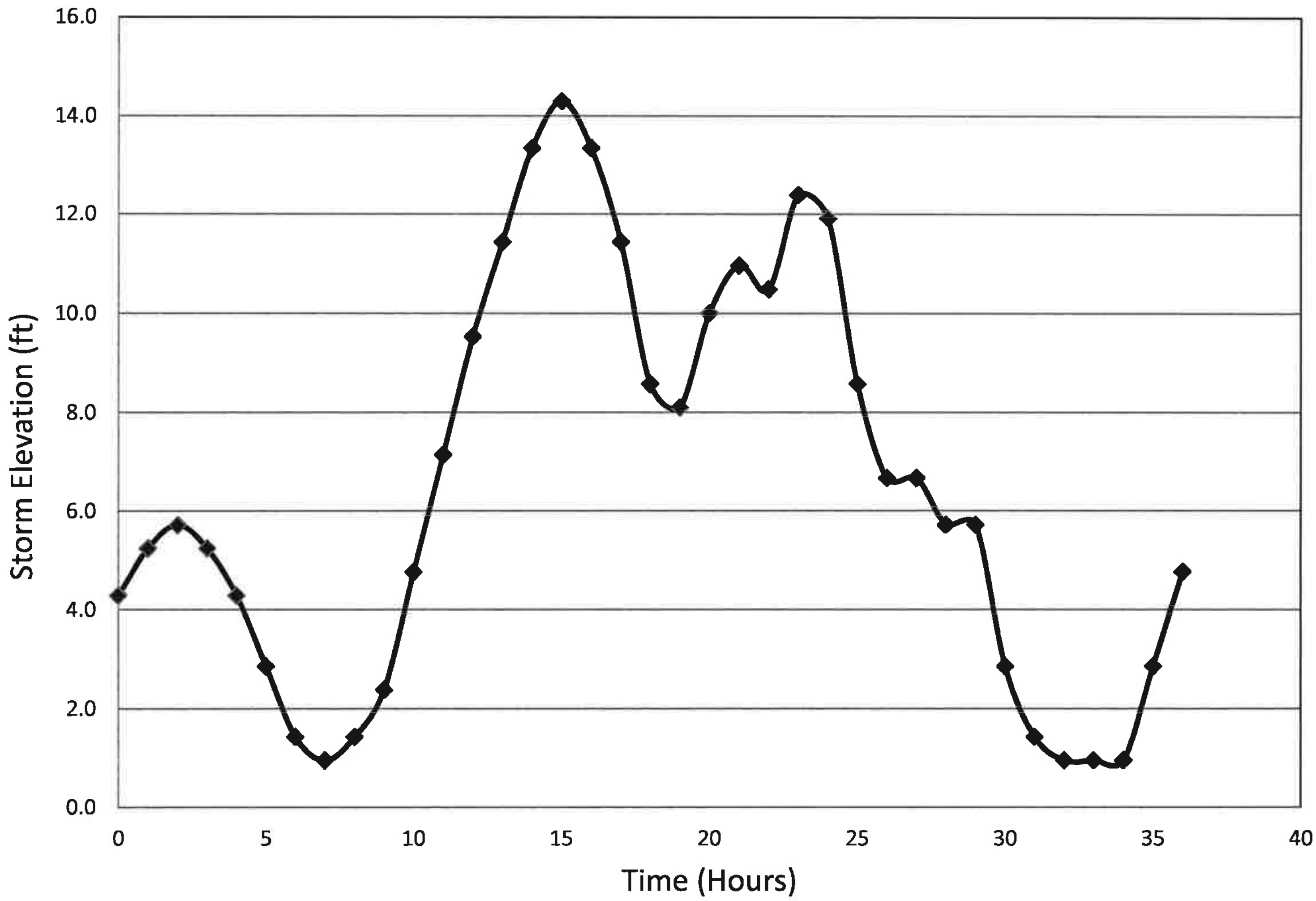


FIGURE-1

FIGURE-1



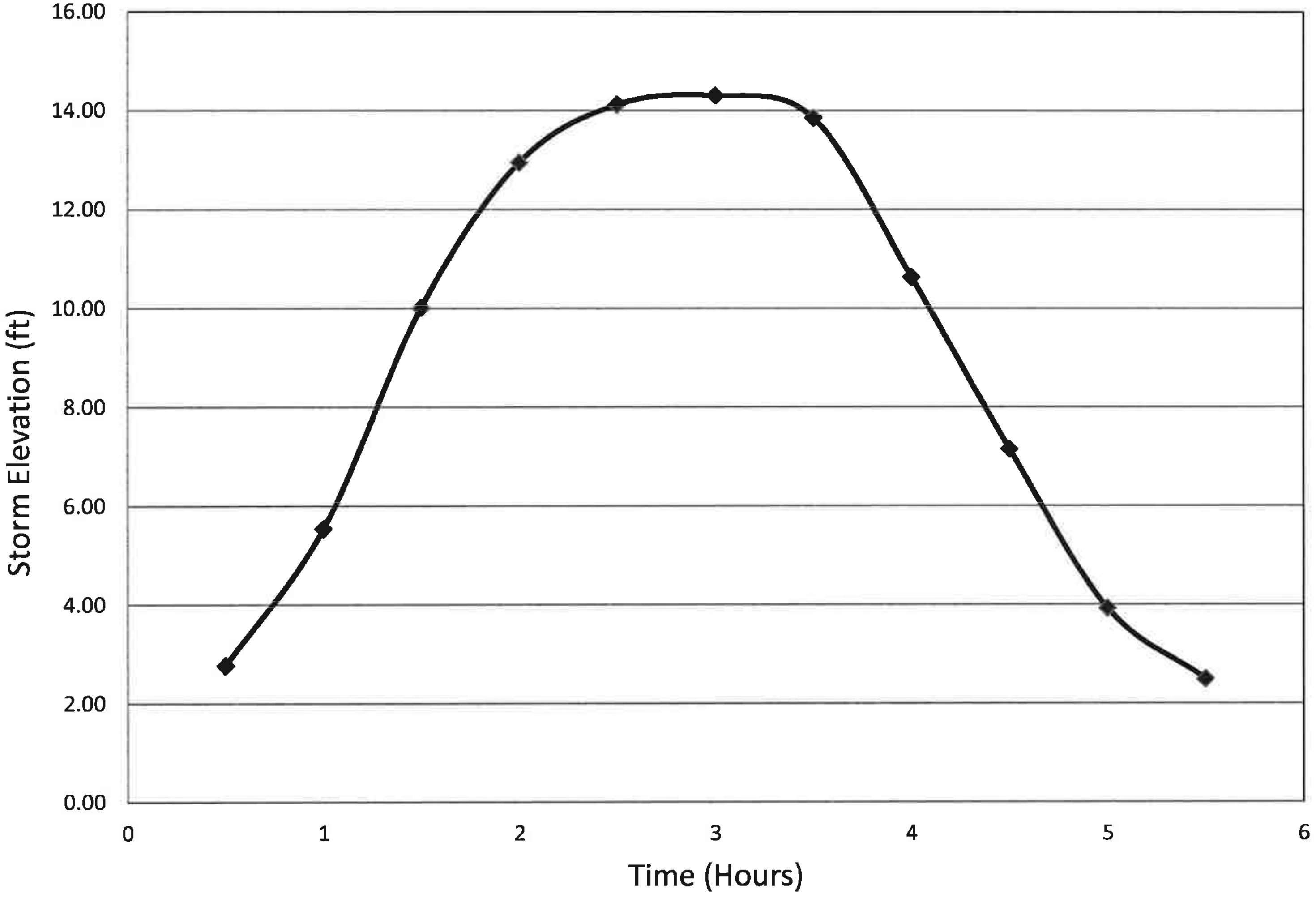
Source:
November 1950 nor'easter in NYC, peak water elevation
modified to match the design storm elevation

Storm (Nor'Easter) Hydrograph
Storm Damage Reduction Feasibility Study
Staten Island, New York

