US Army Corps
of Engineers®
New York District

NEW YORK AND NEW JERSEY HARBOR DEEPENING CHANNEL IMPROVEMENTS

NAVIGATION STUDY

INTEGRATED FEASIBILITY REPORT &
ENVIRONMENTAL ASSESSMENT

APPENDIX B2:

Geotechnical Analysis

TABLE OF CONTENTS

Attachments

Attachment #1	Figures
Attachment #2	SPT Boring Logs
Attachment #3	Slope Analyses

1. Introduction

New York-New Jersey Harbor consists of numerous bays, rivers, and channels of complex shape that are connected to the Hudson River. Some channels and bays within the New York-New Jersey Harbor will go through widening, deepening, and bend easing to improve navigation efficiencies within the New York and New Jersey Harbor and allow passage of Maersk Triple E Ultra Large Container Vessel Class (ULCS) as the design vessel for this study. The Feasibility Study of New York and New Jersey Harbor Deepening Channel Improvement is an evaluation for channel widening, deepening, bend easing, and related improvements throughout the Ports of New York and New Jersey. The study areas include Anchorage, Port Jersey, Kill Van Kull, Arthur Kill, and Newark Bay reaches (Figure 1).

To perform the economic analysis of widening, deepening, and bend easing the channels, a number of factors will need to be considered. These factors include the physical nature of the material to be removed, how much material will be removed, appropriate methods of removal, where to dispose of dredged material, and what effects the project will have on nearby properties. In order to provide proper solutions for these factors, relatively detailed knowledge of the subsurface are required as follows:

- characterizing the nature and extent of the various bedrock formations, and mapping the top of bedrock to delineate where it will occur along the proposed channel improvements so that volumetric calculations can be performed,
- sampling and mapping the thickness of contaminated material throughout the port so that volumetric calculations of contaminated material can be performed,
- performing settle analysis and bench tests to assess whether soft, fine-grained sediment that is not suitable for HARS disposal will dewater passively, or if more aggressive dewatering techniques may be required (geotextile tubes, etc.) before it can be transported to an upland disposal facility,
- other mapping such as top of Pleistocene and sand/gravel to help define the dredgeability and disposal options for the dredged materials in the various reaches,
- defining profiles and cross-sections to illustrate the aerial distribution of the various soil and rock types that will be encountered along each reach. Based on the profiles and cross sections, a specific course of action such as blasting or dredging with a specific type of dredge is determined,
- defining the characteristics (soil or rock classification, density, unit weight, compressive strength etc.) of various soil and rock types to be encountered along each reach so that dredgeability analysis and slope stability analysis can be performed,
- determining which dredging equipment that might be best suited for each stratigraphic reach using available computer programs and dredging records,

- evaluate diggability of broken rock material left by previous blasting (test digs),
- evaluate need for pre-treatment (blasting) of various bedrock formations, based on past construction history, rock testing (strength, seismic velocity, etc.), and structure (bedding, fracture orientation, etc.),
- analyzing the stability of the channel side slopes; and
- evaluating the potential effects that blasting may have on nearby structures.

Recent economic analysis shows that deepening the pathways by 4 feet (to -54 feet MLLW) and by 5 feet (to -55 feet MLLW) have considerable net benefits. Hence, in this study, dredgeability and slope stability analyses for project areas were performed on the basis of both 4 feet and 5 feet deepening.

2. Geological Information

Bedrock geology in the Project Area consists of three primary sequences of rock, separated by erosional unconformities, meaning that there is a gap in the rock record where intervening materials have been removed by erosion. Reference Figure 2 and 3.

The oldest rock is the hard, crystalline metamorphic Manhattan Schist and Serpentinite present along a north-south trending band that runs from Staten Island north through Port Jersey all the way up along the east side of the Hudson River estuary, reflecting a narrow southward extension of the New England Uplands. This series of rock is known as the Manhattan Prong. The schist is mapped as the Hartland Formation. The Serpentinite is present as “bodies of varied size within the Hartland Formation” (Volkert, 2016). Manhattan Schist outcrops in Central Park and Serpentinite outcrops on Todt Hill on Staten Island, forming the highest natural point in New York City (Merguerian, 2008).

These rocks formed during Ordovician time, as part of the Acadian mountain building event, when the Proto-Atlantic Ocean (Iapetus) started closing, and the North American plate collided with a westward moving plate of volcanics. The sediments which had been deposited offshore were metamorphosed by the force of the collision, turning them into schists. The volcanic plate became sutured or welded to the North American plate, and the volcanic/oceanic plate, rich in iron and magnesium, was heavily altered, and turned into Serpentinite. This suture line is known as Cameron’s Line, a thrust fault, where the oceanic plate is believed to have been thrust over the continental plate. Rocks were folded and overturned. Material west of this line is part of the original continental plate. Material to the east of this line represents oceanic crust that was accreted, or welded on during this collision. Subsequent collisions also added landmass east of this area, until the current Atlantic Ocean started opening. The schist and serpentinite surface was exposed and eroded for many years, leaving behind a hard north-south trending “spine” that slopes off to both the west and more steeply to the east.

The next oldest rocks are the Triassic-aged sedimentary beds of sandstone and shale deposited into the Newark Basin to the west, subsequently intruded by igneous rock, diabase sills, preferentially along and parallel to the sedimentary bedding planes during the Jurassic. The diabase is known as the Palisades Sill. The sedimentary bedrock bedding dip gently to the west. The diabase sills outcrop as harder ridges, such as at the southwest tip of Bayonne, and all along the west side of the Hudson River.

The youngest bedrock was deposited during the Cretaceous, as sheets of sediments deposited on the eastern flank of the hard, Ordovician metamorphics, lying unconformably on them, and sloping to the east. Formations include the Raritan overlain by the Magothy, and are present only in the subsurface at depth within the project area, and believed to underlie the Ambrose Channel.

Newark Bay and the Hudson River and its outlet to the Upper Bay likely formed preferentially in the less resistant, more easily eroded Triassic sandstone and shale bedrock, leaving the harder rock types (Serpentinite and Palisades diabase sill) exposed as highlands.

The maximum extent of glaciation during the Wisconinan age deposited the glacial moraine exposed in Brooklyn. The pre-glacial valleys carved into bedrock were later filled with glacial till, sandy and gravelly outwash, and fine-grained deposits in lakes formed when drainages became blocked. Till commonly mantles the bedrock surface.

2.1. Bedrock Lithology and Top Contour Map of Rock

The locations and types of rock which are encountered if the channels are deepened to proposed deepening depths of -54 feet MLLW and -55 feet MLLW are shown in Figure 4. The contour map of top of rock can be employed to determine the volume of rock that will require removal. The location, type, and volumes of rock can be used for blasting analysis and cost analysis.

Bedrock in the Kill Van Kull consists of Serpentinite and Schist metamorphic rocks in the Constable Hook reaches, Sandstone, a sedimentary rock, in the Bergen Point reach, Diabase, an igneous intrusive rock from Bergen Point to the eastern part of Newark Bay, and Shale, a sedimentary rock with the arkosic sandstone member at Shooters Island. Throughout the Kill Van Kull, previously blasted, fractured, or moderately weathered bedrock underlies the channel.

Bedrock in the Newark Bay consists of mainly Sandstone with shale member on the west, and mainly Diabase with Sandstone and Shale on the east. The Sandstone and Shale are members of the Brunswick Formation (Triassic), subsequently intruded by Diabase (Jurassic).

Bedrock in the Port Jersey Channel is mainly Schist. The east of the Port Jersey Channel is known to be in thrust-fault contact with Serpentinite associated with the Hartland Formation. Bedrock was not encountered above the projected project depths (-54 feet MLLW and -55 feet MLLW) in the Anchorage and Port Jersey channels.

Poorly consolidated sandstone and shale of the Atlantic Coastal Plain Physiographic Province (Tertiary-Cretaceous) underlies Ambrose Channel but were not encountered within the depth of El. -75 MLLW.

2.2. Pleistocene Sediments

The bedrock complex is overlain by Pleistocene glacial sediments that range in size from silt and clay to large cobbles and boulders. In most cases glaciation subdued the terrain by leveling the higher peaks and filling the valleys with glacial till (ground moraine). However, in some cases, low relief, elongated hills were formed by debris pushed in front (terminal moraine) or to the sides (lateral moraines) of the advancing glacier. A terminal moraine exists along the south edge of Staten Island up to the Narrows, and then appears again in the Bay Ridge section of Brooklyn. The terminal moraine continues out on Long Island to Nassau County where it splits into two separate terminal moraines that continue out to Montauk Point and Orient Point. The southern terminal moraine is known as the Ronkonkoma and the northern as the Harbor Hill. Adjacent to the Narrows, the Harbor Hill terminal moraine overlies the Ronkonkoma.

Southeast of the terminal moraine are outwash deposits of sand and gravel that extend under Lower New York Bay. These fluvial deposits are the result of ice melt water washing soils out beyond the terminal moraine. Behind the terminal moraine is a ground surface moraine deposit consisting of an unsorted mixture of sand, silt, clay, gravel, cobbles and boulders. These materials were picked up by the advancing ice and dropped as the ice melted. Scattered within this ground moraine are fluvial deposits, such as eskers and kames, which were deposited by concentrated ice melt water that flowed in and under the ice.

As the glacier receded, the terminal moraine became a natural dam that impounded the glacier melt water and formed a number of large lakes. Varved silts and clays were deposited within these lakes. These varved deposits which overlie ground moraines are sometimes as thick as 100 feet. Sands were deposited on top of the varved silt and clay when the lakes became shallow. Eventually the terminal moraine was breached, and the glacial lakes were drained. Subsequent to the draining of these glacial lakes, outwash plains composed of alluvial sand deposits were formed along the perimeter of the lakebeds.

Figure 5 shows the glacial geology of the Project Area, and Figure 6 shows a contour map of the top of the Pleistocene sediments. The map defines where the dense (more difficult to dredge) Pleistocene Sediments will be encountered. It should be noted that Pleistocene sediments (outwash and till) are normally red to brown, rarely contain shells and are relatively dense when compared to Holocene (Recent) sediments, which are normally gray to black and frequently contain shells. Although there are significant differences between Pleistocene and Holocene (Recent) sediments, it is not always easy to define the top of the Pleistocene. Based on N values and soil descriptions of soil borings, it is anticipated that most of the sediments in the Anchorage, Port Jersey, Kill Van Kull, and Newark Bay reaches will be Pleistocene. The top of Pleistocene contour map can be considered a Paleo-structure or Paleo-geographic map. It is known that the top of the Pleistocene normally occurs at an elevation of approximately -20 feet MLLW along the flats adjacent to channels.

2.3. Sand/Gravel Sediments (Pleistocene-Holocene)

A map of the top of Pleistocene sediments is shown on Figure 6. The map can be used to determine where the dredged material will be predominantly sand and gravel, silt and clay, till, or some combination. The map should be used in conjunction with the profiles and cross-sections to help define the most suitable contract limits, possible dredge types, and disposal location. All these factors are employed in the cost analysis.

2.4. Holocene (Recent) Sediments

It is known that during the last 20,000 years, sea level has risen as much as 300 feet and continues to rise at a rate of one to two feet per 100 years. As a result, the project area that was high and dry during the Pleistocene has become a tide-dominated estuary. A blanket of Holocene (Recent) sediments ranging from poorly graded sand, silty sand, slightly organic silt, and occasionally peat has been deposited. The thickness of the Holocene section is a few feet in the flats adjacent to the navigation channels.

The upper portion of the Holocene section often emits a petroleum-like odor and contains man-made debris including toxic chemicals and heavy metals. One objective of this study was to estimate the aerial distribution (location and thickness) of the contaminated material so that volumes could be approximated. This was accomplished through the use of isopach (thickness) maps. The thickness of contaminated material above -60 feet MLLW was determined in those borings in which it was detected. The thickness of the contaminated interval was estimated in each boring from physical characteristics (moisture content, color, odor, and soil density), scanning methods (UV fluorescence and photoionization) and direct testing (total petroleum hydrocarbons). The isopach map shown in Figure 7 shows the thickness and aerial distribution of Holocene sediments. Not all Holocene deposits are assumed to be contaminated. Assumptions as to whether the excavated material is HARS-suitable or in need of upland disposal were based on data collected from the prior deepening project. Additional data collection will be needed to verify these assumptions. Refer to Section 9.1 of Appendix B1. Previous studies and data are located at the New York District.

3. Data Review and Analysis Methodology

3.1. Review and Inventory of Existing Subsurface Data

A review of previous Corps of Engineer reports and dredging contracts was conducted to obtain existing subsurface information. Other public agencies and private sources were contacted to determine the availability of additional subsurface data. As few soil testing borings were located within limits of proposed reaches, soil testing borings located outside of limits of proposed reaches also were considered to obtain existing subsurface information of proposed reaches. The distribution, depth, and quality of the available data was reviewed to determine the need for additional subsurface data. It was shown through the review that some of the channels such as Kill Van Kull, and Anchorage would require very little additional data whereas other channels including Newark Bay and Port Jersey would require more additional subsurface data due to lack of existing subsurface data.

3.2. Field Testing and Subsurface Data

Standard Penetration Test (SPT) methods have been applied to collect continuous soil samples throughout the proposed reaches. It is known that the majority of SPT borings had been performed a few decades ago. The current boring logs do not provide type or dimensions of split spoon sampler, length of rod, type of drilling rig, and type or dimensions of auger necessary to correct SPT data. ASTM D4633 recommends energy correction to standardize SPT data into N_{60} where the energy delivered to the sampler is 60% of the theoretical value. The most dominant factor, the energy efficiency of previously used SPT equipment *was assumed* to be 60%. So, the energy correction of SPT field data was not performed.

In literature, some correlations require a correction for effective overburden stress. It is known that the correction for effective overburden stress mainly is applied to coarse grained soil type as most of the references developed the correction for effective overburden stress on the basis of sand data. For this study, the governing soil types that cause critical failure surfaces on (undersea) submerged slopes are clay and clayey silt. In addition, empirical correlations that do not consider the correction for effective overburden stress and are widely used in the industry were used to estimate soil properties for this study. The correction for effective overburden stress was not applied for this study.

Representative soil samples were selected for testing from both SPT borings and “vibracores” to define the geotechnical properties of the soil necessary for: slope stability analysis, dredging analysis, blasting analysis, and to employ possible low-cost and efficient techniques to determine the thickness of the contaminated interval. Geotechnical testing included grain size distribution, moisture content, unit weight, specific gravity, and liquid and plastic limits. Multiple “undisturbed” (Shelby Tube) samples were recovered from each of the major silt and clay layers. Triaxial tests were performed on the “undisturbed” samples to determine shear strength, cohesion, and other factors that are necessary for slope stability.

The thickness of the contaminated interval was determined by use of ultra-violet fluorescence, photoionization, total petroleum hydrocarbons, and moisture content.

Rock cores were recovered in those areas where shallow bedrock was encountered (above -65 feet MLLW). Cores were described in detail and rock quality designation (RQD) was determined. Point load tests were conducted on representative core samples.

3.3. Soil Profiles and Cross-Sections

In the subsequent subsections, the individual reaches are described in detail through the use of soil profiles and simplified cross-sections. The idealized profiles were employed to illustrate the aerial extent of the various soil and rock types that will be encountered within reaches. Soils that have similar characteristics (i.e., Silty Sand and Silty Gravel) or that are difficult to differentiate in the field (i.e., Silty Clay or Clayey Silt) were grouped together to define stratigraphic units. Soil color was employed as another factor in determining the stratigraphic units illustrated. Pleistocene sediments are commonly reddish-brown whereas the Holocene sediments are frequently gray, tan, or black. Although a stratigraphic unit is, for instance, called Holocene Silt and Clay, it may contain minor sand or gravel sub-units.

Simplified cross sections show the stratigraphy of soil and rock types that are encountered along the middle of reaches. The soil types and their properties such as unit weight, cohesion, and friction angle are very significant factors to be considered in determining side slope stability.

Rock types, structure, strength, and fracturing are key factors in assessing diggability and in determining the need for pre-treatment (blasting).

3.4. Dredgeability Analysis

The program DREDGABL, developed by WES (now ERDC), was used as an aid in determining the suitability of various dredges based on the sediments. The program has guides which lead the engineer to determine if a given sediment type can be dredged and what dredges are most appropriate for the dredging procedure. The guides require the soil type, rock type, fineness (grain size), consistency (i.e., soft, medium, stiff, or hard), and in-situ compactness (i.e., loose, medium, or dense). For compressible sediments (both Organic and Inorganic Clay and Silt), soil types, described by using the Unified Soil Classification System (USCS), and soil consistency are needed to perform the dredgeability analysis. For coarser sediments (Sand and Gravel), specific USCS soil type and density (compactness) are needed. Additionally, the guides provide dredgeability information for rock and shale fragments, cemented soils, shells, and debris.

Boring logs are provided in Attachment 2, and program outputs are provided in Attachment 3.

Table 1 is a summary of the general dredging characteristics of the overall dredge types. Average hourly dredging production rate of each dredge type were estimated by using past dredging data including total hours and total volume of individual dredge types employed in various materials for NYNJ harbor improvements. Table 1 shows the ranges of average hourly production rate of each dredge type employed in various materials. Specific dredges are listed for each reach. Before a final dredge type is selected, coordination with other agencies must be made. Some dredge types are not permitted because of environmental concerns, cost, or availability. Final selection of the dredge type to be used lies with the Contractor in coordination with the USACE and other agencies.

Table 1: Summary of Dredge Operating Characteristics

Dredge Type	% Solids in Slurry By Weight	Turbidity	Open Water Operation	Range of Production (cu.yd. /hr.)	Dredging Depth Limits (ft)	Wave Height Limits (ft)	Limiting Currents
Hopper Dredges	10 - 20	High	Yes	500 - 2000	< 80	< 7	7 Knots
Mechanical Dredges	In Situ	Average	Yes	30 - 500	< 100	< 3	3 Knots
Pipeline Dredges	10 - 20	Average	Depends On Type	25 – 10,000	< 14	< 3	3 - 7 Knots

Each reach can be considered either "soft" or "moderate to hard" as a reference to the ease of dredging. Overall, Ambrose, Anchorage, and Port Jersey Channel can be considered "soft" because the sediments are relatively loose sands or soft to very soft silts and clays and should be easily dredged. Channels such as Kill Van Kull, Newark Bay, and Port Jersey can be considered "moderate to hard" either because the sediments are dense to very dense or rock is present; these channels would require additional efforts during dredging including rock blasting. Based on previous experience, rock having unconfined compressive strengths less than 7,000 psi or rock quality designation (RQD) values less than 30% is considered dredgeable. Rock testing data is on file at the New York District.

Some portion of the hard bedrock to be removed in the proposed deepening would have been fractured and broken up during the previous drilling and blasting process. Hence, it was assumed for the purpose of cost estimates that approximately 30 to 40% of the bedrock areas, in particular, Kill Van Kull Channel, to be deepened may be removed to the design grade without pre-treatments such as drilling and blasting.

3.5. Slope Stability Analysis

It is necessary to determine the stability of the channel side slopes for the following reasons:

- If there are structures close to the top of the slope and failure occurs, the structural stability of the structure is diminished, and very significant damage may occur.
- If reach side slopes are not stable, then failure will result in significant shoaling. Frequent expensive maintenance including dredging will be required.
- Proper measures to remedy unstable slopes can be taken into consideration. The measures can be simulated to verify their effectiveness.
- After estimating approximate full extents of unstable slopes and determining proper measures to remedy unstable slopes, total cost for stabilization of unstable slopes can be approximated.

Slope stability analysis was performed using the computer program SLOPE/W developed by Geo-Slope International, Ltd. The program requires input including data such as channel slope profiles, stratigraphy, and soil properties. The Spencer's method was used to obtain the lowest factor of safety for the governing cross section of each slope. Circular and non-circular potential failure surfaces were searched with optimization.

Side slopes of each reach in non-rock material were constructed and have been maintained at a 1 (rise) on 3 (run) ratio. These slopes are very similar to those that existed along the natural channel prior to dredging. It is known that these side slopes have been proven to be stable near critical structures for all types of soils within the channel. However, even slopes with 1 on 3 may not be stable especially for soft soils such organic silts, peat, and loose sands. Excessive sloughing of these types of soils may occur causing more frequent maintenance dredging. Hence, while in view of these factors, a side slope of 1 on 3 is considered where possible, resulting unstable slopes should be stabilized by low-cost measures, such as using shallower side slopes. The results of slope stability based on a 1 on 3 side slope is summarized for each channel evaluated.

The existing channel side slopes in rock areas were constructed at a 1 (rise) on 1 (run) ratio. This slope has proven to be stable, especially near structures. The 1 on 1 side slopes were basically formed from the blasting. The explosives in the blast holes break and push the rock upward in a shape of a 45-degree angle cone. These 1 on 1 side slopes in rock are relatively easy for a contractor to dredge after blasting. In view of these factors a side slope of 1 on 1 is recommended where possible in rock areas. In areas where a steeper slope is required, more detailed analysis should be performed. Factors such as the orientation (strike and dip) of fractures and bedding planes should be determined.

4. Dredgeability and Slope Analyses

The Recommended Plan involves deepening Ambrose Channel, Anchorage Channel, the Kill Van Kull (KVK), Newark Bay Channel, South Elizabeth Channel, Elizabeth Channel, and Port Jersey Channel. Moving from the port entry on the east side to Newark Bay on the west, the dredgeability and slope stability were assessed for the following reaches: AN-1, PJ-1, KVK-1, NWK-1, and NWK-2. Results of the slope stability analyses performed at several locations within these reaches are presented in Attachment #3 of this Appendix B-2.

The KVK channel is the only channel which has structures in proximity both on its north and south sides. A detailed description about the bathymetry, topography, and surface structures in various reaches of KVK are discussed in Appendix B-3 "Structural" of this report. Based on the discussion presented in Appendix B-3, the slopes of the channel were assumed to be stable at 1V to 3H, which translates to a horizontal distance of about 186 feet from the proposed revised depth of this channel. It is likely that some waterfront structures are located within this 186-foot horizontal distance and would be affected by the proposed channel deepening, requiring steeper channel slopes. It is also indicated that there are not many structures of concern in this area of

KVK channel because the combination of the additional width and blasting mitigation efforts would provide adequate protection.

The stability of the channel bottom, if provided with steeper slopes and the stability of structures that could potentially be impacted by the channel deepening would be evaluated during the PED phase of the project. Based on the estimated soil densities and on the bedrock strength characteristics which are relatively similar in the reaches of the various channels, stability of the slopes resulting from the deepening operations is not expected to be of concern.

All material within the improvement footprint is anticipated to be dredgeable by mechanical methods. Rock materials may require pretreatment prior to removal by clamshell or excavator dredge. In the existing channel footprints, rock previously blasted in the sub-drill of the previous improvement project may not need additional pretreatment, but these areas have not been defined. During PED, additional site characterization and test digging will be conducted to delineate and quantify the dredgeability of soil and rock. No materials are anticipated to be removed by hydraulic suction dredging.

Slope stability and dredgeability analyses will be conducted for all reaches, including KVK-2, KVK-3, KVK-4, KVK-5, AK-1, AK-2, and SE-1, during the pre-construction engineering design phase (PED). During PED additional field and laboratory investigations will be performed to inform the analyses. The results of the additional analyses will be presented in a geotechnical and geological engineering baseline report to support a design analysis report.

4.1. Anchorage Channel (AN-1)

4.1.1. Stratification

Anchorage Channel is the primary channel in the Upper Bay. Reach AN-1 is located at the south end of the Anchorage Channel. Soil test borings performed at this reach are displayed in Figure 8. The stratification of Reach AN-1 was determined based on types and consistencies of each material encountered in the soil test borings. The stratification of Reach AN-1 is shown in Figure 13. The profile indicates that the Reach AN-1 is primarily composed of Holocene (Recent) Silt. Based on proposed deepening depths of fifty-four feet below mean lower low water (-54 feet MLLW) and fifty-five feet below mean lower low water (-55 feet MLLW), Silt can easily be determined as a material to be removed when the reach are deepened.

4.1.2. Dredgeability

For the purpose of DREDGABL analysis, the Silt in Reach AN-1 was classified as either OL or OH with very soft to soft consistencies and medium to high plasticity. These criteria were determined from a review of the boring logs in the reach. The Silts of Reach AN-1 have excavation characteristics classified as “good” for clamshell dredge, “very good to good” for backhoe dredge, and “very good” for cutter dredge as shown in Table 2.

Table 2: Dredgeability of Materials for Reach AN-1

Material Type	**Dredge Type**			
	Clamshell	**Backhoe**	**Cutter**	**Blast**
Silt	Good	Very Good to Good	Very Good	NA

When factors such as dredging records, contamination, disposal, and availability of dredging equipment are considered, an environmentally friendly clamshell dredge would appear to be the most suitable equipment to dredge Reach AN-1.

4.1.3. Slope Stability

Soil test boring location RHF98-25 was used to estimate soil strata and soil properties for analyses of slope stability as overall, the boring provides a representative profile of soil strata within Reach AN-1, as all borings in this vicinity encountered a similar profile to their total depth. The soil properties of soil strata of the boring are shown below.

Table 3: Soil Properties of Soil Strata at Reach AN-1

Boring No.	**Material Type**	**Top Elevation of Stratum (ft)**	**Representative N-Value (blows/ft) /RQD (%)**	**Unit Weight (pcf)**	**Cohesion (psf)**	**Friction Angle (Deg.)**
RHF98-25	Silt	-45.1	0 (blows/ft)	90	50	0
	Silt	-53.0	0 (blows/ft)	100	100	0

Using the above soil properties, circular and non-circular potential failure surfaces were searched by optimized grid-radius, entry-exit, and block analyses. As a result of simulations, the lowest safety factors of slope analyses for four feet and five feet deepening at this reach equals 1.71 and 1.51, respectively; the slope stability criteria with the minimum factor of safety of 1.5 was satisfied. The summary of slope stability analyses at Reach AN-1 is shown in Table 4.

Table 4: Summary of Slope Analyses at Reach AN-1

Boring No.	**Factors of Safety For 4 Foot Deepening**		**Factors of Safety For 5 Foot Deepening**	
	Min	**Max**	**Min**	**Max**
RHF98-25	1.711	1.794	1.505	1.567

4.2. Port Jersey Channel (PJ-1)

4.2.1. Stratification

The Port Jersey Channel is located in Bayonne, New Jersey, between the Military Ocean Terminal on the south and the Global Marine Terminal and the Northeast Automobile Terminal on the north. Reach PJ-1 is a triangle-shaped reach located at the entry of the Port Jersey Channel from Anchorage Channel. Soil test borings performed at this reach are displayed on Figure 9. The stratification of Reach PJ-1 was determined based on material types and material consistencies of the soil test borings. Reach PJ-1 mainly consists of:

- Holocene (Recent) sediments: soft black, grey, and dark grey Silt (OL or OH) and underlying Silty Clay (CL, OH or MH); and
- Pleistocene age sediments: a dense to very dense, fine to medium grained, red-brown Sand (SP-SM) with lenses of stiff Silt and Clay and occasional Gravel.

The stratification of Reach PJ-1 is shown in Figure 14.

4.2.2. Dredgeability

As the other sediments account for a limited amount of the total volume, Silt (OL or OH) and Silty Clay (CL, OH or MH) were analyzed as a main material to be dredged in Reach PJ-1. Based upon the results from the analysis, the Silt and Silty Clay of Reach PJ-1 have excavation characteristics classified as “good” for clamshell dredge, “very good to good” for backhoe dredge, and “very good” for cutter dredge. The Sand (SP-SM) of Reach PJ-1 is classified as “good to fair” for clamshell dredge, “good” for backhoe dredge, and “very good to good” for cutter dredge as shown in Table 5.

Table 5: Dredgeability of Materials for Reach PJ-1

Material Type	**Dredge Type**			
	Clamshell	**Backhoe**	**Cutter**	**Blast**
Silt & Silty Clay	Good	Very Good to Good	Very Good	NA
Sand	Good to Fair	Good	Very Good to Good	NA

Consistencies of Silts and Silty Clays were classified as very soft to soft and the consistencies of Sands were classified as being fine to medium grained with medium density. Based upon previous analyses the Recent Silt and Silty Clay sediments can be dredged by all dredges being used for comparison, therefore, only the Sand was used for determining the suitability of the selected dredge types. All dredge types are proved to be suitable for this reach with the cutter dredge having the best results. In view of dredging records, contamination, disposal, and availability of dredging equipment, a clamshell dredge will be suitable to dredge the Reach PJ-1.

4.2.3. Slope Stability

Soil test boring locations ANC98-81 and PJ-4 were used to estimate soil strata and soil properties for analyses of slope stability as overall, the borings bounded the range of soil profiles present across the reach, ranging from weight of rod (WOR) at ANC98-81, to soft silts overlying dense sand (N>80) at PJ-4. The soil properties of soil strata of the borings are shown in Table 6.

Table 6: Soil Properties of Soil Strata at Reach PJ-1

Boring No.	Material Type	Top Elevation of Stratum (ft)	Representative N-Value (blows/ft) /RQD (%)	Unit Weight (pcf)	Cohesion (psf)	Friction Angle (Deg.)
ANC98-81	Silt	-21.0	0 (blows/ft)	90	50	0
	Silty Clay	-33.0	0 (blows/ft)	100	100	0
	Sand	-63.5	70 (blows/ft)	135	0	42
PJ-4	Silt	-32.0	0 (blows/ft)	90	50	0
	Silty Clay	-35.0	0 (blows/ft)	100	100	0
	Sand	-42.0	80 (blows/ft)	135	0	42
	Schist	-84.0	NA	155	5000	40

Using the above soil properties, circular and non-circular potential failure surfaces were searched by optimized grid-radius, entry-exit, and block analyses. The simulations for the area of boring PJ-4 in the western portion of the Reach PJ-1 resulted in the lowest factors of safety for slope analyses for four feet and five feet deepening as 2.7 and 2.69, respectively. On the other hand, the area of boring ANC98-81 in the eastern portion of the Reach PJ-1 resulted in the lowest safety factors of slope analyses for four feet and five feet deepening as about 0.70 and 0.69, respectively. The area of boring PJ-4 in the western portion of the Reach PJ-1 satisfies the slope stability criteria with the minimum factor of safety of 1.5; however, the area of boring ANC98-81 in the eastern portion of the Reach PJ-1 fails to meet the minimum factor of safety. The summary of slope stability analyses at Reach PJ-1 is shown in Table 7.

Table 7: Summary of Slope Analyses at Reach PJ-1

Boring No.	Factors of Safety for 4 Foot Deepening		Factors of Safety for 5-Foot Deepening	
	Min	Max	Min	Max
ANC98-81	0.696	0.709	0.690	0.700
PJ-4	2.702	2.706	2.690	2.702

Critical slope failures in the area of boring ANC98-81 occur over the bottom of thick, soft consistency Silty Clay layer. The full extent of the soft Silt and Silty Clay should be further investigated to determine a proper type and the scope of application of mitigation measure to stabilize the slopes in the eastern portion of the Reach PJ-1.

As previously mentioned, Reach PJ-1 is abutted by Military Ocean terminal (MOT) on the south, by the GCT (GCT) container terminal on the north and by the Anchorage Channel at it east end. There are no neighboring structures at the east end of reach PJ-1 and in the Anchorage Channel. Limited flattening of slopes in Reach PJ-1, may be feasible at its east end, however, it will not be feasible to flatten slopes in the western portions of Reach PJ-1 where it is abutted by MOT and GCT.

4.3. Kill Van Kull Channel (KVK-1)

4.3.1. Stratification

The Kill Van Kull Channel is located north of Staten Island, New York and south of Bayonne, New Jersey. The channel connects Upper New York Harbor with the Arthur Kill Channel and Newark Bay Complex. Reach KVK-1 is a triangle-shaped reach located on the south of entry to Kill Van Kull from Ambrose Channel. Soil test borings performed at this reach are displayed on Figure 10. The stratification of Reach KVK-1 was determined based on material types and material consistencies of the soil test borings. The Reach KVK-1 mainly consists of:

- Holocene (Recent) sediments: soft black, grey, and dark grey Silt (OL or OH), and a layer of dense to loose consistency Sand (SP-SM) within it between -40 and -50 feet MLLW at the east end of the reach;
- Pleistocene age sediments: thin layer of dense glacial till at the west end of the reach; and
- Serpentinite bedrock, encountered only at the west end of the reach. Given the bedrock geology of the area, serpentinite would be expected, even where previously dredged to -50 feet MLLW, along the northeast-southwest trending band of older Ordovician metamorphic rock passing from Kill Van Kull up through the Port Jersey Channel.

The subsurface stratification of Reach KVK-1 is illustrated in Figure 15. Based on proposed deepening to -54 feet and -55 feet MLLW, Holocene (Recent) sediments (silt and sand) will be the primary materials to be removed when the reach is deepened, with the exception of some serpentinite bedrock present above -55 feet MLLW at the west end of the reach.

4.3.2. Dredgeability

Based upon the results from the analysis of dredgeability, the Silt of Reach KVK-1 has excavation characteristics classified as “good” for clamshell dredge, “good” for backhoe dredge, and “very good” for cutter dredge. Sand is classified as “very good to fair” for clamshell dredge, “very good to good” for backhoe dredge, and “very good” for cutter dredge. Cobble and Boulder are classified as “poor” for clamshell dredge, “fair to good” for backhoe dredge, and “good” for cutter dredge.

Serpentinite rock is encountered at -50 feet to -55 feet MLLW in the western portion of Reach KVK-1. These dredgeabilities of each material are summarized in Table 8.

Table 8: Dredgeability of Materials for Reach KVK-1

Material Type	Dredge Type			
	Clamshell	**Backhoe**	**Cutter**	**Blast**
Silt	Good	Good	Very Good	NA
Sand	Very Good to Fair	Very Good to Good	Very Good	NA
Cobble/Boulder	Poor	Fair to Good	Good	NA
Serpentinite	Very Poor	Poor	Poor	Good

Silt consistency was classified as very soft to soft and the consistencies of Sands were classified as density to loose. The consistency of the Cobble and Boulder layer (which could potentially indicate either a thin mantle of till, weathered bedrock, or an erosional surface) was classified as dense to very dense. and RQD of the Serpentinite rock was estimated as 44%. Based upon previous analyses, the Recent Silt and Sand sediments can be dredged by all dredges. In view of dredging records, contamination, disposal, and availability of dredging equipment, a clamshell dredge will be suitable to dredge the Recent Silt and Sand sediments in the Reach KVK-1. Cobble and Boulder can be dredged by backhoe and cutter dredges.

The Serpentinite rock had an estimated RQD of 44%, and given that the top of rock surface is just marginally above the proposed deepening depth, and is present only on the western end of the reach, it represents a relatively limited portion of the dredge volume here, though it can be expected to also be encountered below the Kill Van Kull Channel. Given the limited thickness of rock to be removed at KVK-1, and its RQD, a heavy cutter dredge may be sufficient to remove it, and pre-treatment (blasting) might not be required.

4.3.3. Slope Stability

Soil test boring locations ANC98-31, ANC98-30, and KVK98-1A were used to estimate soil strata and soil properties for analyses of slope stability as overall the borings can provide whole soil stratification which is useful to understand stabilities of slope proposed for four feet and five feet deepening. The soil properties of strata of the borings are shown in Table 9.

Table 9: Soil Strata Properties at Reach KVK-1

Boring No.	Material Type	Top Elevation of Stratum (ft)	Representative N-Value (blows/ft) /RQD (%)	Unit Weight (pcf)	Cohesion (psf)	Friction Angle (Deg.)
ANC98-31	Silt	-42.0	0 (blows/ft)	90	50	0
	Sand	-44.0	8 (blows/ft)	115	0	31
	Silt	-50.0	0 (blows/ft)	90	50	0
ANC98-30	Silt	-27.0	0 (blows/ft)	90	50	0
	Sand	-43.0	10 (blows/ft)	120	0	30
	Silt	-55.0	0 (blows/ft)	90	50	0
KVK98-1A	Silt	-22.8	0 (blows/ft)	90	50	0
	Sand	-39.0	4 (blows/ft)	110	0	28
	Sand	-43.0	18 (blows/ft)	120	0	32.5
	Serpentinite	-54.0	44%	155	5000	40

Using the above soil properties, circular and non-circular potential failure surfaces were searched by optimized grid-radius, entry-exit, and block analyses.

The simulations for the area of boring ANC98-31 in the eastern portion of the Reach KVK-1 resulted in the lowest factors of safety for slope analyses for four foot and five-foot deepening as about 0.54 and 0.49, respectively.

The area of boring ANC98-30 in the middle of the Reach KVK-1 resulted in the same lowest factor of safety for both four feet and five feet deepening as about 1.15. In addition, the area of boring KVK98-1A in the middle portion of the Reach KVK-1 resulted in the same lowest safety factor of slope analyses for both four feet and five feet deepening as about 1.14.

Overall, most of the KVK-1 reach appears not to satisfy the slope stability criteria of a minimum factor of safety of 1.5. The summary of slope stability analyses at Reach KVK-1 is shown in Table 10.

Table 10: Summary of Slope Analyses at Reach KVK-1

Boring No.	Factors of Safety for 4 Foot Deepening		Factors of Safety for 5 Foot Deepening	
	Min	Max	Min	Max
ANC98-31	0.473	0.481	0.488	0.573
ANC98-30	1.148	1.159	1.148	1.159
KVK98-1A	1.144	1.170	1.144	1.170

It is anticipated that the mode of critical slope failures in the eastern portion of Reach KVK-1 including boring ANC98-31 will occur as deep-seated slope failures due to very thin, soft consistency silt, overlying a five-foot thick medium consistency sand, over a very thick silt layer that extends to greater depth.

On the other hand, the mode of critical slope failures in the middle portion of Reach KVK-1, including borings ANC98-30, and KVK98-1A, will occur as local slope failures due to a ten-foot thick silt layer overlying a relatively thick (10 to 15 feet thick), medium to firm consistency layer of sand in the middle of the reach, overlying the very thick silt layer.

At the western portion of the reach (boring KN-11), silt (5 to 15 feet thick) overlies a very thin one-foot layer of weathered bedrock, dense till, or cobbles and boulders, over Serpentinite bedrock. Slope stability analysis was not performed for this profile.

The full extent of the soft consistency silt should be further investigated to determine a proper type and the scope of application of mitigation measure to stabilize the slopes in the Reach KVK-1.

4.4. Newark Bay (NWK-1)

4.4.1. Stratification

Newark Bay is located at the north of the junction of the Kill Van Kull and Arthur Kill Channels and extends northward to the New Jersey Turnpike Extension Bridge in Jersey City, New Jersey. Reach NWK-1 is a triangle-shaped strip located and extending from south to north on the eastern side of Newark Bay. Soil test borings performed at this reach are displayed in Figure 11. The proposed deepening depths for the reach are -54 and -55 MLLW. The Reach NWK-1 mainly consists of:

- Holocene (Recent) sediments: soft, black, grey, and dark grey Silt (OL or OH);
- Pleistocene age sediments: hard to medium-stiff consistency Clay (CL or CH), very dense to medium consistency Sand (SP), and very dense to medium consistency Gravel (GC-GM), which is most likely glacial Till; and
- Bedrock such as Diabase, Diorite, Serpentinite, Shale, and/or Sandstone.

The stratification of Reach NWK-1 is illustrated in Figure 16. Based on the proposed deepening depths of -54 and -55 feet MLLW, considerable amounts of Holocene (Recent) and Pleistocene sediments will be removed when the reach is deepened, and shallow bedrock at the north end (sandstone and shale).

Serpentinite was encountered at only two borings. At NB 98-35, in the middle of the reach, Serpentinite was logged between -53.5 and -57 feet MLLW, but would not be expected to occur surrounded by the younger Triassic-aged rocks, and so this rock may have been mis-identified in the field, or represents a boulder moved and emplaced by glacial action.

At NB 98-36, at the northern end of the reach, Serpentinite was logged at -28 feet MLLW, and overlain by five feet of Diabase intrusive. Serpentinite could hypothetically be encountered locally, as the surface of the older rock slopes off to the west, and represents an irregular, erosional unconformity surface, subsequently overlain by Triassic-aged sedimentary beds and later intruded by Diabase during the Jurassic, but could also be a boulder emplaced by glacial action.

The cobble and boulder zone logged at NB 98-34 from -49 to -65 feet MLLW included boulders of serpentinite, diabase, and shale, which could reflect either an erosional unconformity surface or glacial deposit. The serpentinite anomaly should be further evaluated during PED.

4.4.2. Dredgeability

Based upon the results from the analysis of dredgeability, the Silt of Reach NWK-1 has excavation characteristics classified as “good” for clamshell dredge, “good” for backhoe dredge, and “very good” for cutter dredge. Clay is classified as “poor” for clamshell dredge, “fair to poor” for backhoe dredge, and “good” for cutter dredge. Sand is classified as “good to fair” for clamshell dredge, “very good to good” for backhoe dredge, and “very good to good” for cutter dredge. Gravel is classified as “poor” for clamshell dredge, “fair to poor” for backhoe dredge, and “good” for cutter dredge, though most of the samples classified as “Gravel” are likely glacial till.

The bedrock sub-crops include primarily Sandstone and Shale at the northern end, Serpentinite at two locations as discussed, and alternating layers of Triassic Shale and Jurassic Diabase intrusives at the southern end. The top of rock is encountered below -50 feet in most portions of Reach NWK-1, except for the northern portion of the reach where bedrock sub-crops occur as shallow as -20 feet MLLW.

The dredgeabilities of each material are summarized in the Table 11.

Table 11: Dredgeability of Materials for Reach NWK-1

Material Type	Dredge Type			
	Clamshell	Backhoe	Cutter	Blast
Silt	Good	Good	Very Good	NA
Clay	Poor	Fair to Poor	Good	NA
Sand	Good to Fair	Very Good to Good	Very Good to Good	NA
Gravel	Poor	Fair to Poor	Good	NA
Bedrock (Diabase, Diorite, Serpentinite, Shale, and/or Sandstone)	Very Poor	Poor	Poor	Good

The consistency of the Silt was classified as very soft to soft, Clay was classified as hard to medium-stiff, and Sands and Gravels were classified as very dense to medium. Material logged as Gravel may actually be glacial till deposits.

RQD of the bedrock ranged from 25% to 85%.

Based upon previous analyses, the Recent Silt sediments can be dredged by all dredge types. In view of dredging records, contamination, disposal, and availability of dredging equipment, a clamshell dredge will be suitable to dredge the Recent Silt sediments in the Reach NWK-1.

While Sand also can be dredged by all dredges, cutter dredges are estimated to be best suited for dredging both Clay and Gravel/Till sediments; however, it is anticipated that many types of clamshell and backhoe dredges also can dredge Clay and Gravel/Till sediments. As the Sand layer lies between the Clay and the Gravel/Till, and the Sand can be dredged by all dredge types, the dredge type should be based on the one that is best suited for the Clay and Gravel/Till. Hence, a cutter dredge will be suitable to dredge the Clay, Sand, and Gravel/Till.

As most of the bedrock encountered in the southern portion of Reach NWK-1 is below -50 feet MLLW, the dredge that is best suited for clay and gravel/till, will also be capable of removing the limited extent of the bedrock to reach the proposed depth.

However, it is anticipated that the significant amount of shallow bedrock encountered in the northern portion of the Reach NWK-1 will need blasting to reach the proposed depths. The full extent of the bedrock in need of blasting in the northern portion should be further investigated to estimate more accurate costs and schedules, as well as the bedrock type.

Bedrock most likely consists of sandstone and shale, with diabase intrusions parallel to bedding planes. It’s not clear whether the serpentinite encountered in two borings reflect the actual in-situ rock type, or are boulders emplaced by glacial action.

4.4.3. Slope Stability

Soil test boring locations PA2-443, PA2-486, NBN-01-SFI-2 and NB98-34 were used to estimate soil strata and soil properties for analyses of slope stability for the proposed deepening. The soil strata and their properties at select borings are shown in Table 12. Using the soil properties, circular and non-circular potential failure surfaces were searched by optimized grid-radius, entry-exit, and block analyses.

Simulations for the area of boring PA2-443 at the northern end of the Reach NWK-1 resulted in the same lowest factor of safety for deepening to both -54 and -55 feet MLLW, of about 0.62.

The area of boring NBN01-SFI-2 just south of PA2-443, resulted in factors of safety for deepening to both -54 and -55 feet MLLW, of about 1.68 and 1.67, respectively.

The area of boring NB98-34 in the middle of Reach NWK -1 resulted in the same factor of safety for deepening to both -54 and -55 feet MLLW, of about 1.94.

The area of boring PA2-486 in the southern portion of Reach NWK-1 resulted in the same factor of safety for deepening to -54 and -55 feet MLLW, of about 1.00.

Table 12: Soil Properties of Soil Strata at Reach NWK-1

Boring No.	Material Type	Top Elevation of Stratum (ft)	Representative N-Value (blows/ft) /RQD (%)	Unit Weight (pcf)	Cohesion (psf)	Friction Angle (Deg.)
PA2-443	Silt	-11.5	0 (blows/ft)	90	50	0
	Clay	-41.5	5 (blows/ft)	110	630	0
	Clay	-45.0	35 (blows/ft)	130	4375	0
	Clay	-64.0	10 (blows/ft)	120	1250	0
	Shale	-82.0	NA	155	5000	40
NBN01-SFI-2	Silt	-6.4	0 (blows/ft)	90	50	0
	Sand	-17.5	35 (blows/ft)	130	0	39.5
	Clay	-21.5	35 (blows/ft)	130	4375	0
	Sandstone	-37.5	80%	155	5000	40
NB98-34	Silt	-15.7	0 (blows/ft)	90	50	0
	Sand	-24.0	3 (blows/ft)	105	0	28
	Clay	-29.0	9 (blows/ft)	115	1125	0
	Decomposed Shale	-44.0	75 (blows/ft)	135	0	37
	Shale, Serpentinite, Diabase, and Sandstone	-49.0	NA	155	5000	40
PA2-486	Silt	-16.5	0 (blows/ft)	90	50	0
	Clay	-35.0	30 (blows/ft)	125	3750	0
	Sand	-48.0	55 (blows/ft)	135	0	41
	Diabase	-58.5	>70%	155	5000	40

Overall, the northern end and southern portion of Reach NWK-1 do not appear to satisfy the slope stability criteria of a minimum factor of safety of 1.5, while the middle portions of the reach do appear to meet the criteria. The summary of slope stability analyses at Reach NWK-1 is in Table 13.

Table 13: Summary of Slope Analyses at Reach NWK-1

Boring No.	Factors of Safety of 4' Deepening		Factors of Safety of 5' Deepening	
	Min	Max	Min	Max
PA2-443	0.617	0.645	0.617	0.637
NBN01-SFI-2	1.678	1.745	1.671	1.688
NB98-34	1.944	1.953	1.944	1.962
PA2-486	1.002	1.050	1.004	1.050

It is anticipated that the critical slope mode of failure in the northern end and southern portion of Reach NWK-1 (including borings PA2-443 and PA2-486), respectively, will occur as local slope failures due to the thick, very soft consistency top layer of silt materials underlain by a relatively medium-stiff to hard consistency second layer of clay. On the other hand, it is anticipated that slopes in the middle portions of Reach NWK-1 (including borings NBN01-SFI-2 and NB98-34), would be predicted to be stable, due to a relatively thinner, soft consistency, top layer of silt materials underlain by a relatively denser sand layer.

The full extent of the very soft consistency silt should be further investigated to determine a proper type and the scope of application of mitigation measure to stabilize the slopes in the Reach NWK-1.

4.5. Newark Bay (NWK-2)

4.5.1. Stratification

Reach NWK-2 is located between South Elizabeth Channel and Arthur Kill Channel and on the southwestern side of Newark Bay. Soil test borings performed at this reach are displayed on Figure 12. The proposed deepening depths for the reach are -54 and -55 feet MLLW. Reach NWK-2 mainly consists of:

- Holocene (Recent) sediments: soft black, grey, and dark grey Silt (OL or OH);
- Pleistocene age sediments: hard to medium-stiff consistency Clay (CL or CH), and very dense to medium consistency Gravel (GC, GM, or GP), which is most likely glacial Till; and
- Bedrock such as Sandstone and/or Shale.

The stratification of Reach NWK-2 is shown on Figure 17. Based on proposed deepening depths of -54 and -55 feet, a majority of Holocene (Recent) and Pleistocene sediments will be removed when the reach is deepened. A significant amount of bedrock also will be removed to reach the design deepening depths.

4.5.2. Dredgeability

Based upon the results from the analysis of dredgeability, the Silt of Reach NWK-2 has excavation characteristics classified as “good” for clamshell dredge, “good” for backhoe dredge, and “very good” for cutter dredge. Clay is classified as “poor” for clamshell dredge, “fair to poor” for backhoe dredge, and “good” for cutter dredge. Gravel is classified as “poor” for clamshell dredge, “good to poor” for backhoe dredge, and “good to fair” for cutter dredge. Most of what is classified as Gravel is likely glacial Till.

Bedrock consisted primarily of Sandstone with Shale beds. Shallow sub-crops occurred at or below -40 feet MLLW at the very northern end of the reach and along the southern half of the reach. Bedrock was found at greater depth in some of the borings in the middle of the reach and along the eastern edge of Reach NWK-2, possibly indicating a buried tributary valley to the larger Newark Bay preglacial bedrock valley. Bedrock is typically mantled by glacial Till and occasional cobble zones (NBS-98-31).

Note that cobble/boulder zones were encountered on either side of the Newark Bay Channel, in boring NBS-98-31 (-45 to -53 feet MLLW) on the west side in NWK-2, and in boring NB-98-34 (-49 to -65 feet MLLW) on the east side in NWK-1, perhaps indicating a high-energy glacial depositional feature that crosses the channel, and may be continuous below the channel, and could impact dredgability along a narrow zone.

The dredgeability of each material is summarized in the below Table 14.

Table 14: Dredgeability of Materials for Reach NWK-2

Material Type	Dredge Type			
	Clamshell	Backhoe	Cutter	Blast
Silt	Good	Good	Very Good	NA
Clay	Poor	Fair to Poor	Good	NA
Gravel	Poor	Good to Poor	Good to Fair	NA
Bedrock (Sandstone or Shale)	Very Poor	Poor	Poor	Good

Consistencies of Silts were classified as very soft to soft, and the consistencies of Clays were classified as hard to medium-stiff. Consistencies of Gravels were classified as very dense to medium. The soil classified as Gravel is most likely glacial Till.

Based upon previous analyses, the Recent Silt sediments can be dredged by all dredges. In view of dredging records, contamination, disposal, and availability of dredging equipment, a clamshell dredge will be suitable to dredge the Recent Silt sediments in the Reach NWK-2. Cutter dredges will be suitable to dredge Clay and Gravel sediments.

Bedrock RQDs ranged from 26% to 100%. Where bedrock occurs at greater depth in the center of Reach NWK-2 (borings PA 2-479, PA 2-488), a heavy cutter dredge may be sufficient to remove the limited amount of bedrock above the dredge depth. Elsewhere bedrock occurs at -40 to -50 feet MLLW over most of the reach, and so there is a significant amount of bedrock that likely requires blasting to reach the proposed dredge depth. The full extent of the bedrock that will need blasting should be further investigated during design to estimate more accurate costs and schedules.

4.5.3. Slope Stability

Soil test boring locations PA2-479 and B4-84 were used to estimate soil strata and soil properties for analyses of slope stability as overall, the borings can provide soil stratification which is useful to understand stabilities of slope proposed for four feet and five feet deepening. The soil properties of soil strata of the borings are shown in Table 15.

Table 15: Soil Properties of Soil Strata at Reach NWK-2

Boring No.	Material Type	Top Elevation of Stratum (ft)	Representative N-Value (blows/ft) /RQD (%)	Unit Weight (pcf)	Cohesion (psf)	Friction Angle (Deg.)
PA2-479	Silt	-2.5	0 (blows/ft)	90	50	0
	Clay	-12.0	11 (blows/ft)	120	1370	0
	Clay	-30.0	41 (blows/ft)	130	5125	0
	Decomposed Shale	-40.5	180 (blows/ft)	140	0	37
	Shale and Sandstone	-61.0	>30%	155	5000	40
B4-84	Silt	-6.1	0 (blows/ft)	90	50	0
	Sand	-24.5	20 (blows/ft)	120	0	33.5
	Gravel & Sand	-27.5	75 (blows/ft)	135	0	41
	Sandstone	-43.0	26%	155	5000	40

Using the above soil properties, circular and non-circular potential failure surfaces were analyzed by optimized grid-radius, entry-exit, and block analyses. Simulations for the area of boring PA2-479 in the middle and northern half of Reach NWK-2 resulted in the same lowest factor of safety for both four feet and five feet deepening as about 1.94. The area of boring B4-84 in the southern portion of Reach NWK-2 resulted in the same lowest safety factor of slope analyses for both four feet and five feet deepening as about 1.00. Overall, the southern portion of Reach NWK-2 appears not to satisfy the slope stability criteria (minimum factor of safety of 1.5), while the rest of the reach meets the slope stability criteria. The summary of slope stability analyses at Reach NWK-2 is shown in Table 16.

Table 16: Summary of Slope Analyses at Reach NWK-2

Boring No.	Factors of Safety of 4' Deepening		Factors of Safety of 5' Deepening	
	Min	Max	Min	Max
PA2-479	1.944	2.099	1.944	1.948
B4-84	1.002	1.102	1.002	1.039

It is anticipated that the critical mode of slope failure in the southern portion of Reach NWK-2 including boring B4-84 will occur as local slope failures due to a thick, very soft consistency top layer of silt materials underlain by clay, and relatively thin, medium to very dense layer of sand and gravel, cobbles, boulders, or till, over bedrock.

On the other hand, it is anticipated that slope failures will not occur in the northern and middle portions of Reach NWK-2 (including boring PA2-479) due to a slightly thinner, soft layer of silt, underlain by a thick layer of relatively stiffer clay.

The full extent of the very soft consistency silt should be further investigated to determine a proper type and the scope of application of mitigation measure to stabilize the slopes in Reach NWK-2.

APPENDIX B2:

Attachment 1

Figures

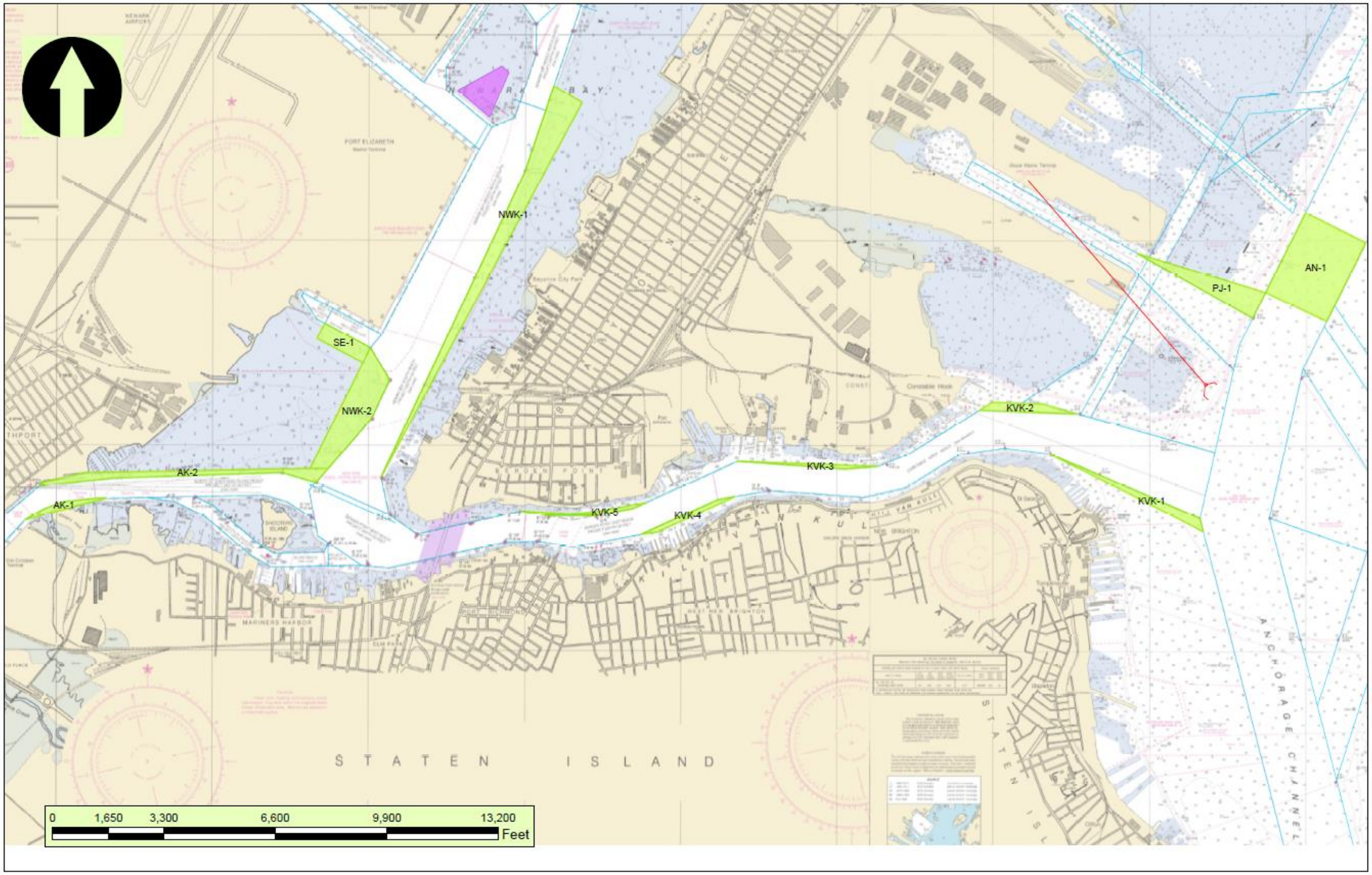


Figure 1: Project Areas for New York and New Jersey Harbor Deepening Channel Improvements

Figure 2: Bedrock Geology of Project Area, Composite from USGS National Geology Map Database. Legend on Following Page

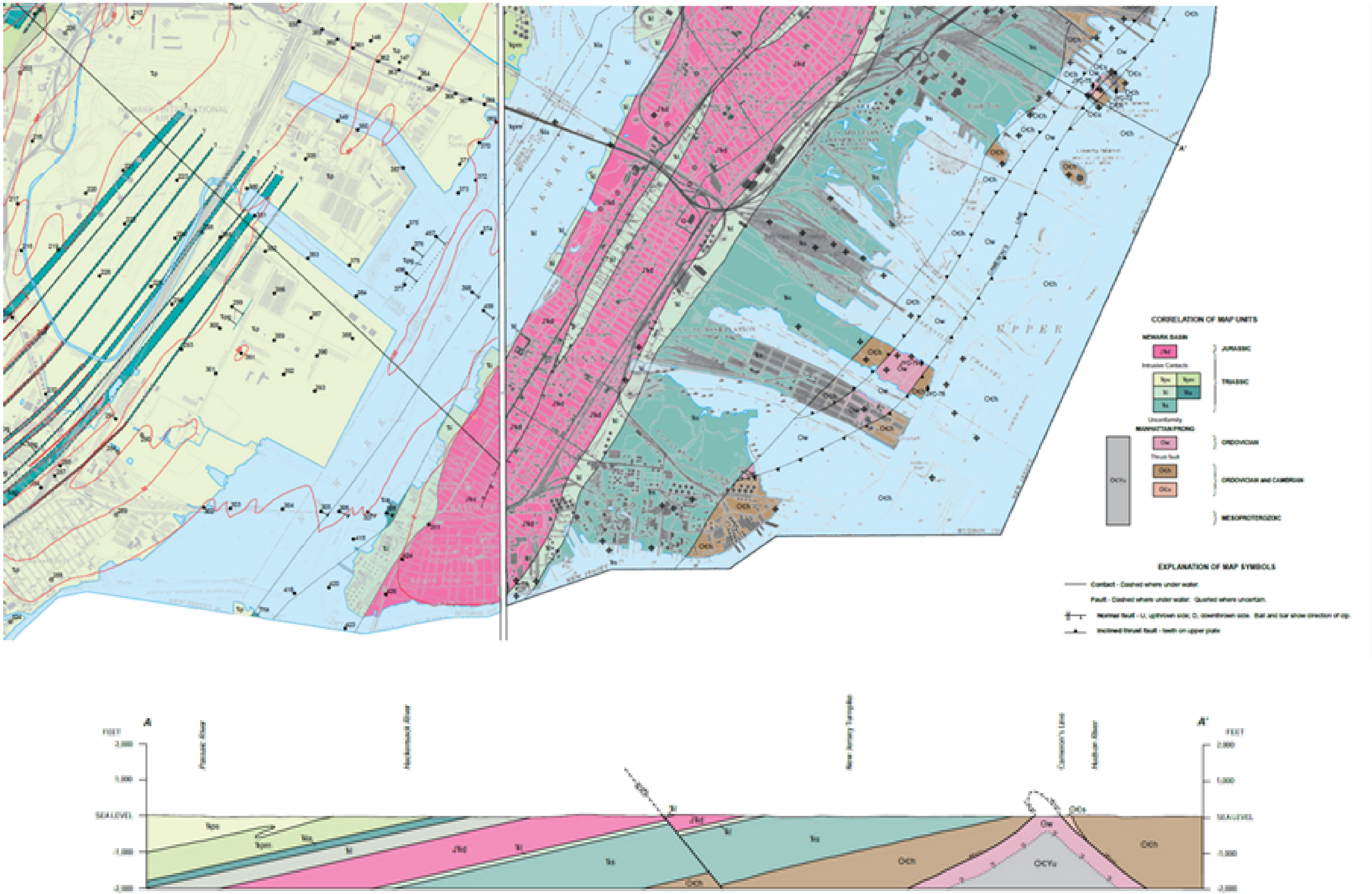
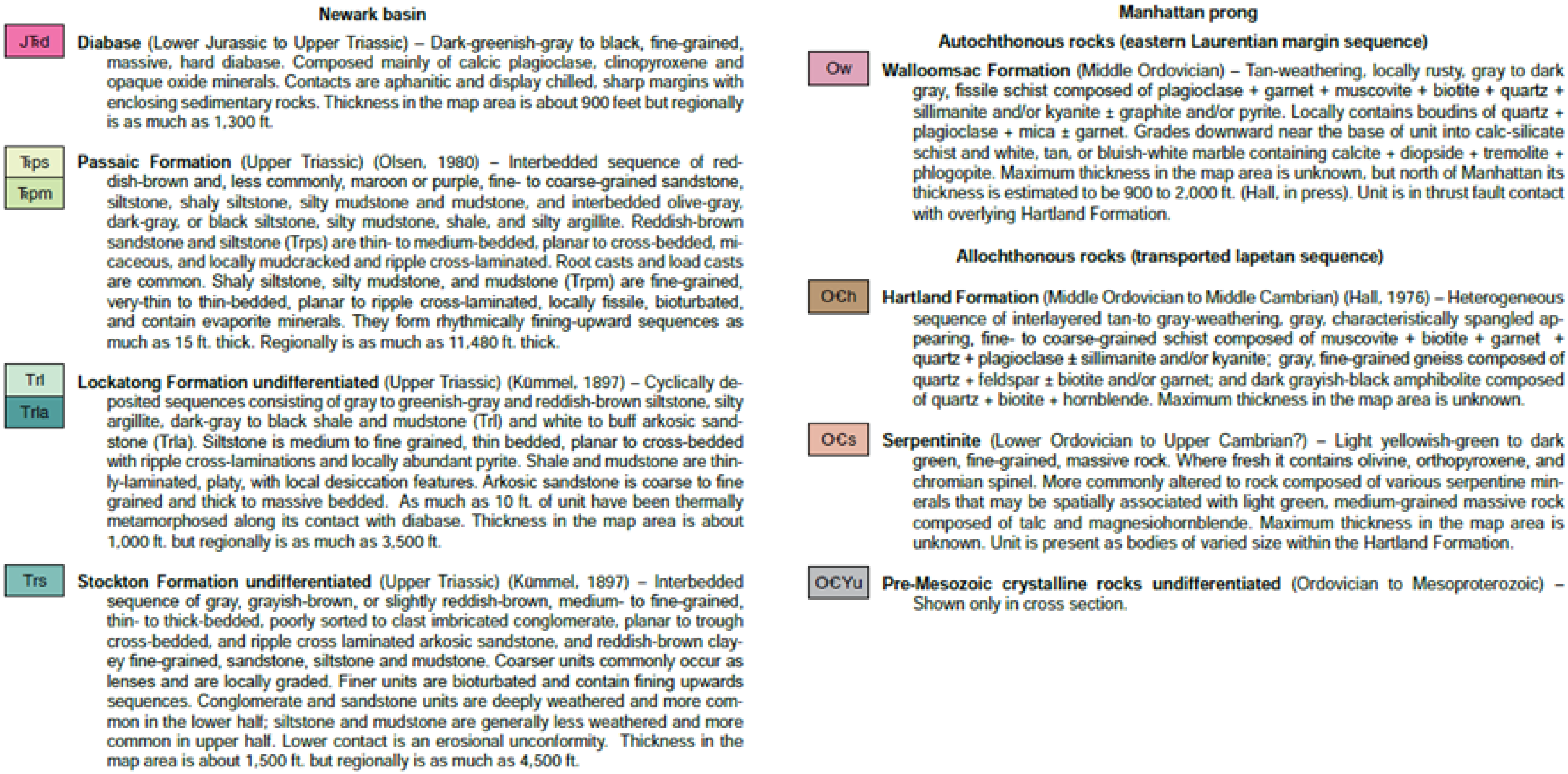


Figure 3: Bedrock Geology of Project Area, and Cross-Section (looking North),excerpted from the Bedrock Geology Map of the Elizabeth Quadrangle, Essex, Hudson, and Union Counties, NJ, Monteverde and Herman, 2015, and the Bedrock Geology Map of the Jersey City Quadrangle, Volkert, 2016. Legend on following page.



Newark basin

JTrd

Diabase (Lower Jurassic to Upper Triassic) – Dark-greenish-gray to black, fine-grained, massive, hard diabase. Composed mainly of calcic plagioclase, clinopyroxene and opaque oxide minerals. Contacts are aphanitic and display chilled, sharp margins with enclosing sedimentary rocks. Thickness in the map area is about 900 feet but regionally is as much as 1,300 ft.

Trps
Trpm

Passaic Formation (Upper Triassic) (Olsen, 1980) – Interbedded sequence of reddish-brown and, less commonly, maroon or purple, fine- to coarse-grained sandstone, siltstone, shaly siltstone, silty mudstone and mudstone, and interbedded olive-gray, dark-gray, or black siltstone, silty mudstone, shale, and silty argillite. Reddish-brown sandstone and siltstone (Trps) are thin- to medium-bedded, planar to cross-bedded, micaceous, and locally mudcracked and ripple cross-laminated. Root casts and load casts are common. Shaly siltstone, silty mudstone, and mudstone (Trpm) are fine-grained, very-thin to thin-bedded, planar to ripple cross-laminated, locally fissile, bioturbated, and contain evaporite minerals. They form rhythmically fining-upward sequences as much as 15 ft. thick. Regionally is as much as 11,480 ft. thick.

Trl
Trla

Lockatong Formation undifferentiated (Upper Triassic) (Kümmel, 1897) – Cyclically deposited sequences consisting of gray to greenish-gray and reddish-brown siltstone, silty argillite, dark-gray to black shale and mudstone (Trl) and white to buff arkosic sandstone (Trla). Siltstone is medium to fine grained, thin bedded, planar to cross-bedded with ripple cross-laminations and locally abundant pyrite. Shale and mudstone are thinly-laminated, platy, with local desiccation features. Arkosic sandstone is coarse to fine grained and thick to massive bedded. As much as 10 ft. of unit have been thermally metamorphosed along its contact with diabase. Thickness in the map area is about 1,000 ft. but regionally is as much as 3,500 ft.

