CTL Engineering, Inc.
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Email: ctl@ctleng.com

AN EMPLOYEE OWNED COMPANY

Consulting Engineers • Testing • Inspection Services • Analytical Laboratories　　　　**Established 1927**

September 28, 2023

IBI Group
23 Triangle Park Drive
Cincinnati, Ohio 45246

Attention:　　Mr. Steven Butler, P.E.
　　　　　　　Associate – Manager, Transportation Engineering

Reference:　　Geohazard Exploration Report - Final
　　　　　　　BRO-52-22.27 Slide Repair
　　　　　　　PID: 115994
　　　　　　　Brown County, Ohio
　　　　　　　CTL Project No. 23050002COL

Dear Mr. Butler:

CTL Engineering, Inc. (CTL) has completed the Geohazard Exploration for the above referenced project. Enclosed is the digital (pdf) copy of the Final report.

Thank you for the opportunity to work with you on this project. If you have any questions or need further information, please feel free to contact our office.

　　　　　　　　　　　　　　　Respectfully Submitted

　　　　　　　　　　　　　　　CTL ENGINEERING, INC.

　　　　　　　　　　　　　　　Joe Grani, P.E.
　　　　　　　　　　　　　　　Project Engineer

GEOHAZARD EXPLORATION REPORT - FINAL

BRO-52-22.57 SLIDE REPAIR
PID: 115994
BROWN COUNTY, OHIO
CTL PROJECT NO. 23050002COL

PREPARED FOR:

IBI GROUP
23 TRIANGLE PARK DRIVE
CINCINNATI, OHIO 45246

PREPARED BY:

CTL ENGINEERING, INC.
2860 FISHER ROAD
COLUMBUS, OHIO 43204
Phone 614-276-8123
Fax 614-276-6377

September 28, 2023

TABLE OF CONTENTS

I.   **EXECUTIVE SUMMARY**

The project involves the exploration of a landslide near mile marker 22.27 of U.S. 52 in Brown County, Ohio, approximately 1.75 miles east of Aberdeen, Ohio. Within the project limits, the U.S. 52 eastbound lanes and guardrail are experiencing instability consisting of rotational/translational movement with a head scarp developed within the roadway pavement (extending to near the centerline and westbound lane of the road) and into the slope below the roadway.

A residential driveway located to the south of U.S. 52 within the project limits is also experiencing instability consisting of cracking and vertical displacement within the pavement/driveway material.

A total of five (5) test borings were performed for this project. Four (4) borings were performed within the eastbound/westbound lanes of U.S. 52 and one (1) boring was performed within the driveway to the south of U.S. 52. All five borings were extended into the underlying bedrock. The top of bedrock was encountered at depths ranging from 23.6 to 28.0 feet below existing grade. The top of bedrock elevations range from 534.1 to 549.6 feet.

Slope stability and drilled shaft analyses were performed at the critical sections (Stations 1180+50 and 1181+50 for the U.S. 52 wall, and Station 1180+04.13 for the driveway wall). Based on the results of the analyses, the following recommendations are provided for the drilled shaft/plug pile retaining walls:

- 3.0-foot diameter reinforced shafts installed at a 5.5-foot center to center spacing with W24x229 steel piles (wall along U.S. 52) and W24x84 steel piles (wall along driveway).

- 3.0 feet diameter plug (unreinforced) shafts installed between the structural shafts at an offset along the proposed centerline of the reinforced drilled shafts.

- Minimum bedrock embedment length of reinforced shafts of 15.0 feet.

- Constructed at a 33.13-foot offset (south) from the centerline of U.S. 52 (wall along U.S. 52), and at a 7.5-foot offset from the edge of the driveway (wall along driveway).

II.   **INTRODUCTION**

The project involves the exploration of a landslide near mile marker 22.27 of U.S. 52 in Brown County, Ohio. The project limits along U.S. 52 begin at Station 1179+00 and end at Station 1181+50, for a project length of 350 feet.

The purpose of this report is to provide findings from the subsurface exploration, and to provide recommendations for the repair of the landslide. This is a Final Report.

III.   **GEOLOGY AND OBSERVATIONS OF THE PROJECT**

According to the Ohio Department of Natural Resources, Physiographic Regions of Ohio Map, the site is located within the Outer Bluegrass Region, which is an unglaciated portion of the Bluegrass Region. Bedrock below the site generally consists of Ordovician Age shale and limestone of the Kope formation.