URS
WAYNE, NEW JERSEY

DR. BY: VN	SCALE: As Shown	PROJ: 11020302
	DATE: July, 2011	FIG NO: 2

i:\projects\92c4235\task3\Tide and Surge History nor-easter



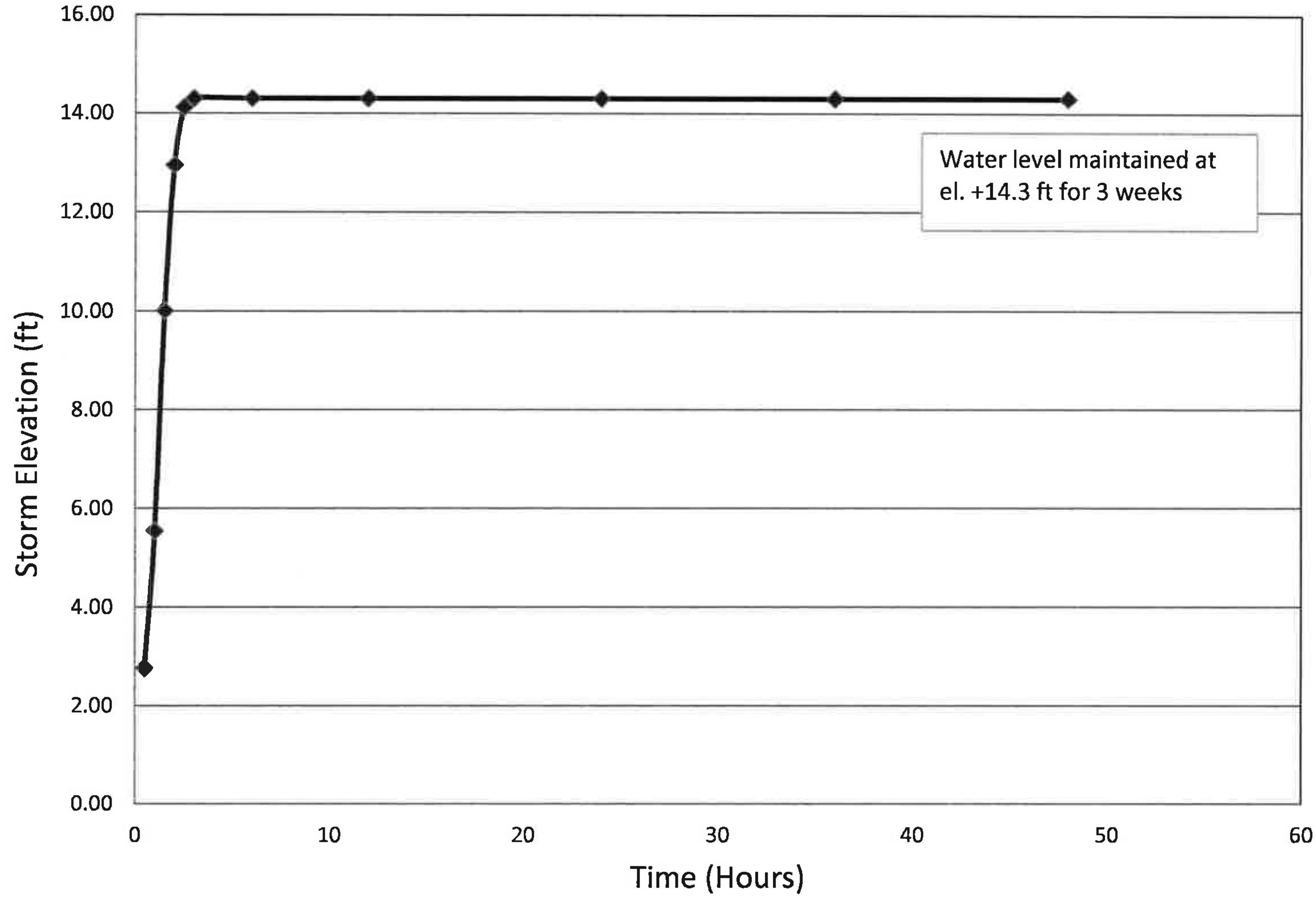
Source:
Huricane hydrograph from another location, peak water elevation modified to match the design storm elevation

Hurricane Hydrograph
Storm Damage Reduction Feasibility Study
Staten Island, New York

URS
WAYNE, NEW JERSEY

DR. BY: VN	SCALE: As Shown	PROJ: 11020302
	DATE: July, 2011	FIG NO: 3

i:\projects\92c4235\task3\Tide and Surge History new-bedford



NOTE:
Maximum still water level hypothetically maintained
for about 3 weeks

Hypothetical Hurricane Hydrograph
Storm Damage Reduction Feasibility Study
Staten Island, New York

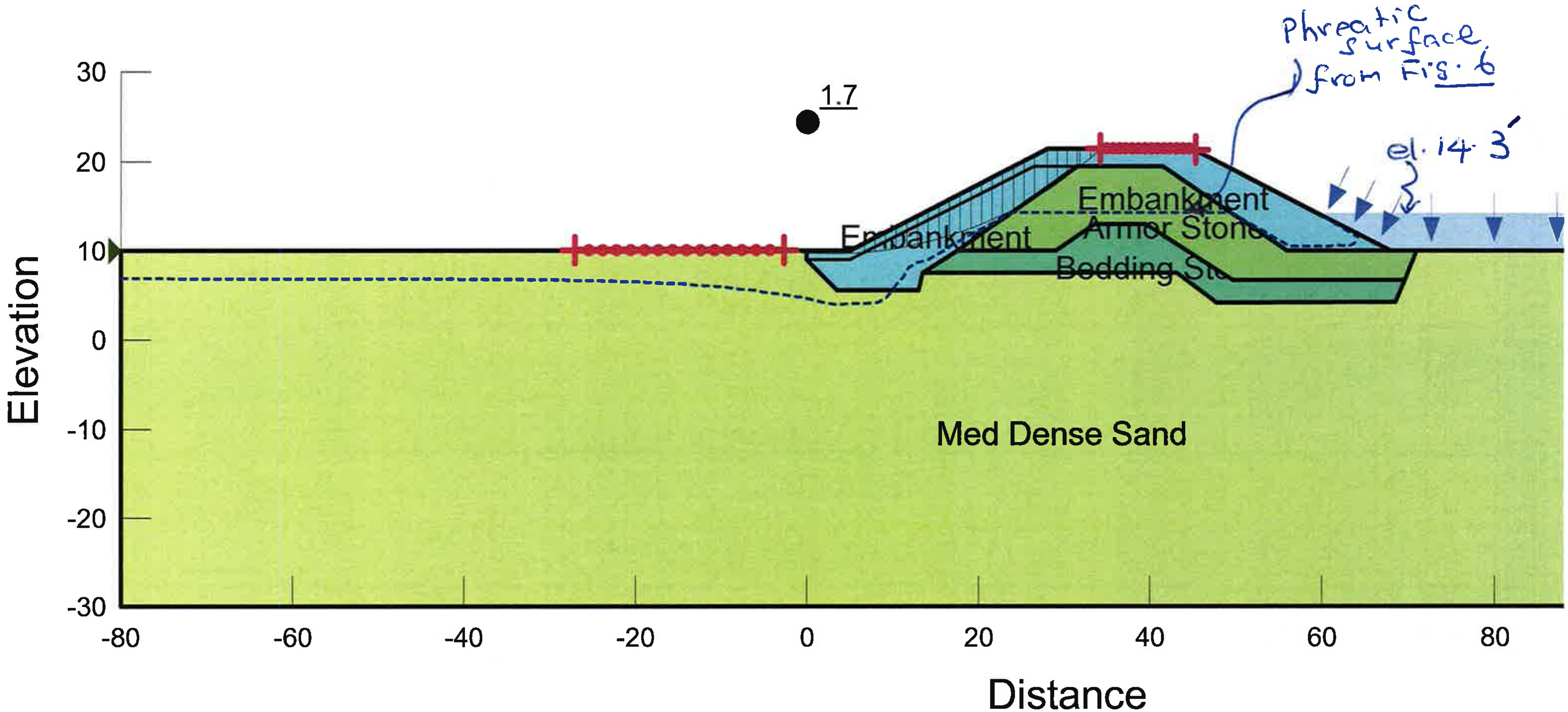
URS
WAYNE, NEW JERSEY

DR. BY: VN	SCALE: As Shown	PROJ: 11020302
	DATE: July, 2011	FIG NO: 4

i:\projects\92c4235\task3\Tide and Surge History new-bedford (2)

