Stantec Consulting Services Inc.
10200 Alliance Road Suite 300, Cincinnati, Ohio 45242

October 22, 2024
File: 175578415

Attention: Christopher Pridemore, PE
Ohio Department of Transportation, District 9
650 Eastern Avenue
Chillicothe, Ohio 45601

Reference: Report of Landslide Exploration (Final)
ROS-772-10.40 Landslide PID 117701
Ross County, Ohio

Dear Mr. Pridemore,

Stantec Consulting Services Inc. (Stantec) has completed the landslide exploration report for the analysis and preliminary design of a drilled shaft wall for ROS-772-10.40 landslide in Ross County, Ohio. The enclosed report contains a brief description of the site, geologic conditions encountered, the scope of work performed, findings and geotechnical recommendations for the landslide repair and stabilization.

Regards,

Stantec Consulting Services Inc.

Gokul Khatri EIT
Geotechnical Engineer in Training

Phone: (513) 842-8208
Gokul.Khatri@stantec.com

Eric Kistner PE
Geotechnical Project Manager

Phone: (513) 842-8213
Eric.Kistner@stantec.com

Attachment: Report of Landslide Exploration

ROS-772-10.40 Landslide
Report of Landslide Exploration
(FINAL)

PID No. 117701

Ross County, Ohio

October 22, 2024

Prepared for:

Ohio Department of Transportation,
District 9

Prepared by:

Stantec Consulting Services Inc.
Cincinnati, Ohio

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Executive Summary

A landslide is located approximately 50 to 200 feet southeast of State Route (SR) 772 near straight line mileage 10.40 in Ross County, Ohio. The landslide head scarp is approximately 200 feet southeast of the road and the slope movement progresses downward toward the road. A rock cut slope is aligned parallel with the uphill side of the road. The toe of the landslide appears to be located about 50 feet southeast of SR 772, just above the rock cut. The project site is located in Huntington Township, Ohio southwest of Chillicothe. The Ohio Department of Transportation (ODOT) is planning to repair and stabilize the landslide. The proposed remediation consists of a drilled shaft wall at the toe of the landslide. Stantec Consulting Services Inc. (Stantec) was contracted by ODOT to perform analysis and preliminary design of a drilled shaft stabilization wall near the toe of the landslide.

Slope instability was observed in 2018 prompting a remediation design project (performed by others) that was completed in 2020. The remediation design consisted of performing a rock cut in bedrock at a 0.5:1 (horizontal to vertical) slope immediately uphill (southeast) of the road and excavating the slope above the rock at a 2:1 slope. During the excavation of the 2:1 slope, a slope failure occurred. Construction was stopped after a catchment bench was constructed above the existing rock slope.

Four borings were then advanced by ODOT to obtain geotechnical data for the landslide and proposed remediation. B-002-2-22, B-003-2-22 and B-005-1-22 were advanced near the top scarp of the landslide while B-003-1-22 was advanced in the toe region of the landslide. All four boreholes had slope inclinometers installed in them. The inclinometers suggested the active landslide occurring at the rock-soil interface. Geophysical testing was performed along the approximate proposed wall alignment by ODOT and provided to Stantec.

The soil profile at the site consists primarily of fine-grained soil. Low plasticity cohesive soil was observed consisting primarily of brown and gray silty clay (A-6b), silt and clay (A-6a), and clay (A-7-6) and cohesionless soil consisting of yellowish-brown sandy silt (A-4a). These materials were described as medium stiff to hard with some soft zones (N_{60} values range from 9 to 48 blows per foot with an average of 28 blows per foot) and damp to moist (moisture contents range from 10 to 21 percent with an average of 15 percent). Bedrock described as grayish black shale was encountered at depths ranging from 6.0 feet in B-003-1-22 to 36.5 feet in B-002-2-22. Recovery of the rock core runs ranged from 92 to 100 percent. The RQD of the rock core runs ranged from 33 to 58 percent. No groundwater was encountered in these four borings.

A drilled shaft tangent wall is recommended along the toe of the landslide near B-003-1-22 at an offset of approximately 75 feet right of centerline. The recommended drilled shaft tangent wall configuration includes 4-foot diameter drilled shafts reinforced with W36x282 steel beams at 4-foot center-to-center spacing. The reinforced drilled shafts should be socketed at least 10 feet into bedrock. Additional structural resistance to shear is required for this retaining wall design. It is recommended that a 10-foot-long shear plates be welded onto each side of the web of the steel sections centered at the soil-bedrock interface. It is recommended that the minimum thickness of the shear plate be 0.5 inches and the width be 24 inches. Regrading should be performed behind the wall to achieve a slope of 3.25:1 or flatter that daylights inside of existing ODOT right-of-way.

The lengths of the drilled shafts and W-sections will depend on the depth to bedrock. At the analysis section near boring B-003-1-22, the ground surface elevation was about 675 feet and the bedrock elevation was approximately 669 feet, resulting in a concrete-filled drilled shaft length of 16 feet (including the 10-foot rock socket). The W-sections would then extend above the ground surface a distance of 15 feet to an elevation of 690 feet to allow for the 3.25:1 backfill slope that daylights inside of ODOT right-of-way. It is recommended that precast concrete lagging be designed to span between the steel beam extending above ground to allow for backfill placement.

The wall length can be estimated to extend approximately from Station 9+75 to 16+50, for a total length of about 675 feet. Before final design, the required length of the wall should be reevaluated based on site observations of slope instability. It is preliminarily recommended that the wall be held at a constant offset from centerline of 75 feet, however, actual wall alignment should be determined during final design.

Lengths of steel sections and drilled shafts along the length of the wall could vary based on depth to bedrock and slope geometry. Because of a lack of borings advanced along the planned offset of the wall, additional borings should be performed along the wall alignment to determine the profile of the bedrock surface. If subsurface conditions along the length of the wall significantly differ from the conditions encountered in boring B-003-1-22, adjustments to the analysis may be needed to determine an adequate steel section.

1.0 INTRODUCTION

A landslide is located approximately 50 to 200 feet southeast of State Route (SR) 772 near straight line mileage 10.40 in Ross County, Ohio. The landslide head scarp is approximately 200 feet southeast of the road and the slope movement progresses downward toward the road. A rock cut slope is aligned parallel with the uphill side of the road. The toe of the landslide appears to be located about 50 feet southeast of SR 772, just above the rock cut. The project site is located in Huntington Township, Ohio southwest from Chillicothe. The Ohio Department of Transportation (ODOT) is planning to repair and stabilize the landslide.

Slope instability was observed in 2018 prompting a remediation design project (performed by others) that was completed in 2020. The remediation design consisted of performing a rock cut in bedrock at a 0.5:1 (horizontal to vertical) slope immediately uphill (southeast) of the road and excavating the slope above the rock at a 2:1 slope. During the excavation of the 2:1 slope, a slope failure occurred. Construction was stopped after a catchment bench was constructed above the existing rock slope. The stationing used for this project started at 7+85 and ended at Station 18+00. This stationing is referenced in this report.

The proposed remediation design consists of a drilled shaft wall along the slope above SR 772. Stantec Consulting Services Inc. (Stantec) was contracted by ODOT to perform analysis and preliminary design of drilled shaft stabilization wall near the toe of the landslide. Figure 1 shows the site vicinity.

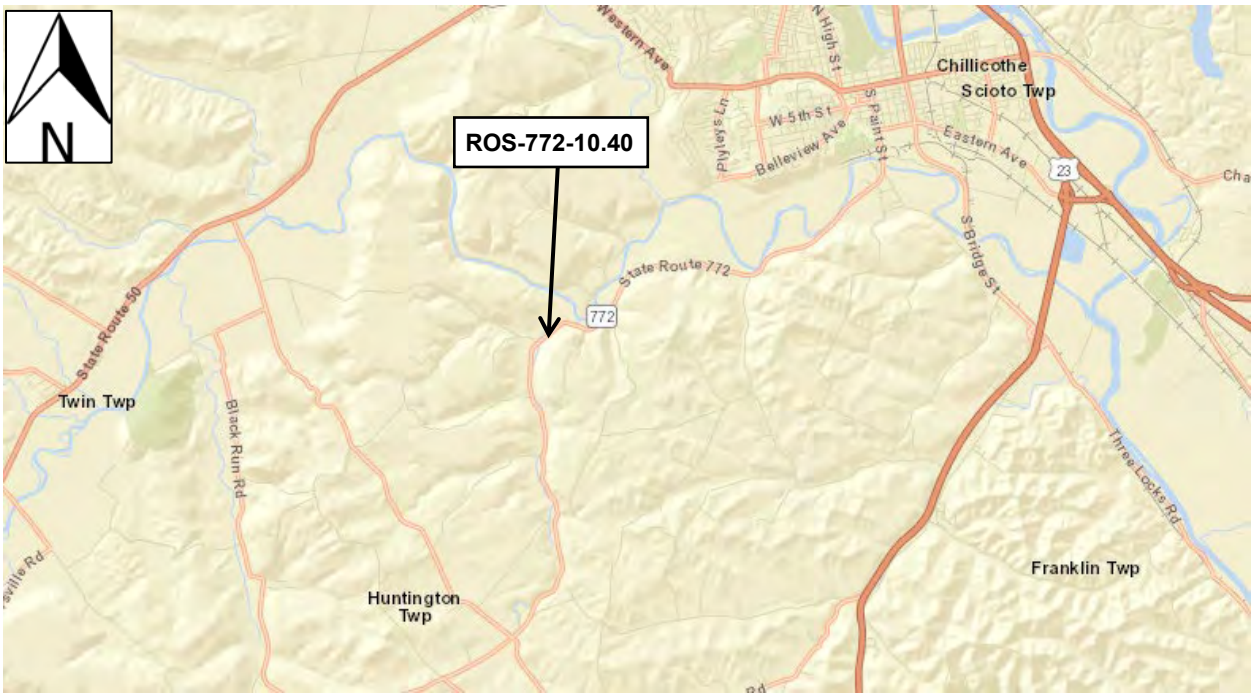


Figure 1. Site Vicinity
(Ohio Department of Natural Resources Interactive Mapping, 2023)

2.0 GEOLOGY AND OBSERVATIONS OF THE PROJECT

2.1 GENERAL

The *Physiographic Regions of Ohio Map* (Ohio Department of Natural Resources (ODNR), 1998) indicates that the project is located within the Columbus Lowland of the Southern Ohio Loamy till Plain. The Columbus Lowland is described as lowlands surrounded in all directions by uplands. It has the broad regional slope towards the Scioto Valley. The geology of the region is composed of loamy, high lime to medium lime Wisconsinan-age till and extensive outwash in Scioto valley over deep Devonian to Mississippian-age carbonate rocks, shales, and siltstones. The region has low relief (generally about 25 feet) with elevations of 600 to 850 feet.

2.2 SOIL GEOLOGY

According to the *Quaternary Geology of Ohio* map (ODNR, 1999), the project site is underlain by Wisconsinan-age high level outwash and consists of sand and gravel with 10 cm to 1 meter of silt or loess cover. A portion of the site is also composed of Illinoian-age outwash in small benches and high terrace areas. These deposits consist of uniform bed of sand and gravel, covered with 10 cm to 3 meters of loess. The soil survey (*Web Soil Survey of Ross County, Ohio*, United States Department of Agriculture [USDA], 2023) indicates that the project site is underlain by soils from the Shelocta-Cruze-Weikert Association, steep complex. The typical profile for soils generally consists of 28 inches of silt and silty clay loam, 10 inches of channery silty clay loam and 10 inches of very channery silty clay loam. Soils from this complex tend to be well drained with a moderate high to high (0.6 to 2.0 in/hr.) capacity to transmit water.

2.3 BEDROCK GEOLOGY

Bedrock mapping (*Reconnaissance Bedrock Geology of the Blue Creek, Ohio Quadrangle* [ODNR, 1994]) and *Descriptions of Geologic Map Units* (ODNR, 2011) indicates that the overburden soils at the site are underlain primarily by Ohio and Olentangy Shales, undivided, from the Devonian age. Ohio Shale is comprised of shale described as brownish black to greenish gray and weathering brown in color. The shale is also described as carbonaceous to clayey, laminated to thin bedded, and containing fissile partings. This shale thickness is more than 250 ft. The upper hill portion consists of Sunbury shale, Bedford shale undivided from the Devonian and Mississippian age. The shale is gray to brown in color with a thickness of 80 to 100 feet.

According to the *Ohio Oil and Gas Well Viewe*r map (ODNR, 2023), there are no active oil and gas wells located within 10 miles of the project location. According to the Ohio Mine Locator (ODNR, 2023), there are three mines within the radius of 5 miles. They are basically used to produce sand, gravels, and clay. The *Ohio Karst Areas* map (ODNR, 2009) indicates no karst areas within 10 miles radius of the project site.

2.4 HYDROLOGY

Surface drainage east of SR 772 collects in a roadside ditch that drains to a culvert that outlets on the west side of SR 772, draining down the bank into Ralston Run. Ralston Run aligns parallel to the SR 772 at the project site and flows east to Paint Creek, which flows east to the Scioto River. The Scioto River flows south into the Ohio River.

2.5 HYDROGEOLOGY

The Ohio Geology Interactive Map shows that the site is underlain by the sand and gravel aquifer, which has a yield of less than 5 gallons per minute. According to the Groundwater Resources of Ross County map (ODNR, 1989), the project site is in an area where wells with yields of less than three gallons per minute can be achieved. Shale, and shaley sandstone bedrock in the area are often overlain by thin layers of clay and silty clay that yield high quantities of water.

A search was performed using the *ODNR Ohio Water Wells Map* (2023) to determine if any water wells are located near the project site. According to the map, four water wells have been drilled within half a mile of the project footprint. The well logs indicate a considerable variation of the bedrock depth, ranging from 1 to 50 feet. The logs also indicate a considerable variation of static water depth in the area surrounding the site ranging from 24 to 45 feet.

2.6 SEISMIC

A review of the seismic data available in the project vicinity included the *Ohio Seis* database developed by the ODNR, Division of Geological Survey. The review was performed using the internet mapping service (rev. 2021) at the following website: https://gis.ohiodnr.gov/website/dgs/earthquakes/.

Overall, Ohio has a relatively limited amount of seismic activity. Within a 10-mile radius of the project, there has been one earthquake epicenter with a magnitude of 3.1. The available data reviewed included events that occurred in Ohio from 1804 to present day.

2.7 SITE RECONNAISSANCE

Stantec representatives visited the site on June 30, 2023. The land surrounding the project site can be described as wooded and rural. The landslide affects approximately 100 feet of slope east of the roadway. The slope head scarp was seen to have displaced and slide a few inches away from its original position. The toe region was recently graded thus the toe bulge was not evident. However, the inclinometer data shows the movement of the land mass in the toe region. The landslide reportedly causes material to slide over the rock cut at the toe of the slope onto the road, causing it to be necessary to close lanes to clean the material from the road.

3.0 EXPLORATION

3.1 HISTORIC EXPLORATION PROGRAMS

The ODOT Traffic Information Management System (TIMS) provides information for a road stabilization project completed on SR 772 in 2020. It consisted of 11 borings along SR 772 to examine soil conditions for the slope stability and road stabilization. Surface material consisted of 12 to 14 inches of asphalt, or 3 inches of topsoil, underlain primarily by sandy silt (A-4a), silt and clay (A-6a), silty clay (A-6b), gravel and/or stone fragments with sand and silt (A-2-4). Clay (A-7-6) was also noted between the silty clay regions in the soil profile. Bedrock was

encountered at depths ranging from 6 to 45 feet. The bedrock was described as gray to black shale slightly to highly weathered, slightly strong to strong, and slightly to highly fractured. Groundwater was encountered at various depths ranging from 14 to 44.5 feet.

A roadway construction project was carried out in 1968-1969 along SR 772 from mileage 9.671 to 10.339. The geotechnical exploration for this project consisted of 14 borings with depths of about 10 feet. The overburden soil was described as brown sandy clay with rock fragments and brown sandy silty clay. The borings often encountered refusal due to rock and boulders.

3.2 PROJECT EXPLORATION PROGRAM

ODOT advanced four borings (named B-002-2-22, B-003-1-22, B-003-2-22, and B-005-1-22) located within the sliding mass of the landslide. Slope inclinometers were installed in these boreholes to determine the depth of the failure plane of the landslide. A summary of these borings is shown in Table 1. Boring locations are shown on the site plans provided in Appendix A. The boring logs are also provided in Appendix A.. Notations reflecting these measurements are included on the logs in Appendix A.

Table 1. Boring Summary

Boring No.	Approx. Station (feet)	Approx. Offset (feet)	Ground Surface Elevation (feet)	Top of Bedrock Elevation (feet)	Bottom of Boring Elevation (feet)
B-002-2-22	10+14	183 right	723.9	689.4	677.4
B-003-1-22	12+07	77 right	675.3	669.3	659.3
B-003-2-22	12+00	185 right	725.1	687.9	669.1
B-005-1-22	16+38	156 right	716.0	693.0	681.0

The borings were performed with a CME 80R track-mounted drill rig using 3¼-inch inside diameter (ID) hollow stem augers to advance the borings through soil. Standard Penetration Test (SPT) sampling was performed at 2.5-foot or continuous intervals until bedrock was encountered.

Upon encountering relatively unweathered bedrock, rock coring was performed in four of the borings using NQ2-size equipment. Recovery, core loss, and rock quality designation (RQD) values were recorded as percentages for each coring run. The recovery is a measurement of the core sample obtained from a core run. The loss is the difference between the core run and the recovery. The RQD is measured by dividing the sum of all pieces of intact rock core longer than four inches in a run by the total length of the core run. These values are shown on the boring logs contained in Appendix A.

The soil samples obtained from the borings were returned to ODOT's geotechnical laboratory for visual classification and tested for water content. Engineering classification testing was performed on samples reflecting each of the main soil horizons. The engineering classification tests conducted on the samples were sieve and hydrometer analysis (ASTM D 422) and Atterberg limits (ASTM D 4318). The samples were classified according to the ODOT classification method.

One undisturbed Shelby tube was extruded in the laboratory and was subjected to unconfined compression (UC) testing (ASTM D 2166). Four rock core samples were subjected to unconfined compressive strength of rock core (UCR) testing (ASTM D 7012). The results of UC and UCR testing are provided in Appendix A.

Geophysical was performed along two lines at approximately the same offset from SR 772 as where Boring B-003-1-22 was advanced, which was where a retaining wall had been planned for remediation of the landslide. The results of the geophysical testing is provided in Appendix A.

4.0 FINDINGS

The soil profile at the site consists primarily of fine-grained soil. Fine-grained cohesionless or low plasticity cohesive soils were observed in all the borings. The cohesionless soils were described as sandy silt (A-4a) while the low plasticity cohesive soils were described as clay (A-7-6) and silty clay (A-6b). These materials were described as medium stiff to hard with some soft zones (N_{60} values ranged from 9 to 48 blows per foot with an average of 28 blows per foot) and damp to moist (moisture contents ranged from 10 to 21 percent with an average of 15 percent). An unconfined compressive strength test resulted in a compressive strength of 3,787 pounds per square foot (psf).

Boring B-002-2-22 encountered silt and clay (A-6a) from 1 to 18 feet and 29.5 to 34.5 feet and silty clay (A-6b) from 18.5 to 28.5 feet. B-003-1-22 consisted of layers of silty clay (A-6b) and silt and clay (A-6a) with shallow rock at a depth of 6 feet. Similarly, B-003-2-22 consisted of silt and clay (A-6a), sandy silt (A-4a), and clay (A-7-6). B-005-1-22 encountered layers of materials that classified as sandy silt (A-4a), clay (A-7-6), and silt and clay (A-6-a) with thicknesses of 4.5, 6.5 and 11.5 feet, respectively.

In Boring B-003-2-22, boulders and cobbles were encountered at a depth of 33.0 to 37.2 feet. This material was described as hard (N_{60} values ranging from 75 to 123 blows per foot) and moist (moisture contents ranging from 13 to 16 percent). Similarly, Boring B-005-1-22 consisted of boulders and cobbles at a depth of 20.4 to 21.5 feet. This material was described as hard (N_{60} values ranging from 38 to 63 blows per foot) and moist (moisture contents ranging from 15 to 17 percent).

Bedrock described as grayish black shale was encountered at depths ranging from 6.0 feet in B-003-1-22 to 36.5 feet in B-002-2-22. Recovery of the rock core runs ranged from 92 to 100 percent. The RQD of the rock core runs ranged from 33 to 58 percent. Four laboratory UCR tests were conducted on representative shale samples. The test results ranged from 2,447 to 3,335 pounds per square inch (psi) with an average of 2,804 psi.

No groundwater was encountered during drilling in the borings.

5.0 ANALYSIS AND RECOMMENDATIONS

5.1 GENERAL

The recommendations that follow are based on the information discussed in this report and the interpretation of the subsurface conditions provided on the boring logs. If future design changes are made, Stantec should be notified so that such changes can be reviewed, and the recommendations are amended as necessary.

These conclusions and recommendations are based on data and subsurface conditions from the borings advanced during this exploration using the degree of care and skill ordinarily exercised under similar circumstances by competent members of the engineering profession. No warranties can be made regarding the continuity of conditions.

5.2 DRILLED SHAFT WALL ANALYSIS

A landslide is located uphill of SR 772 approximately 50 to 200 feet right of centerline near straight line mileage 10.40 in Ross County, Ohio. The slope inclinometers installed by ODOT indicates that the landslide is occurring at the soil-bedrock interface, approximately 35 to 40 feet below existing grade. A sloping weak plane along the soil-bedrock interface is likely the primary cause of the landslide. Surface water runoff and underground seeps near the soil-bedrock interface are likely contributing factors. ODOT had indicated that a drilled shaft wall along the toe of the slope southeast of SR 772 was the preferred repair.

To determine the failure mechanism of the landslide, a back-analysis was performed using conventional, limit equilibrium methods as implemented in GeoStudio SLOPE/W 2018 R2 software. The cross section aligned where borings B-003-2-22 and B-003-1-22 were advanced was selected as representative of where the landslide occurred, based on inclinometer data and the cross section of the contours. A simplified subsurface stratigraphy which included cohesive soil and bedrock was modeled. The failure surface was modeled at the soil-bedrock interface in attempt to replicate the failure observed at the site. The analysis cross section is shown in Appendix B.

The foundation soils were given shear strength parameters based on ODOT Geotechnical Design Manual (GDM) guidelines. To achieve a factor safety of 1.0, the strength parameters of the foundation soils were adjusted. It was assumed that the soil and rock layers had zero drained cohesion at the time of failure. Because the slope inclinometer installed indicated the depth of the sliding surface is at the bedrock interface, a 2-foot layer of weakened material was modeled in GeoStudio. This layer was given a friction angle of 16.5 degrees. The material parameters assigned to the foundation soil material and the results of the slope stability back-analysis can be found in Appendix B.

The UA Slope Program, Version 2.3, was used to estimate the potential loading on the drilled shaft wall. The analysis cross section and failure surface developed in the slope stability back-analysis (Appendix B) were modeled in the UA Slope Program. As described in the ODOT GDM, existing conditions without the drilled shafts were analyzed and the foundation and bedrock materials were assigned the same values as in the back-analysis. A drained friction angle of 16.4 degrees in the weak rock zone was required to achieve a factor of safety of 1.00 in the UA Slope Program, matching closely with the SLOPE/W model.

Using the same material parameters to achieve a factor of safety approaching 1.0 in the UA Slope Program, the proposed drilled shaft wall geometry was analyzed. It was assumed that fill was placed behind the wall to achieve a backslope of 3.25:1 that daylights inside of ODOT right-of-way (approximately 205 feet right of centerline at Station 12+00). The resulting height of the wall was about 14.5 feet. A fill material with effective cohesion of 250 psf, undrained friction angle of 28 degrees, and unit weight of 125 pcf was selected based on ODOT GDM Table 500-2. The drilled shaft wall location was modeled near the B-003-1-22 inclinometer location at an approximate offset of 75 feet right of centerline. A drilled shaft tangent wall consisting of 4-foot diameter drilled shafts at 4-foot center-to-center spacing was analyzed. The resulting loading was 379 kips per shaft with a triangular distribution. The results of the UA Slope analyses are presented in Appendix C.

The loading estimated above was modeled as a triangular distributed load in a drilled shaft analysis using the computer software LPile v2022, supplied by Ensoft. The boring and laboratory testing results were used to estimate soil and bedrock parameters. It was assumed that the soil on the front side of the wall would provide no passive resistance. The Weak Rock p-y curve was used for the bedrock and an unconfined compressive strength of 2,804 psi was assumed, which is the average of the tested samples. The analysis was performed at both Service (I) and Strength (I) Limit States. SLOPE/W was used to check the stability of the 3.25:1 slope behind the drilled shafts wall. This resulted in a factor of safety of 1.7. This analysis cross section is included in Appendix B.

5.3 RECOMMENDATIONS

Using the analysis process discussed in Section 5.2, it was determined that 4-foot diameter drilled shafts installed side-by-side socketed 10 feet into bedrock and reinforced with steel W-sections would adequately resist the anticipated loading with steel plating welded onto each side of the web of the steel section for added shear capacity. W36x282 steel beams reinforced with 0.5-inch thick steel plating centered at the soil-bedrock interface were modeled as reinforcement for the drilled shafts. The analysis resulted in a deflection of 1 inch (top of wall) at Service (I) Limit State, a maximum moment of 32,500 kip-feet at Strength (I) Limit State, and a maximum shear of 1,745 kips at Strength (I) Limit State. The result of this LPile analysis is provided in Appendix D.

The lengths of the drilled shafts and W-sections will depend on the depth to bedrock. At the analysis section near boring B-003-1-22, the ground surface elevation was about 675 feet and the bedrock elevation was approximately 669 feet, resulting in a concrete-filled drilled shaft length of 16 feet (including the 10-foot rock socket). The W-sections would then extend above the ground surface for a length of 15 feet to an elevation of 690 feet to allow for the 3.25:1 backfill slope that daylights inside of ODOT right-of-way. It is recommended that precast concrete lagging be designed to span between the steel beams extending above ground to allow for backfill placement. Figure 2 shows the wall configuration at Station 12+00.