Trs

Stockton Formation undifferentiated (Upper Triassic) (Kümmel, 1897) – Interbedded sequence of gray, grayish-brown, or slightly reddish-brown, medium- to fine-grained, thin- to thick-bedded, poorly sorted to clast imbricated conglomerate, planar to trough cross-bedded, and ripple cross laminated arkosic sandstone, and reddish-brown clayey fine-grained, sandstone, siltstone and mudstone. Coarser units commonly occur as lenses and are locally graded. Finer units are bioturbated and contain fining upwards sequences. Conglomerate and sandstone units are deeply weathered and more common in the lower half; siltstone and mudstone are generally less weathered and more common in upper half. Lower contact is an erosional unconformity. Thickness in the map area is about 1,500 ft. but regionally is as much as 4,500 ft.

Manhattan prong

Autochthonous rocks (eastern Laurentian margin sequence)

Ow

Walloomsac Formation (Middle Ordovician) – Tan-weathering, locally rusty, gray to dark gray, fissile schist composed of plagioclase + garnet + muscovite + biotite + quartz + sillimanite and/or kyanite ± graphite and/or pyrite. Locally contains boudins of quartz + plagioclase + mica ± garnet. Grades downward near the base of unit into calc-silicate schist and white, tan, or bluish-white marble containing calcite + diopside + tremolite + phlogopite. Maximum thickness in the map area is unknown, but north of Manhattan its thickness is estimated to be 900 to 2,000 ft. (Hall, in press). Unit is in thrust fault contact with overlying Hartland Formation.

Allochthonous rocks (transported Iapetan sequence)

OЄh

Hartland Formation (Middle Ordovician to Middle Cambrian) (Hall, 1976) – Heterogeneous sequence of interlayered tan-to gray-weathering, gray, characteristically spangled appearing, fine- to coarse-grained schist composed of muscovite + biotite + garnet + quartz + plagioclase ± sillimanite and/or kyanite; gray, fine-grained gneiss composed of quartz + feldspar ± biotite and/or garnet; and dark grayish-black amphibolite composed of quartz + biotite + hornblende. Maximum thickness in the map area is unknown.

OЄs

Serpentinite (Lower Ordovician to Upper Cambrian?) – Light yellowish-green to dark green, fine-grained, massive rock. Where fresh it contains olivine, orthopyroxene, and chromian spinel. More commonly altered to rock composed of various serpentine minerals that may be spatially associated with light green, medium-grained massive rock composed of talc and magnesiohornblende. Maximum thickness in the map area is unknown. Unit is present as bodies of varied size within the Hartland Formation.

OЄYu

Pre-Mesozoic crystalline rocks undifferentiated (Ordovician to Mesoproterozoic) – Shown only in cross section.

Legend for Figures 2 and 3

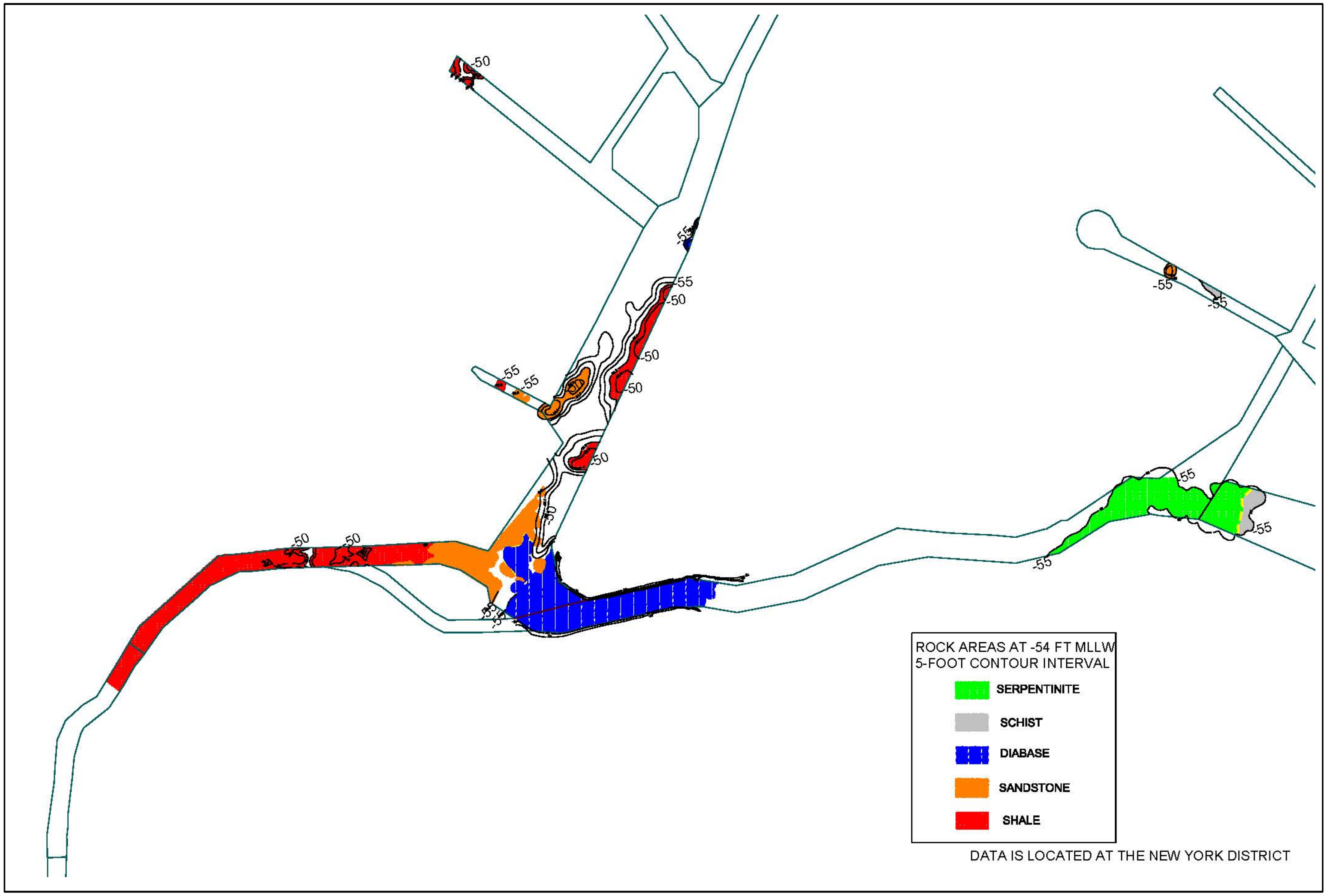


Figure 4: Contour Map of Rock and Rock Type Within Project Area

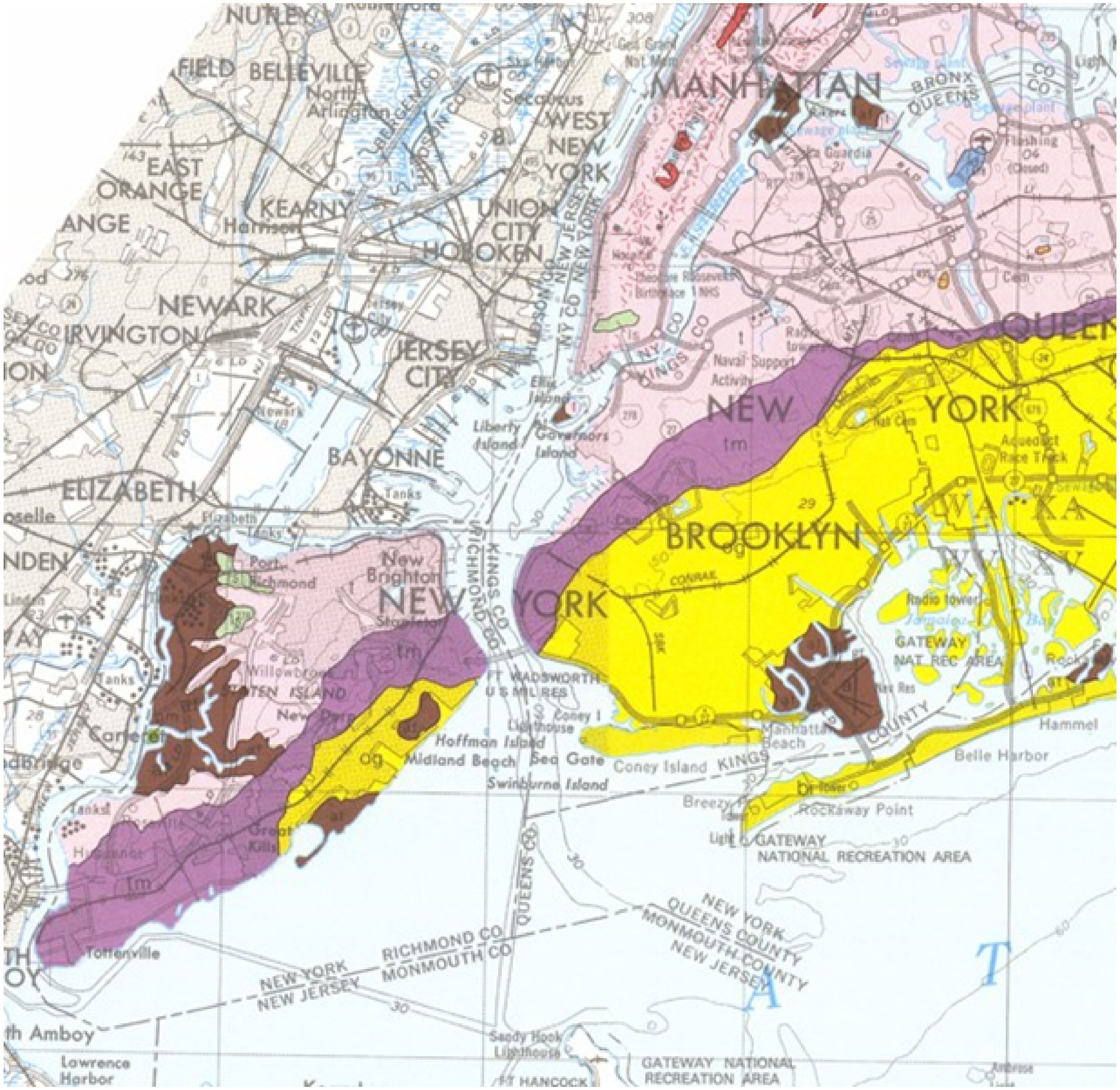


Figure 5: Glacial Geology of Project Area, excerpted from New York Surficial Geology Map. Legend on next page

EXPLANATION

al
al — Recent deposits
Generally confined to floodplains within a valley,
oxidized, non-calcareous, fine sand to gravel,
in larger valleys may be overlain by silt,
subject to frequent flooding, thickness 1–10 meters.

alf
alf — Alluvial fan
Fan shaped accumulations,
poorly stratified silt, sand and boulders,
at the foot of steep slopes,
generally permeable.

b
b — Beach
Sand and gravel deposit at marine shoreline,
thickness variable.

bi
bi — Barrier island
Sand and gravel deposit as barrier island,
south shore of Long Island,
may have associated dunes,
thickness variable.

pm
pm — Swamp deposits
Peat-muck, organic silt and sand in poorly drained areas,
un-oxidized,
may be overlying marl and lake silts,
potential land instability,
thickness generally 2-20 meters.

ld
ld — Lacustrine delta
Coarse to fine gravel and sand,
stratified, generally well sorted,
deposited at a lake shoreline,
thickness variable (3-15 meters).

lsc
lsc — Lacustrine silt and clay
Generally laminated silt and clay,
deposited in proglacial lakes,
generally calcareous,
potential land instability,
thickness variable (up to 100 meters).

ls
ls — Lacustrine sand
Sand deposits associated with large bodies of water,
generally a near-shore deposit or near a sand source,
well sorted, stratified,
generally quartz sand,
thickness variable (2-20 meters).

og
og — Outwash sand and gravel
Coarse to fine gravel with sand,
proglacial fluvial deposition,
well rounded and stratified,
generally finer texture away from ice border,
thickness variable (2-20 meters).

fg
fg — Fluvial sand and gravel
Deposits of sand and gravel,
occasional laterally continuous lenses of silt,
deposition farther from glacier,
age uncertain.

k
k — Kame deposits
Includes kames, eskers, kame terraces, kame deltas,
coarse to fine gravel and/or sand,
deposition adjacent to ice,
lateral variability in sorting, coarseness and thickness,
locally firmly cemented with calcareous cement,
thickness variable (10-30 meters).

km
km — Kame moraine
Variable texture (size and sorting) from boulders to sand,
deposition at an ice margin during deglaciation,
positive constructional relief,
locally cemented with calcareous cement,
thickness variable (10-30 meters).

tm
tm — Till moraine
More variably sorted than till,
generally more permeable than till,
deposition adjacent to ice,
more variably drained,
may include ablation till,
thickness variable (10-30 meters).

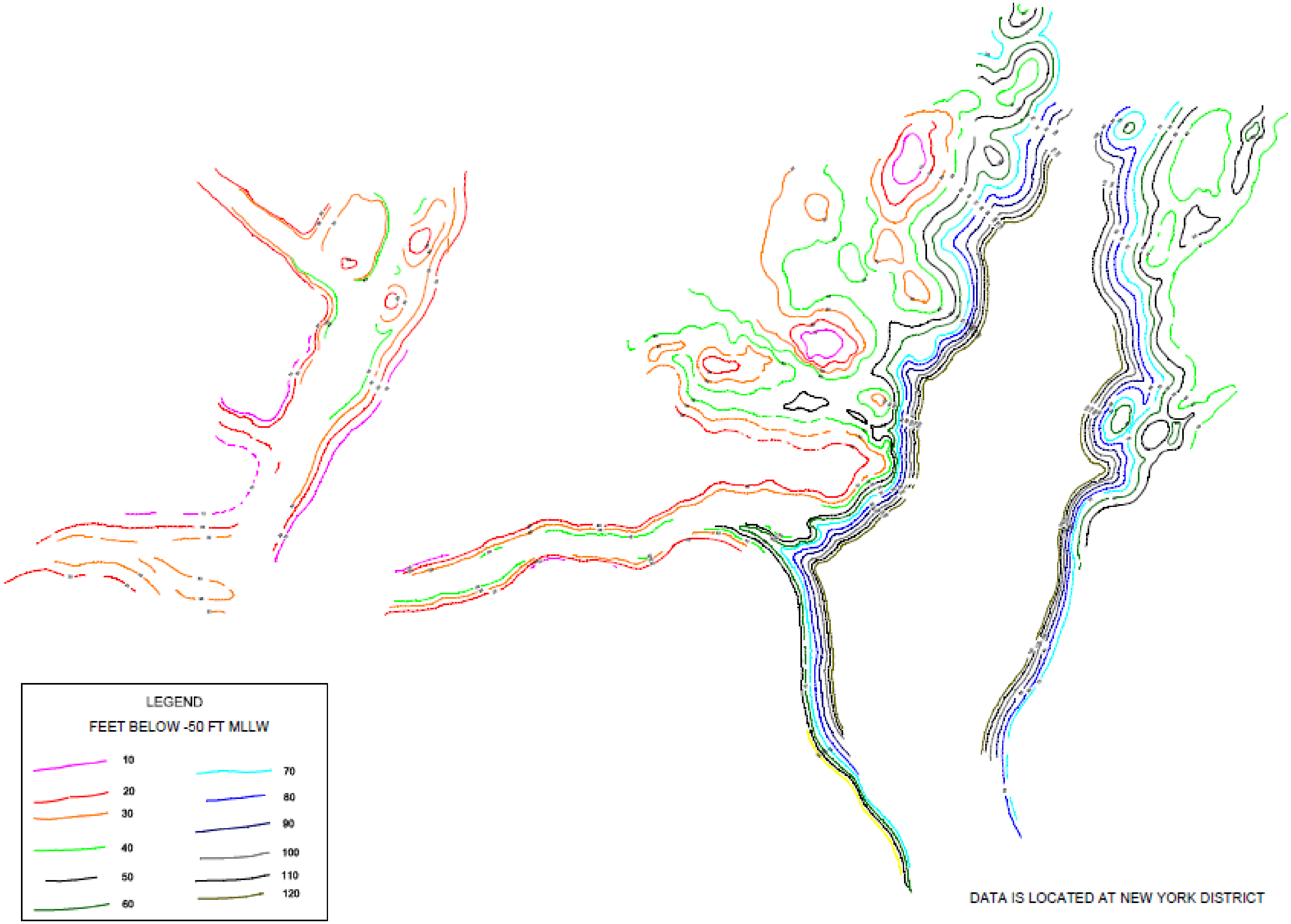
t
t — Till
Variable texture (e.g. clay, silt-clay, boulder clay),
usually poorly sorted diamict,
deposition beneath glacier ice,
relatively impermeable (loamy matrix),
variable clast content — ranging from abundant well-rounded
    diverse lithologies in valley tills to relatively
    angular, more limited lithologies in upland tills,
    tends to be sandy in areas underlain by gneiss or sandstone,
potential land instability on steep slopes,
thickness variable (1-50 meters).

af
af — Artificial fill

r
r — Bedrock
Exposed or generally within 1 meter of surface.

▨
Bedrock stipple overprint
Bedrock may be within 1-3 meters of surface,
may sporadically crop out,
variable mantle of rock debris and glacial till.

Legend for Figure 5



DATA IS LOCATED AT NEW YORK DISTRICT

Figure 6: Contour Map of Top of Pleistocene Deposits in Project Area

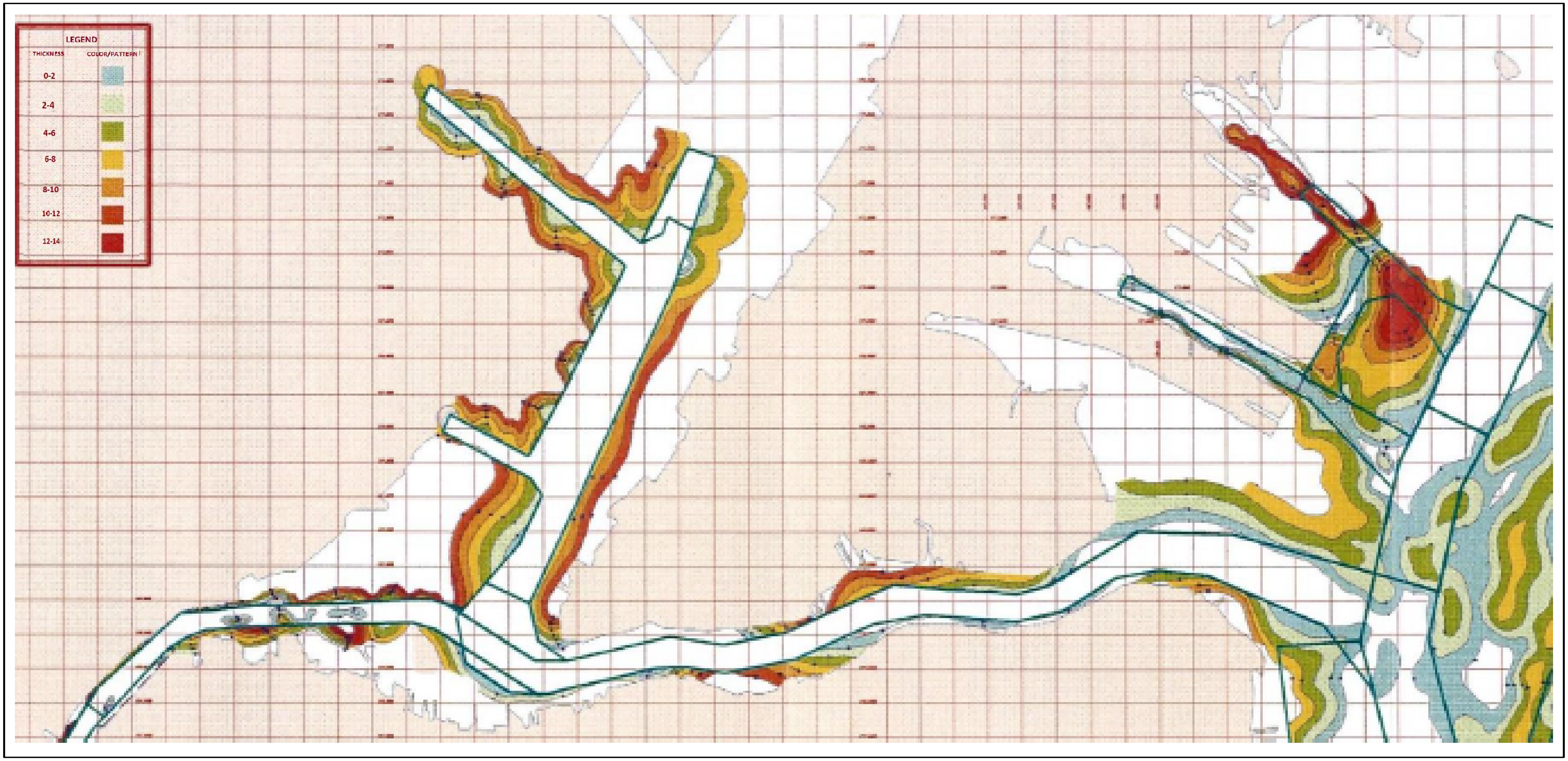


Figure 7: Isopach Map of Holocene Deposits Within Project Area

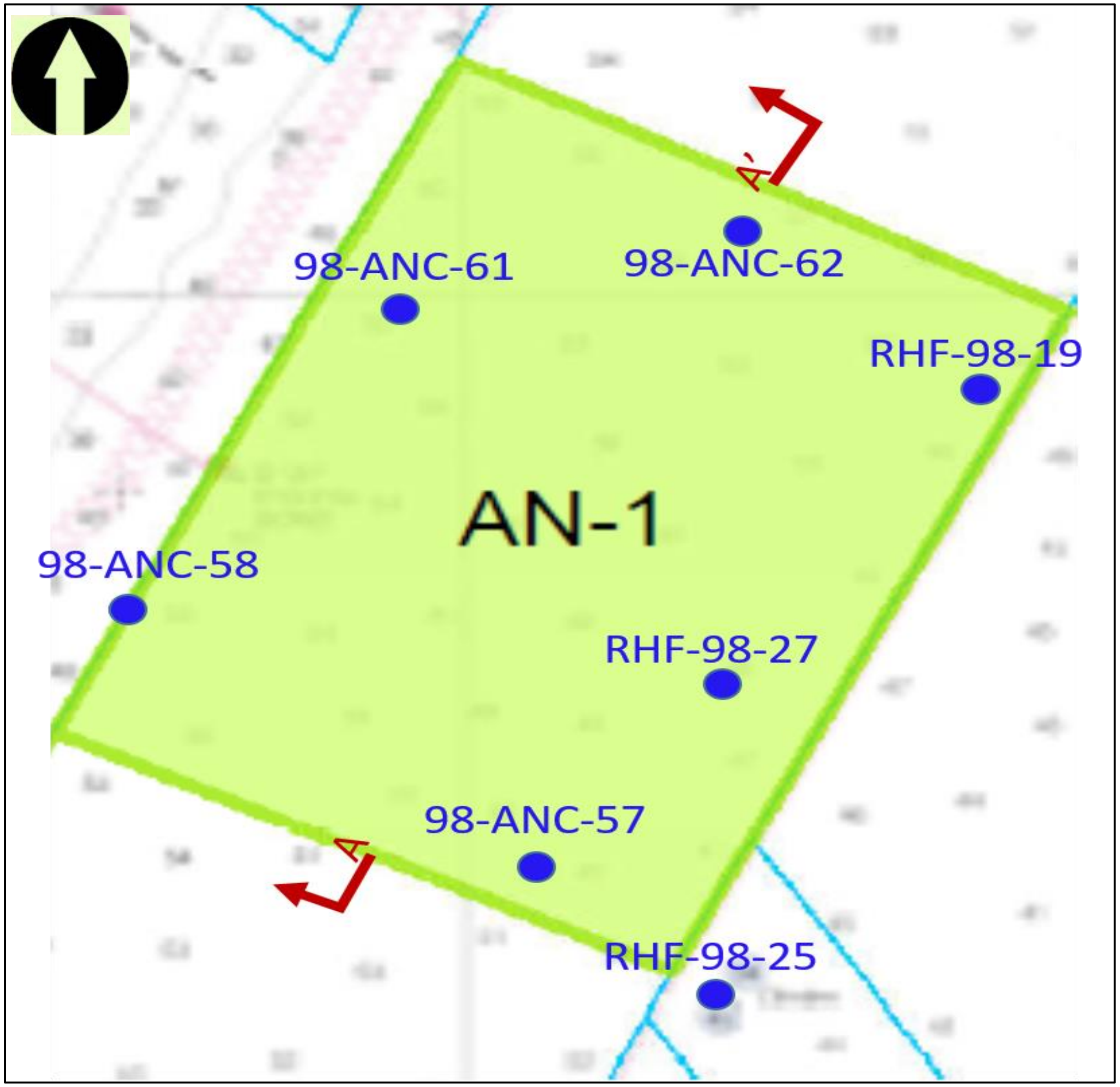


Figure 8: Boring Location Plan of Reach AN-1

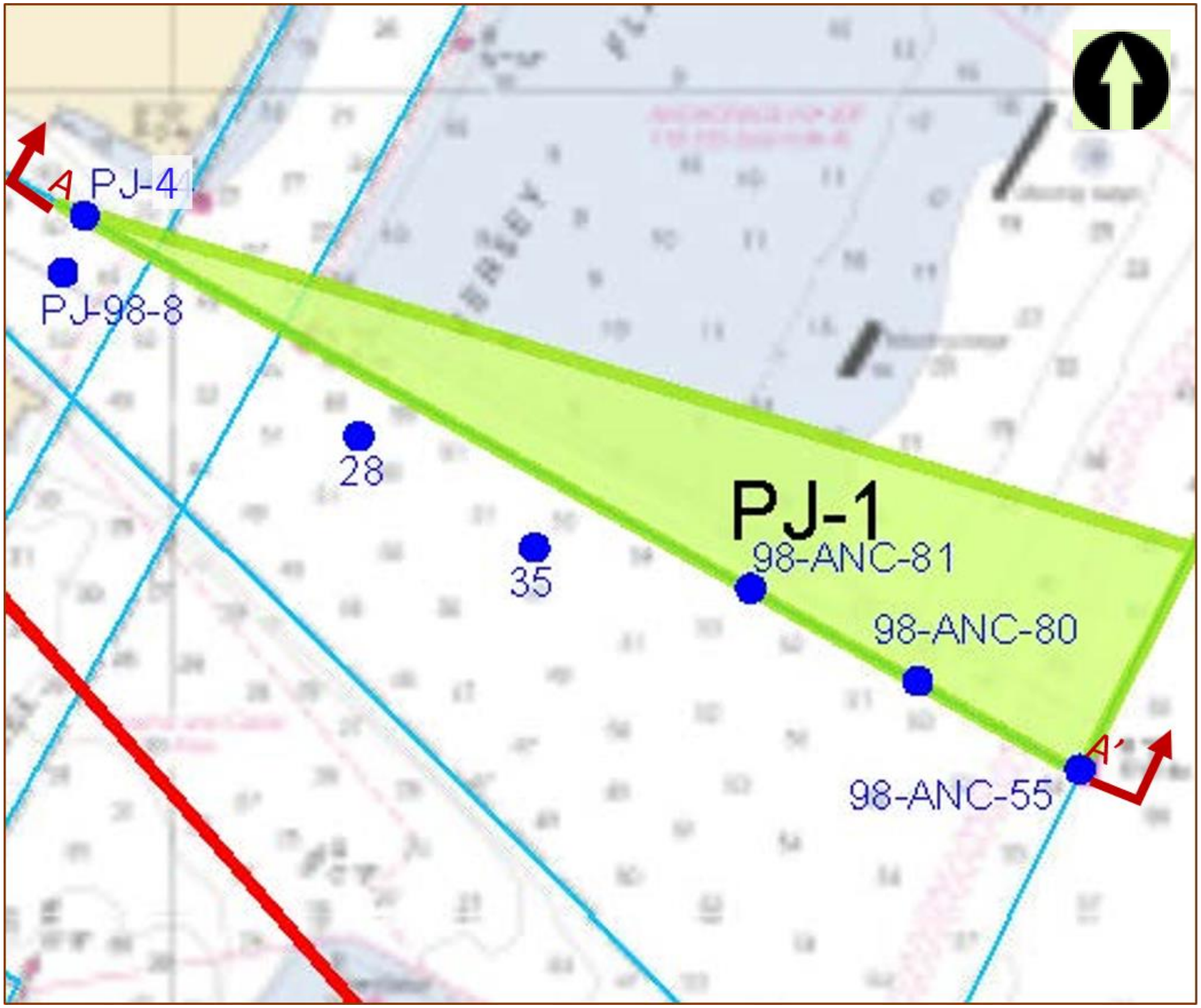


Figure 9: Boring Location Plan of Reach PJ-1

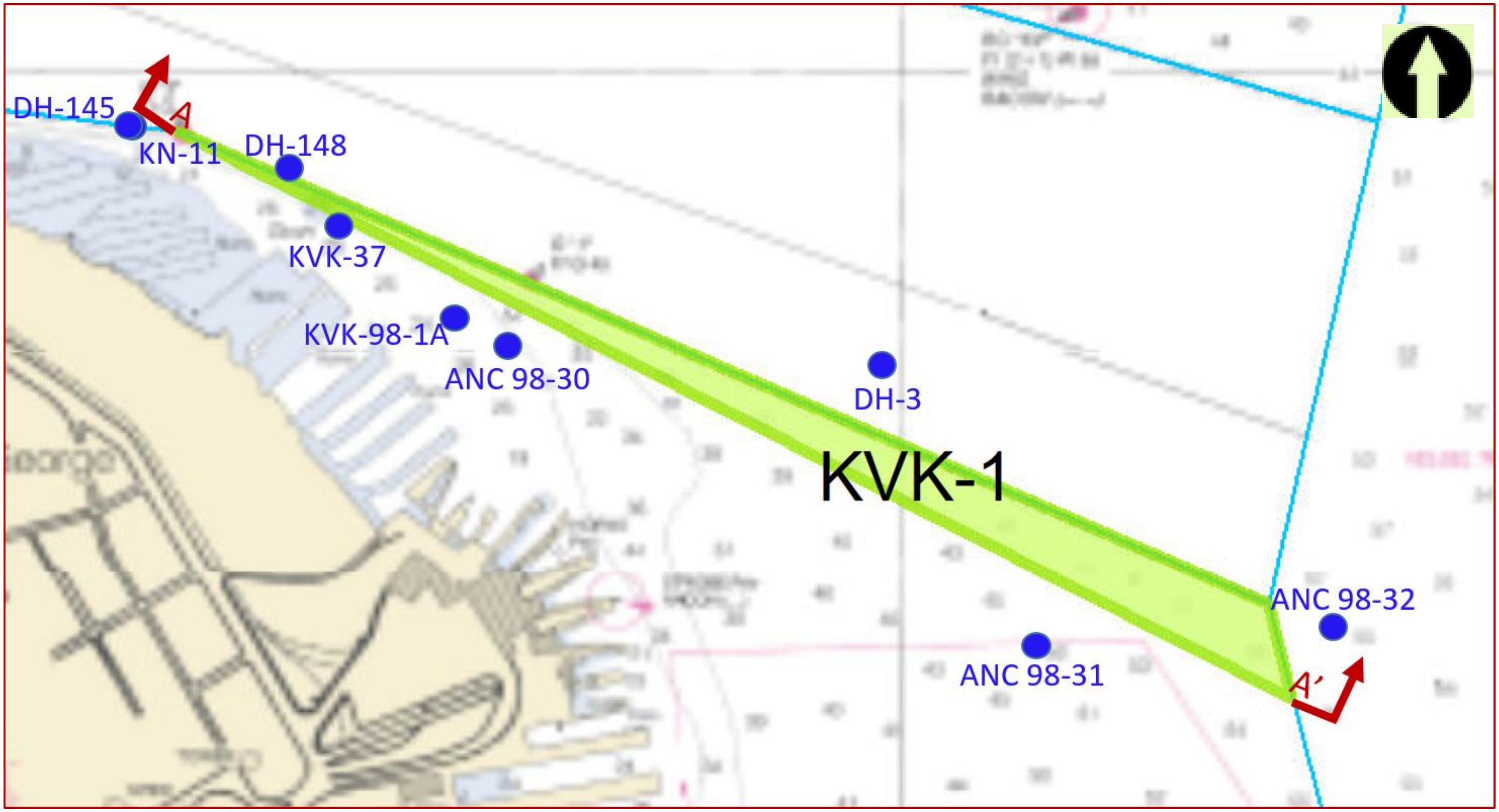


Figure 10: Boring Location Plan of Reach KVK-1

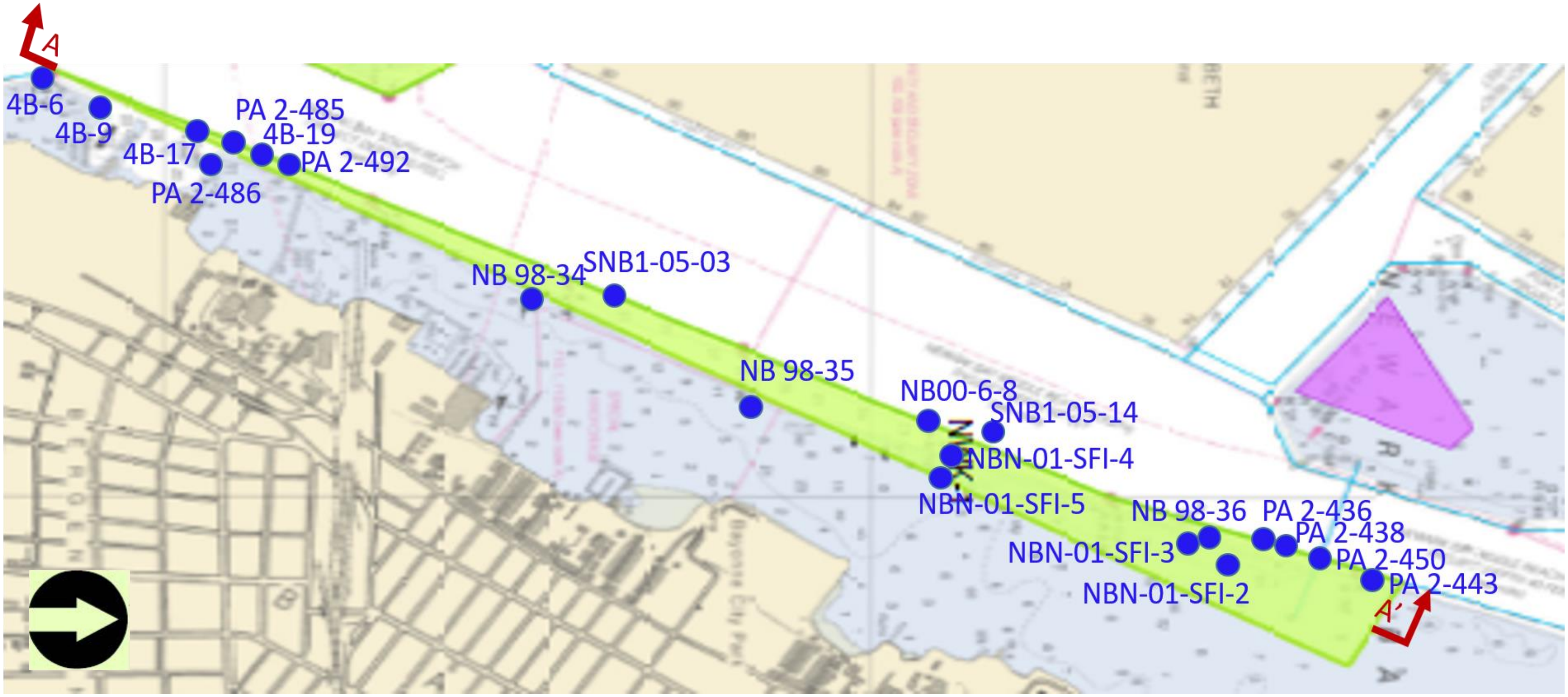


Figure 11: Boring Location Plan of Reach NWK-1

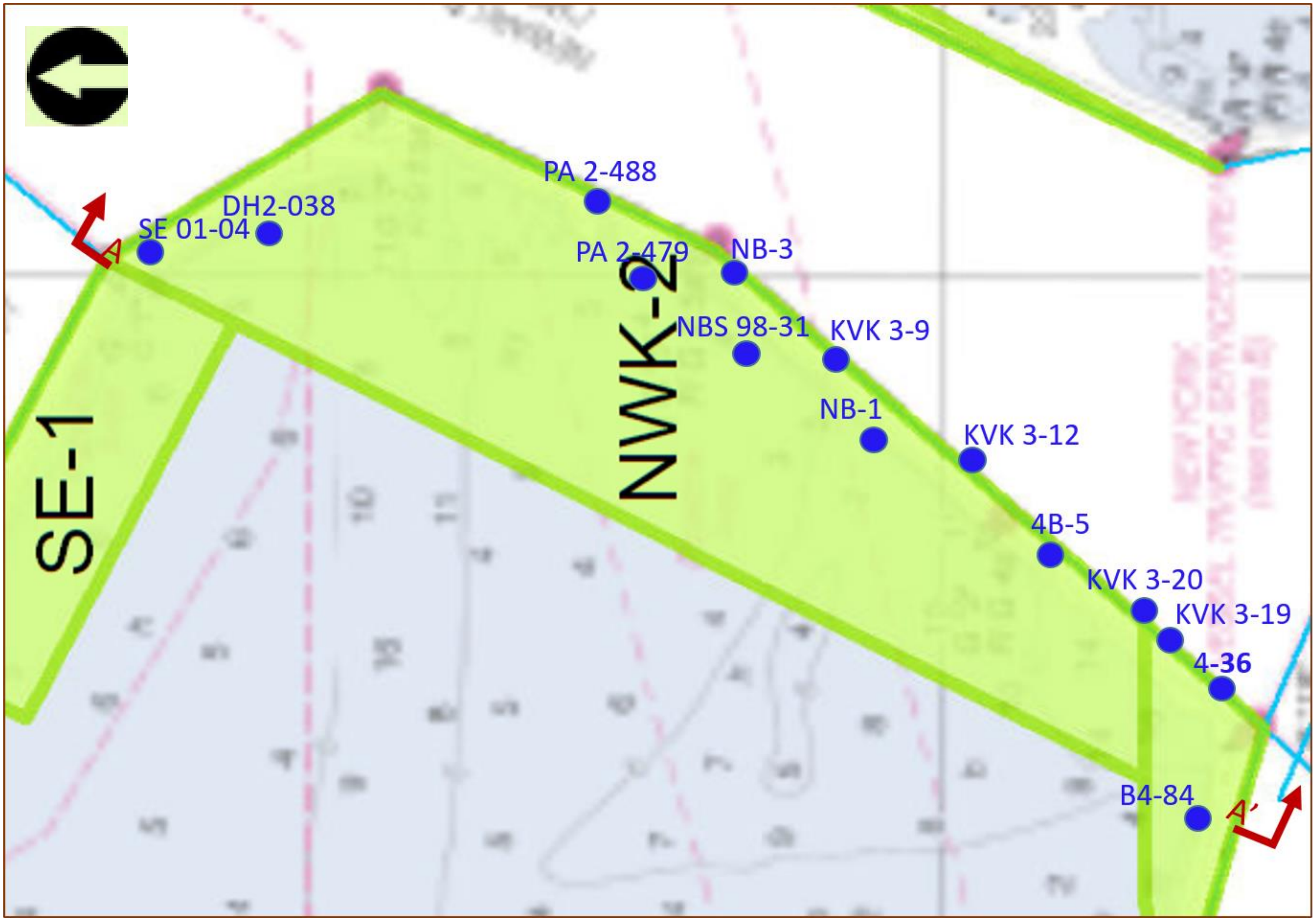


Figure 12: Boring Location Plan of Reach NWK-2

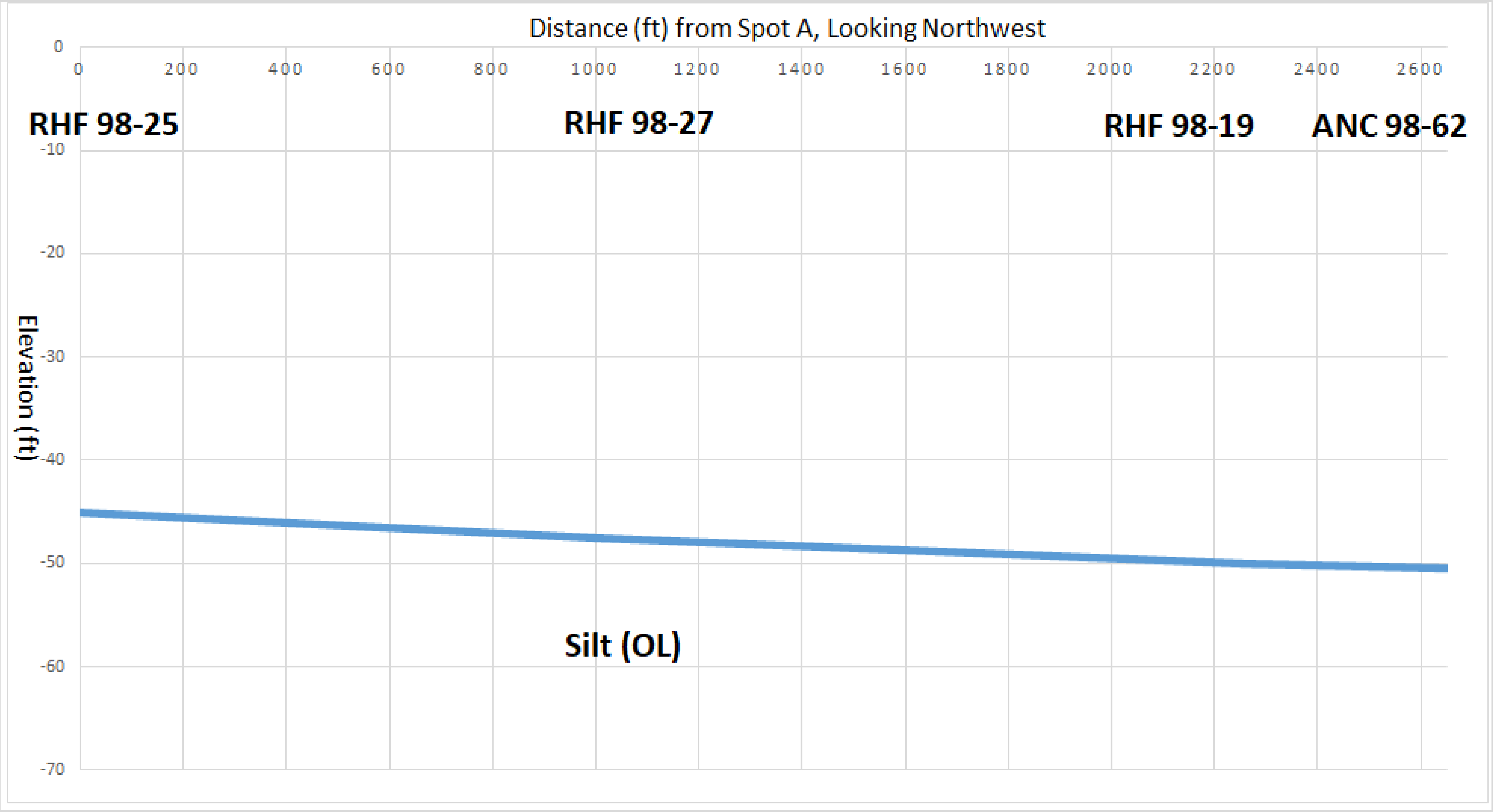


Figure 13: Simplified Cross-Section (A-A') of Reach AN-1

Assumptions:

-Soil consistency was estimated on the basis of methods by Terzaghi and Peck (1948) with exclusion of outliers.

-Suitability of dredge methods was conservatively determined by USCS, N values/soil consistency, or/and RQD values in accordance with Programmer's Guide for DREDGABL (Spigolon and Bakeer, 1993).

-Soil stratification was linearly interpolated between soil testing boring logs.

-The boundaries of top soil strata (i.e., silt and clay) were mainly determined using undredged boring logs; the other boring logs were used to define the boundaries of strata of bottom materials (i.e., Sand, Boulder/Cobble, and Bedrock).

-Soil profiles of each boring log were projected to cross-section (A-A') at a right angle; that is, soil profiles are consistent at any points perpendicular to cross-section (A-A').

-Soil stratification at unknown areas without boring logs were extrapolated from boring logs outside the reach limits nearby the unknown areas.

-All boring logs within the subject reach limits were referred to as possible.

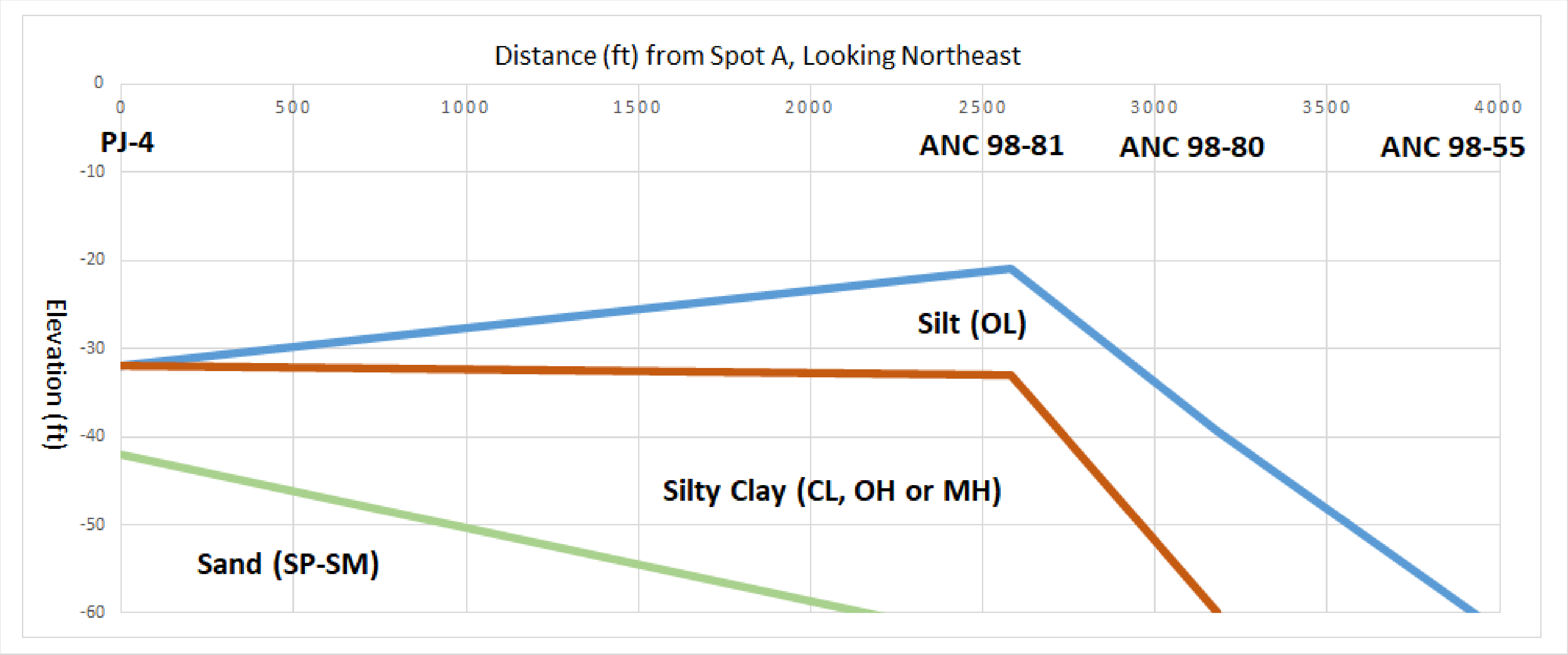


Figure 14: Simplified Cross-Section (A-A') of Reach PJ-1

Assumptions: Refer to Assumptions of Figure 11.

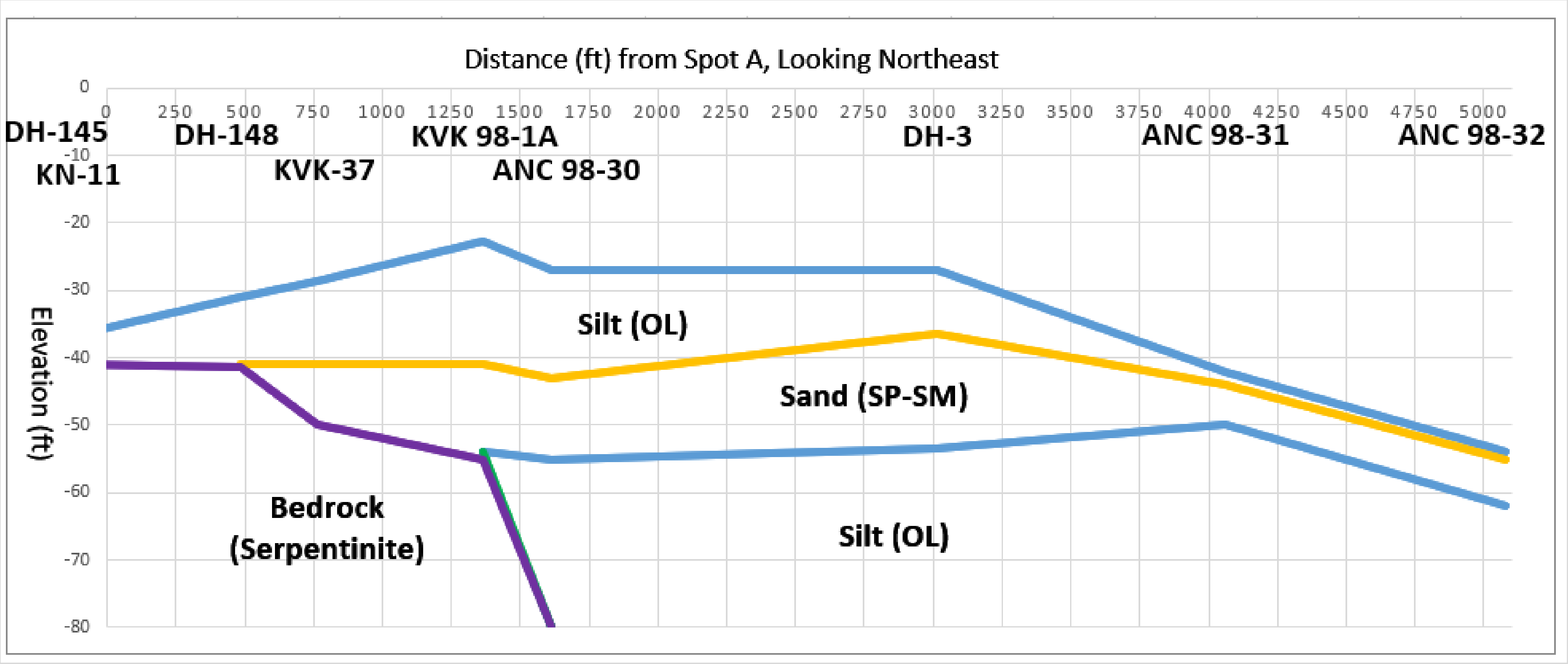


Figure 15: Cross-Section (A-A') of Reach KVK-1

Assumptions: Refer to Assumptions of Figure 11.

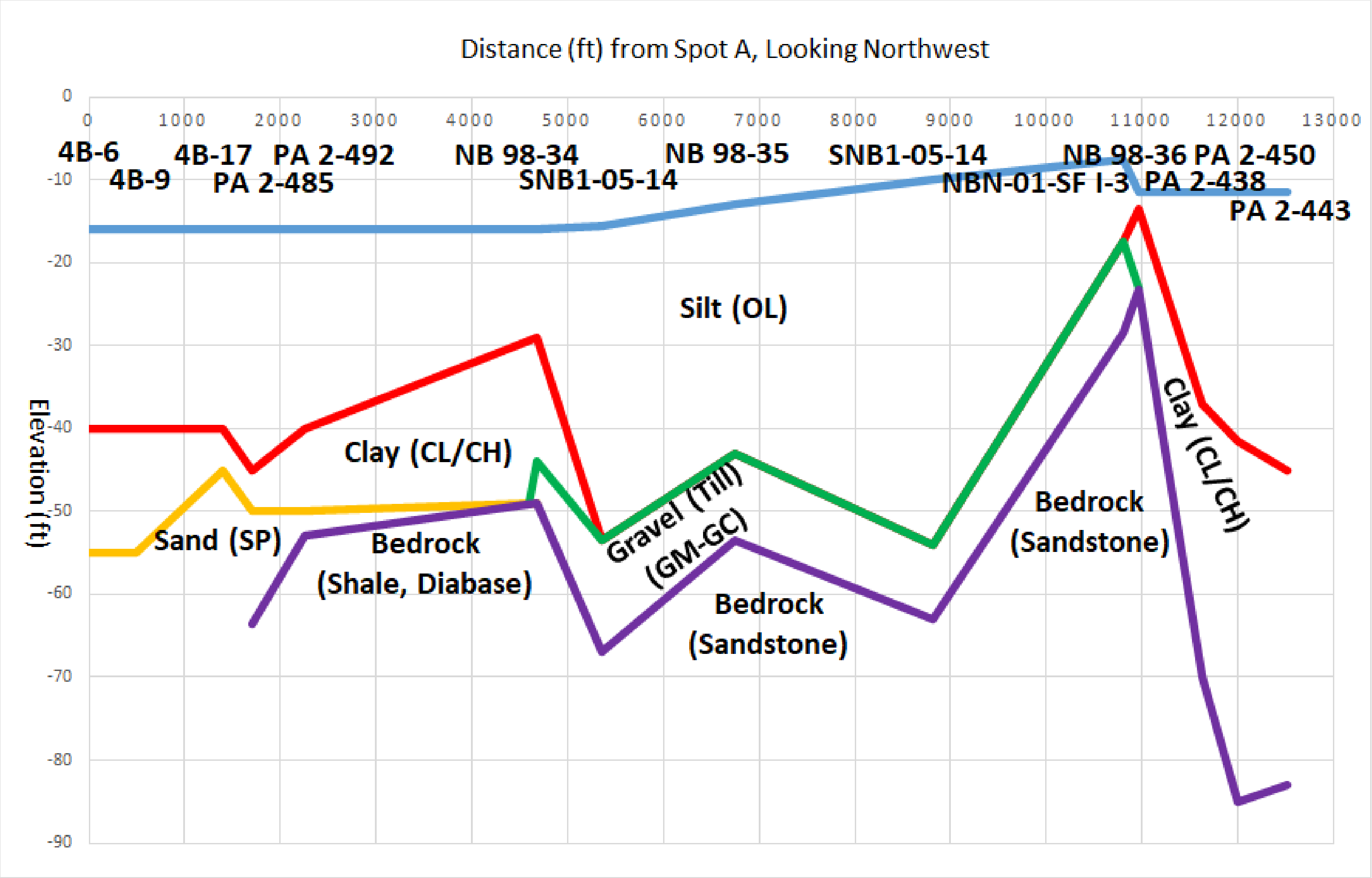


Figure 16: Cross-Section (A-A') of Reach NWK-1

Assumptions: Refer to Assumptions of Figure 11.

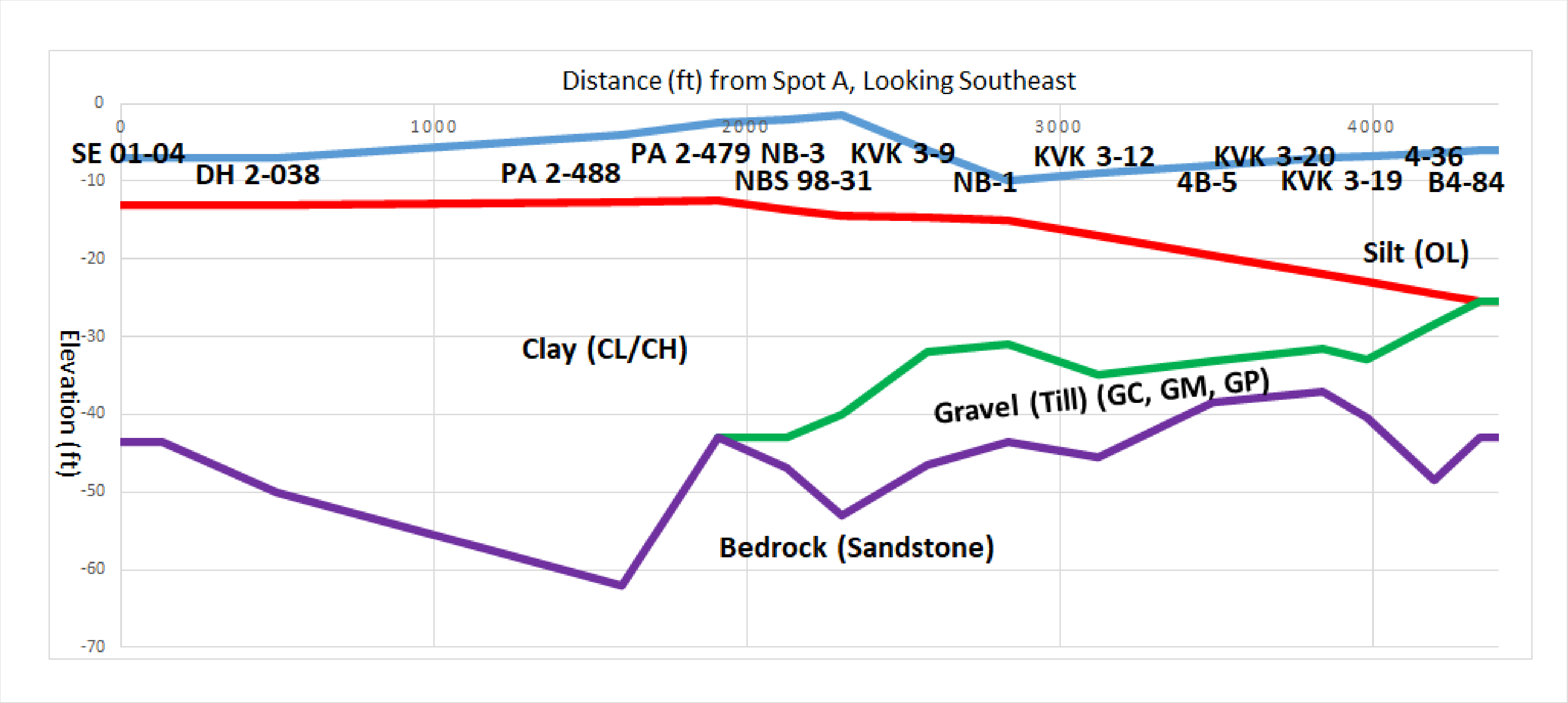


Figure 17: Cross-Section (A-A') of Reach NWK-2

Assumptions: Refer to Assumptions of Figure 11.