Case: Transien Analyses Hydrograph in Figure 2, t=15 hrs

Name: Med Dense Sand Model: Mohr-Coulomb Unit Weight: 120 pcf Phi: 30 °
Name: Armor Stone Model: Mohr-Coulomb Unit Weight: 145 pcf Phi: 38 °
Name: Bedding Stone Model: Mohr-Coulomb Unit Weight: 140 pcf Phi: 36 °
Name: Embankment Model: Mohr-Coulomb Unit Weight: 125 pcf Phi: 32 °

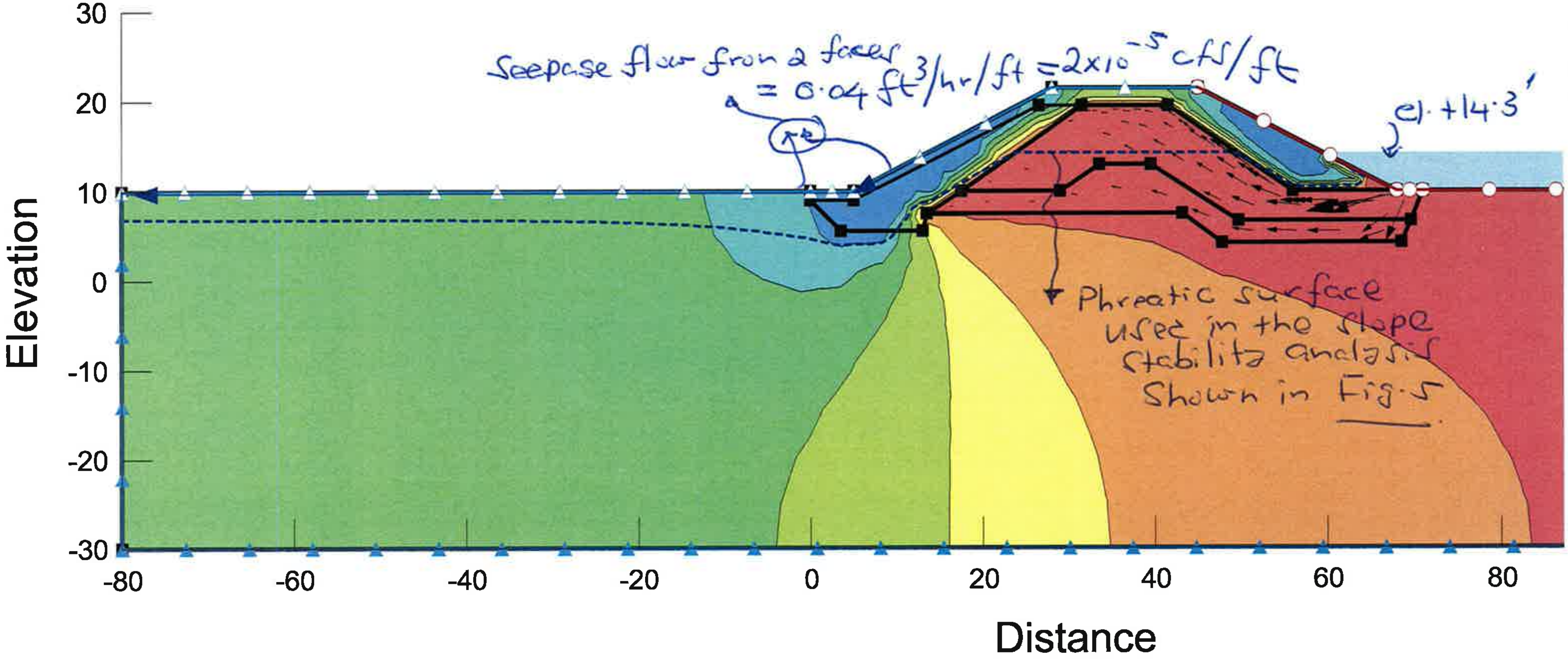


Reach A-7_WT El. 14_transient_k2-constant-long-flood.gsz

FIGURE-5

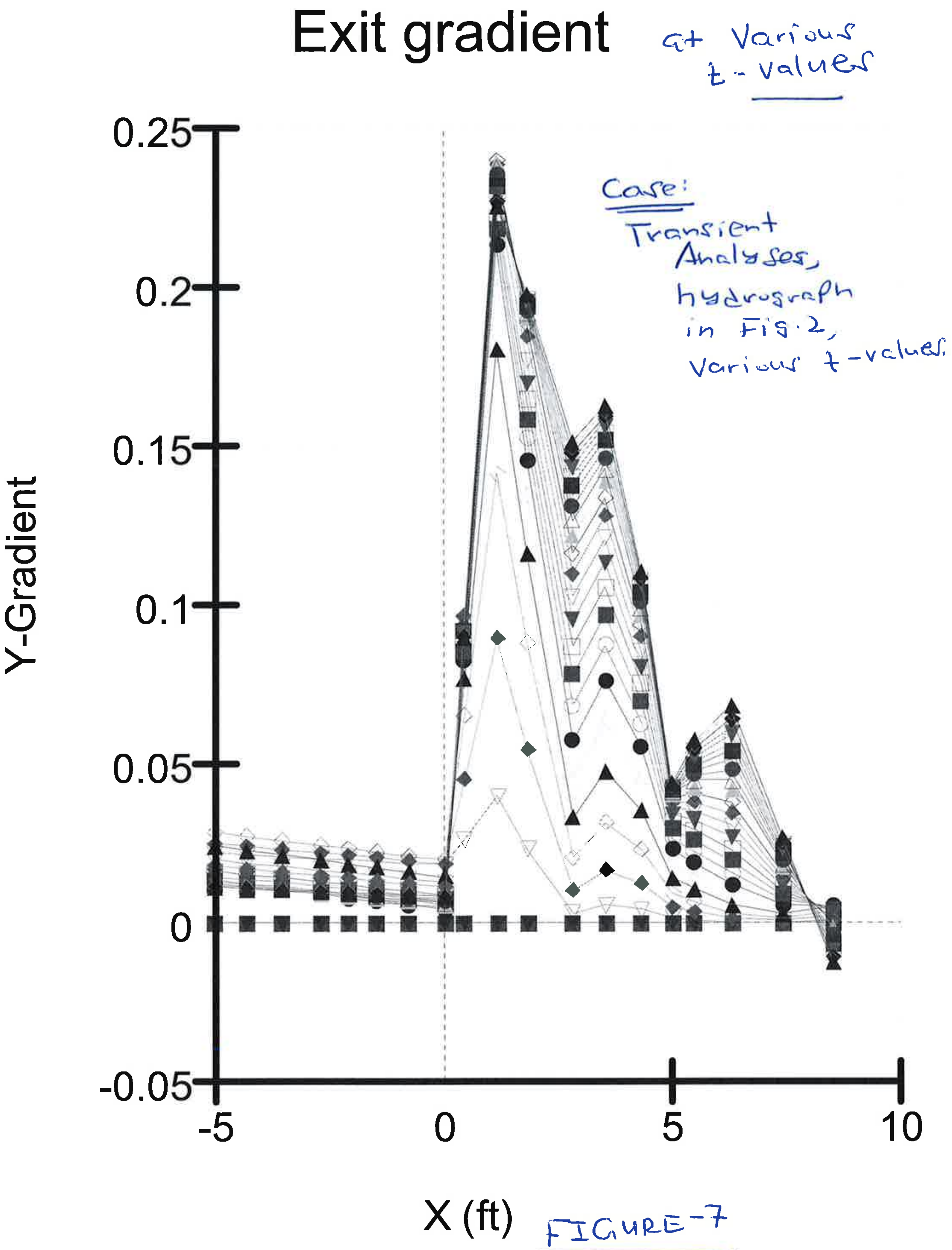
case:- Transient Analases, hydrograph in Fig. 2, t=15hrs.