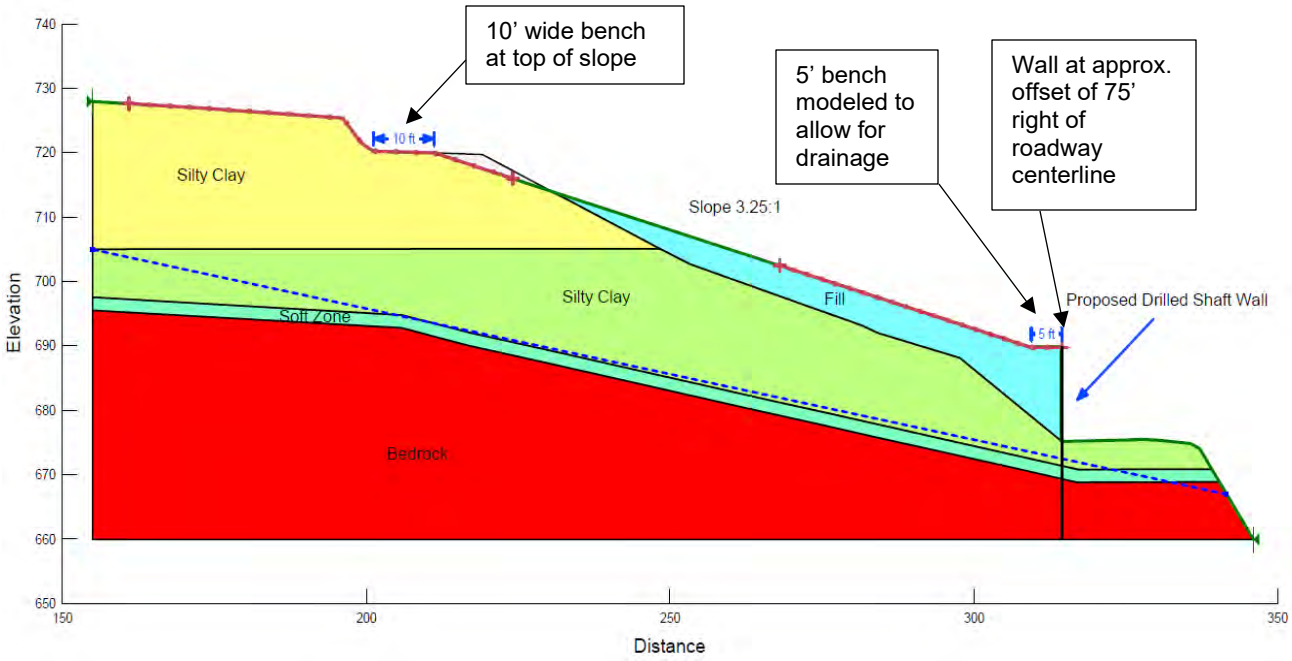


Figure 2: Drilled Shaft Wall and Slope Configuration (looking back station)

It is recommended that 10-foot-long steel plates be welded onto each side of the web of the W36x282 sections centered at the soil-bedrock interface. It is recommended that the minimum thickness of the steel plates be 0.5 inches with widths of at least 24 inches, which spans the width of the web accounting for some room to make the weld.

The wall length can be estimated to extend approximately from Station 9+75 to 16+50, for a total wall length of about 675 feet. Before final design, the required length of the wall should be reevaluated based on site observations of slope instability. It is preliminarily recommended that the wall be held at a constant offset from centerline of 75 feet, however, actual wall alignment should be determined during final design.

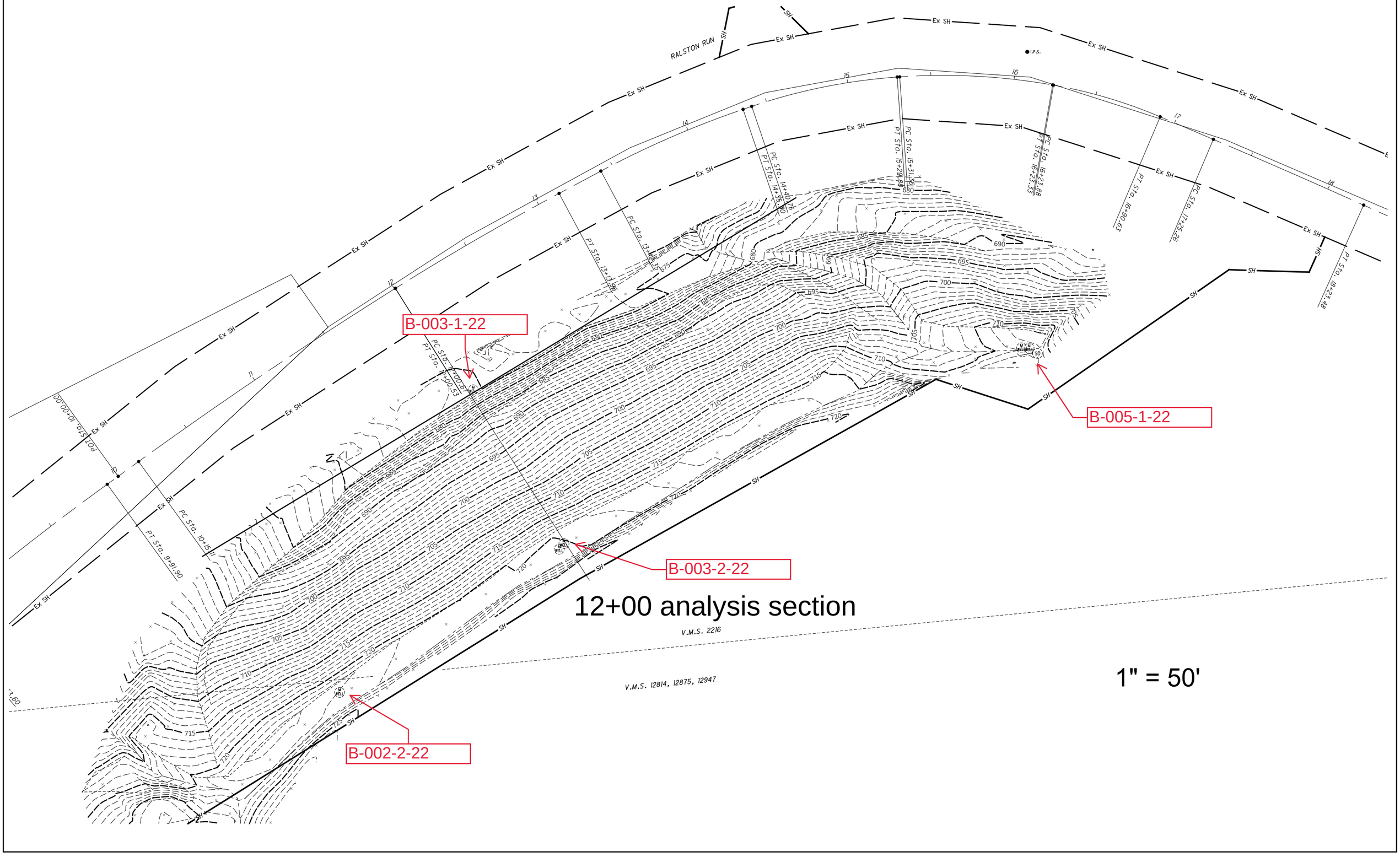
Lengths of steel sections and drilled shafts along the length of the wall could vary based on depth to bedrock and slope geometry. Because of a lack of borings advanced along the planned offset of the wall, additional borings should be performed along the proposed wall alignment to determine the profile of the bedrock surface. If subsurface conditions along the length of the wall significantly differ from the conditions encountered in boring B-003-1-22, adjustments to the analysis may be needed to determine an adequate steel section. A typical cross section of the proposed wall and wall details are provided in Appendix E.

The results of the geophysical testing provided by ODOT and presented in Appendix A was used to develop an estimate of the top of rock along the length of the wall. The top of bedrock along the length of the wall should (1) be taken as elevation 669 from the beginning of the wall to the location of B-003-1-22, (2) account for a dip to elevation 666 starting at the boring B-003-1-22 location, centered at 100 feet upstation of the boring, and returning to elevation 669 at 220 feet upstation of the boring, and (3) be extrapolated upward to elevation 681 (average top of rock in borings B-003-1-22 and B-005-1-22) at the end of the wall.

Special benching with internal drainage should be performed on the existing slope receiving new fill in accordance with the ODOT GDM “Figure 800-5: Example Section of Special Benching for Landslide Stabilization” and “Figure 800-6: Example Section Showing Slope Drain Details”.

APPENDIX A
EXPLORATION AND SLOPE INCLINOMETER DATA


ROS-772-10.4
Instruments
Legend
Ralston Run
Ralston Run
772
772
772
772
772
B3-1
B5-1
B3-2
B2-2
N
300 ft
Google Earth


RALSTON RUN
Ex SH
SH
I.P.S.
B-003-1-22
B-005-1-22
B-003-2-22
B-002-2-22
PC Sta. 13+13.96
PT Sta. 13+43.96
PC Sta. 14+40.75
PT Sta. 14+75.10
PC Sta. 15+29.88
PT Sta. 15+61.88
PC Sta. 16+23.88
PT Sta. 16+90.63
PC Sta. 17+25.26
PT Sta. 18+23.48
PC Sta. 11+04.53
PT Sta. 11+40.03
PC Sta. 10+15.00
PT Sta. 9+91.90
POT Sta. 10+00.00
12+00 analysis section
V.M.S. 2216
V.M.S. 12814, 12875, 12947
1" = 50'

PROJECT: ROS-772-10.40	DRILLING FIRM / OPERATOR: ODOT / LEWIS	DRILL RIG: CME 850R TRACKED	STATION / OFFSET: 10+14, 183 ft Rt (Approx)
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / MCINTOSH	HAMMER: CME AUTOMATIC	ALIGNMENT: CL SR 772
PID: 117701 SFN:	DRILLING METHOD: 3.75" HSA / NQ2	CALIBRATION DATE: 4/19/21	ELEVATION: 723.9 (ft) EOB: 46.5 ft.
START: 10/19/22 END: 10/20/22	SAMPLING METHOD: SPT / NQ2	ENERGY RATIO (%): 90*	LAT / LONG: 39.292584, -83.049184

EXPLORATION ID B-002-2-22

PAGE 1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 723.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	INCL.
STIFF, MOTTLED BROWN AND GRAY, **SILT AND CLAY**, SOME STONE FRAGMENTS, TRACE SAND, DAMP		1																
		2	4 5 4	14	50	SS-1	-	35	4	5	27	29	34	19	15	15	A-6a (6)	
		3																
		4	6 5 5	15	50	SS-2	-	-	-	-	-	-	-	-	-	13	A-6a (V)	
@6.0'; MEDIUM STIFF		5																
		6	3 3 3	9	56	SS-3	-	-	-	-	-	-	-	-	-	16	A-6a (V)	
@8.5'; VERY STIFF		7																
		8	3 5 7	18	56	SS-4	-	-	-	-	-	-	-	-	-	17	A-6a (V)	
@11.0'; HARD, LITTLE SAND		9																
		10	5 8 12	30	67	SS-5	4.50	31	3	8	28	30	32	18	14	15	A-6a (6)	
@13.5'; VERY STIFF		11																
		12	2 6 7	20	50	SS-6	4.00	-	-	-	-	-	-	-	-	16	A-6a (V)	
		13																
		14	6 6 9	23	72	SS-7	3.50	-	-	-	-	-	-	-	-	16	A-6a (V)	
	705.4	15																
VERY STIFF, MOTTLED BROWN AND GRAY, **SILTY CLAY**, LITTLE STONE FRAGMENTS, TRACE SAND, DAMP		16																
		17	4 6 9	23	61	SS-8	3.50	14	5	4	30	47	39	22	17	17	A-6b (11)	
		18																
		19	6 8 10	27	78	SS-9	4.00	-	-	-	-	-	-	-	-	16	A-6b (V)	
		20																
		21	5 8 9	26	72	SS-10	3.50	-	-	-	-	-	-	-	-	16	A-6b (V)	
@26.0'; HARD		22																
		23	8 11 17	42	83	SS-11	4.5+	-	-	-	-	-	-	-	-	16	A-6b (V)	
	695.4	24																
HARD, GRAY, **SILT AND CLAY**, SOME STONE FRAGMENTS, LITTLE SAND, DAMP		25																
		26	8 7 8	23	78	SS-12	4.50	25	6	5	30	34	31	19	12	14	A-6a (7)	
		27																
		28	6 9 13	33	100	SS-13	4.50	-	-	-	-	-	-	-	-	17	A-6a (V)	
	689.4	29																
SHALE, GRAY, HIGHLY WEATHERED, VERY WEAK TO WEAK, LAMINATED TO THIN BEDDED, RUST STAINED.		TR	4 11 18	44	100	SS-14A	4.50	-	-	-	-	-	-	-	-	17	A-6a (V)	
						SS-14B	-	-	-	-	-	-	-	-	-	17	Rock (V)	
	687.4		54	-	100	SS-15	-	-	-	-	-	-	-	-	-	12	Rock (V)	
SHALE, GRAYISH BLACK, MODERATELY WEATHERED, SLIGHTLY TO MODERATELY STRONG, LAMINATED, CARBONACEOUS, PYRITIC, JOINT, MODERATELY FRACTURED, NARROW, SLIGHTLY ROUGH; BLOCKY, FAIR; RQD 58%, REC 100%.			17		100	NQ2-1											CORE	
@40.5'; SLIGHTLY WEATHERED.																		
			23		100	NQ2-2											CORE	
@ 45.8' - 46.2'; γ = 153 pcf; Qu = 3,281 psi	677.4	EOB																

NOTES: LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM USGS 3DEP MAP SERVICE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 60 GAL. BENTONITE CEMENT GROUT

STANDARD ODOT SOIL BORING LOG (11 X 17) - OH DOT.GDT - 12/19/22 11:47 - X:\GINT\PROJECTS\601011.GPJ

PROJECT: ROS-772-10.40	DRILLING FIRM / OPERATOR: ODOT / LEWIS	DRILL RIG: CME 850R TRACKED	STATION / OFFSET: 12+07, 77' Rt. (Approx)	EXPLORATION ID B-003-1-22
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / MCINTOSH	HAMMER: CME AUTOMATIC	ALIGNMENT: CL SR 772	
PID: 117701 SFN:	DRILLING METHOD: 3.75" HSA / NQ2	CALIBRATION DATE: 4/19/21	ELEVATION: 675.3 (ft) EOB: 16.0 ft.	PAGE 1 OF 1
START: 10/24/22 END: 10/25/22	SAMPLING METHOD: SPT / NQ2	ENERGY RATIO (%): 90*	LAT / LONG: 39.293080, -83.048900	

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	INCL.
VERY STIFF, MOTTLED BROWN AND GRAY, **SILTY CLAY**, LITTLE SAND, TRACE STONE FRAGMENTS, MOIST	675.3	1																
		2	6 6 8	21	83	SS-1	4.00	10	3	8	33	46	39	20	19	20	A-6b (V)	
	671.8	3																
HARD, MOTTLED BROWN AND GRAY, **SILT AND CLAY**, LITTLE SAND, TRACE STONE FRAGMENTS, MOIST		4	5 7 8	23	100	SS-2	4.50	2	3	13	40	42	34	19	15	20	A-6a (V)	
	669.3	5																
SHALE, GRAYISH BLACK, MODERATELY WEATHERED, SLIGHTLY STRONG, LAMINATED, SLIGHTLY PYRITIC, CARBONACEOUS, JOINT, HIGHLY FRACTURED, NARROW, SLIGHTLY ROUGH; VERY BLOCKY, FAIR; RQD 54%, REC 96%. @7.5' - 8.4'; HIGHLY WEATHERED @8.8'; FRACTURED; BLOCKY, GOOD. @9.7' - 9.8'; HIGH ANGLE FRACTURE		TR 6																
		7																
		8	13		92	NQ2-1											CORE	
		9																
		10																
@11.2' - 11.4'; HIGH ANGLE FRACTURE @11.5'; SLIGHTLY WEATHERED, SLIGHTLY FRACTURED.		11																
		12																
		13																
		14	95		100	NQ2-2											CORE	
@ 15.0' - 15.4'; γ = 157 pcf; Qu = 2,153 psi		15																
	659.3	EOB 16																

NOTES: LAT/LONG/ELEV FROM OGE SURVEY GRADE INSTRUMENTS.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 30 GAL. BENTONITE CEMENT GROUT

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 8/14/24 11:38 - X:\GINT\PROJECTS\2022 COMPLETE\601011.GPJ

PROJECT: ROS-772-10.40	DRILLING FIRM / OPERATOR: ODOT / LEWIS	DRILL RIG: CME 850R TRACKED	STATION / OFFSET: 12+00, 185 ft Rt (Approx)
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / MCINTOSH	HAMMER: CME AUTOMATIC	ALIGNMENT: CL SR 772
PID: 117701 SFN:	DRILLING METHOD: 3.75" HSA / NQ2	CALIBRATION DATE: 4/19/21	ELEVATION: 725.1 (ft) EOB: 56.0 ft.
START: 10/17/22 END: 10/19/22	SAMPLING METHOD: SPT / NQ2	ENERGY RATIO (%): 90*	LAT / LONG: 39.292827, -83.048711

EXPLORATION ID B-003-2-22

PAGE 1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 725.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	INCL.
STIFF, MOTTLED BROWN AND GRAY, **SILT AND CLAY**, LITTLE STONE FRAGMENTS, LITTLE SAND, DAMP		1																
		2	2 4	9	44	SS-1	1.50	17	7	9	38	29	32	19	13	19	A-6a (8)	
@3.0'; VERY STIFF		3	3 5 6	17	50	SS-2	3.00	-	-	-	-	-	-	-	-	18	A-6a (V)	
		5	4 4 4	12	72	SS-3	3.00	-	-	-	-	-	-	-	-	15	A-6a (V)	
		6	4 4 7	17	67	SS-4	3.00	-	-	-	-	-	-	-	-	14	A-6a (V)	
	717.6	7																
DENSE, YELLOWISH BROWN, **SANDY SILT**, SOME STONE FRAGMENTS, TRACE CLAY, DAMP		8	7 9 13	33	61	SS-5	2.50	32	1	28	29	10	NP	NP	NP	13	A-4a (1)	
		9	9 11 11	33	39	SS-6	-	-	-	-	-	-	-	-	-	10	A-4a (V)	
	714.6	10																
VERY STIFF, MOTTLED BROWN AND GRAY, **SANDY SILT**, SOME STONE FRAGMENTS, SOME CLAY, DAMP		11	9 10 10	30	89	SS-7	2.50	33	3	13	28	23	25	17	8	15	A-4a (3)	
@12.0'; STIFF		12	5 6 4	15	61	SS-8	2.00	-	-	-	-	-	-	-	-	17	A-4a (V)	
@13.5'; VERY STIFF		14	3 4 4	12	61	SS-9	2.50	-	-	-	-	-	-	-	-	17	A-4a (V)	
		15	3 4 5	14	44	SS-10	4.00	24	7	13	34	22	26	16	10	15	A-4a (4)	
@16.5'; STIFF		17	4 4 5	14	22	SS-11	2.00	-	-	-	-	-	-	-	-	14	A-4a (V)	
		18	4 5 5	15	33	SS-12	2.00	-	-	-	-	-	-	-	-	12	A-4a (V)	
	705.6	19																
HARD, BROWN MOTTLED WITH GRAY, **CLAY**, SOME SILT, LITTLE STONE FRAGMENTS, TRACE SAND, DAMP		20	4 7 8	23	67	SS-13	4.50	12	5	4	25	54	43	22	21	19	A-7-6 (13)	
		21	6 9 11	30	78	SS-14	4.5+	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
		22	5 8 9	26	56	SS-15	4.50	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
@24.0'; VERY STIFF		24	6 7 10	26	72	SS-16	3.50	12	7	3	26	52	41	22	19	18	A-7-6 (12)	
		25	5 7 10	26	61	SS-17	3.00	-	-	-	-	-	-	-	-	17	A-7-6 (V)	
@27.0'; HARD, BLACK, BROWN AND GRAY		27	5 6 9	23	83	SS-18	4.50	9	3	5	28	55	43	24	19	24	A-7-6 (12)	
		28	4 9 11	30	78	SS-19	4.50	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
		30	7 8 10	27	94	SS-20	4.00	-	-	-	-	-	-	-	-	21	A-7-6 (V)	
	693.6	31																
HARD, REDDISH BROWN AND GRAY, **SILT AND CLAY**, SOME STONE FRAGMENTS, LITTLE SAND, MOIST		32	9 13 13	39	100	SS-21	4.00	33	6	12	24	25	33	18	15	19	A-6a (5)	
@33.0' - 37.2'; ENCOUNTERED BOULDERS/COBBLES		34	8 21 29	75	83	SS-22	4.5+	-	-	-	-	-	-	-	-	16	A-6a (V)	
		35	16 33 49	123	100	SS-23	4.5+	-	-	-	-	-	-	-	-	13	A-6a (V)	
	687.9	36																
SHALE, GRAYISH BLACK, MODERATELY WEATHERED, WEAK, LAMINATED, CARBONACEOUS, JOINT, FRACTURED, NARROW, SLIGHTLY ROUGH; VERY BLOCKY, FAIR; RQD 58%, REC 100%.	TR	37																
@39.6' - 39.7'; HIGH ANGLE FRACTURE		39	0		100	NQ2-1											CORE	
		42																
@43.8'; SLIGHTLY WEATHERED, SLIGHTLY TO MODERATELY STRONG, MODERATELY FRACTURED; BLOCKY, GOOD.		44	29		100	NQ2-2											CORE	
@43.9' - 44.5'; HIGH ANGLE FRACTURE @44.5' - 44.6'; HIGH ANGLE FRACTURE @45.1' - 45.2'; HIGH ANGLE FRACTURE		46																
@ 46.9' - 47.4'; γ = 157 pcf; Qu = 3,335 psi		49	94		100	NQ2-3											CORE	
@51.35'; VERY THIN CLAY SEAM		52																
		54	100		100	NQ2-4											CORE	
	669.1	56	EOB															

NOTE:
PIEZOMETER INSTALLED IN OFFSET BORING.
SCREEN FROM 15.0' TO 20.0' AND 26.0' TO 36.0'.
BENTONITE SEAL 20.0' T 23.0'.
REMAINING ANNULUS GROUTED.

NOTES: LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM USGS 3DEP MAP SERVICE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 90 GAL. BENTONITE CEMENT GROUT

PROJECT: ROS-772-10.40
TYPE: LANDSLIDE
PID: 117701 SFN:
START: 10/11/22 END: 10/17/22

DRILLING FIRM / OPERATOR: ODOT / LEWIS
SAMPLING FIRM / LOGGER: ODOT / MCINTOSH
DRILLING METHOD: 3.75" HSA / NQ2
SAMPLING METHOD: SPT / NQ2

DRILL RIG: CME 850R TRACKED
HAMMER: CME AUTOMATIC
CALIBRATION DATE: 4/19/21
ENERGY RATIO (%): 90*

STATION / OFFSET: 16+38, 156 ft Rt (Approx)
ALIGNMENT: CL SR 772
ELEVATION: 716.0 (ft) EOB: 35.0 ft.
LAT / LONG: 39.293164, -83.047737

EXPLORATION ID B-005-1-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 716.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	INCL.
STIFF, BROWN AND REDDISH BROWN, **SANDY SILT**, SOME STONE FRAGMENTS, LITTLE CLAY, DAMP		1																
		2	4 4 3	11	44	SS-1	1.75	34	7	11	31	17	27	17	10	15	A-4a (3)	
@3.0'; MOIST		3	1 4 3	11	44	SS-2	1.00	-	-	-	-	-	-	-	-	19	A-4a (V)	
	711.5	4																
STIFF, BROWN MOTTLED WITH GRAY, **CLAY**, SOME SILT, LITTLE STONE FRAGMENTS, TRACE SAND, DAMP		5			54	ST-3	4.00	13	3	3	26	55	46	20	26	19	A-7-6 (16)	
@5.0'; QU = 3,787 PSF @ 6.3% STRAIN; γ_d = 110.30 PCF		6																
@6.5'; VERY STIFF		7	2 4 4	12	44	SS-4	3.00	-	-	-	-	-	-	-	-	19	A-7-6 (V)	
		8																
		9	2 4 6	15	56	SS-5	4.00	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
	705.0	10	2 4 9	20	72	SS-6	3.00	16	4	6	27	47	42	19	23	20	A-7-6 (13)	
HARD, MOTTLED BROWN AND GRAY, **SILT AND CLAY**, LITTLE SAND, LITTLE STONE FRAGMENTS,, CONTAINS COBBELS AND BOULDERS, DAMP		11	23 32 56	132	83	SS-7	4.50	10	4	13	44	29	28	16	12	15	A-6a (8)	
@20.4' - 21.5'; DROVE ON BOULDERS/COBBLES		12																
		13	18 14 13	41	83	SS-8	4.50	-	-	-	-	-	-	-	-	15	A-6a (V)	
		14																
		15	11 12 15	41	100	SS-9	4.50	19	6	9	37	29	31	17	14	16	A-6a (8)	
MOIST @15.5' - 17.0'; ENCOUNTERED BOULDERS/COBBLES, MOVED HOLE 5' EAST AFTER ENCOUNTERING BOULDERS		16	9 12 13	38	100	SS-10	4.5+	-	-	-	-	-	-	-	-	18	A-6a (V)	
		17																
@18.5'; VERY STIFF		18	7 18 20	57	89	SS-11	4.50	-	-	-	-	-	-	-	-	15	A-6a (V)	
		19	10 25 17	63	72	SS-12	3.50	14	4	12	42	28	27	15	12	17	A-6a (8)	
@20.0'; HARD		20	50/5"	-	100	SS-13	4.5+	-	-	-	-	-	-	-	-	17	A-6a (V)	
	694.5	21																
VERY STIFF, GRAY, **CLAY**, SOME SILT, TRACE STONE FRAGMENTS, TRACE SAND, DAMP		22	3 7 9	24	39	SS-14	3.00	8	1	6	31	54	42	21	21	18	A-7-6 (13)	
	693.0	23																
SHALE, GRAY, MODERATELY WEATHERED, VERY WEAK, LAMINATED.	TR	23	20 56	-	100	SS-15	-	-	-	-	-	-	-	-	-	10	Rock (V)	
		24																
	691.0	25	53	-	100	SS-16	-	-	-	-	-	-	-	-	-	6	Rock (V)	
SHALE, GRAYISH BLACK, HIGHLY TO MODERATELY WEATHERED, SLIGHTLY STRONG, LAMINATED, CARBONACEOUS, JOINT, MODERATELY FRACTURED TO HIGHLY FRACTURED, NARROW, SLIGHLTY ROUGH; BLOCKY, FAIR TO POOR; RQD 33%, REC 100%.		26	0		100	NQ2-1											CORE	
		27																
		28	11		100	NQ2-2											CORE	
		29																
		30																
@ 30.5' - 30.9'; γ = 159 pcf; Qu = 2,447 psi		31																
		32																
		33	60		100	NQ2-3											CORE	
		34																
	681.0	35	EOB															

NOTE:
PIEZOMETER INSTALLED IN OFFSET BORING.
SCREEN FROM 20.0' TO 30.0' WITH SAND TO 18.5'.
REMAINING ANNULUS GROUTED.