According to web based mapping from *United States Department of Agriculture, Natural Resources Conservation Service,* the project area contains two primary soil types:

1. Pate Silty Clay, eroded *(PaE2)*: Colluvium derived from limestone and shale over residuum weathered from limestone and shale, 25 to 35 percent slopes, well-drained, very low to moderately low hydraulic conductivity (0.0 to 0.06 in/hr).

2. Elkinsville Silt Loam, eroded *(EkC2)*: Alluvium, 6 to 12 percent slopes, well-drained, moderately high to high hydraulic conductivity (0.6 to 2.0 in/hr).

According to the Ohio Department of Natural Resources (ODNR) Ohio Karst Areas map, no karst features have been mapped within the project site. However, one area described as "Karst – Suspect – Not Visited" is located approximately 0.3 mile northwest of the project area.

According to mapping from the ODNR Website, No underground mines have been mapped in the project area.

A site visit was performed by ODOT and CTL personnel on December 1, 2022. The slip is located along U.S. 52, about 1.75 miles east of Aberdeen, Ohio. A major portion of the distresses appear to be along the eastbound U.S. 52 shoulder and the drive off U.S. 52 to the south. Existing pile and lagging walls were observed south of the guardrail, just outside the eastern and western project limits.

IV.   EXPLORATION

A total of five (5) test borings were performed for this project. Four borings (B-001-0-22, B-002-0-22, B-002-1-22 and B-003-0-22) were performed by ODOT, within the eastbound and westbound lanes of U.S. 52. One boring (B-002-2-22) was performed by CTL, along the driveway south of U.S. 52. The borings were drilled at the approximate locations shown on the Geotechnical Profile – Landslide sheets in Appendix A.

The test borings completed by ODOT were performed with a truck mounted drill rig, utilizing 3.25-inch hollow stem augers (HSA), between June 15 and July 6, 2022. Rock coring was performed in all four borings, using an NQ-size core barrel. The hammer system used was calibrated on April 18, 2022. The hammer system had a drill rod energy ratio of 86.7 percent.

The test boring completed by CTL was performed with a track mounted drill rig, utilizing 3.25-inch hollow stem augers (HSA), on June 23 and 24, 2023. Rock coring was performed in all four borings, using an NQ-size core barrel. The hammer system used was calibrated on August 7, 2020. The hammer system had a drill rod energy ratio of 76.4 percent.

Split spoon soil samples were collected at either continuous or 2.5-foot intervals until split spoon refusal was encountered. Representative soil samples were subjected to laboratory testing including moisture content, hand penetrometer, grain size distribution and Atterberg limits.

Rock from the coring operation was visually classified. The Rock Quality Designation (RQD) and percent core loss values were determined. A representative sample of the recovered rock from boring B-002-2-22 was subjected to compressive strength testing.

Latitude and Longitude coordinates and ground surface elevations of the test boring locations were included on the test boring records prepared by ODOT when provided to CTL. The coordinates and elevation for boring B-002-2-22 was provided by IBI Group.

The boring logs, laboratory test results and rock core photos are shown on the Geotechnical Profile – Landslide sheets in Appendix A.

V.   FINDINGS

Borings B-001-0-22, B-002-0-22, B-002-1-22 and B-003-0-22 were drilled through the existing pavement of U.S. 52. Borings B-001-0-22, B-002-0-22 and B-002-1-22 exhibited 16 to 42 inches of asphalt at the surface. Boring B-001-0-22 contained 10 inches of concrete beneath the asphalt, and boring B-003-0-22 contained a combined 60 inches of asphalt and base material.

Boring B-002-2-22 was drilled through the existing driveway pavement and exhibited approximately 2 inches of asphalt over 10 inches of aggregate base course.

Beneath the existing pavement, the borings encountered both cohesive and granular soils extending to depths ranging from 23.6 to 28.0 feet below existing grade. These correspond to elevations ranging from 534.1 to 549.6. These soils were described as gravel and/or stone fragments with sand (A-1-b), gravel and/or stone fragments with sand and silt (A-2-4), gravel and/or stone fragments with sand, silt and clay (A-2-6 or A-2-7), sandy silt (A-4a), silt and clay (A-6-a), silty clay (A-6b) or clay (A-7-6). The soils exhibited N_{60} values ranging from 3 blows per foot (bpf) to 50 blows for 1 inch of penetration, and natural moisture content values ranging from 6 to 31 percent.