Name: Med Dense Sand Model: Saturated Only K-Sat: 0.0118 ft/hr Volumetric Wa
Name: Armor Stone Model: Saturated / Unsaturated K-Function: k=10cm/s Vol. W
Name: Bedding Stone Model: Saturated / Unsaturated K-Function: k=10cm/s Vol.
Name: Embankment Model: Saturated / Unsaturated K-Function: k=1x10-5cm/s V



Reach A-7_WT El. 14_transient_k2-constant-long-flood.gsz

FIGURE -6



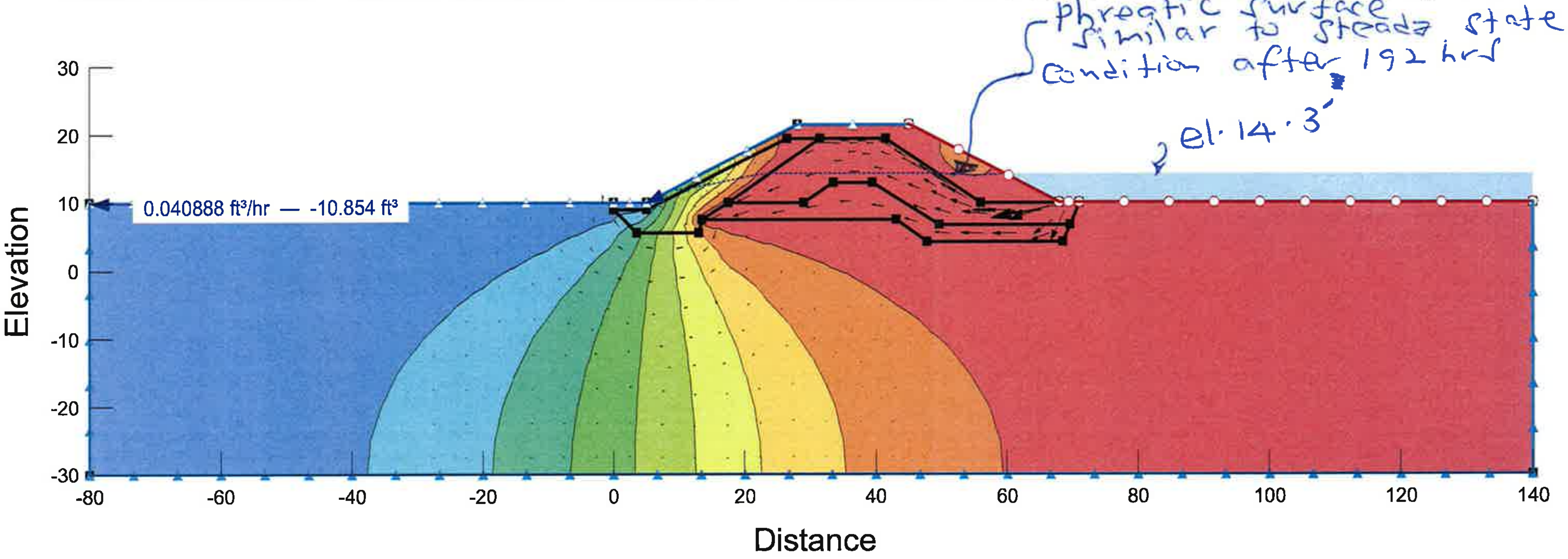
at Various t-values

Case:
Transient Analyses, hydrograph in Fig. 2, Various t-values

FIGURE-7

Case: Transient Analyses, hypothetical hydrograph in Figure 4.
t=192 hrs

Name: Med Dense Sand Model: Saturated Only K-Sat: 0.0118 ft/hr Volumetric Water Content: 0 ft³/ft³
Name: Armor Stone Model: Saturated / Unsaturated K-Function: k=10cm/s Vol. WC. Function: Silty Sand
Name: Bedding Stone Model: Saturated / Unsaturated K-Function: k=10cm/s Vol. WC. Function: Silty Sand
Name: Embankment Model: Saturated / Unsaturated K-Function: k=1x10-5cm/s Vol. WC. Function: Silty Sand

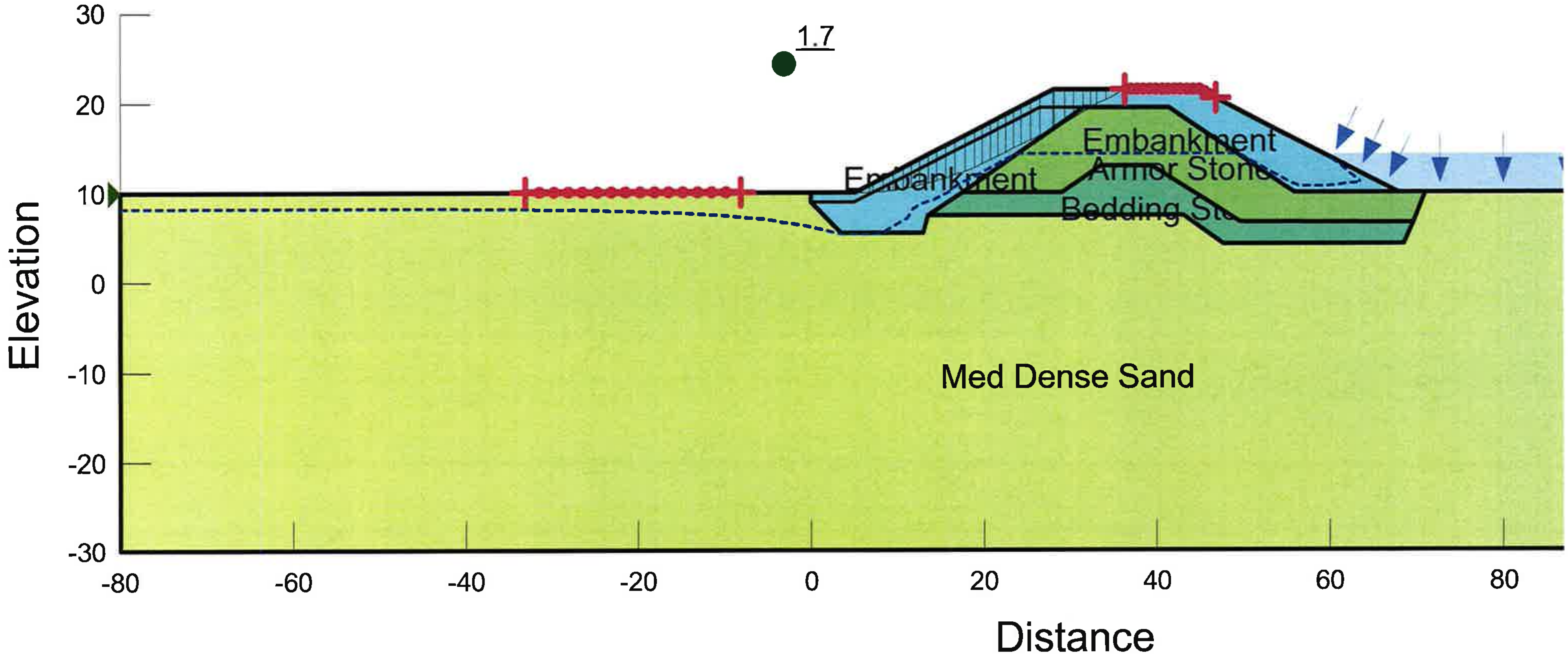


Reach A-7_WT El. 14_transient_k-constant_TimeToSS.gsz

FIGURE-8

Case: Transient analyses, hypothetical hydrograph in Fig. 4
t=15 hrs

Name: Med Dense Sand Model: Mohr-Coulomb Unit Weight: 120 pcf Phi: 30 °
Name: Armor Stone Model: Mohr-Coulomb Unit Weight: 145 pcf Phi: 38 °
Name: Bedding Stone Model: Mohr-Coulomb Unit Weight: 140 pcf Phi: 36 °
Name: Embankment Model: Mohr-Coulomb Unit Weight: 125 pcf Phi: 32 °