APPENDIX B2:

Attachment 2

Boring Logs

TABLE OF CONTENTS

ORIGINAL BORING LOGS ARE LOCATED AT THE NEW YORK DISTRICT

4. BORING LOGS USED TO CREATE CROSS-SECTION OF NWK-1 ....

5. BORING LOGS USED TO CREATE CROSS-SECTION OF NWK-2 ....

ANC 98-57		179977
-49.4		970985

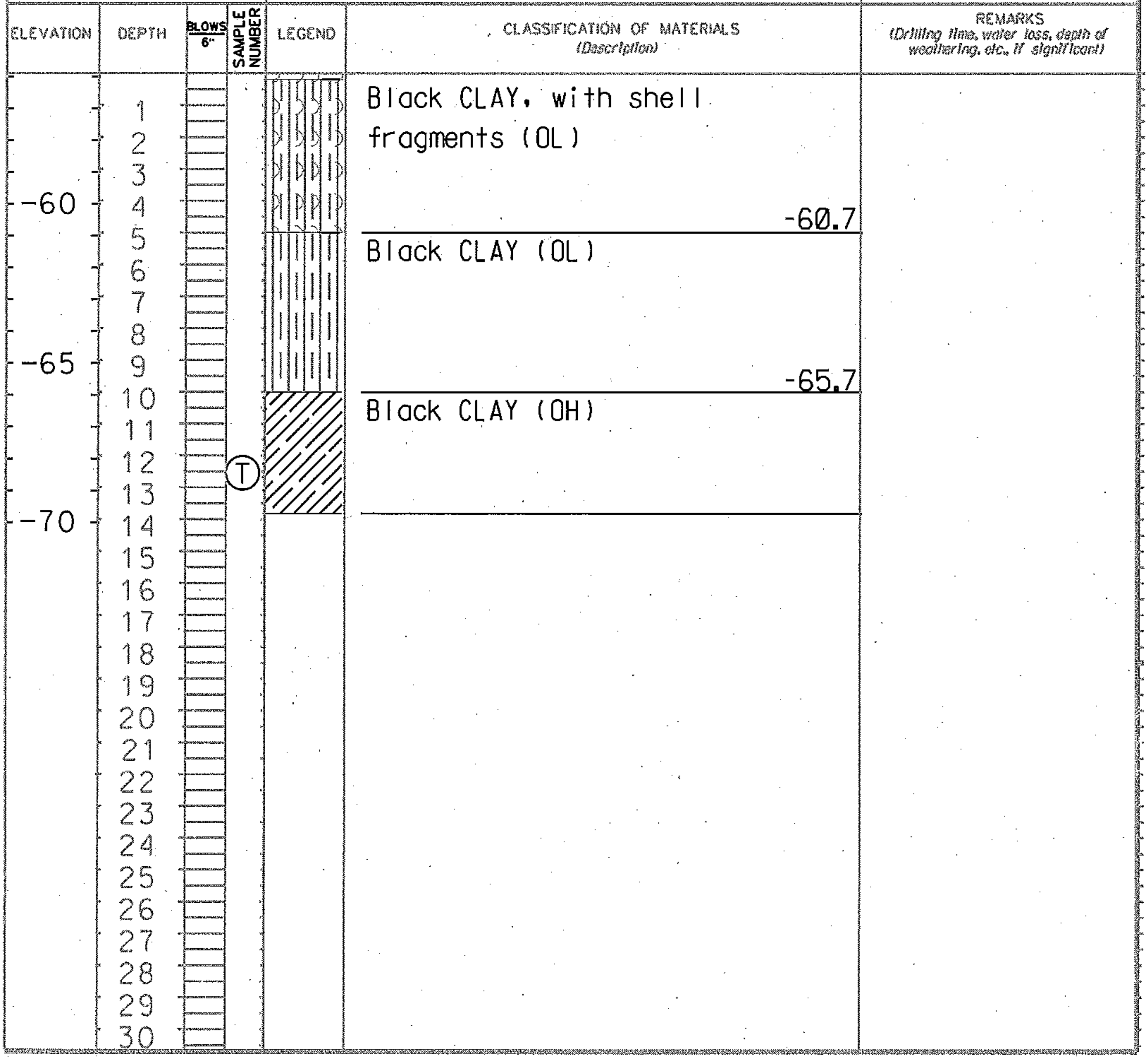
ELEVATION	DEPTH	BLOWS/6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
-50			Ⓣ	▨	Black CLAY, with small shell fragments (OH)	Shell Fragments 0-TD
	1			▨		
	2			▨		
	3			▨		
	4			▨		
-55	5			▨		
	6			▨		
	7			▨		
	8		Ⓣ	▨		
	9			▨	-59.2	
-60	10			▨	Dark gray CLAY, with small shell fragments (OH)	
	11			▨		
	12		Ⓣ	▨		
	13			▨		
	14			▨		
-65	15			▨		
	16		Ⓣ	▨	TD = -66.0'	
	17					
	18					
	19					
	20					
	21					
	22					
	23					
	24					
	25					
	26					
	27					
	28					
	29					
	30					

ANC 98-58

180980

-55.9

969943



Black CLAY, with shell fragments (OL)

-60.7

Black CLAY (OL)

-65.7

Black CLAY (OH)

ANC 98-61

667812

-53.0

617426

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER
	1	WOR	Ⓢ1
-55	2		
	3	WOR	S2
	4		
	5	WOR	S3
	6	WOR	
-60	7		S4
	8	WOR	
	9		S5
	10	WOR	
	11		S6
-65	12	WOR	
	13		S7
	14	WOR	
	15		S8
	16	WOR	
-70	17		S9
	18	WOR	
	19		S10
	20	WOR	
	21		S11
-75	22		
	23		
	24		
	25		
	26		
	27		
	28		
	29		
	30		
	31		
	32		
	33		
	34		
	35		
	36		
	37		
	38		
	39		
	40		
	41		
	42		
	43		
	44		
	45		
	46		
	47		
	48		
	49		

LEGEND

CLASSIFICATION OF MATERIALS (Description)

REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)

Black, very soft SILT, some fine Sand, trace shell fragments (OL) -55.0

Black, very soft, slightly plastic SILT, trace fine Sand, trace shell fragments (OL)

-59.0

-61.0

Dark gray to black, very soft, slightly plastic SILT, trace fine Sand, trace shell fragments (OL)

-67.0

Dark gray, very soft, slightly plastic SILT, trace fine Sand, trace shell fragments (OL)

Gray, very soft, slightly plastic SILT, trace fine Sand, trace shell fragments (OL)

Trace Shell fragments 0'-TD

TD = -75.0'

ANC 98-62						667858
-50.0						618436
ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
		WOR				
	1	↓	ⓢ1		Dark gray to black, very	
	2	WOR			soft, slightly plastic	-52.0
	3	↓	S2		SILT, trace fine Sand (OL)	
	4	WOR			Dark gray, very soft, slightly	
-55	5	↓	S3		plastic SILT, some fine Sand	
	6	WOR			(OL)	
	7	↓	S4			
	8	WOR				
	9	↓	S5			
-60	10	WOR				
	11	↓	S6		-62.0	
	12	WOR			Gray, very soft, slightly	
	13	↓	S7		plastic SILT, some fine Sand	
	14	WOR			(OL)	
-65	15	↓	S8			
	16	WOR				
	17	↓	S9			
	18	WOR				
	19	↓	S10			
-70	20	WOR				
	21	↓	S11			
	22	WOR				
	23	↓	S12			
	24	WOR				
-75	25	↓	S13		TD -76.0'	
	26					
	27					
	28					
	29					
	30					
	31					
	32					
	33					
	34					
	35					
	36					
	37					
	38					
	39					
	40					
	41					
	42					
	43					
	44					
	45					
	46					
	47					
	48					
	49					

RHF 98-19

667332

-49.7

618946

SMPL NOATION	SMPLE	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
-50	1	W O R	1		Black, slightly organic, Clayey SILT, trace fine Sand and Gravel (ML)	Petroleum odor, Shell fragments 0.0'-8.5'
	2					
	3					
	4					
-55	5					
	6					
	7					
	8				-58.2	
	9		2		Gray, Clayey SILt (MH)	
-60	10					
	11					
	12					
	13					
	14					
-65	15					
	16					
	17				TD = -67.1	Pushed last 1.0'
	18					
	19					
	20					
	21					
	22					
	23					
	24					
	25					
	26					
	27					
	28					
	29					
	30					
	31					
	32					
	33					
	34					
	35					
	36					
	37					
	38					
	39					
	40					
	41					
	42					
	43					
	44					
	45					
	46					
	47					
	48					
	49					

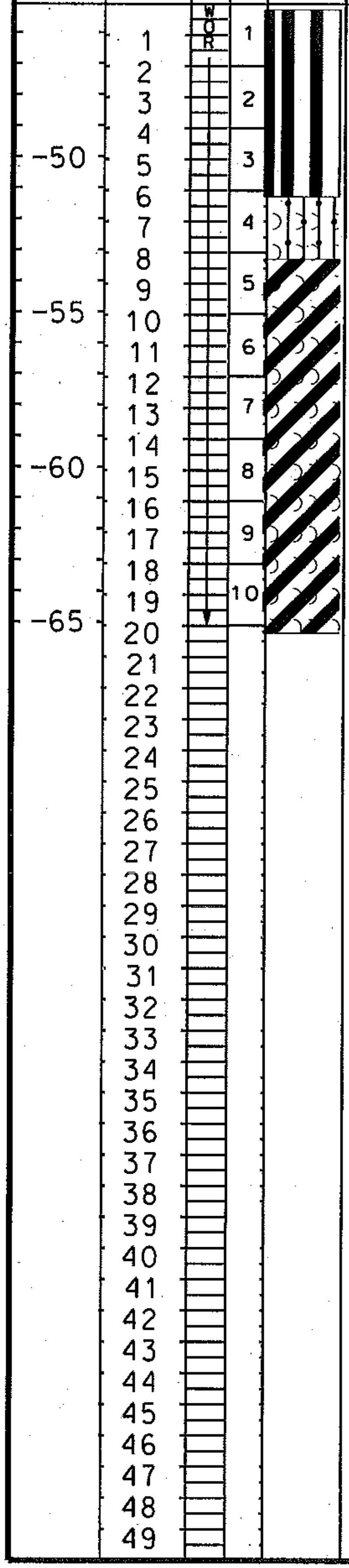
RHF 98-25

665395

-45.1

617954

SWPL NOATION	SMPLE	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)



Black, slightly organic, Clayey SILT, little fine Sand (MH)

-51.1

Very dark gray, slightly fossiliferous, fine SAND, some Silt and Clay (SM)

Dark gray, slightly fossiliferous, CLAY (CH)

TD = -65.1

Slight odor 0.0'-8.0'

-53.1

Trace of small shell fragments 6.0'-20.0'

RHF 98-27

666401

-47.6

618146

SMPL NOATION	SMPL NO	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
	1	WOR			Black, slighly organic, Clayey SILT, trace Sand (ML)	Organic/petroleum odor 0.0'-6.1'
-50	2					
	3		1			
	4					
	5				-53.2	
	6				Dark gray, Silty SAND (SM)	-53.7
-55	7					
	8		2		Gray, slightly fossiliferous Clayey SILT, trace Sand (MH)	Trace shell frag. 6.1'-10.6'
	9					
	10					
	11					
-60	12					
	13		3			
	14					
	15					
	16					
-65	17					
	18					
	19					
	20		4			
	21					
-70	22					
	23					
	24				TD = -72.5'	
	25					
	26					
	27					
	28					
	29					
	30					
	31					
	32					
	33					
	34					
	35					
	36					
	37					
	38					
	39					
	40					
	41					
	42					
	43					
	44					
	45					
	46					
	47					
	48					
	49					

28

666847

-10.0'

613058

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
	1	WOR WOR WOR WOR	S1		Black, SILT (OL)	Start:7/18/89 Finish: 7/18/89
	2 3	WOR WOR WOR WOR	S2			
-15	4 5	WOR WOR WOR WOR	S3			
	6	WOR WOR			Gray SILT, trace fine Sand (ML)	-16.0'
	7 8	WOR WOR WOR WOR	S4			
-20	9 10	WOR WOR WOR WOR	S5		Gray to brown, fine SAND (SP)	-19.0'
	11 12	WOH WOH WOH 1	S6			
	13 14	0 7 4 3	S7			
-25	15 16	5 5 6 8	S8			
	17 18	5 4 6 7	S9			
-30	19 20	8 10 8 8	S10			
	21 22	8 6 9 11	S11			
	23 24	8 8 10 9	S12			
-35	25 26 27 28	10 8 12 9 13 12 18 16	S13			
-40	29 30 31 32	8 9 10 11 11 10 13 18	S14		Yellow, medium to coarse SAND (SP)	-30.0'
-45	33 34 35 36	5 5 7 7 9 9 7 14	S15			
-50	37 38 39 40	3 3 9 15 13 16 16 33	S16		Red-brown, fine-medium SAND and coarse GRAVEL (SP-GP)	-37.0'
	41 42 43 44	42 42 27 25 55 98 100	S17			
-55	45 46				Red-brown, fine SAND, some Silt (SM)	-44.5'
-60	47 48 49 50	5 7 12 15 17 20 22 22	S18			
	51 52 53 54	10 15 16 19 22 20 25 25	S19			
-65	55 56	9 12 14	S20			TD= -66.0'

35

666526

-11.0'

613647

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
	1 2	WOR WOR WOR WOR	S1		Black SILT (OL)	Start:7/20/89 Finish: 7/20/89
-15	3 4	WOR WOR WOR WOR	S2		-15.0'	
	5 6	WOR WOR WOR WOR	S3		Gray, CLAY, trace-little Sand (CL)	
	7 8	WOR WOR WOR WOR	S4			
-20	9 10	WOR WOR WOR WOR	S5			
	11 12	WOR WOR WOR WOR	S6			
-25	13 14	WOR WOR WOR WOR	S7			
	15 16	WOR 5 7 8	S8			-27.0'
	17 18	6 12 10 7	S9		Gray to brown, medium to coarse SAND, some Gravel (SP)	
-30	19 20	10 7 8 8	S10			-31.0'
	21 22	11 10 9 9	S11		Red-brown, fine-medium SAND, trace Gravel (SP)	
-35	23 24	10 10 14 14	S12			
	25 26	6 9 9 12	S13			
	27 28	8 19 17 23	S14			-34.0'
-40	29 30	16 16 24 15	S15		Red-brown, CLAY and GRAVEL (CL-GC)	
	31 32	13 13 10 8	S16			
-45	33 34	4 5 4 5	S17			
	35 36	8 7 8 7	S18			
	37 38	5 8 10 12	S19			
-50	39 40	4 5 8 9	S20			
	41 42	5 6 9 9	S21			
-55	43 44	7 5 7 10	S22			
	45 46	2 3 4 3	S23			
	47 48	5 6 7 10	S24			
-60	49 50	3 3 5 5	S25			
	51 52	8 6 5 5	S26			TD= -63.0'

ANC 98-55

665816

-61.0

615769

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
		WOR				
	1				Black, very soft, slightly plastic SILT, trace shell fragments (OL)	Trace Shell Fragments 0-4'
	2	WOR				
	3					
-65	4	WOR			-65.0	
	5				Dark gray, very soft, slightly plastic SILT (OL)	
	6	WOR				
	7					
	8	WOR				
-70	9					
	10	WOR				
	11				-72.0	
	12	WOR			Gray, very soft, slightly plastic SILT (OL)	
	13					
-75	14	WOR				
	15				TD = -76.0'	
	16					
	17					
	18					
	19					
	20					
	21					
	22					
	23					
	24					
	25					
	26					
	27					
	28					
	29					
	30					
	31					
	32					
	33					
	34					
	35					
	36					
	37					
	38					
	39					
	40					
	41					
	42					
	43					
	44					
	45					
	46					
	47					
	48					
	49					

ANC 98-80 | 666180

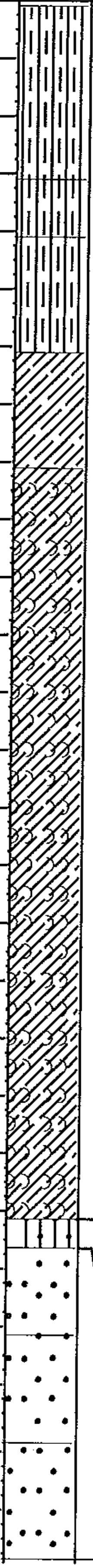
-39.3 | 615112

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
-40	1 2 3 4	WOR WOR	S1 S2	Dark gray Clayey SILT, very soft, medium plasticity, trace shell fragments. (OL)	Shell fragments (0'-12') -43.3
-45	5 6 7 8	WOR WOR	S3 S4	Gray to dark gray SILT, very soft, low to medium plasticity, trace shell fragments. (OL)	Strong Odor (8'-12') -47.3
-50	9 10 11 12	WOR WOR	S5 S6	Dark gray Clayey SILT, very soft, medium plasticity, strong odor, trace shell fragments. (OL)	-51.3
	13 14	WOR	S7	Dark gray SILT, very soft, slightly plastic. (OL)	-53.3
-55	15 16 17 18 19 20	WOR WOR WOR	S8 S9 S10	Gray to dark gray SILT, very soft, low to medium plasticity, trace fine sand. (OL)	-59.3
-60 -65	21 22 23 24 25 26 27 28	WOR WOR WOR WOR	S11 S12 S13 S14	Gray Silty CLAY, very soft, highly plastic, trace shell fragments. (OH)	Shell Fragments (20'-32') -67.3
-70	29 30 31 32	WOR WOR	S15 S16	Gray Clayey SILT, very soft, medium plasticity, trace shell fragments. (OL)	-71.3
-75	33 34 35 36	WOR WOR	S17 S18	Gray to light gray SILT, very soft, low to medium plasticity, trace fine sand, trace peat. (OL)	TD = -75.3'
	37 38 39 40 41 42 43 44 45 46 47 48 49				

DEPTH	USCS	% G	% S	% F	LL	PL	PI	% H2O	SG
0-2	CL/OL		25.3	74.7				101.4	

ANC 98-81 666473

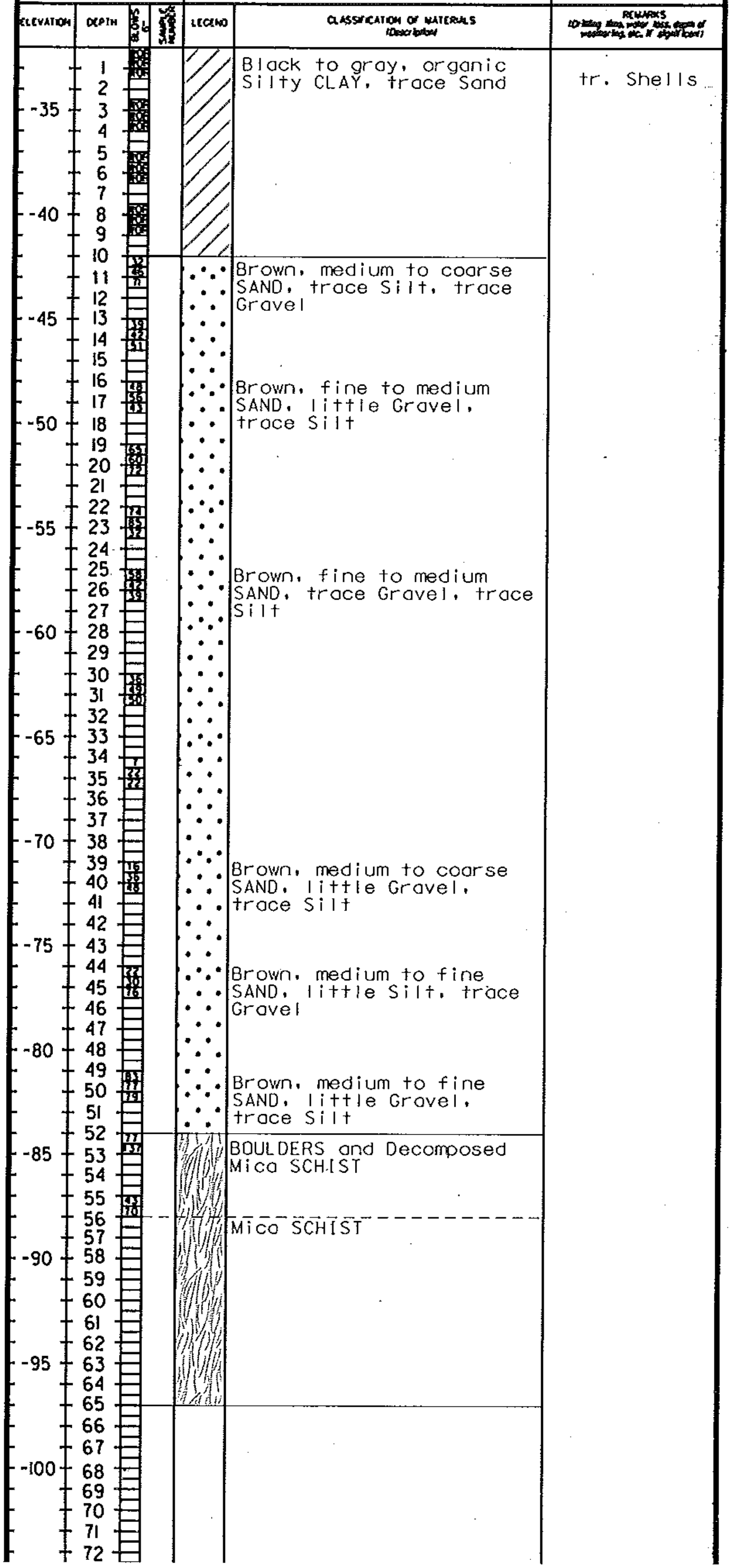
-21.0 614535



ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
		WOR			
	1	↓		Dark gray SILT, very soft, slightly plastic, trace shell fragments and fine Gravel (OL)	Trace shell fragments 0-6'
	2	WOR			
	3	↓			
-25	4	WOR			
	5	↓			
	6	WOR		-27.0	
	7	↓		Gray SILT, very soft, slightly plastic. (OL)	
	8	WOR			-29.0
-30	9	↓		Gray SILT, very soft, slightly plastic trace fine Sand, trace shell fragments. (OL)	Trace shell fragments 8'-12'
	10	WOR			
	11	↓			
	12	WOR			-33.0
	13	↓		Gray Silty CLAY, very soft, medium to high plasticity. (OH)	
-35	14	WOR			
	15	↓			
	16	WOR			-37.0
	17	↓		Light gray Silty CLAY, very soft, medium to high plasticity trace shell fragments, trace fine Gravel (OH)	Trace shell fragments 16'-42'
	18	WOR			
-40	19	↓			
	20	WOR			
	21	↓			
	22	WOR			
	23	↓			
-45	24	WOR			
	25	↓			
	26	WOR			
	27	↓			
	28	WOR			
-50	29	↓			
	30	WOR			
	31	↓			
	32	WOR		Trace wood fragments below 32.0' and some wood fragments below 40'	
	33	↓			
-55	34	WOR			
	35	↓			
	36	WOR			
	37	↓			
	38	WOR			
-60	39	↓			
	40	WOR		Color change to gray	
	41	↓			
	42	WOR 60		-63.0	
	43	65 100		Gray to light gray fine Silty SAND, very dense. (SM)	-64.0
-65	44	28 33			Large (1/2") wood fragments 44-46'
	45	63 85			
	46				
	47	30 36		Light gray fine SAND, dense, poorly graded. (SP)	
	48	32 35			
-70	49	30			
	50	42			
	51	36 33			
	52	30 39			
	53	7 8			
-75	54	12			TD = -75.0'

PJ-4 612139

-32.0 667760



CLASSIFICATION OF MATERIALS (Description)

REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)

Black to gray, organic Silty CLAY, trace Sand

tr. Shells

Brown, medium to coarse SAND, trace Silt, trace Gravel

Brown, fine to medium SAND, little Gravel, trace Silt

Brown, fine to medium SAND, trace Gravel, trace Silt

Brown, medium to coarse SAND, little Gravel, trace Silt

Brown, medium to fine SAND, little Silt, trace Gravel

Brown, medium to fine SAND, little Gravel, trace Silt

BOULDERS and Decomposed Mica SCHIST

Mica SCHIST

PJ 98-08

667449

-41.0

611990

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
	1	WOR WOR WOR WOR	S-1		Black SILT, very soft, wet, highly plastic. (OL)	
	2	7 6				-43.5
	3	6 5	S-2		Dark gray to brown, Silty SAND, medium density to very dense, moist wet, some fine to coarse Gravel. (SM)	
-45	4					
	5					
	6					
	7	4 4				
	8	7 14	S-3			
-50	9					
	10					
	11					
	12	25 30				
	13	34 34	S-4			
-55	14					
	15					
	16					
	17	30 50				
	18	50 75	S-5			
-60	19					
	20					
	21					
	22					-63.0
	23		S-6		Brown SAND, very dense, moist, poorly graded, trace fine Gravel. (SP)	
-65	24					
	25					
	26					
	27				TD = -65.0	
	28					
-70	29					
	30					
	31					
	32					
	33					
	34					
	35					
	36					
	37					
	38					
	39					
	40					
	41					
	42					
	43					
	44					

ELEV.	USCS	%G	%S	%F	LL	PL	PI	%H20	SG
-53to-55'	SM	16.3	40	43.7				11.7	

ANC 98-30

661000

-27.0

610637

SAMPLE NUMBER	BLOWS 6"
S1	WOR
Shelby Tube	
S2	WOR
S3	WOR
S4	WOR
S5	WOR
S6	WOR
S7	WOR
S8	15 18 22 18
S9	1 4 5 5
S10	3 4 5 7
S11	6 9 15 15
S12	10 9 8 7
S13	6 4 1 6 1
S14	WOR
S15	WOR
S16	WOR
S17	WOR
S18	WOR
S19	WOR
S20	WOR
S21	WOR
S22	WOR
S23	WOR

ELEVATION	CLASSIFICATION OF MATERIALS (Description)
-30.0	Dark gray, very soft, slightly plastic SILT, trace fine Sand (OL)
-37.0	Dark gray, very soft, slightly plastic SILT, some fine Sand, trace shell fragments (OL)
-43.0	Dark gray, very soft, slightly plastic SILT, trace fine Sand, trace shell fragments (OL)
-45.0	Olive gray, moderately dense to dense, fine to medium SAND, trace Silt (SP)
-49.0	Olive gray, soft, fine to medium SAND, trace Silt (SP)
-55.0	Olive gray, loose to moderately dense, fine to medium SAND, some Silt, trace shell fragments (SM)
	Olive gray, very soft, slightly plastic SILT, trace to little Sand (OL)

TD = -75.0'

REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)

Petroleum Odor (0'-2')

Shelby Tube 2'(29') - 4'(31') Recovered 24"

Trace Shell Fragments(4'-16')

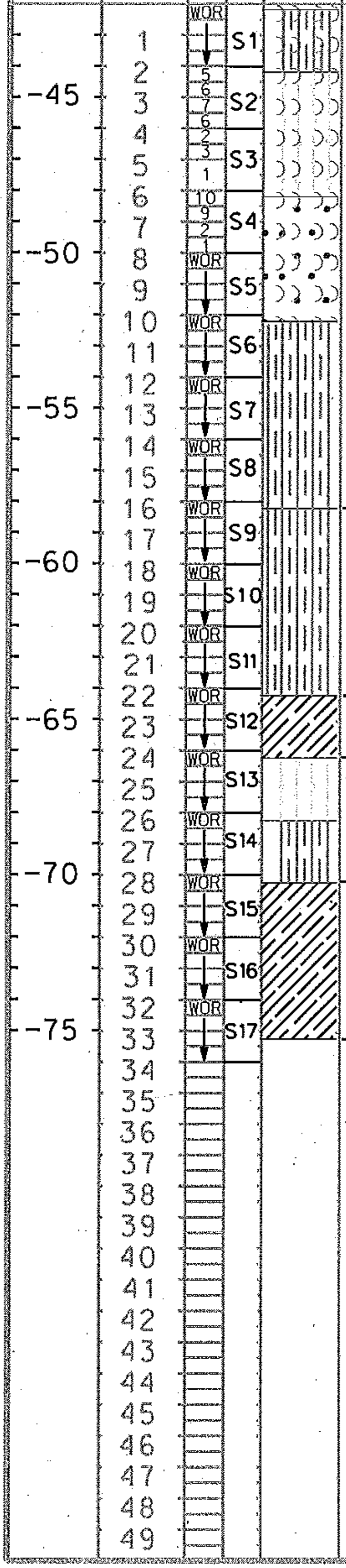
High Amount Shell Fragments (16'-22')

Trace Shell Fragments(22'-28')

Putrid Odor (30'-TD)

ANC 98-31		659960
-42.0		612497

ELEVATION	DEPTH	BLOWS/6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)



Black, very soft, slightly plastic SILT, trace shell fragments (OL) -44.0

Dark gray, loose to moderately dnse, fine to medium SAND, some Silt, trace shell fragments (SM) -48.0

Dark gray, loose, fine to medium SAND, trace shell fragments (SP) -52.0

Gray, very soft, moderately plastic, Clayey SILT (OL) -58.0

Gray, very soft, slightly plastic SILT, trace to little Sand (OL) -64.0

Gray, very soft, highly plastic Silty CLAY (OH) -66.0

Gray to dark gray, very loose, fine to coarse SAND, little to some Silt (SM) -68.0

Gray, very soft, slightly plastic SILT, trace of wood fragments (OL) -70.0

Gray, very soft, moderately high to highly plastic, Silty CLAY, trace of wood fragments (OH)

Trace Shell Fragments(0'-10')

TD = -75.0'

ANC 98-32 659929

-54.0 613509

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER
-55	1	WOR ↓	S1
	2	9	
	3	10 8	S2
	4	3 WOR	
	5	↓	S3
-60	6	5	
	7	6 4	S4
	8	3 WOR	
	9	↓	S5
	10	1	
-65	11	1	S6
	12	WOR	
	13	2 1	S7
	14	1 WOR	
	15	1 1	S8
-70	16	1 3	
	17	1 1	S9
	18	WOR	
	19	↓	S10
	20	WOR	S11
-75	21		
	22		
	23		
	24		
	25		
	26		
	27		
	28		
	29		
	30		
	31		
	32		
	33		
	34		
	35		
	36		
	37		
	38		
	39		
	40		
	41		
	42		
	43		
	44		
	45		
	46		
	47		
	48		
	49		

LEGEND

CLASSIFICATION OF MATERIALS
(Description)

No Recovery

-56.0

Dark gray, loose to moderately dense, fine SAND, some Silt, trace shell fragments (SM)

-60.2

Gray to dark gray, loose, fine SAND, trace shell fragments (SP)

-72.0

Gray, very soft, highly plastic, Silty CLAY, trace shell fragments (OL)

REMARKS
(Drilling time, water loss, depth of weathering, etc., if significant)

Trace Shell Fragments(2'-20')

TD = -75.0'

DH-3

660880

-36.3

611942

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS *(Description)*	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)*
		WOR			Dark gray SAND, little Silt, trace of Gravel (SW)	DR = Drove Rod
	1	↓				
	2	↓				
	3	2 1				
-40	4	2 2				
	5	DR				
	6	↓				
	7					TD: -43.3
	8					
-45	9					
	10					
	11					
	12					
	13					
	14					
	15					
	16					
	17					
	18					
	19					
	20					
	21					
	22					
	23					
	24					
	25					
	26					
	27					
	28					
	29					
	30					
	31					
	32					
	33					
	34					
	35					
	36					
	37					
	38					
	39					
	40					
	41					
	42					
	43					
	44					
	45					
	46					
	47					
	48					
	49					

DH-145	661754
-37	609338

ELEVATION	DEPTH	BLOWS/6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
	1	P P		▥	Black SILT, some Sand	Petroleum odor
	2	P P		▥		
-40	3	P P		▥		
	4	6 8		▨		-41.0
	5	61 17		▨	SERPENTINE	
	6	23 30		▨	SAPROLITE	
	7	28 23		▨		
-45	8	26 32		▨		TD: -45.0
	9					
	10					
	11					
	12					
-50	13					
	14					
	15					
	16					
	17					
	18					
	19					
	20					
	21					
	22					
	23					
	24					
	25					
	26					
	27					
	28					
	29					
	30					
	31					
	32					
	33					
	34					
	35					
	36					
	37					
	38					
	39					
	40					
	41					
	42					
	43					
	44					
	45					
	46					
	47					
	48					
	49					

DH-148

661588

-38.5

609849

ELEVATION	DEPTH	BLOWS/6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
-40	1	P P			Black, oily SILT, trace Sand	
	2	P P				
	3	P P				-41.5
	4	9 11			Decomposed SERPENTINITE	
	5					
-45	6					
	7					
	8					TD: -46.5
	9					
	10					
-50	11					
	12					
	13					
	14					
	15					
	16					
	17					
	18					
	19					
	20					
	21					
	22					
	23					
	24					
	25					
	26					
	27					
	28					
	29					
	30					
	31					
	32					
	33					
	34					
	35					
	36					
	37					
	38					
	39					
	40					
	41					
	42					
	43					
	44					
	45					
	46					
	47					
	48					
	49					

KN-11		661754
-41.7		609328

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS *(Description)*	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)*
		3 7		▥	Black SILT & Sand. (ML-SM)	
	1	4 3		●	Red-brown gravelly, dense glacial TILL. (GM)	-42.7'
	2	3*				
-45.0	3	2*				
	4	2*				
	5	4*				
	6	4*		▒	Decomposed SERPENTINE bedrock.	-47.6'
	7	3*				
-50.0	8	3*				
	9	3*				
	10	3*				
	11	4*			TD = 53.7'	
	12					
	13					
	14					
	15					
	16					
	17					
	18					
	19					
	20					
	21					
	22					
	23					
	24					
	25					
	26					
	27					
	28					
	29					
	30					
	31					
	32					
	33					
	34					
	35					
	36					
	37					
	38					
	39					
	40					
	41					
	42					
	43					
	44					
	45					
	46					
	47					
	48					
	49					

KVK-37	661423
-40.1	610028

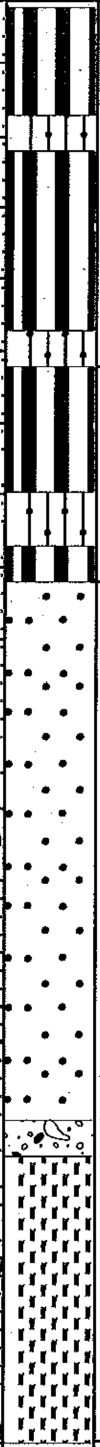
ELEVATION	DEPTH	BLOWS / 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS *(Description)*	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)*
		10 19			Brown, fine SAND, some Silt and Clay, trace to some Gravel (SM)	
	1	43 37				
	2	36 29				
	3	19 22				
	4	23 27				
-45.0	5	42 51				
	6	39 47				
	7	62 54				
	8	49 62				
	9	84 100/5				
-50.0	10					TD = 50.2'
	11					
	12					
	13					
	14					
	15					
	16					
	17					
	18					
	19					
	20					
	21					
	22					
	23					
	24					
	25					
	26					
	27					
	28					
	29					
	30					
	31					
	32					
	33					
	34					
	35					
	36					
	37					
	38					
	39					
	40					
	41					
	42					
	43					
	44					
	45					
	46					
	47					
	48					
	49					

KVK 98-1A

661096

-22.8

610448



ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
	1	WOR	S1		Dark gray to black Clayey SILT, trace very fine Sand. (MH)	Moderate - strong Petroleum odor. Trace of Shell fragments.
-25	2	WOR	S2			
	3				-25.8	
	4	WOR	S3		Dark gray to black very fine SAND, some Silt. (SM)	-26.8
	5					
	6	WOR	S4			Mod Petroleum odor. Trace of Sand Silt and Shell fragments.
-30	7				Dark gray to black Clayey SILT, slightly organic, little very fine Sand. (MH)	
	8	WOR	S5			
	9					-31.8
	10	WOR	S6			-32.8
	11				Dark gray fine to medium SAND, some Silt. (SM)	Weak - mod Petroleum odor.
-35	12	WOR	S7			
	13				Dark gray to black Clayey SILT, slightly organic, trace very fine Sand. (MH)	
	14	WOH WOR	S8			-36.3 WOH on last 6"
	15	2				-37.8 Weak sour odor.
	16	4 1	S9		Dark gray fine to medium SAND, little Silt. (SM)	-38.8
-40	17	2 2				Trace of Shell Hash. (Marine).
	18				Dark gray Clayey SILT. (MH)	
	19				Gray to dark gray fine to medium SAND, micaceous, trace silt. (SP-SM)	
	20					
	21					
-45	22					
	23	7 12 10 8	S10			Trace of Shell Hash, large, coarse, Sand-sized Mica frags.
	24					
	25					
	26					
-50	27					Oyster Shells.
	28	6 10 8 7	S11			
	29					
	30				-53.8	
	31				Cobbles and Boulders. -54.8	Erratic Drilling
-55	32					Smooth Drilling
	33				SERPENTINITE, Dark green with red-brown bands, high angle fractures (60°) with white minerals along fracture faces.	
	34					
	35					C1 = 57.8' to 62.8' Cut 5' Rec 5' ROD = 44%
	36					
-60	37					
	38					
	39					
	40					
	41					
-65	42					
	43					
	44					
	45					
	46					
	47					
	48					
	49					

DEPTH	USCS	% G	% S	% F	LL	PL	PI	% H2O	SG
	SW/SM	0.8	89.2	10.0					2.78

4B-6		660569
-43.2		589415

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
	1	WOR ↓		▥	Gray SILT (OL)	
-45	2	↓ ↓		▥		-45.0
	3	10 12		▨	Red-brown SILT, some Clay, little to some Gravel (CL)	
	4	12 16		▨		
	5	28 30		▨		
	6	34 41		▨		
-50	7	32 38		▨		
	8	41 49		▨		TD = -51.2
	9					
	10					
	11					
-55	12					
	13					
	14					
	15					
	16					
	17					
	18					
	19					
	20					
	21					
	22					
	23					
	24					
	25					
	26					
	27					
	28					
	29					
	30					
	31					
	32					
	33					
	34					
	35					
	36					
	37					
	38					
	39					
	40					
	41					
	42					
	43					
	44					
	45					
	46					
	47					
	48					
	49					

4B-9		661171
-34.6		589686

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS	REMARKS
	1 2 3 4	0 0 1 0 1 1 1 2			Gray SILT (ML)	
-40 -45 -50	5 6 7 8 9 10 11 12 13 14 15 16 17	4 4 6 6 6 9 13 17 12 16 19 23 14 23 29 71 33 65 58 91 35 26 67 70 42 31 69 26			Red-brown Clayey SILT. little to some Gravel. trace Sand (ML)	-38.6
	18 19					TD = -52.6

4B-17 662279

-39.7 590191

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
-40		11 10			Red-brown CLAY, some Silt, little to some Gravel, trace of fine-medium Sand (SM)	
	1	14 11				
	2	9 9				
	3	11 12				
	4	20 20				
-45	5	20 20			Red-brown, fine-medium SAND, some Silt, little to some Gravel (SM)	-45.0
	6	15 18				
	7	20 20				
	8	40 39				
	9	57 79			TD = -50'	
-50	10					
	11					
	12					
	13					
	14					
-55	15					
	16					
	17					
	18					
	19					
	20					
	21					
	22					
	23					
	24					
	25					
	26					
	27					
	28					
	29					
	30					
	31					
	32					
	33					
	34					
	35					
	36					
	37					
	38					
	39					
	40					
	41					
	42					
	43					
	44					
	45					
	46					
	47					
	48					
	49					

NB 98-34		665150
-15.7		591781

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
	1	WOR	S-1		Black SILT and CLAY, very very soft, trace Sand. (MH)	Strong petrol odor
	2					
	3		S-2			
-20	4					
	5		S-3			
	6					
	7		S-4			
	8	3				-23.7
-25	9	2 1	S-5		Gray fine SAND, trace Silt, trace Shell fragments. (SP)	
	10	2				
	11					
	12					
	13	3				-28.7
-30	14	1 3	S-6		Red-brown CLAY, soft to firm, fat, highly plastic, trace Silt. (CH)	
	15	7				
	16					
	17					
	18	2				
-35	19	4 4	S-7			
	20	5				
	21					
	22					
	23	6				
-40	24	6 9	S-8			
	25	10				
	26					
	27					
	28	9				-43.7
-45	29	19 25	S-9		Red brown SILT, fat, little Clay, trace Sand and Gravel. (MH)	
	30	25				
	31					
	32					
	33	50	S-10			-48.9
-50	34				COBBLES and BOULDERS-SHALE, Serpentinite, Diabase and Sandstone	
	35					
	36					
	37					
	38					
-55	39					C1=-49.0to-60.7' Cut 11.7' Rec 50% Cobbles and Boulders
	40					
	41					
	42					
	43					
-60	44					
	45					
	46					
	47	RB				RB= Roller Bit
	48					
-65	49					TD= -64.7'

NB 98-35	667120
-25.3'	592891

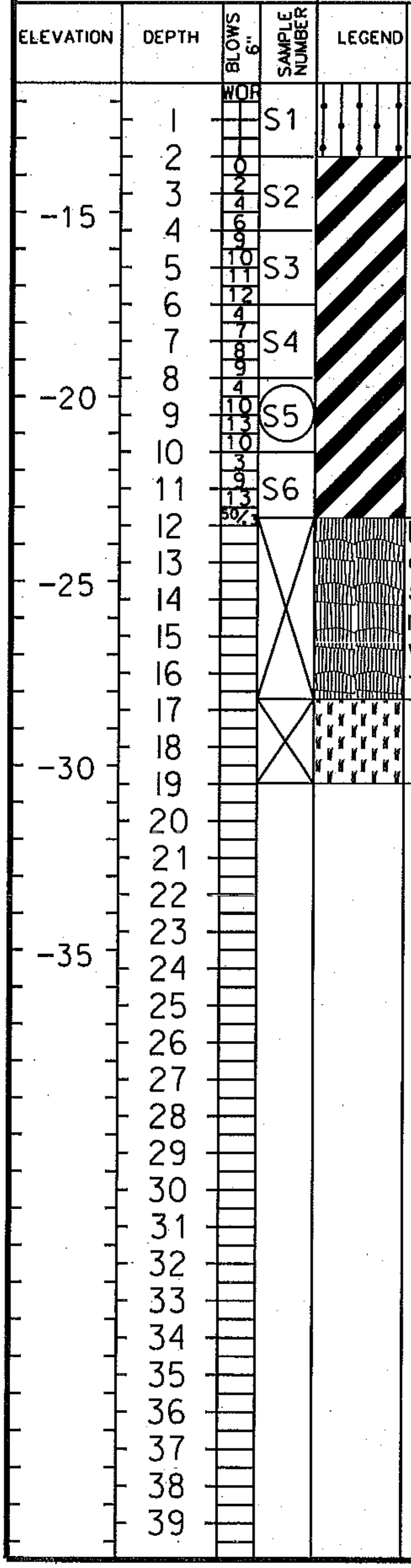
ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
	1	WOR	S1		Black SILT, trace Clay, trace fine Sand (MH)	Slight odor
	2					trace Shell fragments
	3	WOR	S2			
	4					
-30	5		S3			
	6					
	7		S4			
	8					
	9		S5			
-35	10					
	11		S6			
	12					
	13	0 0	S7			
	14	2 2			-39.5'	
-40	15	0 2	S8		Dark gray, fine to medium SAND, some Silt, trace fine to coarse Gravel (SM)	Shell fragments
	16	2 2				
	17	3 3				
	18	6 11				-43.5'
	19	3 3	S9		Gray, fine to medium SAND, trace fine Gravel, trace Silt (SP)	Shell fragments
-45	20	6 11				
	21	3 3				
	22	2 7				-47.5'
	23	4 5	S10		Reddish-brown fine to coarse GRAVEL, some Clay, some fine to medium Sand (GC)	Shell Fragments
	24	9 8				-49.5'
-50	25	8 9	S13		Reddish brown CLAY, some fine to coarse Gravel, Sand (CL)	Shell Fragments
	26	8 11				-51.5' Lean
	27	4 9	S14		Reddish brown fine to coarse GRAVEL, some Clay (GC)	
	28	21 50/3				-53.5'
	29				Gray-green to light green SERPENTINITE, slightly to moderately fractured	C1:-53.5-57.0' Cut3.5',Rec2.9% RQD 68.5%
-55	30					
	31				-57.0'	
	32					
	33					
	34					
-60	35					
	36					

NB 98-36

670741

-11.5'

594176



CLASSIFICATION OF MATERIALS
(Description)

Gray, medium to coarse SAND, some Silt and Clay, trace fine to coarse Gravel (SM)

Reddish brown CLAY, trace to little fine to coarse, rounded Gravel (CH)

-23.3'

Light-gray, fine to medium grain Hornblende DIORITE, slightly weathered, very hard, moderate to highly fractured w/iron stain and Clay along fractures

-28.2'

Black to green, Hornblende SERPENTINITE, medium to coarse grain, hard, moderate to highly weathered, intensely fractured

DEPTH	USCS	% G	% S	% F	LL	PL	PI	%H_2O	SG
8.0-10.0	CL	1.7	17.2	81.1	33	17	16		2.83

REMARKS
(Drilling time, water loss, depth of weathering, etc., if significant)

-13.5'

C1:-23.3'-28.2'
Cut4.9',Rec4.9'
RQD 43%

C2:-28.2'-30.5'
Cut2.7',Rec2.7'
RQD 42.9%

TD=-30.5'

NBN-01-SFI-2	670866
-6.4'	594403

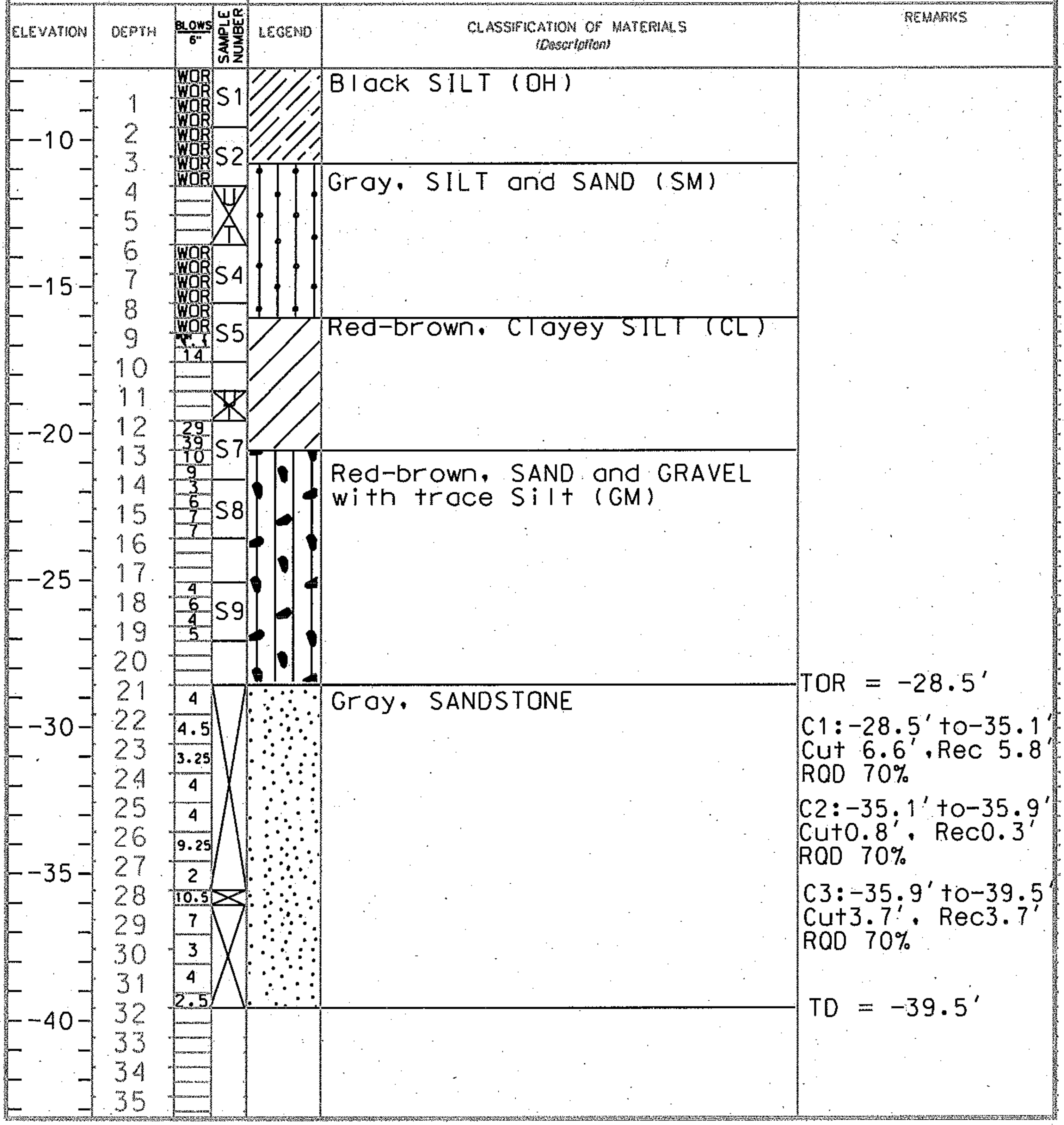
ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS *(Description)*	REMARKS
	1	WOR WOR WOR WOR	S1		Black SILT (OH)	
-10	2 3	WOR WOR WOR WOR	S2			
	4 5		UT		Gray, SAND and SILT (SM)	Shelby Tube 2.0
	6 7	WOR WOR WOR WOR	S4			
-15	8 9	WOR WOR WOR WOR	S5			
	10 11	WOR WOR 18 25	S6		Gray, GRAVEL and SAND (SM)	
-20	12 13	23 17 17 20	S7		Brown, SAND (SM)	
	14 15	15 17 19 14	S8		Red-brown, Clayey SILT (CL)	
	16		UT			Shelby Tube 1.1'
-25	17 18	10 10 18 17	S10			
	19 20	15 21 23 23	S11			
	21 22	9 11 16 18	S12			
-30	23 24	20 26 32 36	S13			
	25 26	11 10 12 12	S14			
-35	27 28	26 32 37 14	S15		Red-brown, SAND and GRAVEL trace Silt (GM)	
	29 30	2 10 14 17	S16			
-40	31 32 33 34 35 36 37	6.5 4.3 7 5.5 5.3 4.5 5			Light-gray, SANDSTONE TD = -44.2'	TOR = -37.6' C1:-37.6' to-43.2' Cut 6.2', Rec 6.2' RQD 83% C2:-43.2' to-44.2' Cut 1', Rec 0.3'
-45	38 39 40					

NBN-01-SFI-3

670672

-7.5′

594251



Black SILT (OH)

Gray, SILT and SAND (SM)

Red-brown, Clayey SILT (CL)

Red-brown, SAND and GRAVEL with trace Silt (GM)

Gray, SANDSTONE

TOR = -28.5′

C1:-28.5′to-35.1′
Cut 6.6′,Rec 5.8′
RQD 70%

C2:-35.1′to-35.9′
Cut0.8′, Rec0.3′
RQD 70%

C3:-35.9′to-39.5′
Cut3.7′, Rec3.7′
RQD 70%

TD = -39.5′

PA 2-438 671364

-29.5' 594315

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
-30	1	WOR WOR WOR	S1		Black, Silty CLAY and SAND (SC)	
	2					
	3	WOR WOR WOR	S2			
	4				-34.5'	
	5					
-35	6	WOR WOR WOR	S3		Red-brown, Silty CLAY, little fine Sand (CL)	
	7					
	8					
	9	4 5 9	S4			
	10					
-40	11					
	12	4 6 10	S5			
	13					
.3'→	14					
	15	5 6 5	S6			
	16					
-45	17					
	18		UT			Shelby Tube
	19					
	20	6 5 8	S8			
	21					
	22					
-50	23		UT			Shelby Tube
	24				-54.0'	
	25	5 8 8	S 10		Red-brown, Clayey SILT (ML)	
	26					
	27	6 7 8	S 11			
-55	28					
	29	1 4 5	S 12		-59.0'	
	30				Red-brown, Silty CLAY, trace Gravel (CL)	
	31					
	32					
	33					
-60	34				-64.0'	
	35	3 8 12	S 13		Red-brown, Clayey SILT (ML)	
	36					
	37					
	38					
	39					
-65	40	17 11 16	S 14			
	41					
	42					
	43					
	44					
-70	45	75/0"				
	46				Seamy, fractured SANDSTONE	C1:-70.5'to-75.5' Cut 5' Rec 50% 4+ pieces
	47					
	48					
	49					
	50					
-75	51					C2:-7.5'to-80.0' Cut 4.5' Rec 66% 4+ pieces
	52					
	53					
	54					
	55					
-80	56					TD =-80.0'
	57					

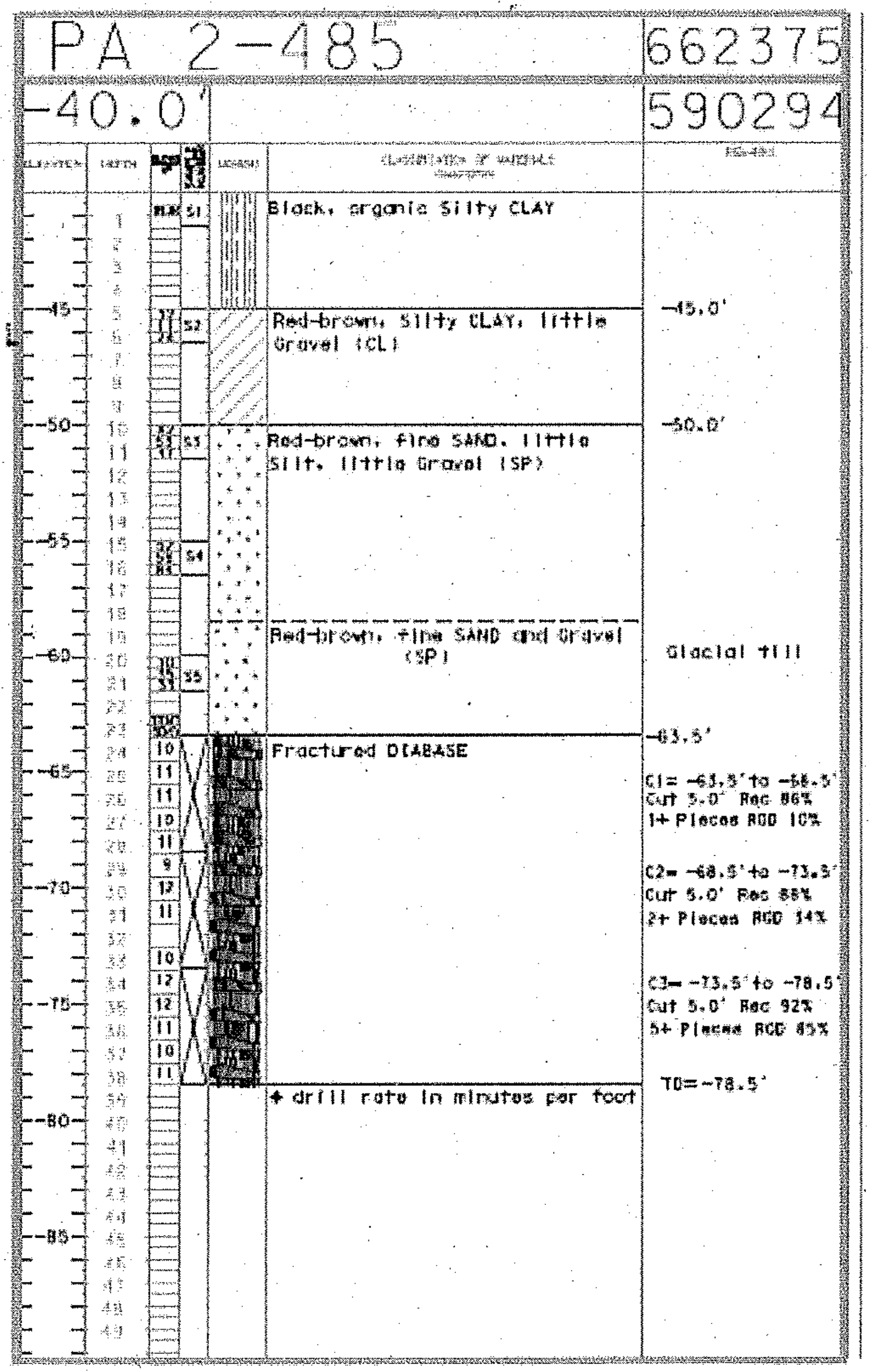
PA 2-443 672220

-33.5 594590

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
-35	1	WOR WOR WOR	S1	▨	Black-red brown silty CLAY, little Gravel (CL)	
	2	WOR WOR WOR	S2			
	3					
	4					
	5	WOR WOR WOR	S3			
-40	6					
	7	WOR WOR 10	S4			
	8					
	9	2 3 2	S5			
	10					
-45	11					
	12	10 12 25	S6			
	13					
	14	13 14 17	S7			
	15					
-50	16					
	17	5 6 9	S8			
	18					
	19					
	20	PH PH PH	9U			
-55	21	10 11 25	S10			
	22					
	23					
	24	12 14 21	S11			
	25					
-60	26	PH PH PH PH	12U			
	27					
	28	8 21 23	S13			
	29					
	30					
-65	31					
	32	1 5 7	S14			
	33					
	34					C1 83 - 85 CUT 2 REC 50% 1 PIECE
	35					
-70	36	4 4 6	S15			
	37					
	38					
	39					C2 85 - 88 CUT 3 REC 83% 6 PIECES
	40					
-75	41					
	42	3 3 5	S16			
	43					
	44					C3 88 - 93 CUT 5 REC 20% 1 PIECE
	45					
-80	46					
	47	10 14 20	S17			
	48	98*				
	49					-83.0
	50			▤	Red SHALE	* 300 LBS HAMMER, 50/0
-85	51					
	52					
	53					
	54					
	55					
-90	56					
	57					
	58					
	59					
	60					
	61					

PA 2-450	672032
-37.5	214838

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
	1			▨	Black to red-brown silty CLAY,	
-40	2			▨	trace to some Gravel (CL)	
	3			▨		
	4			▨		
	5			▨		
	6			▨		
-45	7			▨		
	8			▨		
	9			▨		
	10			▨		
	11			▨		
-50	12			▨		
	13			▨		
	14			▨		
	15			▨		
	16			▨		
-55	17			▨		
	18			▨		
	19			▨		
	20			▨		
	21			▨		
-60	22			▨		
	23			▨		
	24			▨		
	25			▨		
	26			▨		
-65	27			▨		
	28			▨		
	29			▨		
	30			▨		
	31			▨		
-70	32			▨		
	33			▨		
	34			▨		
	35			▨		
	36			▨		
-75	37			▨		
	38			▨		
	39			▨		
	40			▨		
	41			▨		
-80	42			▨		
	43			▨		
	44			▨		
	45			▨		
	46			▨		
-85	47			▨		-85.0
	48			▤	Red SHALE	
	49			▤		
	50			▤		
	51			▤		
-90	52			▤		
	53					
	54					
	55					
	56					
-95	57					
	58					
	59					



Black, organic Silty CLAY

-45.0'

Red-brown, Silty CLAY, little Gravel (CL)

-50.0'

Red-brown, fine SAND, little Silt, little Gravel (SP)

Red-brown, fine SAND and Gravel (SP)

Glacial till

-63.5'

Fractured DIABASE

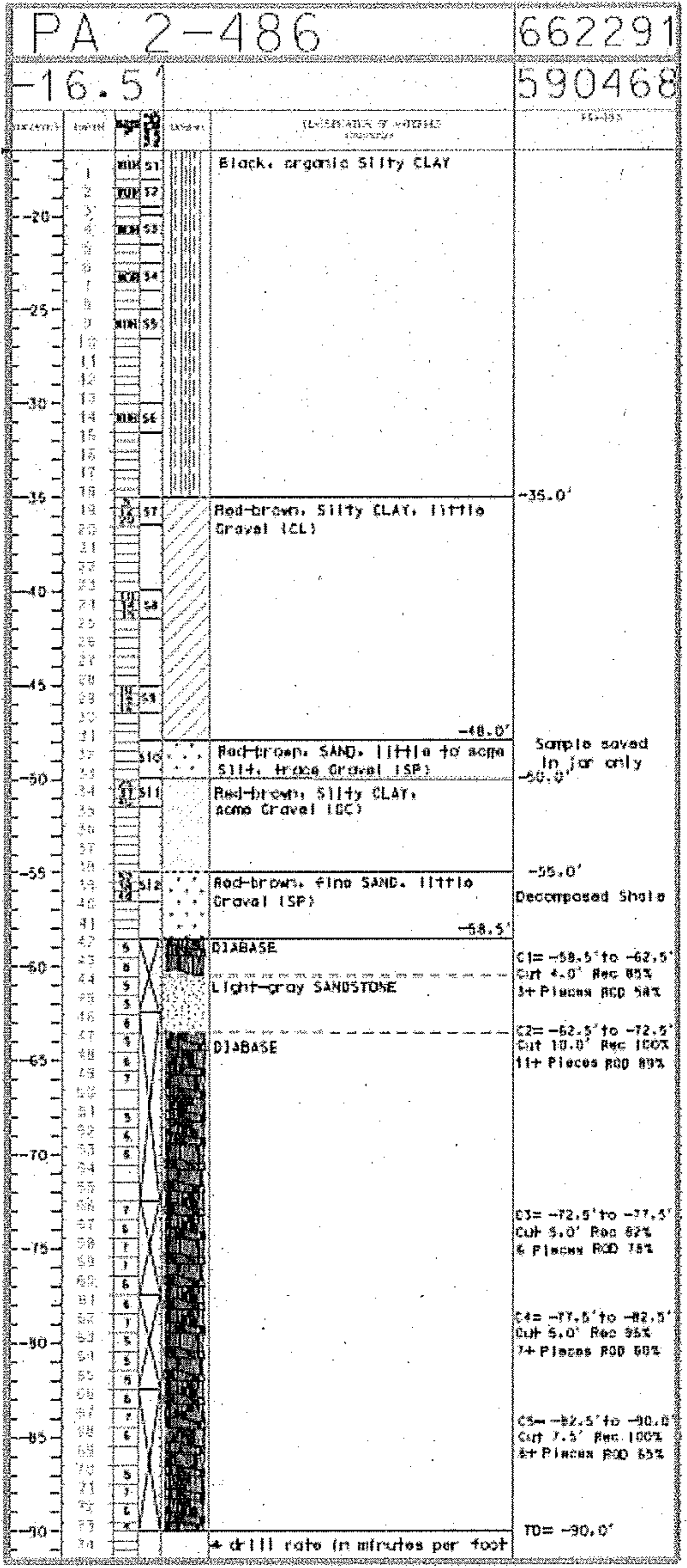
C1= -63.5' to -68.5'
Cut 5.0' Rec 86%
1+ Pieces RQD 10%

C2= -68.5' to -73.5'
Cut 5.0' Rec 88%
2+ Pieces RQD 34%

C3= -73.5' to -78.5'
Cut 5.0' Rec 92%
5+ Pieces RQD 85%

TD= -78.5'

+ drill rate in minutes per foot



Black, organic Silty CLAY

-35.0'

Red-brown, Silty CLAY, little Gravel (CL)

-48.0'

Red-brown, SAND, little to some Silt, trace Gravel (SP)

Sample saved in jar only

-50.0'

Red-brown, Silty CLAY, some Gravel (GC)

-55.0'

Red-brown, fine SAND, little Gravel (SP)

Decomposed Shale

-58.5'

DIABASE

C1= -58.5' to -62.5'
Cut 4.0' Rec 85%
3+ Pieces RQD 58%

Light-gray SANDSTONE

DIABASE

C2= -62.5' to -72.5'
Cut 10.0' Rec 100%
11+ Pieces RQD 89%

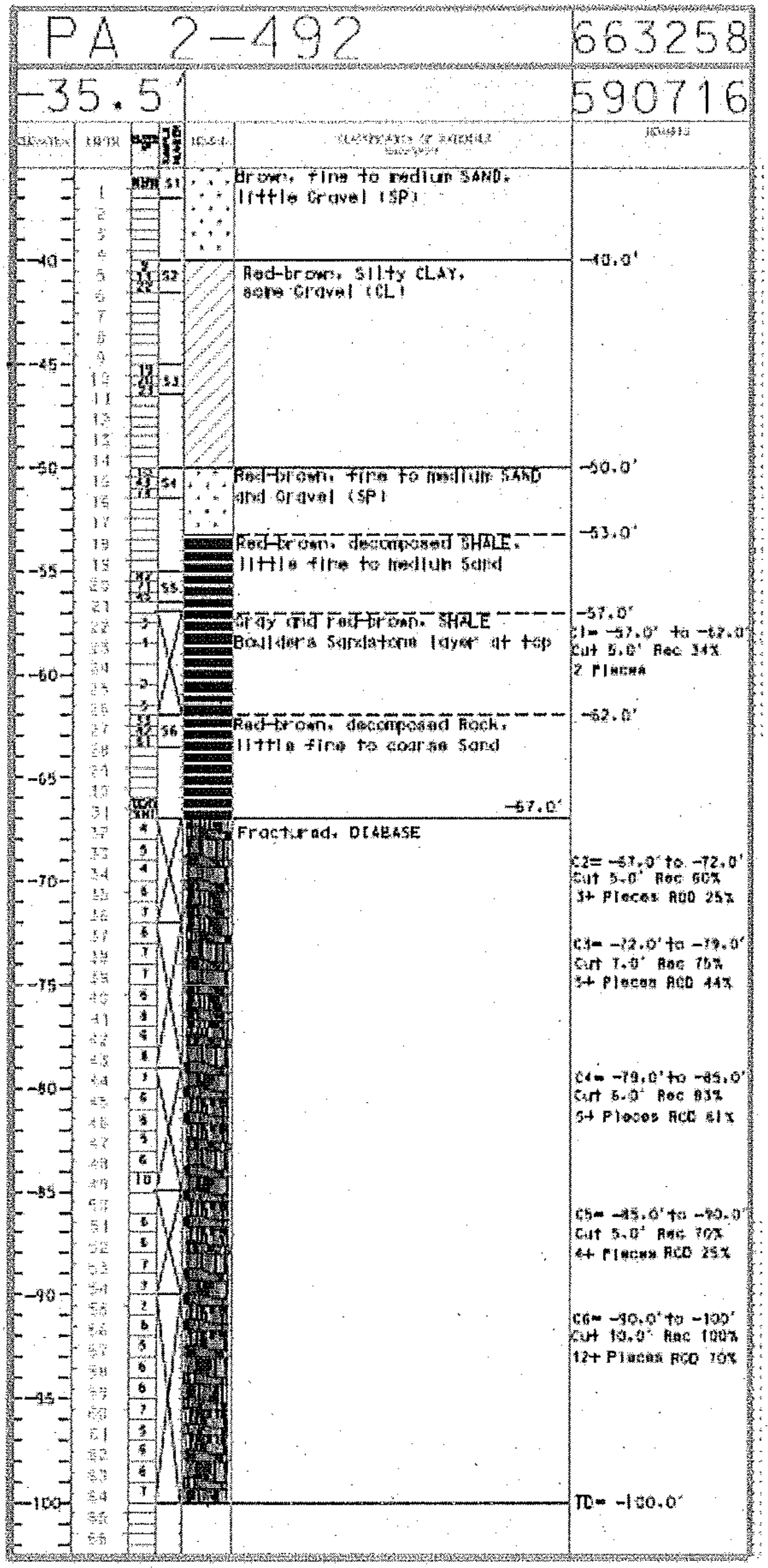
C3= -72.5' to -77.5'
Cut 5.0' Rec 82%
6 Pieces RQD 78%

C4= -77.5' to -82.5'
Cut 5.0' Rec 95%
7+ Pieces RQD 60%

C5= -82.5' to -90.0'
Cut 7.5' Rec 100%
8+ Pieces RQD 65%

TD= -90.0'

* drill rate in minutes per foot



PA 2-492

663258

-35.5'

590716

Brown, fine to medium SAND, little Gravel (SP)

-40.0'

Red-brown, Silty CLAY, some Gravel (CL)

-50.0'

Red-brown, fine to medium SAND and Gravel (SP)

-53.0'

Red-brown, decomposed SHALE, little fine to medium Sand

-57.0'

Gray and red-brown, SHALE Boulders Sandstone layer at top

C1= -57.0' to -62.0'
Cut 5.0' Rec 34%
2 Pieces

-62.0'

Red-brown, decomposed Rock, little fine to coarse Sand

-67.0'

Fractured, DIABASE

C2= -67.0' to -72.0'
Cut 5.0' Rec 60%
3+ Pieces RQD 25%

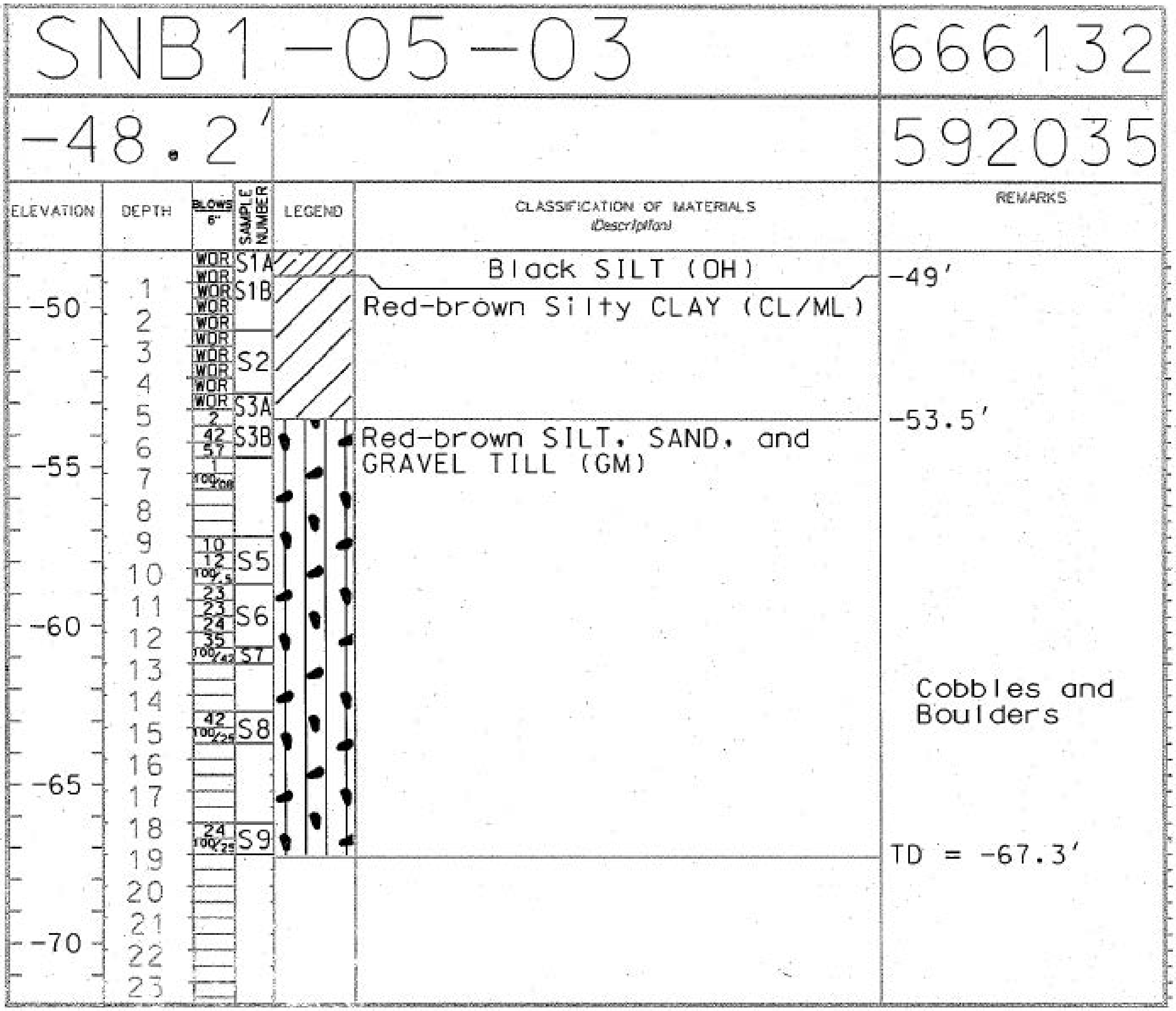
C3= -72.0' to -79.0'
Cut 7.0' Rec 75%
5+ Pieces RQD 44%

C4= -79.0' to -85.0'
Cut 6.0' Rec 83%
5+ Pieces RQD 61%

C5= -85.0' to -90.0'
Cut 5.0' Rec 70%
4+ Pieces RQD 25%

C6= -90.0' to -100'
Cut 10.0' Rec 100%
12+ Pieces RQD 70%

TD= -100.0'


SNB1-05-03
666132
-48.2'
592035
ELEVATION
DEPTH
BLOWS 6"
SAMPLE NUMBER
LEGEND
CLASSIFICATION OF MATERIALS (Description)
REMARKS
-50
-55
-60
-65
-70
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
WOR
WOR
WOR
WOR
WOR
WOR
WOR
WOR
WOR
WOR
2
42
57
1
100/08
10
12
100/.5
23
23
24
35
100/42
42
100/25
24
100/25
S1A
S1B
S2
S3A
S3B
S5
S6
S7
S8
S9
Black SILT (OH)
Red-brown Silty CLAY (CL/ML)
Red-brown SILT, SAND, and GRAVEL TILL (GM)
-49'
-53.5'
Cobbles and Boulders
TD = -67.3'

SNB1-05-14

669100

-47.7'

593305

BLOWS 6"	SAMPLE NUMBER	CLASSIFICATION OF MATERIALS (Description)	REMARKS
WOR WOR	S1A	Black SILT (OH/OL)	
WOR WOR	S1B	Red-brown Silty CLAY (CH/CL)	-49.2'
WOR WOR WOR WOR			
WOR WOR	S3A		
5 5	S3B	Red-brown Clayey SILT, GRAVEL, and rounded Rock fragments TILL (GM/GC)	-53.6
9 6 2 4	S4		
4 4 8 12	S5		
16 23 44 100/.3	S6		
21 22 48 31	S7		
45 100/.5	S8		TOR = -63.3'
4 3 2 2 3		SANDSTONE	Cut 5.3', Rec 3.8' RQD 72% FPF 4+,3,4,2,3 LCS .4,.9,1.65
			TD = -69.5'