NOTES: LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM USGS 3DEP MAP SERVICE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 60 GAL. BENTONITE CEMENT GROUT

UNCONFINED COMPRESSION TEST
AASHTO T - 208

OHIO DEPARTMENT OF TRANSPORTION
OFFICE OF GEOTECHNICAL ENGINEERING

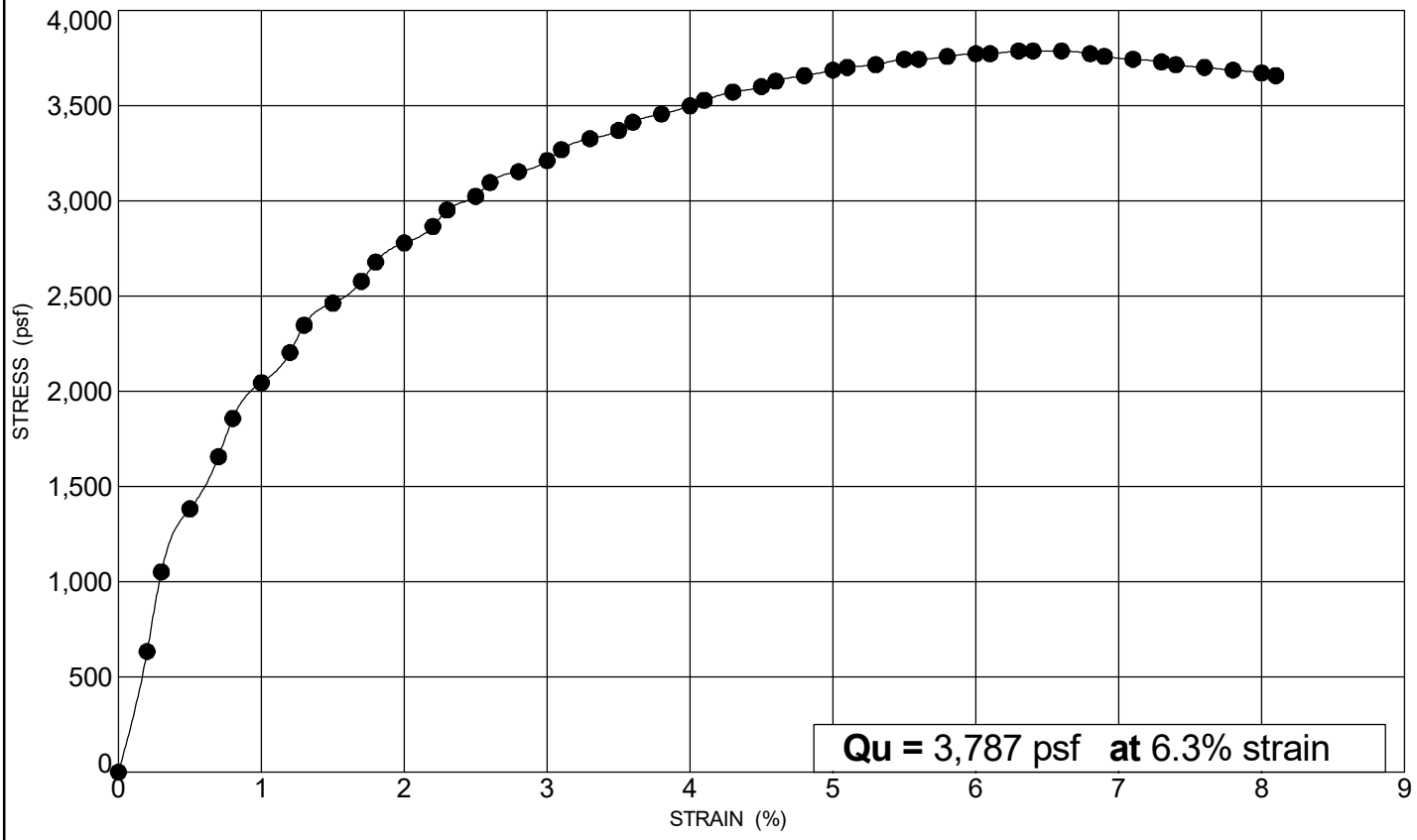
PROJECT ROS-772-10.40 **PID** 117701

OGE NUMBER 601011 **PROJECT TYPE** GEOHAZARD EXPLORATION

SAMPLE IDENTIFICATION

BORING ID: B-005-1-22 SAMPLE ID: ST-3

STATION: NOT RECORDED DEPTH: 5.0 - 5.5 feet



SPECIMEN FAILURE SKETCHES OR PHOTOGRAPHS

FRONT VIEW

SIDE VIEW

SPECIMEN DETAILS

HEIGHT: 5.75 inches

DIAMETER: 2.89 inches

WET UNIT WT: 131.29 pcf

DRY UNIT WT: 110.30 pcf

TESTED BY: AW 10/18/2022

CLASSIFICATION RESULTS

GRADATION (%)

GR	CS	FS	SI	CL
13	3	3	26	55

ATTERBERG LIMITS			MOISTURE
LL	PL	PI	WC
46	20	26	19

ODOT CLASS: A-7-6 HP (tsf): 4.00

DESCRIPTION: Stiff, Brown Mottled With Gray, **CLAY**, Some Silt, Trace Sand, Trace Stone Fragments, Damp

OHDOT UNCONFINED COMPRESSION - OH DOT.GDT - 11/7/22 11:18 - X:\GINT\PROJECTS\601011.GPJ

OHIO DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING

Office of Geotechnical Engineering

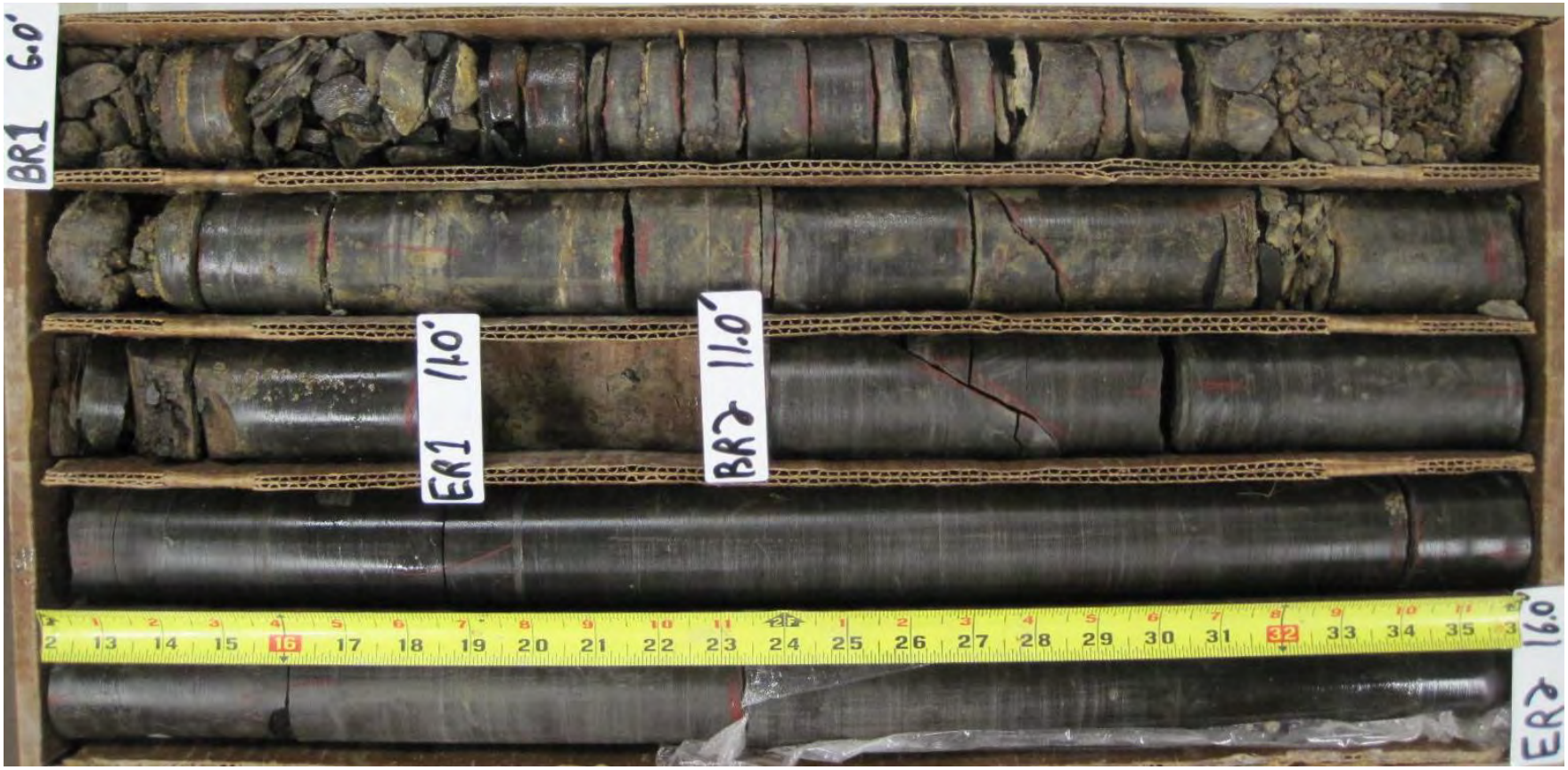
B-002-2-22

Run #:	Depth		Recovery		RQD	
NQ2-1	36.5’	41.5’	60/60	100%	10/60	17%
NQ2-2	41.5’	46.5’	60/60	100%	60/60	100%
ROS-772-10.40 PID 117701						

OHIO DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING

Office of Geotechnical Engineering

B-003-1-22



Run #:	Depth		Recovery		RQD	
NQ2-1	6.0’	11.0’	55/60	92%	8/60	13%
NQ2-2	11.0’	16.0’	60/60	100%	57/60	95%
ROS-772-10.40 PID 117701						

OHIO DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING

Office of Geotechnical Engineering

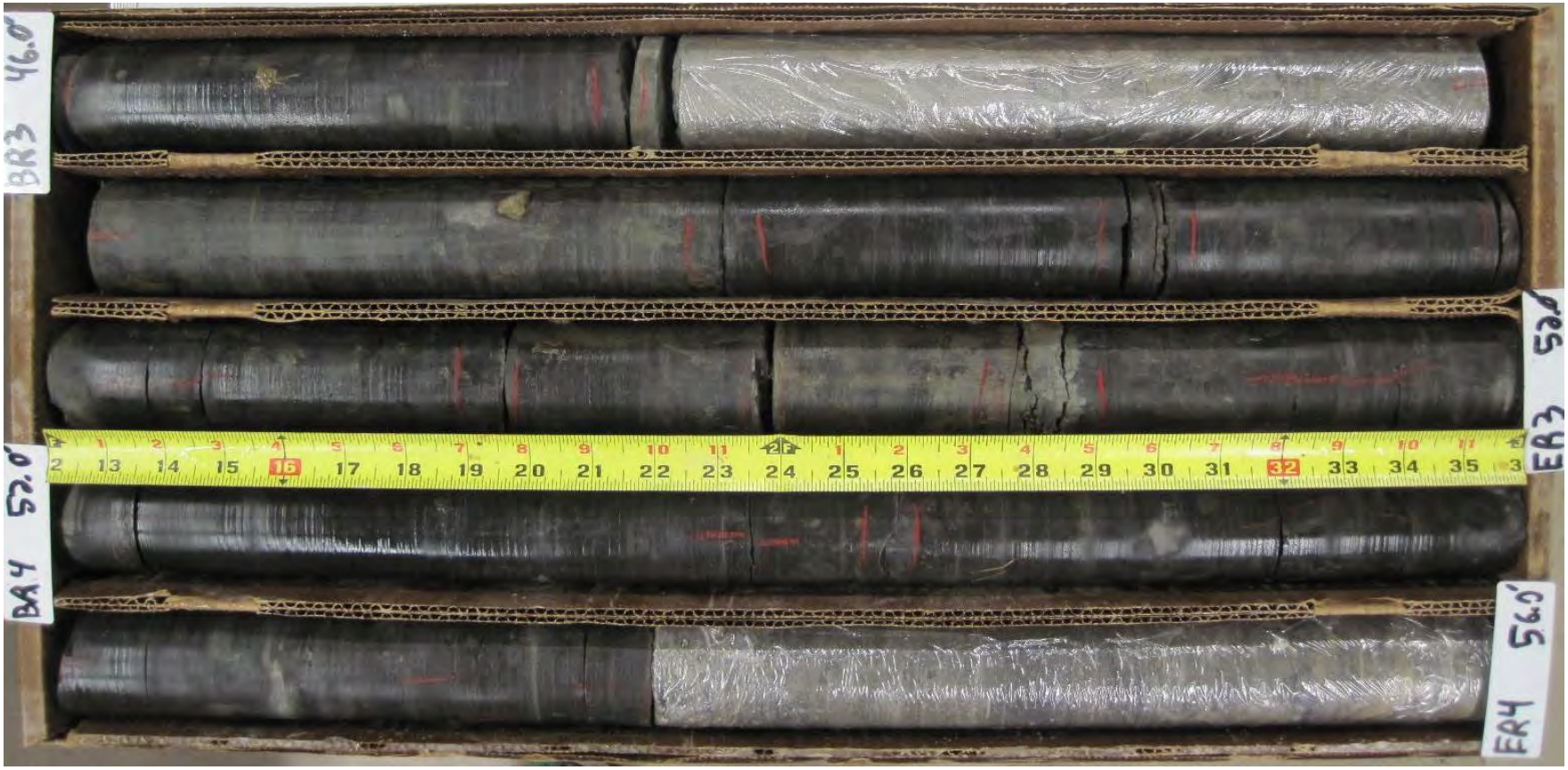
B-003-2-22

Run #:	Depth		Recovery		RQD	
NQ2-1	36.0’	42.0’	72/72	100%	0/72	0%
NQ2-2	42.0’	46.0’	48/48	100%	14/48	29%
ROS-772-10.40 PID 117701						

OHIO DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING

Office of Geotechnical Engineering

B-003-2-22



Run #:	Depth		Recovery		RQD	
NQ2-3	46.0’	52.0’	72/72	100%	68/72	94%
NQ2-4	52.0’	56.0’	48/48	100%	48/48	100%
ROS-772-10.40 PID 117701						

OHIO DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING

Office of Geotechnical Engineering

B-005-1-22

Run #:	Depth		Recovery		RQD	
NQ2-1	25.0’	27.0’	24/24	100%	0/24	0%
NQ2-2	27.0’	30.0’	36/36	100%	4/36	11%
NQ2-3	30.0’	35.0’	60/60	100%	36/60	60%
ROS-772-10.40 PID 117701						

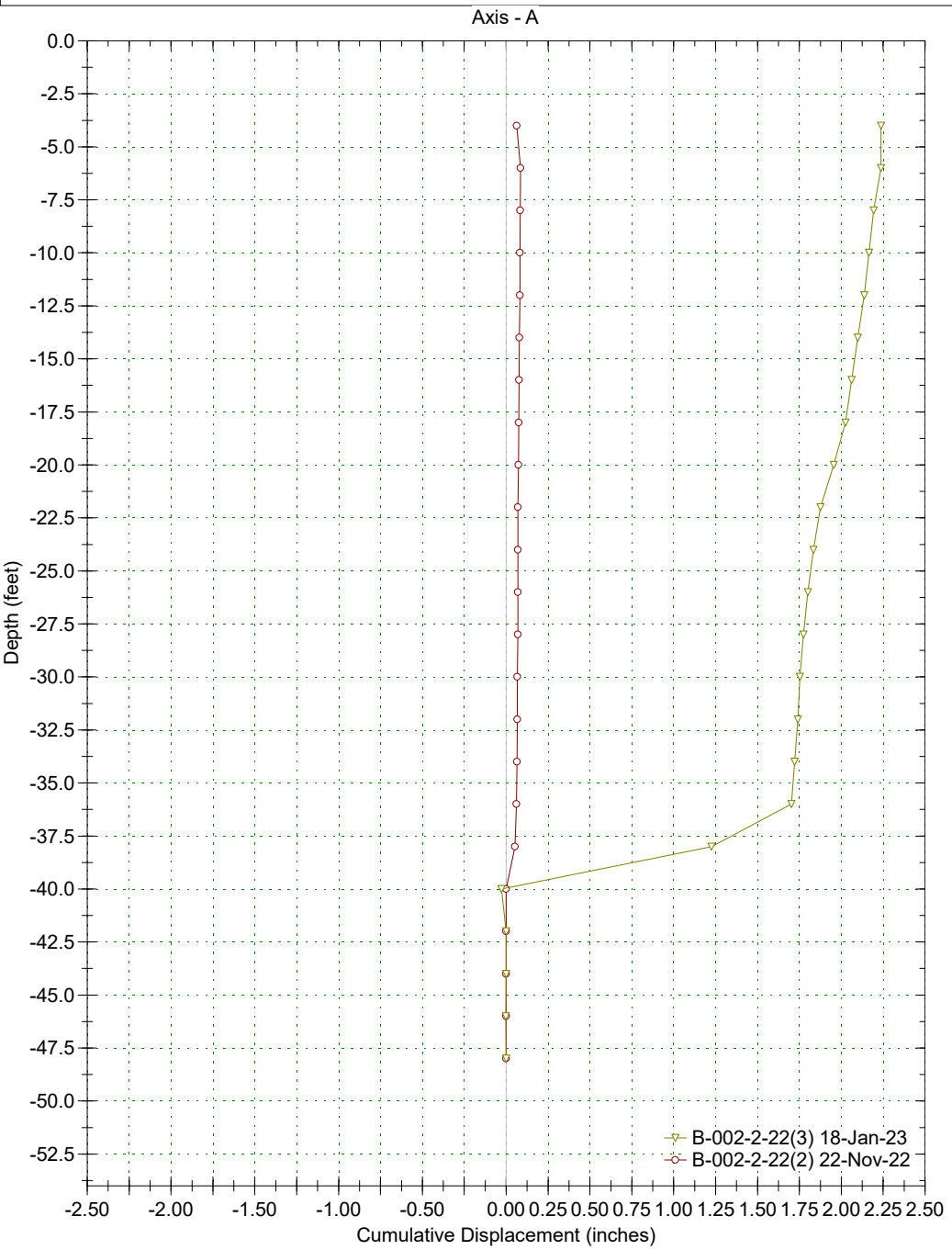
RST Instruments Ltd.

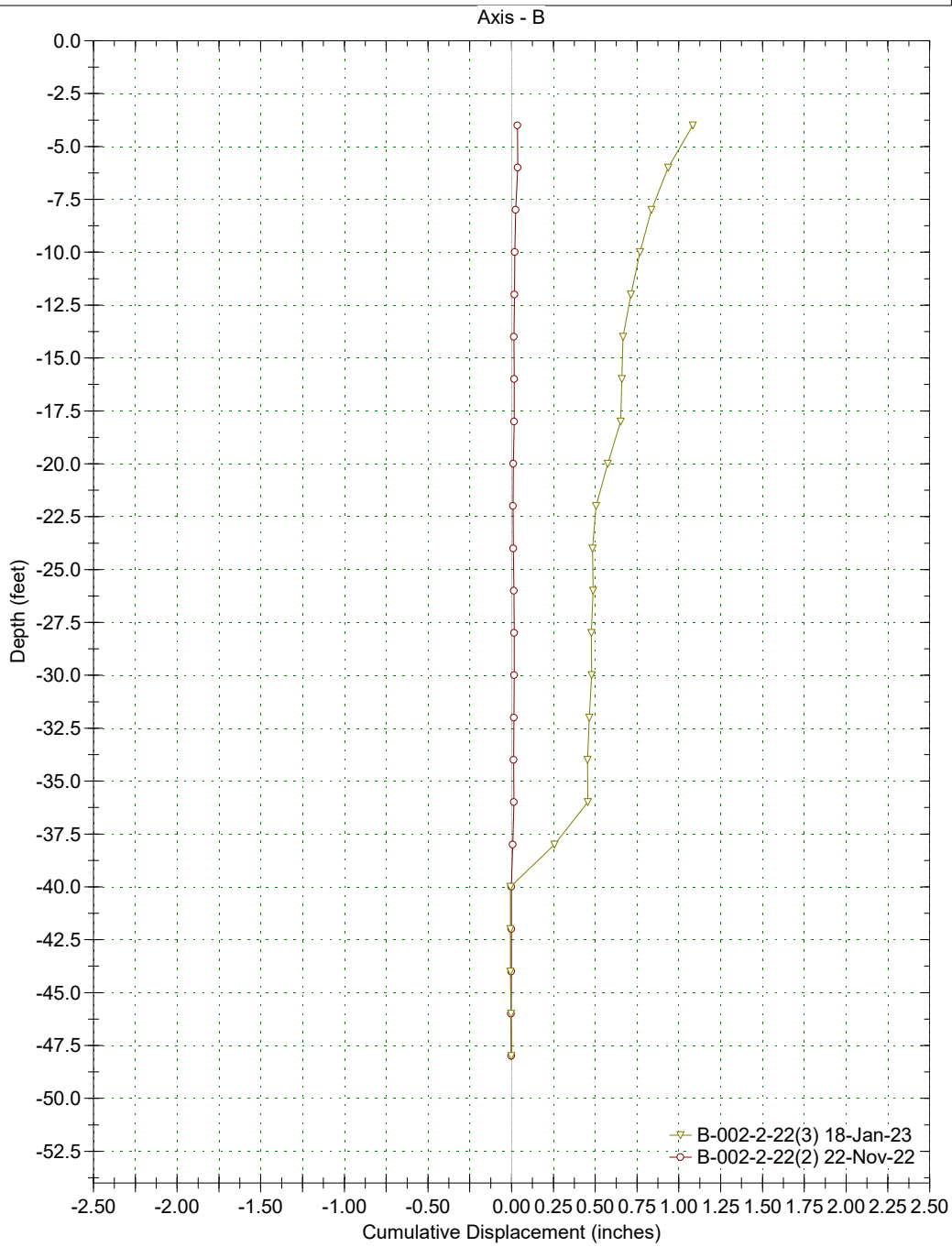
CUMULATIVE DISPLACEMENT

Inclinalysis v. 2.48.7

Borehole : B-002-2-22
Project : ROS-772-10.4
Location :
Northing :
Easting :
Collar :

Spiral Correction : N/A
Collar Elevation : 0.00 feet
Reading Depth : 48.0 feet
A+ Groove Azimuth :
Base Reading : 2022 Nov 08 13:20
Applied Azimuth : 0.0 degrees





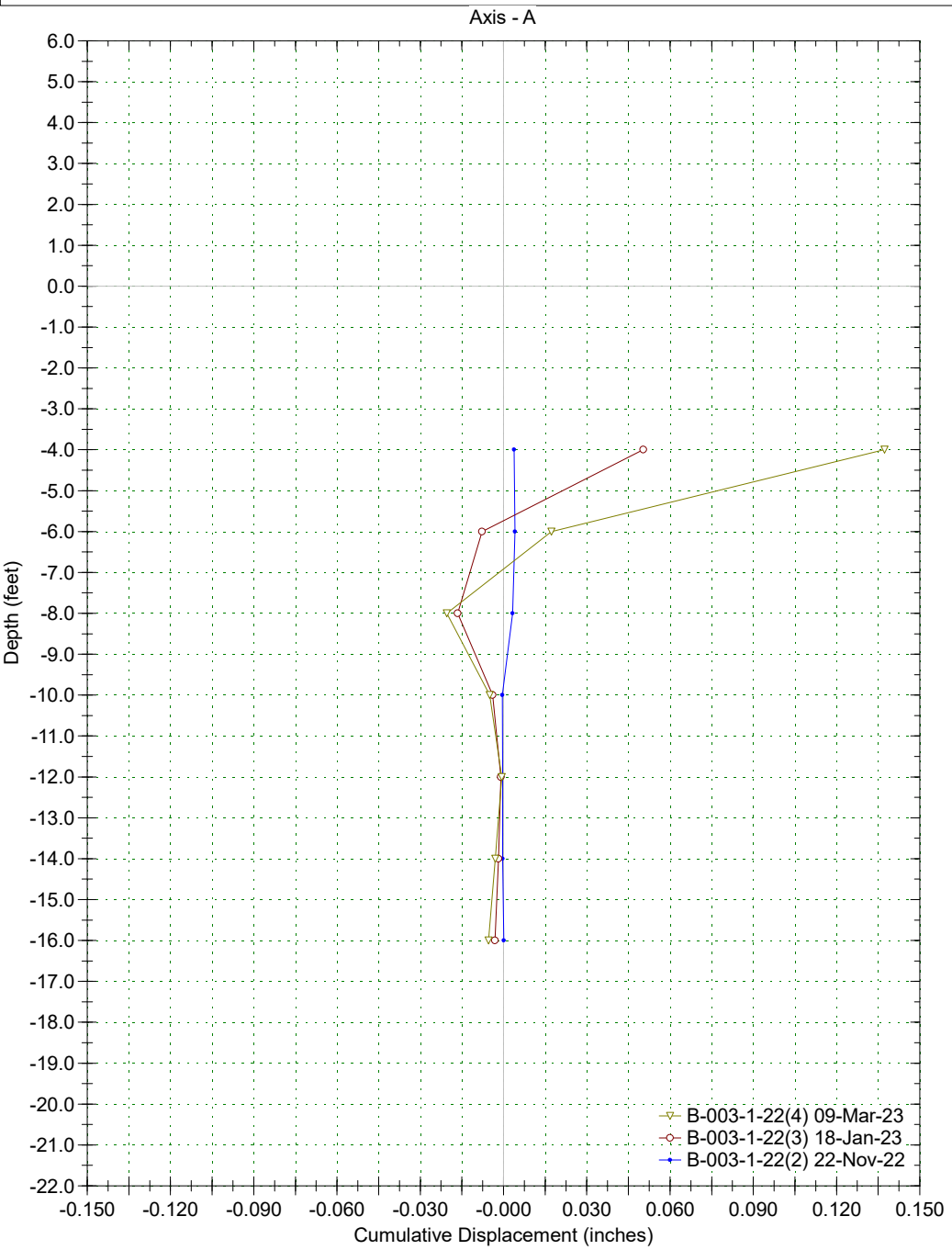
RST Instruments Ltd.