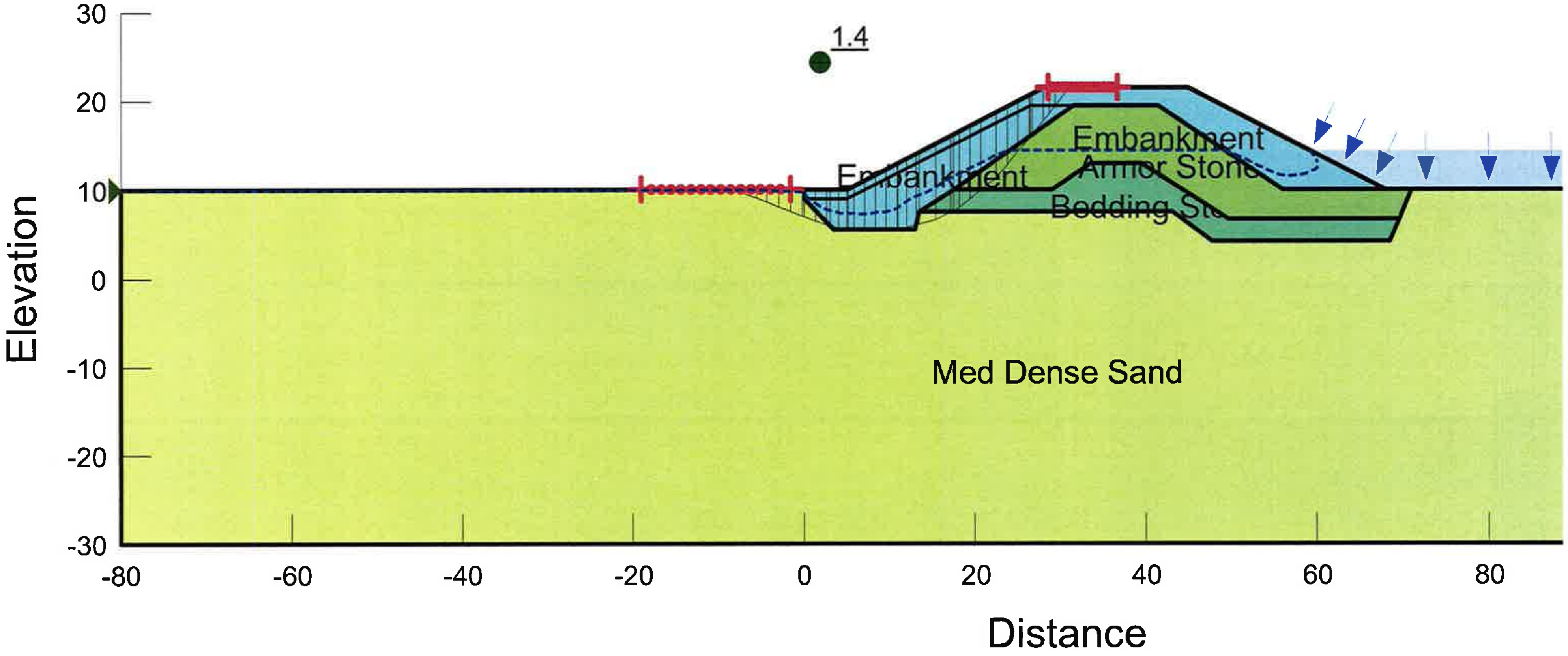


Reach A-7_WT El. 14_transient_k-constant_TimeToSS.gsz

FIGURE-9

Case: Transient analyses, hypothetical hydrograph in Fig-4
t=48 hrs

Name: Med Dense Sand Model: Mohr-Coulomb Unit Weight: 120 pcf Phi: 30 °
Name: Armor Stone Model: Mohr-Coulomb Unit Weight: 145 pcf Phi: 38 °
Name: Bedding Stone Model: Mohr-Coulomb Unit Weight: 140 pcf Phi: 36 °
Name: Embankment Model: Mohr-Coulomb Unit Weight: 125 pcf Phi: 32 °

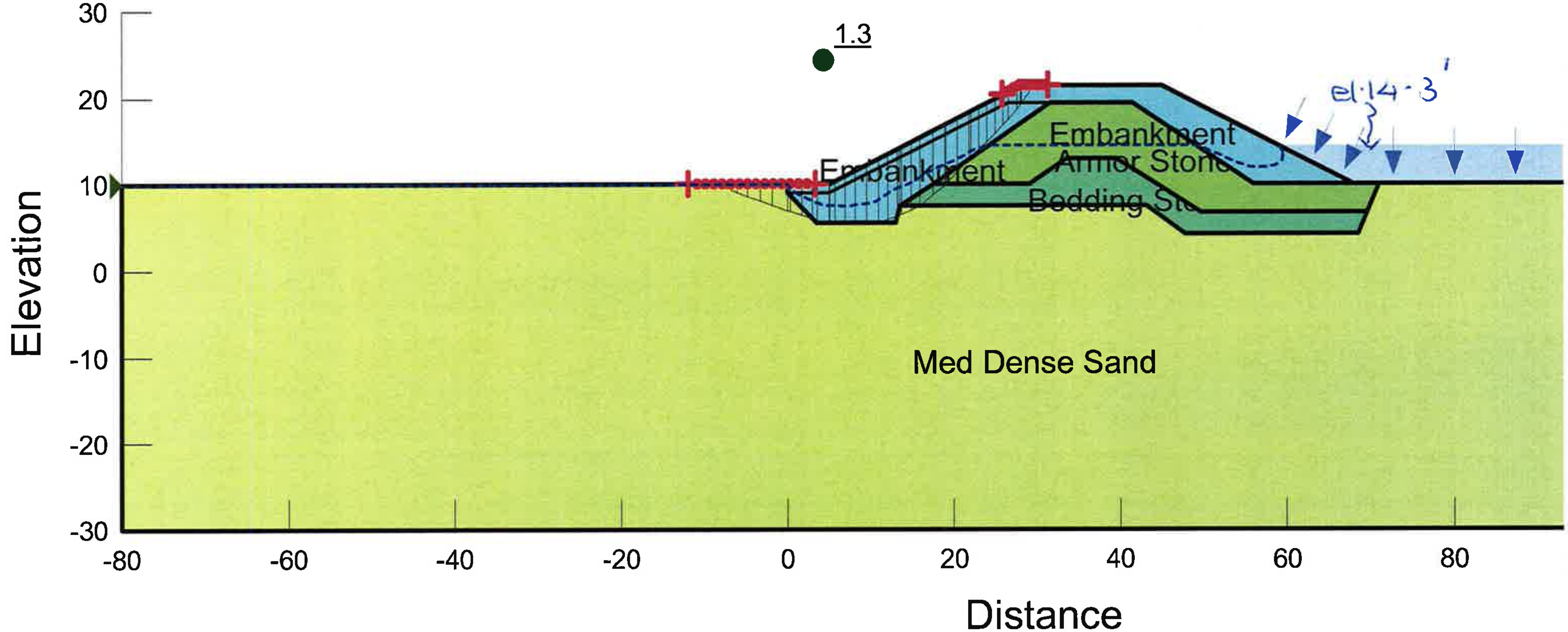


Reach A-7_WT El. 14_transient_k-constant_TimeToSS.gsz

FIGURE-10

Case: Transient analyses, hypothetical hydrograph in Fig. 4
t=60 hrs

Name: Med Dense Sand   Model: Mohr-Coulomb   Unit Weight: 120 pcf   Phi: 30 °
Name: Armor Stone   Model: Mohr-Coulomb   Unit Weight: 145 pcf   Phi: 38 °
Name: Bedding Stone   Model: Mohr-Coulomb   Unit Weight: 140 pcf   Phi: 36 °
Name: Embankment   Model: Mohr-Coulomb   Unit Weight: 125 pcf   Phi: 32 °