The soil in boring B-002-2-22 beneath the surface cover to a depth of 5.5 feet below existing grade was visually described as fill. The remaining four borings performed by ODOT did not have fill depths identified on the boring logs provided to CTL.

Boulders and cobbles were encountered in borings B-001-0-22, B-002-0-22, B-002-1-22 and B-003-0-22 at elevations ranging from 564.7 feet to 544.2 feet.

Below the soil in borings B-002-2-22 and B-003-0-22, augerable shale or limestone bedrock was encountered at depths ranging from 26.0 to 28.0 feet. These depths correspond to elevations ranging from 549.1 to 534.1 feet. The augerable bedrock exhibited N_{60} values ranging from 52 blows for 6 inches of penetration to 50 blows for 1 inch of penetration.

Below the soil overburden or augerable bedrock, the borings exhibited coreable bedrock. The recovered bedrock from the coring operations was described as shale or interbedded shale and limestone. The bedrock recovered from the coring operations exhibited Rock Quality Designation (RQD) values ranging from 22 to 73 percent, and core recovery values ranging from 83 to 100 percent.

Groundwater was encountered during drilling in borings B-002-0-22, B-002-1-22 and B-002-2-22 at depths ranging from 8.5 to 19.9 feet below existing grade. These depths correspond to elevations ranging from 564.7 to 553.3 feet.

VI.   ANALYSES AND RECOMMENDATIONS

A.   Global Stability Analyses

Three global stability analyses were performed for this project to estimate the shape and depth of the failure surface for the existing site conditions. These analyses included the estimated slip surface beneath U.S. 52 at Stations 1180+50 and 1181+50, and the estimated slip surface beneath the driveway at Station 1180+04.13. The stability of the existing slopes were evaluated using the *Rocscience*

Slide computer program, and the analysis was based on the Morgenstern-Price method.

Cross sections within the area of the slip were prepared by IBI Group, and were provided to CTL.

The stability of the slopes were evaluated from laboratory test results, parameters provided in ODOT's Geotechnical Design Manual (GDM) and engineering judgment. Soil and rock strength parameters used in the analysis are summarized in Tables 1,2 and 3.

Table 1 – Soil and Rock Parameters (Station 1180+50 for U.S. 52 Wall)

Material No.	γ_T (pcf)	Effective Stress Parameters		Material Types
		C (psf)	$\varnothing$ (deg)	
1	145	50*	0	Pavement
2	120	125	19	Embankment Fill
3	122	150	25	Driveway Fill
4	128	200	27	A-6b, A-7-6
5	135	50*	34	A-2-4, A-2-6 with Boulders/Cobbles
5	140	0	18	Soft Rock
6	145	2000	40	Firm Rock

* A low value for cohesion was used so that the analysis would not exhibit shallow sloughing in these layers.

Table 2 – Soil and Rock Parameters (Station 1181+50 for U.S. 52 Wall)

Material No.	γ_T (pcf)	Effective Stress Parameters		Material Types
		C (psf)	$\varnothing$ (deg)	
1	145	50*	0	Pavement
2	120	150	22	Embankment Fill
3	122	150	25	Driveway Fill
4	128	200	27	A-6b, A-7-6
5	135	50*	34	A-2-4, A-2-6 with Boulders/Cobbles
5	140	0	13	Soft Rock
6	145	2000	40	Firm Rock

* A low value for cohesion was used so that the analysis would not exhibit shallow sloughing in these layers.

Table 3 – Soil and Rock Parameters (Station 1180+04.13 for Driveway Wall)

Material No.	γ_T (pcf)	Effective Stress Parameters		Material Types
		C (psf)	$\varnothing$ (deg)	
2	122	150	25	Driveway Fill
3	128	200	27	A-6b, A-7-6
4	135	50*	34	A-2-4, A-2-6 with Boulders/Cobbles
5	140	0	18	Soft Rock
6	145	2000	40	Firm Rock

* A low value for cohesion was used so that the analysis would not exhibit shallow sloughing in these layers.