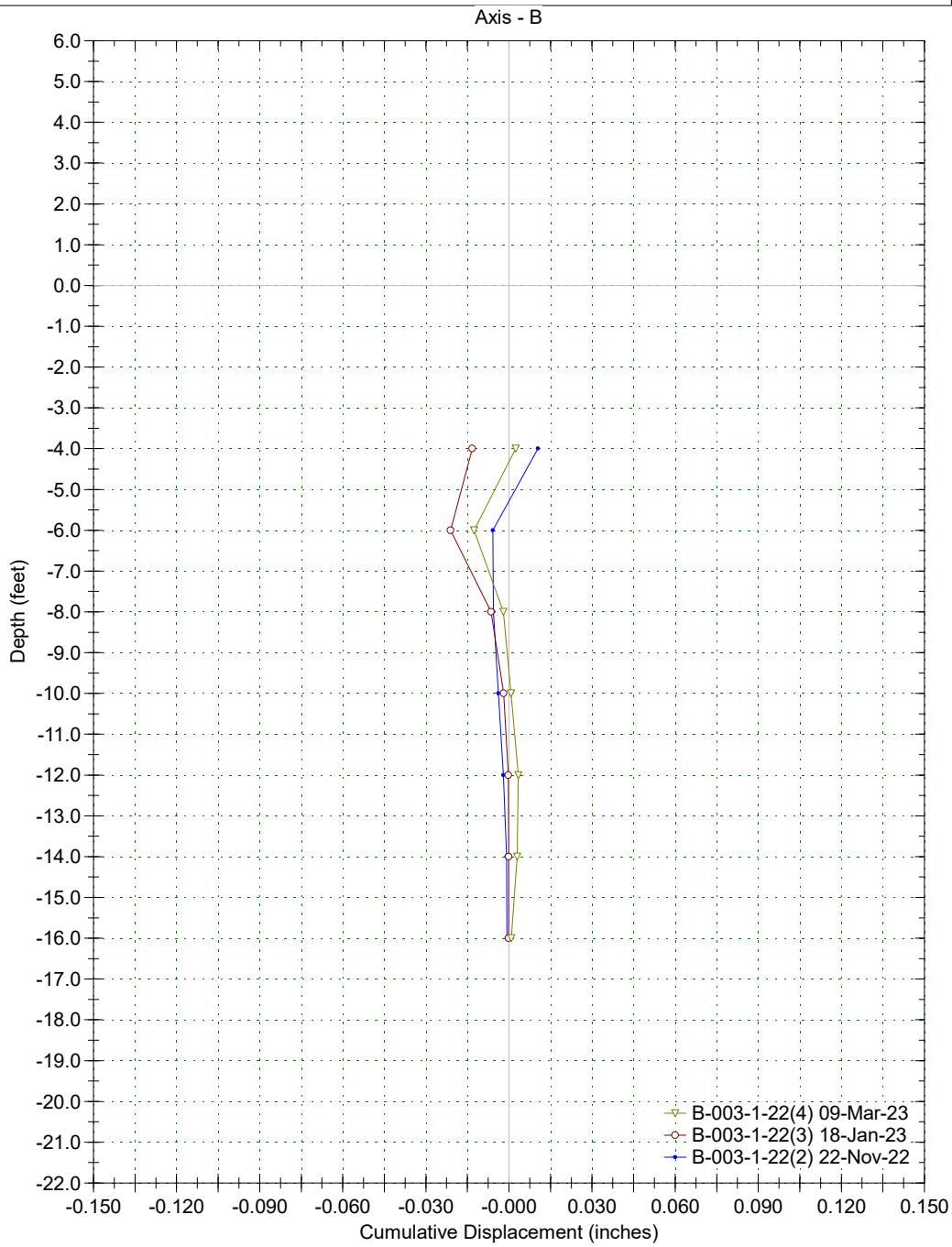
CUMULATIVE DISPLACEMENT

Inclinalysis v. 2.48.7

Borehole : B-003-1-22
Project : ROS-772-10.4
Location :
Northing :
Easting :
Collar :

Spiral Correction : N/A
Collar Elevation : 0.00 feet
Reading Depth : 16.0 feet
A+ Groove Azimuth :
Base Reading : 2022 Nov 08 14:14
Applied Azimuth : 0.0 degrees





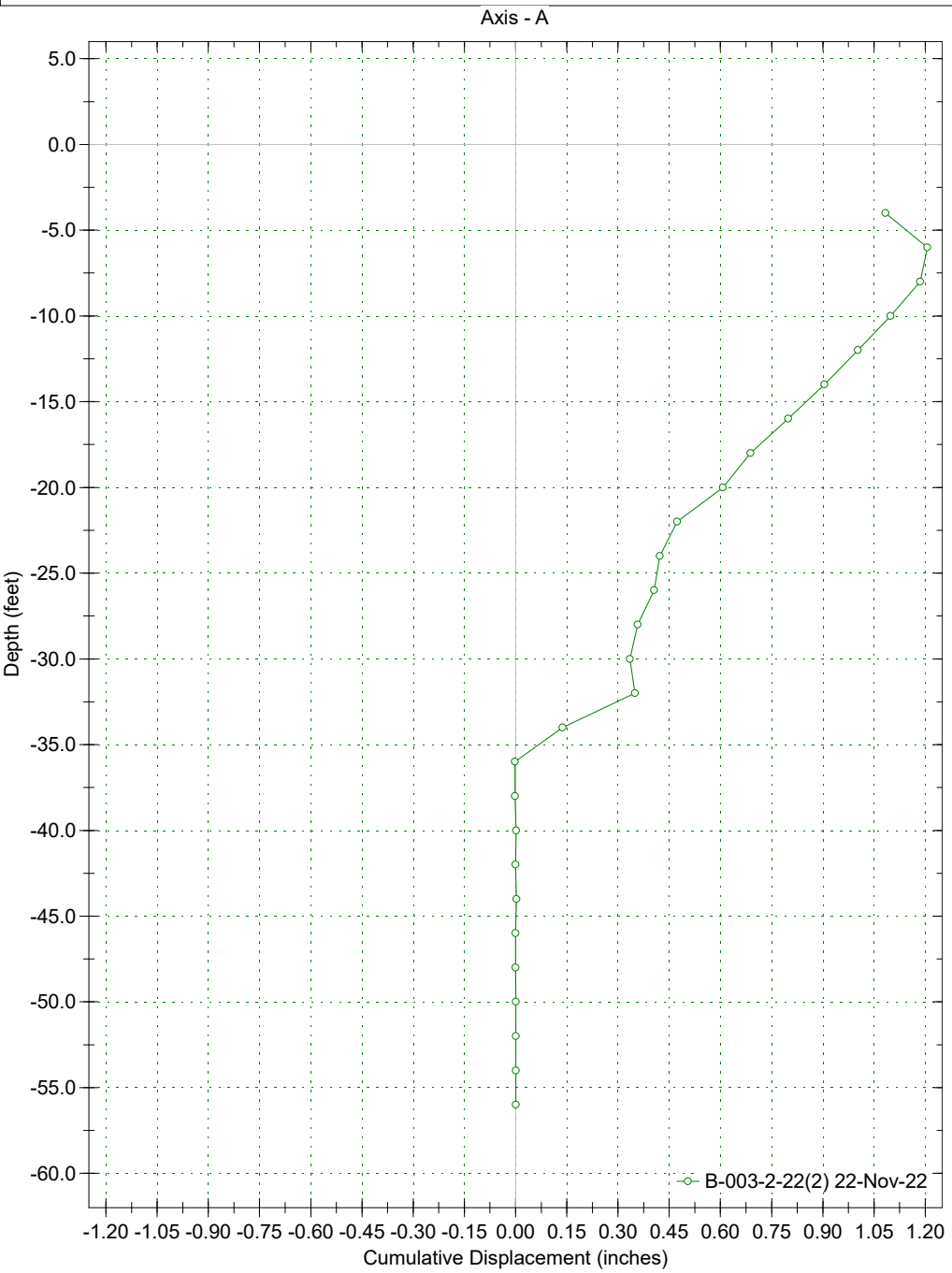
RST Instruments Ltd.

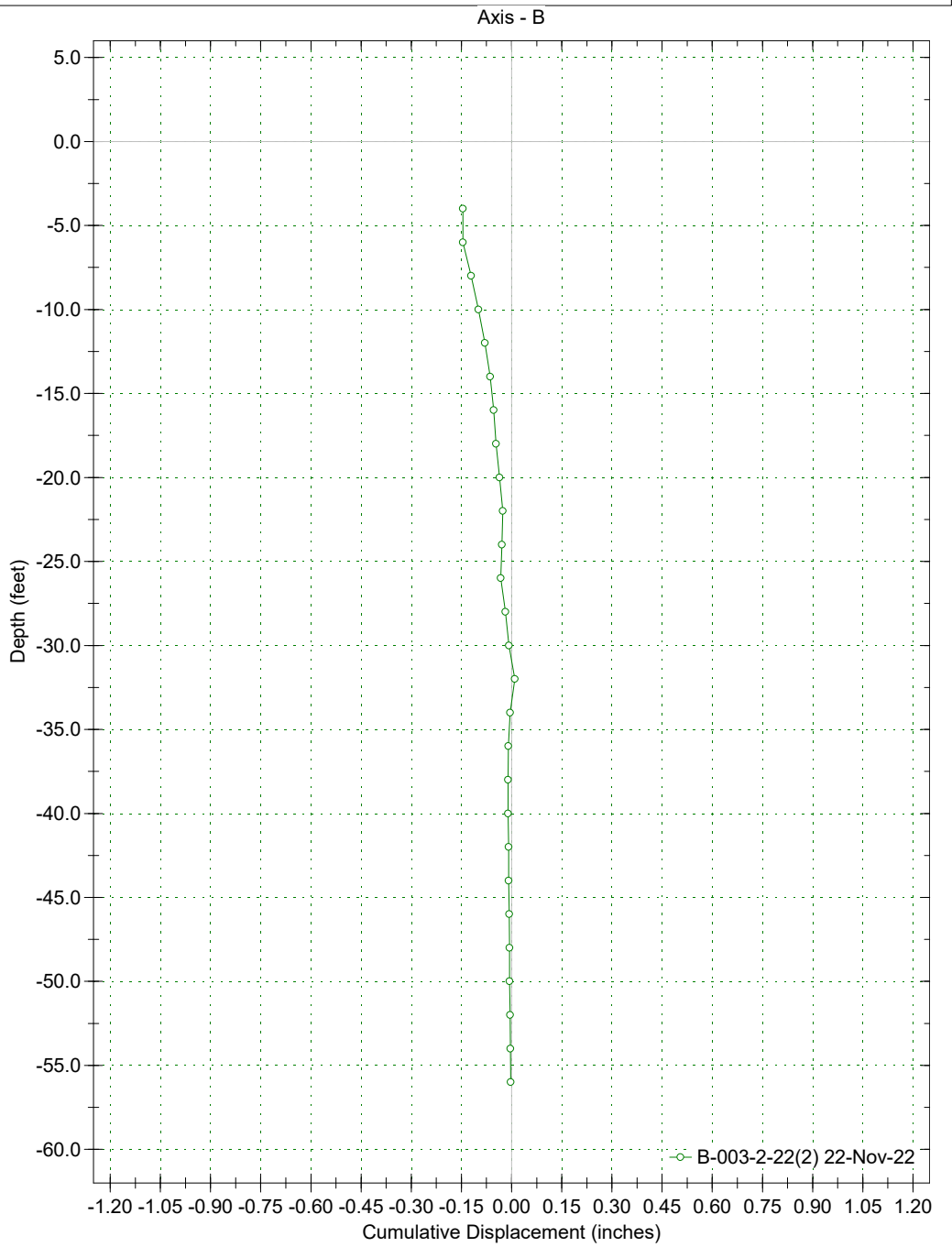
CUMULATIVE DISPLACEMENT

Inclinalysis v. 2.48.7

Borehole : B-003-2-22
Project : ROS-772-10.4
Location :
Northing :
Easting :
Collar :

Spiral Correction : N/A
Collar Elevation : 0.00 feet
Reading Depth : 56.0 feet
A+ Groove Azimuth :
Base Reading : 2022 Nov 08 13:37
Applied Azimuth : 0.0 degrees





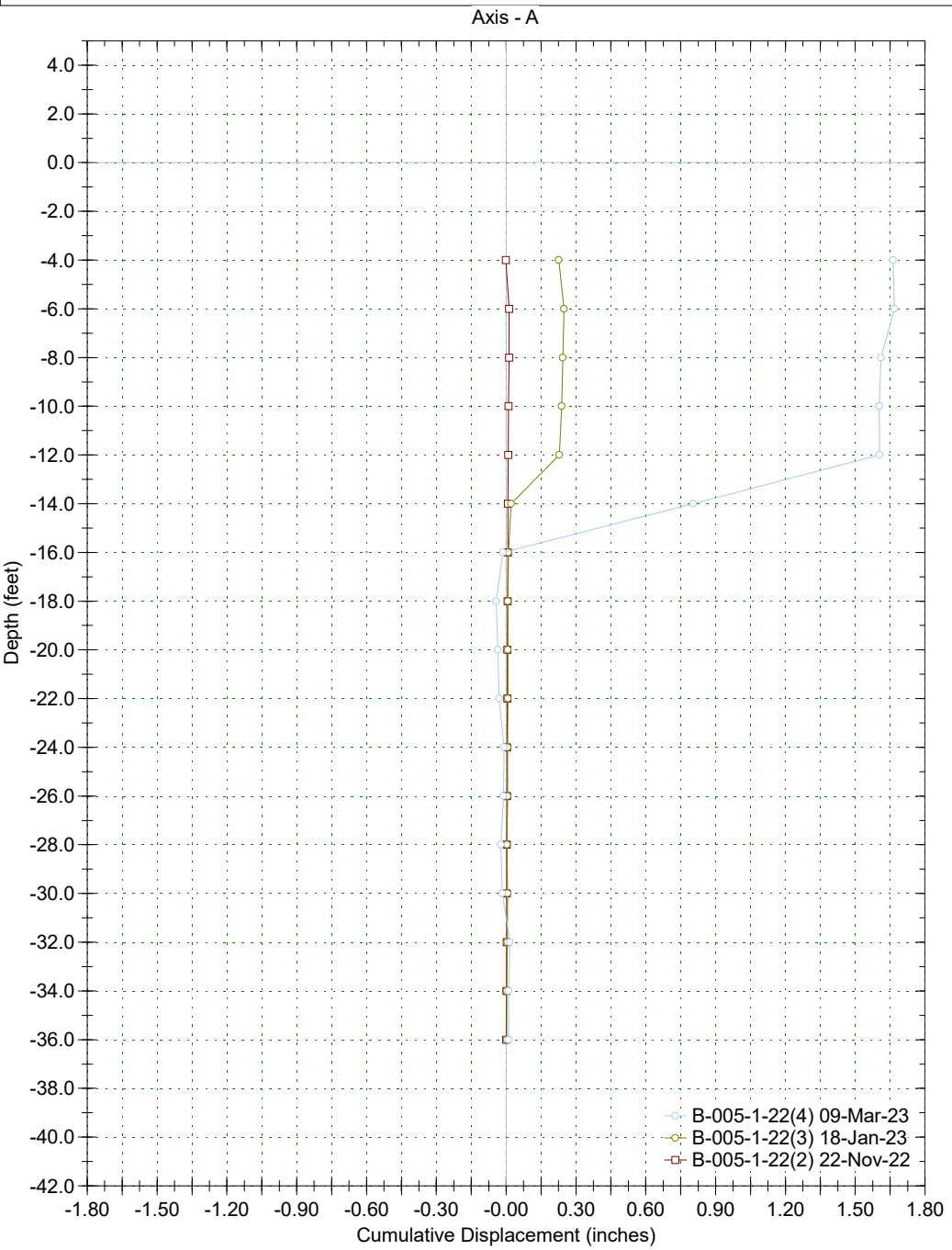
RST Instruments Ltd.

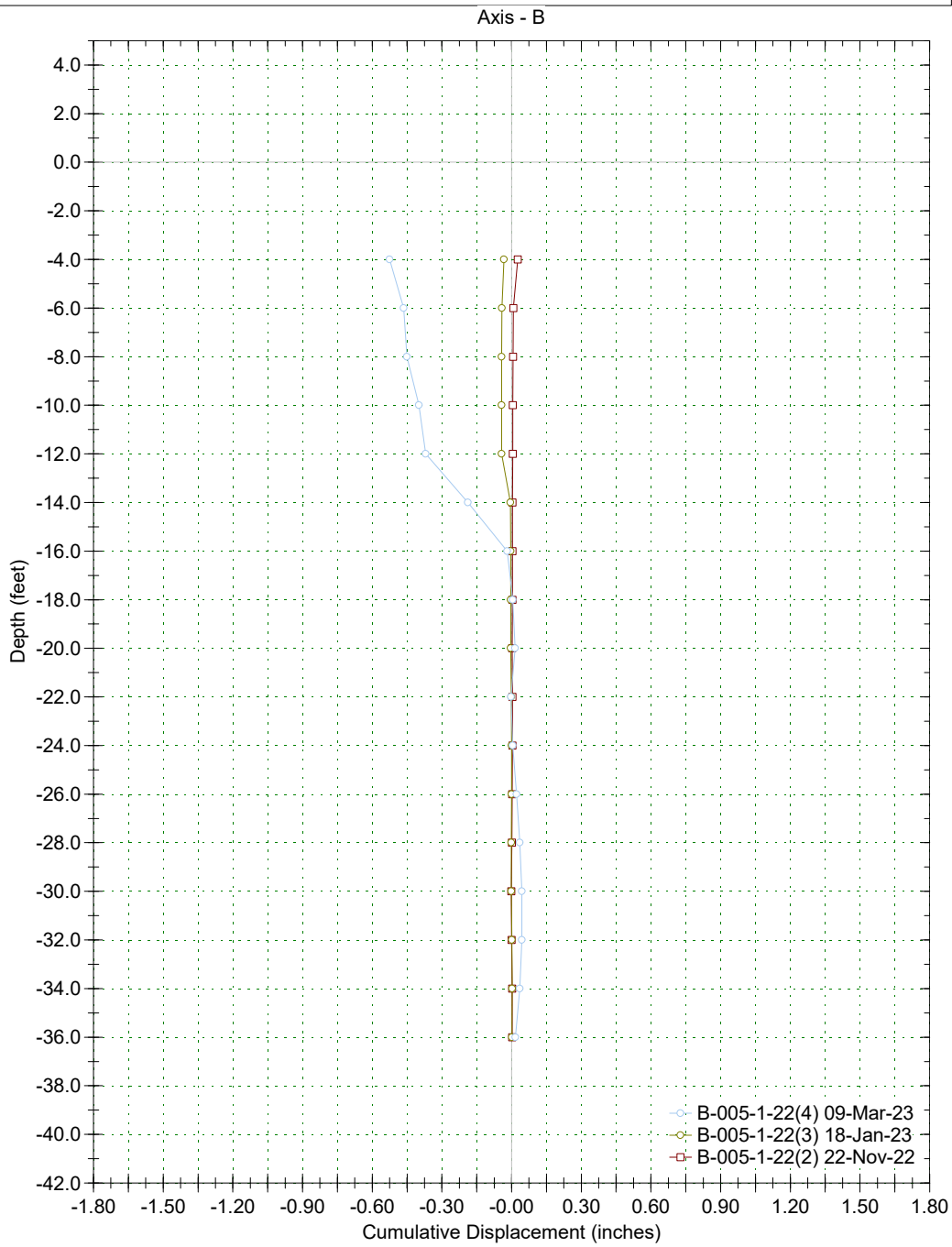
CUMULATIVE DISPLACEMENT

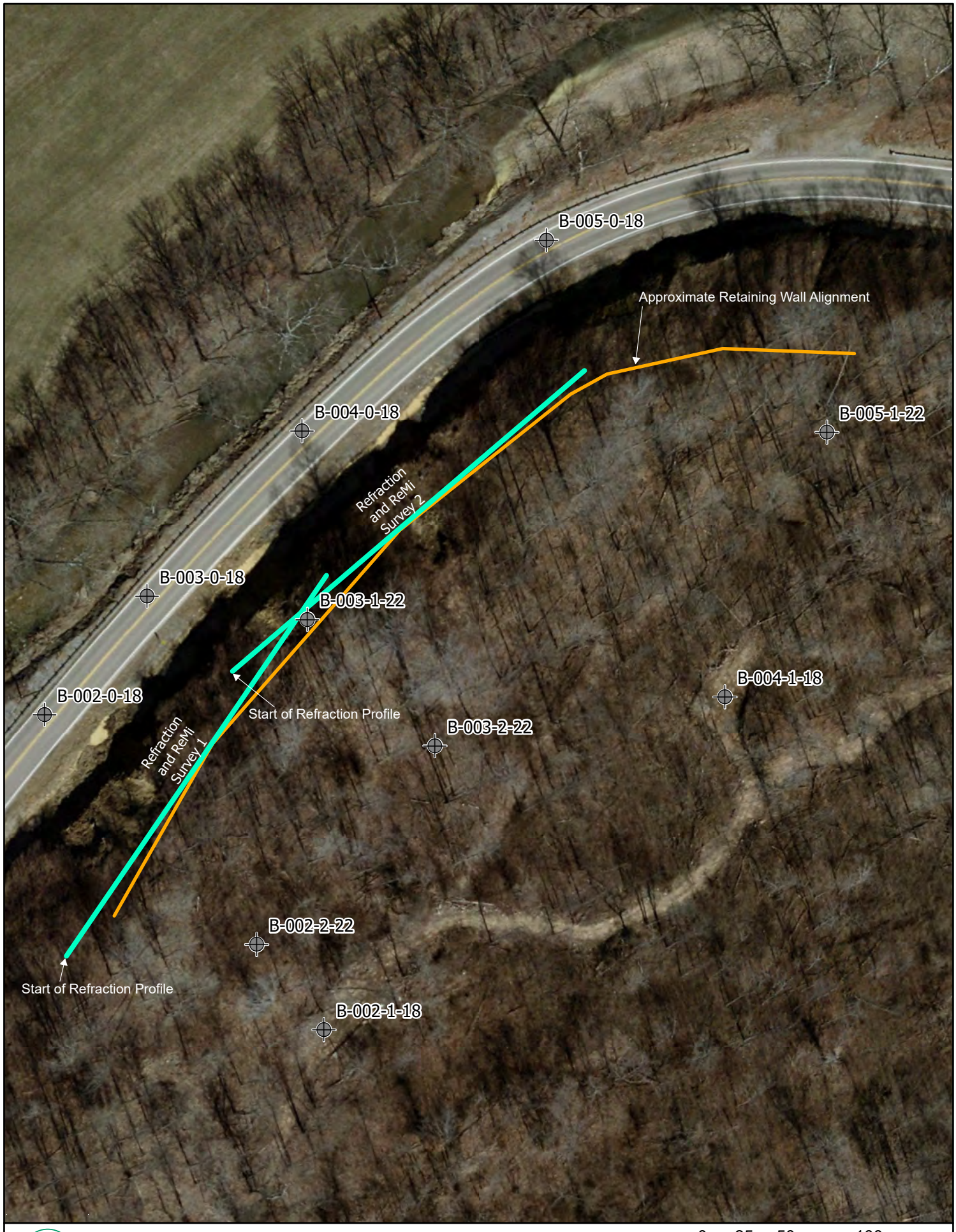
Inclinalysis v. 2.48.7

Borehole : B-005-1-22
Project : ROS-772-10.4
Location :
Northing :
Easting :
Collar :

Spiral Correction : N/A
Collar Elevation : 0.00 feet
Reading Depth : 36.0 feet
A+ Groove Azimuth :
Base Reading : 2022 Nov 08 13:57
Applied Azimuth : 0.0 degrees