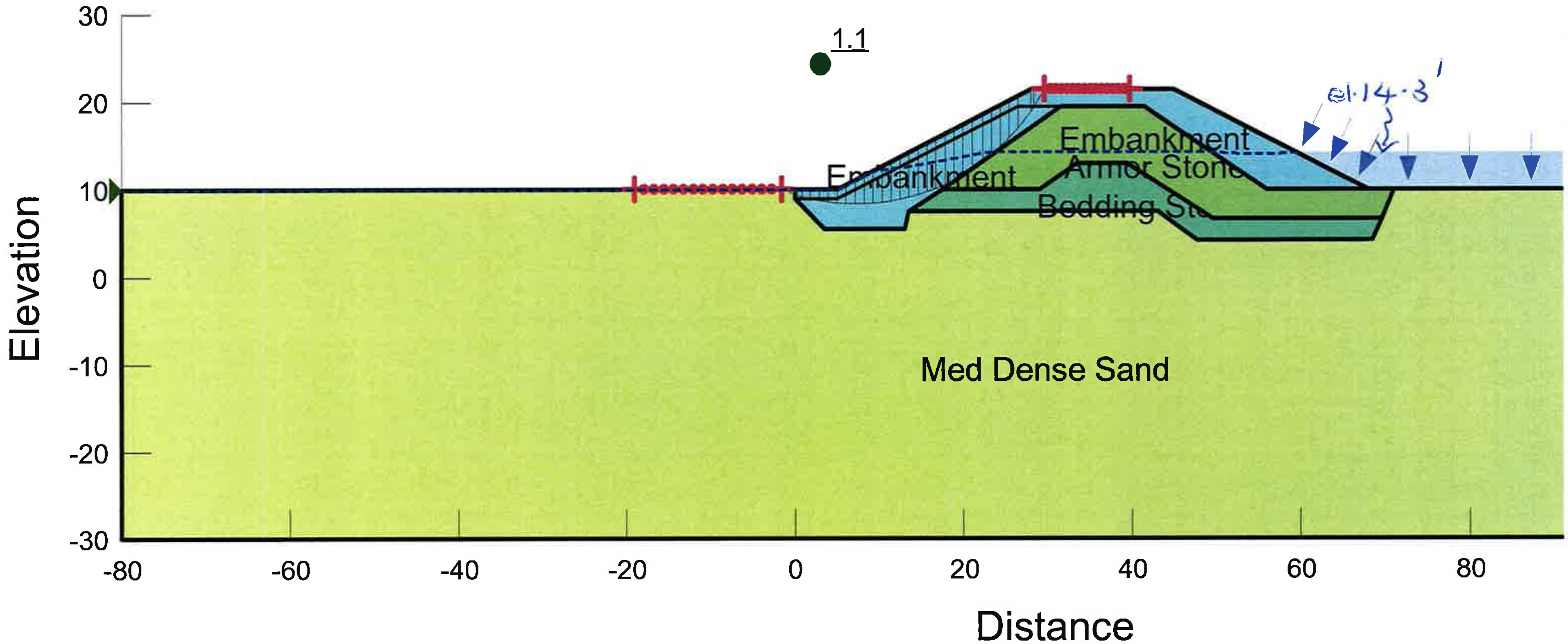


Reach A-7_WT El. 14_transient_k-constant_TimeToSS.gsz

FIGURE-11

Case: Transient analyses, hypothetical hydrograph in FIG-4
t = 192 hrs

Name: Med Dense Sand Model: Mohr-Coulomb Unit Weight: 120 pcf Phi: 30 °
Name: Armor Stone Model: Mohr-Coulomb Unit Weight: 145 pcf Phi: 38 °
Name: Bedding Stone Model: Mohr-Coulomb Unit Weight: 140 pcf Phi: 36 °
Name: Embankment Model: Mohr-Coulomb Unit Weight: 125 pcf Phi: 32 °

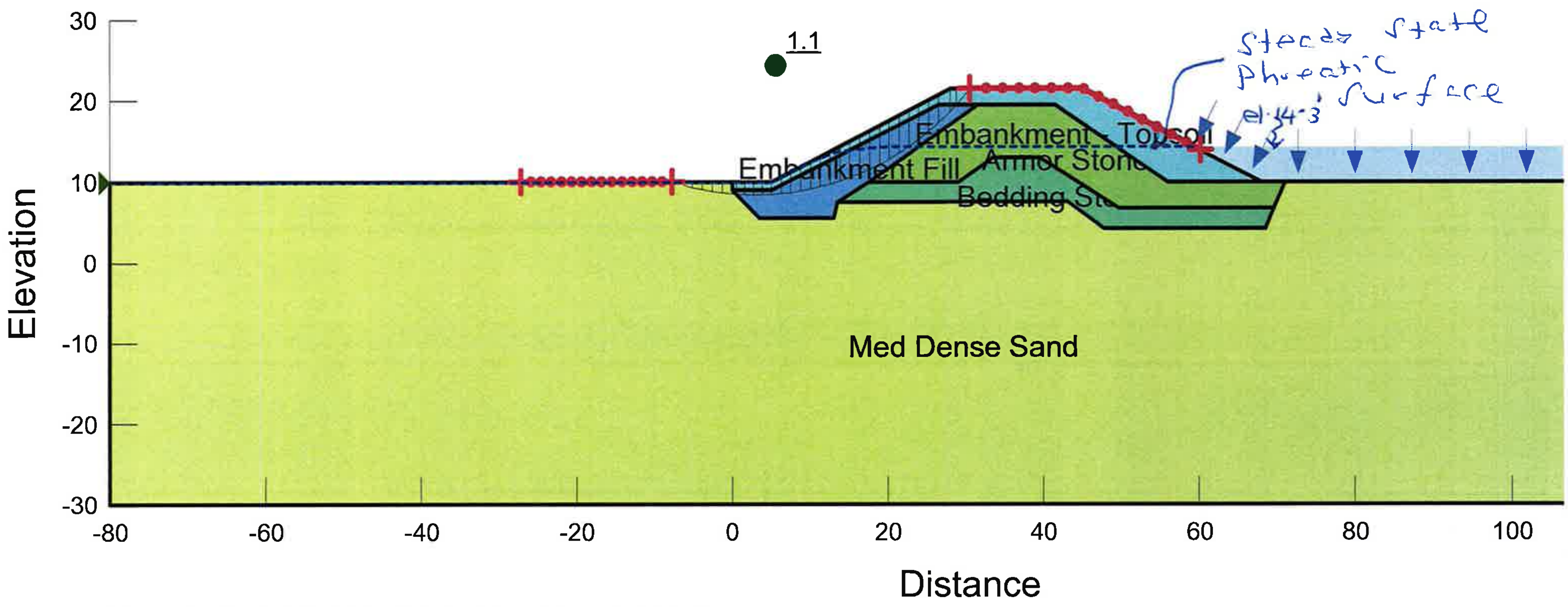


Reach A-7_WT El. 14_transient_k-constant_TimeToSS.gsz

FIGURE-12

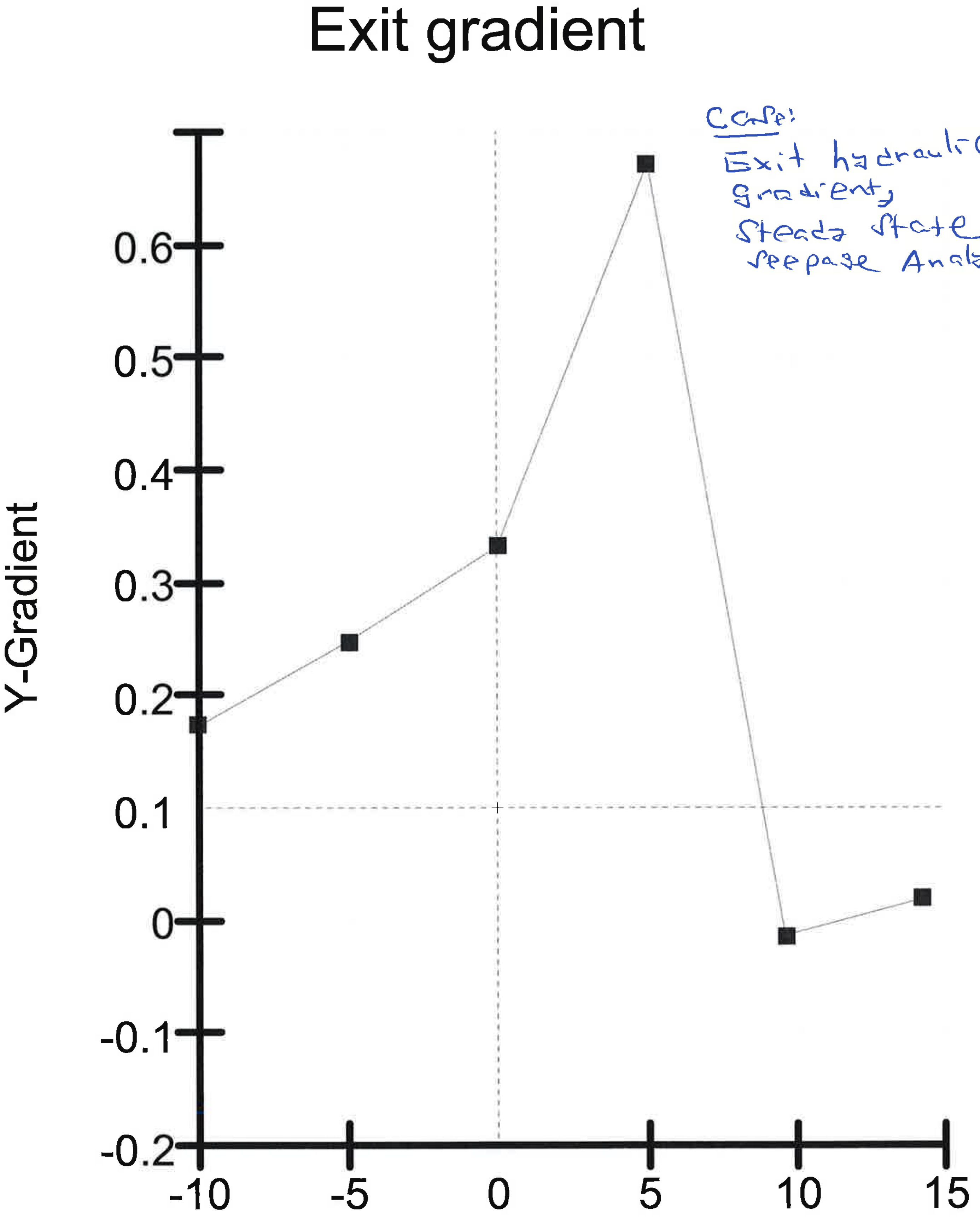
Case: Phreatic Surface from Steady State Seepage Analyses.