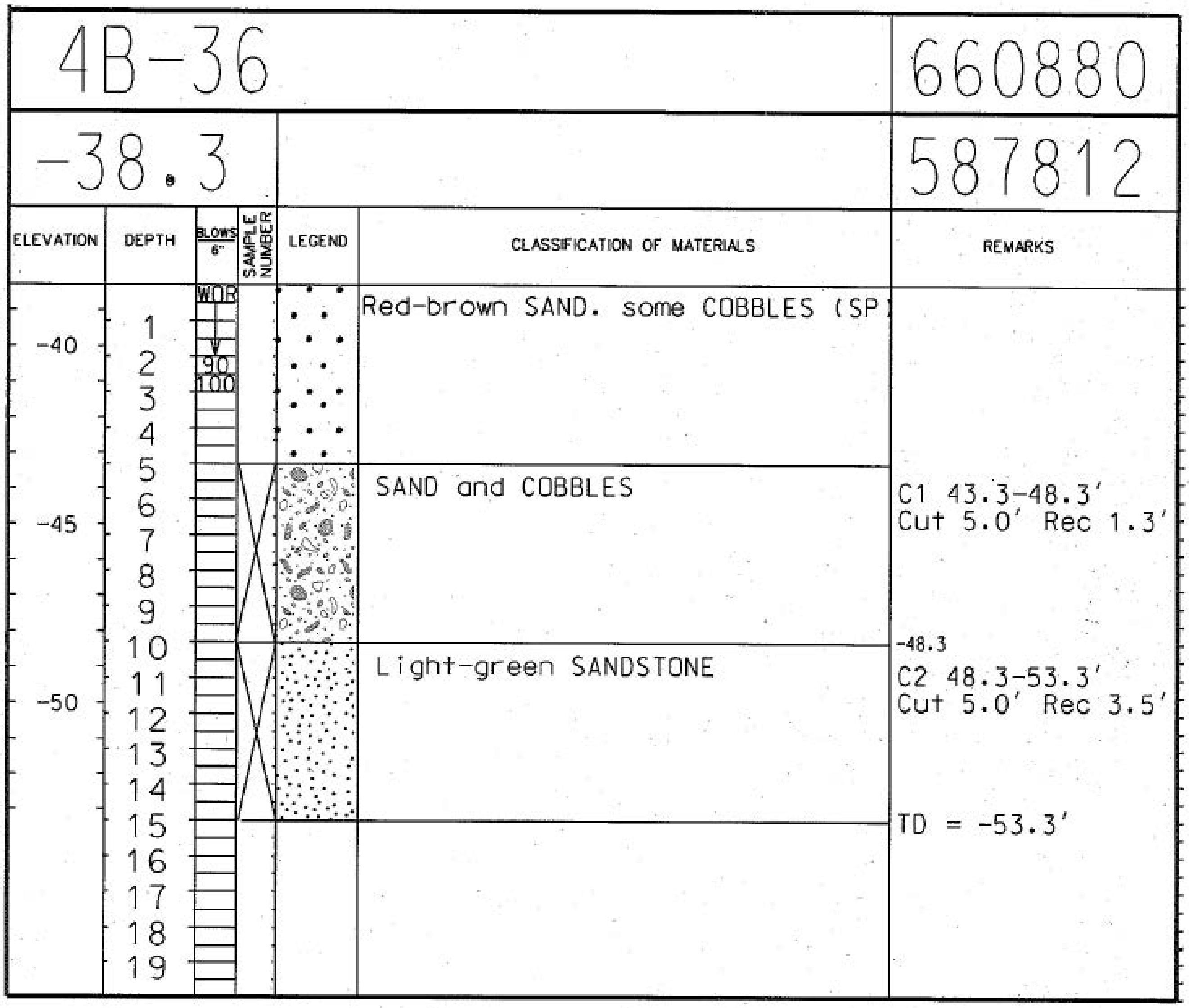
ELEVATION: -50, -55, -60, -65, -70, -75

DEPTH: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36

LEGEND

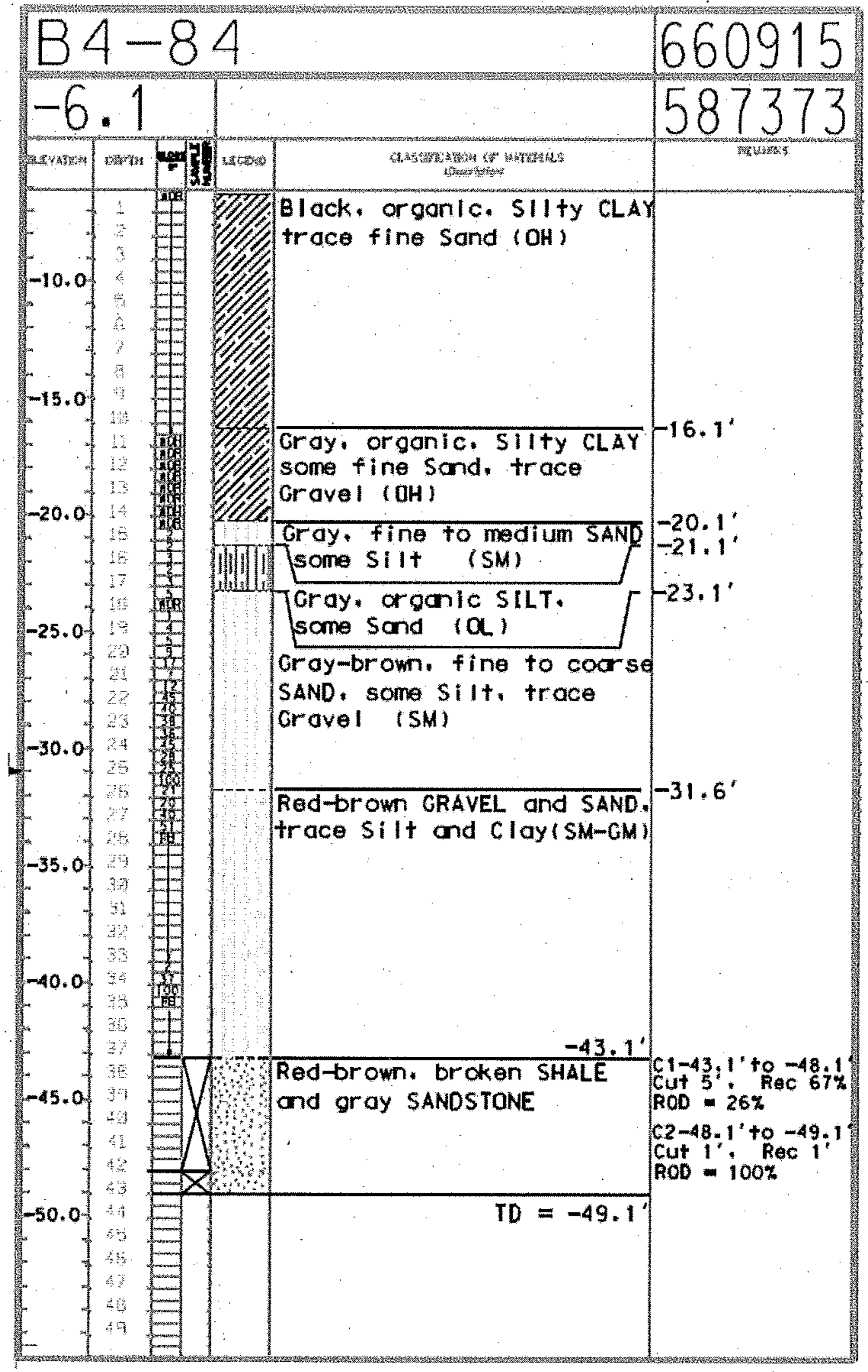
4B-5		661479
-38.3		588287

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
		RB			Rock fragments and GRAVEL (GP)	-38.4
	1					RB = Roller Bit
-40	2				Weathered Sandstone Bedrock	-40.0
	3					
	4				Light green SANDSTONE	
	5					
	6					
-45	7					TD = -45.0
	8					
	9					
	10					
	11					
	12					
	13					
	14					
	15					
	16					
	17					
	18					
	19					
	20					
	21					
	22					
	23					
	24					
	25					
	26					
	27					
	28					
	29					
	30					
	31					
	32					
	33					
	34					
	35					
	36					
	37					
	38					
	39					
	40					
	41					
	42					
	43					
	44					
	45					
	46					
	47					
	48					
	49					



4B-36	660880
-38.3	587812

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS	REMARKS
-40	1 2 3 4	WOR 90 100			Red-brown SAND. some COBBLES (SP	
-45	5 6 7 8 9				SAND and COBBLES	C1 43.3-48.3' Cut 5.0' Rec 1.3'
-50	10 11 12 13 14				Light-green SANDSTONE	-48.3 C2 48.3-53.3' Cut 5.0' Rec 3.5'
	15 16 17 18 19					TD = -53.3'



B4-84

660915

-6.1

587373

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

Black, organic, Silty CLAY trace fine Sand (OH)

-16.1'

Gray, organic, Silty CLAY some fine Sand, trace Gravel (OH)

-20.1'

Gray, fine to medium SAND some Silt (SM)

-21.1'

-23.1'

Gray, organic SILT, some Sand (OL)

Gray-brown, fine to coarse SAND, some Silt, trace Gravel (SM)

-31.6'

Red-brown GRAVEL and SAND, trace Silt and Clay(SM-GM)

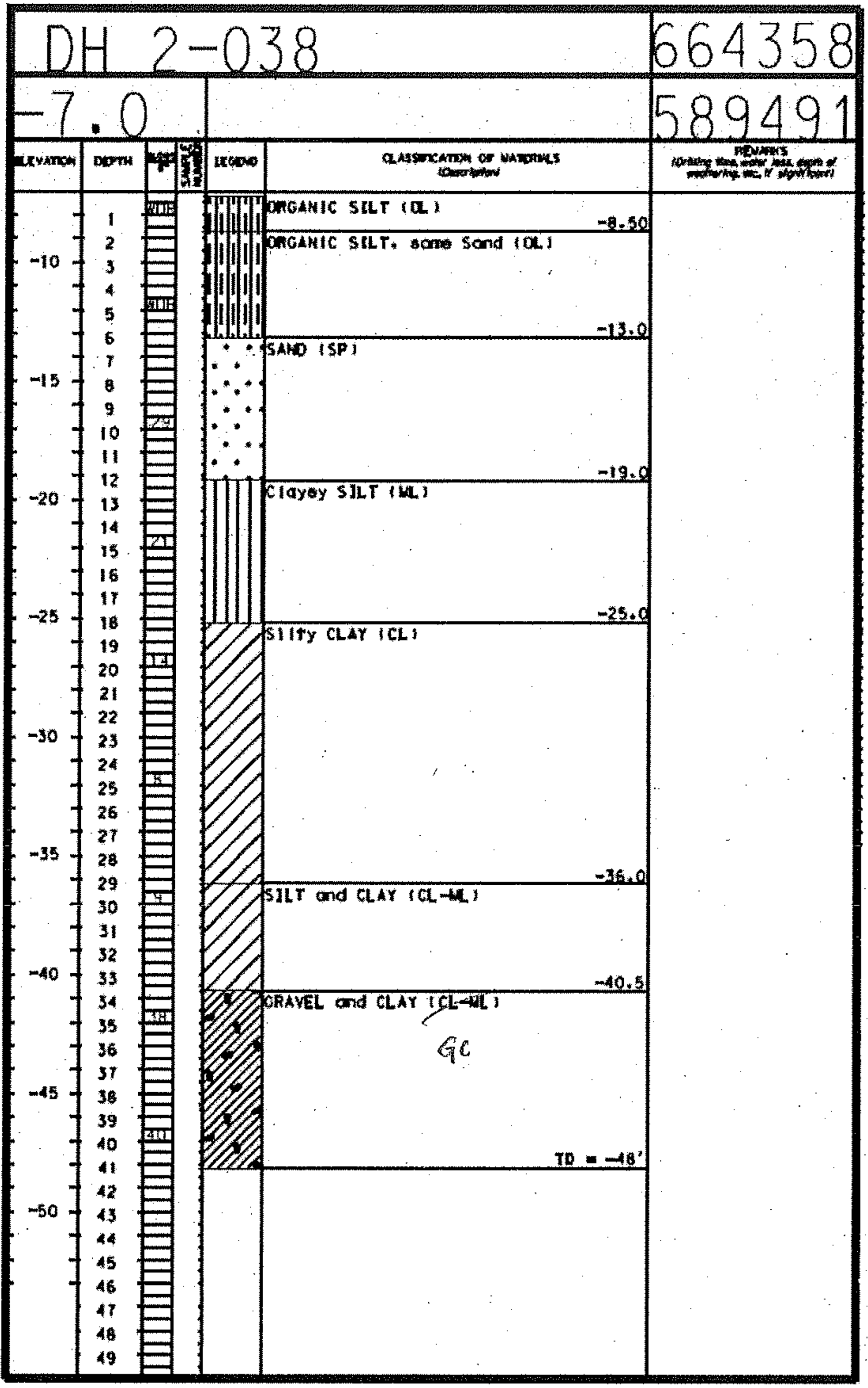
-43.1'

Red-brown, broken SHALE and gray SANDSTONE

C1-43.1' to -48.1'
Cut 5', Rec 67%
RQD = 26%

C2-48.1' to -49.1'
Cut 1', Rec 1'
RQD = 100%

TD = -49.1'


DH 2-038
664358
-7.0
589491
ELEVATION
DEPTH
BLOWS
SAMPLE NUMBER
LEGEND
CLASSIFICATION OF MATERIALS
(Description)
REMARKS
(Drilling time, water loss, depth of weathering, etc., if significant)
-10
-15
-20
-25
-30
-35
-40
-45
-50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
WOH
WOH
29
21
14
8
9
38
40
ORGANIC SILT (OL)
-8.50
ORGANIC SILT, some Sand (OL)
-13.0
SAND (SP)
-19.0
Clayey SILT (ML)
-25.0
Silty CLAY (CL)
-36.0
SILT and CLAY (CL-ML)
-40.5
GRAVEL and CLAY (CL-ML)
GC
TD = -48'

KVK 3-9

662211

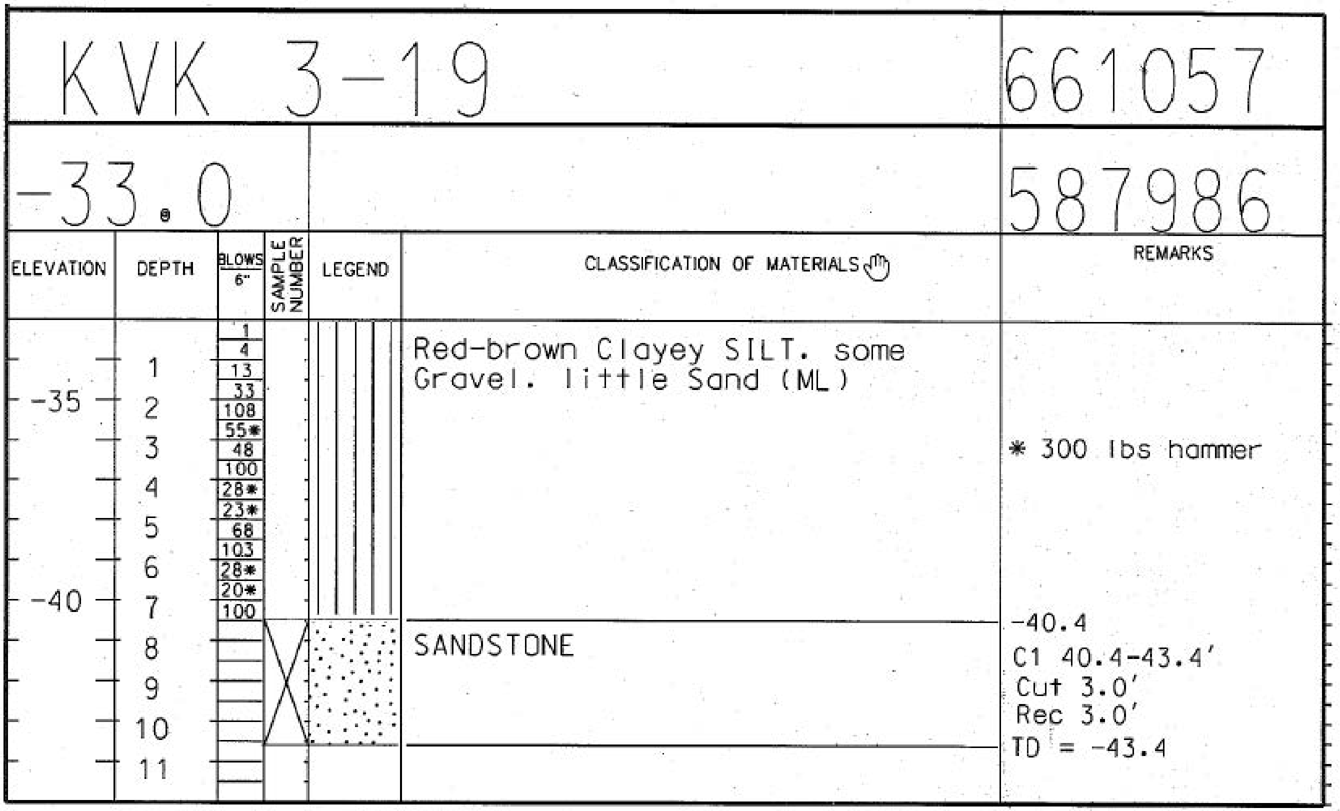
-17.6

588957

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS	REMARKS
		4 10			Red-brown, Silty CLAY and GRAVEL. trace Sand (CH-GM)	
	1	8 8				
-20	2	25 15				
	3	23 100				
	4	100				
	5	16 16				
	6	18 24				
-25	7	6 6				
	8	13 17				
	9	5 9				
	10	15 22				
	11	12 19				
-30	12	27 34				
	13	23 39			Red-brown Clayey SILT. trace Sand (ML)	-30.6
	14	71 105				
	15	117 100			Red-brown Clayey SILT and GRAVEL. some Sand (MH-GM)	-32.6
	16					
-35	17	30 76				
	18	55 79				
	19	79 100				
	20					
	21	88 100				
-40	22					
	23	53 108				
	24	97 100				
	25	87 83				
	26	92 100				
-45	27	100				
	28					
	29				Gray, fractured SANDSTONE.	-46.6
	30					C1 46.6 - 51.6
	31					Cut 5' Rec 3'
-50	32					
	33					
	34					TD = -51.6
	35					

KVK 3-12	661750
-21.0	588598

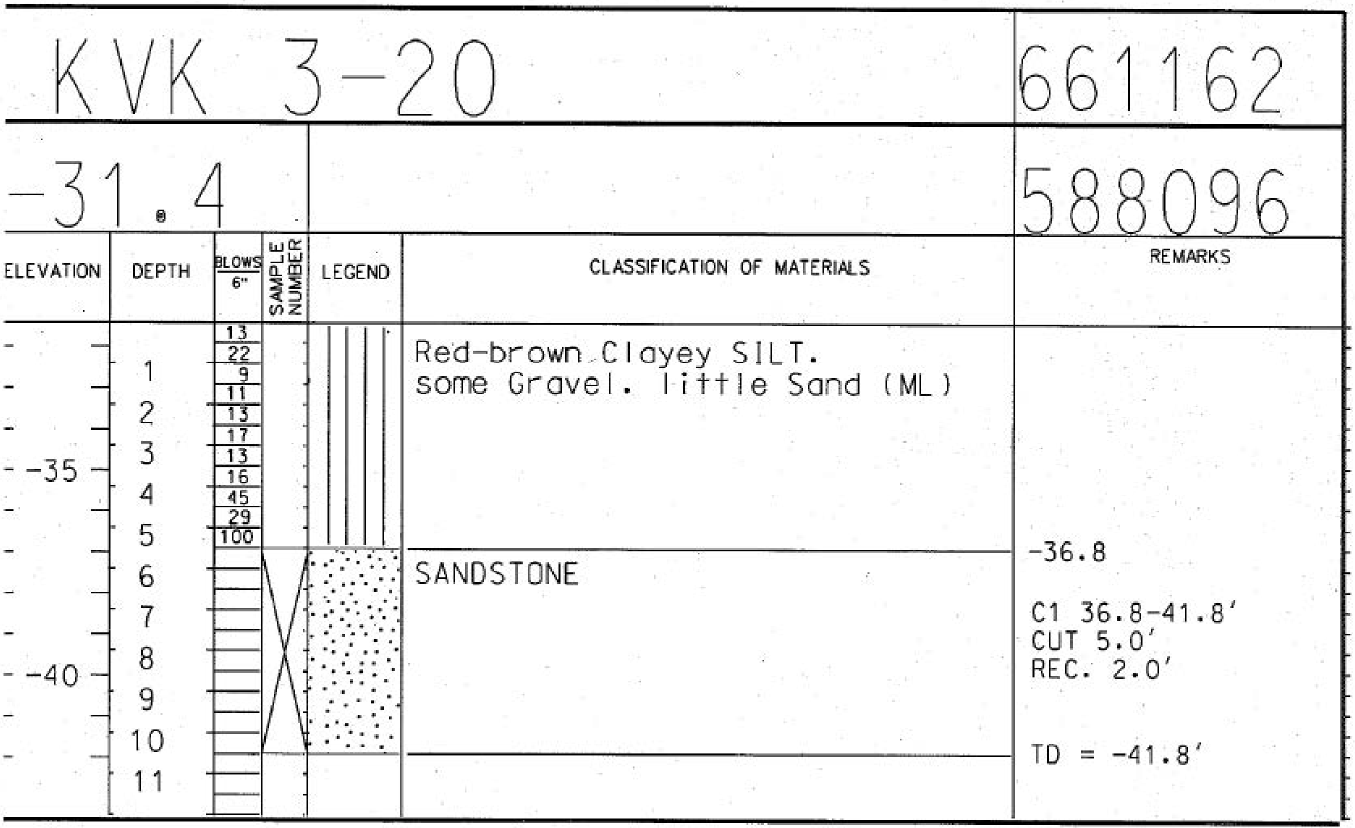
ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS	REMARKS
	1	5 9			Red-brown Silty CLAY and GRAVEL. some Sand. trace BOULDERS (CL)	Glacial till
	2	13 16				
	3	9 17				
	4	24 24				
-25	5	17 29				
	6	41 67				
	7	20 25				
	8	35 49				
	9	17 25				
-30	10	39 51				
	11	37 35				
	12	79 29				
	13	29 41				
	14	41 67				
-35	15	100				-35.2
	16				BOULDERS	C1 35.2-38.0' CUT 2.8'
	17					REC. 0.8'
	18	105				-38.0
	19	135 47*				
-40	20	35* 98			Red-brown Silty CLAY and GRAVEL. some Sand. trace BOULDERS (CL)	* 300 lbs hammer
	21	54 73				
	22	70 63				
	23	88 85				
	24	73				
-45	25	100 20*				
	26				Gray, fractured SANDSTONE.	-45.7
	27					C2 45.8-50.8'
	28					CUT 5.0'
	29					REC. 2.3'
-50	30					TD = -50.8



KVK 3-19 | 661057

-33.0 | 587986

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS	REMARKS
-35 -40	1 2 3 4 5 6 7	1 4 13 33 108 55* 48 100 28* 23* 68 103 28* 20* 100			Red-brown Clayey SILT. some Gravel. little Sand (ML)	* 300 lbs hammer
	8 9 10				SANDSTONE	-40.4 C1 40.4-43.4' Cut 3.0' Rec 3.0' TD = -43.4
	11					


KVK 3-20
661162
-31.4
588096
ELEVATION
DEPTH
BLOWS 6"
SAMPLE NUMBER
LEGEND
CLASSIFICATION OF MATERIALS
REMARKS
-35
-40
1
2
3
4
5
6
7
8
9
10
11
13
22
9
11
13
17
13
16
45
29
100
Red-brown Clayey SILT. some Gravel. little Sand (ML)
SANDSTONE
-36.8
C1 36.8-41.8'
CUT 5.0'
REC. 2.0'
TD = -41.8'

NB-1

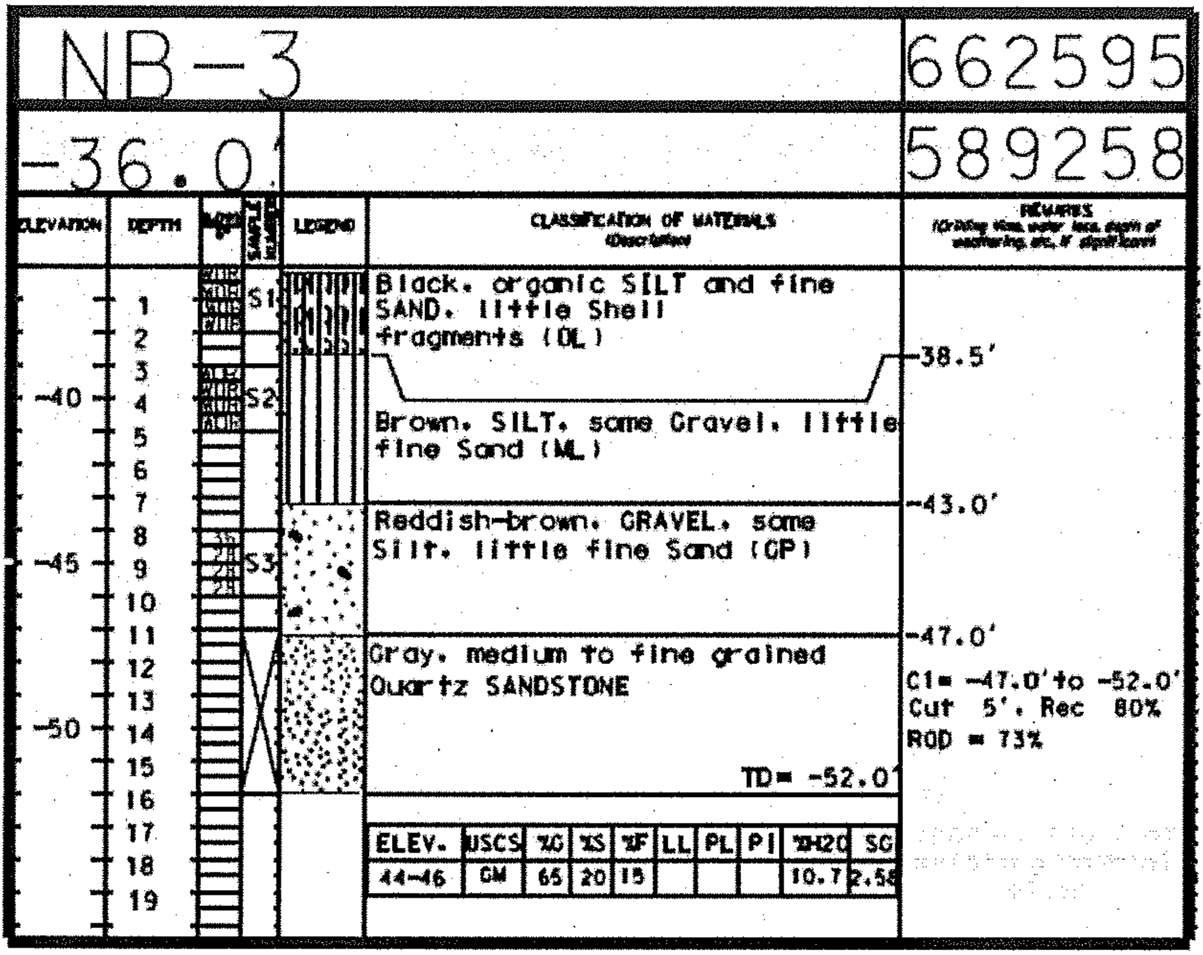
662037

-10.0

588710

ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER	LEGEND	CLASSIFICATION OF MATERIALS	REMARKS
	1	WOR	S1		Dark gray, Organic SILT, little fine Sand, some Shell Fragments (OL)	
	2					
	3					
	4				Brown SILT, little fine Sand, trace fine Gravel (ML)	-13.5
-15	5	7				
	6	10 16 27	S2			
	7					
	8					
	9				Red-brown, Clayey SILT, little to fine Sand, some Rock Fragments (ML)	-19.0
-20	10	15				
	11	9 10 13	(S3)			
	12					
	13					
	14					
-25	15	21				
	16	22 29 23	S4			
	17					
	18					
	19					
-30	20	28				
	21	37 74 100	S5			
	22					
	23					
	24				Red-brown SILTand fine to medium GRAVEL, little Sand (ML)	-33.5
-35	25	75 100	S6			
	26					
	27					
	28					
	29					
-40	30	100	S7			
	31					
	32					
	33					
	34				Green-gray coarse to fine quartz SANDSTONE	-43.5
-45	35					
	36					
	37					
	38					TD = -48.3
	39					
	40					
	41					
	42					
	43					
	44					
	45					
	46					
	47					
	48					
	49					

ELEV.	USCS	% G	% S	% F	LL	PL	PI	% H2O	SG
20.0-22.0	SM	6	82	12				29.7	2.56



NB-3

662595

-36.0'

589258

CLASSIFICATION OF MATERIALS (Description)

REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)

Black, organic SILT and fine SAND, little Shell fragments (OL)

-38.5'

Brown, SILT, some Gravel, little fine Sand (ML)

-43.0'

Reddish-brown, GRAVEL, some Silt, little fine Sand (GP)

-47.0'

Gray, medium to fine grained Quartz SANDSTONE

C1= -47.0' to -52.0'
Cut 5', Rec 80%
ROD = 73%

TD= -52.0'

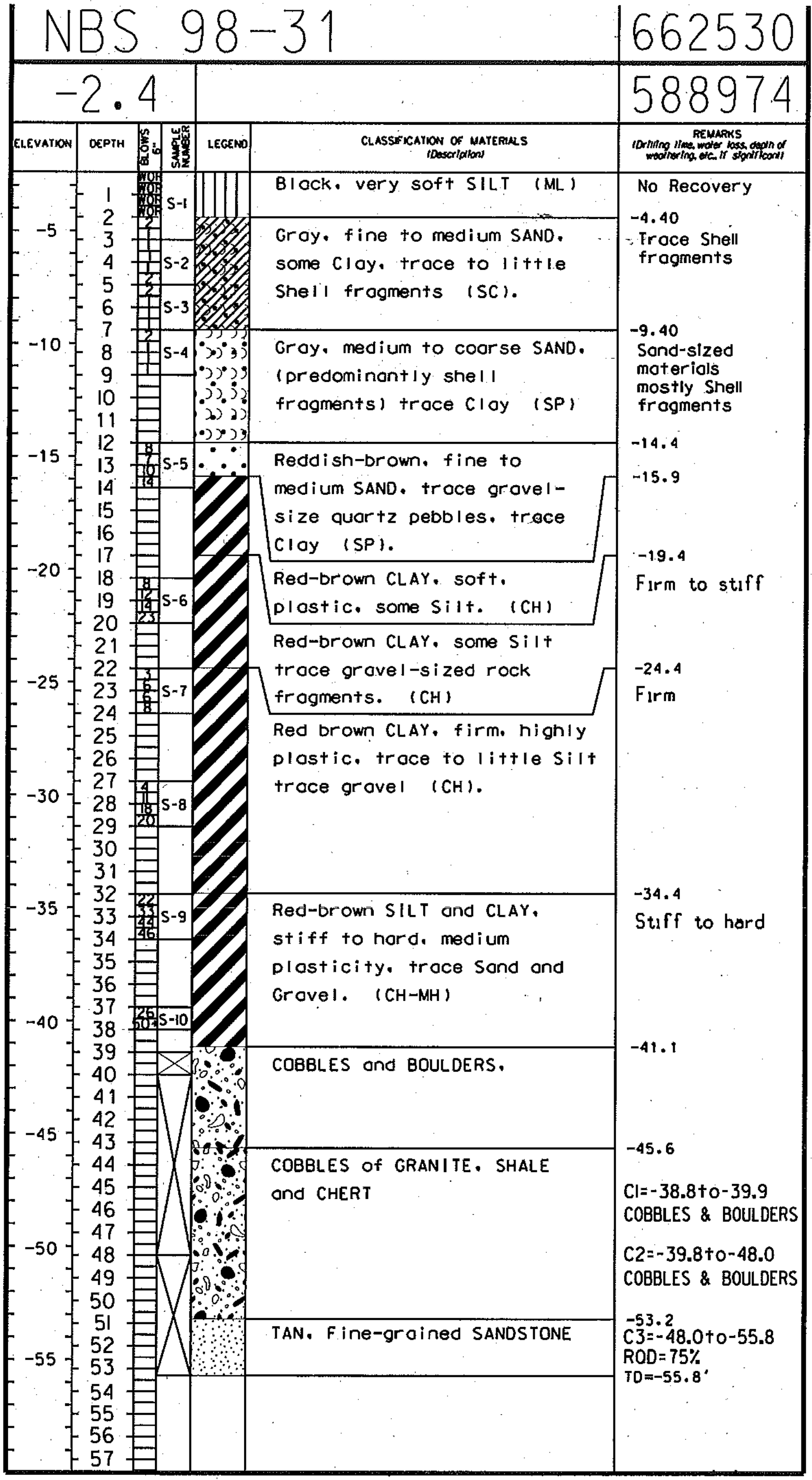
ELEV.	USCS	%G	%S	%F	LL	PL	PI	%H2O	SG
44-46	GM	65	20	15				10.7	2.58

NBS 98-31

662530

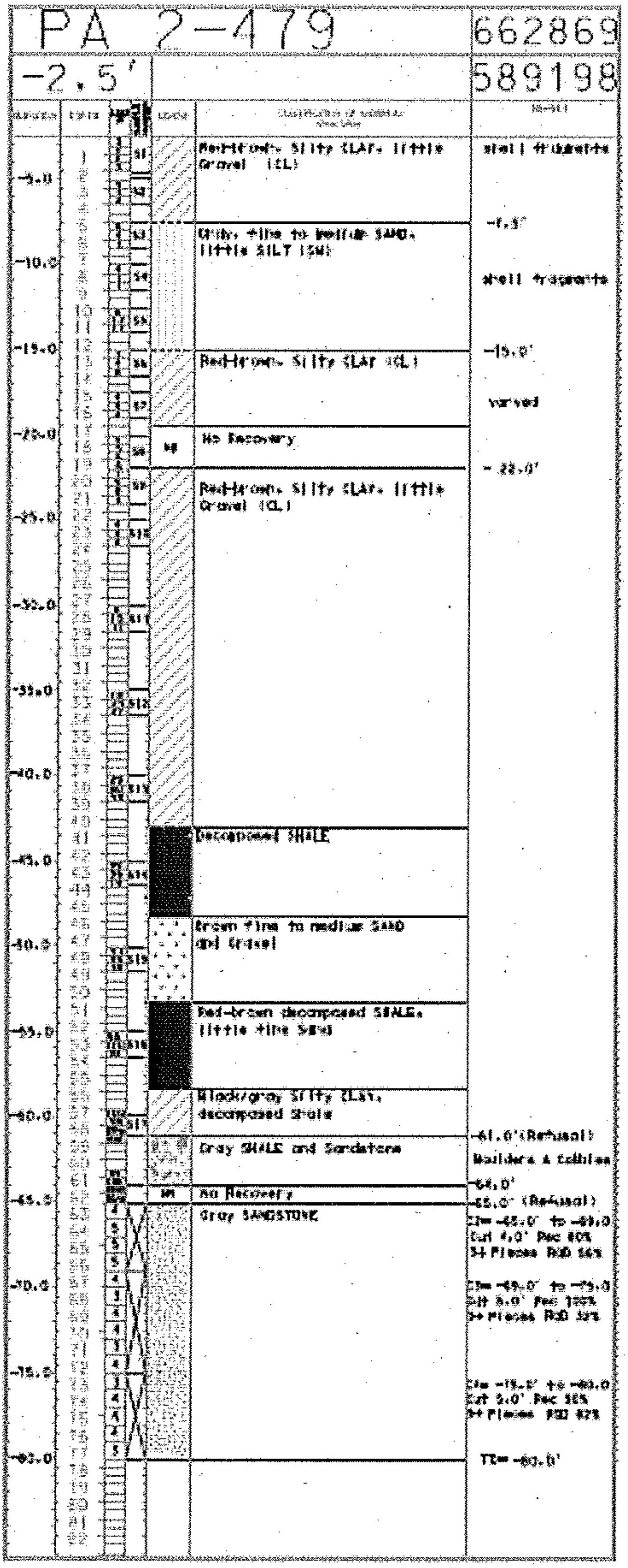
-2.4

588974



ELEVATION	DEPTH	BLOWS 6"	SAMPLE NUMBER
	0–3	WOR WOR WOR WOR 2 1	S-1
-5	3–5	1 1 1 2	S-2
	5–7	2 1 1 1	S-3
-10	7–9	2 1 1 1	S-4
-15	12–14	8 7 10 14	S-5
-20	18–20	8 12 14 23	S-6
-25	22–24	3 6 6 8	S-7
-30	27–29	4 11 18 20	S-8
-35	32–34	22 33 44 46	S-9
-40	37–38	26 50+	S-10

CLASSIFICATION OF MATERIALS (Description)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Black, very soft SILT (ML)	No Recovery
Gray, fine to medium SAND, some Clay, trace to little Shell fragments (SC).	-4.40 Trace Shell fragments
Gray, medium to coarse SAND, (predominantly shell fragments) trace Clay (SP)	-9.40 Sand-sized materials mostly Shell fragments
Reddish-brown, fine to medium SAND, trace gravel-size quartz pebbles, trace Clay (SP).	-14.4 -15.9
Red-brown CLAY, soft, plastic, some Silt. (CH)	-19.4 Firm to stiff
Red-brown CLAY, some Silt trace gravel-sized rock fragments. (CH)	-24.4 Firm
Red brown CLAY, firm, highly plastic, trace to little Silt trace gravel (CH).	
Red-brown SILT and CLAY, stiff to hard, medium plasticity, trace Sand and Gravel. (CH-MH)	-34.4 Stiff to hard
COBBLES and BOULDERS.	-41.1
COBBLES of GRANITE, SHALE and CHERT	-45.6 C1=-38.8to-39.9 COBBLES & BOULDERS C2=-39.8to-48.0 COBBLES & BOULDERS
TAN, Fine-grained SANDSTONE	-53.2 C3=-48.0to-55.8 RQD=75% TD=-55.8'

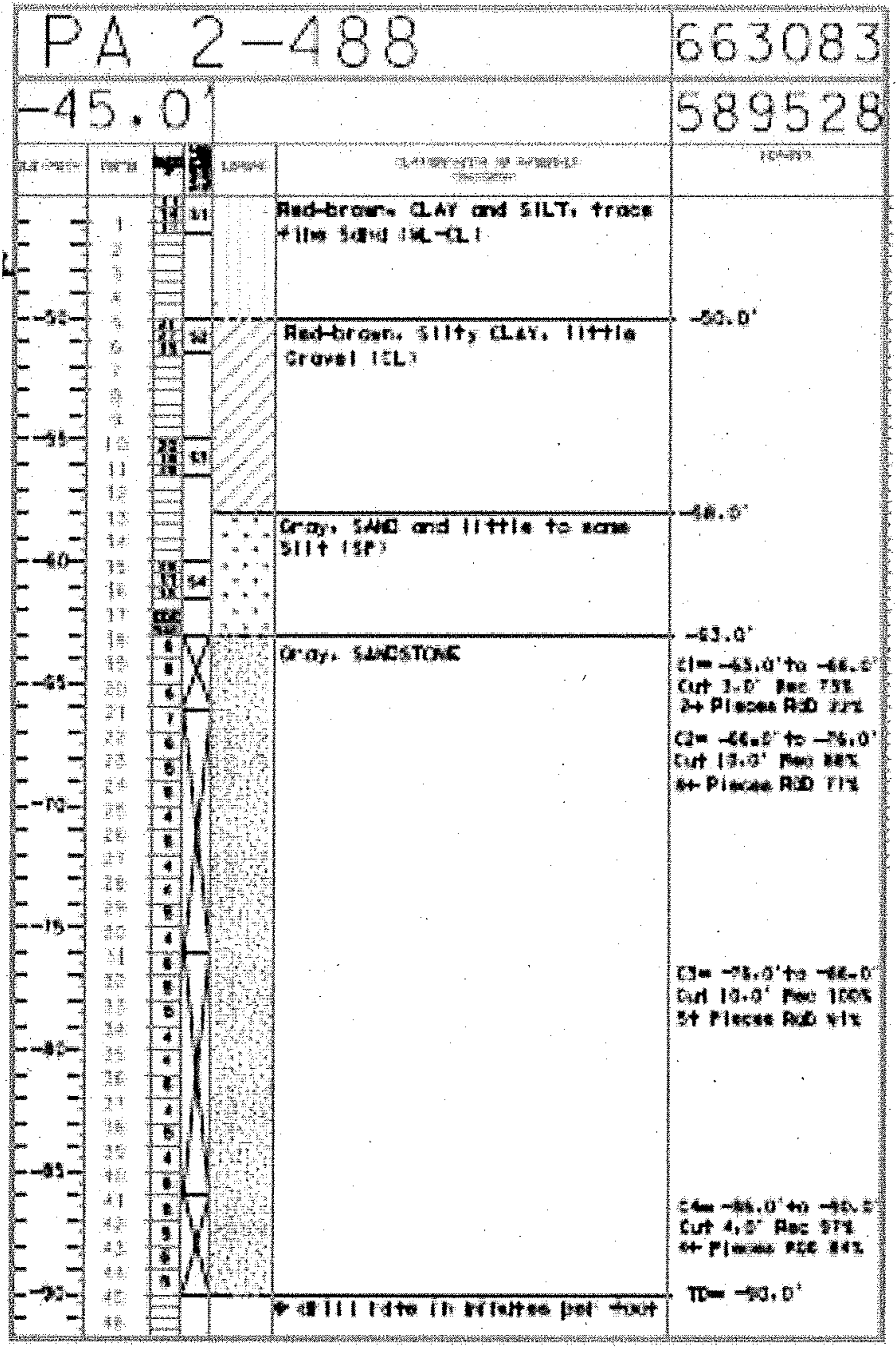

PA 2-479
662869
-2.5'
589198
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
-55.0
-60.0
-65.0
-70.0
-75.0
-80.0
S1
S2
S3
S4
S5
S6
S7
S8
S9
S10
S11
S12
S13
S14
S15
S16
S17
Red-brown, Silty CLAY, little Gravel (CL)
shell fragments
-7.5'
Gray, fine to medium SAND, little SILT (SM)
shell fragments
-15.0'
Red-brown, Silty CLAY (CL)
varved
NR
No Recovery
-22.0'
Red-brown, Silty CLAY, little Gravel (CL)
Decomposed SHALE
Brown fine to medium SAND and Gravel
Red-brown decomposed SHALE, little fine SAND
Black/gray Silty CLAY, decomposed Shale
-61.0'(Refusal)
Gray SHALE and Sandstone
Boulders & Cobbles
-64.0'
NR
No Recovery
-65.0' (Refusal)
Gray SANDSTONE
C1= -65.0' to -69.0
Cut 4.0' Rec 80%
3+ Pieces RQD 56%
C2= -69.0' to -75.0
Cut 6.0' Rec 100%
5+ Pieces RQD 32%
C3= -75.0' to -80.0
Cut 5.0' Rec 98%
5+ Pieces RQD 87%
TD= -80.0'

PA 2-488

663083

-45.0'

589528



Red-brown, CLAY and SILT, trace fine Sand (ML-CL)

-50.0'

Red-brown, Silty CLAY, little Gravel (CL)

-58.0'

Gray, SAND and little to some Silt (SP)

-63.0'

Gray, SANDSTONE

C1= -63.0' to -66.0'
Cut 3.0' Rec 75%
2+ Pieces RQD 22%

C2= -66.0' to -76.0'
Cut 10.0' Rec 88%
6+ Pieces RQD 71%

C3= -76.0' to -86.0'
Cut 10.0' Rec 100%
5+ Pieces RQD 61%

C4= -86.0' to -90.5'
Cut 4.5' Rec 97%
6+ Pieces RQD 84%

TD= -90.0'

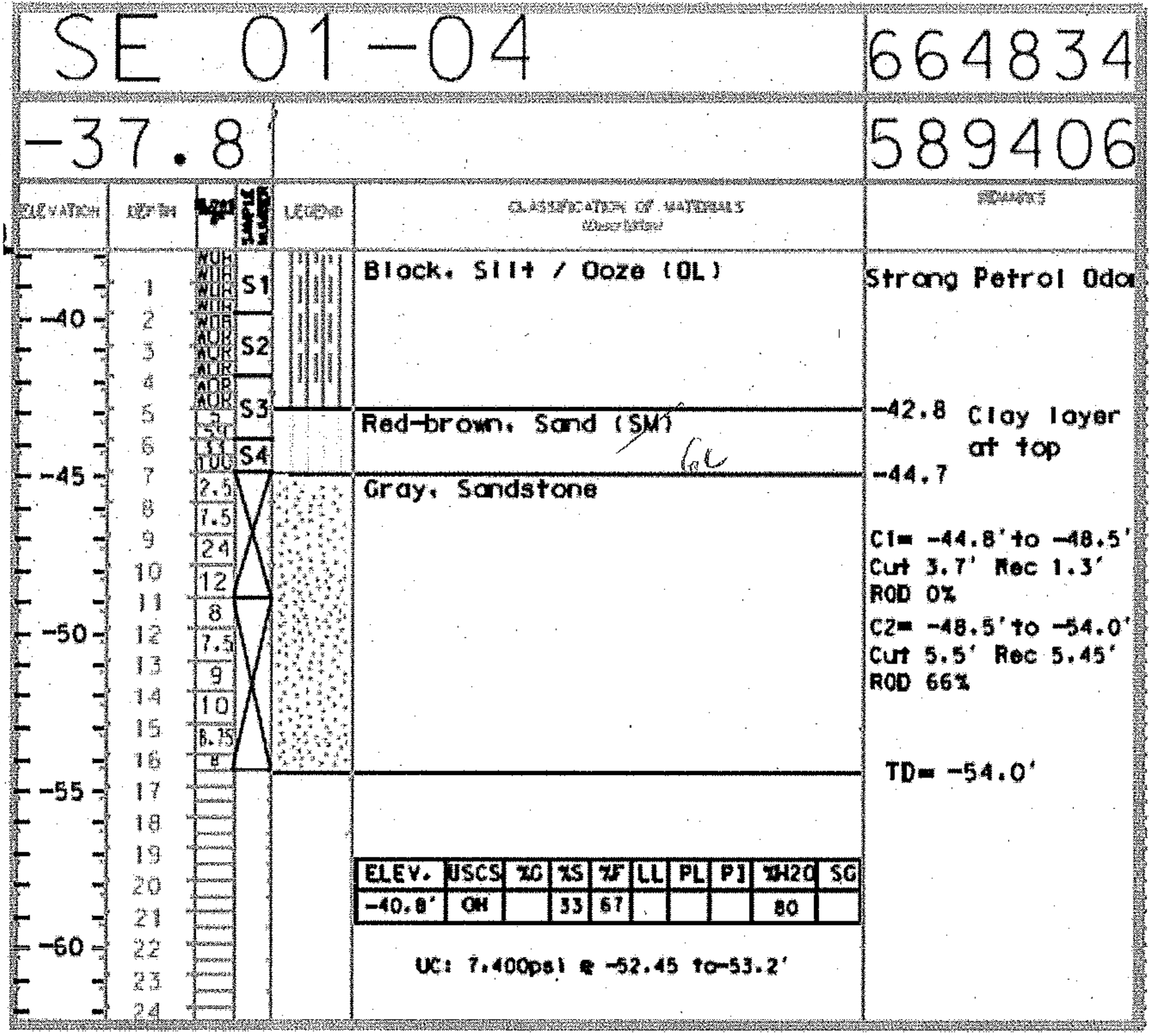
* drill rate in minutes per foot

SE 01-04

664834

-37.8

589406



Black, Silt / Ooze (OL)

Red-brown, Sand (~~SM~~) GC

Gray, Sandstone

Strong Petrol Odor

-42.8 Clay layer at top

-44.7

C1= -44.8' to -48.5'
Cut 3.7' Rec 1.3'
ROD 0%

C2= -48.5' to -54.0'
Cut 5.5' Rec 5.45'
ROD 66%

TD= -54.0'

ELEV.	USCS	%G	%S	%F	LL	PL	PI	%H2O	SG
-40.8'	OH		33	67				80	

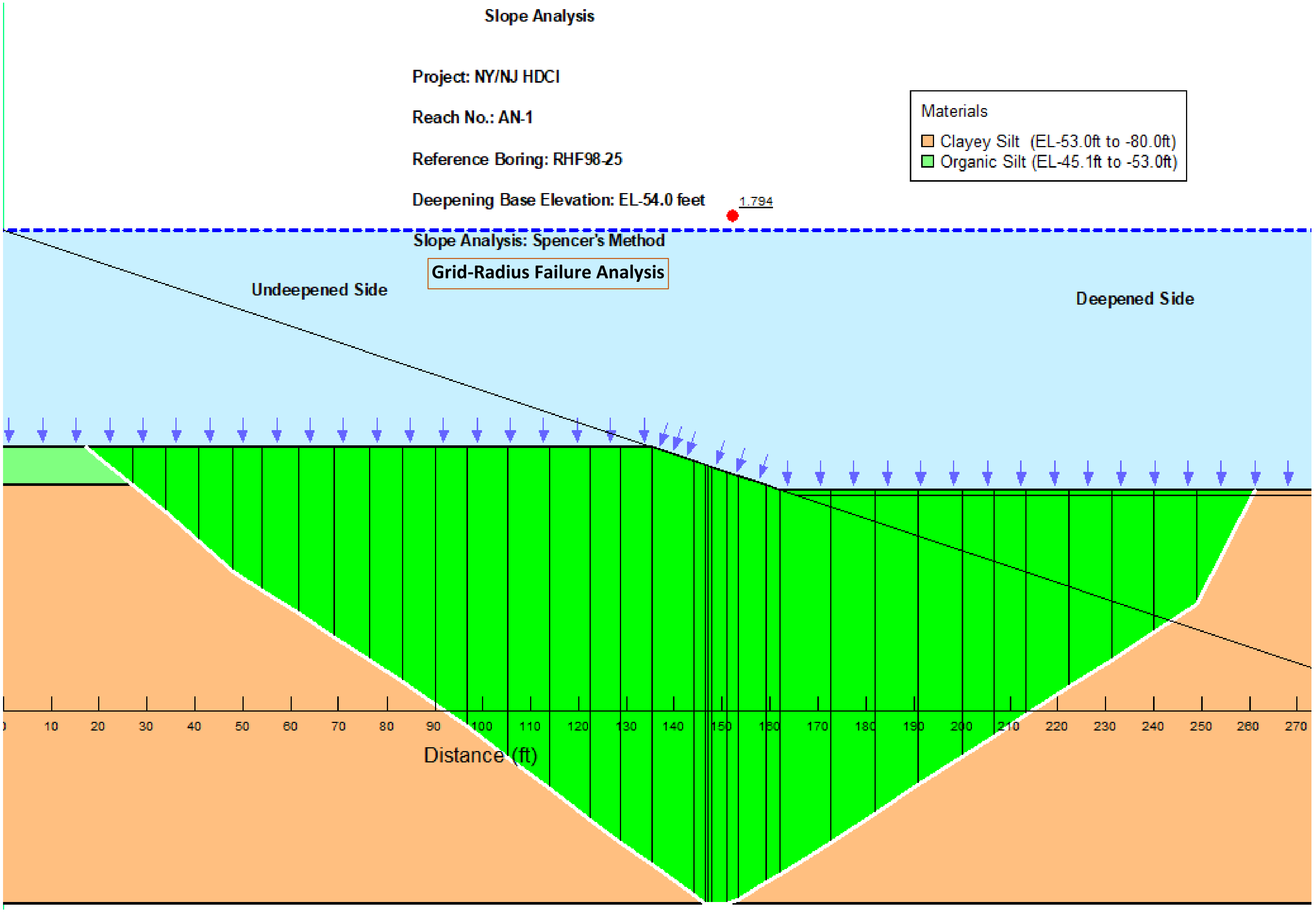
UC: 7,400psi @ -52.45 to -53.2'

APPENDIX B2:

Attachment 3

Slope Stability Analyses

Designed by:	JK	Date:	October 1, 2020
Checked by:	PR	Date:	November 1, 2021



Slope Analysis

Project: NY/NJ HDCI

Reach No.: AN-1

Reference Boring: RHF98-25

Deepening Base Elevation: EL-54.0 feet

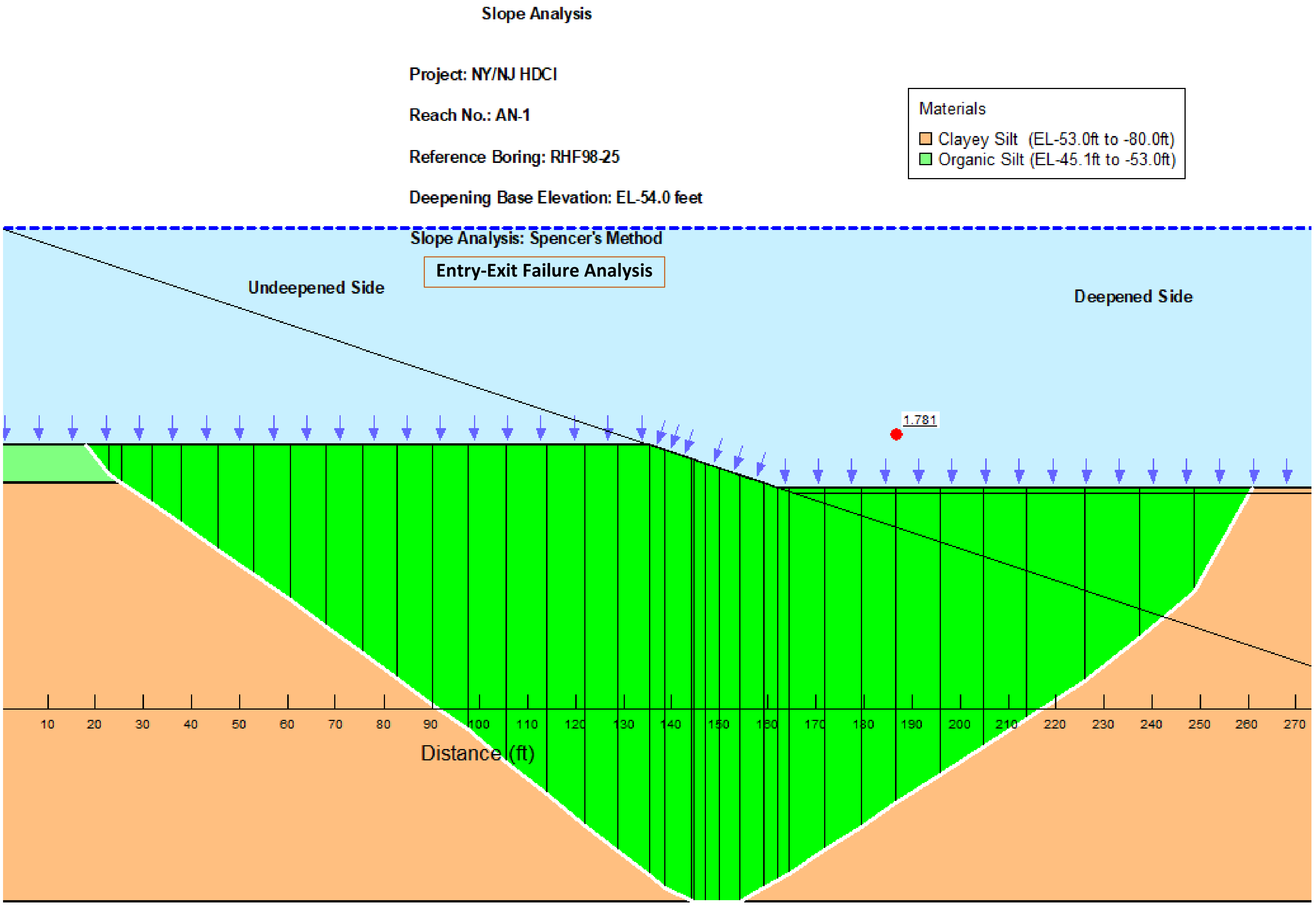
Slope Analysis: Spencer's Method

Grid-Radius Failure Analysis

Materials

🟧 Clayey Silt (EL-53.0ft to -80.0ft)

🟩 Organic Silt (EL-45.1ft to -53.0ft)


Slope Analysis
Project: NY/NJ HDCI
Reach No.: AN-1
Reference Boring: RHF98-25
Deepening Base Elevation: EL-54.0 feet
Slope Analysis: Spencer's Method
Entry-Exit Failure Analysis
Materials
🟧 Clayey Silt (EL-53.0ft to -80.0ft)
🟩 Organic Silt (EL-45.1ft to -53.0ft)
Undeepened Side
Deepened Side
1.781
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
Distance (ft)

Slope Analysis

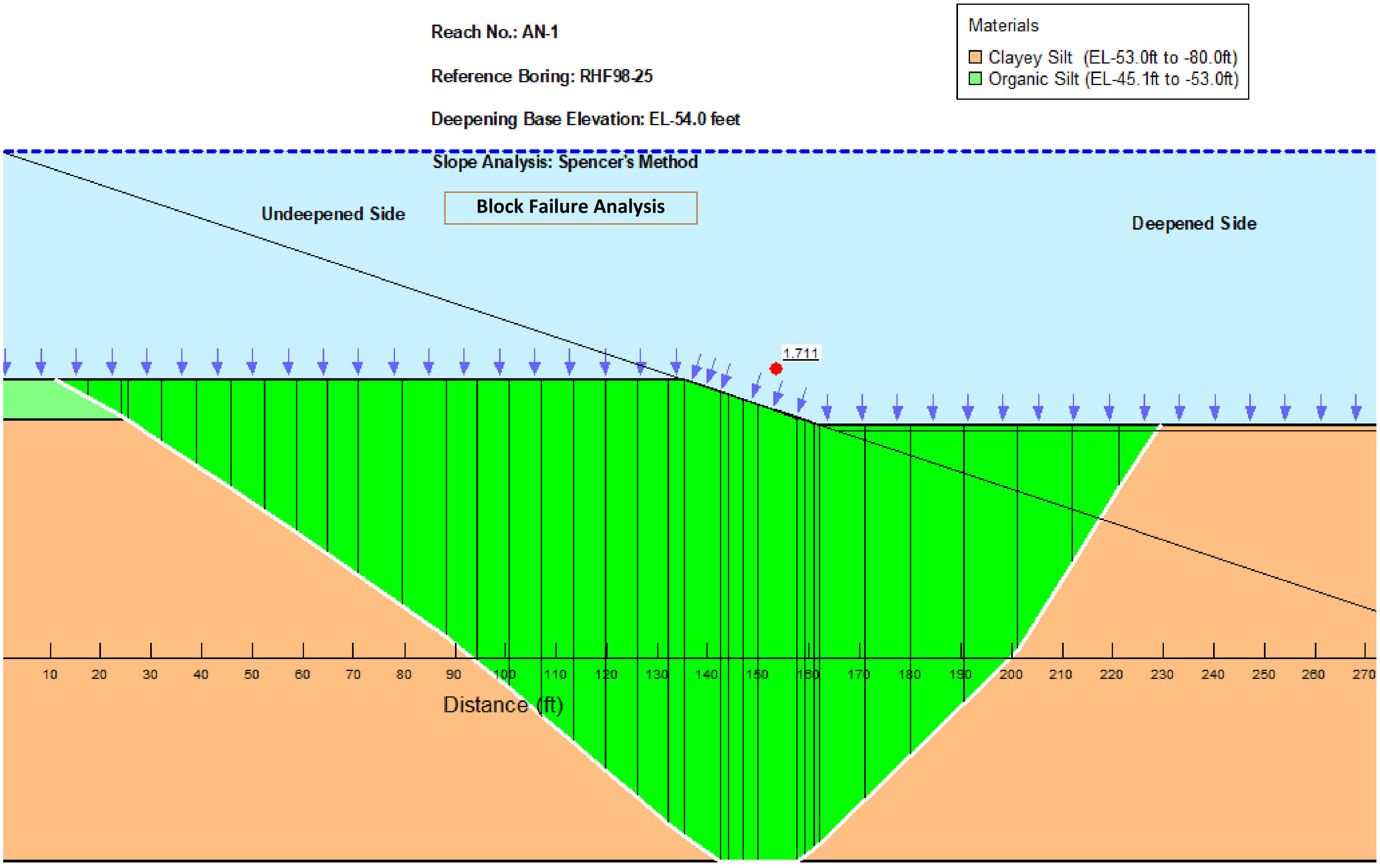
Project: NY/NJ HDCI

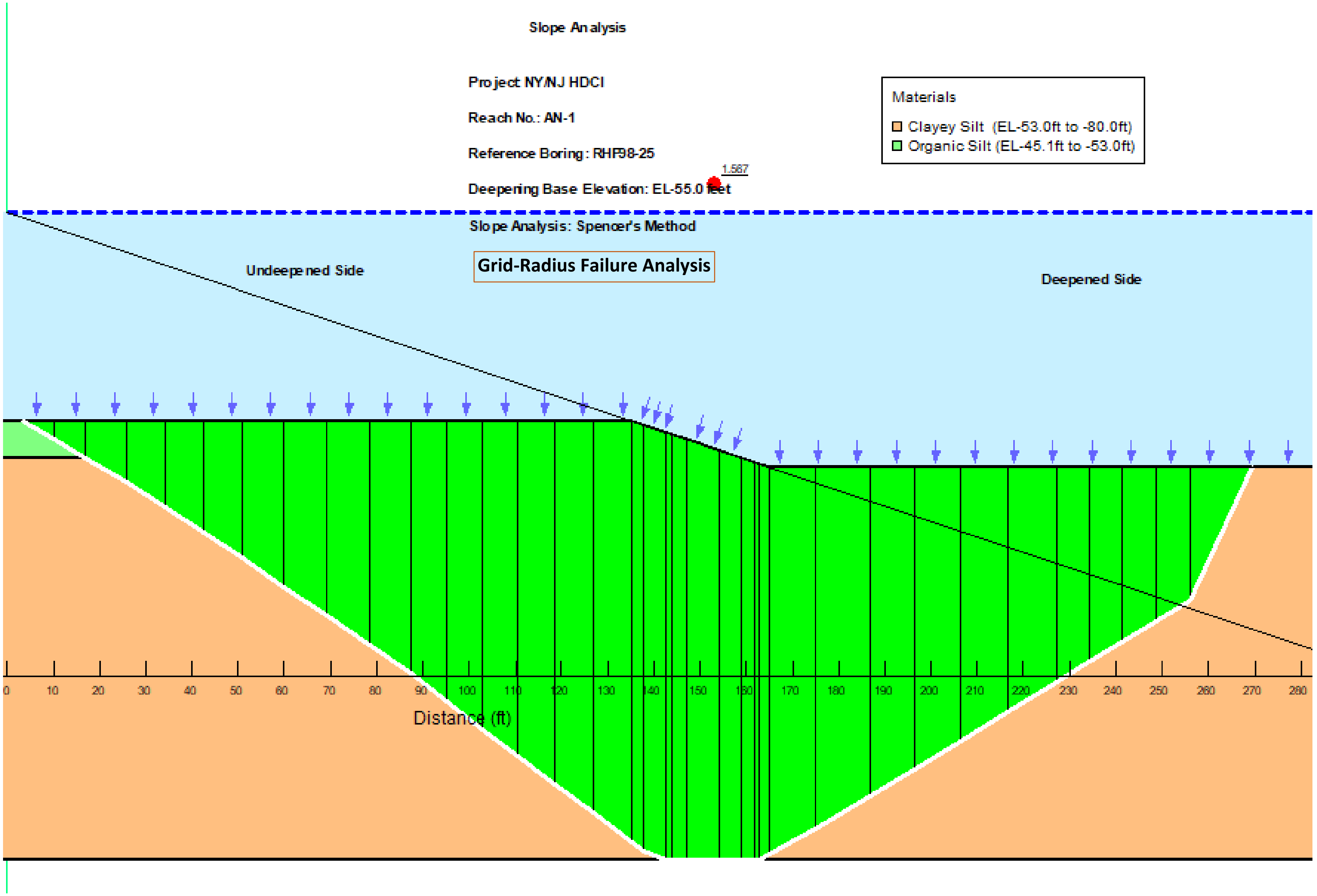
Reach No.: AN-1

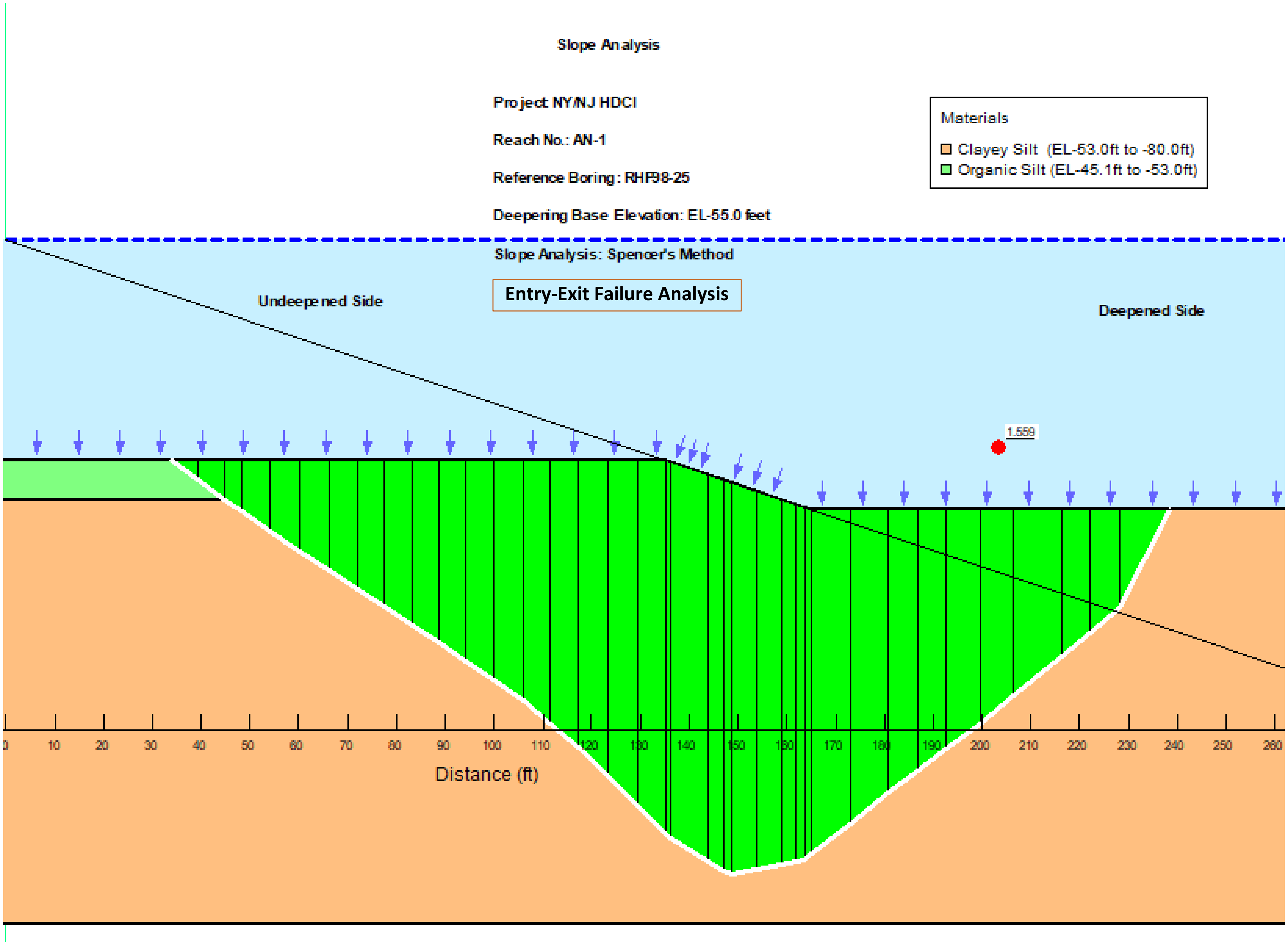
Reference Boring: RHF98-25

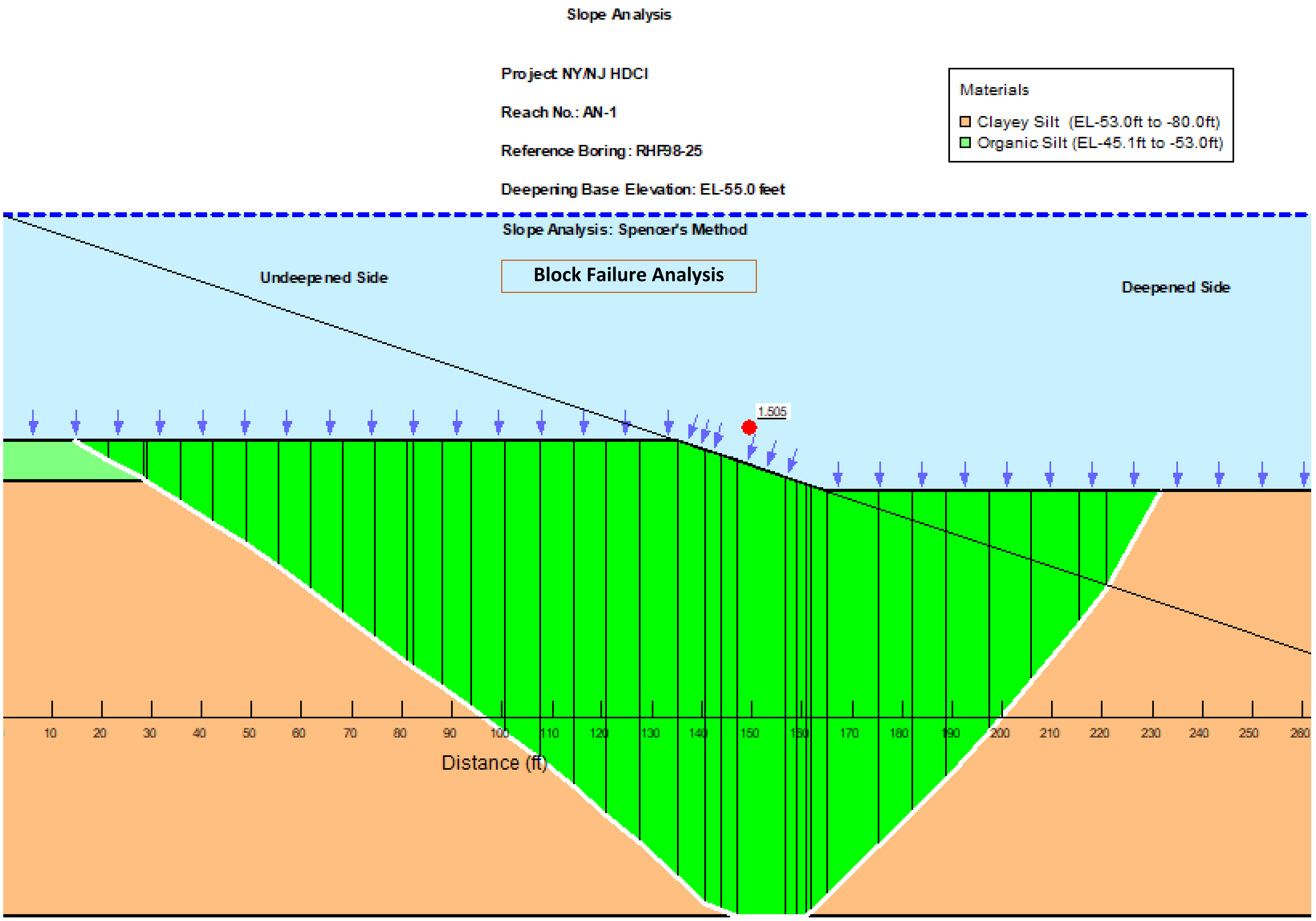
Deepening Base Elevation: EL-54.0 feet

Slope Analysis: Spencer's Method




Slope Analysis
Project NY/NJ HDCI
Reach No.: AN-1
Reference Boring: RHF98-25
1.567
Deepening Base Elevation: EL-55.0 feet
Slope Analysis: Spencer's Method
Grid-Radius Failure Analysis
Undeepened Side
Deepened Side
Materials
🟧 Clayey Silt (EL-53.0ft to -80.0ft)
🟩 Organic Silt (EL-45.1ft to -53.0ft)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
Distance (ft)