Results of the global stability analyses are provided in Appendix C. During the site reconnaissance visit, cracking from the head scarp extended to the northern edge of U.S. 52 near the shoulder. Therefore, for the analyses along U.S. 52, the shear surface was estimated to intercept the ground surface at the observed head scarp for the global stability model. The failure surface is also assumed to travel along top of rock and exit near the toe of slope.

B.   Drilled Shaft Analyses

Drilled shaft analyses were also performed at the critical sections being along U.S. 52 at Stations 1180+50 and 1181+50, and along the driveway at Station 1180+04.13.

The analyses were performed to determine the steel size that will be required for drilled shaft/plug pile retaining walls for the project. The following additional information was used in the analyses:

- 3.0-foot diameter reinforced shafts will be installed at a 5.5-foot center to center spacing.
- 3.0 feet diameter plug (unreinforced) shafts will be installed between the structural shafts at an offset to the proposed centerline of the reinforced drilled shafts.
- The retaining wall along U.S. 52 is understood to be constructed at a 33.13-foot offset from the centerline of U.S. 52. The wall along the southern edge of the driveway will be constructed at approximately a 7.5-foot offset from the southern edge of the driveway.

UA SLOPE Analysis

The shear plane surfaces obtained from the *Slide* analysis were input into the *UA Slope Program Version 2.3* software. The model was initially checked to verify the

FS of existing conditions closely resembled the results from the *Slide* analysis, which was at 1.0. The output of this initial run is also provided in Appendix C.

The analysis then involves modeling drilled shafts at a 33.13-foot offset (right) from the centerline of U.S. 52, and at a 7.5-foot offset from the southern edge of the driveway pavement for the driveway wall. The output of the *UA Slope Program* showing the force per shaft value at these assumed drilled shaft locations are provided in Appendix C.

L-Pile Analysis

The force per shaft values obtained from the *UA Slope Program* were then entered into the L-pile computer program to estimate the deflection, shear, and bending moments within the shafts. Procedures outlined in the ODOT GDM along with AASHTO and LRFD manuals were followed while performing the L-pile analyses.

Design checks per the ODOT GDM were performed for each case. Results of the drilled shaft analyses are provided in Appendix C.

Based on the analyses, the steel section which satisfied the necessary design checks for both the wall along U.S. 52 (at Station 1180+50 and 1181+50), and the wall along the driveway (at Station 1180+04.13) are provided in Tables 4 and 5 below.

Table 4- Steel Section (U.S. 52 Wall)

Description	Wall Location	Shaft Diameter (feet)	Center to Center Spacing (feet)	Station	Minimum Steel Section
Plug Pile Retaining Wall	33.13' offset from US 52 centerline	3.0	5.5	1180+50	W24x229*
				1181+50	W24x162

* Recommended steel section for entire wall along U.S. 52

Table 5- Steel Section (Driveway Wall)

Description	Wall Location	Shaft Diameter (feet)	Center to Center Spacing (feet)	Station	Minimum Steel Section
Plug Pile Retaining Wall	7.5' offset from southern edge of driveway	3.0	5.5	1180+04.13	W24x84*

* Recommended steel section for entire wall along driveway

Results of the L-pile analyses are provided in the appended analysis package. It was determined from the L-pile analysis that reinforced shafts should extend at least 15.0 feet into bedrock.

The failure plane at the shaft location for both wall locations were estimated to extend down to the top of bedrock at the proposed wall locations. However, it is understood the non-reinforced shafts (plugs) will not extend to the top of bedrock in either wall. Therefore, it is our recommendation that the plugs should extend a minimum of 3 feet below the estimate artificially lowered ground surface downslope of the walls.

While determining the top of rock depths/elevations at the retaining wall locations, CTL recommends using a slope rate of 22 degrees for the rock surface between U.S. 52 and the wall along U.S. 52, and a slope rate of 20 degrees for the rock surface between the driveway and wall along the driveway. These slope rates were estimated based on the existing grades, and top of rock depths/elevations from borings B-002-0-22, B-002-1-22 and B-002-2-22.