Name: Med Dense Sand   Model: Mohr-Coulomb   Unit Weight: 120 pcf   Phi: 30 °
Name: Armor Stone   Model: Mohr-Coulomb   Unit Weight: 145 pcf   Phi: 38 °
Name: Bedding Stone   Model: Mohr-Coulomb   Unit Weight: 140 pcf   Phi: 36 °
Name: Embankment - Topsoil   Model: Mohr-Coulomb   Unit Weight: 125 pcf   Phi: 32 °
Name: Embankment Fill   Model: Mohr-Coulomb   Unit Weight: 125 pcf   Phi: 32 °



Reach A-7_WT El. 14.3_No_Grout(AR3).gsz

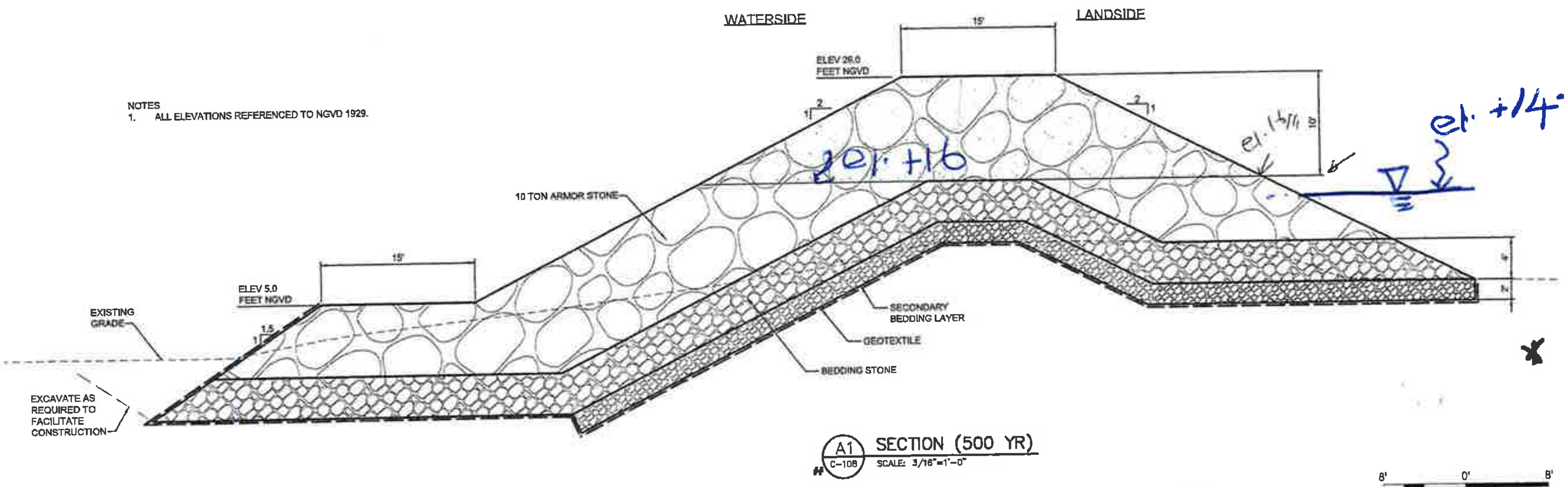
FIGURE-13



Case:
Exit hydraulic gradient,
Steady State
Seepage Analyses

FIGURE-14

NOTES
1. ALL ELEVATIONS REFERENCED TO NGVD 1929.



A1 / C-108 SECTION (500 YR)
SCALE: 3/16"=1'-0"

8' 0' 8'
SCALE:3/16"=1'-0"

F I GURE - 15

PRELIMINARY
NOT FOR CONSTRUCTION

U.S. ARMY CORPS OF ENGINEERS
U.S. ARMY ENGINEER DISTRICT
NEW YORK, NEW YORK

DESIGNED BY:		DATE:
DWN BY:	CKD BY:	SOLICITATION NO.:
SUBMITTED BY:		CONTRACT NO.:
PLOT SCALE:	PLOT DATE:	FILE NUMBER:
SIZE:	FILE NAME:	

HURRICANE AND STORM DAMAGE REDUCTION
FEASIBILITY STUDY FOR THE SOUTH SHORE
OF STATEN ISLAND, NEW YORK

TYPICAL SECTION REACH A-8
(SHEET 2 OF 2)

SHEET
IDENTIFICATION
C-507

FIGURE- 15

ATTACHMENT E – SETTLEMENT ANALYSES RESULTS

Levee Settlement Analysis:

Given:

Width of Levee (ft)	Length of Levee (ft)	Depth of Levee Base (ft)	Average N-Value over Depth
$B := 65$	$L := 1$	$D := 0$	$N_{ave} := 14$

Depth to GWT (ft)	Bearing Pressure (tsf)	Saturated Unit Weight (pcf)
$D_w := 0$	$q_{tsf} := 1.2$	$\gamma_{pcf} := 120$

Find:

Immediate settlement by:

1. "Modified Terzaghi and Peck Approximation"

2. "Burland and Burbidge Approximation"

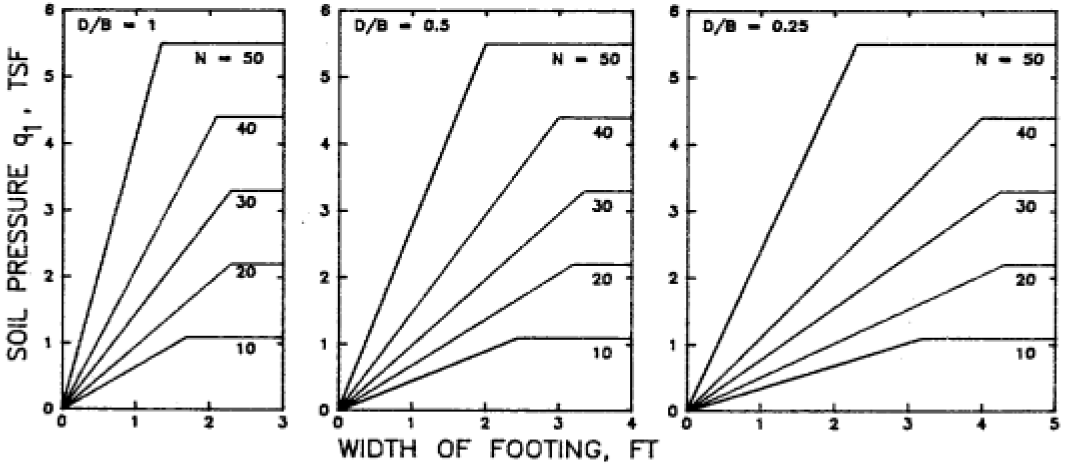
according to the:

"U.S. Army Corps of Engineers, September 30 1990 "Engineer Manual 1110-1-1904 - SETTLEMENT ANALYSIS".