Slope Analysis
Project NY/NJ HDCI
Reach No.: AN-1
Reference Boring: RHF98-25
Deepening Base Elevation: EL-55.0 feet
Slope Analysis: Spencer's Method
Entry-Exit Failure Analysis
Materials
🟧 Clayey Silt (EL-53.0ft to -80.0ft)
🟩 Organic Silt (EL-45.1ft to -53.0ft)
Undeepened Side
Deepened Side
1.559
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
Distance (ft)



Slope Analysis

Project NY/NJ HDCI

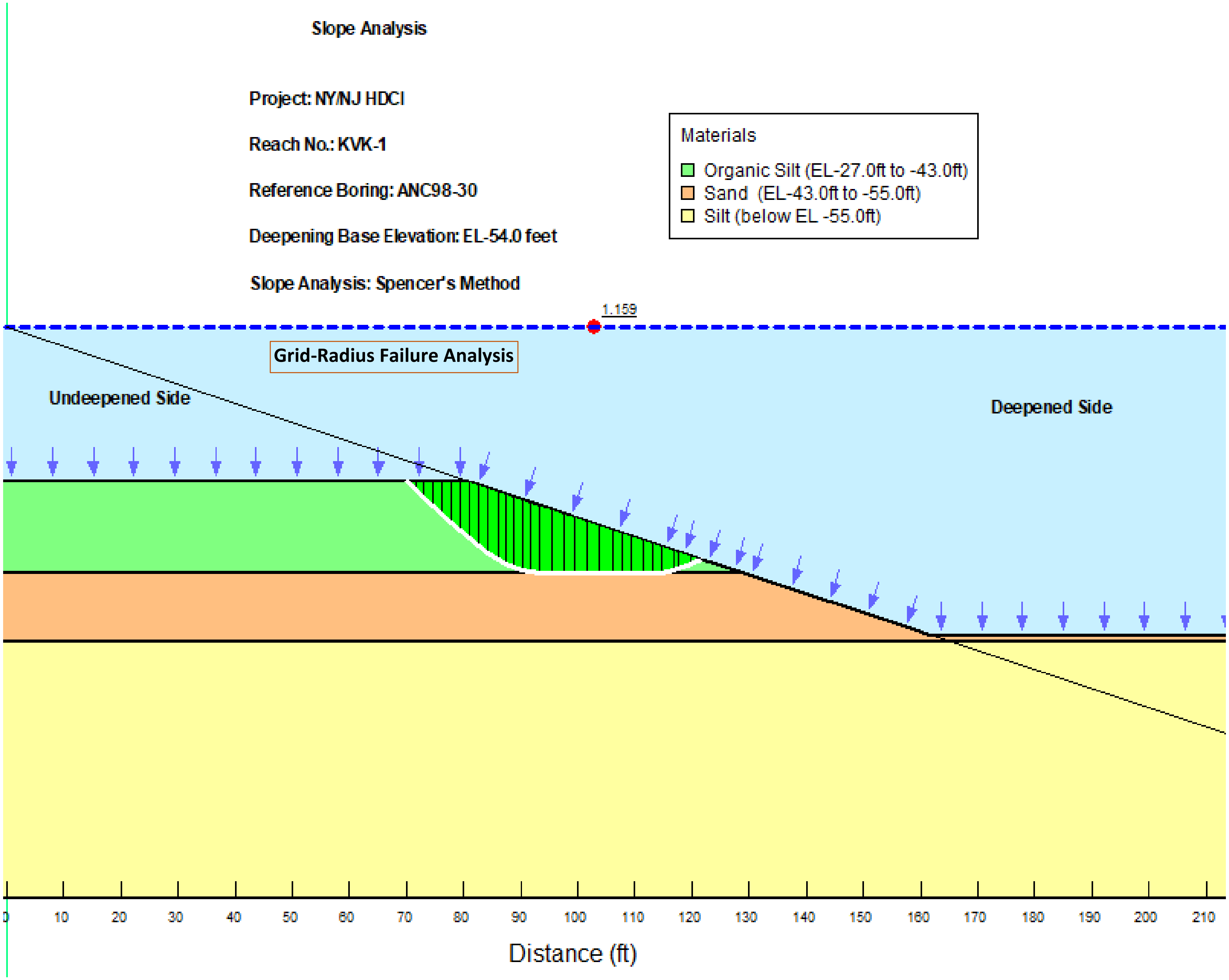
Reach No.: AN-1

Reference Boring: RHF98-25

Deepening Base Elevation: EL-55.0 feet

Slope Analysis: Spencer's Method

Block Failure Analysis



Slope Analysis

Project: NY/NJ HDCI

Reach No.: KVK-1

Reference Boring: ANC98-30

Deepening Base Elevation: EL-54.0 feet

Slope Analysis: Spencer's Method

Slope Analysis

Project: NY/NJ HDCI

Reach No.: KVK-1

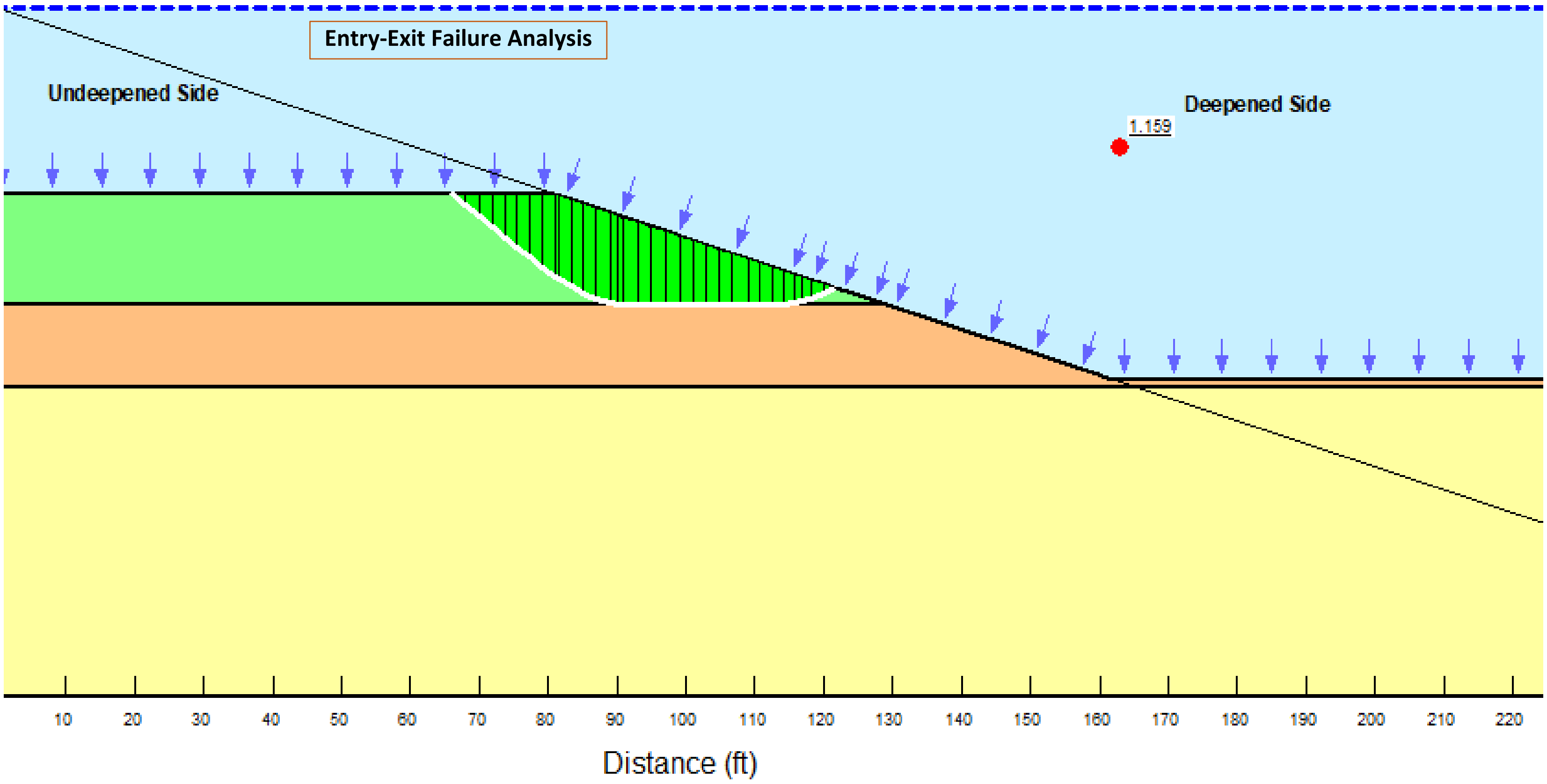
Reference Boring: ANC98-30

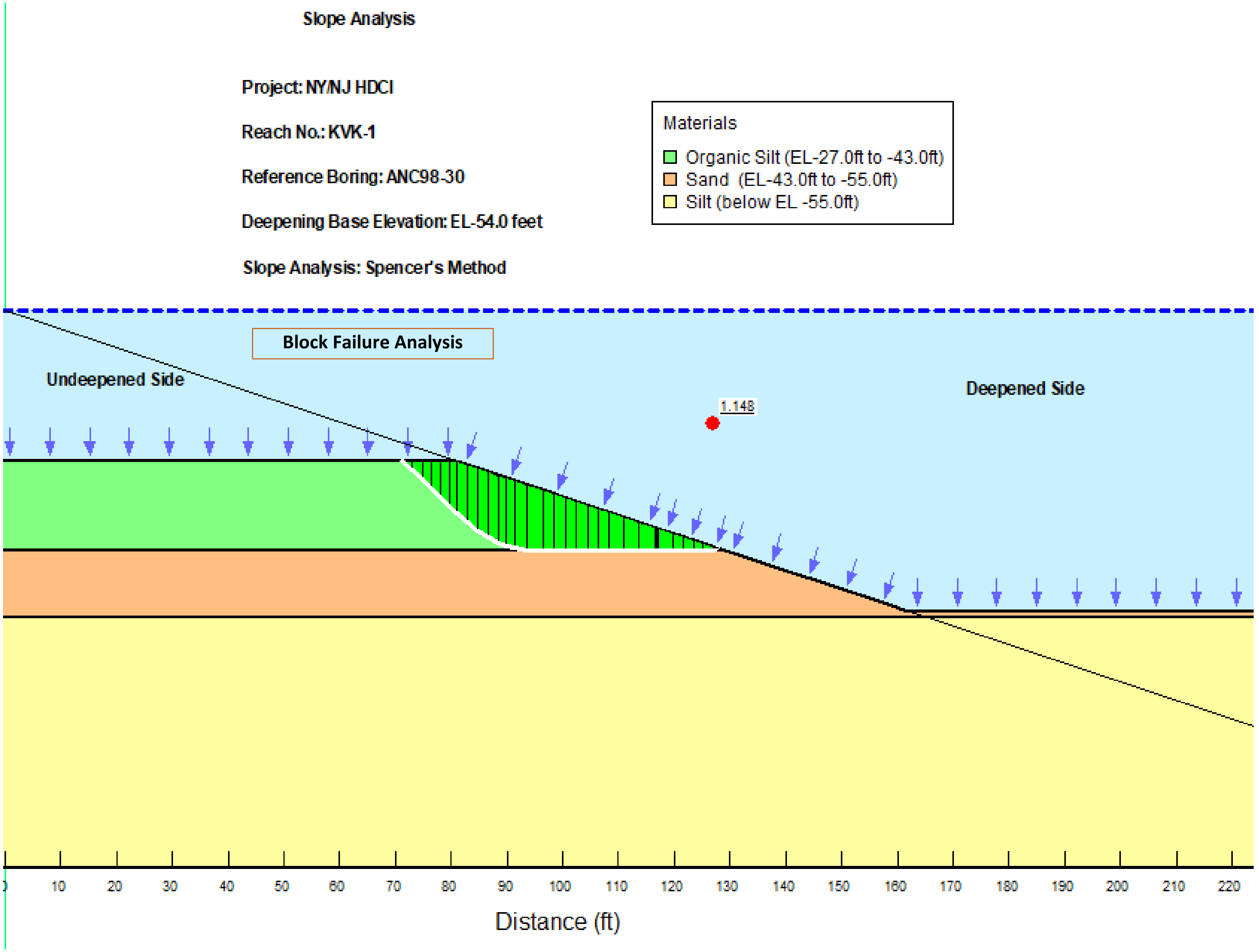
Deepening Base Elevation: EL-54.0 feet

Slope Analysis: Spencer's Method

Materials

🟩 Organic Silt (EL-27.0ft to -43.0ft)
🟧 Sand (EL-43.0ft to -55.0ft)
🟨 Silt (below EL -55.0ft)





Slope Analysis

Project: NY/NJ HDCI

Reach No.: KVK-1

Reference Boring: ANC98-30

Deepening Base Elevation: EL-54.0 feet

Slope Analysis: Spencer's Method

Slope Analysis

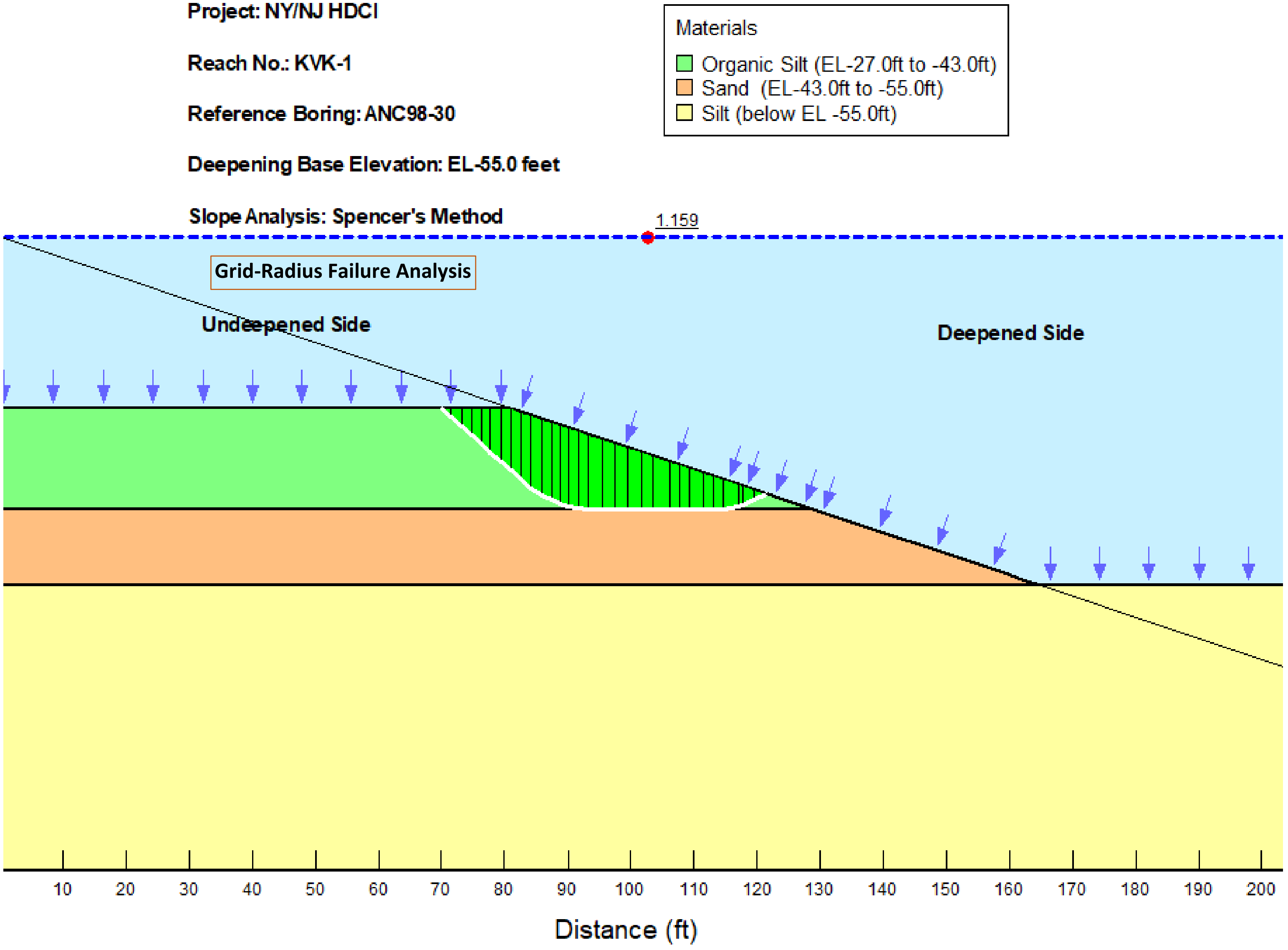
Project: NY/NJ HDCI

Reach No.: KVK-1

Reference Boring: ANC98-30

Deepening Base Elevation: EL-55.0 feet

Slope Analysis: Spencer's Method



Slope Analysis

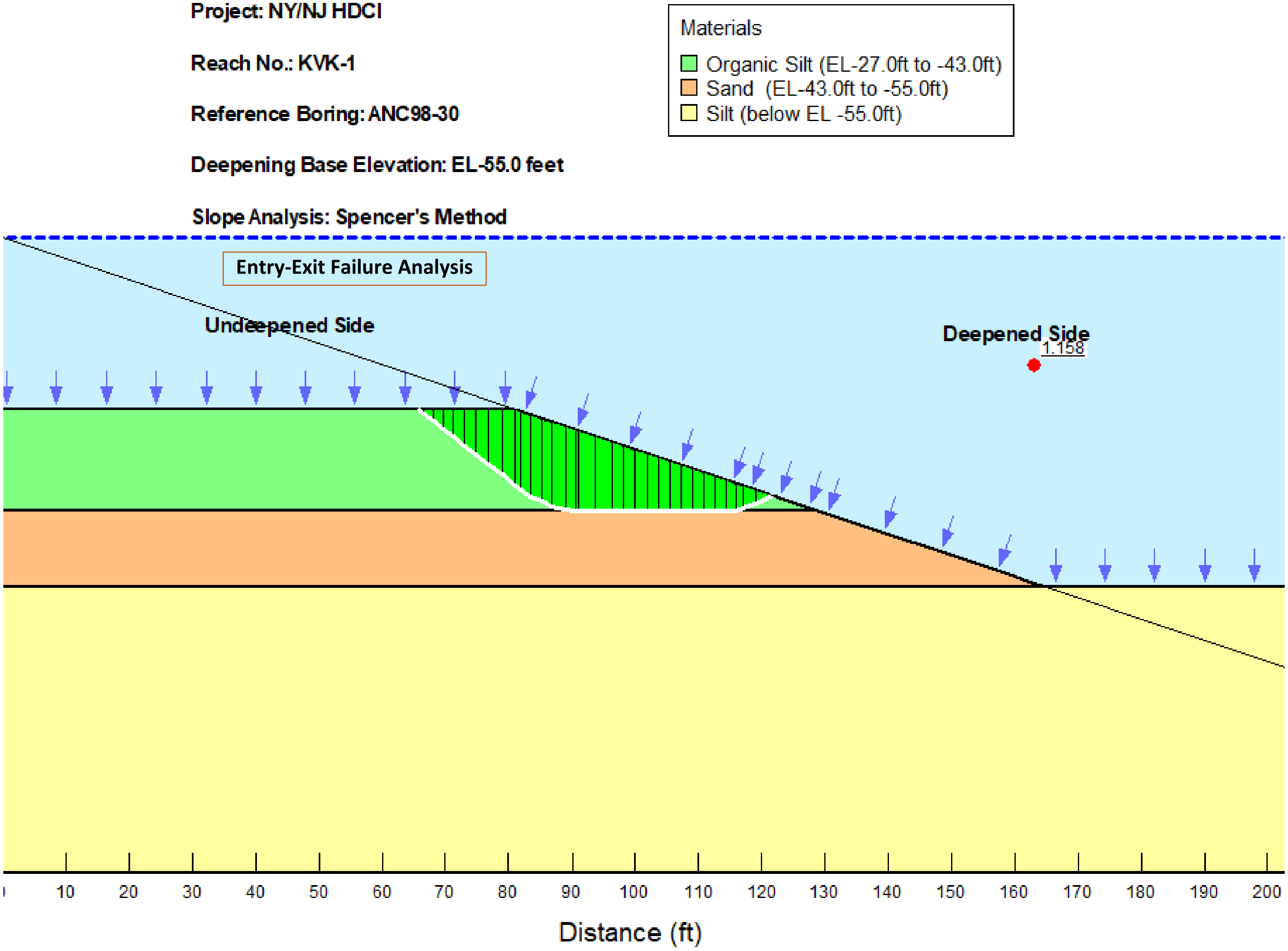
Project: NY/NJ HDCI

Reach No.: KVK-1

Reference Boring: ANC98-30

Deepening Base Elevation: EL-55.0 feet

Slope Analysis: Spencer's Method



Slope Analysis

Project: NY/NJ HDCI

Reach No.: KVK-1

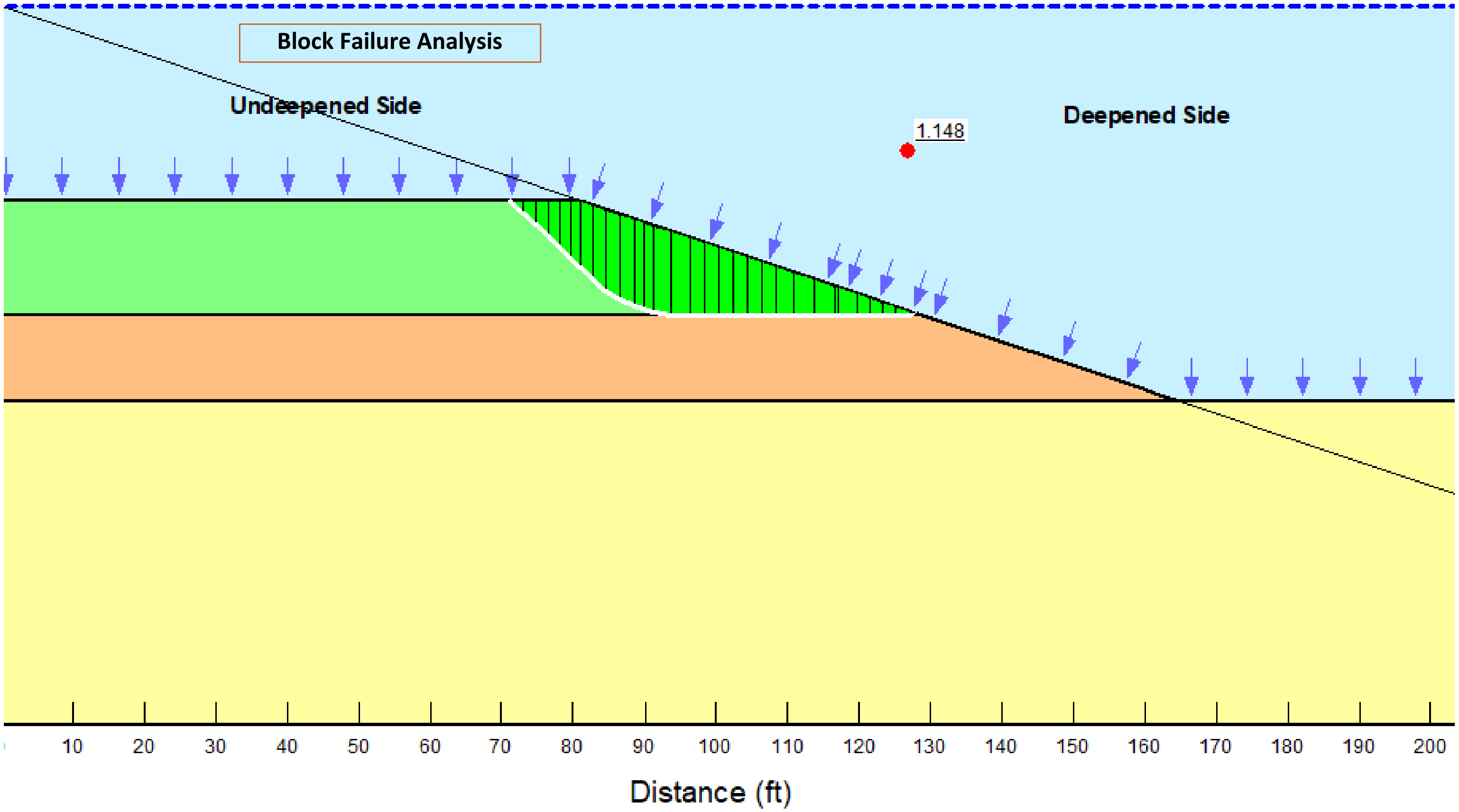
Reference Boring: ANC98-30

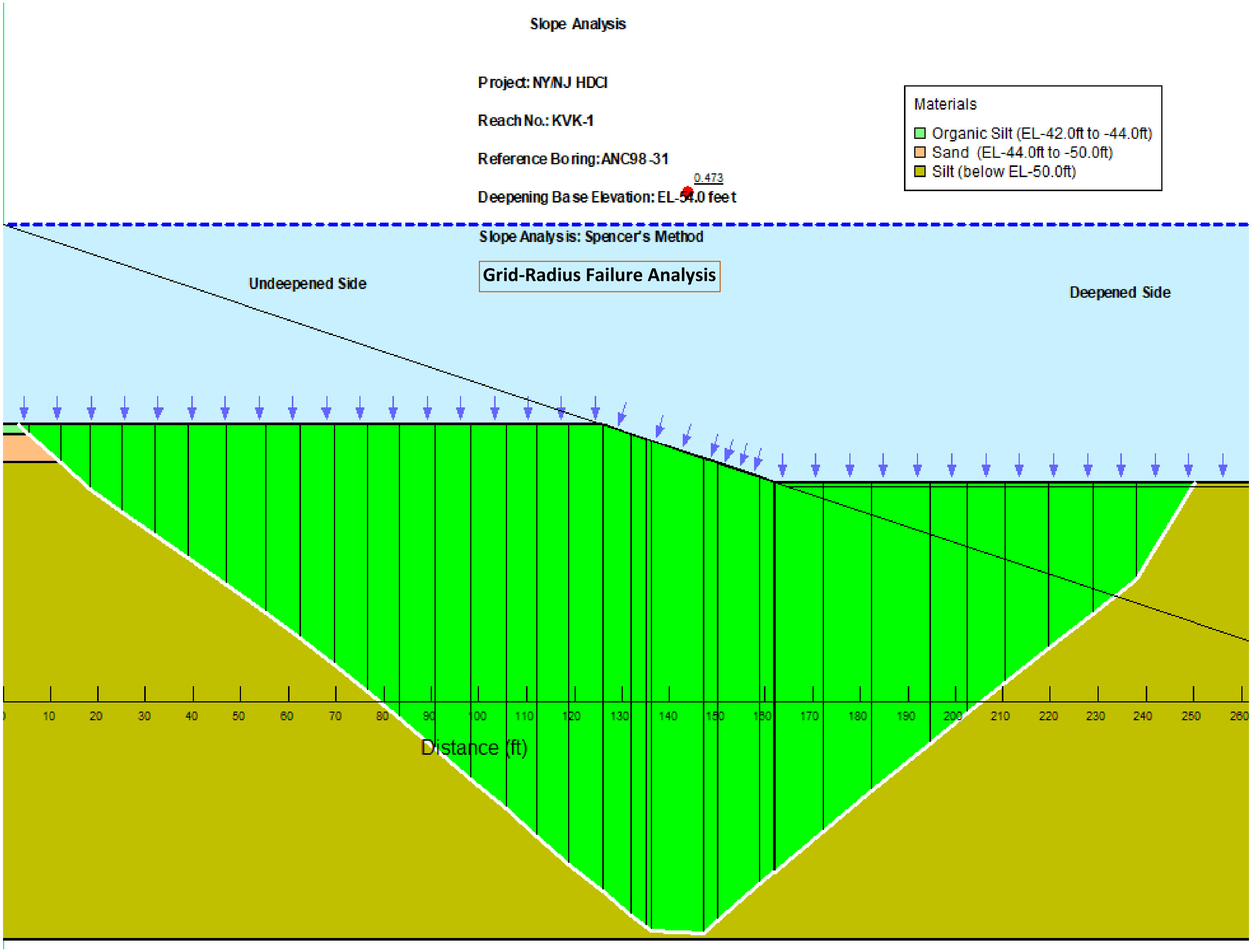
Deepening Base Elevation: EL-55.0 feet

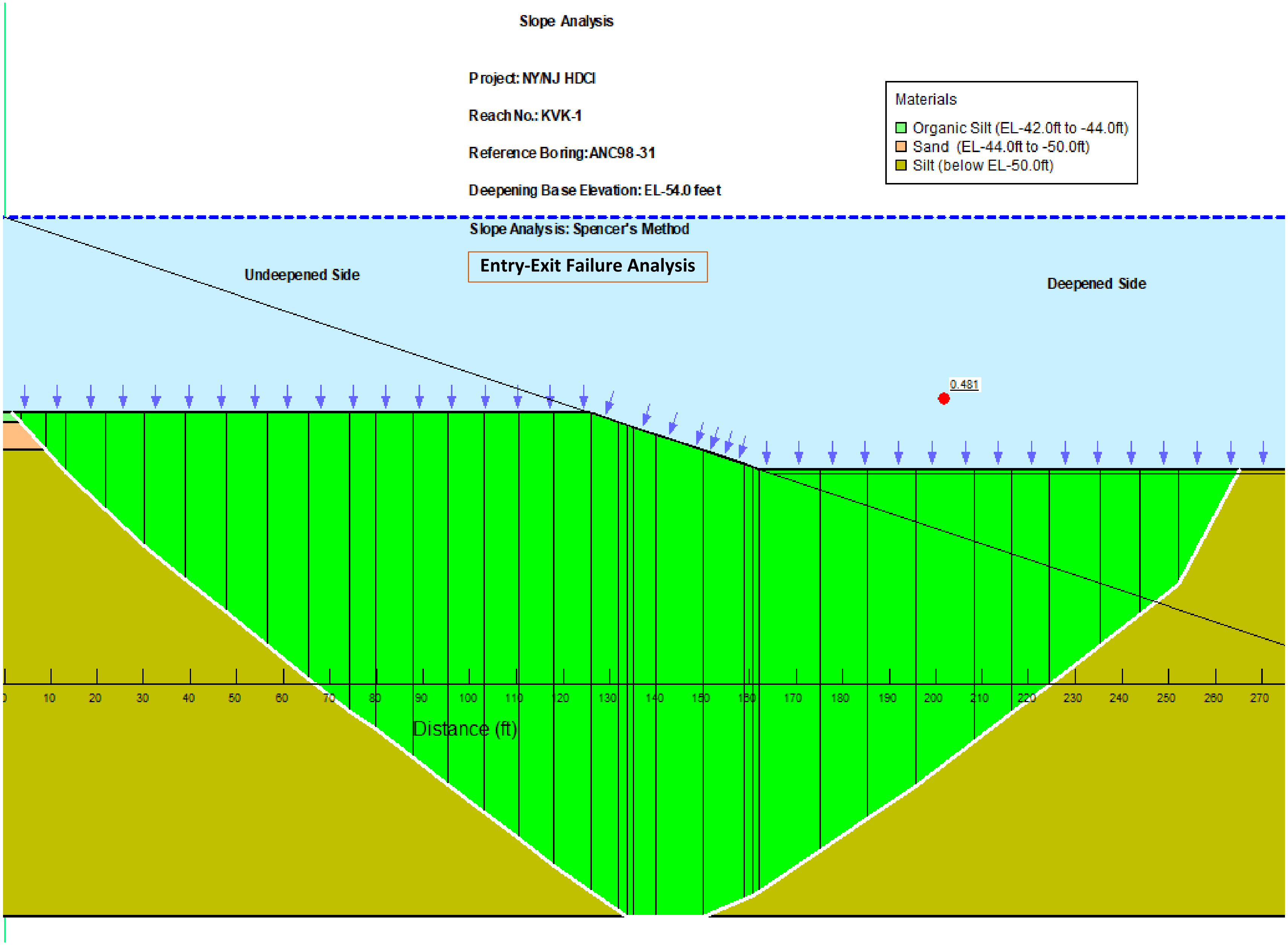
Slope Analysis: Spencer's Method

Materials

🟩 Organic Silt (EL-27.0ft to -43.0ft)
🟧 Sand (EL-43.0ft to -55.0ft)
🟨 Silt (below EL -55.0ft)




Slope Analysis
Project: NY/NJ HDCI
Reach No.: KVK-1
Reference Boring: ANC98-31
0.473
Deepening Base Elevation: EL-54.0 feet
Slope Analysis: Spencer's Method
Grid-Radius Failure Analysis
Undeepened Side
Deepened Side
Materials
🟩 Organic Silt (EL-42.0ft to -44.0ft)
🟧 Sand (EL-44.0ft to -50.0ft)
▨ Silt (below EL-50.0ft)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
Distance (ft)


Slope Analysis
Project: NY/NJ HDCI
Reach No.: KVK-1
Reference Boring: ANC98-31
Deepening Base Elevation: EL-54.0 feet
Slope Analysis: Spencer's Method
Entry-Exit Failure Analysis
Materials
🟩 Organic Silt (EL-42.0ft to -44.0ft)
🟧 Sand (EL-44.0ft to -50.0ft)
🟨 Silt (below EL-50.0ft)
Undeepened Side
Deepened Side
0.481
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
Distance (ft)

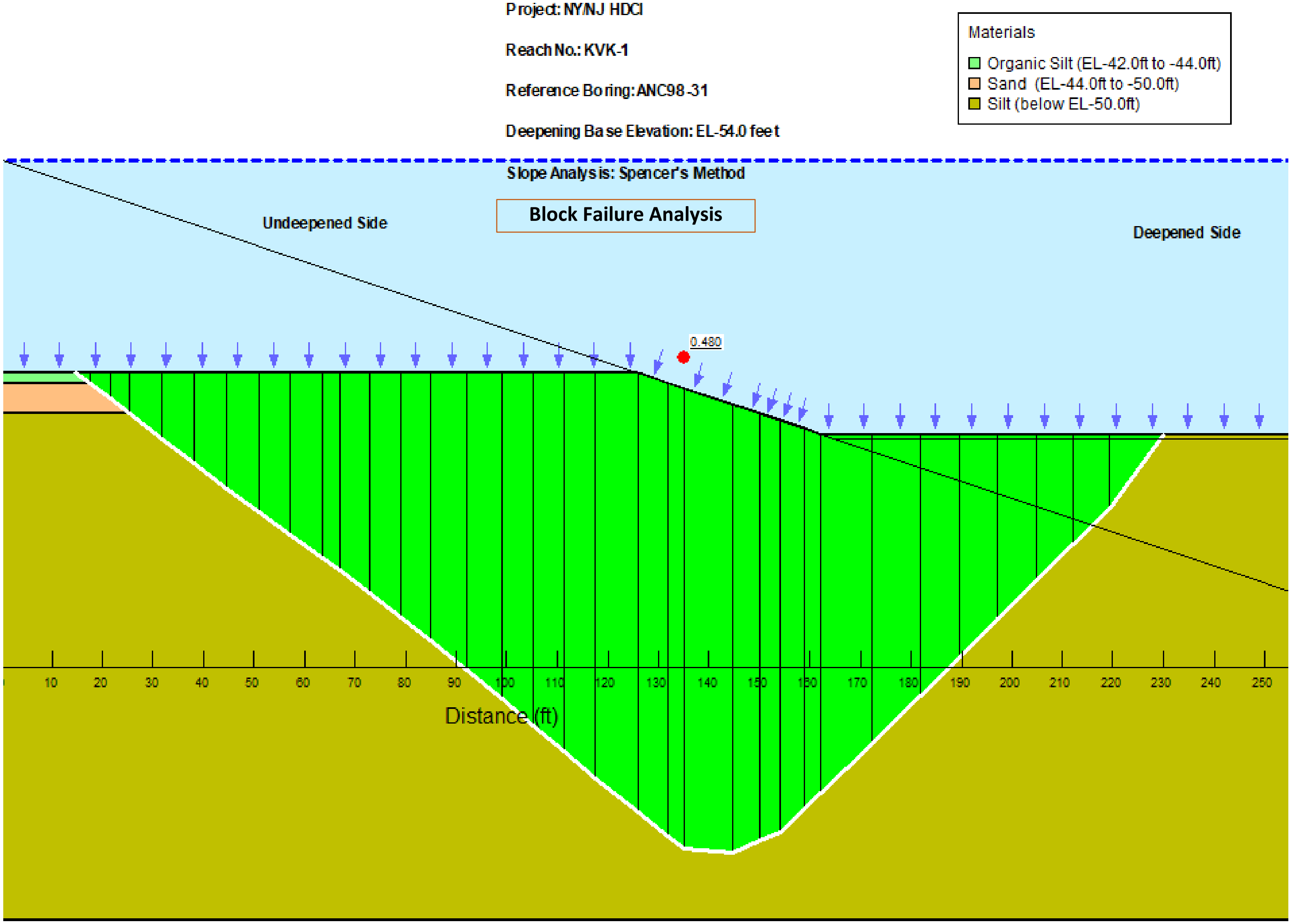
Slope Analysis

Project: NY/NJ HDCI

Reach No.: KVK-1

Reference Boring: ANC98-31

Deepening Base Elevation: EL-54.0 feet



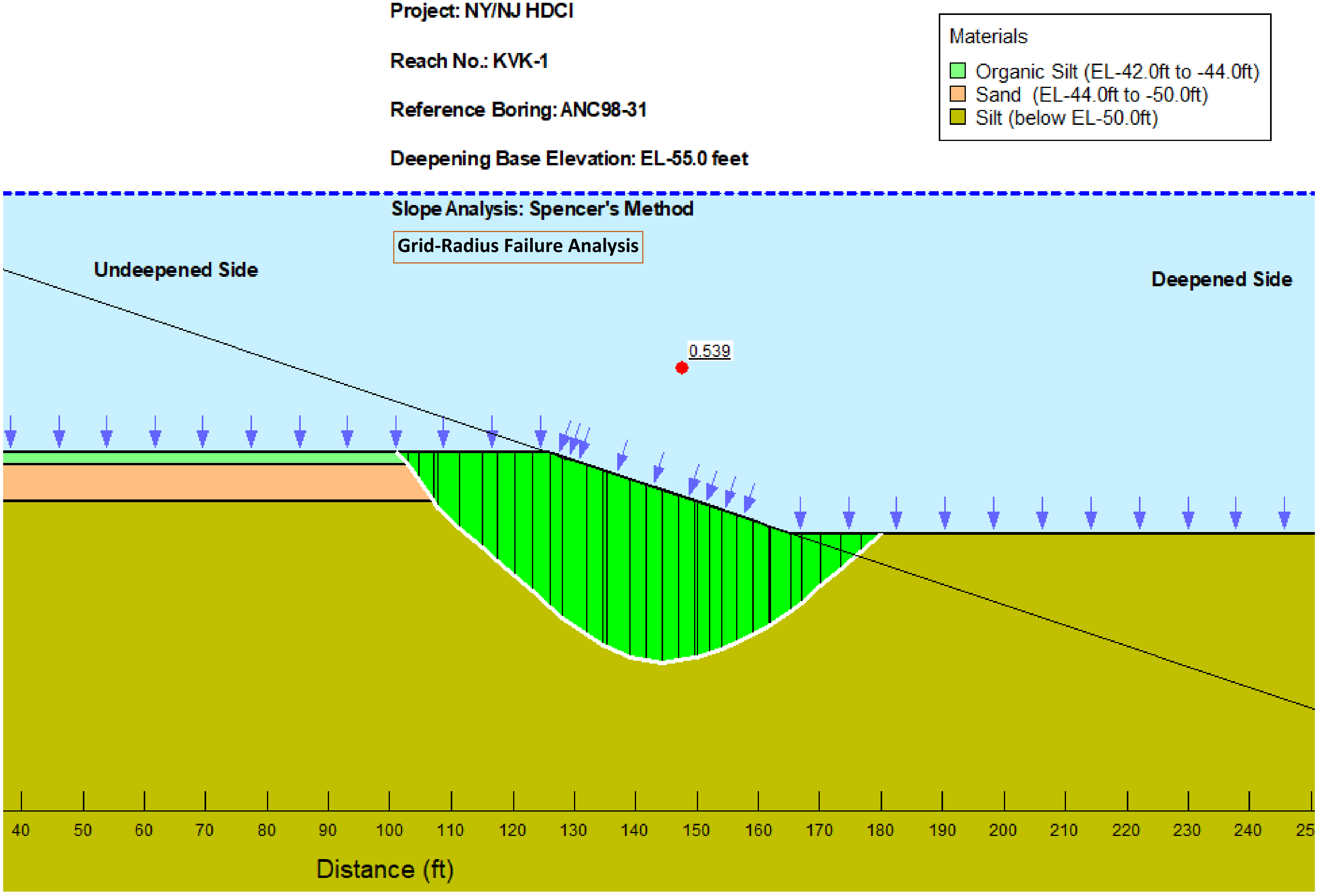
Slope Analysis

Project: NY/NJ HDCI

Reach No.: KVK-1

Reference Boring: ANC98-31

Deepening Base Elevation: EL-55.0 feet



Slope Analysis

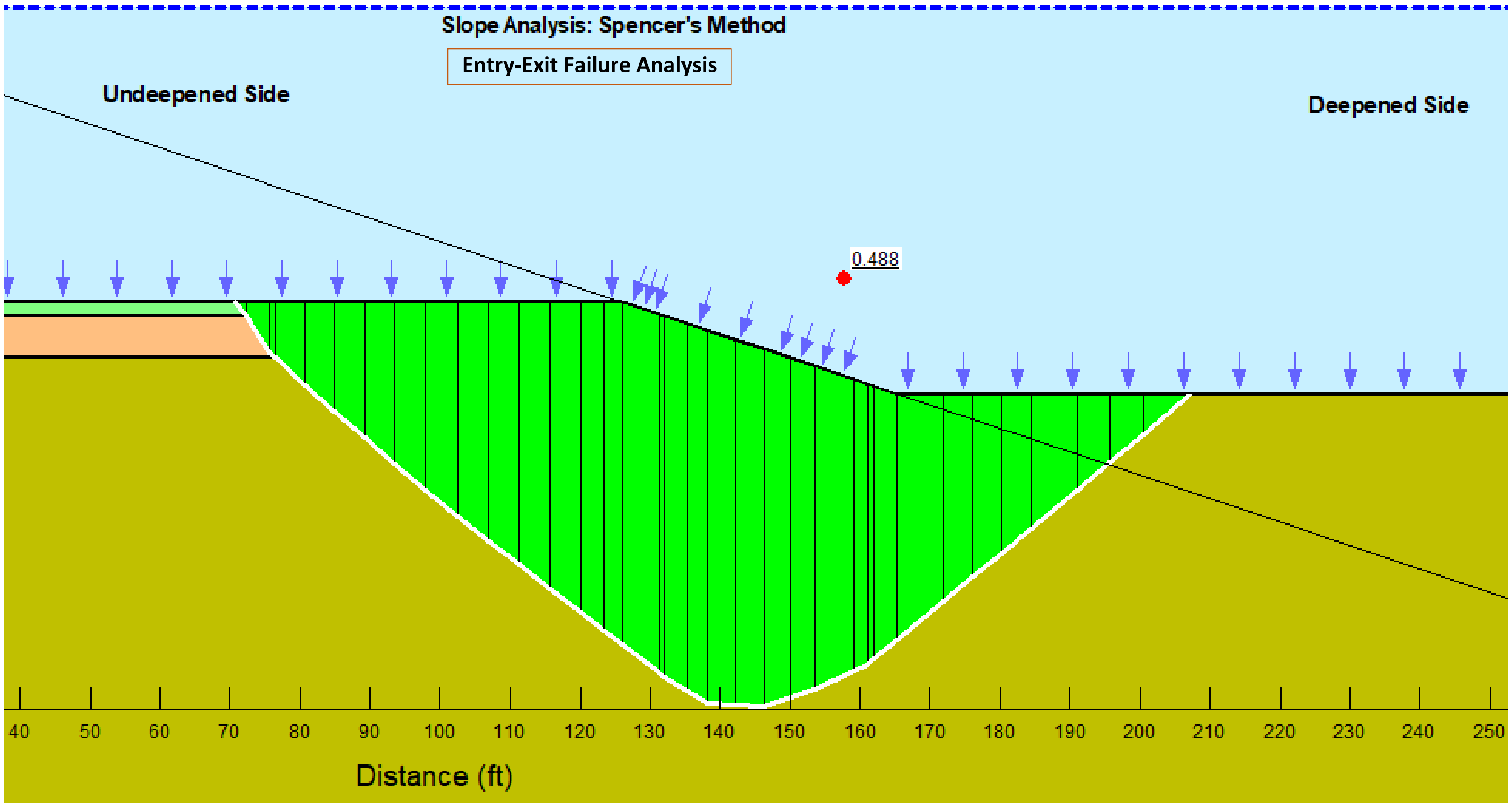
Project: NY/NJ HDCI

Reach No.: KVK-1

Reference Boring: ANC98-31

Deepening Base Elevation: EL-55.0 feet

Materials
- 🟩 Organic Silt (EL-42.0ft to -44.0ft)
- 🟧 Sand (EL-44.0ft to -50.0ft)
- 🟨 Silt (below EL-50.0ft)



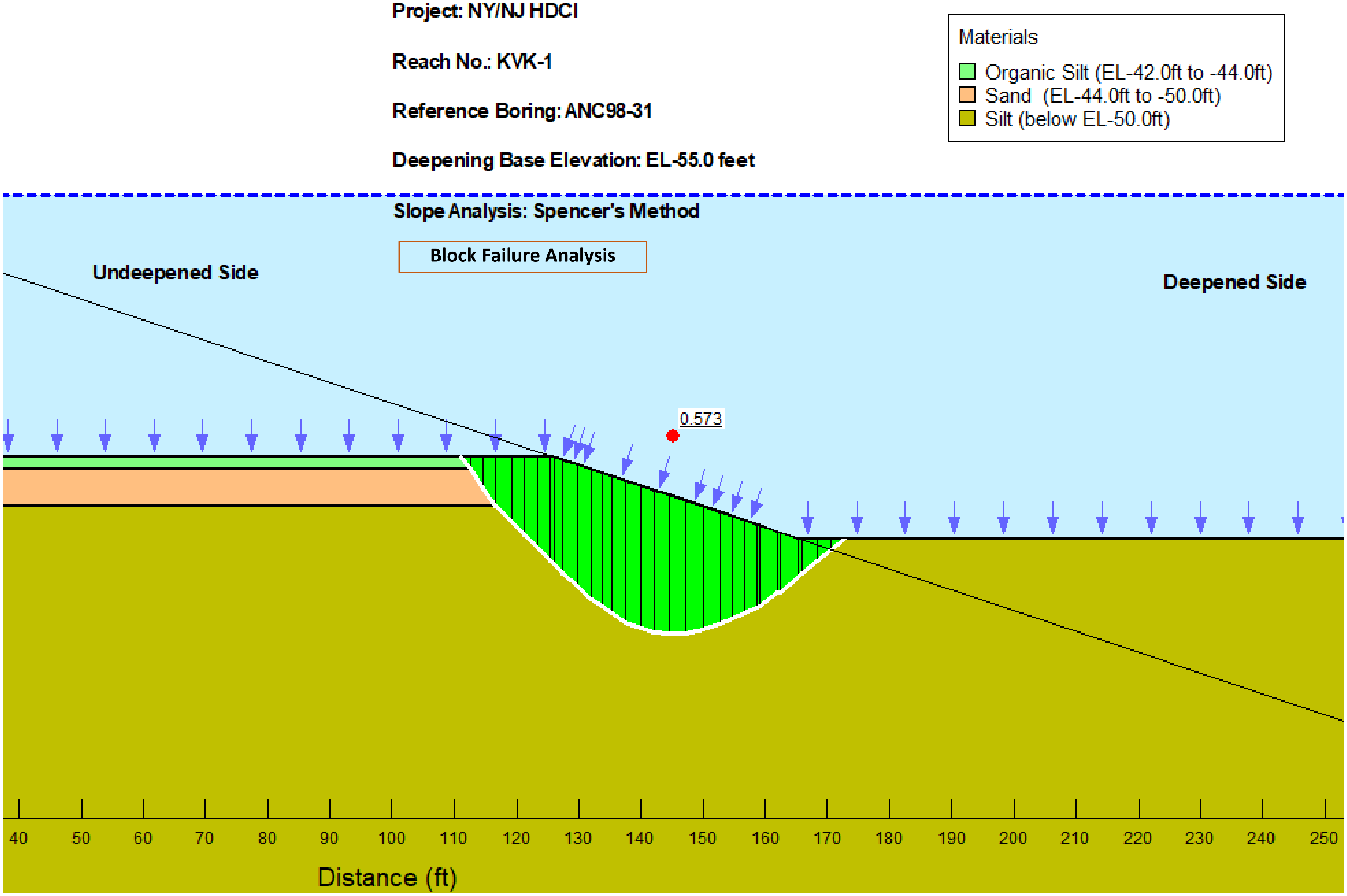
Slope Analysis

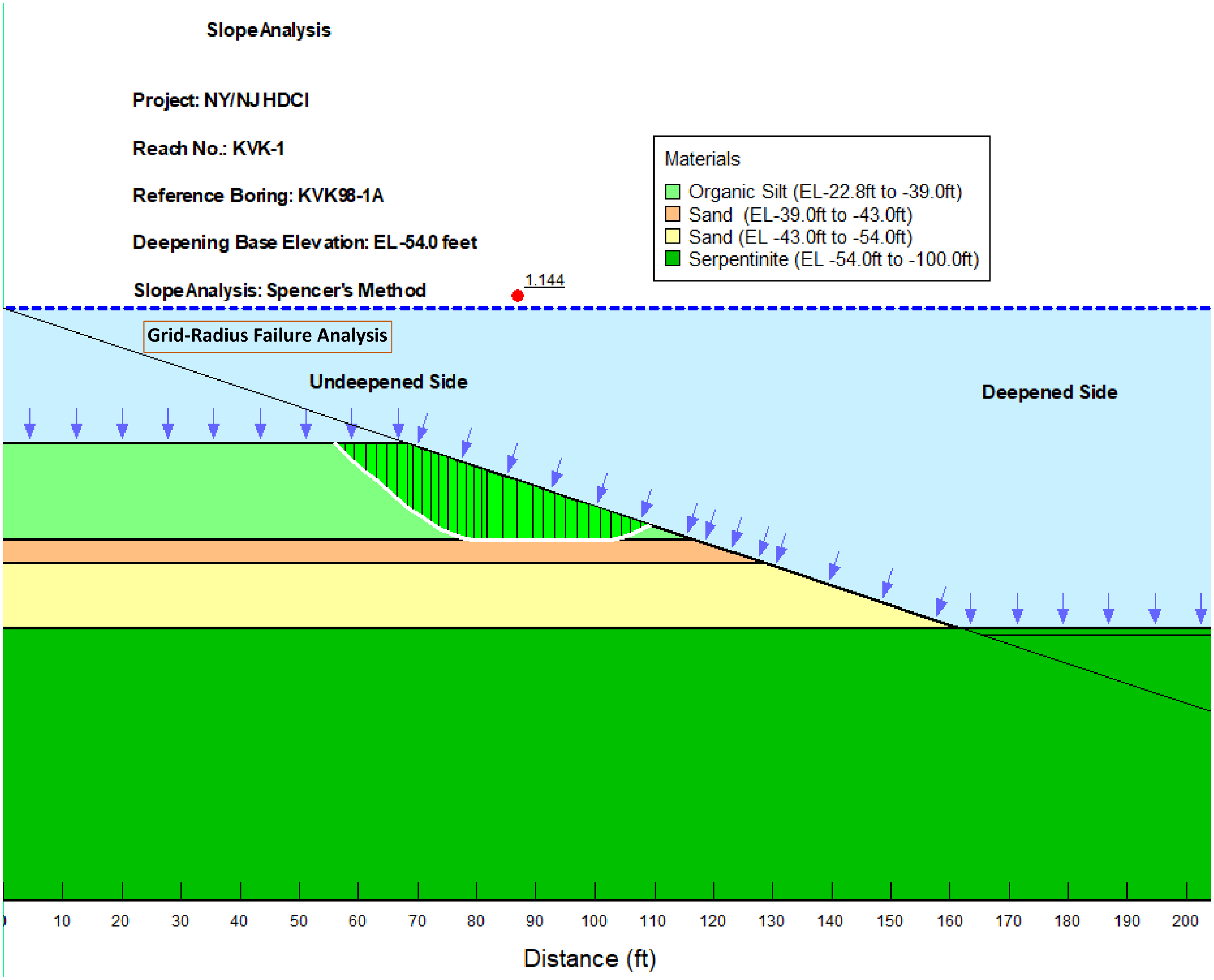
Project: NY/NJ HDCI

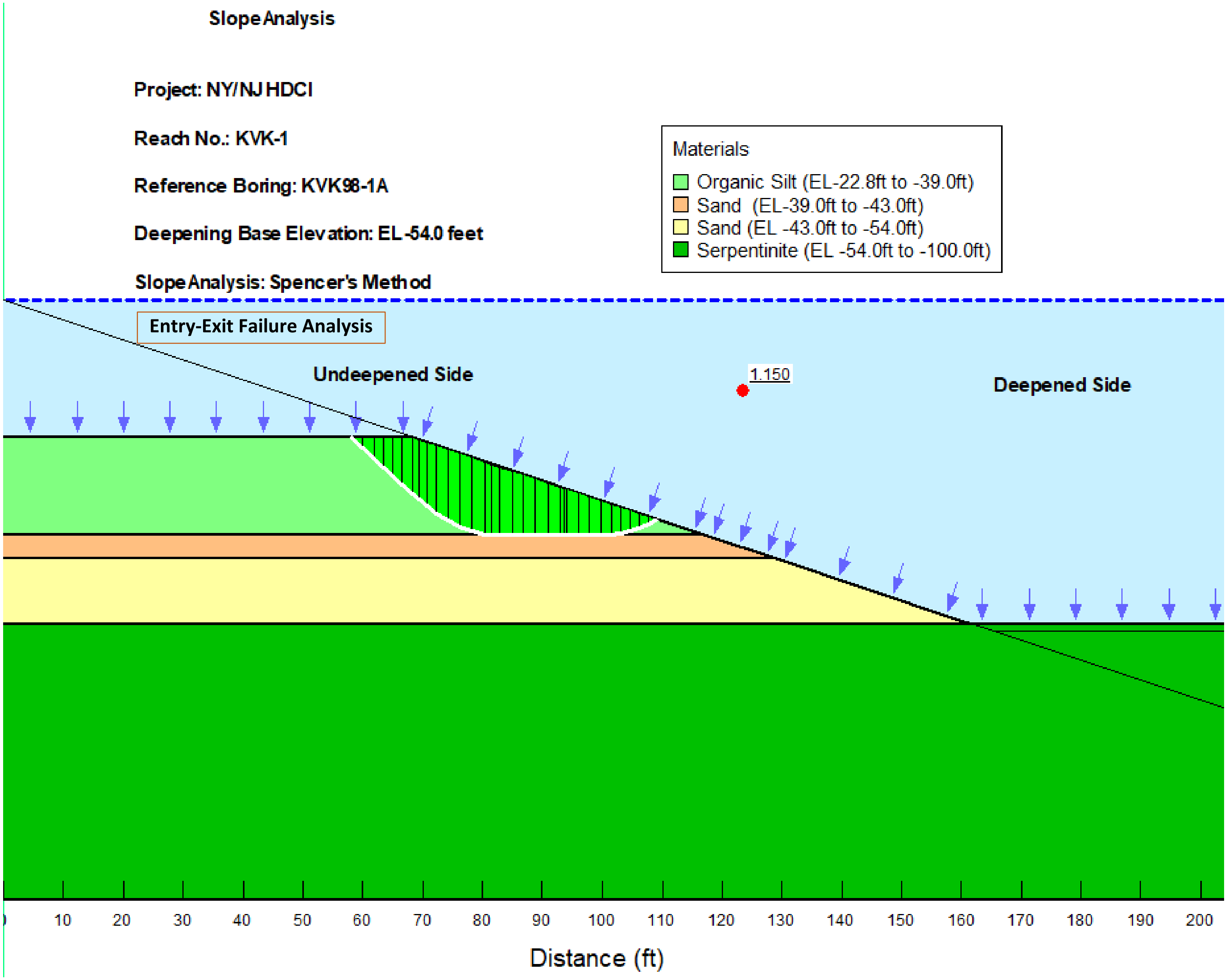
Reach No.: KVK-1

Reference Boring: ANC98-31

Deepening Base Elevation: EL-55.0 feet




Slope Analysis
Project: NY/NJ HDCI
Reach No.: KVK-1
Reference Boring: KVK98-1A
Deepening Base Elevation: EL-54.0 feet
Slope Analysis: Spencer's Method
1.144
Grid-Radius Failure Analysis
Undeepened Side
Deepened Side
Materials
🟩 Organic Silt (EL-22.8ft to -39.0ft)
🟧 Sand (EL-39.0ft to -43.0ft)
🟨 Sand (EL -43.0ft to -54.0ft)
🟩 Serpentinite (EL -54.0ft to -100.0ft)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance (ft)



Slope Analysis

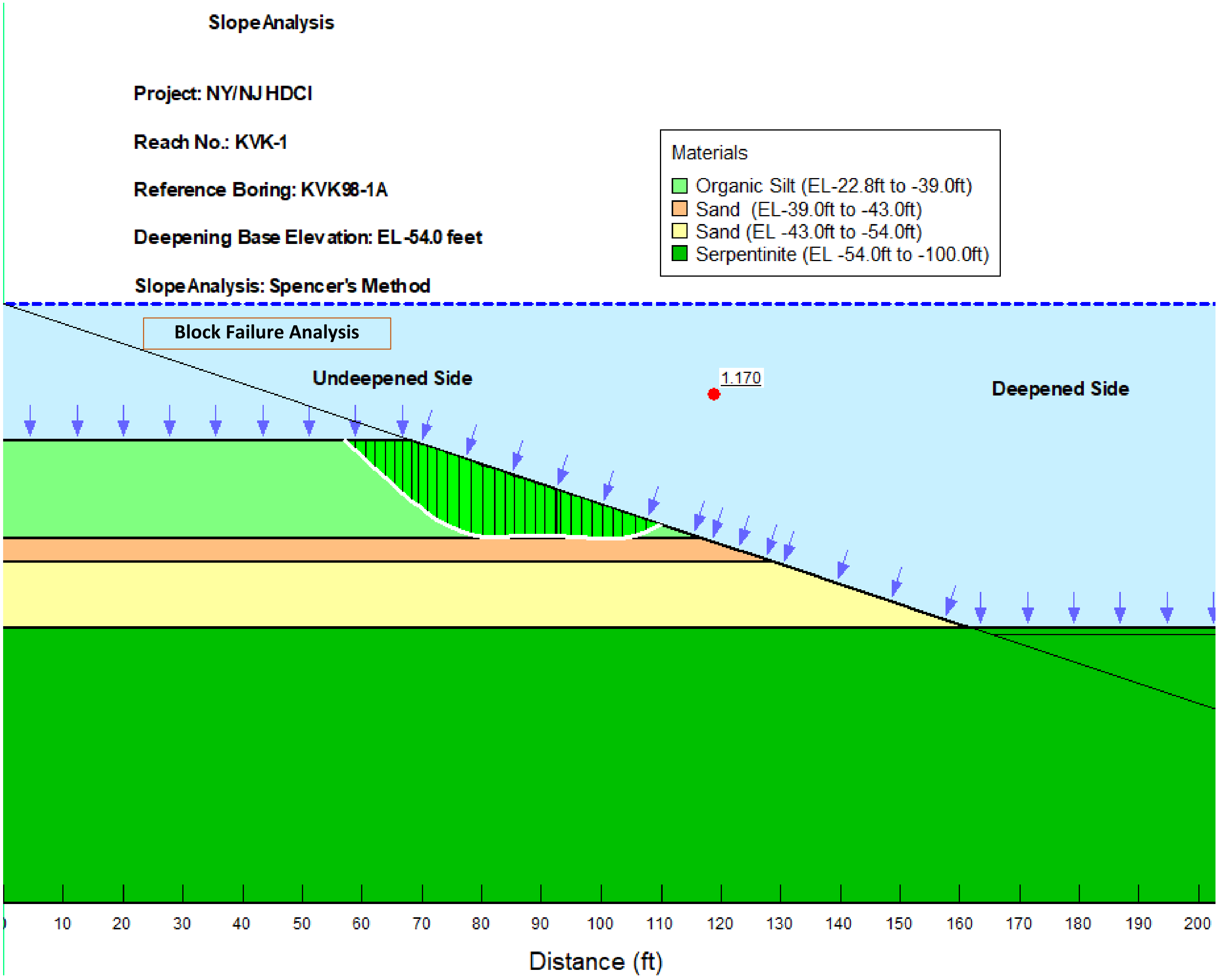
Project: NY/NJ HDCI

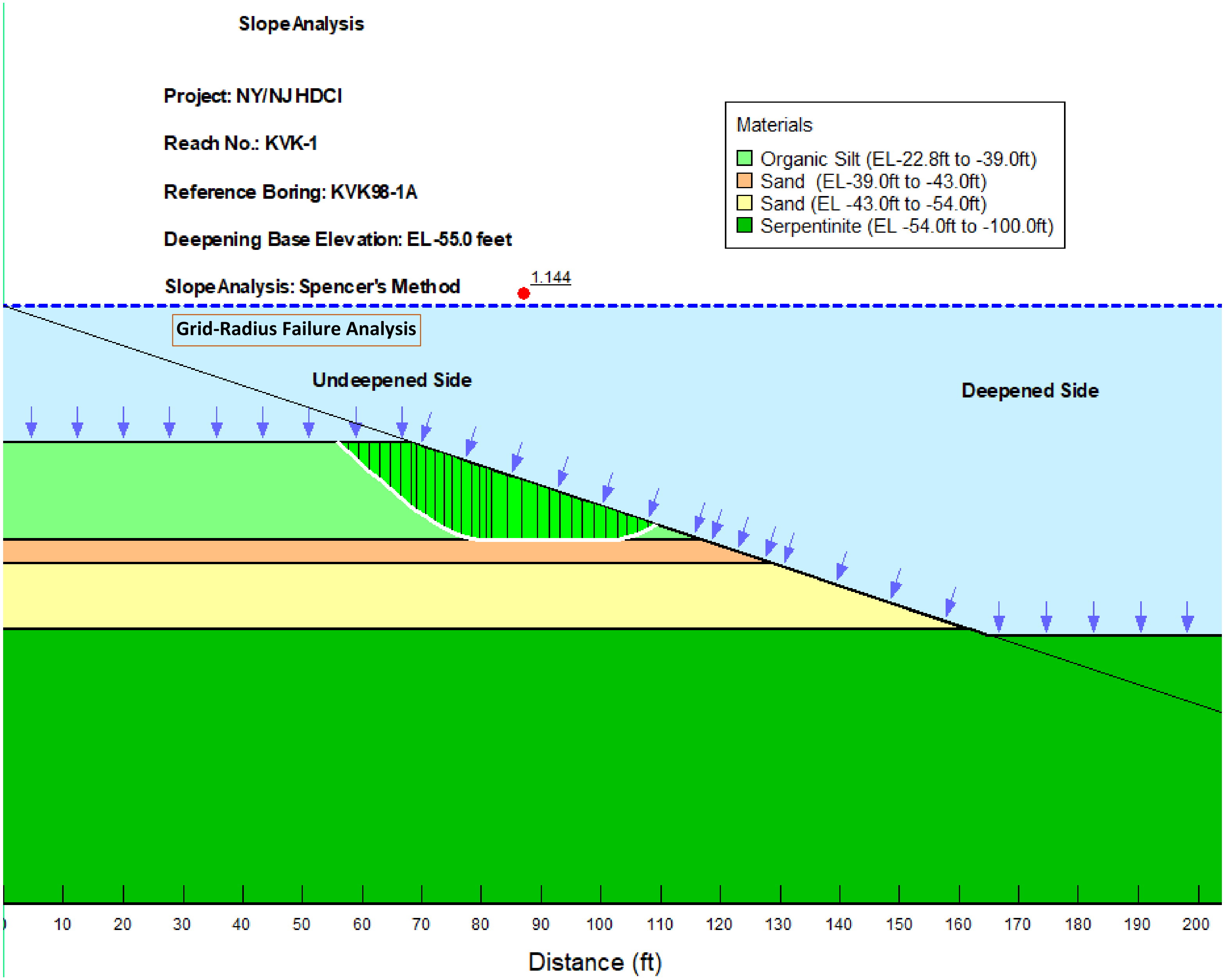
Reach No.: KVK-1

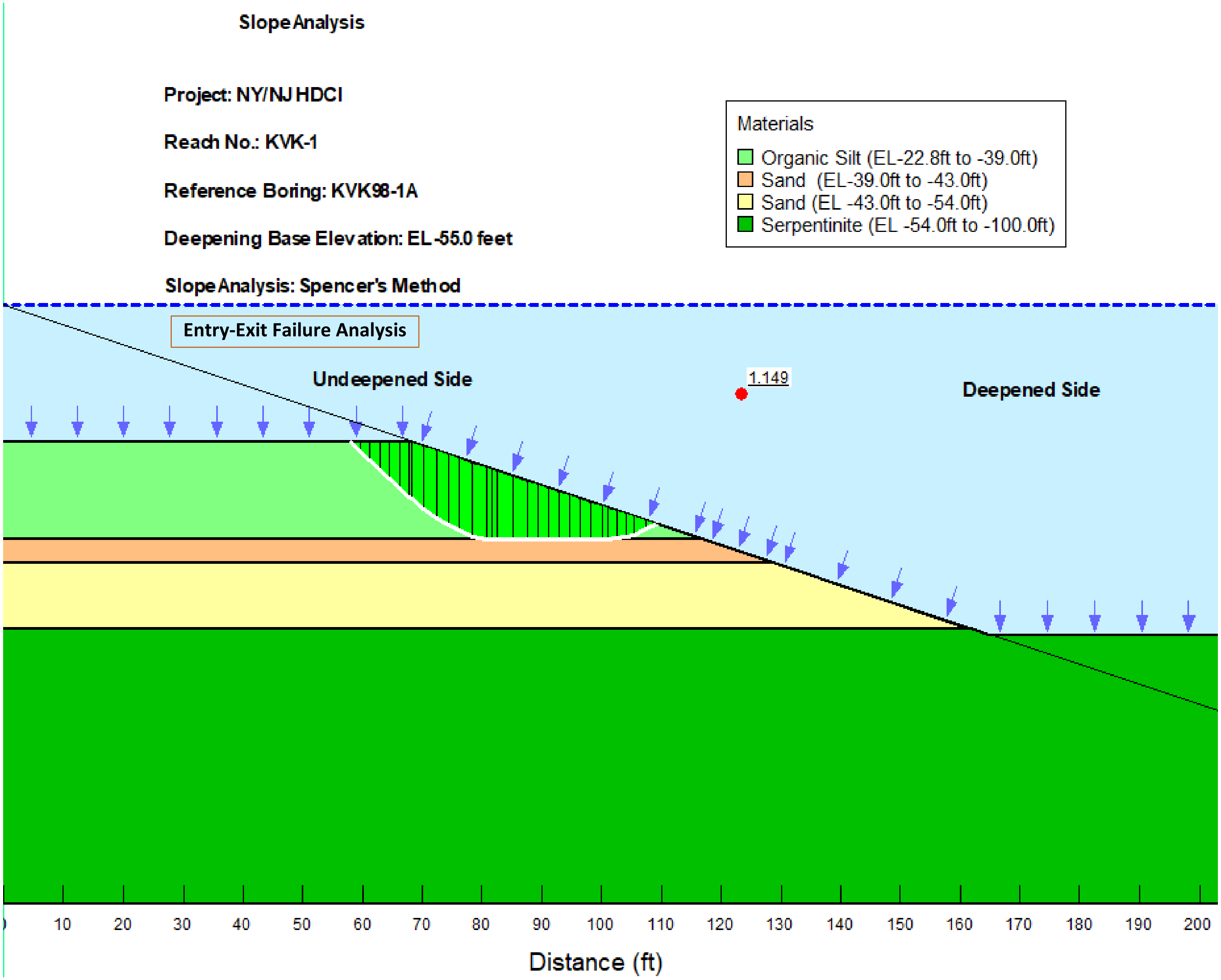
Reference Boring: KVK98-1A

Deepening Base Elevation: EL -54.0 feet

Slope Analysis: Spencer's Method


Slope Analysis
Project: NY/NJ HDCI
Reach No.: KVK-1
Reference Boring: KVK98-1A
Deepening Base Elevation: EL -54.0 feet
Slope Analysis: Spencer's Method
Materials
🟩 Organic Silt (EL-22.8ft to -39.0ft)
🟧 Sand (EL-39.0ft to -43.0ft)
🟨 Sand (EL -43.0ft to -54.0ft)
🟩 Serpentinite (EL -54.0ft to -100.0ft)
Block Failure Analysis
Undeepened Side
1.170
Deepened Side
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance (ft)