VII.   CHANGED CONDITIONS

The evaluations, conclusions, and recommendations in this report are based on our interpretation of the field and laboratory data obtained during the exploration, our understanding of the project and our experience with similar sites and subsurface conditions using generally accepted geotechnical engineering practices. Although individual test borings are representative of the subsurface conditions at the boring locations on the dates drilled, they are not necessarily representative of the subsurface conditions between boring locations or subsurface conditions during other seasons of the year.

In the event that changes in the project are proposed, additional information becomes available, or if it is apparent that subsurface conditions are different from those provided in this report, CTL Engineering should be notified so that our recommendations can modified, if required.

VIII.   TESTING AND OBSERVATION

During the design process, it is recommended that CTL Engineering work with the project designers to confirm that the geotechnical recommendations are properly incorporated into the final plans and specifications, and to assist with establishing criteria for the construction observation and testing.

CTL Engineering is not responsible for independent conclusions, opinions and recommendations made by others based on the data and recommendations provided in this report.

IX. CLOSING

This report has been prepared for the exclusive use by the client for use only on this project. Our services have been performed in accordance with generally accepted Geotechnical Engineering principles and practices. No warranty is either expressed or implied.

CTL Engineering's assignment does not include, nor does this geotechnical report address the environmental aspects of this particular site.

Specific design and construction recommendations have been provided in this report. Therefore, the report should be used in its entirety.

Respectfully Submitted,
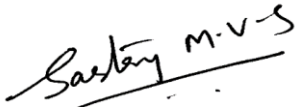
CTL ENGINEERING, INC.

Evan Holcombe, P.E.   Joe Grani, P.E.
Geotechnical Engineer   Project Engineer

Sastry Malladi, P.E.
Project Engineer

APPENDIX A
GEOTECHNICAL PLAN AND PROFILE SHEETS

PROJECT DESCRIPTION

EXPLORATION OF SLOPE INSTABILITY ALONG US 52 IN BROWN COUNTY NEAR MILE MARKER 22.27. THE SLOPE INSTABILITY EXTENDS ALONG US 52 FOR APPROXIMATELY 255 FEET. A NEW RETAINING WALL IS PLANNED TO BE CONSTRUCTED ALONG THE AFFECTED ALIGNMENT ALONG US 52 ANAD ALONG THE SOUTHERN EDGE OF THE EXISTING DRIVEWAY EXTENDING SOUTH FROM US 52.

HISTORIC RECORDS

NO HISTORIC BORING RECORDS WERE FOUND WITHIN THE PROJECT LIMITS.

GEOLOGY

ACCORDING TO PHYSIOGRAPHIC MAPS (ODNR, 1998), THE PROJECT SITE LIES WITHIN THE OUTER BLUEGRASS REGION OF THE BLUEGRASS SECTION. ACCORDING TO BEDROCK GEOLOGIC MAP OF OHIO (2006), THE BEDROCK UNDERLYING THE SITE CONSISTS OF SHALE AND LIMESTONE OF THE ORDOVICIAN-AGE FORMATION.

RECONNAISSANCE

A FIELD RECONNAISSANCE WAS PERFORMED ON DECEMBER 1, 2022. THE SLIP IS LOCATED ALONG U.S. 52, ABOUT 1.75 MILES EAST OF ABERDEEN, OHIO. A MAJOR PORTION OF THE DISTRESSES APPEAR TO BE ALONG THE EASTBOUND U.S. 52 SHOULDER AND THE DRIVE OFF U.S. 52 TO THE SOUTH. EXISTING PILE AND LAGGING WALLS WERE OBSERVED SOUTH OF THE GUARDRAIL, JUST OUTSIDE THE EASTERN AND WESTERN PROJECT LIMITS.