1. Modified Terzaghi and Peck Approximation (ρ_{it}):

$$\rho_{it}(q_1) := \frac{q_{tsf}}{(18 \cdot q_1)}$$

where q_1 = soil pressure from Figure 3-3a using corrected blowcount N' and the ratio of embedment depth D to footing width B, tsf.



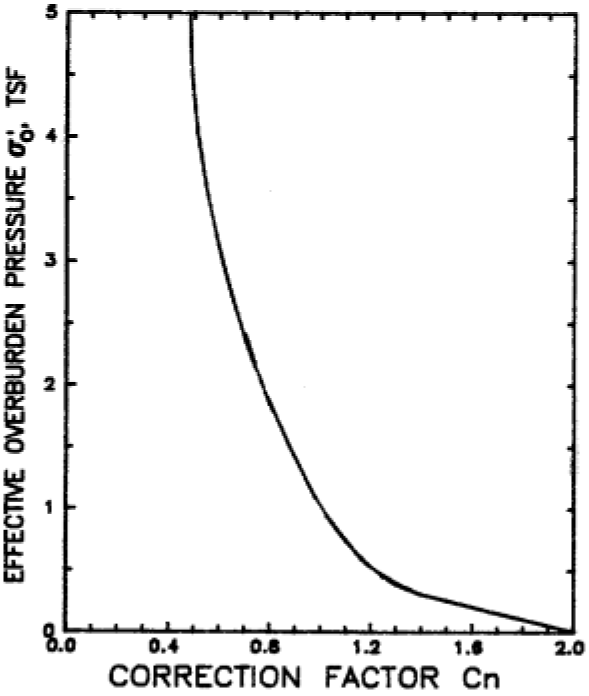
a. EVALUATION OF SOIL PRESSURE q_1 FROM CORRECTED BLOWCOUNT N' AND EMBEDMENT DEPTH/FOOTING WIDTH RATIO D/B

$$N_{prime}(C_w, C_n) := N_{ave} \cdot C_w \cdot C_n$$

$$C_w := \begin{array}{|l} 0.5 \ \text{ if } \ D_w = 0 \\ 1 \ \text{ if } \ D_w > D + B \\ 0.5 + 0.5 \cdot \dfrac{D_w}{D + B} \ \text{ otherwise} \end{array}$$

$$C_w = 0.5$$

(2) Overburden pressure correction. The correction factor Cn is found from Figure 3-3b as a function of the effective vertical overburden pressure σ_o'.



b. CORRECTION Cn FOR EFFECTIVE OVERBURDEN PRESSURE σ_o'

$$\sigma_o := \gamma_{pcf} \cdot \frac{D}{2000}$$

$$\sigma_o = 0$$

$$C_n := 1.6$$

$N_{prime}(C_w, C_n) = 11$

$\frac{D}{B} = 0$

$q_1 := 2.2$

$\rho_{ifeet} := \rho_{it}(q_1)$

$\rho_{ifeet} = 0.0303$

$\rho_{iinches} := \rho_{ifeet} \cdot 12$ Convert feet to inches

$\rho_{iinches} = 0.4$ Final answer in inches; approximately 0.5 inches

2. Burland and Burbidge Approximation (ρ_{ib}):

$\rho_{ibmm}(q_{Kpa}, B_m, I_c) := \left(q_{Kpa} \cdot B_m^{0.7} \cdot I_c\right)$ Gives settlement in mm

$q_{Kpa} := q_{tsf} \cdot 95.76$ Convert tsf to Kpa

$q_{Kpa} = 114.912$

$B_m := \frac{B}{3.28}$ Convert feet to meters

$B_m = 19.817$

Note that Nave is identical to the average SPT blowcount measured over a depth of $B_m^{0.75}$

$I_c := \frac{1.7}{N_{ave}^{1.4}}$

$I_c = 0.042$

$\rho_{ibmm1} := \rho_{ibmm}(q_{Kpa}, B_m, I_c) = 39.279$

$\rho_{ib} := \rho_{ibmm1} \cdot \frac{12 \cdot 3.28}{1000}$ Convert mm to inches

$\rho_{ib} = 1.5$ Final answer in inches; approximately 1.5 inches

Note:

1. Stress at the bottom of the embankment will be less than γh (full stress) because of the slopes. But, in this analysis, the full stress was conservatively considered. The embankment base width, B, was considered as the width between mid of slopes (65ft <= 50/2 + 15 + 50/2).

ATTACHMENT F – FLOODWALL PILE ANALYSIS RESULTS

Summary of Floodwall Pile Designs

It is our understanding that the floodwall is to be supported on piles. Based on the subsurface conditions and DRIVEN pile capacity analyses, we recommend HP14x89 friction piles driven to sandy stratum for this purpose. As per the DRIVEN analysis results, attached, the following recommendations are provided:

1) **70 tons (Tension/Compression):**
   - 70 tons Tension = 115 feet
   - 70 tons Compression = 95 feet

2) **50 tons (Tension/Compression):**
   - 50 tons Tension = 95 feet
   - 50 tons Compression = 80 feet

3) **35 tons (Tension/Compression):**
   - 35 tons Tension = 80 feet
   - 35 tons Compression = 70 feet

It should be noted that the maximum depths of available soils borings is only about 50 feet, and the above preliminary results were estimated without any deep boring details. Also note that when the required tension and compression capacities are same, the pile length should be determined based on the length corresponding to the tension capacity.

DRIVEN 1.2

GENERAL PROJECT INFORMATION

Filename: C:\PROGRA~1\DRIVEN\SSSI.DVN
Project Name: SSSI   Project Date: 07/31/2014 → 01/20/15
Project Client: USACE
Computed By: VN
Project Manager: VN

VN

PILE INFORMATION

Pile Type: H Pile - HP14X89
Top of Pile: 0.00 ft
Perimeter Analysis: Box
Tip Analysis: Pile Area

ULTIMATE CONSIDERATIONS

Water Table Depth At Time Of:	- Drilling:	0.00 ft
	- Driving/Restrike	0.00 ft
	- Ultimate:	0.00 ft
Ultimate Considerations:	- Local Scour:	0.00 ft
	- Long Term Scour:	0.00 ft
	- Soft Soil:	0.00 ft

ULTIMATE PROFILE

Layer	Type	Thickness	Driving Loss	Unit Weight	Strength	Ultimate Curve
1	Cohesionless	100.00 ft	0.00%	120.00 pcf	30.0/30.0	Nordlund
2	Cohesionless	50.00 ft	0.00%	120.00 pcf	32.0/32.0	Nordlund

ULTIMATE - SUMMARY OF CAPACITIES

Depth	Skin Friction	End Bearing	Total Capacity
0.01 ft	0.00 Kips	0.00 Kips	0.00 Kips
9.01 ft	4.01 Kips	1.64 Kips	5.65 Kips
18.01 ft	16.03 Kips	2.41 Kips	18.45 Kips
27.01 ft	36.06 Kips	2.41 Kips	38.47 Kips
36.01 ft	64.09 Kips	2.41 Kips	66.51 Kips
45.01 ft	100.13 Kips	2.41 Kips	102.55 Kips
54.01 ft	144.18 Kips	2.41 Kips	146.59 Kips
63.01 ft	196.23 Kips	2.41 Kips	198.65 Kips
72.01 ft	256.29 Kips	2.41 Kips	258.71 Kips
81.01 ft	324.36 Kips	2.41 Kips	326.78 Kips
90.01 ft	400.44 Kips	2.41 Kips	402.85 Kips
99.01 ft	484.52 Kips	2.41 Kips	486.93 Kips
99.99 ft	494.16 Kips	2.41 Kips	496.57 Kips
100.01 ft	494.38 Kips	5.98 Kips	500.36 Kips
109.01 ft	608.07 Kips	5.98 Kips	614.05 Kips
118.01 ft	731.56 Kips	5.98 Kips	737.54 Kips
127.01 ft	864.83 Kips	5.98 Kips	870.82 Kips
136.01 ft	1007.90 Kips	5.98 Kips	1013.88 Kips
145.01 ft	1160.76 Kips	5.98 Kips	1166.74 Kips
149.99 ft	1249.55 Kips	5.98 Kips	1255.53 Kips