Slope Analysis
Project: NY/NJ HDCI
Reach No.: KVK-1
Reference Boring: KVK98-1A
Deepening Base Elevation: EL -55.0 feet
Slope Analysis: Spencer's Method
1.144
Grid-Radius Failure Analysis
Materials
🟩 Organic Silt (EL-22.8ft to -39.0ft)
🟧 Sand (EL-39.0ft to -43.0ft)
🟨 Sand (EL -43.0ft to -54.0ft)
🟩 Serpentinite (EL -54.0ft to -100.0ft)
Undeepened Side
Deepened Side
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance (ft)



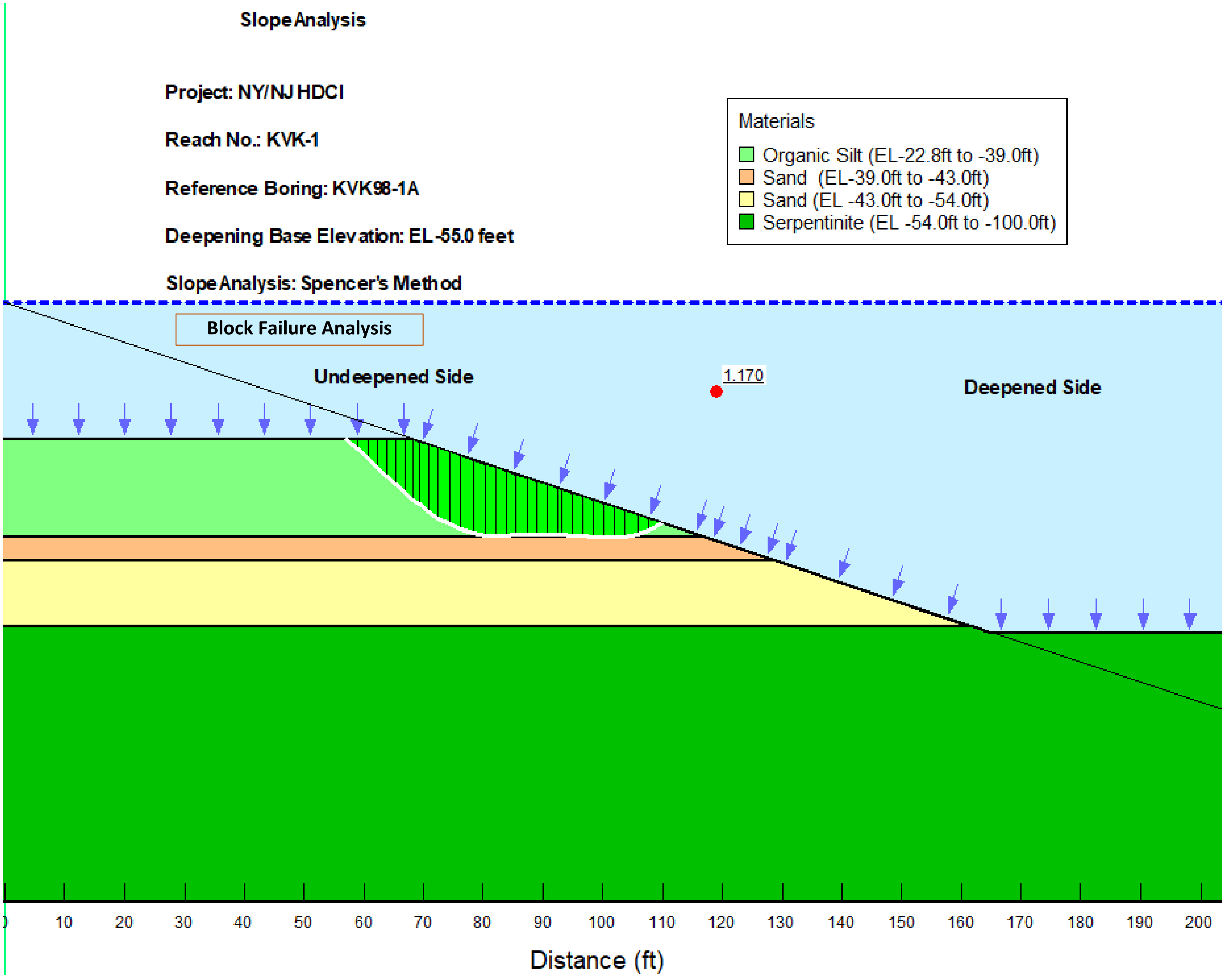
Project: NY/NJ HDCI

Reach No.: KVK-1

Reference Boring: KVK98-1A

Deepening Base Elevation: EL -55.0 feet

Slope Analysis: Spencer's Method



Slope Analysis

Project: NY/NJ HDCI

Reach No.: KVK-1

Reference Boring: KVK98-1A

Deepening Base Elevation: EL-55.0 feet

Slope Analysis: Spencer's Method

Slope Analysis

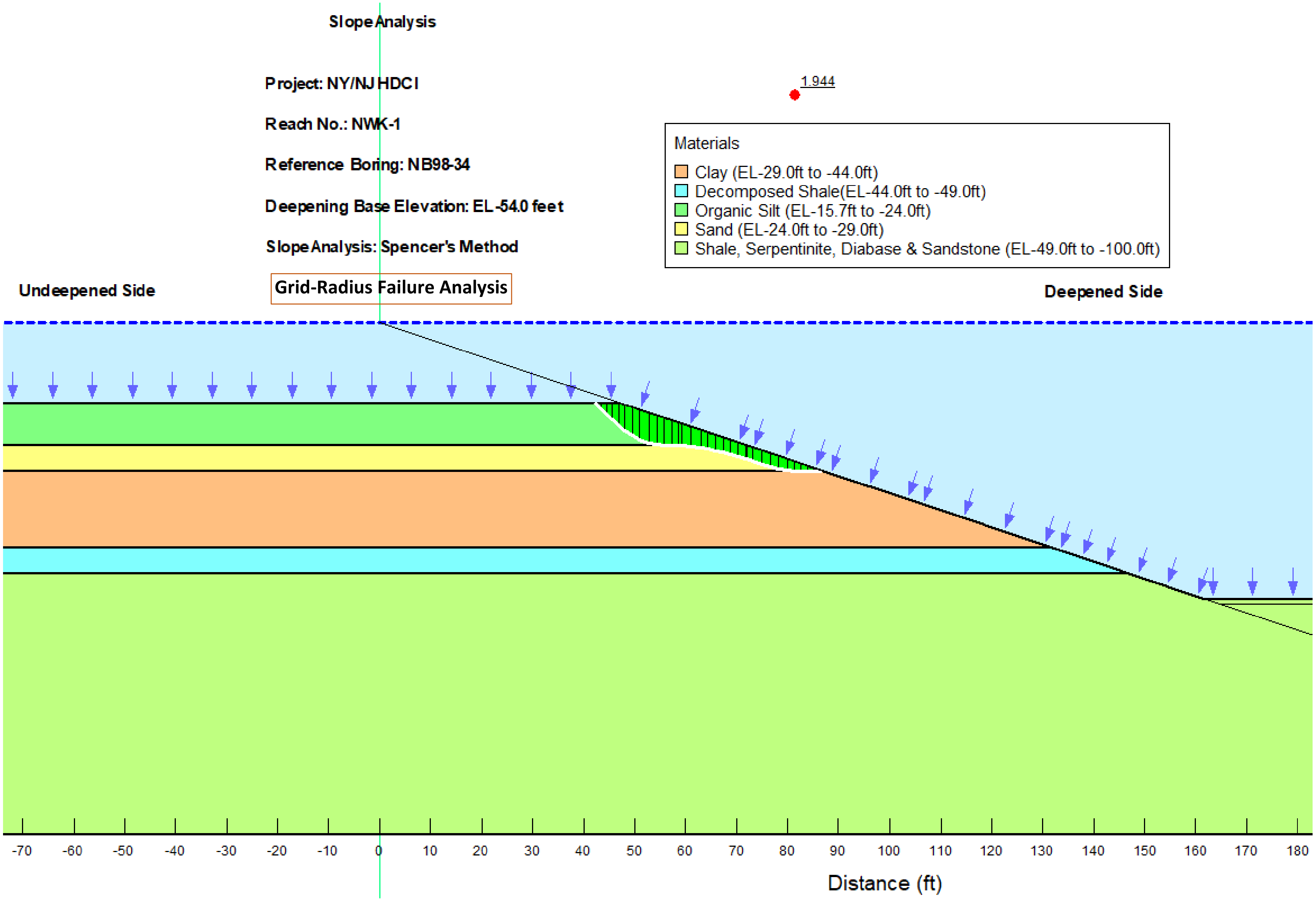
Project: NY/NJ HDCI

Reach No.: NWK-1

Reference Boring: NB98-34

Deepening Base Elevation: EL-54.0 feet

Slope Analysis: Spencer's Method



Slope Analysis

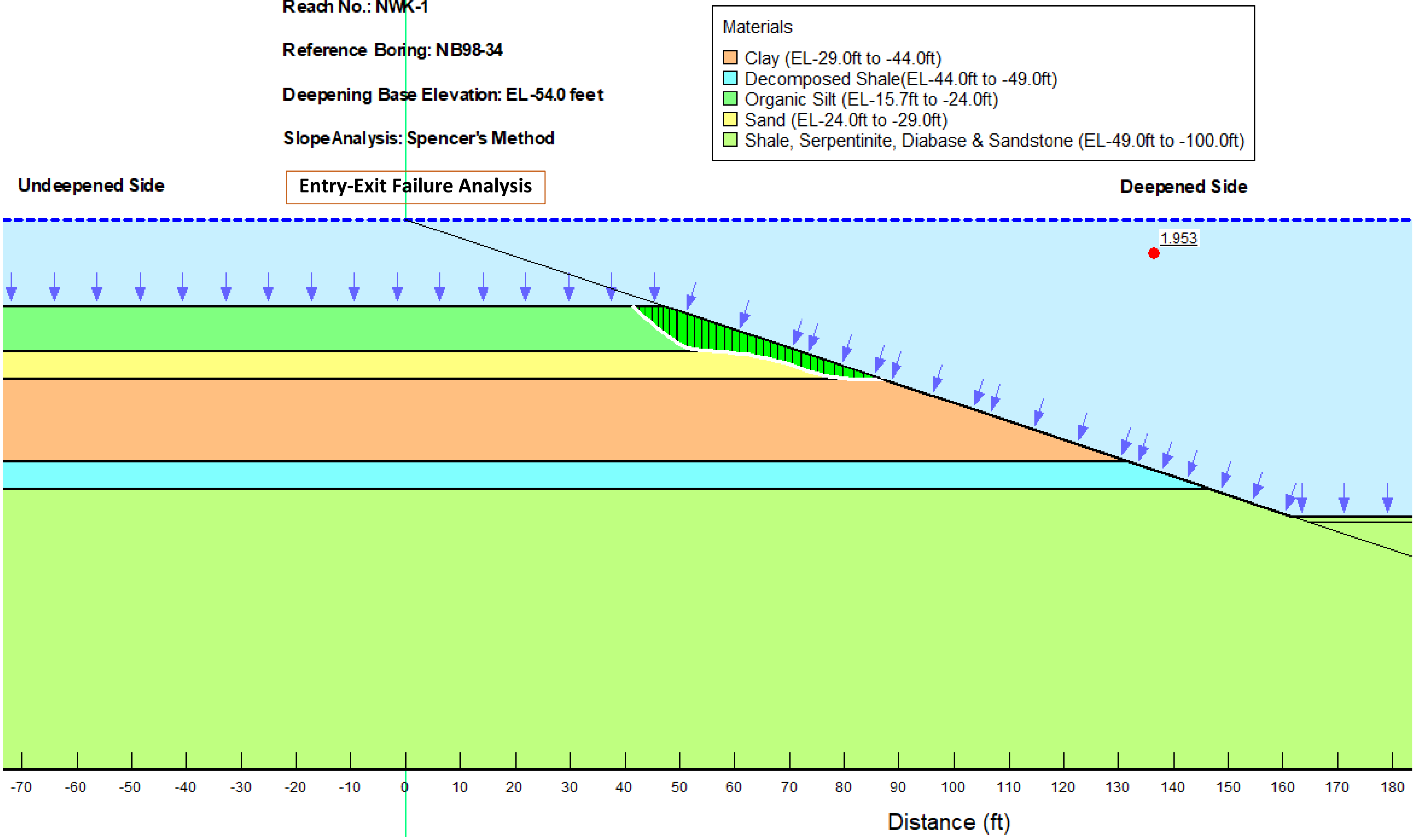
Project: NY/NJ HDCI

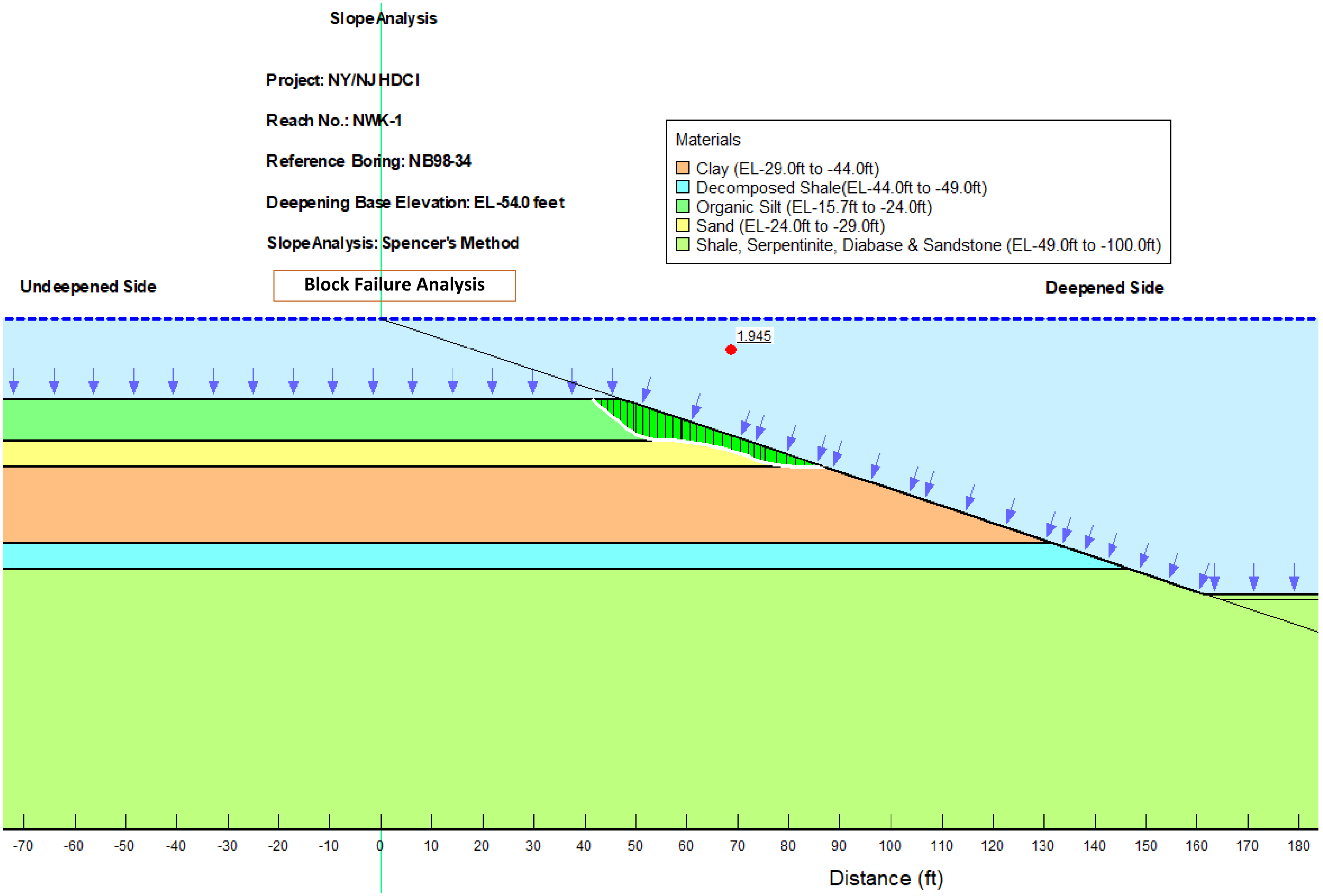
Reach No.: NWK-1

Reference Boring: NB98-34

Deepening Base Elevation: EL-54.0 feet

Slope Analysis: Spencer's Method





Slope Analysis

Project: NY/NJ HDCI

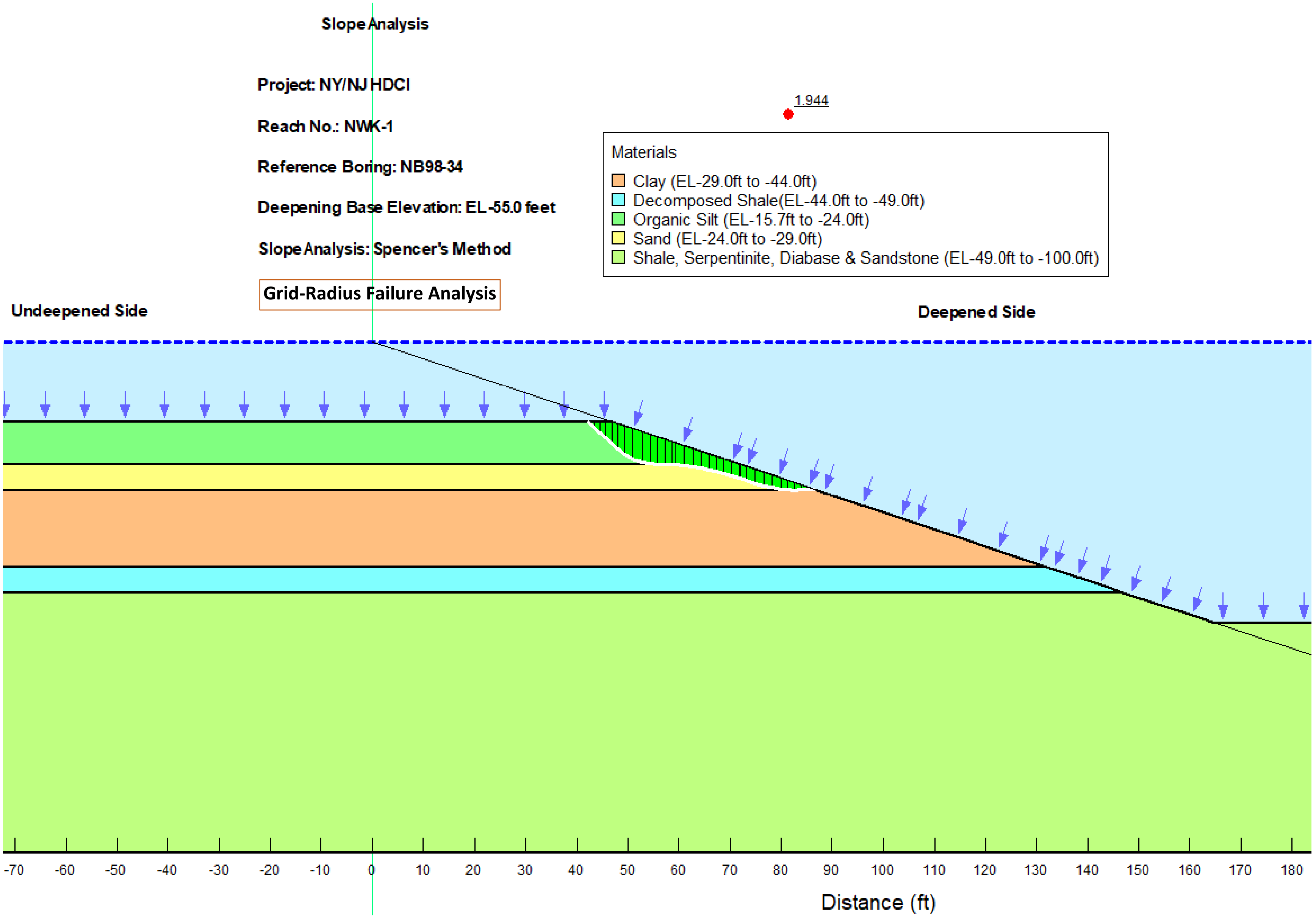
Reach No.: NWK-1

Reference Boring: NB98-34

Deepening Base Elevation: EL-54.0 feet

Slope Analysis: Spencer's Method

Block Failure Analysis



Slope Analysis

Project: NY/NJ HDCI

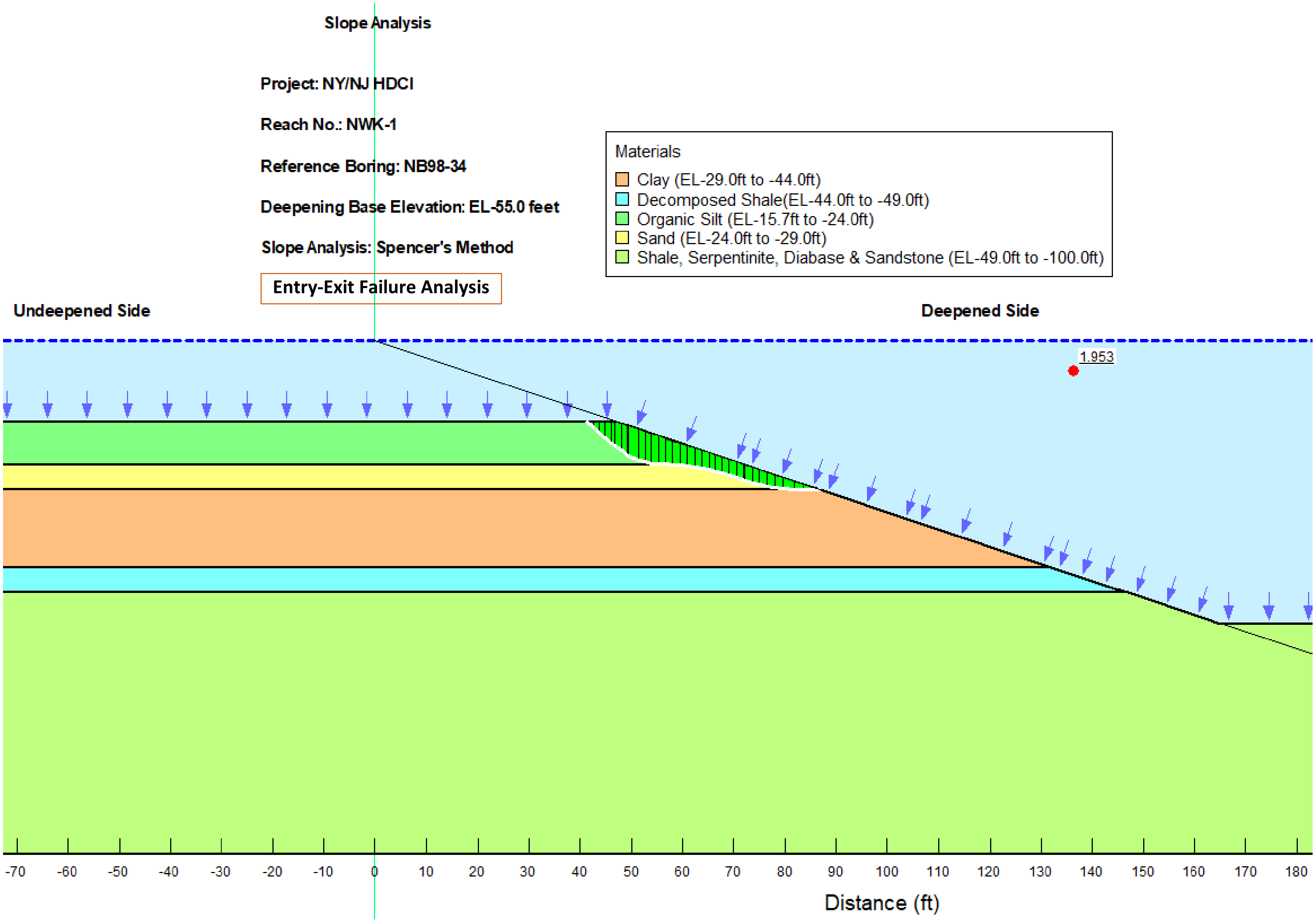
Reach No.: NWK-1

Reference Boring: NB98-34

Deepening Base Elevation: EL-55.0 feet

Slope Analysis: Spencer's Method

Grid-Radius Failure Analysis



Slope Analysis

Project: NY/NJ HDCI

Reach No.: NWK-1

Reference Boring: NB98-34

Deepening Base Elevation: EL-55.0 feet

Slope Analysis: Spencer's Method

Entry-Exit Failure Analysis

Slope Analysis

Project: NY/NJ HDCI

Reach No.: NWK-1

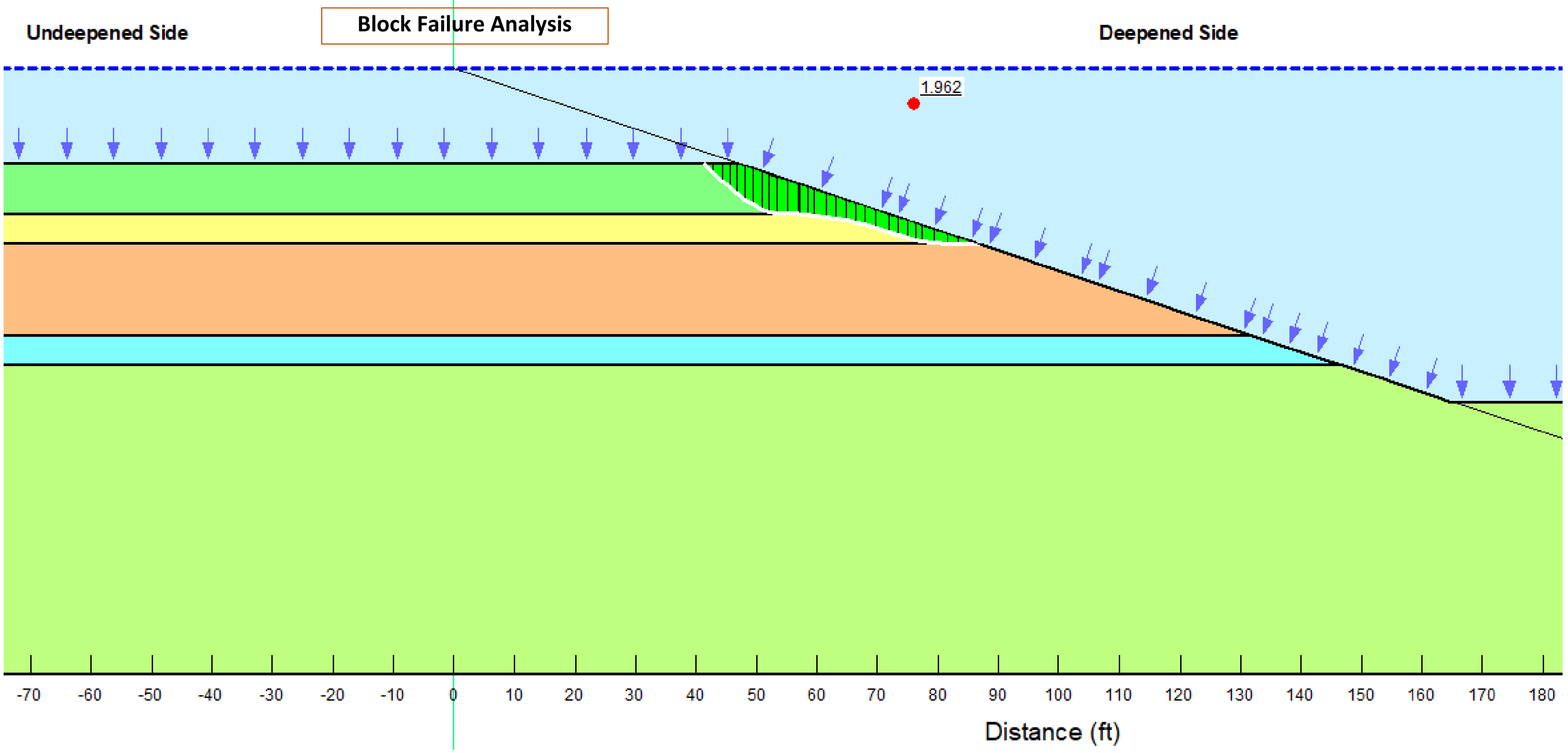
Reference Boring: NB98-34

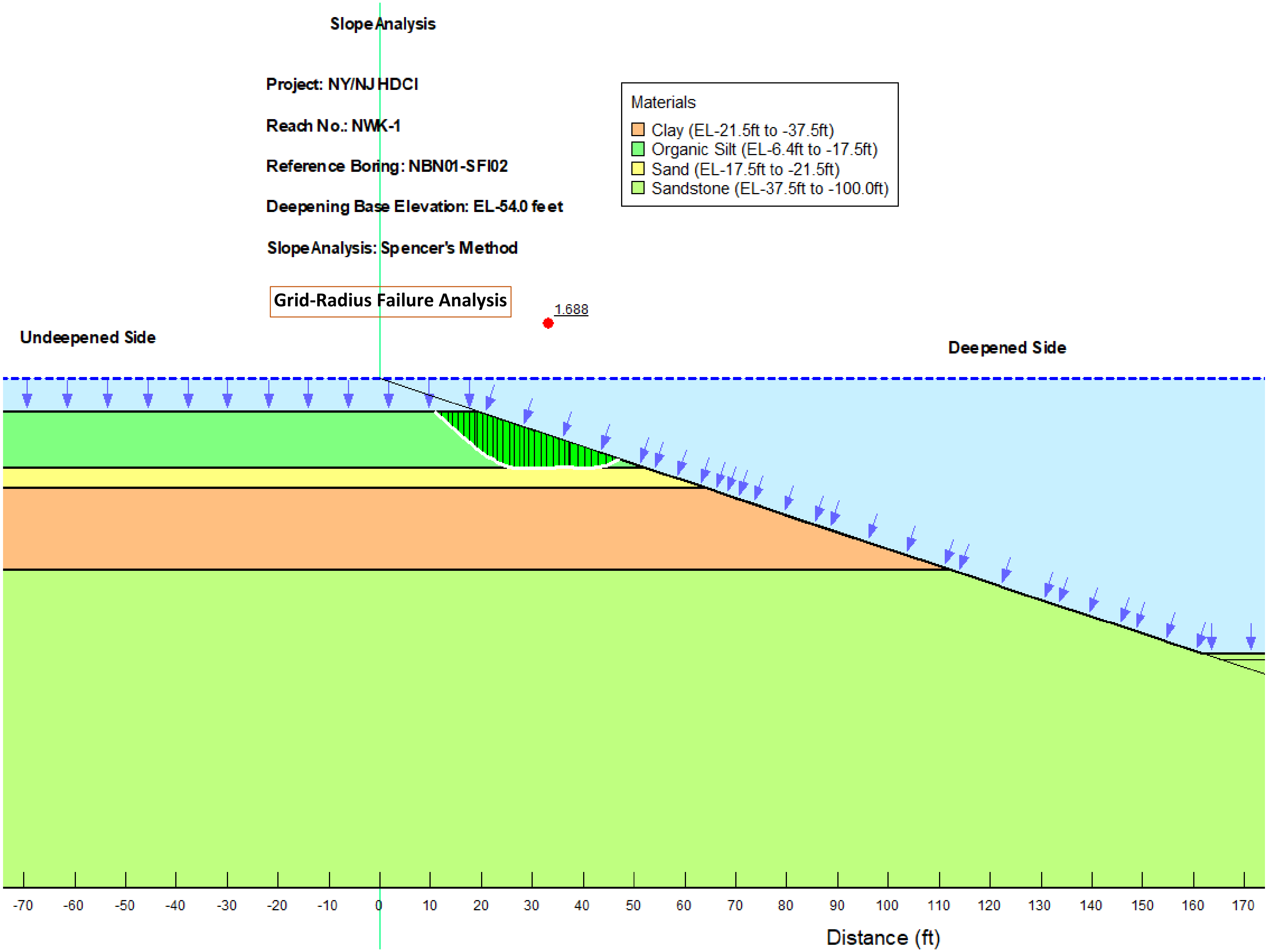
Deepening Base Elevation: EL-55.0 feet

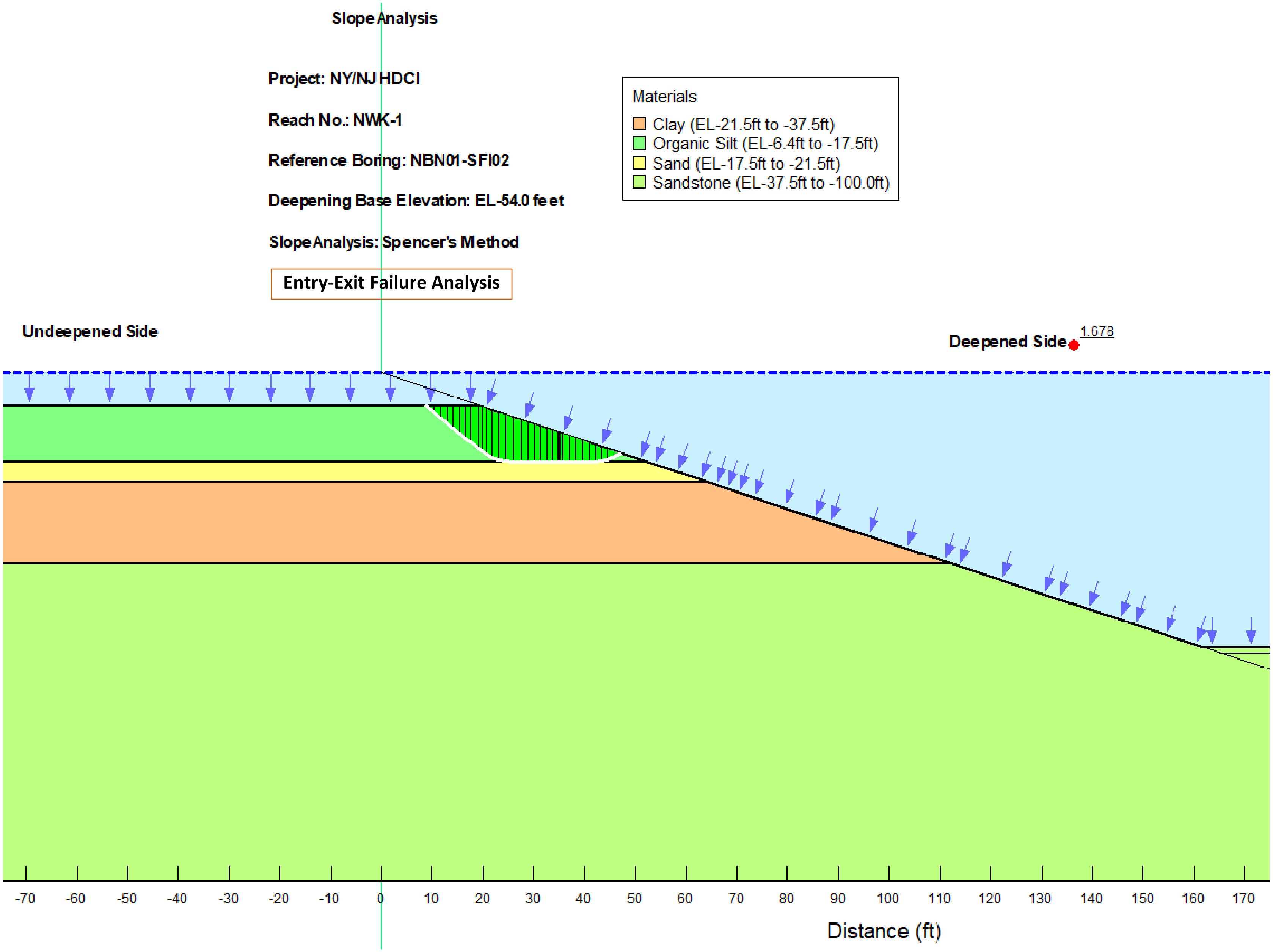
Slope Analysis: Spencer's Method

Materials

- 🟧 Clay (EL-29.0ft to -44.0ft)
- 🟦 Decomposed Shale(EL-44.0ft to -49.0ft)
- 🟩 Organic Silt (EL-15.7ft to -24.0ft)
- 🟨 Sand (EL-24.0ft to -29.0ft)
- 🟩 Shale, Serpentinite, Diabase & Sandstone (EL-49.0ft to -100.0ft)




Slope Analysis
Project: NY/NJ HDCI
Reach No.: NWK-1
Reference Boring: NBN01-SFI02
Deepening Base Elevation: EL-54.0 feet
Slope Analysis: Spencer's Method
Grid-Radius Failure Analysis
1.688
Materials
🟧 Clay (EL-21.5ft to -37.5ft)
🟩 Organic Silt (EL-6.4ft to -17.5ft)
🟨 Sand (EL-17.5ft to -21.5ft)
🟩 Sandstone (EL-37.5ft to -100.0ft)
Undeepened Side
Deepened Side
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
Distance (ft)



Slope Analysis

Project: NY/NJ HDCI

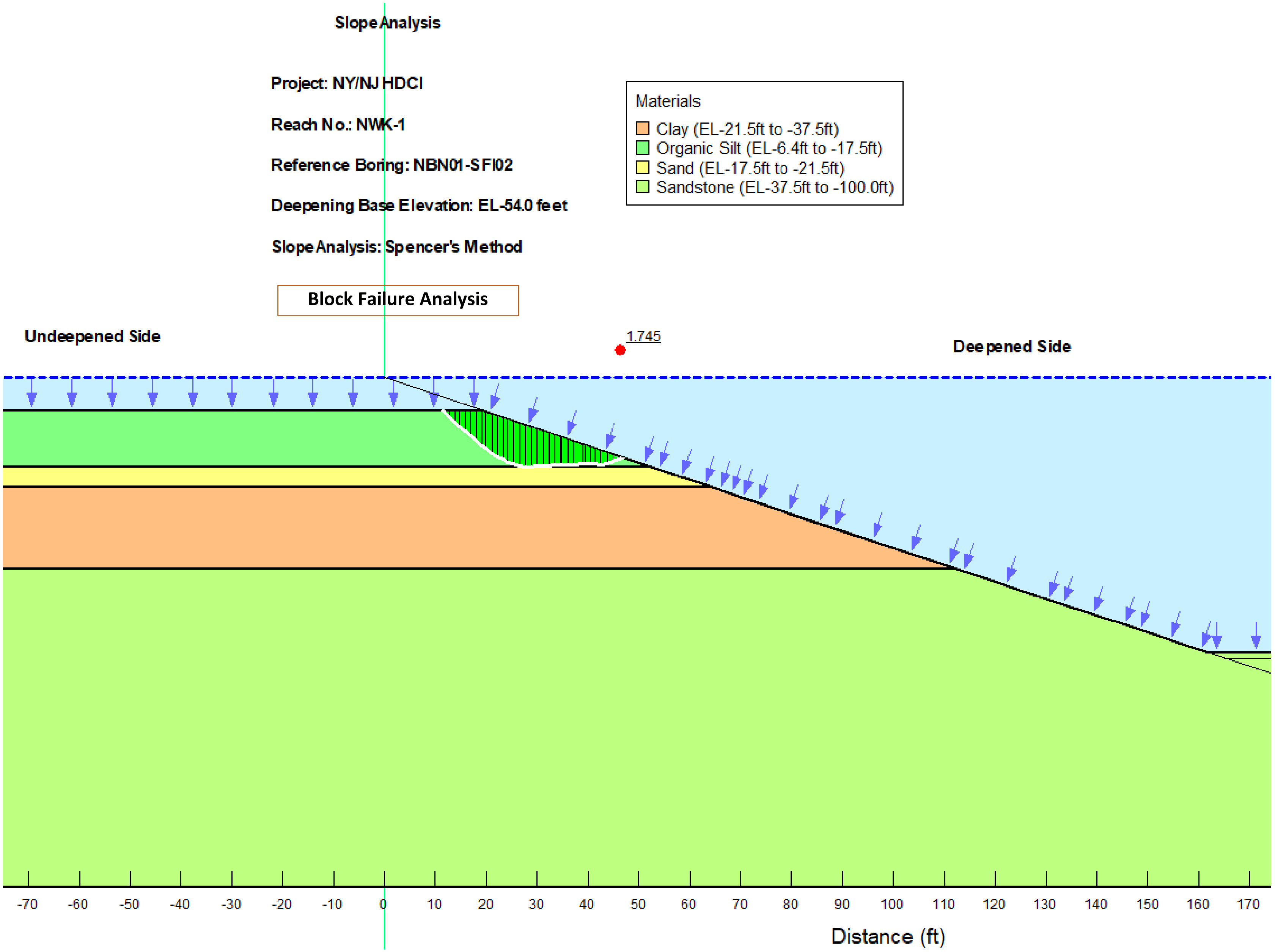
Reach No.: NWK-1

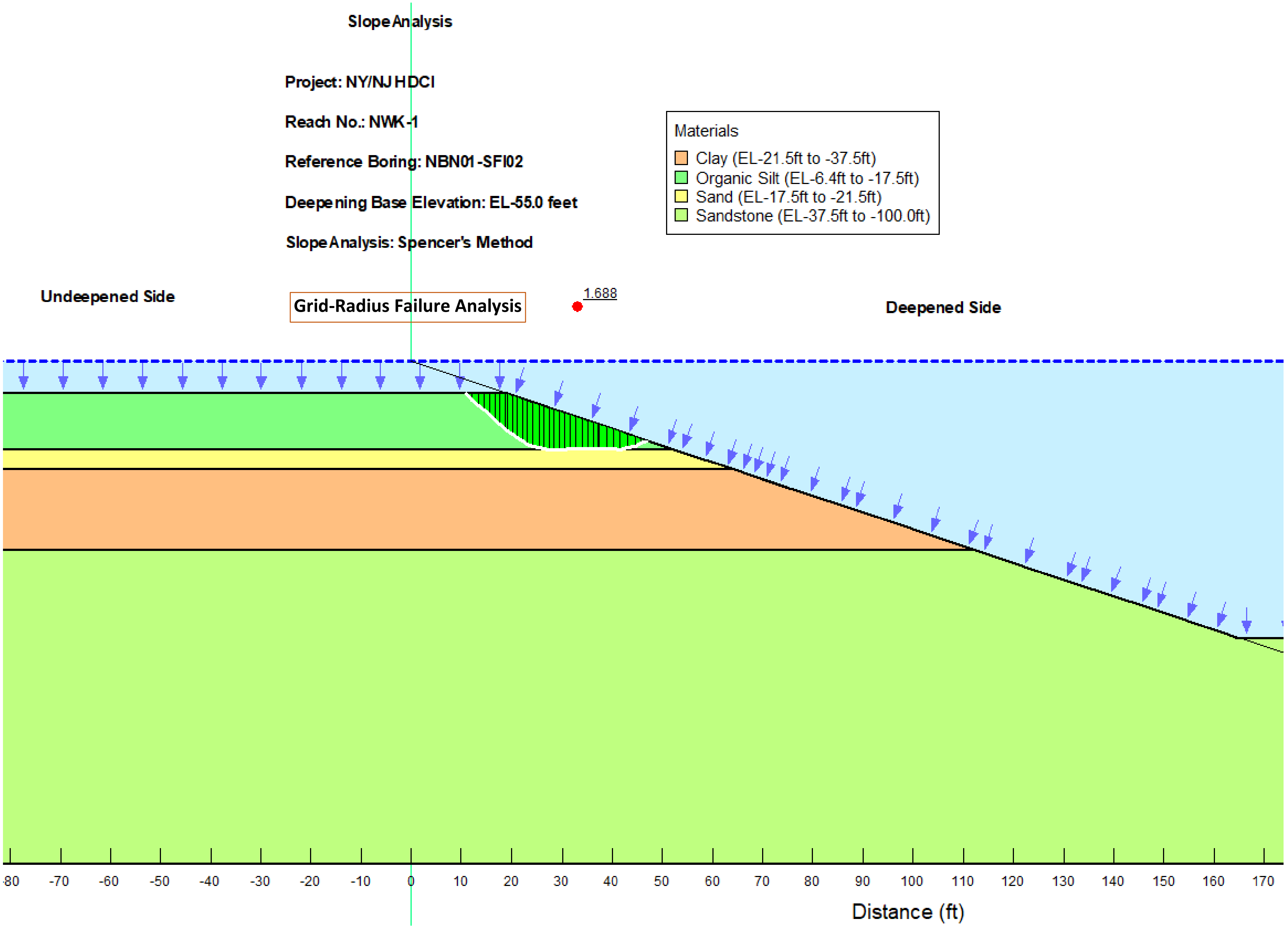
Reference Boring: NBN01-SFI02

Deepening Base Elevation: EL-54.0 feet

Slope Analysis: Spencer's Method

Entry-Exit Failure Analysis


Slope Analysis
Project: NY/NJ HDCI
Reach No.: NWK-1
Reference Boring: NBN01-SFI02
Deepening Base Elevation: EL-54.0 feet
Slope Analysis: Spencer's Method
Block Failure Analysis
Materials
🟧 Clay (EL-21.5ft to -37.5ft)
🟩 Organic Silt (EL-6.4ft to -17.5ft)
🟨 Sand (EL-17.5ft to -21.5ft)
🟩 Sandstone (EL-37.5ft to -100.0ft)
Undeepened Side
1.745
Deepened Side
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
Distance (ft)



Slope Analysis

Project: NY/NJ HDCI

Reach No.: NWK-1

Reference Boring: NBN01-SFI02

Deepening Base Elevation: EL-55.0 feet

Slope Analysis: Spencer's Method

Slope Analysis

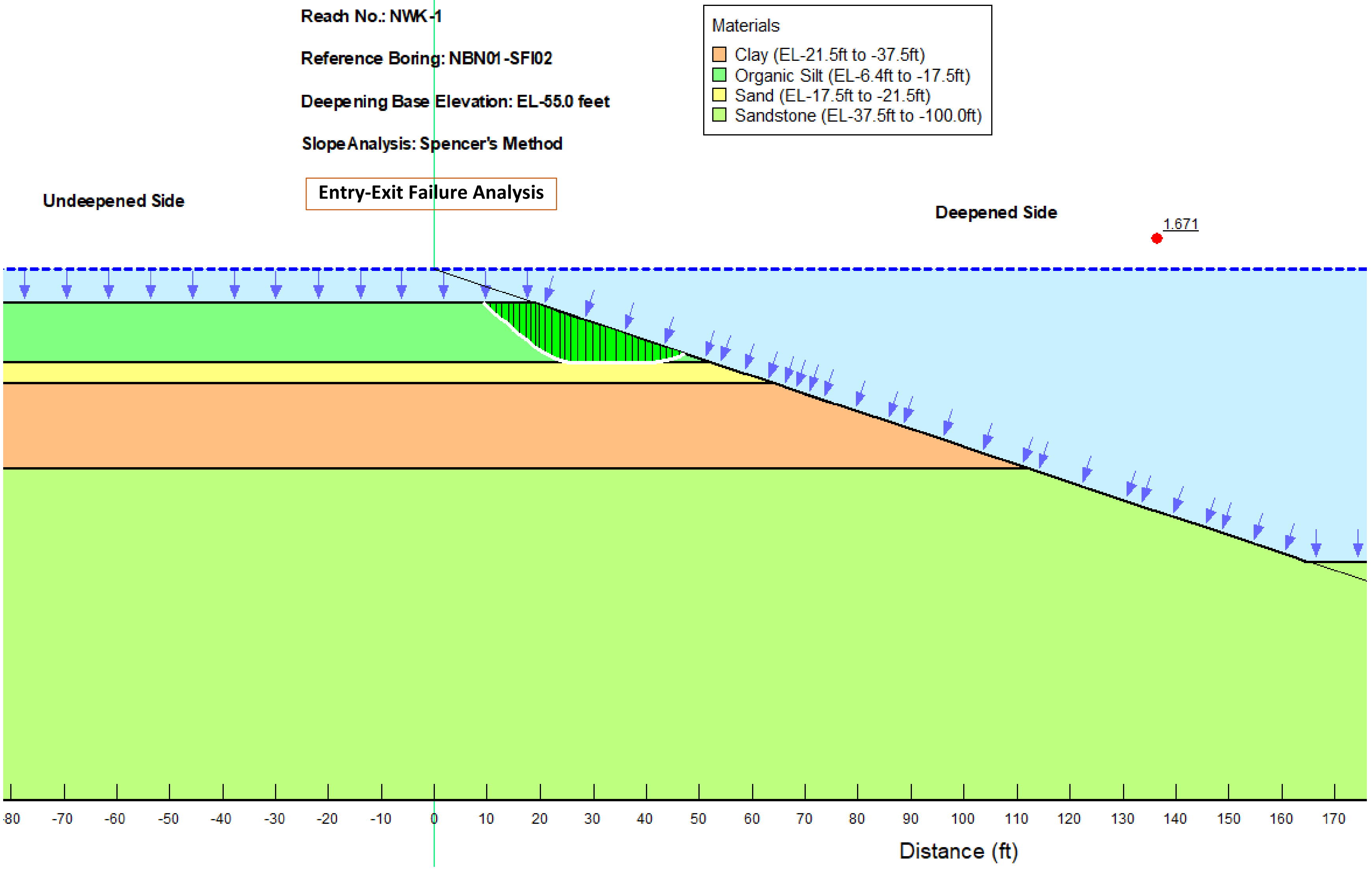
Project: NY/NJ HDCI

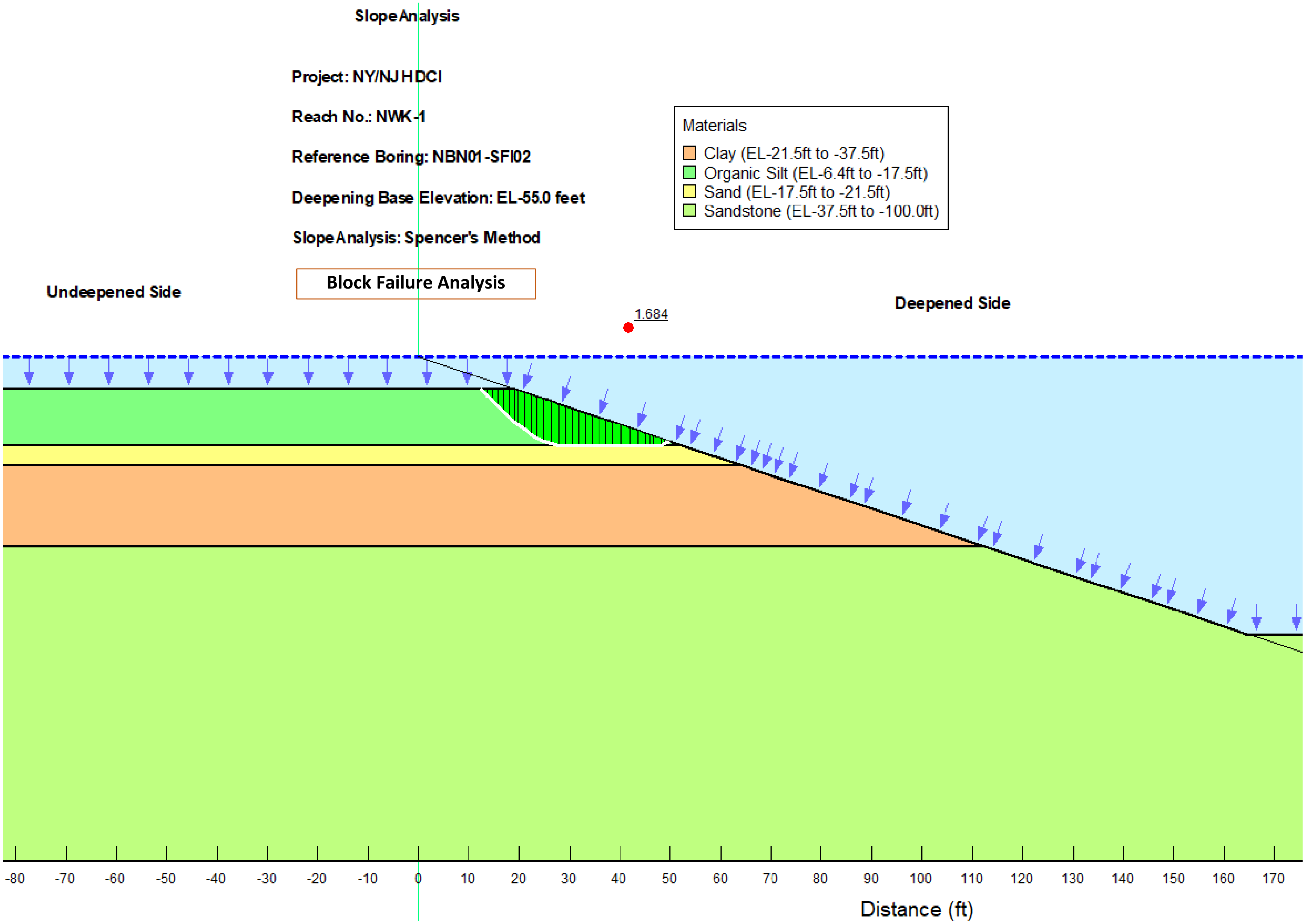
Reach No.: NWK-1

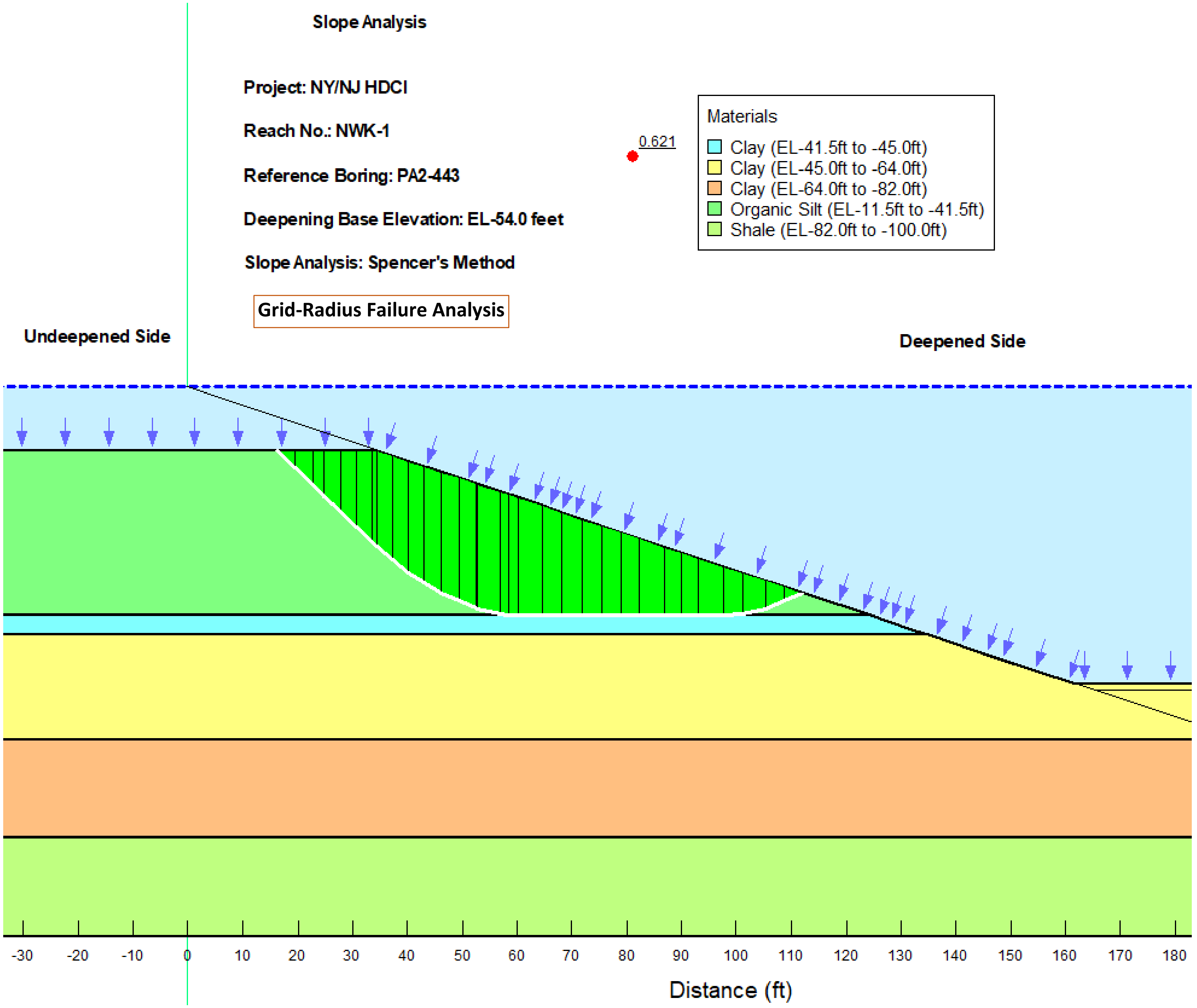
Reference Boring: NBN01-SFI02

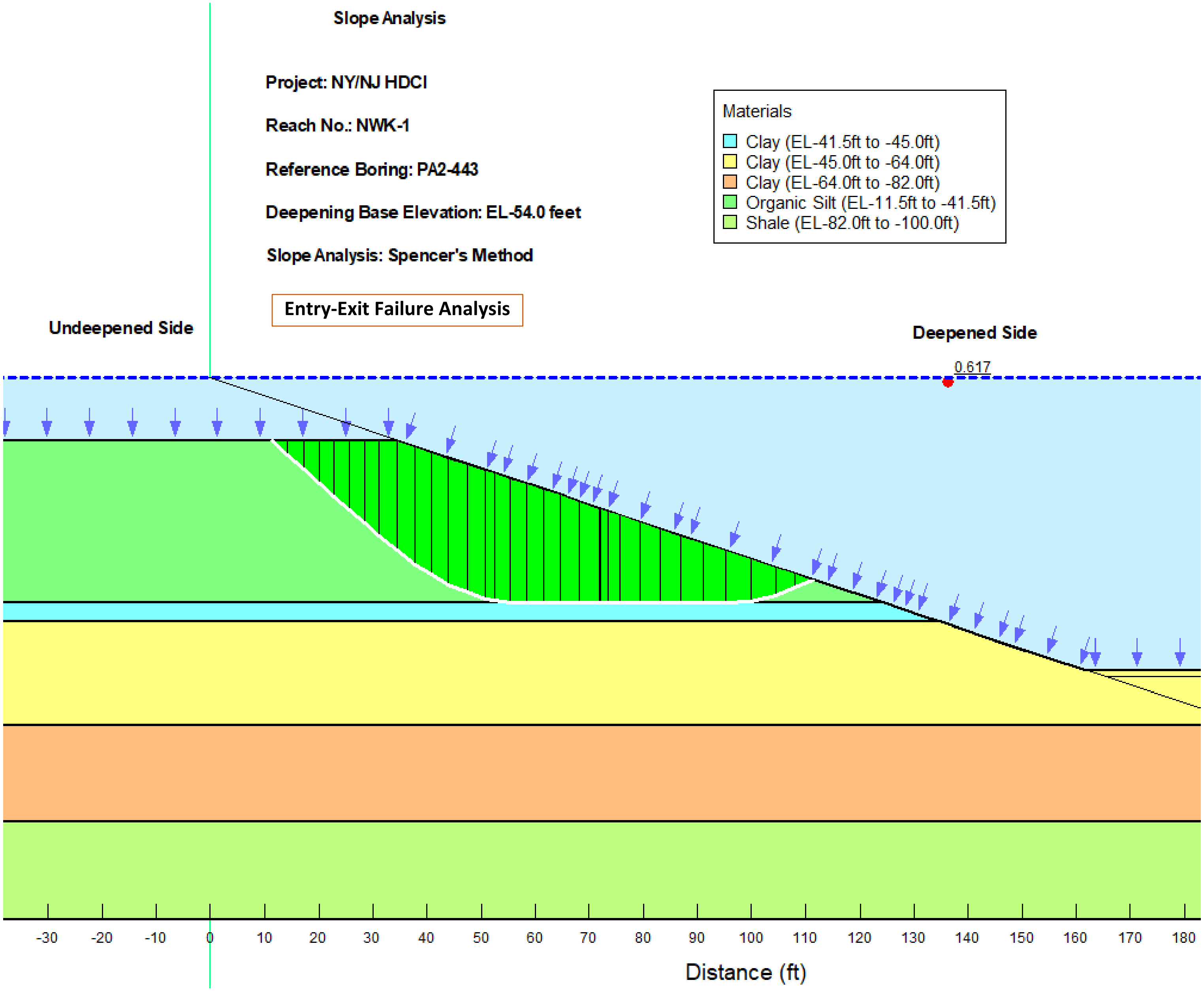
Deepening Base Elevation: EL-55.0 feet

Slope Analysis: Spencer's Method




Slope Analysis
Project: NY/NJ HDCI
Reach No.: NWK-1
Reference Boring: NBN01-SFI02
Deepening Base Elevation: EL-55.0 feet
Slope Analysis: Spencer's Method
Block Failure Analysis
Undeepened Side
Deepened Side
1.684
Materials
Clay (EL-21.5ft to -37.5ft)
Organic Silt (EL-6.4ft to -17.5ft)
Sand (EL-17.5ft to -21.5ft)
Sandstone (EL-37.5ft to -100.0ft)
-80
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
Distance (ft)


Slope Analysis
Project: NY/NJ HDCI
Reach No.: NWK-1
Reference Boring: PA2-443
Deepening Base Elevation: EL-54.0 feet
Slope Analysis: Spencer's Method
Grid-Radius Failure Analysis
0.621
Materials
Clay (EL-41.5ft to -45.0ft)
Clay (EL-45.0ft to -64.0ft)
Clay (EL-64.0ft to -82.0ft)
Organic Silt (EL-11.5ft to -41.5ft)
Shale (EL-82.0ft to -100.0ft)
Undeepened Side
Deepened Side
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
Distance (ft)