SUBSURFACE EXPLORATION

FIVE BORINGS WERE ADVANCED ALONG THE AFFECTED ALIGNMENT FOR THIS PROJECT. BORING B-002-2-22 WAS PERFORMED BY CTL AND WAS DRILLED ALONG THE DRIVEWAY SOUTH OF U.S. 52. BORINGS B-001-0-22, B-002-0-22, B-002-1-22 AND B-003-0-22 WERE PERFORMED BY ODOT AND WERE DRILLED WITHIN THE EASTBOUND AND WESTBOUND LANES OF U.S. 52. THE BORINGS PERFORMED BY CTL WERE DRILLED USING A TRACK MOUNTED ROTARY DRILL RIG AND 3.25-INCH I.D. HOLLOW STEM AUGERS AND THE BORINGS PERFORMED BY ODOT WERE DRILLED USING A TRUCK MOUNTED ROTARY DRILL RIG AND 3.25-INCH I.D. HOLLOW STEM AUGERS TO ADVANCE THE BORINGS THROUGH THE SOIL. THE HAMMER SYSTEM USED BY ODOT WAS LAST CALIBRATED ON APRIL 18, 2022, AND THE AVERAGE DRILL ROD RATIO (ER) WAS 86.7 PERCENT. THE HAMMER SYSTEM USED BY CTL WAS LAST CALIBRATED ON MAY 3, 2023, AND THE AVERAGE DRILL ROD RATIO (ER) WAS 76.8 PERCENT. DISTURBED SAMPLES WERE COLLECTED IN ACCORDANCE WITH THE STANDARD PENETRATION TEST (AASHTO T206) AT EITHER CONTINUOUS OR 2.5-FOOT INTERVALS FOR THE SOIL DEPTH OF THE BORINGS. THE BORINGS WERE ADVANCE INTO BEDROCK AND SAMPLED (AASHTO T225) USING AN NQ WIRELINE CORE BARREL.

EXPLORATION FINDINGS

BORINGS B-001-0-22, B-002-0-22, B-002-1-22 AND B-003-0-22 WERE DRILLED THROUGH THE EXISTING PAVEMENT OF US 52 AND ENCOUNTERED 16 TO 42 INCHES OF ASPHALT PAVEMENT. BORING B-001-0-22 ENCOUNTERED 10 INCHES OF CONCRETE BASE BENEATH THE ASPHALT. BORING B-003-0-22 CONTAINED A COMBINED 60 INCHES OF ASPHALT AND BASE MATERIAL. BORING B-002-2-22 WAS DRILLED THROUGH THE EXISTING DRIVEWAY AND ENCOUNTERED 2 INCHES OF ASPHALT PAVEMENT OVER 10 INCHES OF AGGREGATE BASE. BENEATH THE PAVEMENT, COHESIVE AND GRANULAR SOILS WERE ENCOUNTERED CONSISTING OF GRAVEL AND/OR STONE FRAGMENTS WITH SAND (A-1-b), GRAVEL AND/OR STONE FRAGMENTS WITH SAND, SILT AND CLAY (A-2-6), SANDY SILT (A-4a), SILT AND CLAY (A-6-a), SILTY CLAY (A-6b) OR CLAY (A-7-6). IN BORINGS B-002-2-22 AND B-003-0-22, AUGERABLE, WEATHERED LIMESTONE OR SHALE WAS ENCOUNTERED AT DEPTHS RANGING FROM 26.0 TO 28.0 FEET BELOW GRADE. BORINGS B-001-0-22, B-002-0-222, B-002-1-22 AND B-003-0-22 ENCOUNTERED ZONES OF COBBLES AND BOULDERS WITHIN THE SOIL. BENEATH THE AUGERABLE BEDROCK OR SOIL OVERBURDEN, COREABLE BEDROCK DESCRIBED AS SHALE OR INTERBEDDED SHALE AND LIMESTONE WAS ENCOUNTERED.

BORINGS B-002-0-22, B-002-1-22 AND B-002-2-22 ENCOUNTERED GROUNDWATER DURING DRILLING AT A DEPTHS RANGING FROM 8.5 TO 19.9 FEET BELOW GRADE.

SPECIFICATIONS

THIS GEOTECHNICAL EXPLORATION WAS PERFORMED IN ACCORDANCE WITH THE STATE OF OHIO, DEPARTMENT OF TRANSPORTATION, OFFICE OF GEOTECHNICAL ENGINEERING, SPECIFICATIONS FOR GEOTECHNICAL EXPLORATIONS, DATED JANUARY 2023.