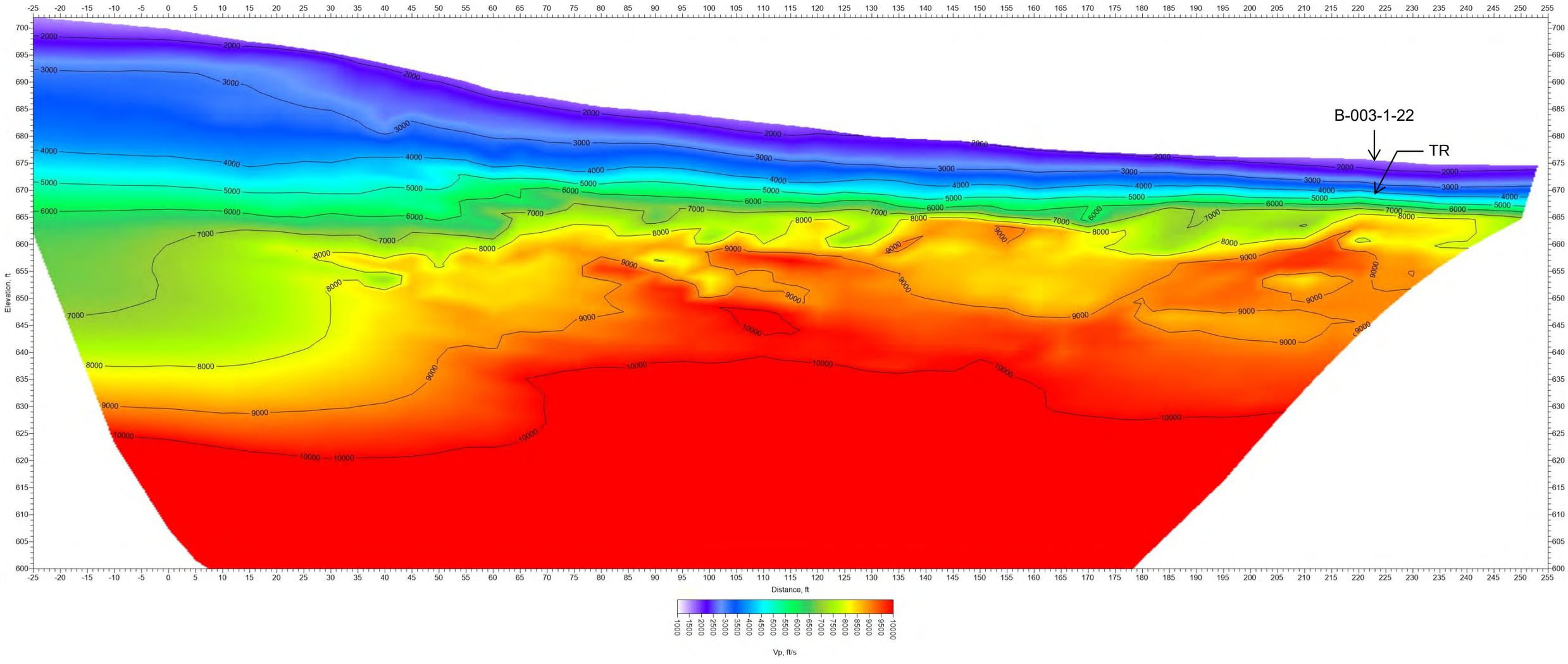




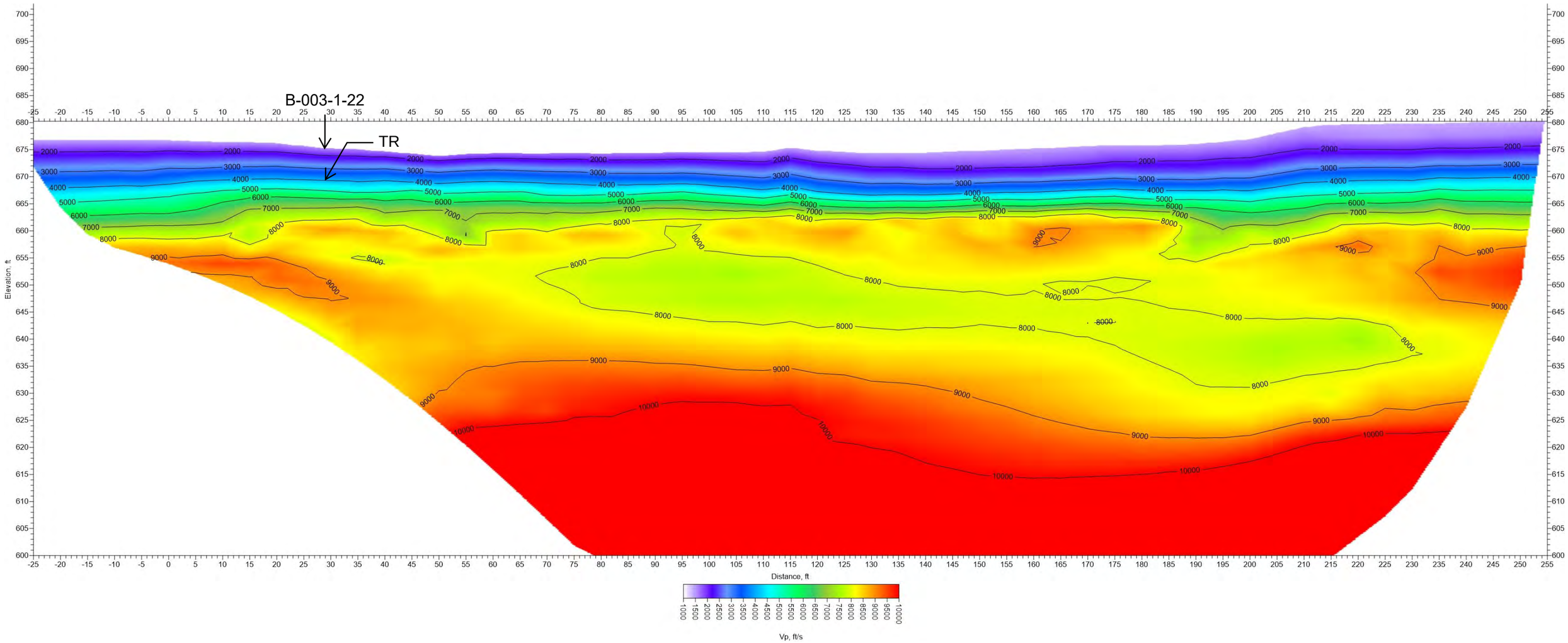
ROS-772-10.40
Exploration Plan

0 25 50 100
Feet

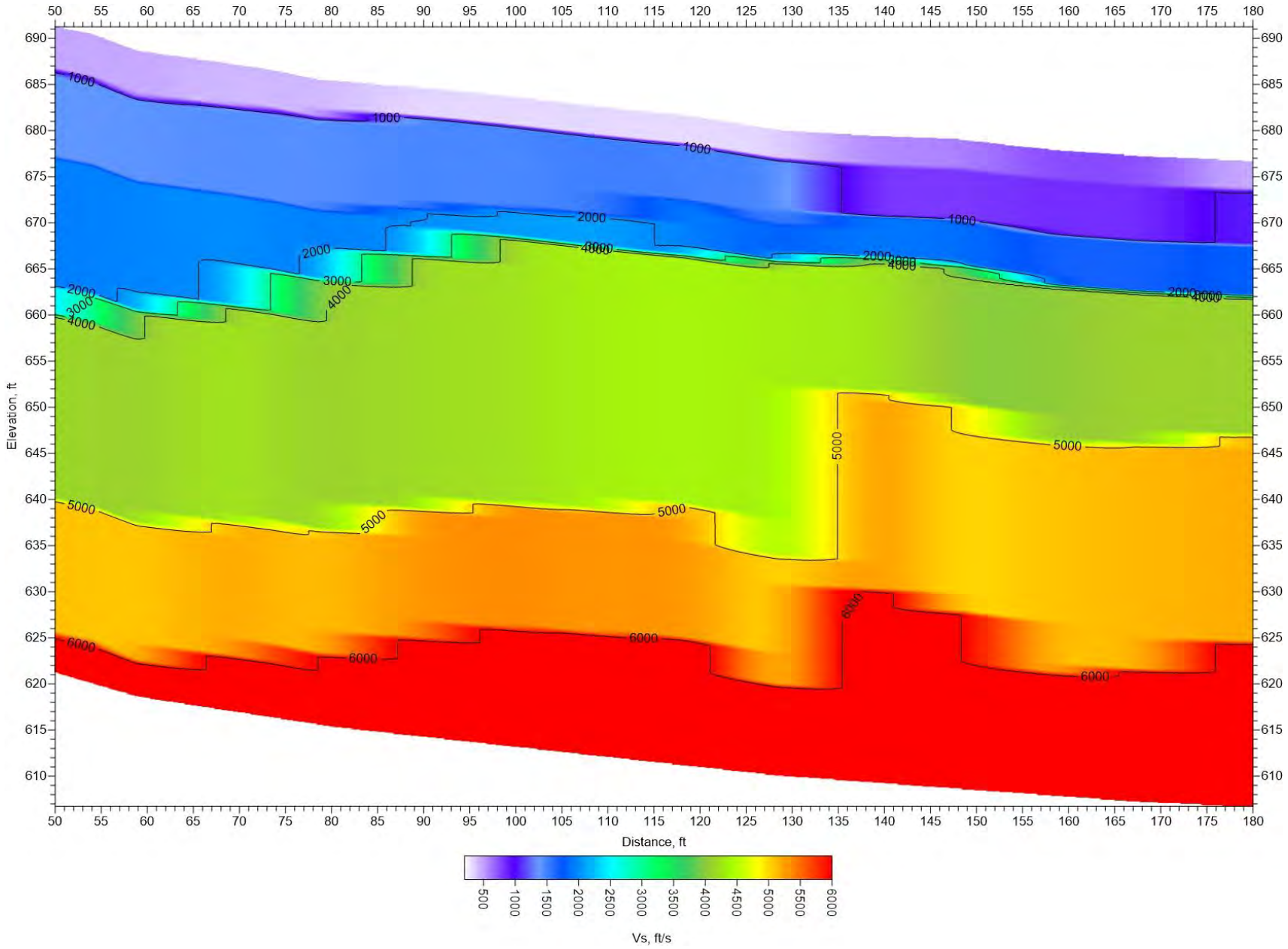
ROS-772-1040 Refraction Survey Line 1



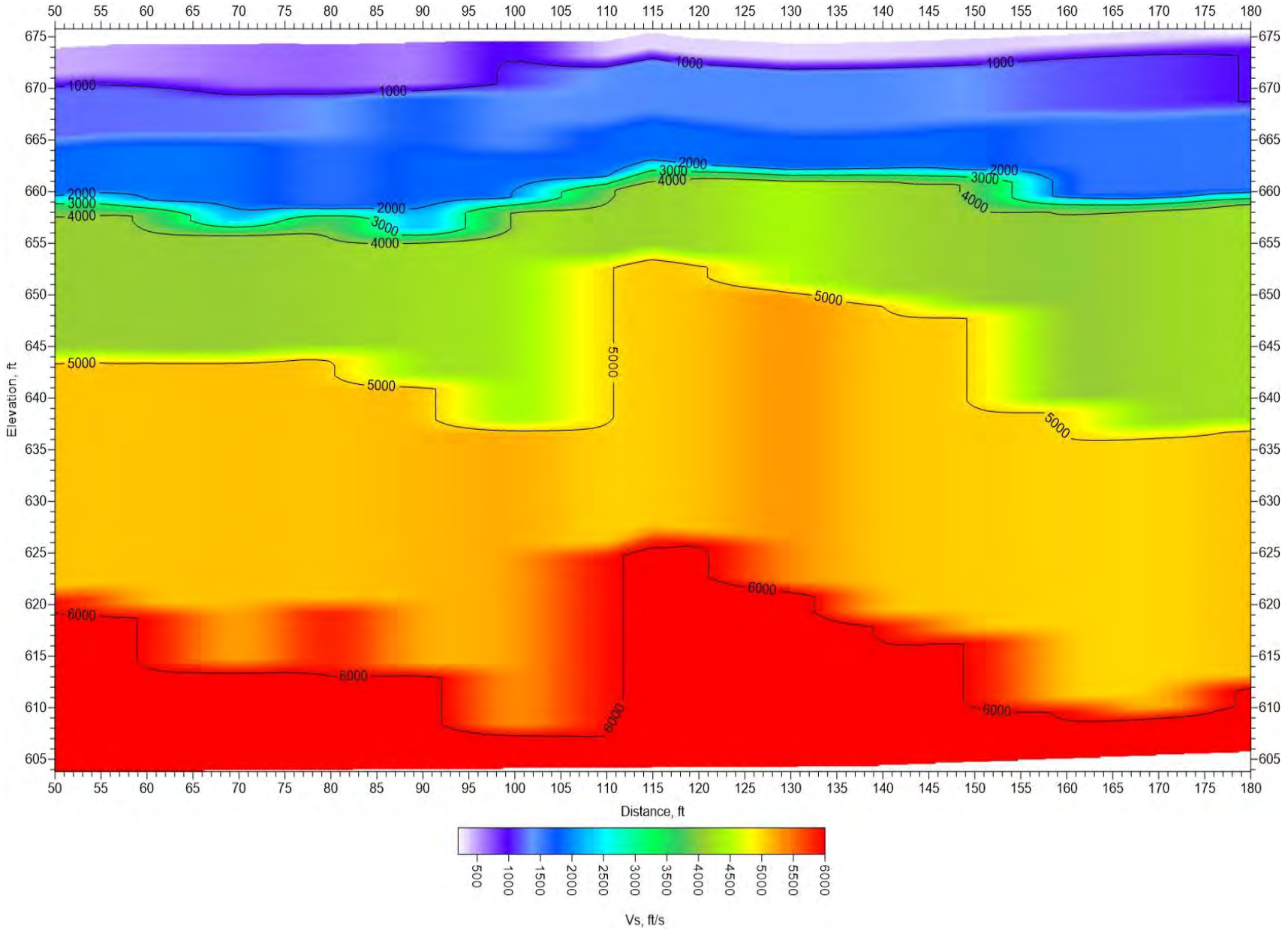
ROS-772-1040 Refraction Survey Line 2



ROS-772-1040 Refraction Microtremor Survey Line 2

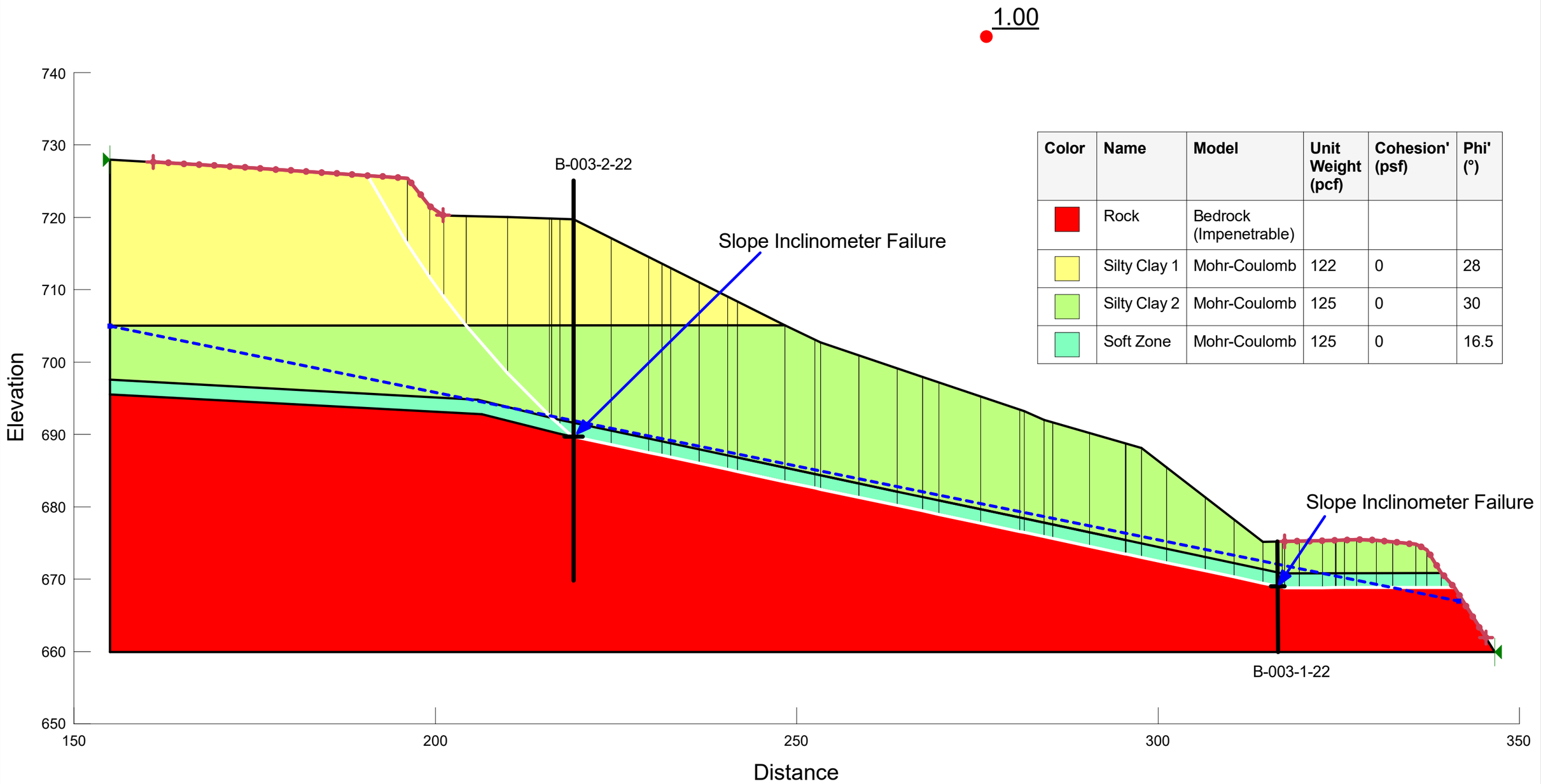


ROS-772-1040 Refraction Microtremor Survey Line 2



APPENDIX B
SLOPE STABILITY ANALYSIS

ROS-772-10.40	**Slope Stability Analysis - FS = 1.00**	Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.
ODOT District 9		
Analysis Cross-Section-Back Analysis	Slope Stability	



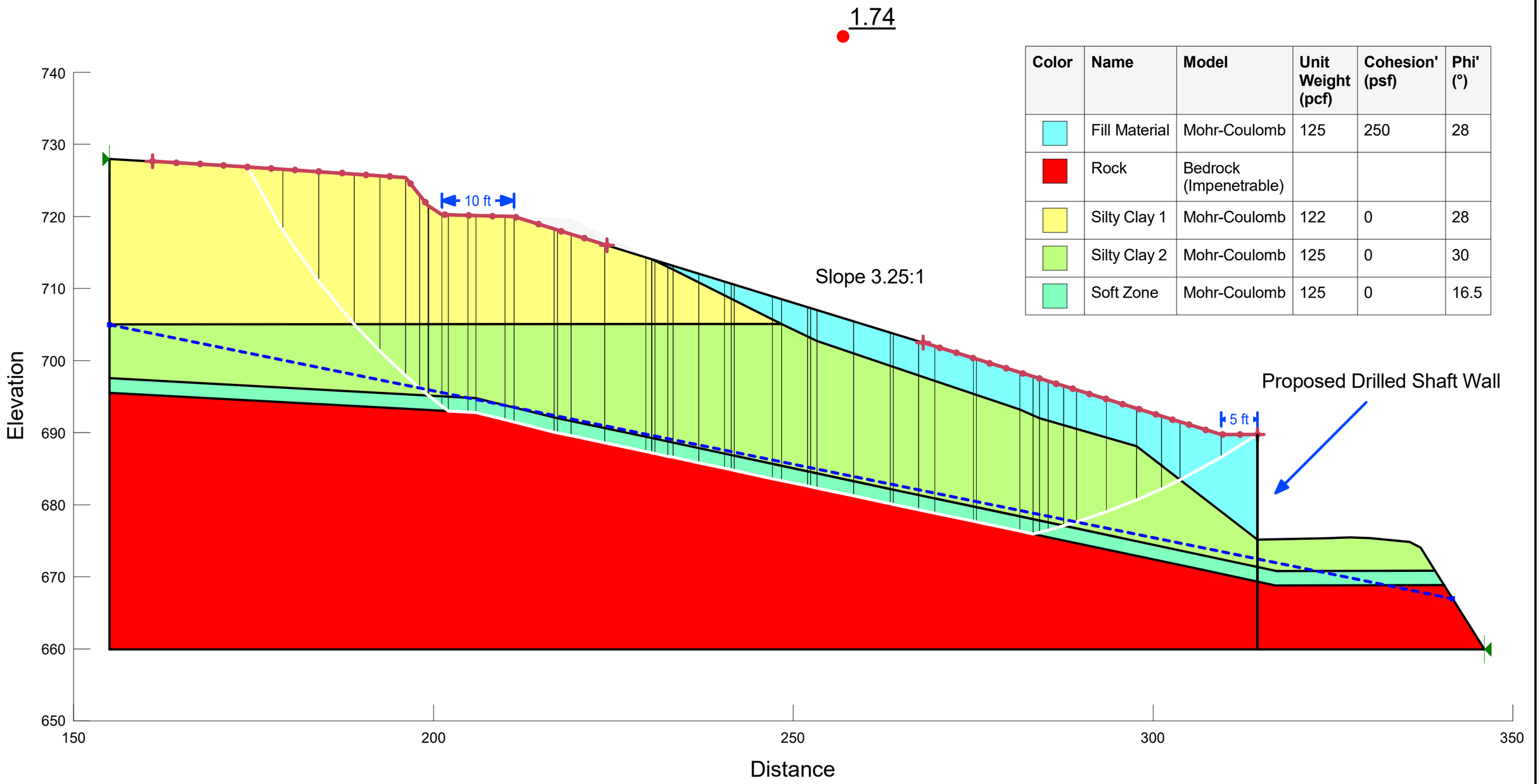
Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Rock	Bedrock (Impenetrable)			
	Silty Clay 1	Mohr-Coulomb	122	0	28
	Silty Clay 2	Mohr-Coulomb	125	0	30
	Soft Zone	Mohr-Coulomb	125	0	16.5

Project No. 175578415

Performed By: G. Khatri 07/05/2023
Checked By: R. Lopina 07/12/2023

07/05/2023: 09:45:27 AM

ROS-772-10.40	**Slope Stability Analysis - FS = 1.74**	Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.
ODOT District 9		
Analysis Cross-Section-Proposed Drilled Shaft Wall	Slope Stability	



Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Fill Material	Mohr-Coulomb	125	250	28
	Rock	Bedrock (Impenetrable)			
	Silty Clay 1	Mohr-Coulomb	122	0	28
	Silty Clay 2	Mohr-Coulomb	125	0	30
	Soft Zone	Mohr-Coulomb	125	0	16.5

Project No. 175578415

Performed By: G. Khatri 7/11/2023
Checked By: R. Lopina 7/12/2023

07/11/2023: 10:25:08 AM

APPENDIX C
UA SLOPE ANALYSIS

Stantec

ROS-772-10.40
PAGE 1 OF 2: UA SLOPE BACK ANALYSIS (NO DRILLED SHAFT)

File Run Options Help

Calculated Results

Factor of Safety: 1.00
Force per Shaft: 0.000 lb
Acting Point X: 0.000 ft Y: 0.000 ft

Analysis Unit System

(•) English ( ) Metric

Number of Vertical Sections and Soil Layers

Vertical Section Num: 22 Soil Layer Num: 4

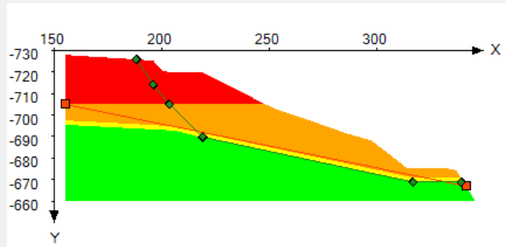
Analysis Method

( ) Total Stress (•) Effective Stress

Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
Layer1	0.0	28.0	122.0
Layer2	0.0	30.0	125.0
Layer3	0.0	16.4	125.0
Layer4	2000.0	40.0	145.0

Chart (Double-Click for More Options)



Slope Profile Vertical Sections

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Section 10	Section 11	Section 12	Section 13	Section 14
X (ft)	155.00	196.12	199.24	201.18	205.89	219.10	248.39	253.31	267.41	281.50	284.20	297.72	314.49	317.17
Y1 (ft)	-728.00	-725.40	-721.54	-720.26	-720.12	-719.73	-705.00	-702.71	-697.97	-693.23	-692.01	-688.14	-675.17	-675.20
Y2 (ft)	-705.00	-705.00	-705.00	-705.00	-705.00	-705.00	-705.00	-702.71	-697.97	-693.23	-692.01	-688.14	-675.17	-675.20
Y3 (ft)	-697.58	-695.38	-695.16	-695.06	-694.80	-691.63	-685.42	-684.38	-681.38	-678.39	-677.83	-674.96	-671.41	-670.83
Y4 (ft)	-695.51	-693.36	-693.23	-693.05	-692.80	-689.59	-683.37	-682.32	-679.34	-676.35	-675.78	-672.92	-669.29	-668.83
Y5 (ft)	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00

Section 15	Section 16	Section 17	Section 18	Section 19	Section 20	Section 21	Section 22
324.63	325.78	330.21	335.68	337.18	339.20	340.45	346.04
-675.37	-675.42	-675.40	-674.84	-674.09	-670.85	-668.85	-660.00
-675.37	-675.42	-675.40	-674.84	-674.09	-670.85	-668.85	-660.00
-670.85	-670.85	-670.85	-670.85	-670.85	-670.85	-668.85	-660.00
-668.85	-668.85	-668.85	-668.85	-668.85	-668.85	-668.85	-660.00
-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00

Coordinates of Crest X: 196.12 ft Y: -725.43 ft Coordinates of Toe X: 314.48 ft Y: -675.17 ft

Drilled Shaft Information

(•) Calculate without Drilled Shaft
( ) Automatic Load Transfer Factor
( ) Manually Defined Load Transfer Factor
[ ] Anchor (On/Off)

Anchor force: 0.00 lb
Anchor angle: 0.00
Anchor spacing: 0.00 ft

Auto ( ) On (•) Off 0.000 (n)
Xmin 0.00 Diameter: 0.30 ft
Xmax 0.00 CTC Spacing: 0.00 ft
XDelta 0.00 X Coordinate: 0.00 ft

[ ] Auto Save Data

Run

Pore Water Pressure

Pore Pressure Options: ( ) No Pore Pressure ( ) Constant Ratio (•) Specified phreatic surface

	Point 1	Point 2
X (ft)	155.00	341.59
Y (ft)	-705.00	-667.00

Slip Surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6
X (ft)	188.32	196.12	203.48	219.10	316.96	339.45
Y (ft)	-725.90	-714.13	-705.06	-689.79	-668.87	-668.87

Performed By: G. Khatri 07/12/2023
Checked By: R. Lopina 07/12/2023

Stantec

ROS-772-10.40
PAGE 2 OF 2: UA SLOPE ANALYSIS (4-FT SHAFTS AT 4-FT CENTER-TO-CENTER SPACING)

File Run Options Help

Calculated Results

Factor of Safety: 40.84
Force per Shaft: 378826.436 lb
Acting Point X: 314.490 ft Y: -676.114 ft

Analysis Unit System

(•) English ( ) Metric

Number of Vertical Sections and Soil Layers

Vertical Section Num: 24 Soil Layer Num: 5

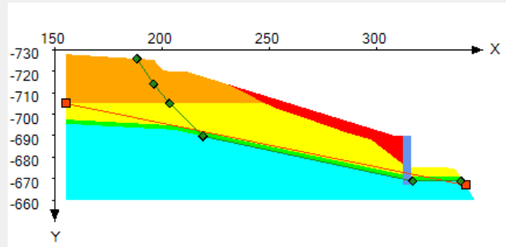
Analysis Method

( ) Total Stress (•) Effective Stress

Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
Layer1	250.0	28.0	125.0
Layer2	0.0	28.0	122.0
Layer3	0.0	30.0	125.0
Layer4	0.0	16.4	125.0
Layer5	2000.0	40.0	145.0