Slope Analysis

Project: NY/NJ HDCI

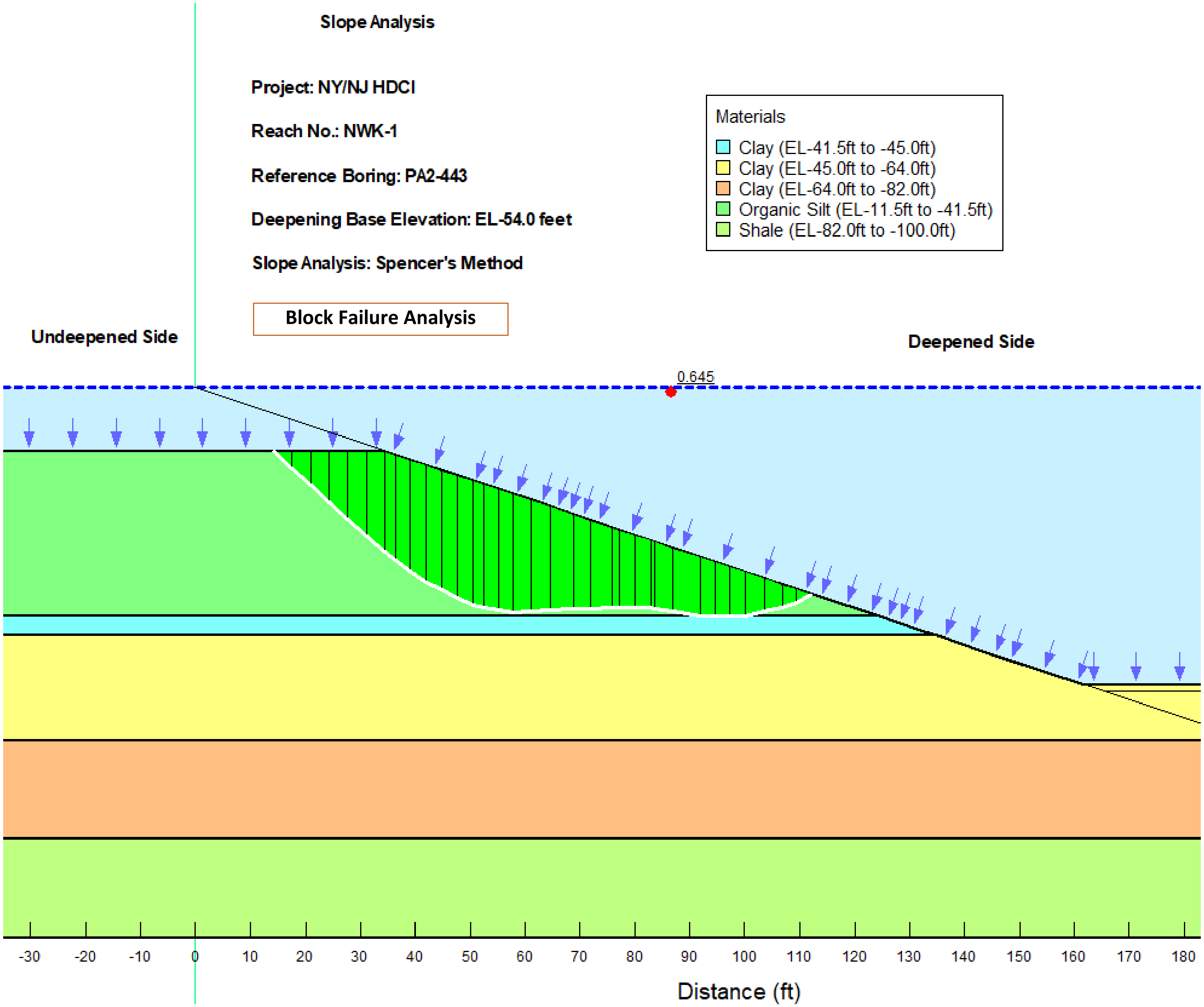
Reach No.: NWK-1

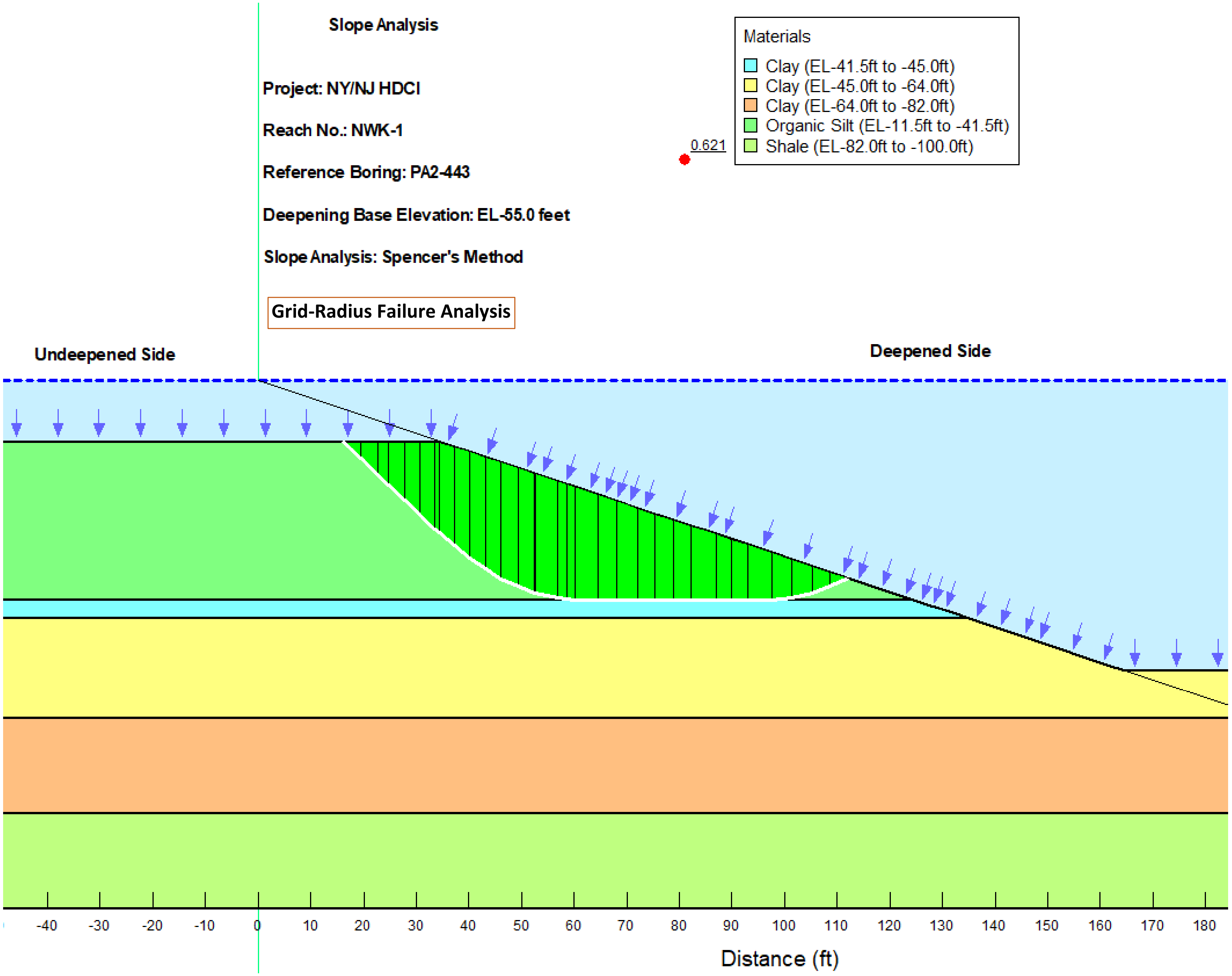
Reference Boring: PA2-443

Deepening Base Elevation: EL-54.0 feet

Slope Analysis: Spencer's Method

Entry-Exit Failure Analysis


Slope Analysis
Project: NY/NJ HDCI
Reach No.: NWK-1
Reference Boring: PA2-443
Deepening Base Elevation: EL-54.0 feet
Slope Analysis: Spencer's Method
Block Failure Analysis
Materials
Clay (EL-41.5ft to -45.0ft)
Clay (EL-45.0ft to -64.0ft)
Clay (EL-64.0ft to -82.0ft)
Organic Silt (EL-11.5ft to -41.5ft)
Shale (EL-82.0ft to -100.0ft)
Undeepened Side
Deepened Side
0.645
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
Distance (ft)



Slope Analysis

Project: NY/NJ HDCI

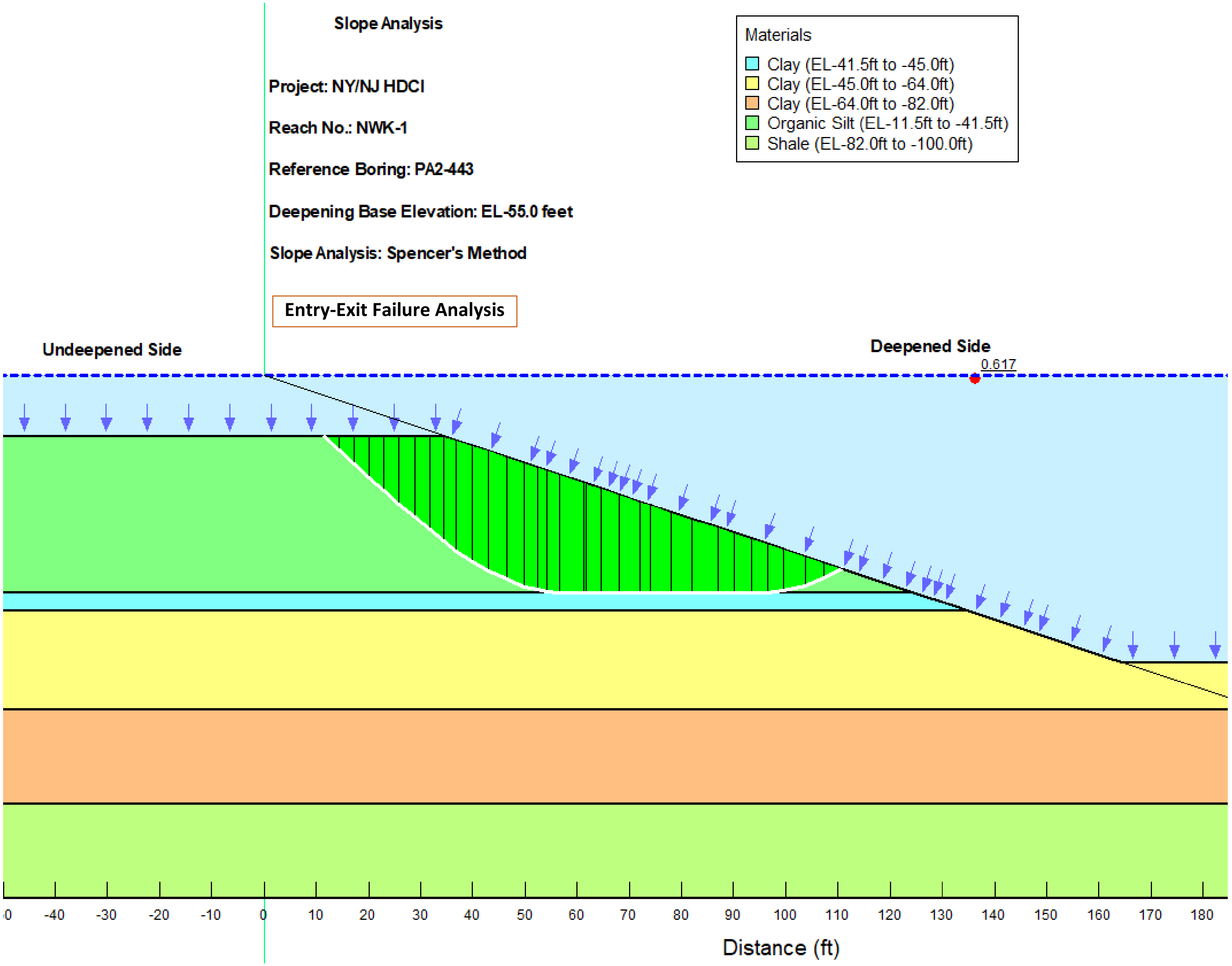
Reach No.: NWK-1

Reference Boring: PA2-443

Deepening Base Elevation: EL-55.0 feet

Slope Analysis: Spencer's Method

Grid-Radius Failure Analysis



Slope Analysis

Project: NY/NJ HDCI

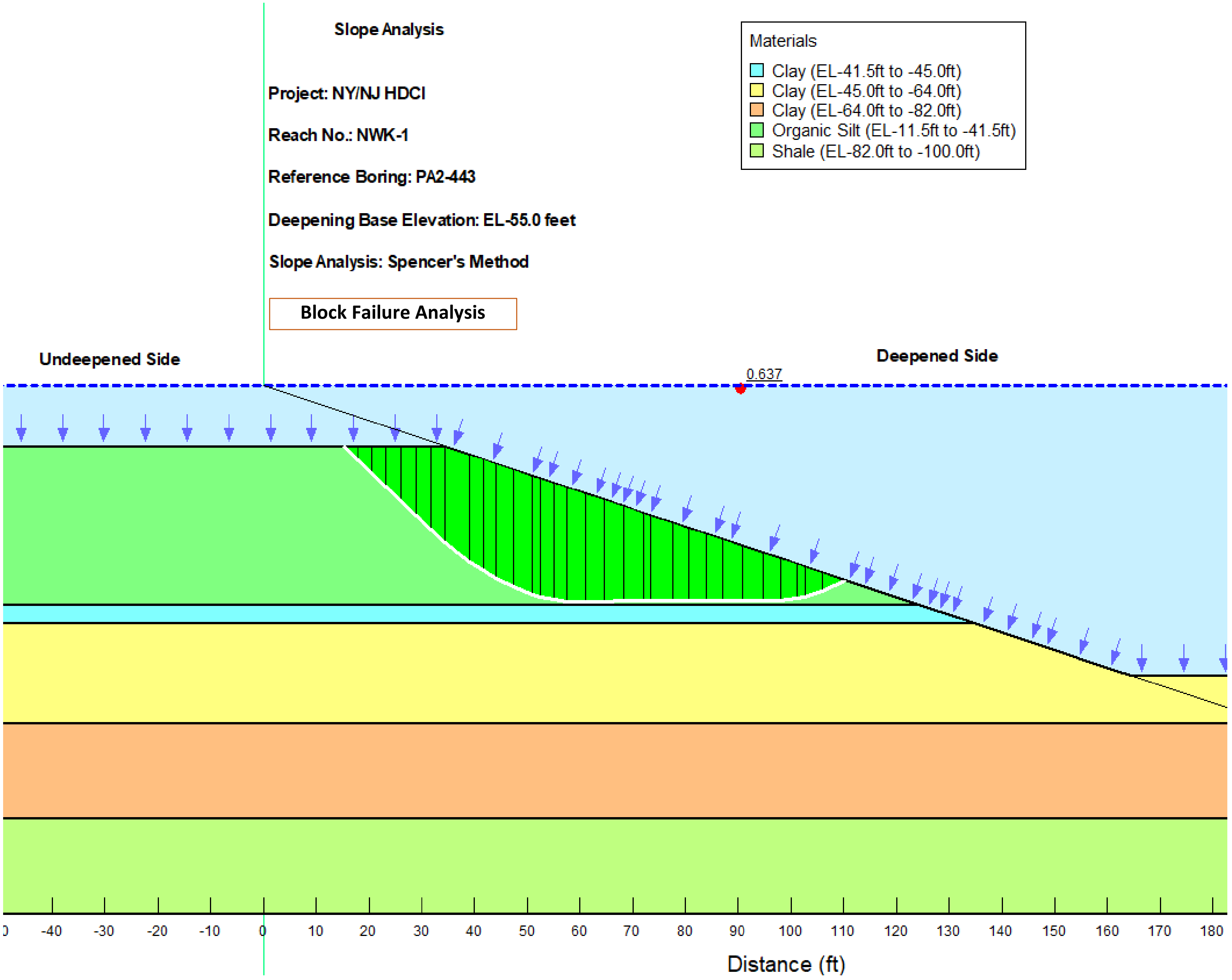
Reach No.: NWK-1

Reference Boring: PA2-443

Deepening Base Elevation: EL-55.0 feet

Slope Analysis: Spencer's Method

Entry-Exit Failure Analysis



Slope Analysis

Project: NY/NJ HDCI

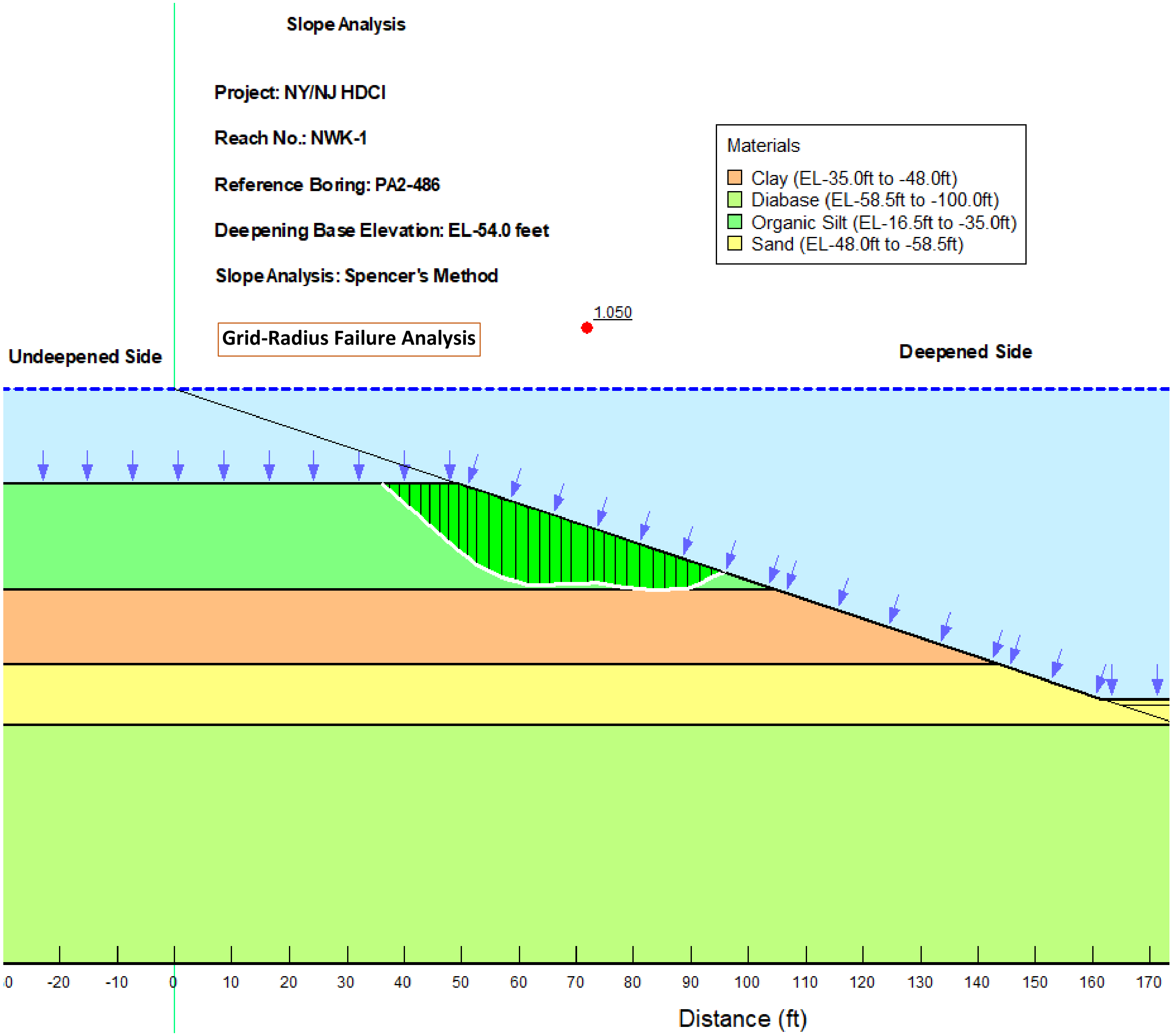
Reach No.: NWK-1

Reference Boring: PA2-443

Deepening Base Elevation: EL-55.0 feet

Slope Analysis: Spencer's Method

Block Failure Analysis



Slope Analysis

Project: NY/NJ HDCI

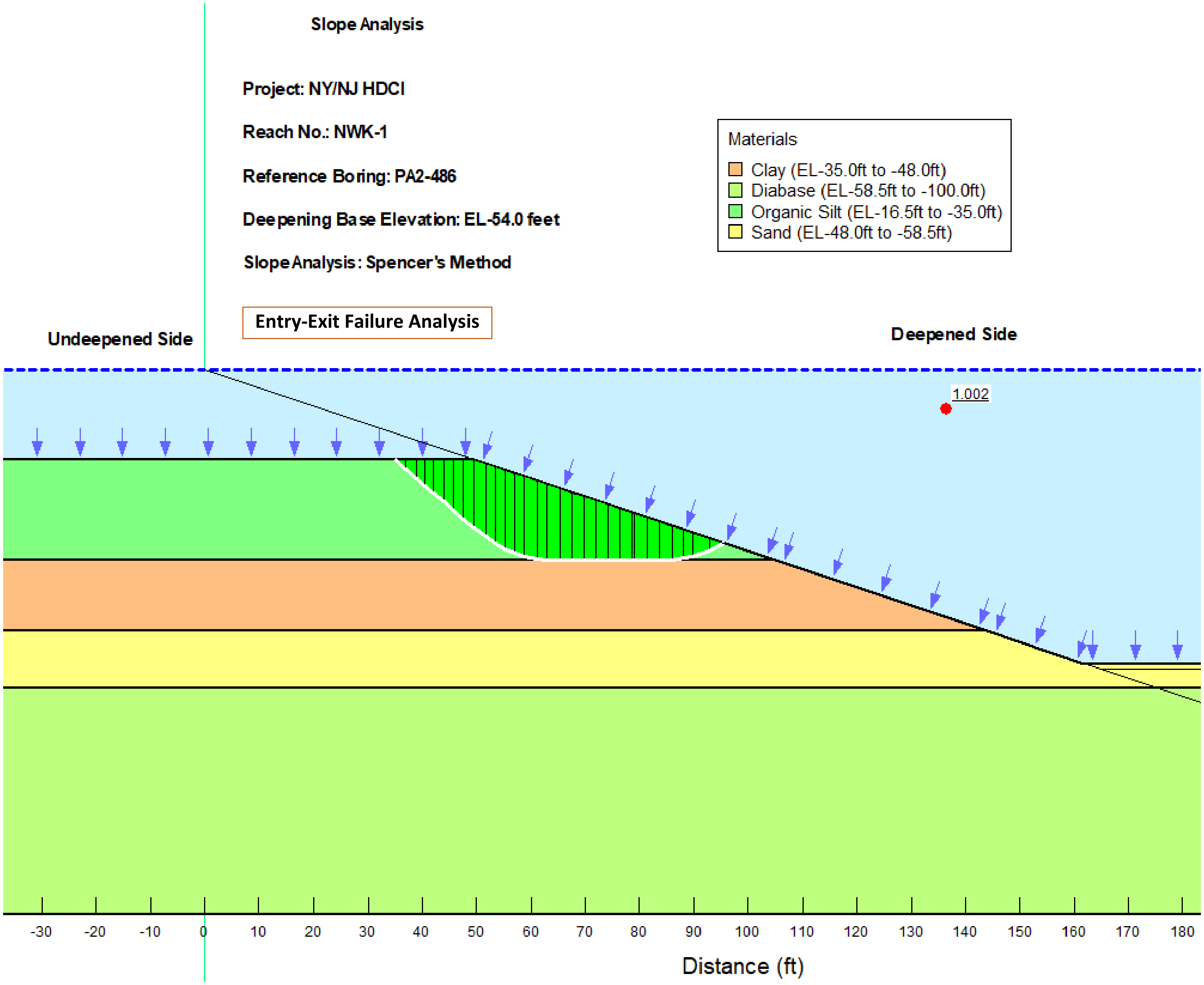
Reach No.: NWK-1

Reference Boring: PA2-486

Deepening Base Elevation: EL-54.0 feet

Slope Analysis: Spencer's Method

Grid-Radius Failure Analysis



Slope Analysis

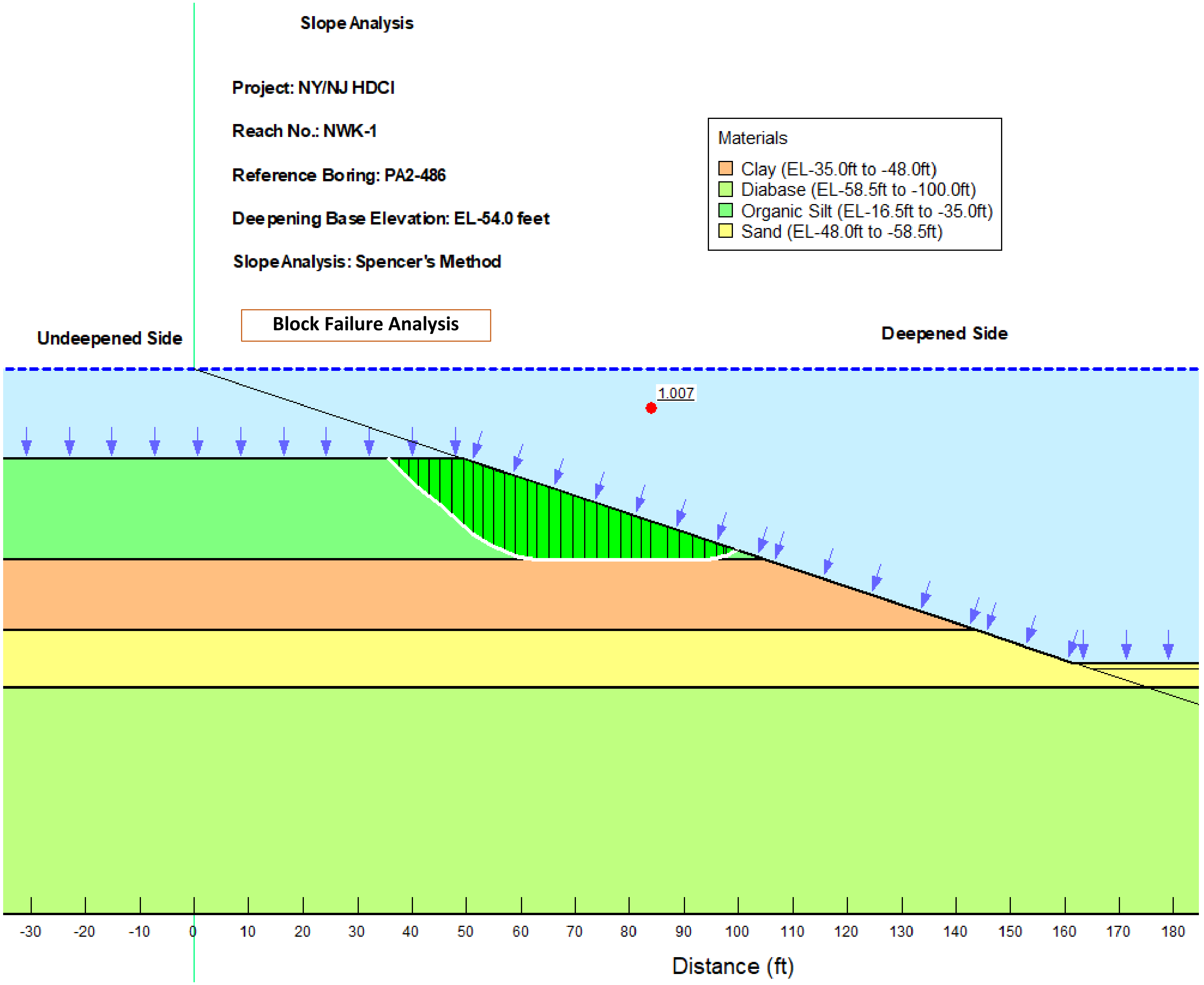
Project: NY/NJ HDCI

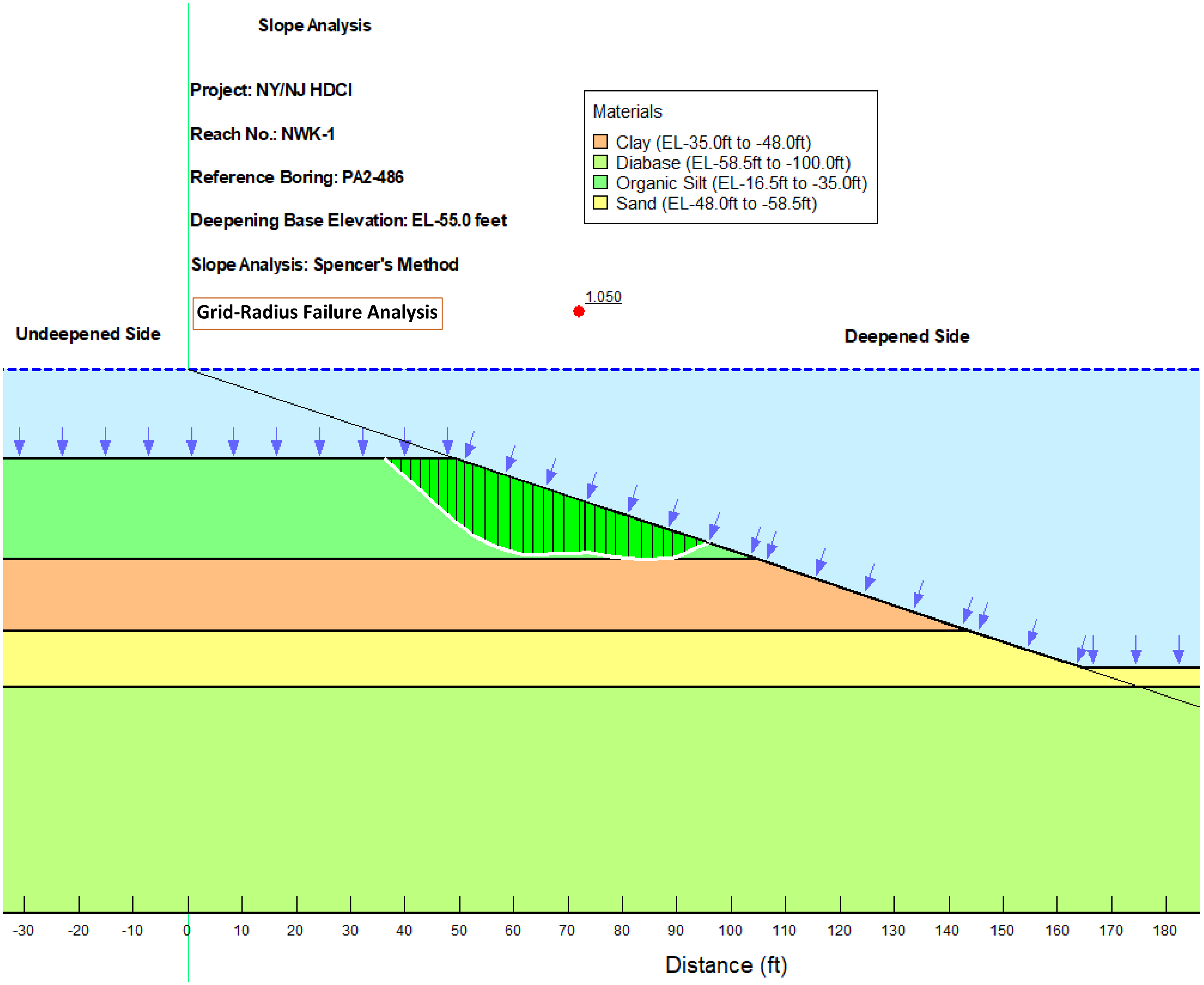
Reach No.: NWK-1

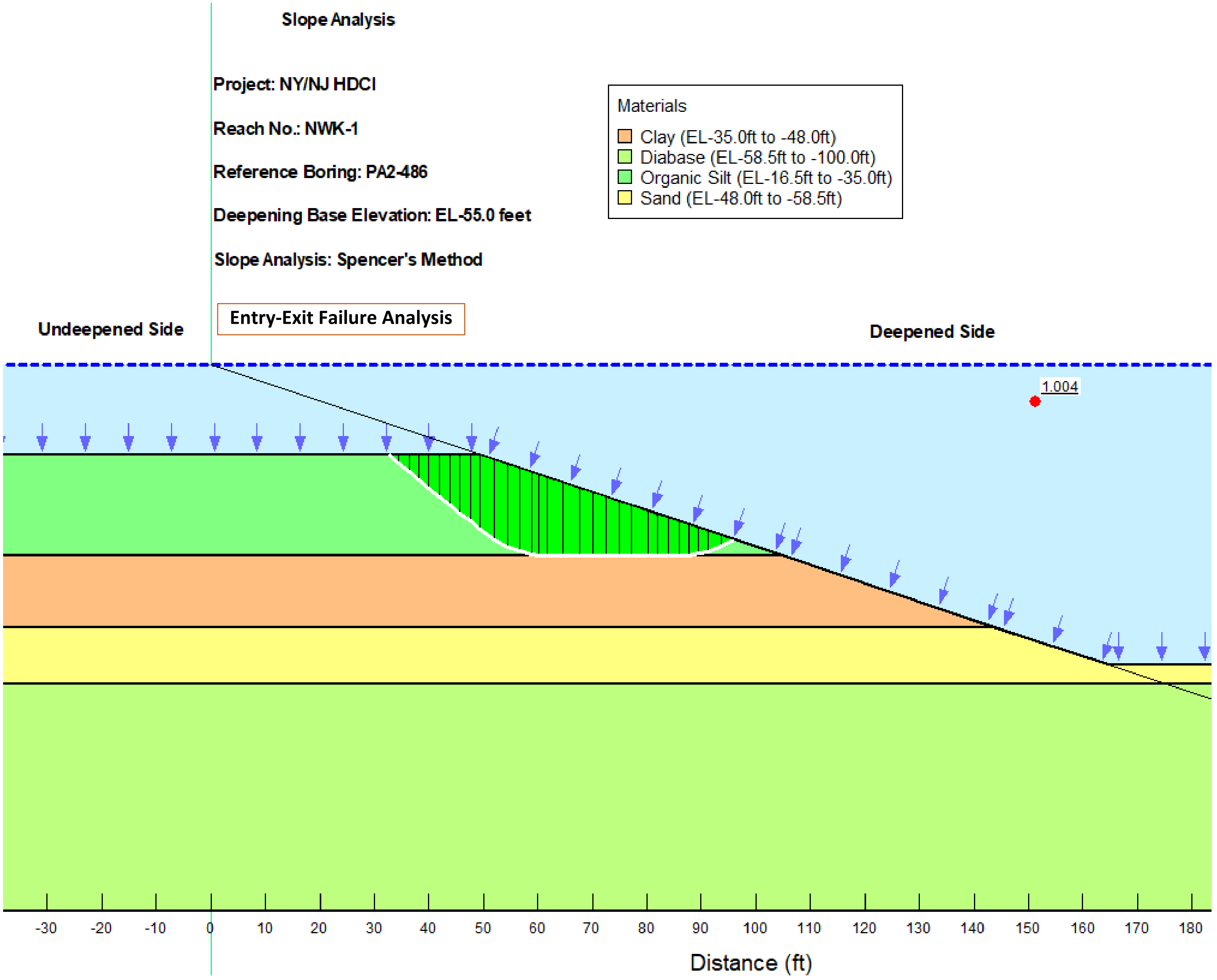
Reference Boring: PA2-486

Deepening Base Elevation: EL-54.0 feet

Slope Analysis: Spencer's Method


Slope Analysis
Project: NY/NJ HDCI
Reach No.: NWK-1
Reference Boring: PA2-486
Deepening Base Elevation: EL-54.0 feet
Slope Analysis: Spencer's Method
Block Failure Analysis
Materials
Clay (EL-35.0ft to -48.0ft)
Diabase (EL-58.5ft to -100.0ft)
Organic Silt (EL-16.5ft to -35.0ft)
Sand (EL-48.0ft to -58.5ft)
Undeepened Side
Deepened Side
1.007
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
Distance (ft)


Slope Analysis
Project: NY/NJ HDCI
Reach No.: NWK-1
Reference Boring: PA2-486
Deepening Base Elevation: EL-55.0 feet
Slope Analysis: Spencer's Method
Grid-Radius Failure Analysis
Materials
🟧 Clay (EL-35.0ft to -48.0ft)
🟩 Diabase (EL-58.5ft to -100.0ft)
🟩 Organic Silt (EL-16.5ft to -35.0ft)
🟨 Sand (EL-48.0ft to -58.5ft)
1.050
Undeepened Side
Deepened Side
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
Distance (ft)



Slope Analysis

Project: NY/NJ HDCI

Reach No.: NWK-1

Reference Boring: PA2-486

Deepening Base Elevation: EL-55.0 feet

Slope Analysis: Spencer's Method

Entry-Exit Failure Analysis

Slope Analysis

Project: NY/NJ HDCI

Reach No.: NWK-1

Reference Boring: PA2-486

Deepening Base Elevation: EL-55.0 feet

Slope Analysis: Spencer's Method

Block Failure Analysis

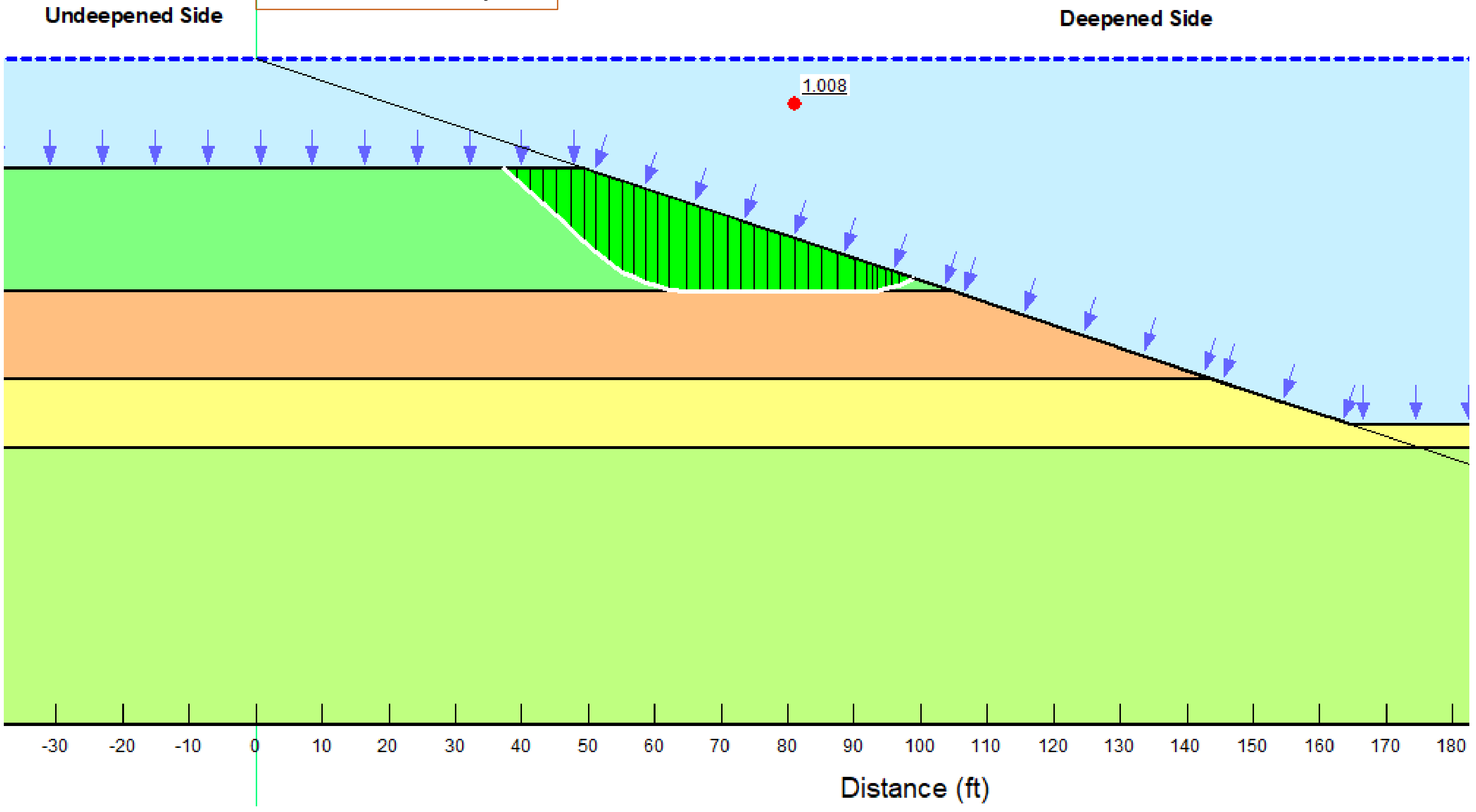
Materials

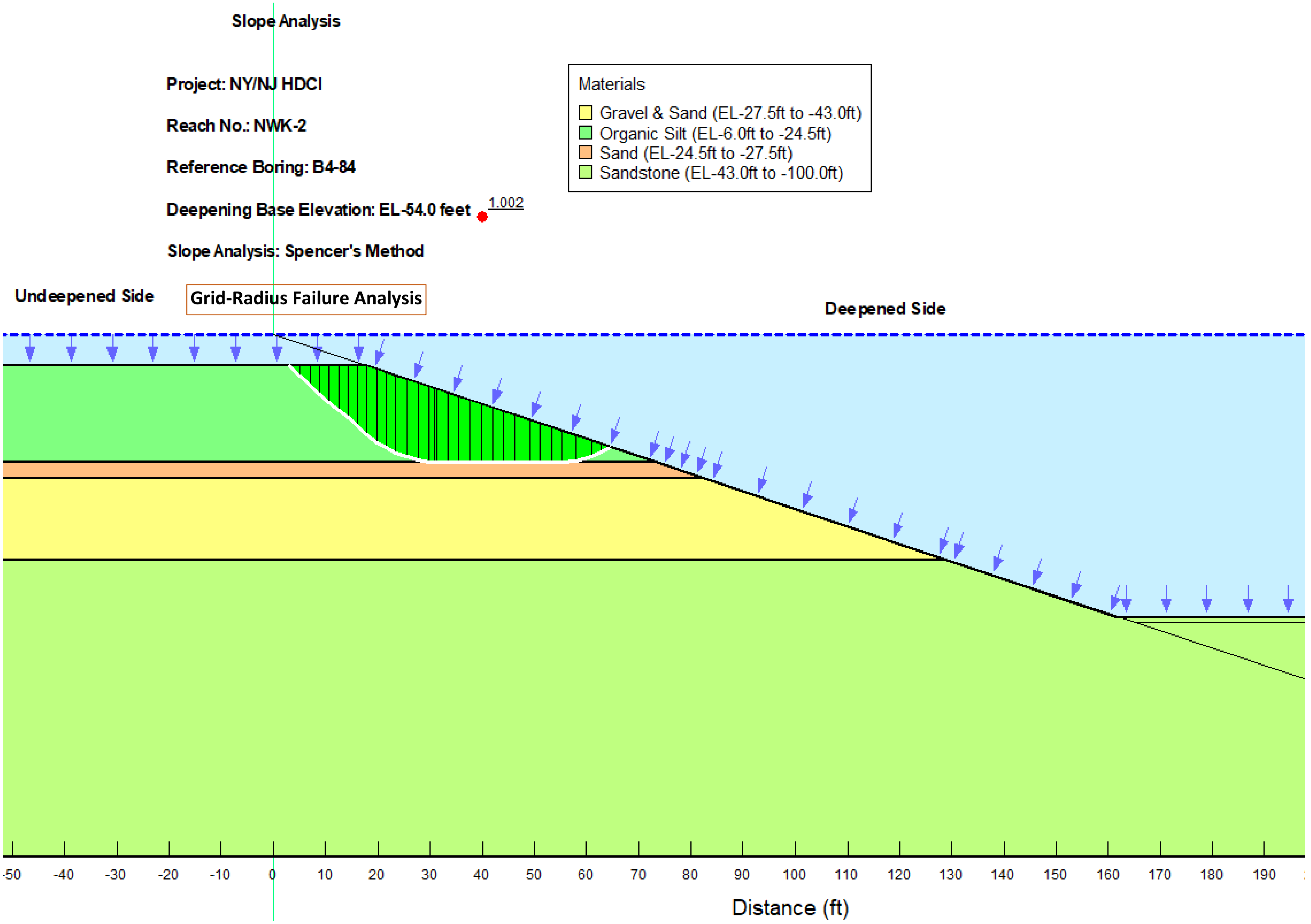
🟧 Clay (EL-35.0ft to -48.0ft)

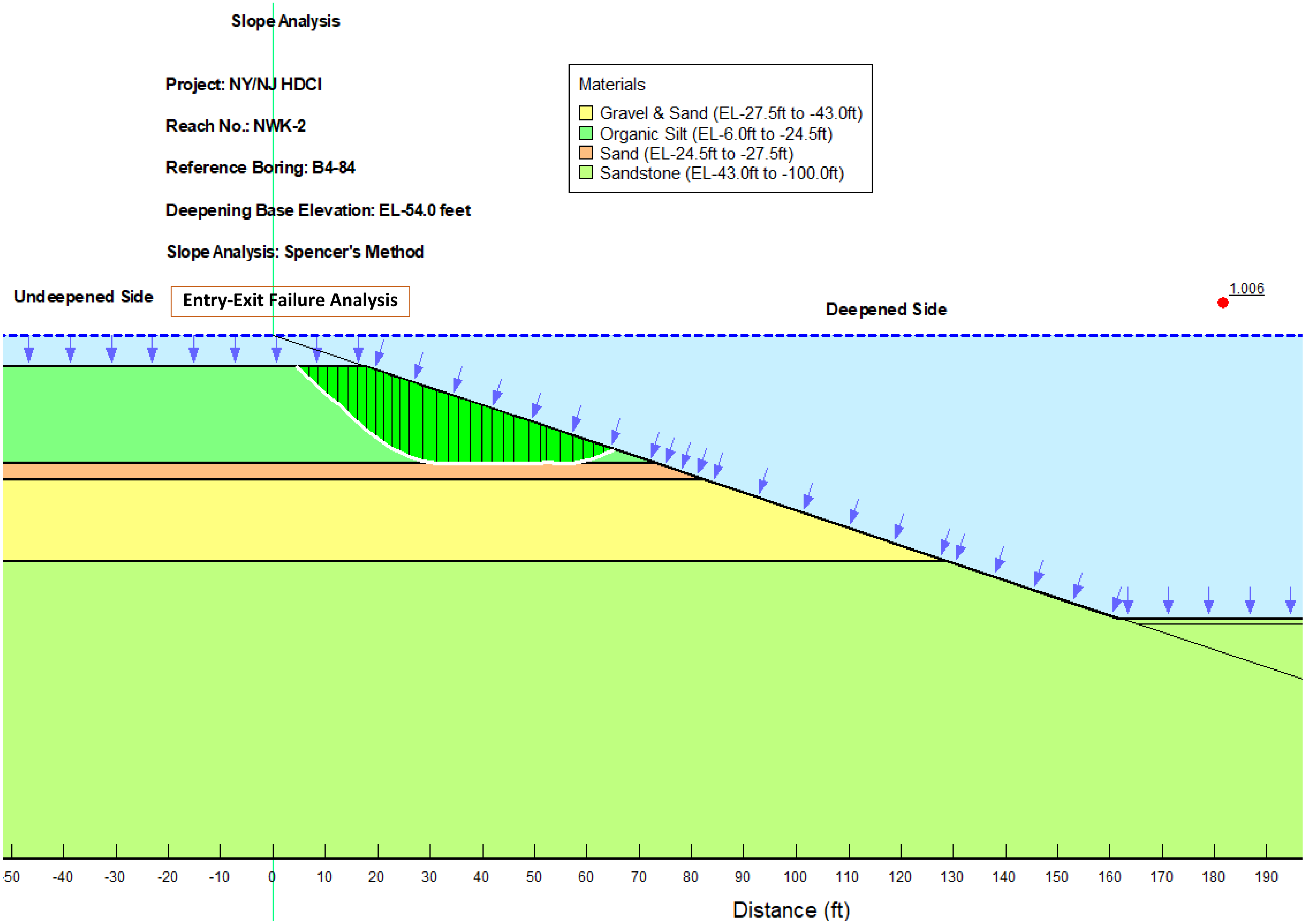
🟩 Diabase (EL-58.5ft to -100.0ft)

🟩 Organic Silt (EL-16.5ft to -35.0ft)

🟨 Sand (EL-48.0ft to -58.5ft)




Slope Analysis
Project: NY/NJ HDCI
Reach No.: NWK-2
Reference Boring: B4-84
Deepening Base Elevation: EL-54.0 feet
1.002
Slope Analysis: Spencer's Method
Materials
🟨 Gravel & Sand (EL-27.5ft to -43.0ft)
🟩 Organic Silt (EL-6.0ft to -24.5ft)
🟧 Sand (EL-24.5ft to -27.5ft)
🟩 Sandstone (EL-43.0ft to -100.0ft)
Undeepened Side
Grid-Radius Failure Analysis
Deepened Side
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
Distance (ft)


Slope Analysis
Project: NY/NJ HDCI
Reach No.: NWK-2
Reference Boring: B4-84
Deepening Base Elevation: EL-54.0 feet
Slope Analysis: Spencer's Method
Materials
🟨 Gravel & Sand (EL-27.5ft to -43.0ft)
🟩 Organic Silt (EL-6.0ft to -24.5ft)
🟧 Sand (EL-24.5ft to -27.5ft)
🟩 Sandstone (EL-43.0ft to -100.0ft)
Undeepened Side
Entry-Exit Failure Analysis
Deepened Side
1.006
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
Distance (ft)

Slope Analysis

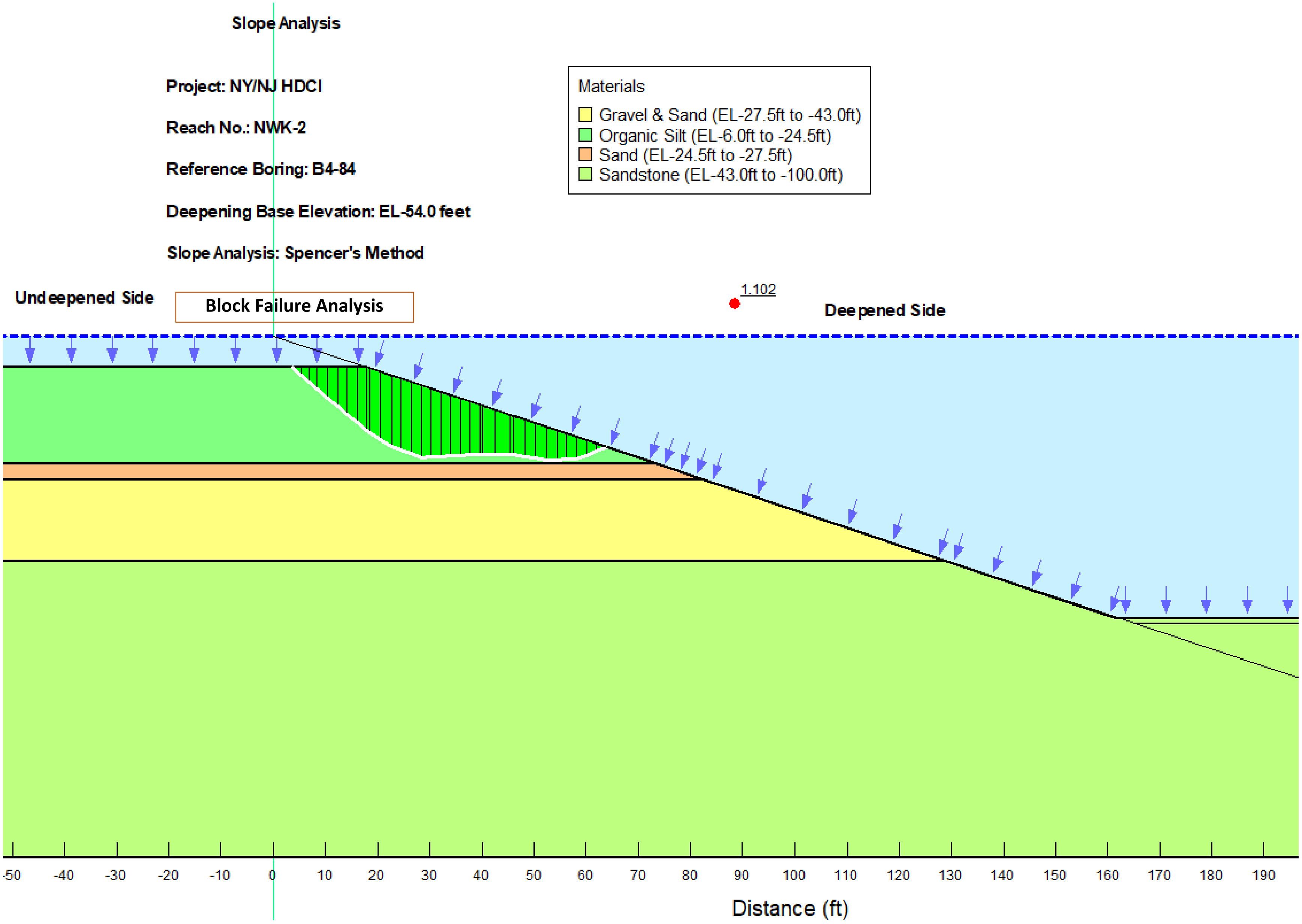
Project: NY/NJ HDCI

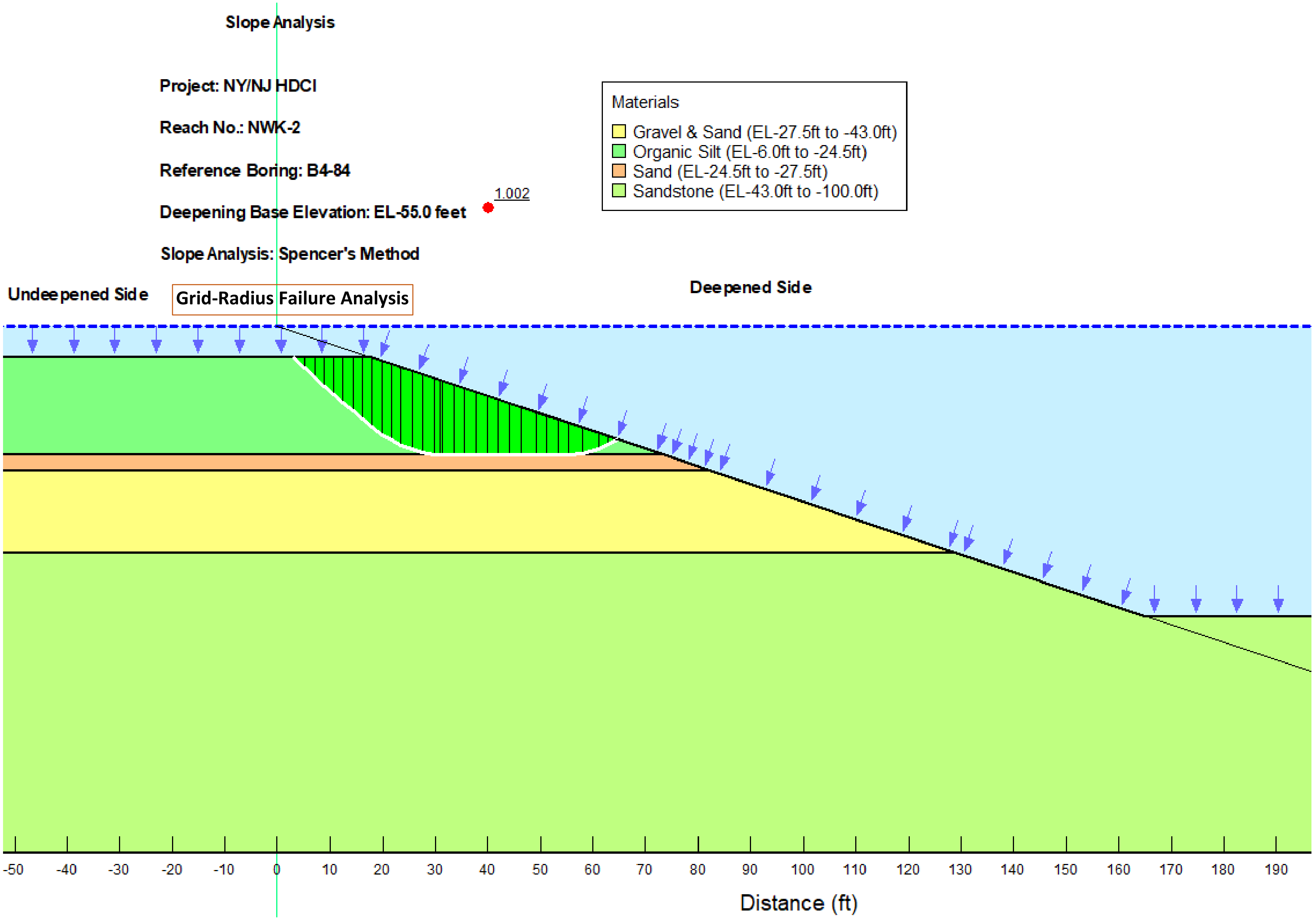
Reach No.: NWK-2

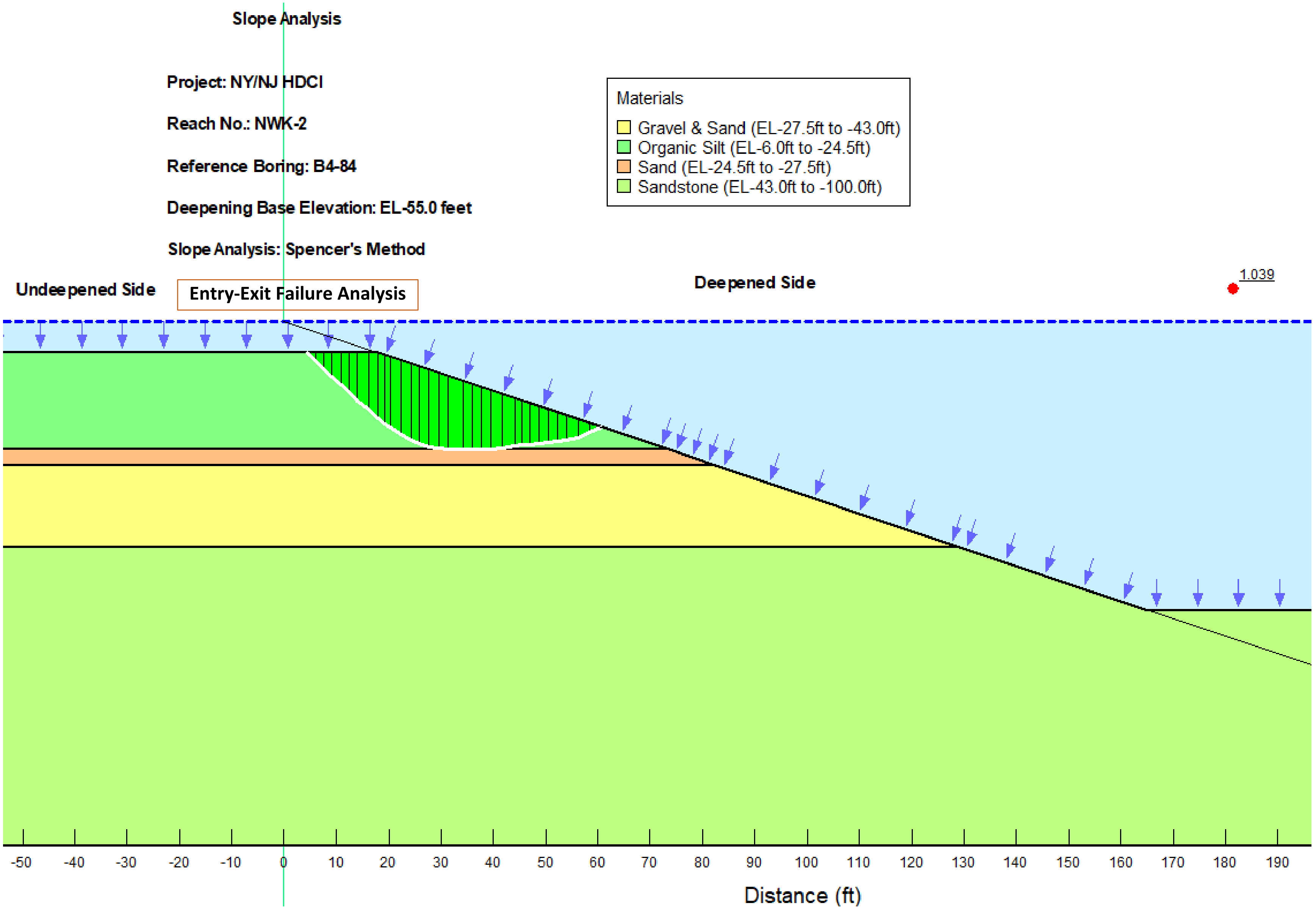
Reference Boring: B4-84

Deepening Base Elevation: EL-54.0 feet

Slope Analysis: Spencer's Method




Slope Analysis
Project: NY/NJ HDCI
Reach No.: NWK-2
Reference Boring: B4-84
Deepening Base Elevation: EL-55.0 feet
Slope Analysis: Spencer's Method
1.002
Materials
🟨 Gravel & Sand (EL-27.5ft to -43.0ft)
🟩 Organic Silt (EL-6.0ft to -24.5ft)
🟧 Sand (EL-24.5ft to -27.5ft)
🟩 Sandstone (EL-43.0ft to -100.0ft)
Undeepened Side
Grid-Radius Failure Analysis
Deepened Side
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
Distance (ft)