LEGEND

DESCRIPTION	ODOT CLASS	CLASSIFIED MECH./VISUAL	
GRAVEL AND/OR STONE FRAGMENTS WITH SAND	A-1-b (0)	2	0
GRAVEL AND/OR STONE FRAGMENTS W/SAND AND SILT	A-2-4 (0)	0	3
GRAVEL AND/OR STONE FRAGMENTS W/SAND, SILT AND CLAY	A-2-6 (1)	3	3
GRAVEL AND/OR STONE FRAGMENTS W/SAND, SILT AND CLAY	A-2-7 (0)	0	2
SANDY SILT	A-4a (4)	2	1
SILT AND CLAY	A-6a (7)	5	7
SILTY CLAY	A-6b (8)	6	4
CLAY	A-7-6 (15)	3	12
	TOTAL	25	32
LIMESTONE	VISUAL		
SHALE	VISUAL		
BOULDERS	VISUAL		
INTERBEDDED SHALE AND LIMESTONE	VISUAL		
SHALE	VISUAL		

PAVEMENT OR BASE = X = APPROXIMATE THICKNESS

BORING LOCATION - PLAN VIEW

DRIVE SAMPLE AND/OR ROCK CORE BORING PLOTTED TO VERTICAL SCALE ONLY. HORIZONTAL BAR INDICATES A CHANGE IN STRATIGRAPHY.

WC   INDICATES WATER CONTENT IN PERCENT.

N_{60} INDICATES STANDARD PENETRATION RESISTANCE NORMALIZED TO 60% DRILL ROD ENERGY RATIO.

W   INDICATES FREE WATER ELEVATION.

X/Y/D"   NUMBER OF BLOWS FOR STANDARD PENETRATION TEST (SPT): X=NUMBER OF BLOWS FOR 6 INCHES (UNCORRECTED). Y/D"=NUMBER OF BLOWS (UNCORRECTED) FOR D" OF PENETRATION AT REFUSAL.

SS   INDICATES A SPLIT-SPOON SAMPLE.

TR   INDICATES TOP OF ROCK ELEVATION.

NP   INDICATES A NON-PLASTIC SAMPLE.

AVAILABLE INFORMATION

THE SOIL, BEDROCK, AND GROUNDWATER INFORMATION COLLECTED FOR THIS SUBSURFACE EXPLORATION THAT CAN BE CONVENIENTLY DISPLAYED ON THE SOIL PROFILE SHEETS HAS BEEN PRESENTED. GEOTECHNICAL REPORTS, IF PREPARED, ARE AVAILABLE FOR REVIEW ON THE OFFICE OF CONTRACT SALES WEBSITE.

BEDROCK TEST SUMMARY

BORING ID	SAMPLE ELEVATION	SAMPLE DEPTH	QU (PSI)	LITHOLOGY
B-002-2-22	526.5' - 526.0'	35.6' - 36.1'	1,180	SHALE
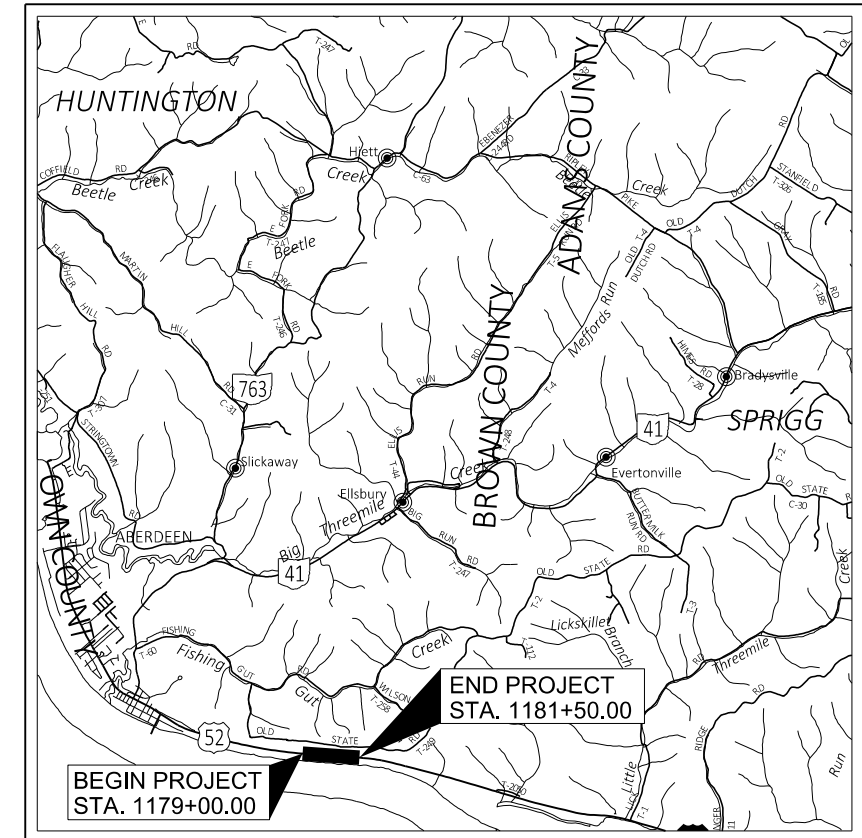
LOCATION MAP