Chart (Double-Click for More Options)



Slope Profile Vertical Sections

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Section 10	Section 11	Section 12	Section 13	Section 14
X (ft)	155.00	196.12	199.31	201.18	205.89	211.32	230.37	248.39	253.31	281.50	284.20	297.72	309.49	314.49
Y1 (ft)	-728.00	-725.43	-721.50	-720.26	-720.13	-719.95	-714.09	-708.55	-707.03	-698.36	-697.53	-693.37	-689.75	-689.75
Y2 (ft)	-728.00	-725.43	-721.50	-720.26	-720.13	-719.95	-714.09	-705.00	-702.71	-693.23	-692.01	-688.14	-679.04	-675.17
Y3 (ft)	-705.00	-705.00	-705.00	-705.00	-705.00	-705.00	-705.00	-705.00	-702.71	-693.23	-692.01	-688.14	-679.04	-675.17
Y4 (ft)	-697.58	-695.33	-695.16	-695.06	-694.80	-693.47	-689.26	-685.42	-684.37	-678.40	-677.84	-674.96	-672.46	-671.40
Y5 (ft)	-695.58	-693.33	-693.16	-693.06	-692.80	-691.47	-687.26	-683.42	-682.37	-676.40	-675.83	-672.96	-670.46	-669.40
Y6 (ft)	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00

Section 15	Section 16	Section 17	Section 18	Section 19	Section 20	Section 21	Section 22	Section 23	Section 24
314.49	317.17	324.63	325.78	330.21	335.68	337.18	339.20	340.45	346.04
-675.17	-675.17	-675.37	-675.42	-675.40	-674.84	-674.09	-670.85	-668.85	-660.00
-675.17	-675.17	-675.37	-675.42	-675.40	-674.84	-674.09	-670.85	-668.85	-660.00
-675.17	-675.17	-675.37	-675.42	-675.40	-674.84	-674.10	-670.85	-668.85	-660.00
-671.40	-670.85	-670.85	-670.85	-670.85	-670.85	-670.85	-670.85	-668.85	-660.00
-669.40	-668.85	-668.85	-668.85	-668.85	-668.85	-668.85	-668.85	-668.85	-660.00
-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00	-660.00

Coordinates of Crest X: 172.50 ft Y: -726.99 ft Coordinates of Toe X: 314.49 ft Y: -675.17 ft

Drilled Shaft Information

( ) Calculate without Drilled Shaft
( ) Automatic Load Transfer Factor
(•) Manually Defined Load Transfer Factor
[ ] Anchor (On/Off)

Anchor force: 0.00 lb
Anchor angle: 0.00
Anchor spacing: 0.00 ft

Auto ( ) On (•) Off 0.000 (n)
Xmin 0.00 Diameter: 4.00 ft
Xmax 0.00 CTC Spacing: 4.00 ft
XDelta 0.00 X Coordinate: 314.49 ft

[ ] Auto Save Data

Run

Pore Water Pressure

Pore Pressure Options: ( ) No Pore Pressure ( ) Constant Ratio (•) Specified phreatic surface

	Point 1	Point 2
X (ft)	155.00	341.59
Y (ft)	-705.00	-667.00

Slip Surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6
X (ft)	188.32	196.12	203.48	219.10	316.96	339.45
Y (ft)	-725.90	-714.13	-705.06	-689.79	-668.87	-668.87

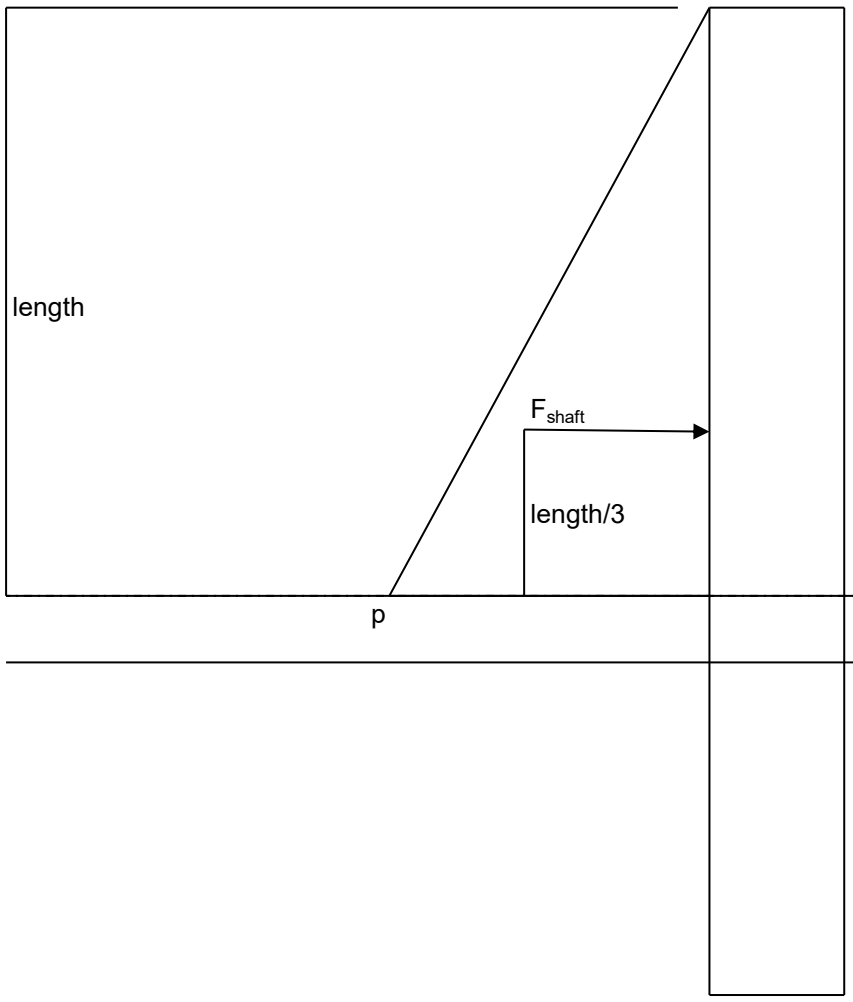
Performed By: G. Khatri 07/12/2023
Checked By: R. Lopina 07/12/2023

APPENDIX D
LPILE ANALYSIS

SUMMARY OF DRILLED SHAFT CALCULATIONS

LOADING CONDITIONS

Loading conditions were evaluated using shaft loads determined from the UA SLOPE (Version 2.3) computer program. This shaft load, combined with an assumed traffic surcharge live load, was applied to the drilled shaft above the assumed failure surface. The drilled shaft was evaluated using LPILEv2022 which is a program for the analysis of piles and drilled shafts under lateral loads. Unfactored loads (Service I Limit State) were utilized to estimate shaft head deflection and factored loads (Strength I Limit State) were used to evaluate geotechnical resistance.



Projected Ground line Depth = 0.00

Note:
x_2 represents the maximum value of the triangular distributed load that will be used in LPILE determined from F_{shaft} from the University of Akron program.

Assumed Failure Surface Depth = 20.50

Top of Rock Depth = 20.50

Bottom of Drilled Shaft Depth = 30.50

Estimated Depth to Bedrock =	20.50	feet	UA Slope Input
Estimated Depth to Failure Surface=	20.50	feet	UA Slope Input
Shaft Size =	4	feet	UA Slope Input
Center to Center Spacing =	4.00	feet	UA Slope Input
F_{shaft} =	378,826	pounds	UA Slope Output
Factor of Safety =	40.84		UA Slope Output
p = (2*Fshaft)/H * (1 ft/12 in)	3080	pounds per inch	

Performed By: G. Khatri 7/12/2023
Checked By: R. Lopina 7/12/2023

DISTRIBUTED LOAD FOR LPILE INPUT

F_{live} = assumed traffic surcharge load =	0	psf
Phi =	28.0	degrees
K_a =	0.361	
x1 = F_{live} * s * Ka * (1 ft/12 in)	0	pounds per inch
x2 = [2*Fshaft/(Depth to Failure Surface)] + x1		

Service (I) Limit State:

x1 =	0	pounds per inch
x2 =	3080	pounds per inch
Total Load =	378826	pounds

Strength (I) Limit State:

x1 =	0	pounds per inch (Load Factor = 1.75)
x2 =	4620	pounds per inch (Load Factor = 1.5)
Total Load =	568240	pounds

CHOOSE MATERIAL p-y CURVES for LPILE Program

Material Type	*Value*	*Units*	
Soft Clay			
γ=	0	pcf	based on ODOT recommendations
c=	0	psf	based on ODOT recommendations
Bedrock - Shale (Weak Rock)			
γ'=	95	pcf	based on average UCR from B-002-2-22, B-003-1-22, B-003-2-22, and B-005-1-22
E=	252,360	psi	=90 x qu
qu=	2,804	psi	based on average UCR from B-002-2-22, B-003-1-22, B-003-2-22, and B-005-1-22
RQD=	51	%	based on average UCR from B-002-2-22, B-003-1-22, B-003-2-22, and B-005-1-22
Km=	0.00005		conservative for weak rock
p-y Modification Factor			
p = 0.64 (Spacing/Diameter)$^{0.34}$	0.64		

SHAFT CONCRETE AND STEEL MATERIAL PROPERTIES FOR LPILE

Parameter	*Value*		*Note*
f'_c =	4,000	psi	(ODOT Class S Concrete)
E_c =	3,604,997	psi	E_c = 57,000 * SQRT(f'c)
$f_{y\ steel}$=	50,000	psi	
E_{steel}=	2.9E+07	psi	

Performed By: G. Khatri 7/12/2023
Checked By: R. Lopina 7/12/2023

LPILE VERSION 2022 RUNS

SERVICE (I) AND STRENGTH (I) LIMIT STATES

Purpose: Achieve a shaft head deflection of 1% or less of the drilled shaft length above bedrock for Service (I) Limit State. Recommend a rock socket length by observation of the shear and moment curves. Provide shear and moment design parameters for the selection of steel beam reinforcement.

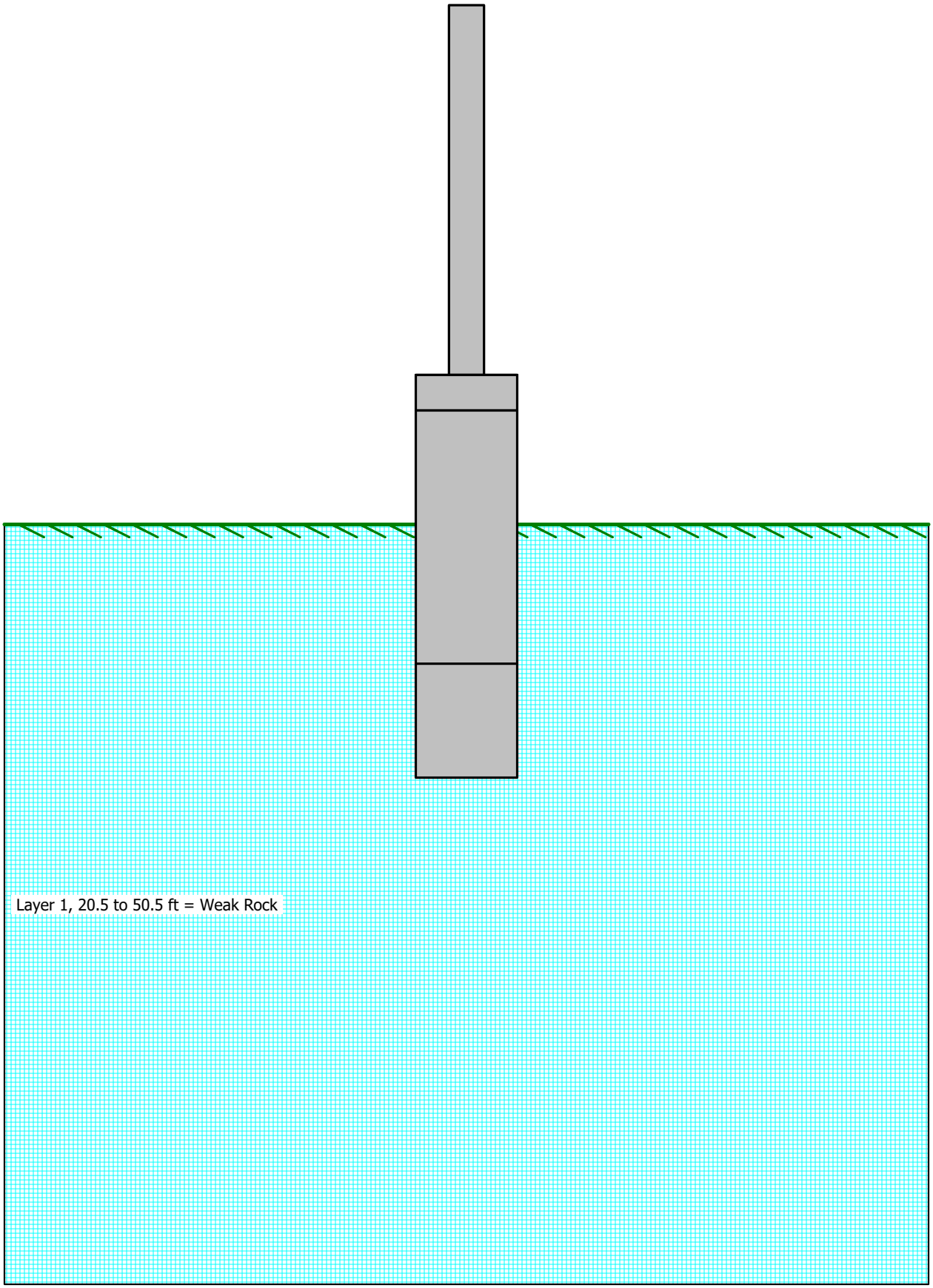
Run ID	Filename	Reinforcement Description	Deflection at Pile Head (in)	Maximum Moment (in-lbs)	Maximum Shear (lbs)
1	W36x282_4ftD_4ftCTC	W36x282	1.0108	32,500,000	1,211,020
2	W36x282_4ftD_4ftCTC	W36x282	1.5931	49,100,000	1,745,049

Based on the calculations and assumptions presented above, it appears a 48-inch diameter drilled shaft with a center-to-center spacing of 48 inches can provide tolerable deflections when placed approximately at toe of the graded 3.25H:1V slope. A minimum 10-foot rock socket is recommended.

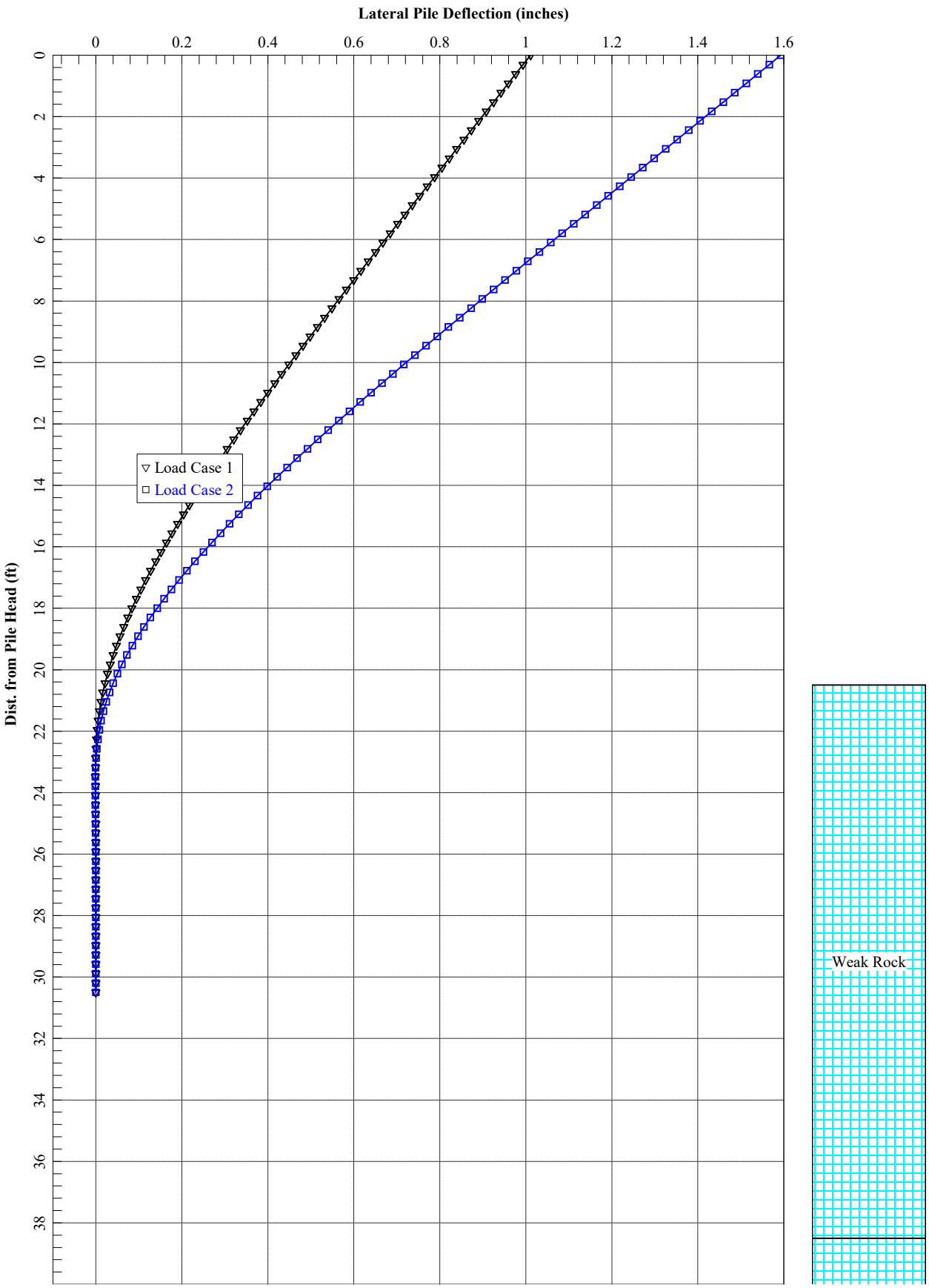
PROPERTIES OF SELECTED SECTIONS

Run ID	Source	Reinforcement Description	Area of Steel (in^2)	Moment of Inertia (in^4)	Section Modulus (in^3)
1 & 2	AISC Manual of Steel Construction	W36x282	82.9	19,600	1,050

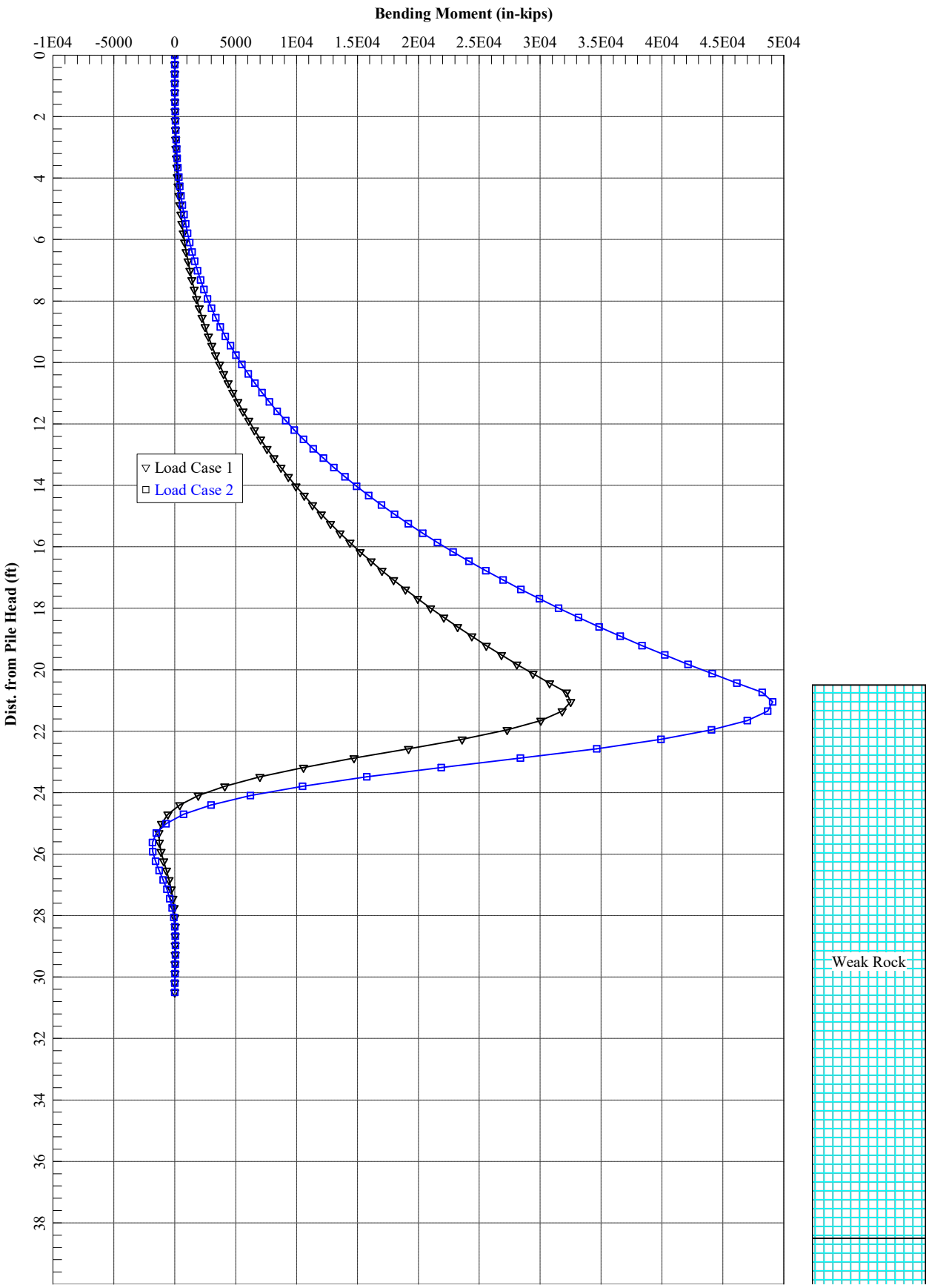
Performed By: G. Khatri 7/12/2023
Checked By: R. Lopina 7/12/2023



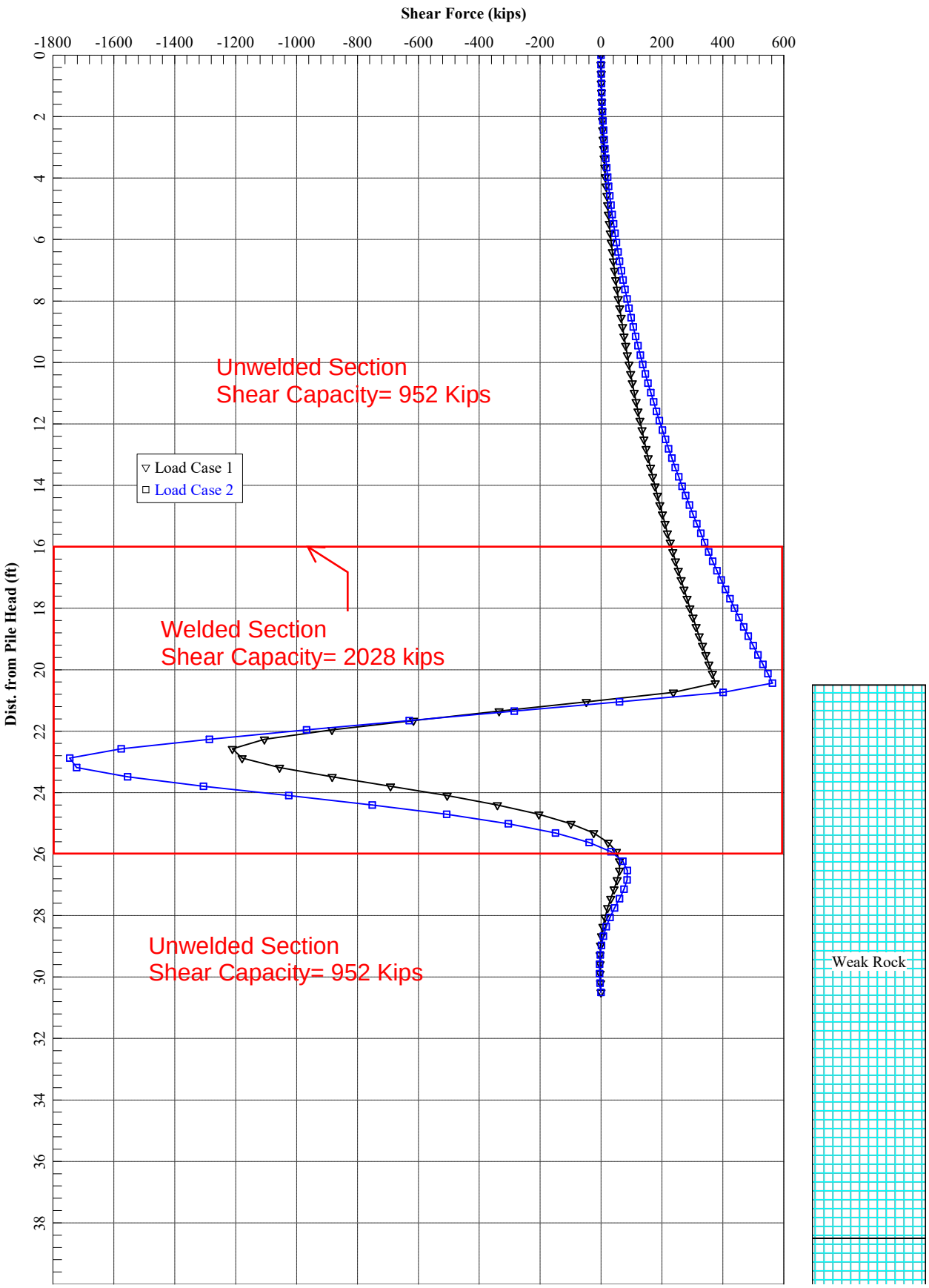
Performed By: G. Khatri 7/12/2023
Checked By: R. Lopina 7/12/2023



Performed By: G. Khatri 7/12/2023
Checked By: R. Lopina 7/12/2023



Performed By: G. Khatri 7/12/2023
Checked By: R. Lopina 7/12/2023



Performed By: G. Khatri 7/12/2023
Checked By: R. Lopina 7/12/2023

```
================================================================================

                     LPile for Windows, Version 2022-12.006

                  Analysis of Individual Piles and Drilled Shafts
                 Subjected to Lateral Loading Using the p-y Method
                           © 1985-2022 by Ensoft, Inc.
                               All Rights Reserved

================================================================================

This copy of LPile is being used by:

d
d


Serial Number of Security Device: 253581973

This copy of LPile is licensed for exclusive use by:

STANTEC, LPILE Global, Global License

Use of this software by employees of STANTEC
other than those of the office site in LPILE Global, Global License
is a violation of the software license agreement.

--------------------------------------------------------------------------------
                             Files Used for Analysis
--------------------------------------------------------------------------------

Path to file locations:
\Users\gkhatri\Stantec\175578415 - Documents\977324 ROS-772-10.30 Landslide\analysis\Lpile\Proposed
Analysis\Updated\

Name of input data file:
ROS-772-10.40 LPile W36x282 (USCS units).lp12d
```

Name of output report file:
ROS-772-10.40 LPile W36x282 (USCS units).lp12o

Name of plot output file:
ROS-772-10.40 LPile W36x282 (USCS units).lp12p

Name of runtime message file:
ROS-772-10.40 LPile W36x282 (USCS units).lp12r

Date and Time of Analysis

Date: July 12, 2023 Time: 11:23:57

Problem Title

Project Name: ROS-772-10.40

Job Number: 175578415

Client: ODOT

Engineer: Gokul Khatri

Description: Drilled Shaft for ROS-772 -10.40 Landslide

```
--------------------------------------------------------------------------------
                          Program Options and Settings
--------------------------------------------------------------------------------

Computational Options:
 - Conventional Analysis
Engineering Units Used for Data Input and Computations:
 - US Customary System Units (pounds, feet, inches)

Analysis Control Options:
 - Maximum number of iterations allowed                =          500
 - Deflection tolerance for convergence                =   1.0000E-05 in
 - Maximum allowable deflection                        =     100.0000 in
 - Number of pile increments                           =          100

Loading Type and Number of Cycles of Loading:
 - Static loading specified

 - Use of p-y modification factors for p-y curves not selected
 - Analysis uses layering correction (Method of Georgiadis)
 - Analysis includes loading by multiple distributed lateral loads acting on pile
 - Loading by lateral soil movements acting on pile not selected
 - Input of shear resistance at the pile tip not selected
 - Input of moment resistance at the pile tip not selected
 - Computation of pile-head foundation stiffness matrix not selected
 - Push-over analysis of pile not selected
 - Buckling analysis of pile not selected

Output Options:
 - Output files use decimal points to denote decimal symbols.
 - Values of pile-head deflection, bending moment, shear force, and
   soil reaction are printed for full length of pile.
```

- Printing Increment (nodal spacing of output points) = 1
- No p-y curves to be computed and reported for user-specified depths
- Print using wide report formats

Pile Structural Properties and Geometry

Number of pile sections defined = 4
Total length of pile = 30.500 ft
Depth of ground surface below top of pile = 20.5000 ft

Pile diameters used for p-y curve computations are defined using 8 points.

p-y curves are computed using pile diameter values interpolated with depth over the length of the pile. A summary of values of pile diameter vs. depth follows.