Slope Analysis

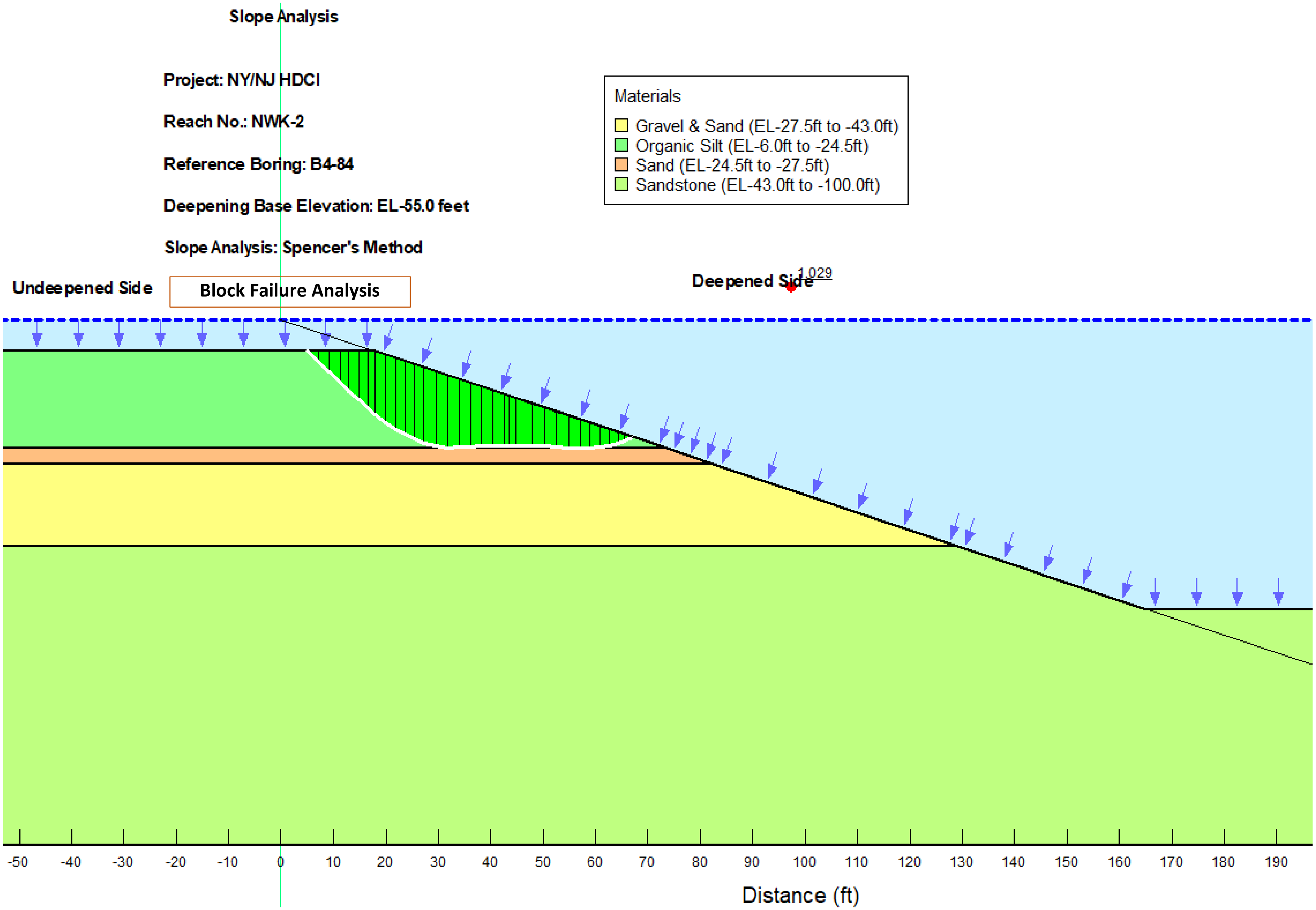
Project: NY/NJ HDCI

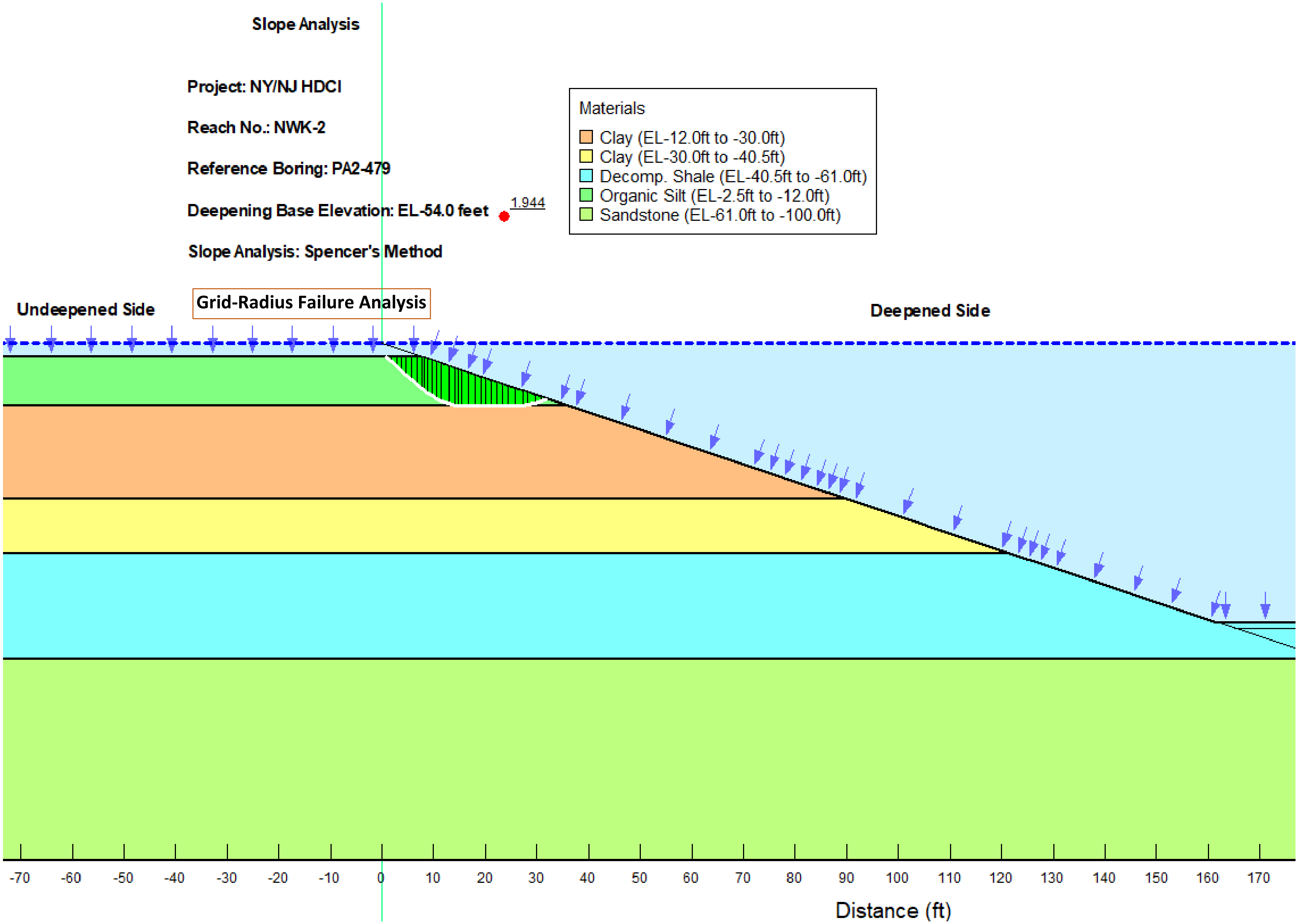
Reach No.: NWK-2

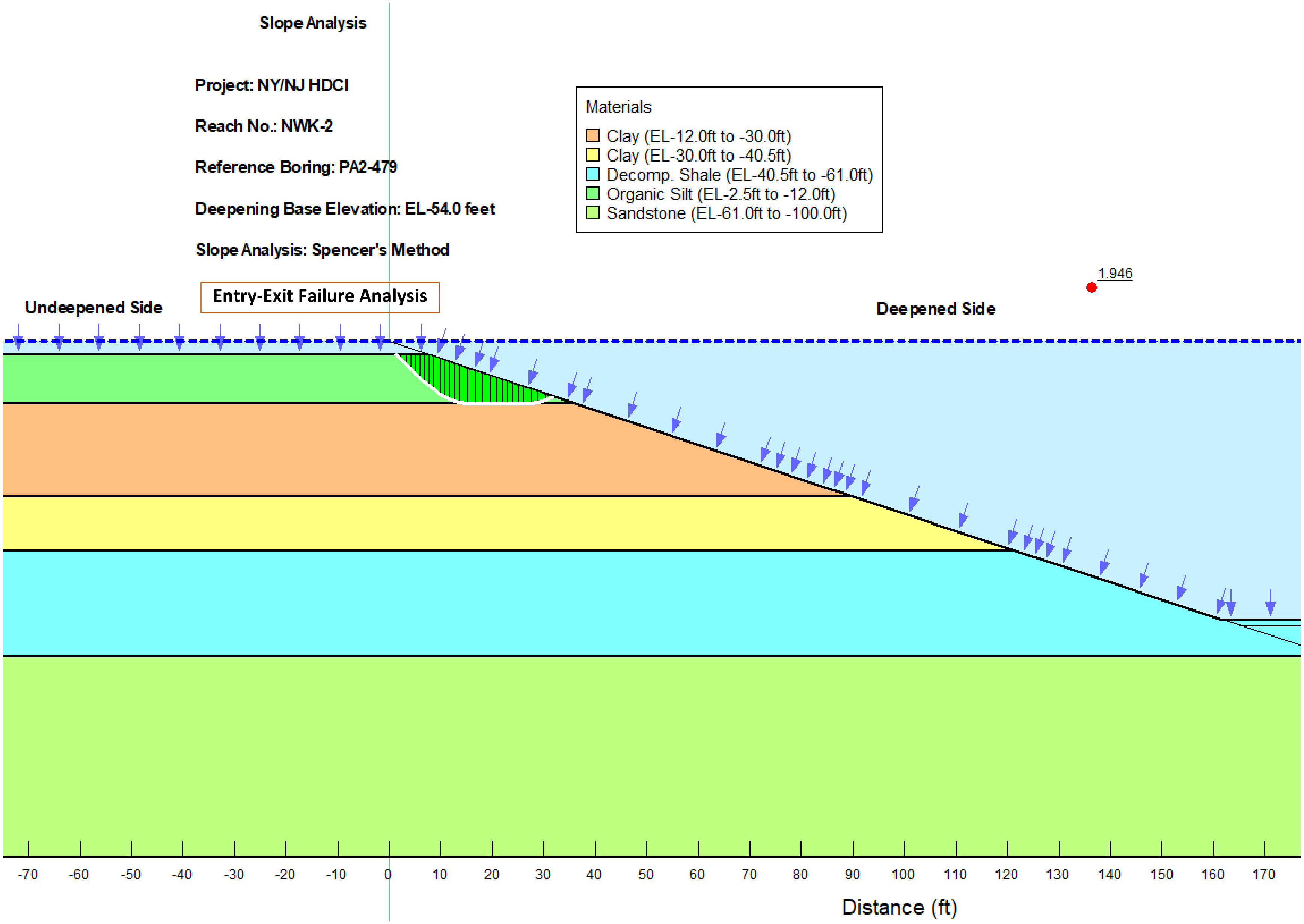
Reference Boring: B4-84

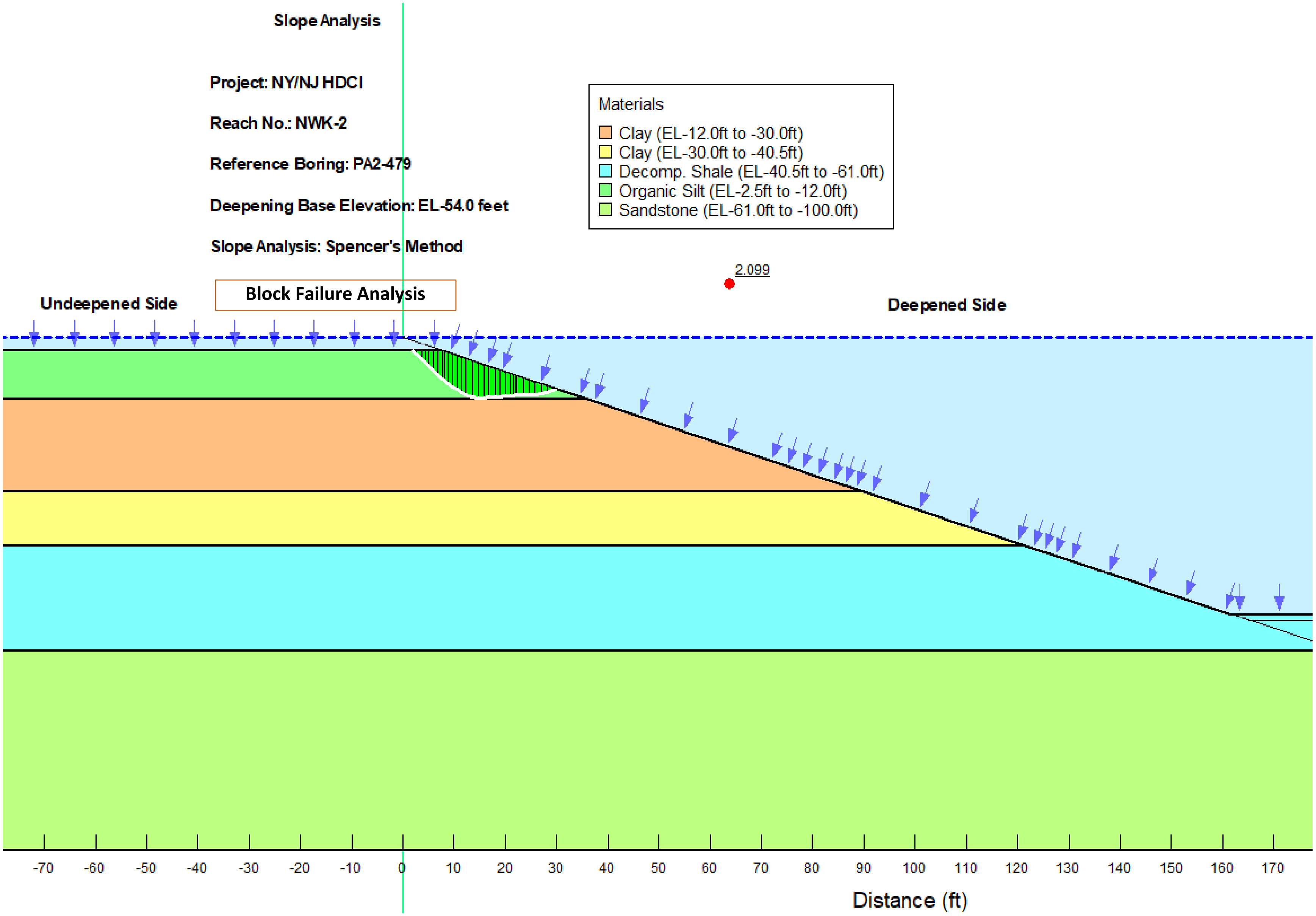
Deepening Base Elevation: EL-55.0 feet

Slope Analysis: Spencer's Method


Slope Analysis
Project: NY/NJ HDCI
Reach No.: NWK-2
Reference Boring: B4-84
Deepening Base Elevation: EL-55.0 feet
Slope Analysis: Spencer's Method
Materials
Gravel & Sand (EL-27.5ft to -43.0ft)
Organic Silt (EL-6.0ft to -24.5ft)
Sand (EL-24.5ft to -27.5ft)
Sandstone (EL-43.0ft to -100.0ft)
Undeepened Side
Block Failure Analysis
Deepened Side
1.029
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
Distance (ft)


Slope Analysis
Project: NY/NJ HDCI
Reach No.: NWK-2
Reference Boring: PA2-479
Deepening Base Elevation: EL-54.0 feet
1.944
Slope Analysis: Spencer's Method
Materials
🟧 Clay (EL-12.0ft to -30.0ft)
🟨 Clay (EL-30.0ft to -40.5ft)
🟦 Decomp. Shale (EL-40.5ft to -61.0ft)
🟩 Organic Silt (EL-2.5ft to -12.0ft)
🟩 Sandstone (EL-61.0ft to -100.0ft)
Grid-Radius Failure Analysis
Undeepened Side
Deepened Side
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
Distance (ft)


Slope Analysis
Project: NY/NJ HDCI
Reach No.: NWK-2
Reference Boring: PA2-479
Deepening Base Elevation: EL-54.0 feet
Slope Analysis: Spencer's Method
Entry-Exit Failure Analysis
Materials
🟧 Clay (EL-12.0ft to -30.0ft)
🟨 Clay (EL-30.0ft to -40.5ft)
🟦 Decomp. Shale (EL-40.5ft to -61.0ft)
🟩 Organic Silt (EL-2.5ft to -12.0ft)
🟩 Sandstone (EL-61.0ft to -100.0ft)
1.946
Undeepened Side
Deepened Side
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
Distance (ft)



Slope Analysis

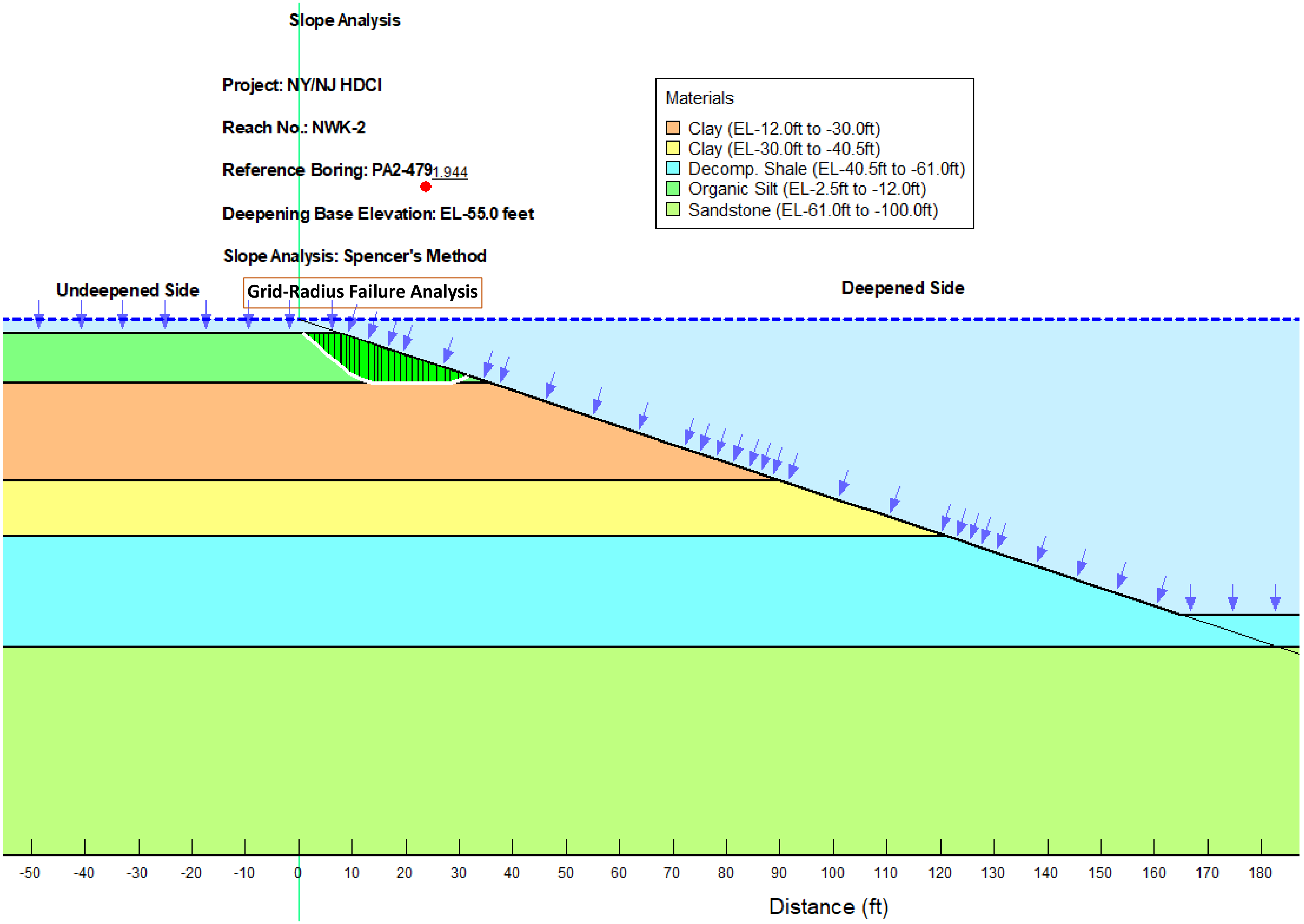
Project: NY/NJ HDCI

Reach No.: NWK-2

Reference Boring: PA2-479

Deepening Base Elevation: EL-54.0 feet

Slope Analysis: Spencer's Method



Slope Analysis

Project: NY/NJ HDCI

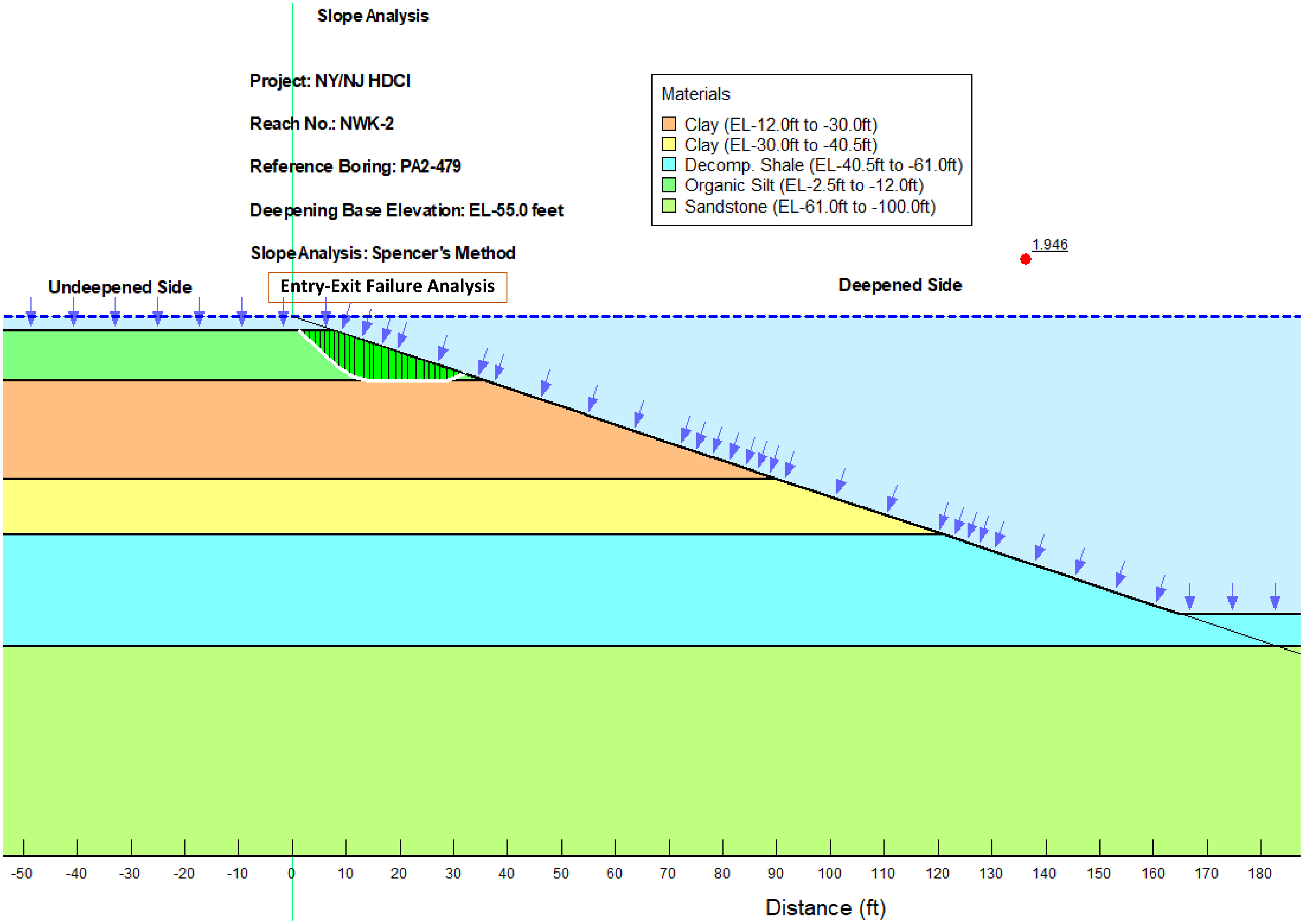
Reach No.: NWK-2

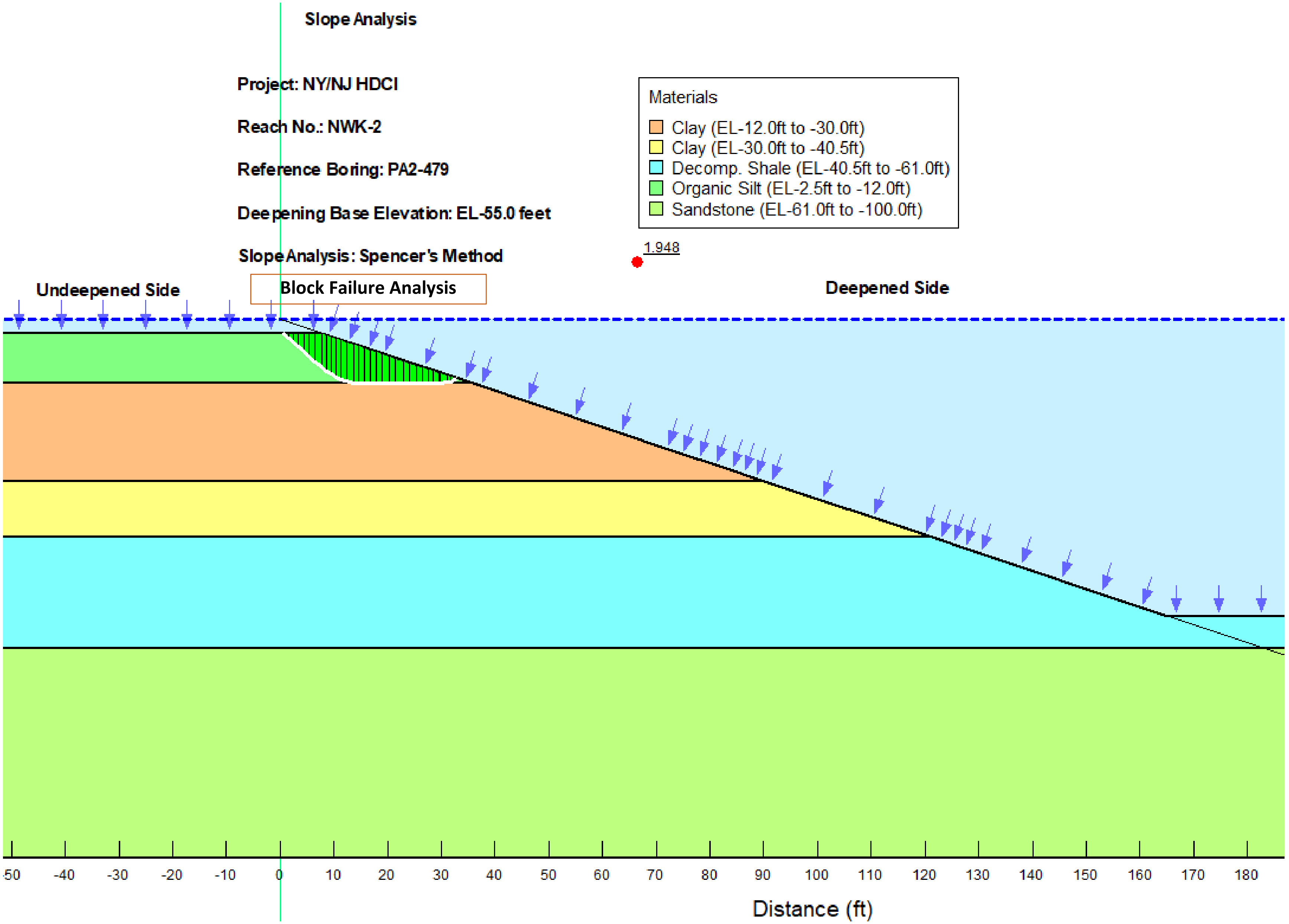
Reference Boring: PA2-479

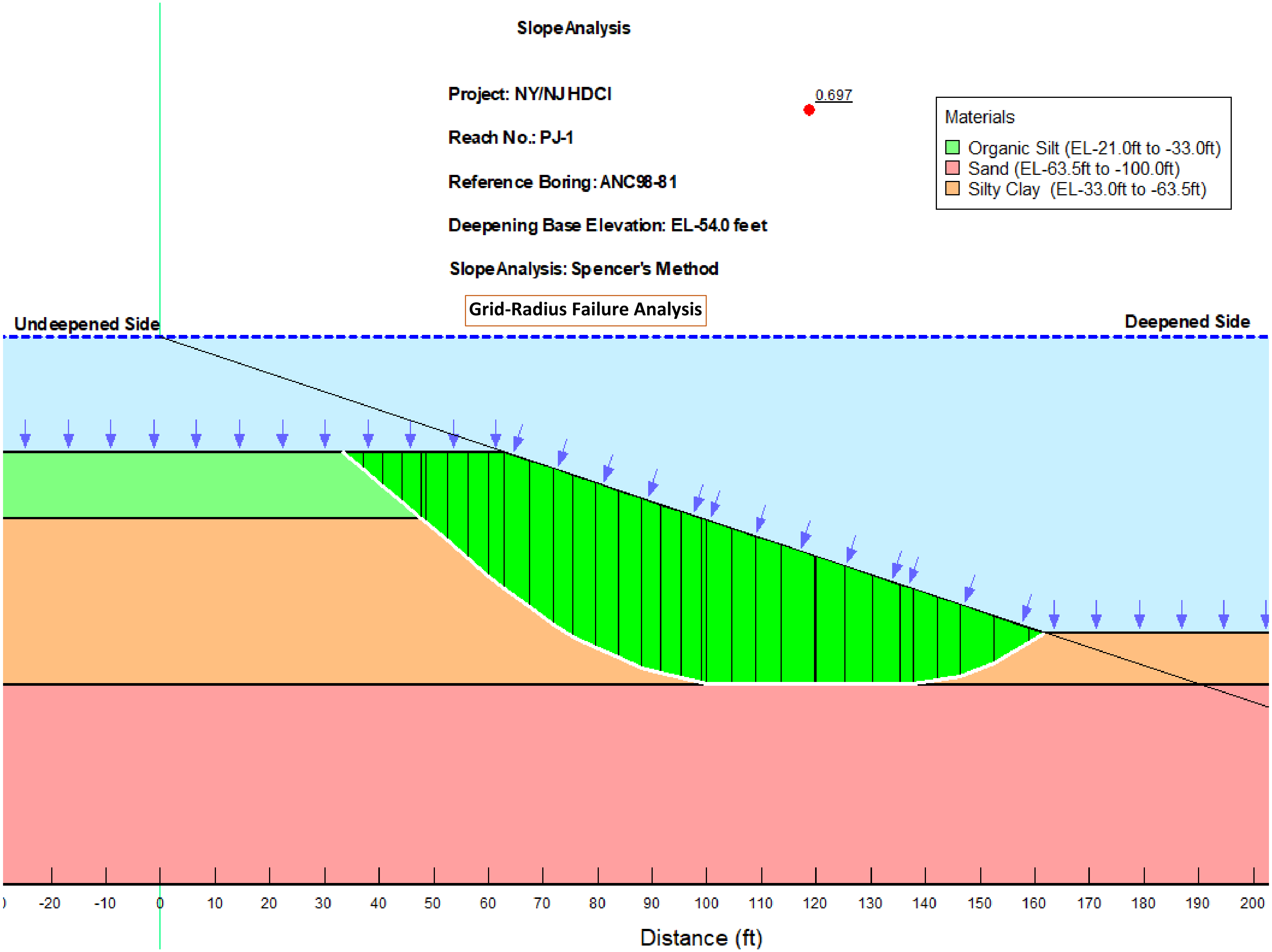
Deepening Base Elevation: EL-55.0 feet

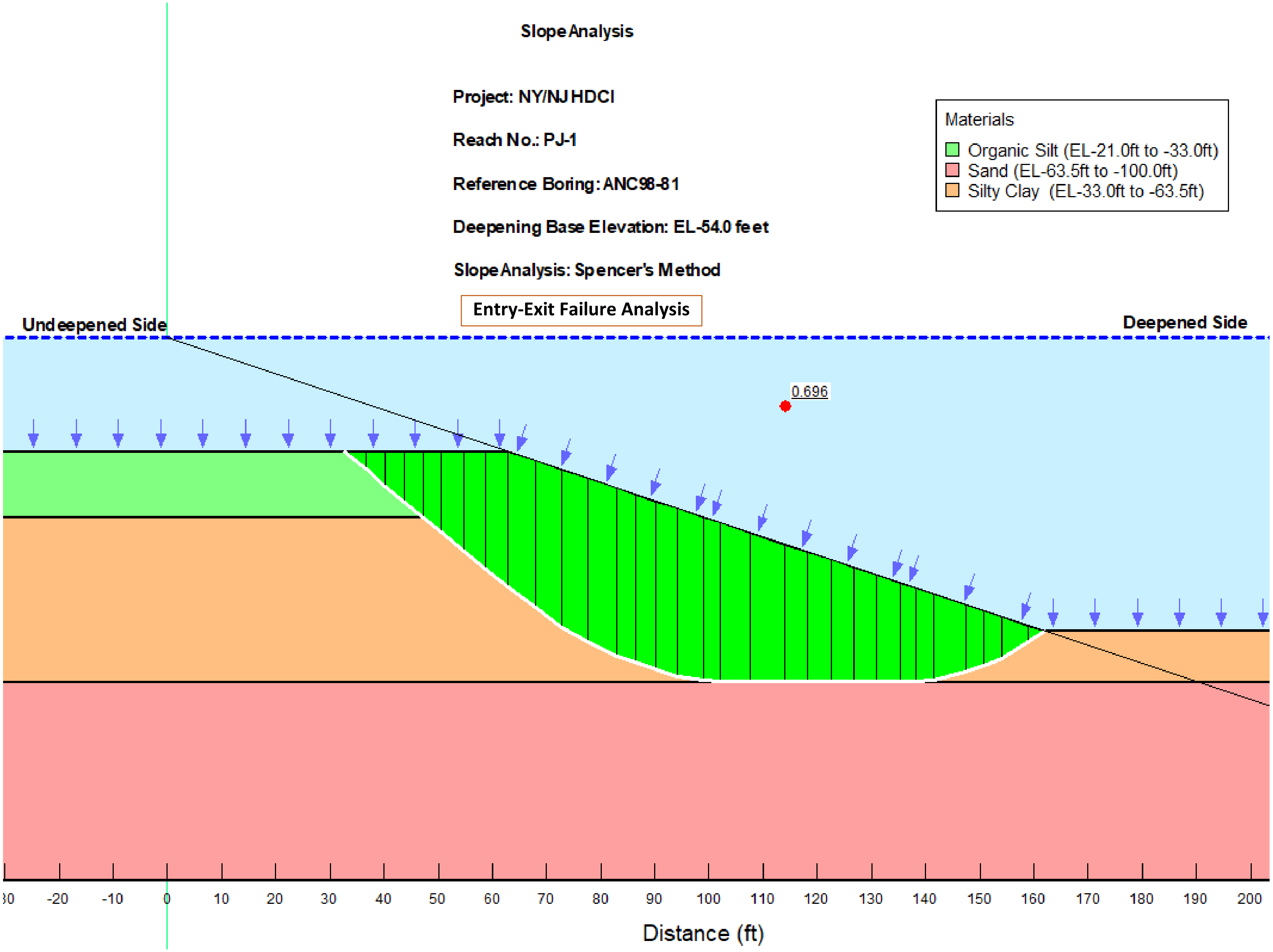
Slope Analysis: Spencer's Method

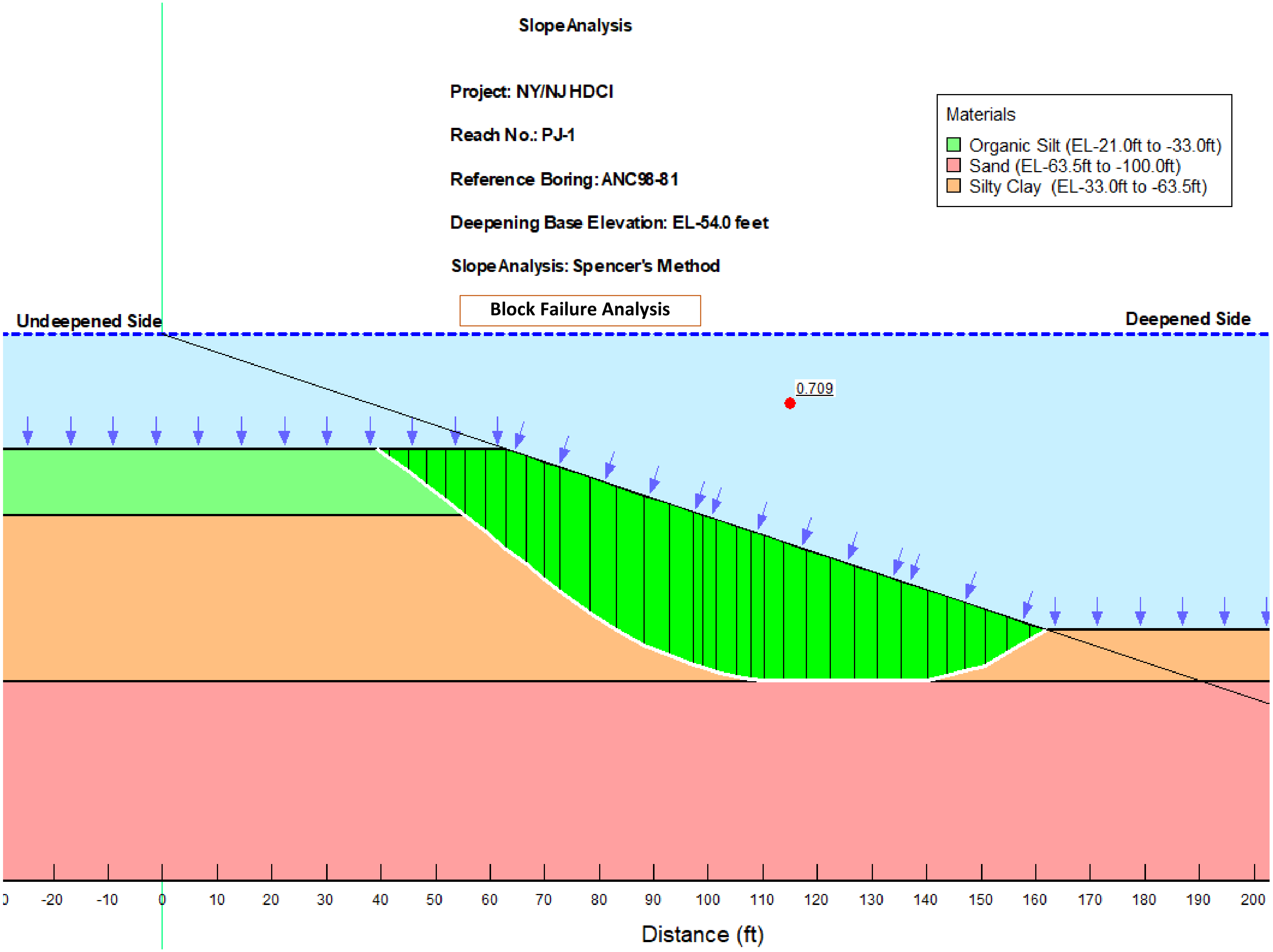
Grid-Radius Failure Analysis


Slope Analysis
Project: NY/NJ HDCI
Reach No.: NWK-2
Reference Boring: PA2-479
Deepening Base Elevation: EL-55.0 feet
Slope Analysis: Spencer's Method
Entry-Exit Failure Analysis
Undeepened Side
Deepened Side
Materials
Clay (EL-12.0ft to -30.0ft)
Clay (EL-30.0ft to -40.5ft)
Decomp. Shale (EL-40.5ft to -61.0ft)
Organic Silt (EL-2.5ft to -12.0ft)
Sandstone (EL-61.0ft to -100.0ft)
1.946
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
Distance (ft)


Slope Analysis
Project: NY/NJ HDCI
Reach No.: NWK-2
Reference Boring: PA2-479
Deepening Base Elevation: EL-55.0 feet
Slope Analysis: Spencer's Method
Block Failure Analysis
Materials
Clay (EL-12.0ft to -30.0ft)
Clay (EL-30.0ft to -40.5ft)
Decomp. Shale (EL-40.5ft to -61.0ft)
Organic Silt (EL-2.5ft to -12.0ft)
Sandstone (EL-61.0ft to -100.0ft)
1.948
Undeepened Side
Deepened Side
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
Distance (ft)


Slope Analysis
Project: NY/NJ HDCI
Reach No.: PJ-1
Reference Boring: ANC98-81
Deepening Base Elevation: EL-54.0 feet
Slope Analysis: Spencer's Method
Grid-Radius Failure Analysis
0.697
Materials
🟩 Organic Silt (EL-21.0ft to -33.0ft)
🟥 Sand (EL-63.5ft to -100.0ft)
🟧 Silty Clay (EL-33.0ft to -63.5ft)
Undeepened Side
Deepened Side
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance (ft)


Slope Analysis
Project: NY/NJ HDCI
Reach No.: PJ-1
Reference Boring: ANC98-81
Deepening Base Elevation: EL-54.0 feet
Slope Analysis: Spencer's Method
Entry-Exit Failure Analysis
Materials
🟩 Organic Silt (EL-21.0ft to -33.0ft)
🟥 Sand (EL-63.5ft to -100.0ft)
🟧 Silty Clay (EL-33.0ft to -63.5ft)
Undeepened Side
Deepened Side
0.696
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance (ft)



Slope Analysis

Project: NY/NJ HDCI

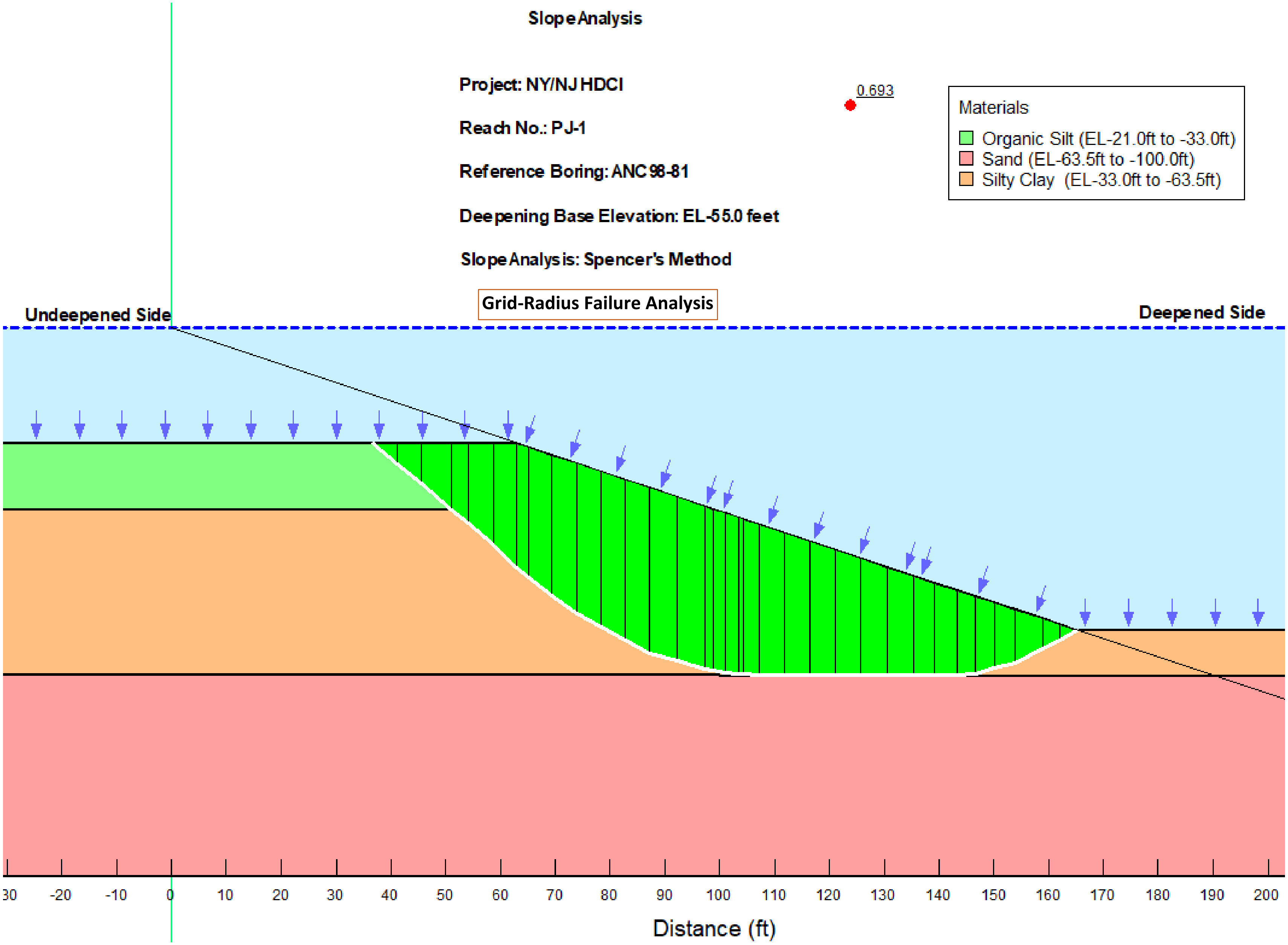
Reach No.: PJ-1

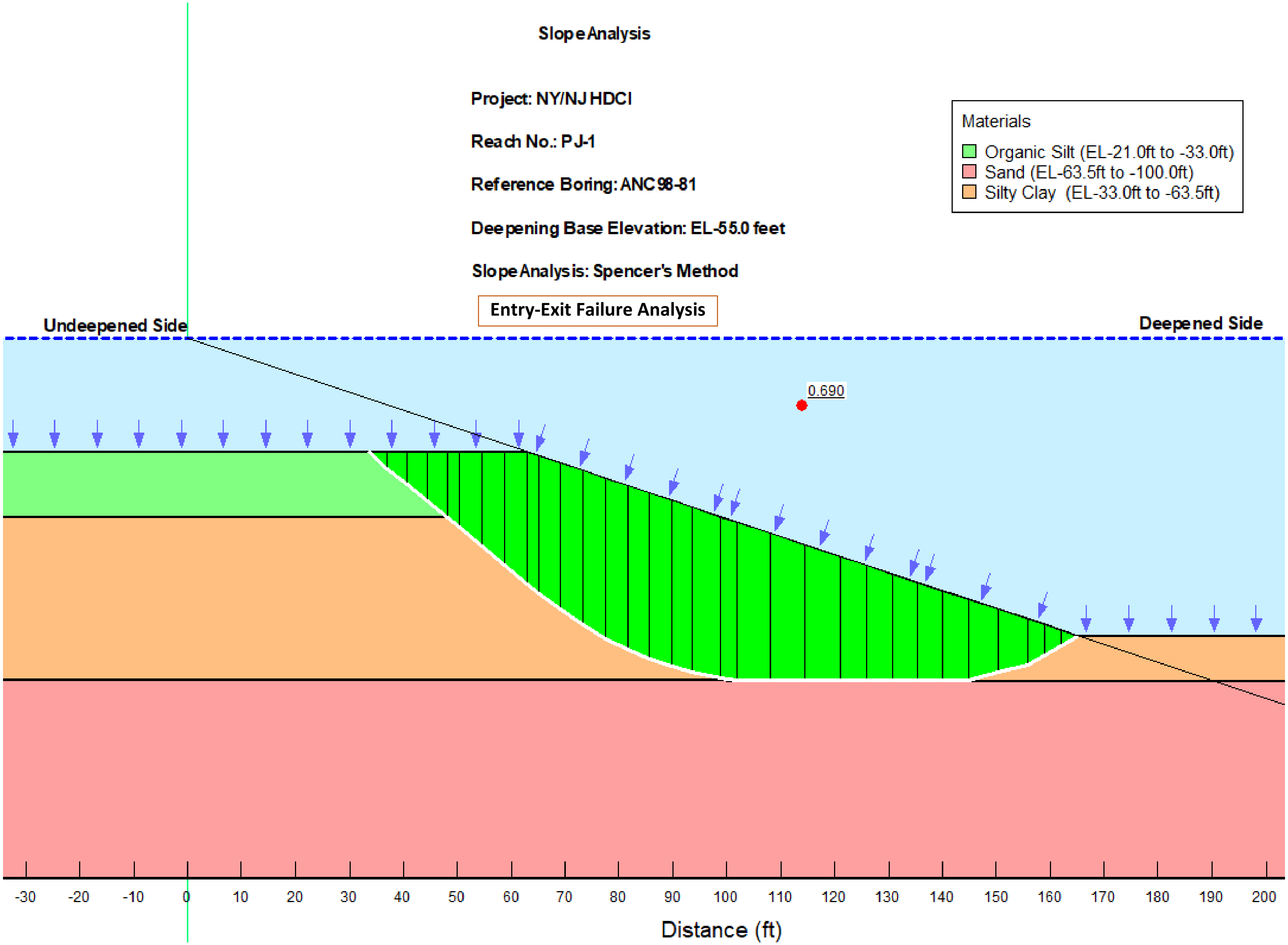
Reference Boring: ANC98-81

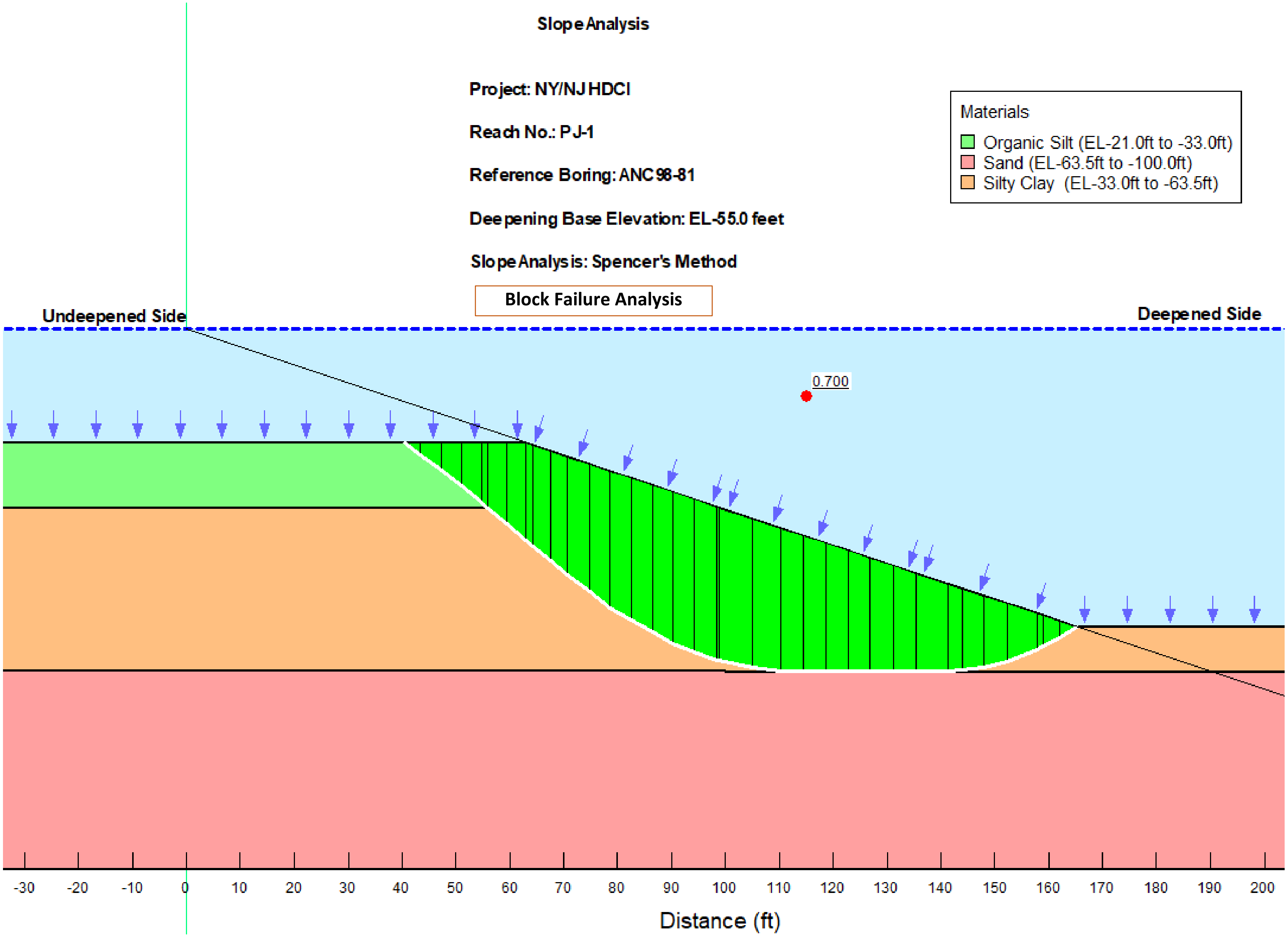
Deepening Base Elevation: EL-54.0 feet

Slope Analysis: Spencer's Method

Block Failure Analysis


Slope Analysis
Project: NY/NJ HDCI
Reach No.: PJ-1
Reference Boring: ANC 98-81
Deepening Base Elevation: EL-55.0 feet
Slope Analysis: Spencer's Method
Grid-Radius Failure Analysis
0.693
Materials
🟩 Organic Silt (EL-21.0ft to -33.0ft)
🟥 Sand (EL-63.5ft to -100.0ft)
🟧 Silty Clay (EL-33.0ft to -63.5ft)
Undeepened Side
Deepened Side
30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance (ft)


Slope Analysis
Project: NY/NJ HDCI
Reach No.: PJ-1
Reference Boring: ANC98-81
Deepening Base Elevation: EL-55.0 feet
Slope Analysis: Spencer's Method
Entry-Exit Failure Analysis
Materials
🟩 Organic Silt (EL-21.0ft to -33.0ft)
🟥 Sand (EL-63.5ft to -100.0ft)
🟧 Silty Clay (EL-33.0ft to -63.5ft)
Undeepened Side
Deepened Side
0.690
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance (ft)



Slope Analysis

Project: NY/NJ HDCI

Reach No.: PJ-1

Reference Boring: ANC98-81

Deepening Base Elevation: EL-55.0 feet

Slope Analysis: Spencer's Method

Block Failure Analysis

Slope Analysis

Project: NY/NJ HDCI

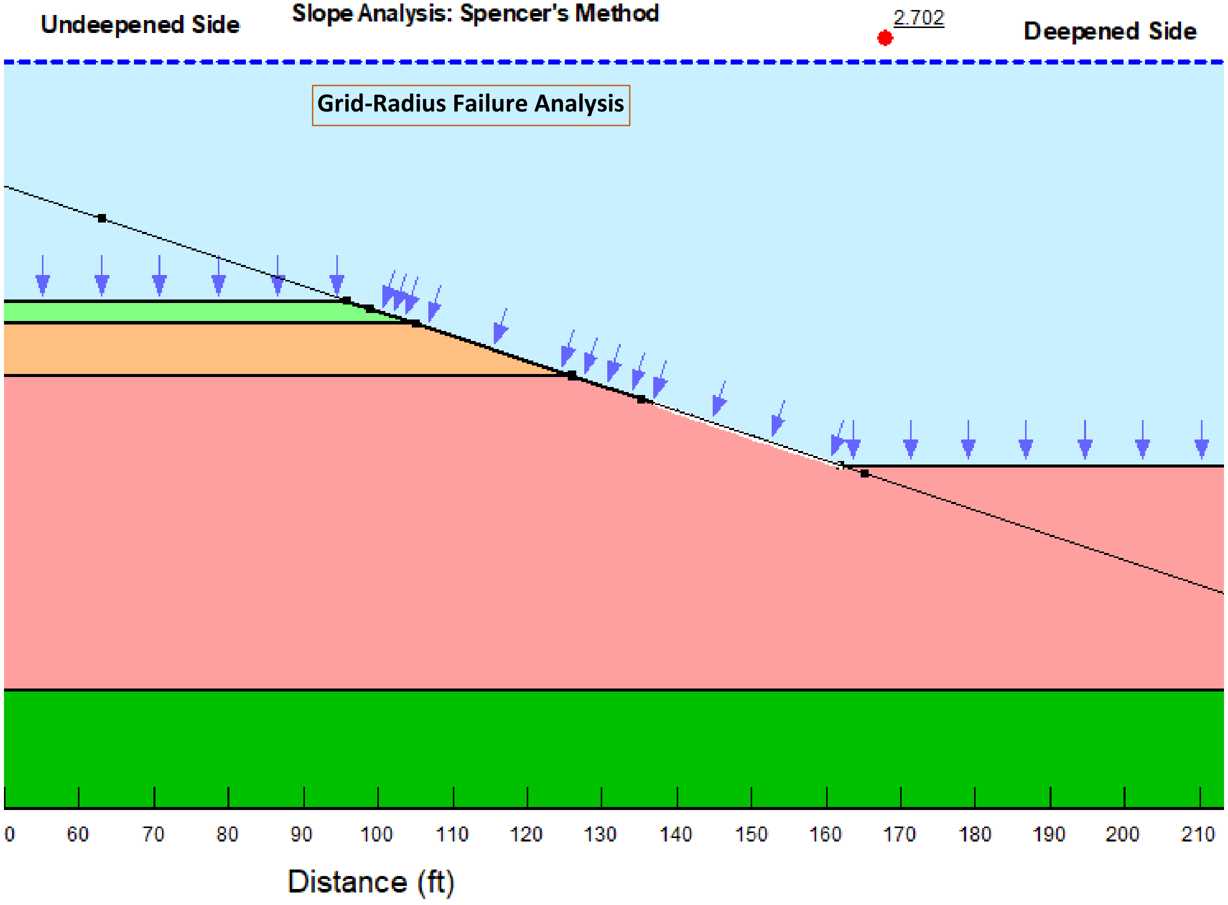
Reach No.: PJ-1

Reference Boring: PJ-4

Deepening Base Elevation: EL-54.0 feet

Slope Analysis: Spencer's Method

Materials
- 🟩 Organic Silt (EL-32.0ft to -35.0ft)
- 🟥 Sand (EL-42.0ft to -84.0ft)
- 🟩 Schist (EL-84.0ft to -100ft)
- 🟧 Silty Clay (EL-35.0ft to -42.0ft)



Slope Analysis

Project: NY/NJ HDCI

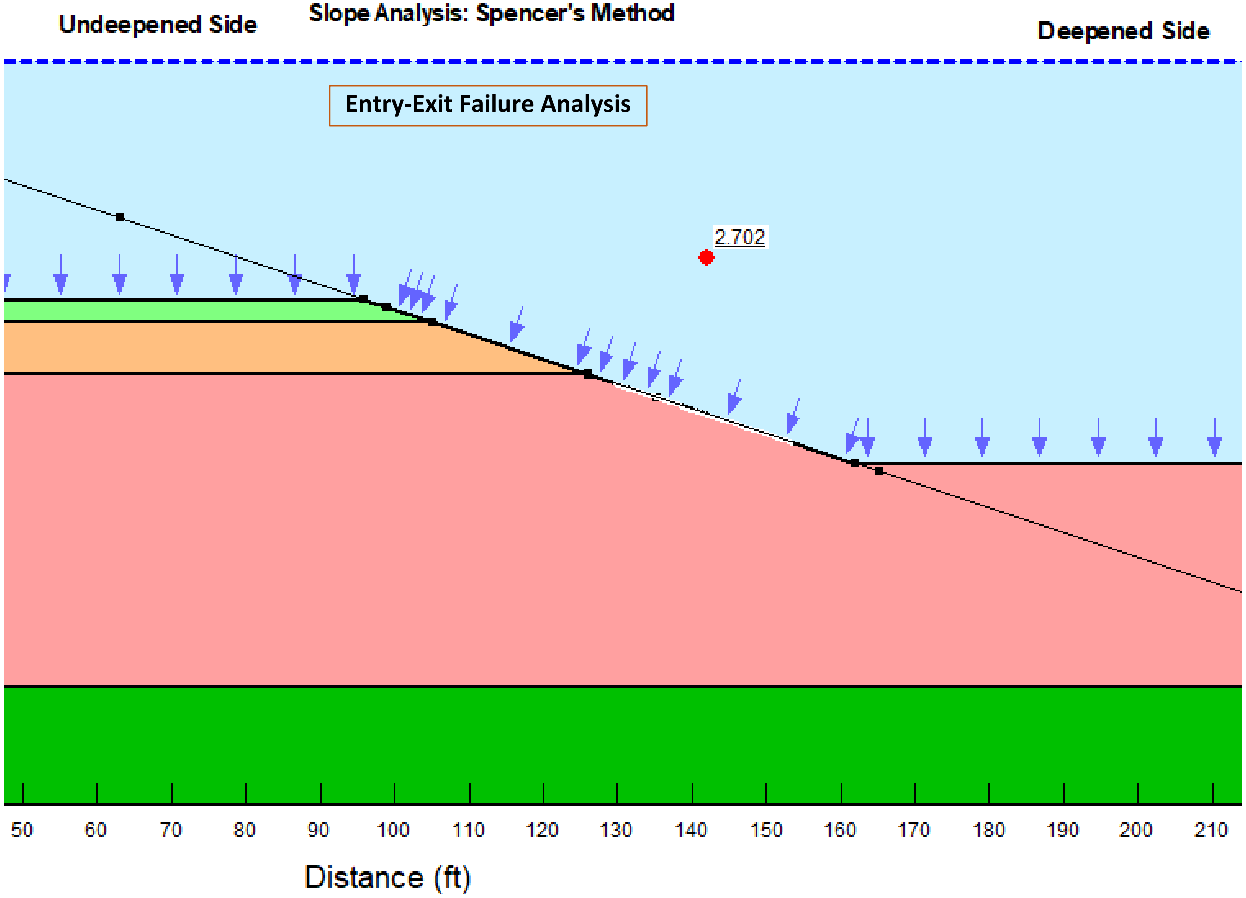
Reach No.: PJ-1

Reference Boring: PJ-4

Deepening Base Elevation: EL-54.0 feet

Slope Analysis: Spencer's Method

Materials
- 🟩 Organic Silt (EL-32.0ft to -35.0ft)
- 🟥 Sand (EL-42.0ft to -84.0ft)
- 🟩 Schist (EL-84.0ft to -100ft)
- 🟧 Silty Clay (EL-35.0ft to -42.0ft)



Slope Analysis

Project: NY/NJ HDCI

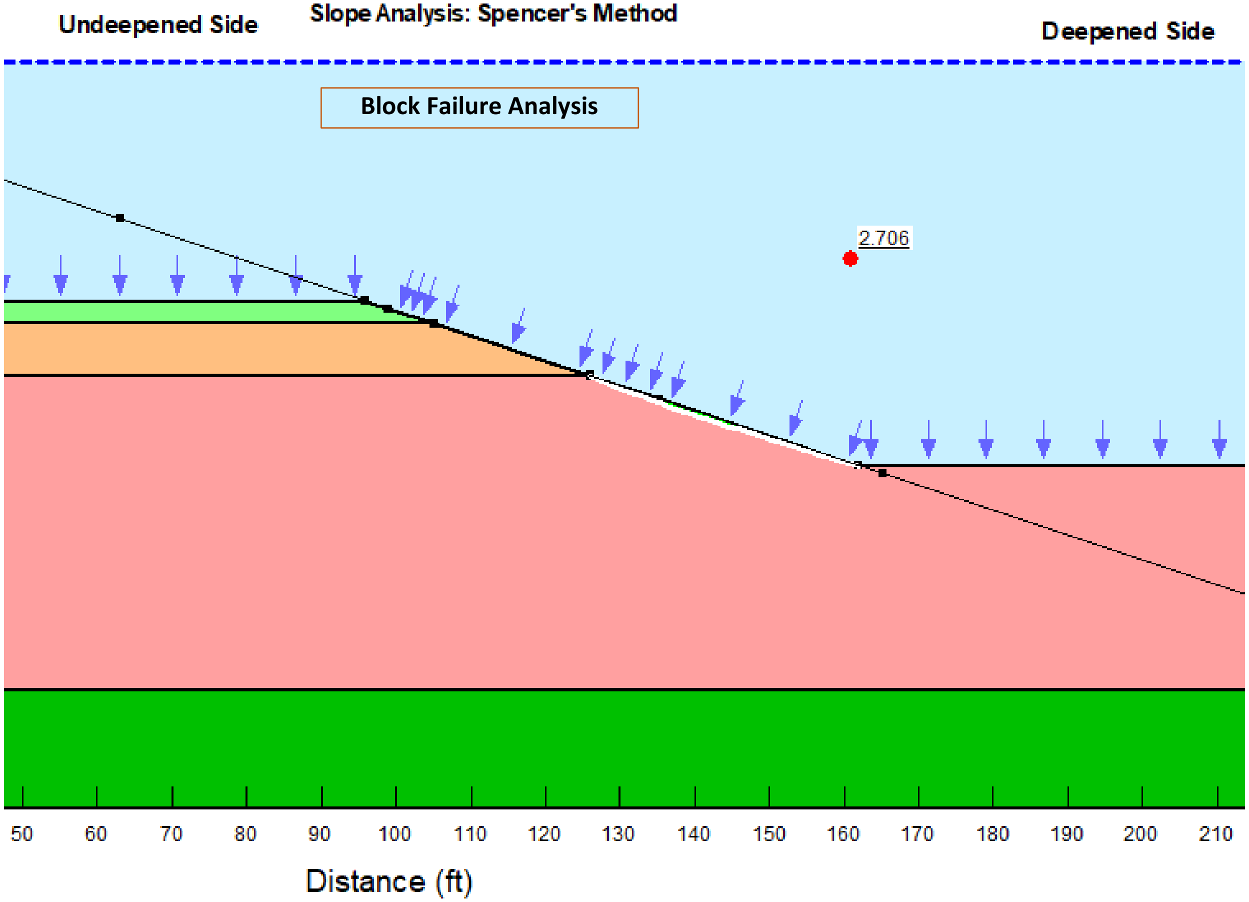
Reach No.: PJ-1

Reference Boring: PJ-4

Deepening Base Elevation: EL-54.0 feet

Slope Analysis: Spencer's Method

Materials
- 🟩 Organic Silt (EL-32.0ft to -35.0ft)
- 🟥 Sand (EL-42.0ft to -84.0ft)
- 🟩 Schist (EL-84.0ft to -100ft)
- 🟧 Silty Clay (EL-35.0ft to -42.0ft)



Slope Analysis

Project: NY/NJ HDCI

Reach No.: PJ-1

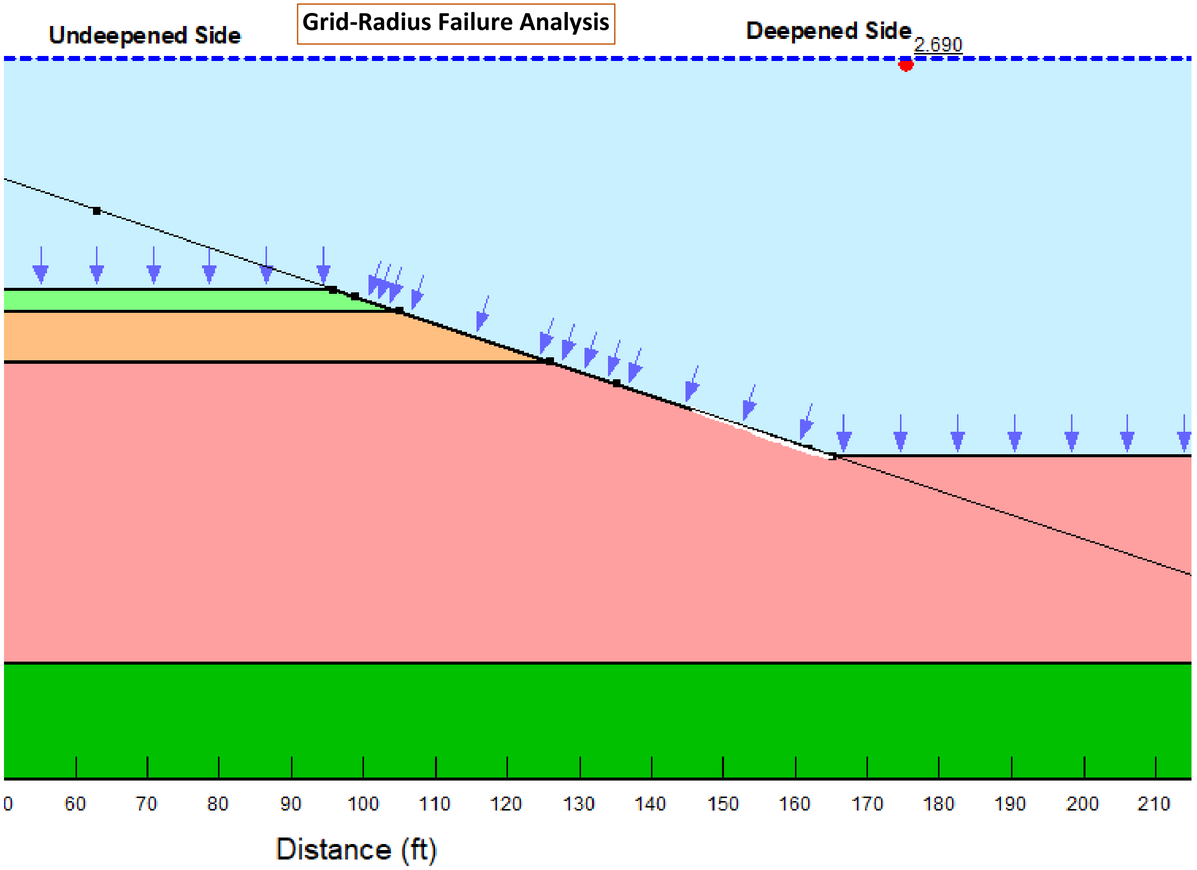
Reference Boring: PJ-4

Deepening Base Elevation: EL-55.0 feet

Slope Analysis: Spencer's Method

Materials

🟩 Organic Silt (EL-32.0ft to -35.0ft)
🟥 Sand (EL-42.0ft to -84.0ft)
🟩 Schist (EL-84.0ft to -100ft)
🟧 Silty Clay (EL-35.0ft to -42.0ft)



Slope Analysis

Project: NY/NJ HDCI

Reach No.: PJ-1

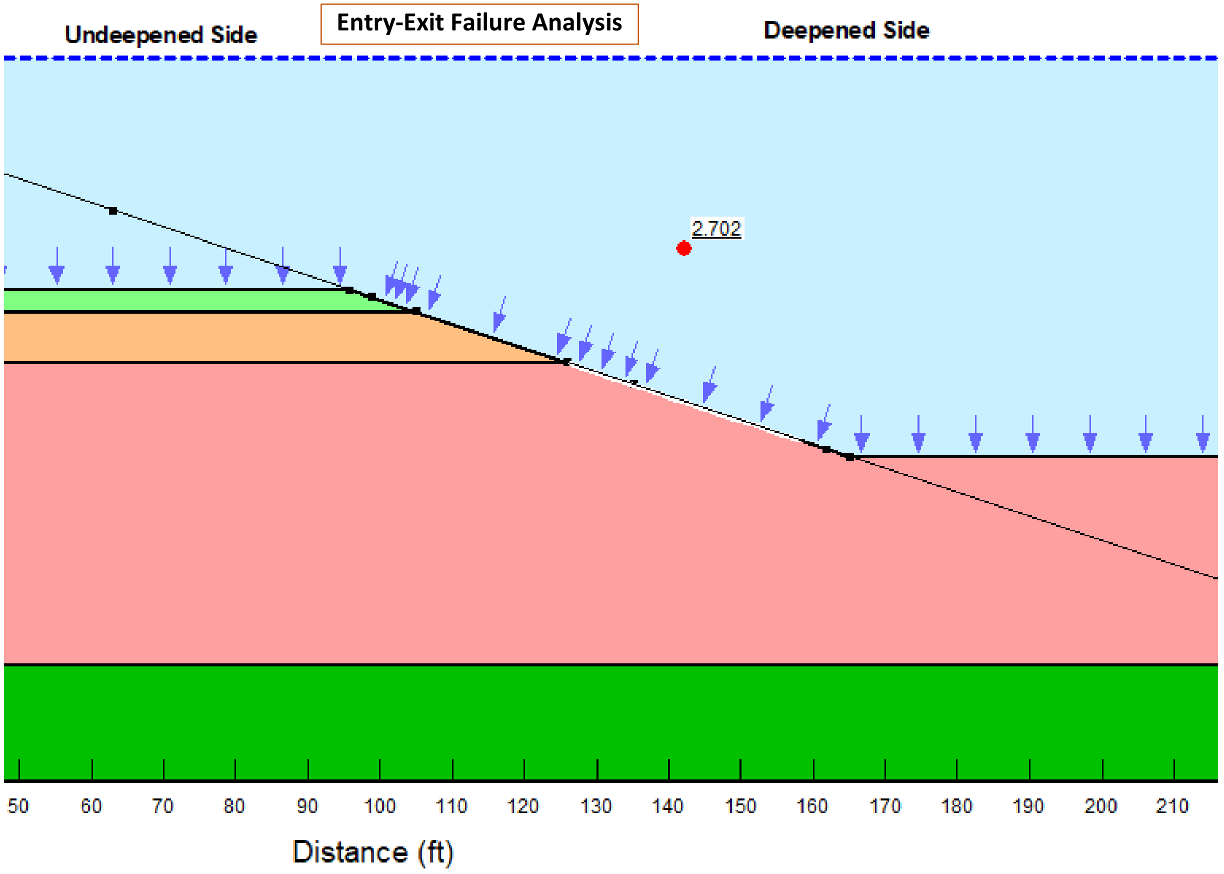
Reference Boring: PJ-4

Deepening Base Elevation: EL-55.0 feet

Slope Analysis: Spencer's Method

Materials

- 🟩 Organic Silt (EL-32.0ft to -35.0ft)
- 🟥 Sand (EL-42.0ft to -84.0ft)
- 🟩 Schist (EL-84.0ft to -100ft)
- 🟧 Silty Clay (EL-35.0ft to -42.0ft)



Slope Analysis

Project: NY/NJ HDCI

Reach No.: PJ-1

Reference Boring: PJ-4

Deepening Base Elevation: EL-55.0 feet

Slope Analysis: Spencer's Method

Materials

- 🟩 Organic Silt (EL-32.0ft to -35.0ft)
- 🟥 Sand (EL-42.0ft to -84.0ft)
- 🟩 Schist (EL-84.0ft to -100ft)
- 🟧 Silty Clay (EL-35.0ft to -42.0ft)