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	16.6000
2	14.600	16.6000
3	14.600	48.0000
4	16.000	48.0000
5	16.000	48.0000
6	26.000	48.0000
7	26.000	48.0000
8	30.500	48.0000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is a AISC strong axis steel pile		
Length of section	=	14.600000 ft
AISC Section Type	=	W
AISC Section Name	=	W36X282
Pile width	=	16.600000 in

Pile Section No. 2:

Section 2 is an elastic pile		
Cross-sectional Shape	=	Circular Pile
Length of section	=	1.400000 ft
Width of top of section	=	48.000000 in
Width of bottom of section	=	48.000000 in
Top Area	=	82.900000 sq. in
Bottom Area	=	82.900000 sq. in
Moment of Inertia at Top	=	19600. in^4
Moment of Inertia at Bottom	=	19600. in^4
Elastic Modulus	=	29000000. psi

Pile Section No. 3:

Section 3 is an elastic pile		
Cross-sectional Shape	=	Circular Pile
Length of section	=	10.000000 ft
Width of top of section	=	48.000000 in
Width of bottom of section	=	48.000000 in
Top Area	=	106.900000 sq. in
Bottom Area	=	106.900000 sq. in
Moment of Inertia at Top	=	20752. in^4
Moment of Inertia at Bottom	=	20752. in^4
Elastic Modulus	=	29000000. psi

Pile Section No. 4:

Section 4 is an elastic pile		
Cross-sectional Shape	=	Circular Pile
Length of section	=	4.500000 ft
Width of top of section	=	48.000000 in
Width of bottom of section	=	48.000000 in
Top Area	=	82.900000 sq. in
Bottom Area	=	82.900000 sq. in
Moment of Inertia at Top	=	19600. in^4
Moment of Inertia at Bottom	=	19600. in^4
Elastic Modulus	=	29000000. psi

Soil and Rock Layering Information

The soil profile is modelled using 1 layers

Layer 1 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	20.500000 ft
Distance from top of pile to bottom of layer	=	50.500000 ft
Effective unit weight at top of layer	=	95.000000 pcf
Effective unit weight at bottom of layer	=	95.000000 pcf
Uniaxial compressive strength at top of layer	=	2804. psi
Uniaxial compressive strength at bottom of layer	=	2804. psi
Initial modulus of rock at top of layer	=	252360. psi
Initial modulus of rock at bottom of layer	=	252360. psi
RQD of rock at top of layer	=	51.000000 %
RQD of rock at bottom of layer	=	51.000000 %
k rm of rock at top of layer	=	0.0000500
k rm of rock at bottom of layer	=	0.0000500

(Depth of the lowest soil layer extends 20.000 ft below the pile tip)

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Uniaxial qu psi	RQD %	E50 or krm	Rock Mass Modulus psi
1	Weak Rock	20.5000 50.5000	95.0000 95.0000	2804. 2804.	51.0000 51.0000	5.00E-05 5.00E-05	252360. 252360.

Static Loading Type

Static loading criteria were used when computing p-y curves for all analyses.

Distributed Lateral Loading for Individual Load Cases

Distributed lateral load intensity for Load Case 1 defined using 2 points

Point No.	Depth X ft	Dist. Load lb/in
1	0.000	0.000
2	20.500	3080.000

Distributed lateral load intensity for Load Case 2 defined using 2 points

Point No.	Depth X ft	Dist. Load lb/in
1	0.000	0.000
2	20.500	4620.000

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 2

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length	Run Analysis
1	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0.0000000	Yes	Yes
2	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0.0000000	Yes	Yes

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with
specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

---

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 4

Pile Section No. 1:

Dimensions and Properties of Steel AISC Strong Axis:

Length of Section	=	14.600000 ft
Flange Width	=	16.600000 in
Section Depth	=	37.100000 in
Flange Thickness	=	1.570000 in
Web Thickness	=	0.885000 in
Yield Stress of Pipe	=	50.000000 ksi
Elastic Modulus	=	29000. ksi
Cross-sectional Area	=	82.900000 sq. in.
Moment of Inertia	=	19600. in^4
Elastic Bending Stiffness	=	568400000. kip-in^2
Plastic Modulus, Z	=	1190.in^3
Plastic Moment Capacity = Fy Z	=	59500.in-kip

Axial Structural Capacities:

Nom. Axial Structural Capacity = Fy As	=	4145.000 kips
Nominal Axial Tensile Capacity	=	-4145.000 kips

Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

Number	Axial Thrust Force kips
1	0.000

Definition of Run Messages:

Y = part of pipe section has yielded.

Axial Thrust Force = 0.000 kips

Bending Curvature rad/in.	Bending Moment in-kip	Bending Stiffness kip-in2	Depth to N Axis in	Max Total Stress ksi	Run Msg
0.00000441	2475.	560722877.	18.5500000	2.3508773	
0.00000883	4950.	560722877.	18.5500000	4.7017545	
0.00001324	7425.	560722877.	18.5500000	7.0526318	
0.00001766	9901.	560722877.	18.5500000	9.4035091	
0.00002207	12376.	560722877.	18.5500000	11.7543864	
0.00002649	14851.	560722877.	18.5500000	14.1052636	
0.00003090	17326.	560722877.	18.5500000	16.4561409	
0.00003531	19801.	560722877.	18.5500000	18.8070182	
0.00003973	22276.	560722877.	18.5500000	21.1578954	
0.00004414	24751.	560722877.	18.5500000	23.5087727	
0.00004856	27227.	560722877.	18.5500000	25.8596500	
0.00005297	29702.	560722877.	18.5500000	28.2105273	
0.00005738	32177.	560722877.	18.5500000	30.5614045	
0.00006180	34652.	560722877.	18.5500000	32.9122818	
0.00006621	37127.	560722877.	18.5500000	35.2631591	
0.00007063	39602.	560722877.	18.5500000	37.6140363	
0.00007504	42078.	560722877.	18.5500000	39.9649136	
0.00007946	44553.	560722877.	18.5500000	42.3157909	
0.00008387	47028.	560722877.	18.5500000	44.6666682	
0.00008828	49503.	560722877.	18.5500000	47.0175454	
0.00009270	51978.	560722877.	18.5500000	49.3684227	

0.00009711	53915.	555178944.	18.5500000	50.0000000	Y
0.0001015	54770.	539462792.	18.5500000	50.0000000	Y
0.0001059	55130.	520388419.	18.5500000	50.0000000	Y
0.0001104	55437.	502348075.	18.5500000	50.0000000	Y
0.0001148	55710.	485405894.	18.5500000	50.0000000	Y
0.0001192	55950.	469446072.	18.5500000	50.0000000	Y
0.0001236	56168.	454440012.	18.5500000	50.0000000	Y
0.0001280	56362.	440286150.	18.5500000	50.0000000	Y
0.0001324	56537.	426930645.	18.5500000	50.0000000	Y
0.0001368	56695.	414318132.	18.5500000	50.0000000	Y
0.0001413	56840.	402390914.	18.5500000	50.0000000	Y
0.0001457	56971.	391097653.	18.5500000	50.0000000	Y
0.0001501	57090.	380392434.	18.5500000	50.0000000	Y
0.0001545	57200.	370233989.	18.5500000	50.0000000	Y
0.0001589	57301.	360585055.	18.5500000	50.0000000	Y
0.0001633	57395.	351411829.	18.5500000	50.0000000	Y
0.0001677	57479.	342668722.	18.5500000	50.0000000	Y
0.0001722	57558.	334337566.	18.5500000	50.0000000	Y
0.0001810	57699.	318809931.	18.5500000	50.0000000	Y
0.0001898	57821.	304626575.	18.5500000	50.0000000	Y
0.0001986	57927.	291617760.	18.5500000	50.0000000	Y
0.0002075	58019.	279654744.	18.5500000	50.0000000	Y
0.0002163	58101.	268618991.	18.5500000	50.0000000	Y
0.0002251	58173.	258402047.	18.5500000	50.0000000	Y
0.0002340	58236.	248922025.	18.5500000	50.0000000	Y
0.0002428	58293.	240106020.	18.5500000	50.0000000	Y
0.0002516	58346.	231889929.	18.5500000	50.0000000	Y
0.0002604	58391.	224201850.	18.5500000	50.0000000	Y
0.0002693	58433.	217006852.	18.5500000	50.0000000	Y
0.0002781	58471.	210253900.	18.5500000	50.0000000	Y
0.0002869	58505.	203903406.	18.5500000	50.0000000	Y
0.0002958	58536.	197923461.	18.5500000	50.0000000	Y
0.0003046	58565.	192280346.	18.5500000	50.0000000	Y
0.0003134	58591.	186946971.	18.5500000	50.0000000	Y
0.0003222	58616.	181902867.	18.5500000	50.0000000	Y
0.0003311	58637.	177115975.	18.5500000	50.0000000	Y
0.0003399	58658.	172577753.	18.5500000	50.0000000	Y

0.0003487	58677.	168263177.	18.5500000	50.0000000	Y
0.0003576	58694.	164155857.	18.5500000	50.0000000	Y
0.0003664	58711.	160246481.	18.5500000	50.0000000	Y
0.0003752	58727.	156517335.	18.5500000	50.0000000	Y
0.0003840	58740.	152953883.	18.5500000	50.0000000	Y
0.0003929	58753.	149550586.	18.5500000	50.0000000	Y
0.0004017	58766.	146296884.	18.5500000	50.0000000	Y
0.0004105	58778.	143177713.	18.5500000	50.0000000	Y
0.0004193	58788.	140187878.	18.5500000	50.0000000	Y
0.0004282	58798.	137321334.	18.5500000	50.0000000	Y
0.0004370	58808.	134570611.	18.5500000	50.0000000	Y
0.0004458	58818.	131926728.	18.5500000	50.0000000	Y
0.0004547	58825.	129381967.	18.5500000	50.0000000	Y
0.0004635	58833.	126934149.	18.5500000	50.0000000	Y
0.0004723	58841.	124577839.	18.5500000	50.0000000	Y

Summary of Results for Nominal Moment Capacity for Section 1

Load No.	Axial Thrust kips	Nominal Moment Capacity in-kips
1	0.00000000	58841.

Note that the values in the above table are not factored by a strength reduction factor for LRFD.

The value of the strength reduction factor depends on the provisions of the LRFD code being followed.

The above values should be multiplied by the appropriate strength reduction factor to compute ultimate moment capacity according to the LRFD structural design standard being followed.

Pile Section No. 2:

Moment-curvature properties were derived from elastic section properties

Pile Section No. 3:

Moment-curvature properties were derived from elastic section properties

Pile Section No. 4:

Moment-curvature properties were derived from elastic section properties

---

Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 1

Pile-head conditions are Shear and Moment (Loading Type 1)

Shear force at pile head = 0.0 lbs
Applied moment at pile head = 0.0 in-lbs
Axial thrust load on pile head = 0.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/inch	Soil Spr. Es*H lb/inch	Distrib. Lat. Load lb/inch
0.00	1.0108	-2.88E-04	0.00	-0.00469	1.22E-07	5.61E+11	0.00	0.00	11.4561

0.3050	0.9937	76.7305	104.8233	-0.00469	0.03249	5.61E+11	0.00	0.00	45.8244
0.6100	0.9765	767.3064	356.3992	-0.00469	0.3249	5.61E+11	0.00	0.00	91.6488
0.9150	0.9593	2686.	775.6924	-0.00469	1.1373	5.61E+11	0.00	0.00	137.4732
1.2200	0.9421	6445.	1363.	-0.00469	2.7294	5.61E+11	0.00	0.00	183.2976
1.5250	0.9250	12661.	2117.	-0.00469	5.3614	5.61E+11	0.00	0.00	229.1220
1.8300	0.9078	21945.	3040.	-0.00469	9.2930	5.61E+11	0.00	0.00	274.9463
2.1350	0.8906	34912.	4130.	-0.00469	14.7844	5.61E+11	0.00	0.00	320.7707
2.4400	0.8734	52177.	5388.	-0.00469	22.0953	5.61E+11	0.00	0.00	366.5951
2.7450	0.8562	74352.	6814.	-0.00469	31.4858	5.61E+11	0.00	0.00	412.4195
3.0500	0.8391	102052.	8407.	-0.00469	43.2158	5.61E+11	0.00	0.00	458.2439
3.3550	0.8219	135890.	10168.	-0.00469	57.5452	5.61E+11	0.00	0.00	504.0683
3.6600	0.8047	176480.	12097.	-0.00469	74.7341	5.61E+11	0.00	0.00	549.8927
3.9650	0.7876	224437.	14193.	-0.00469	95.0423	5.61E+11	0.00	0.00	595.7171
4.2700	0.7704	280374.	16457.	-0.00469	118.7297	5.61E+11	0.00	0.00	641.5415
4.5750	0.7533	344904.	18889.	-0.00468	146.0564	5.61E+11	0.00	0.00	687.3659
4.8800	0.7361	418642.	21489.	-0.00468	177.2823	5.61E+11	0.00	0.00	733.1902
5.1850	0.7190	502202.	24256.	-0.00468	212.6672	5.61E+11	0.00	0.00	779.0146
5.4900	0.7019	596197.	27191.	-0.00468	252.4712	5.61E+11	0.00	0.00	824.8390
5.7950	0.6848	701241.	30294.	-0.00467	296.9543	5.61E+11	0.00	0.00	870.6634
6.1000	0.6677	817949.	33564.	-0.00467	346.3762	5.61E+11	0.00	0.00	916.4878
6.4050	0.6506	946933.	37003.	-0.00466	400.9971	5.61E+11	0.00	0.00	962.3122
6.7100	0.6336	1088808.	40609.	-0.00465	461.0768	5.61E+11	0.00	0.00	1008.
7.0150	0.6165	1244187.	44382.	-0.00465	526.8753	5.61E+11	0.00	0.00	1054.
7.3200	0.5995	1413686.	48324.	-0.00464	598.6525	5.61E+11	0.00	0.00	1100.
7.6250	0.5826	1597916.	52433.	-0.00463	676.6684	5.61E+11	0.00	0.00	1146.
7.9300	0.5657	1797492.	56709.	-0.00462	761.1829	5.61E+11	0.00	0.00	1191.
8.2350	0.5488	2013029.	61154.	-0.00460	852.4560	5.61E+11	0.00	0.00	1237.
8.5400	0.5320	2245139.	65766.	-0.00459	950.7476	5.61E+11	0.00	0.00	1283.
8.8450	0.5152	2494437.	70546.	-0.00458	1056.	5.61E+11	0.00	0.00	1329.
9.1500	0.4985	2761536.	75494.	-0.00456	1169.	5.61E+11	0.00	0.00	1375.
9.4550	0.4818	3047051.	80609.	-0.00454	1290.	5.61E+11	0.00	0.00	1421.
9.7600	0.4652	3351595.	85892.	-0.00452	1419.	5.61E+11	0.00	0.00	1466.
10.0650	0.4487	3675782.	91343.	-0.00450	1557.	5.61E+11	0.00	0.00	1512.
10.3700	0.4323	4020226.	96962.	-0.00447	1702.	5.61E+11	0.00	0.00	1558.
10.6750	0.4160	4385540.	102748.	-0.00444	1857.	5.61E+11	0.00	0.00	1604.
10.9800	0.3998	4772340.	108702.	-0.00441	2021.	5.61E+11	0.00	0.00	1650.
11.2850	0.3837	5181237.	114823.	-0.00438	2194.	5.61E+11	0.00	0.00	1696.

Performed By: G. Khatri 7/12/2023
Checked By: R. Lopina 7/12/2023

11.5900	0.3677	5612847.	121113.	-0.00435	2377.	5.61E+11	0.00	0.00	1741.
11.8950	0.3519	6067783.	127570.	-0.00431	2570.	5.61E+11	0.00	0.00	1787.
12.2000	0.3362	6546659.	134195.	-0.00427	2772.	5.61E+11	0.00	0.00	1833.
12.5050	0.3207	7050089.	140987.	-0.00422	2985.	5.61E+11	0.00	0.00	1879.
12.8100	0.3053	7578686.	147948.	-0.00417	3209.	5.61E+11	0.00	0.00	1925.
13.1150	0.2901	8133065.	155076.	-0.00412	3444.	5.61E+11	0.00	0.00	1970.
13.4200	0.2751	8713840.	162371.	-0.00407	3690.	5.61E+11	0.00	0.00	2016.
13.7250	0.2604	9321623.	169835.	-0.00401	3947.	5.61E+11	0.00	0.00	2062.
14.0300	0.2458	9957030.	177466.	-0.00395	4216.	5.61E+11	0.00	0.00	2108.
14.3350	0.2315	1.06E+07	185265.	-0.00388	4498.	5.61E+11	0.00	0.00	2154.
14.6400	0.2174	1.13E+07	193231.	-0.00381	13853.	5.68E+11	0.00	0.00	2200.
14.9450	0.2036	1.20E+07	201366.	-0.00373	14737.	5.68E+11	0.00	0.00	2245.
15.2500	0.1901	1.28E+07	209668.	-0.00365	15658.	5.68E+11	0.00	0.00	2291.
15.5550	0.1769	1.36E+07	218137.	-0.00357	16616.	5.68E+11	0.00	0.00	2337.
15.8600	0.1640	1.44E+07	226775.	-0.00348	17613.	5.68E+11	0.00	0.00	2383.
16.1650	0.1514	1.52E+07	235580.	-0.00338	17614.	6.02E+11	0.00	0.00	2429.
16.4700	0.1392	1.61E+07	244553.	-0.00329	18630.	6.02E+11	0.00	0.00	2475.
16.7750	0.1273	1.70E+07	253693.	-0.00319	19684.	6.02E+11	0.00	0.00	2520.
17.0800	0.1158	1.80E+07	263002.	-0.00308	20777.	6.02E+11	0.00	0.00	2566.
17.3850	0.1048	1.89E+07	272478.	-0.00297	21910.	6.02E+11	0.00	0.00	2612.
17.6900	0.09410	2.00E+07	282121.	-0.00285	23084.	6.02E+11	0.00	0.00	2658.
17.9950	0.08388	2.10E+07	291933.	-0.00273	24299.	6.02E+11	0.00	0.00	2704.
18.3000	0.07413	2.21E+07	301912.	-0.00260	25555.	6.02E+11	0.00	0.00	2749.
18.6050	0.06488	2.32E+07	312059.	-0.00246	26855.	6.02E+11	0.00	0.00	2795.
18.9100	0.05614	2.44E+07	322374.	-0.00231	28197.	6.02E+11	0.00	0.00	2841.
19.2150	0.04794	2.56E+07	332856.	-0.00216	29584.	6.02E+11	0.00	0.00	2887.
19.5200	0.04031	2.68E+07	343506.	-0.00200	31015.	6.02E+11	0.00	0.00	2933.
19.8250	0.03328	2.81E+07	354324.	-0.00184	32492.	6.02E+11	0.00	0.00	2979.
20.1300	0.02688	2.94E+07	365309.	-0.00166	34015.	6.02E+11	0.00	0.00	3024.
20.4350	0.02113	3.08E+07	374842.	-0.00148	35584.	6.02E+11	0.00	0.00	2185.
20.7400	0.01606	3.22E+07	237126.	-0.00129	37188.	6.02E+11	-77439.	1.76E+07	0.00
21.0450	0.01171	3.25E+07	-48436.	-0.00109	37592.	6.02E+11	-78606.	2.46E+07	0.00
21.3500	0.00808	3.18E+07	-335160.	-8.94E-04	36778.	6.02E+11	-78073.	3.54E+07	0.00
21.6550	0.00516	3.01E+07	-616281.	-7.06E-04	34754.	6.02E+11	-75545.	5.35E+07	0.00
21.9600	0.00291	2.73E+07	-883462.	-5.32E-04	31561.	6.02E+11	-70456.	8.85E+07	0.00
22.2650	0.00127	2.36E+07	-1105687.	-3.77E-04	27275.	6.02E+11	-50979.	1.47E+08	0.00
22.5700	1.54E-04	1.92E+07	-1211020.	-2.47E-04	22200.	6.02E+11	-6580.	1.56E+08	0.00

Performed By: G. Khatri 7/12/2023
Checked By: R. Lopina 7/12/2023

22.8750	-5.36E-04	1.47E+07	-1178711.	-1.44E-04	17023.	6.02E+11	24235.	1.65E+08	0.00
23.1800	-8.99E-04	1.06E+07	-1055788.	-6.69E-05	12222.	6.02E+11	42937.	1.75E+08	0.00
23.4850	-0.00103	6991031.	-882682.	-1.36E-05	8085.	6.02E+11	51657.	1.84E+08	0.00
23.7900	-9.98E-04	4106402.	-691531.	2.02E-05	4749.	6.02E+11	52797.	1.94E+08	0.00
24.0950	-8.78E-04	1929021.	-505752.	3.85E-05	2231.	6.02E+11	48722.	2.03E+08	0.00
24.4000	-7.16E-04	404297.	-340572.	4.56E-05	467.5753	6.02E+11	41540.	2.12E+08	0.00
24.7050	-5.44E-04	-563967.	-204200.	4.52E-05	652.2369	6.02E+11	32980.	2.22E+08	0.00
25.0100	-3.85E-04	-1090449.	-99320.	4.01E-05	1261.	6.02E+11	24332.	2.31E+08	0.00
25.3150	-2.50E-04	-1290992.	-24665.	3.29E-05	1493.	6.02E+11	16464.	2.41E+08	0.00
25.6200	-1.44E-04	-1270995.	23520.	2.51E-05	1470.	6.02E+11	9867.	2.50E+08	0.00
25.9250	-6.68E-05	-1118824.	50236.	1.78E-05	1294.	6.02E+11	4732.	2.59E+08	0.00
26.2300	-1.40E-05	-903270.	60773.	1.15E-05	1106.	5.68E+11	1026.	2.69E+08	0.00
26.5350	1.75E-05	-673967.	60214.	6.44E-06	825.2656	5.68E+11	-1332.	2.78E+08	0.00
26.8400	3.31E-05	-462504.	53012.	2.78E-06	566.3311	5.68E+11	-2604.	2.88E+08	0.00
27.1450	3.79E-05	-285918.	42627.	3.68E-07	350.1033	5.68E+11	-3071.	2.97E+08	0.00
27.4500	3.58E-05	-150473.	31518.	-1.04E-06	184.2530	5.68E+11	-2999.	3.06E+08	0.00
27.7550	3.03E-05	-55204.	21252.	-1.70E-06	67.5967	5.68E+11	-2611.	3.16E+08	0.00
28.0600	2.34E-05	5094.	12672.	-1.86E-06	6.2374	5.68E+11	-2078.	3.25E+08	0.00
28.3650	1.66E-05	37554.	6085.	-1.72E-06	45.9849	5.68E+11	-1521.	3.35E+08	0.00
28.6700	1.08E-05	49637.	1448.	-1.44E-06	60.7802	5.68E+11	-1013.	3.44E+08	0.00
28.9750	6.09E-06	48152.	-1481.	-1.13E-06	58.9613	5.68E+11	-587.372	3.53E+08	0.00
29.2800	2.53E-06	38798.	-3014.	-8.48E-07	47.5079	5.68E+11	-250.220	3.63E+08	0.00
29.5850	-1.20E-07	26093.	-3449.	-6.39E-07	31.9502	5.68E+11	12.2452	3.72E+08	0.00
29.8900	-2.15E-06	13551.	-3016.	-5.11E-07	16.5934	5.68E+11	224.1948	3.81E+08	0.00
30.1950	-3.86E-06	4013.	-1851.	-4.55E-07	4.9140	5.68E+11	412.4589	3.91E+08	0.00
30.5000	-5.48E-06	0.00	0.00	-4.42E-07	0.00	5.68E+11	599.1615	2.00E+08	0.00

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 1:

```
Pile-head deflection             =     1.01084212 inches
Computed slope at pile head      =     -0.0046935 radians
Maximum bending moment           =      32504371. inch-lbs
Maximum shear force              =      -1211020. lbs
Depth of maximum bending moment  =    21.04500000 feet below pile head
Depth of maximum shear force     =    22.57000000 feet below pile head
Number of iterations             =             14
Number of zero deflection points =              3
Pile deflection at ground        =     0.02004633 inches
```

Pile-head Deflection vs. Pile Length for Load Case 1

Boundary Condition Type 1, Shear and Moment

```
Shear      =              0. lbs
Moment     =              0. in-lbs
Axial Load =              0. lbs
```

Pile Length feet	Pile Head Deflection inches	Maximum Moment ln-lbs	Maximum Shear lbs
30.50000	1.01084212	32504371.	-1211020.
28.97500	0.98182494	31821004.	-1178882.
27.45000	0.98610236	31907041.	-1186656.
25.92500	1.01506797	32579873.	-1210749.
24.40000	1.02608723	32585329.	-1320381.

Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 2

Pile-head conditions are Shear and Moment (Loading Type 1)

Shear force at pile head = 0.0 lbs
Applied moment at pile head = 0.0 in-lbs
Axial thrust load on pile head = 0.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/inch	Soil Spr. Es*H lb/inch	Distrib. Lat. Load lb/inch
0.00	1.5931	0.00	0.00	-0.00732	0.00	5.61E+11	0.00	0.00	17.1841
0.3050	1.5663	115.0959	157.2349	-0.00732	0.04874	5.61E+11	0.00	0.00	68.7366
0.6100	1.5395	1151.	534.5988	-0.00732	0.4874	5.61E+11	0.00	0.00	137.4732
0.9150	1.5127	4028.	1164.	-0.00732	1.7059	5.61E+11	0.00	0.00	206.2098
1.2200	1.4860	9668.	2044.	-0.00732	4.0941	5.61E+11	0.00	0.00	274.9463
1.5250	1.4592	18991.	3176.	-0.00732	8.0420	5.61E+11	0.00	0.00	343.6829
1.8300	1.4324	32917.	4560.	-0.00732	13.9395	5.61E+11	0.00	0.00	412.4195
2.1350	1.4056	52369.	6195.	-0.00732	22.1765	5.61E+11	0.00	0.00	481.1561
2.4400	1.3788	78265.	8082.	-0.00732	33.1429	5.61E+11	0.00	0.00	549.8927
2.7450	1.3520	111528.	10220.	-0.00732	47.2287	5.61E+11	0.00	0.00	618.6293
3.0500	1.3252	153078.	12610.	-0.00732	64.8237	5.61E+11	0.00	0.00	687.3659
3.3550	1.2985	203835.	15252.	-0.00732	86.3179	5.61E+11	0.00	0.00	756.1024
3.6600	1.2717	264721.	18145.	-0.00731	112.1011	5.61E+11	0.00	0.00	824.8390
3.9650	1.2449	336656.	21290.	-0.00731	142.5634	5.61E+11	0.00	0.00	893.5756
4.2700	1.2182	420561.	24686.	-0.00731	178.0946	5.61E+11	0.00	0.00	962.3122
4.5750	1.1914	517356.	28334.	-0.00731	219.0846	5.61E+11	0.00	0.00	1031.
4.8800	1.1647	627964.	32233.	-0.00730	265.9234	5.61E+11	0.00	0.00	1100.
5.1850	1.1380	753303.	36384.	-0.00730	319.0008	5.61E+11	0.00	0.00	1169.
5.4900	1.1113	894296.	40787.	-0.00729	378.7069	5.61E+11	0.00	0.00	1237.
5.7950	1.0846	1051862.	45441.	-0.00729	445.4314	5.61E+11	0.00	0.00	1306.
6.1000	1.0579	1226923.	50347.	-0.00728	519.5644	5.61E+11	0.00	0.00	1375.
6.4050	1.0313	1420399.	55504.	-0.00727	601.4957	5.61E+11	0.00	0.00	1443.
6.7100	1.0047	1633212.	60913.	-0.00726	691.6152	5.61E+11	0.00	0.00	1512.
7.0150	0.9782	1866281.	66573.	-0.00725	790.3130	5.61E+11	0.00	0.00	1581.
7.3200	0.9517	2120528.	72485.	-0.00724	897.9788	5.61E+11	0.00	0.00	1650.

7.6250	0.9252	2396874.	78649.	-0.00722	1015.	5.61E+11	0.00	0.00	1718.
7.9300	0.8988	2696238.	85064.	-0.00720	1142.	5.61E+11	0.00	0.00	1787.
8.2350	0.8725	3019543.	91731.	-0.00719	1279.	5.61E+11	0.00	0.00	1856.
8.5400	0.8462	3367708.	98649.	-0.00716	1426.	5.61E+11	0.00	0.00	1925.
8.8450	0.8200	3741655.	105819.	-0.00714	1584.	5.61E+11	0.00	0.00	1993.
9.1500	0.7939	4142304.	113241.	-0.00712	1754.	5.61E+11	0.00	0.00	2062.
9.4550	0.7679	4570576.	120914.	-0.00709	1935.	5.61E+11	0.00	0.00	2131.
9.7600	0.7421	5027392.	128838.	-0.00706	2129.	5.61E+11	0.00	0.00	2200.
10.0650	0.7163	5513673.	137015.	-0.00702	2335.	5.61E+11	0.00	0.00	2268.
10.3700	0.6907	6030339.	145442.	-0.00698	2554.	5.61E+11	0.00	0.00	2337.
10.6750	0.6652	6578310.	154122.	-0.00694	2786.	5.61E+11	0.00	0.00	2406.
10.9800	0.6398	7158509.	163053.	-0.00690	3031.	5.61E+11	0.00	0.00	2475.
11.2850	0.6147	7771856.	172235.	-0.00685	3291.	5.61E+11	0.00	0.00	2543.
11.5900	0.5897	8419271.	181669.	-0.00680	3565.	5.61E+11	0.00	0.00	2612.
11.8950	0.5649	9101675.	191355.	-0.00674	3854.	5.61E+11	0.00	0.00	2681.
12.2000	0.5404	9819989.	201292.	-0.00668	4158.	5.61E+11	0.00	0.00	2749.
12.5050	0.5160	1.06E+07	211481.	-0.00661	4478.	5.61E+11	0.00	0.00	2818.
12.8100	0.4920	1.14E+07	221921.	-0.00654	4814.	5.61E+11	0.00	0.00	2887.
13.1150	0.4682	1.22E+07	232613.	-0.00646	5166.	5.61E+11	0.00	0.00	2956.
13.4200	0.4447	1.31E+07	243557.	-0.00638	5535.	5.61E+11	0.00	0.00	3024.
13.7250	0.4215	1.40E+07	254752.	-0.00629	5921.	5.61E+11	0.00	0.00	3093.
14.0300	0.3986	1.49E+07	266199.	-0.00620	6325.	5.61E+11	0.00	0.00	3162.
14.3350	0.3761	1.59E+07	277897.	-0.00610	6746.	5.61E+11	0.00	0.00	3231.
14.6400	0.3540	1.70E+07	289847.	-0.00599	20779.	5.68E+11	0.00	0.00	3299.
14.9450	0.3323	1.81E+07	302048.	-0.00588	22105.	5.68E+11	0.00	0.00	3368.
15.2500	0.3110	1.92E+07	314501.	-0.00576	23487.	5.68E+11	0.00	0.00	3437.
15.5550	0.2901	2.04E+07	327206.	-0.00563	24924.	5.68E+11	0.00	0.00	3506.
15.8600	0.2697	2.16E+07	340162.	-0.00550	26419.	5.68E+11	0.00	0.00	3574.
16.1650	0.2499	2.28E+07	353370.	-0.00536	26420.	6.02E+11	0.00	0.00	3643.
16.4700	0.2305	2.42E+07	366829.	-0.00521	27944.	6.02E+11	0.00	0.00	3712.
16.7750	0.2117	2.55E+07	380540.	-0.00506	29526.	6.02E+11	0.00	0.00	3781.
17.0800	0.1935	2.69E+07	394502.	-0.00490	31166.	6.02E+11	0.00	0.00	3849.
17.3850	0.1758	2.84E+07	408717.	-0.00473	32866.	6.02E+11	0.00	0.00	3918.
17.6900	0.1588	2.99E+07	423182.	-0.00456	34626.	6.02E+11	0.00	0.00	3987.
17.9950	0.1425	3.15E+07	437899.	-0.00437	36448.	6.02E+11	0.00	0.00	4055.
18.3000	0.1268	3.31E+07	452868.	-0.00417	38333.	6.02E+11	0.00	0.00	4124.
18.6050	0.1119	3.48E+07	468088.	-0.00397	40282.	6.02E+11	0.00	0.00	4193.

18.9100	0.09781	3.66E+07	483560.	-0.00375	42296.	6.02E+11	0.00	0.00	4262.
19.2150	0.08450	3.84E+07	499284.	-0.00352	44376.	6.02E+11	0.00	0.00	4330.
19.5200	0.07203	4.02E+07	515259.	-0.00328	46523.	6.02E+11	0.00	0.00	4399.
19.8250	0.06047	4.21E+07	531486.	-0.00303	48738.	6.02E+11	0.00	0.00	4468.
20.1300	0.04984	4.41E+07	547964.	-0.00277	51022.	6.02E+11	0.00	0.00	4537.
20.4350	0.04019	4.62E+07	562263.	-0.00250	53377.	6.02E+11	0.00	0.00	3277.
20.7400	0.03157	4.82E+07	400455.	-0.00221	55782.	6.02E+11	-91697.	1.06E+07	0.00
21.0450	0.02403	4.91E+07	60483.	-0.00191	56767.	6.02E+11	-94080.	1.43E+07	0.00
21.3500	0.01758	4.87E+07	-285179.	-0.00162	56294.	6.02E+11	-94806.	1.97E+07	0.00
21.6550	0.01221	4.70E+07	-630090.	-0.00132	54352.	6.02E+11	-93670.	2.81E+07	0.00
21.9600	0.00788	4.41E+07	-966857.	-0.00105	50960.	6.02E+11	-90356.	4.19E+07	0.00
22.2650	0.00454	3.99E+07	-1286446.	-7.92E-04	46167.	6.02E+11	-84282.	6.79E+07	0.00
22.5700	0.00209	3.46E+07	-1576076.	-5.65E-04	40069.	6.02E+11	-73985.	1.30E+08	0.00
22.8750	4.06E-04	2.84E+07	-1745049.	-3.73E-04	32825.	6.02E+11	-18349.	1.65E+08	0.00
23.1800	-6.45E-04	2.19E+07	-1722236.	-2.21E-04	25296.	6.02E+11	30815.	1.75E+08	0.00
23.4850	-0.00121	1.58E+07	-1554471.	-1.06E-04	18245.	6.02E+11	60860.	1.84E+08	0.00
23.7900	-0.00142	1.05E+07	-1305449.	-2.62E-05	12136.	6.02E+11	75218.	1.94E+08	0.00
24.0950	-0.00140	6219802.	-1025592.	2.46E-05	7193.	6.02E+11	77709.	2.03E+08	0.00
24.4000	-0.00124	2986618.	-751518.	5.26E-05	3454.	6.02E+11	72058.	2.12E+08	0.00
24.7050	-0.00102	718694.	-506996.	6.39E-05	831.1801	6.02E+11	61560.	2.22E+08	0.00
25.0100	-7.74E-04	-724596.	-304867.	6.39E-05	838.0063	6.02E+11	48893.	2.31E+08	0.00
25.3150	-5.48E-04	-1512933.	-149428.	5.70E-05	1750.	6.02E+11	36046.	2.41E+08	0.00
25.6200	-3.56E-04	-1818412.	-38920.	4.69E-05	2103.	6.02E+11	24341.	2.50E+08	0.00
25.9250	-2.05E-04	-1797826.	32197.	3.59E-05	2079.	6.02E+11	14520.	2.59E+08	0.00
26.2300	-9.34E-05	-1582732.	71323.	2.54E-05	1938.	5.68E+11	6861.	2.69E+08	0.00
26.5350	-1.93E-05	-1275738.	86557.	1.62E-05	1562.	5.68E+11	1464.	2.78E+08	0.00
26.8400	2.48E-05	-949134.	85666.	8.99E-06	1162.	5.68E+11	-1951.	2.88E+08	0.00
27.1450	4.66E-05	-648664.	75183.	3.85E-06	794.2823	5.68E+11	-3777.	2.97E+08	0.00
27.4500	5.30E-05	-398795.	60153.	4.75E-07	488.3201	5.68E+11	-4436.	3.06E+08	0.00
27.7550	5.00E-05	-208345.	44137.	-1.48E-06	255.1163	5.68E+11	-4316.	3.16E+08	0.00
28.0600	4.22E-05	-75715.	29383.	-2.39E-06	92.7126	5.68E+11	-3746.	3.25E+08	0.00
28.3650	3.25E-05	6740.	17091.	-2.62E-06	8.2529	5.68E+11	-2971.	3.35E+08	0.00
28.6700	2.30E-05	49392.	7696.	-2.44E-06	60.4795	5.68E+11	-2163.	3.44E+08	0.00
28.9750	1.47E-05	63075.	1145.	-2.07E-06	77.2344	5.68E+11	-1417.	3.53E+08	0.00
29.2800	7.84E-06	57772.	-2870.	-1.68E-06	70.7409	5.68E+11	-776.694	3.63E+08	0.00
29.5850	2.35E-06	42064.	-4730.	-1.36E-06	51.5074	5.68E+11	-239.327	3.72E+08	0.00
29.8900	-2.14E-06	23151.	-4760.	-1.15E-06	28.3483	5.68E+11	222.8568	3.81E+08	0.00

Performed By: G. Khatri 7/12/2023
Checked By: R. Lopina 7/12/2023

30.1950	-6.09E-06	7223.	-3163.	-1.06E-06	8.8447	5.68E+11	649.8272	3.91E+08	0.00
30.5000	-9.86E-06	0.00	0.00	-1.03E-06	0.00	5.68E+11	1078.	2.00E+08	0.00

* This analysis computed pile response using nonlinear moment-curvature rela-
  tionships. Values of total stress due to combined axial and bending stresses
  are computed only for elastic sections only and do not equal the actual
  stresses in concrete and steel. Stresses in concrete and steel may be inter-
  polated from the output for nonlinear bending properties relative to the
  magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 2:

Pile-head deflection	=	1.59310048 inches
Computed slope at pile head	=	-0.0073189 radians
Maximum bending moment	=	49084240. inch-lbs
Maximum shear force	=	-1745049. lbs
Depth of maximum bending moment	=	21.04500000 feet below pile head
Depth of maximum shear force	=	22.87500000 feet below pile head
Number of iterations	=	17
Number of zero deflection points	=	3
Pile deflection at ground	=	0.03835644 inches

Pile-head Deflection vs. Pile Length for Load Case 2

Boundary Condition Type 1, Shear and Moment

Shear	=	0. lbs
Moment	=	0. in-lbs
Axial Load	=	0. lbs

Pile	Pile Head	Maximum	Maximum

Length feet	Deflection inches	Moment ln-lbs	Shear lbs
30.50000	1.59310048	49084240.	-1745049.
28.97500	1.54964110	48011842.	-1712729.
27.45000	1.55528892	48115251.	-1719198.
25.92500	1.59960391	49108454.	-1749366.
24.40000	1.81414272	49070582.	-2163736.

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	0.00	M, in-lb	0.00	0.00	1.0108	-0.00469	-1211020.	3.25E+07
2	V, lb	0.00	M, in-lb	0.00	0.00	1.5931	-0.00732	-1745049.	4.91E+07

Maximum pile-head deflection = 1.5931004832 inches
Maximum pile-head rotation = -0.0073188569 radians = -0.419340 deg.

Summary of Warning Messages

The following warning was reported 3273 times

**** Warning ****

An unreasonable input value for unconfined compressive strength has been specified for a soil defined using the weak rock criteria. The input value is greater than 500 psi. Please check your input data for correctness.

The analysis ended normally.

CHECK FOR BEAM CLEARANCE

- Chosen beam size: W36x282
- d = 37.1 in
- b_f = 16.60 in
- $\sqrt{37.1^2+16.6^2}$ = 40.6 in
- 3-inch clearance for a drilled shaft size of 48 inches = 48 in - 2 (3 in) = 42 in
- 40.6 in < 42 in → **ACCEPTABLE**

CHECK FOR DEFLECTION

- Allowable Deflection – 1% or less of the drilled shaft length above bedrock (1% of 20.5 feet = 2.46 inches) (Page 31 of GB-7)
- W36x282 deflection from LPILE is 1.01 inches
- 1.01 in < 2.46 in → **ACCEPTABLE**

CHECK FOR SHEAR CAPACITY OF BEAM

- Section 6 of 8th edition of LRFD Bridge Design Manual
- Chosen beam size: W36x282
- Welded Section
    - Maximum Shear from LPILE – 1745.049 kips
- $V_n = C\ V_p$

$$V_p = 0.58 F_{yw} D t_w \qquad (6.10.9.3.2\text{-}3)$$

where:

d_o = transverse stiffener spacing (in.)
V_n = nominal shear resistance of the web panel (kip)
V_p = plastic shear force (kip)
C = ratio of the shear-buckling resistance to the shear yield strength

- $V_n = 1.0\ (0.58\ F_{yw}\ D\ t_w)$
- V_n = 1.0 (0.58) (50 ksi) (37.1 in) (1.885 in)

[1 inch thick section of steel is proposed to be welded on the web]

- V_n = 2028.07 kips > 1745.049 kips → **ACCEPTABLE**
- Unwelded Section
    - Maximum Shear from LPILE – 360 kips
- V_n = 1.0 (0.58 F_{yw} D t_w)
- V_n = 1.0 (0.58) (50 ksi) (37.1 in) (0.885 in)
- V_n = 952.17 kips > 360 kips → **ACCEPTABLE**

CHECK FOR BUCKLING OF BEAM

- Chosen beam size: W36x282
- If $\frac{D}{t_w} \le 1.12\sqrt{\frac{Ek}{F_{yw}}}$, then:

$$C = 1.0 \qquad (6.10.9.3.2\text{-}4)$$

in which:

k = shear-buckling coefficient

$$= 5 + \frac{5}{\left(\frac{d_o}{D}\right)^2} \qquad (6.10.9.3.2\text{-}7)$$

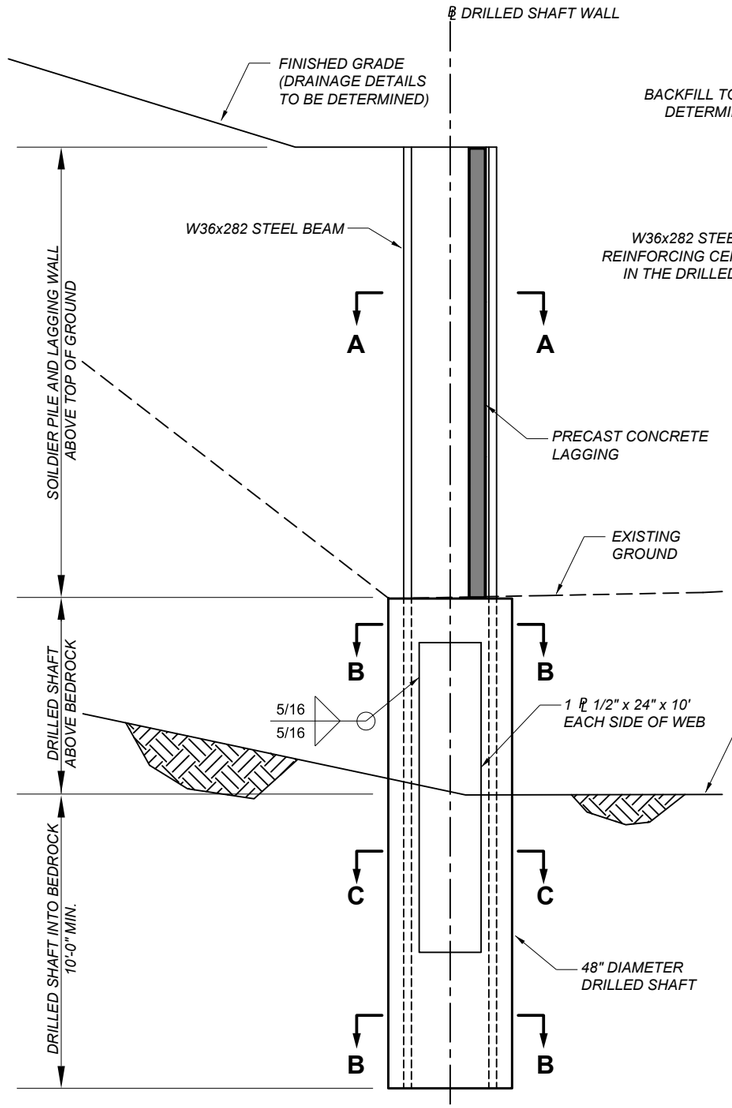
- $k = 5 + \frac{5}{(\frac{48\text{in}}{37.1\text{ in}})^2} = 7.98$
- $1.12\sqrt{\frac{(29{,}000\text{ ksi})\ (7.987)}{50\text{ ksi}}} = 76.23$
- $\frac{D}{t_w} = \frac{37.1}{0.885} = 41.92 < 76.23$ → **ACCEPTABLE**

CHECK MOMENT CAPACITY

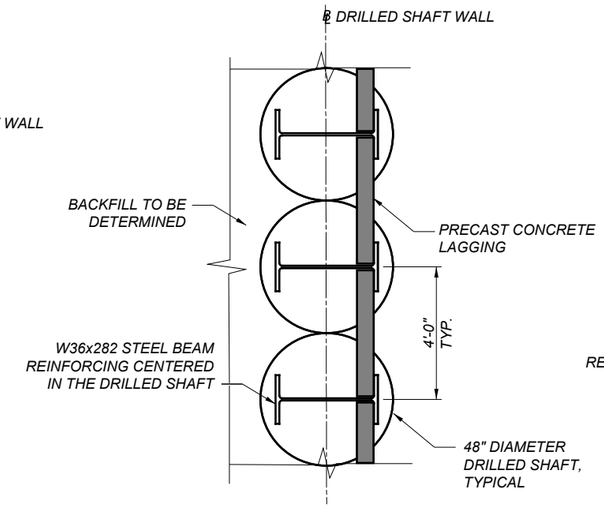
- Chosen beam size: W36x282
    - Beam stickup is approx. 14.6 feet for moment calculation
    - Maximum moment from LPILE – 4091.7 ft-kips
    - From “Steel Construction Manual”, AISC 14th Edition – an unbraced length of 14.6 feet for a W36x282 beam can support a moment capacity of approximately 4350 ft-kips; which is greater than 4091.7 ft-kips → **ACCEPTABLE**

APPENDIX E

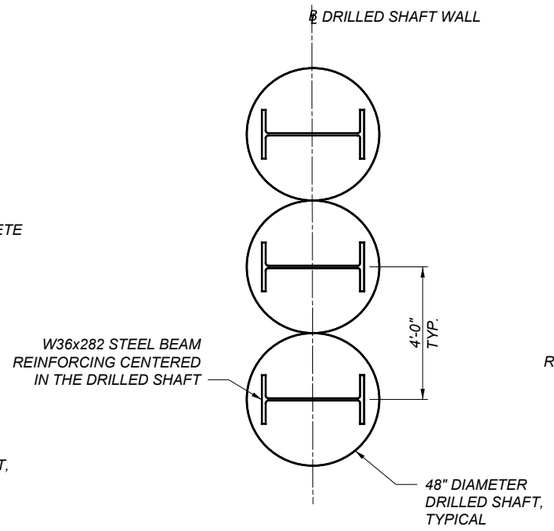
TYPICAL CROSS SECTIONS AND WALL DETAILS



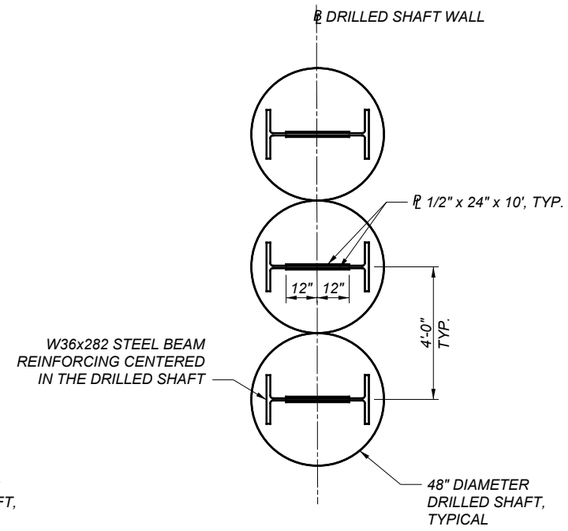
DRILLED SHAFT WALL SECTION
NOT TO SCALE



SECTION A-A
NOT TO SCALE



SECTION B-B
NOT TO SCALE



SECTION C-C
NOT TO SCALE

WALL SECTION AND DETAILS

DESIGN AGENCY

Stantec
10200 Alliance Road,
Suite 300
Cincinnati, OH 45242
(513) 842-8200

DESIGNER

REVIEWER

PROJECT ID

SHEET TOTAL