SCALE IN MILES

0   1   2   3   4

N

END PROJECT STA. 1181+50.00

BEGIN PROJECT STA. 1179+00.00

PARTICLE SIZE DEFINITIONS

12"	3"	2.0 mm	0.42 mm	0.074 mm	0.005 mm
BOULDERS	COBBLES	GRAVEL	COARSE SAND	FINE SAND	SILT	CLAY

No. 10 SIEVE   No. 40 SIEVE   No. 200 SIEVE
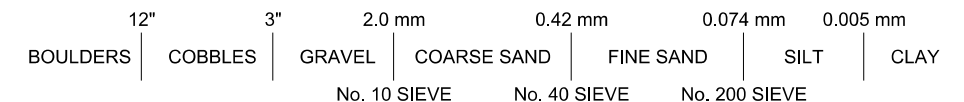
RECON. -   SM 01/05/2023

DRILLING -   CTL 01/23/23 TO 01/24/23

DRAWN -   N.K.S 09/26/23

REVIEWED -   JG 09/26/23

GEOTECHNICAL PROFILE - LANDSLIDE
BRO-52-22.27

BRO-52-22.27

MODEL: BRO-52 - Plan 1-1 PAPERSIZE: 17x11 (in.)   DATE: 26-09-2023   TIME: 14:32:50 USER: hp
D:\Drop Box\CTL 2023\September\Dept 05\COLEvan\230500\02COL_ODOTMOD_25.09.23\115994GP001.dgn

GEOTECHNICAL PROFILE - LANDSLIDE
STA. 1177+46.45 TO STA. 1182+96.41

HORIZONTAL
SCALE IN FEET
0 10 20 40

INTERSECTION
STA. 1179+75.00 CONST. S.R. 52 &
EXISTING R/W STA. 0+00.00 CENTER LINE DRIVEWAY

BEGIN WORK
STA. 1178+50.00

BEGIN PROJECT
STA. 1179+00.00

EDGE OF SLIP (TYP.)

CONST. S.R. 52 &
EXISTING R/W

END PROJECT
STA. 1181+50.00

END WORK
STA. 1182+00.00

EDGE OF SLIP
(TYP.)

B-002-1-22

B-002-0-22

B-003-0-22

B-001-0-22

CP01

EX. GR

GUARDRAIL TYPE MGS

CL CONST. DRIVEWAY

B-002-2-22

PROPOSED DRILLED
SHAFT WALL

GUARDRAIL
TRANSITION

50.0'

575 570 565 560

1178+00 1179+00 1180+00 1181+00 1182+00

Ex SH

EXISTING GRADE

PROPOSED GRADE

B-001-0-22
6.3' RT.
ASPHALT=1.5'
CONCRETE=0.83'

N_{60}	WC
27	12
49	10
68	13
52	11
39	15
56	15
55	14
78	13 11
37/53/6"	10 TR

B-002-0-22
13.2' RT.
ASPHALT=3.5'

N_{60}	WC
22	6
17	22 W
27	7
134	6
17	22
123	19
59	9
87	16
30/57/6"	15 14 TR

B-003-0-22
13.68' RT.
ASPHALT & BASE=5.0'

N_{60}	WC
35/50/6"	-
94	14
16	13
29	20
14	17
27	15
77	13
65	14
88	13 TR
26/52/6"	10

Top elevations: 570.30 570.89 571.49 572.09 572.69 573.29 573.88 574.48 575.08 575.68

Bottom elevations: 568.13 568.45 568.82 569.24 569.67 570.30 571.05 571.80 572.46 572.88 573.20 573.67 574.27 574.95 575.62 576.28 576.79 577.21 577.63 578.04

Left axis: 590 580 570 560 550 540 530 520 510
Right axis: 590 580 570 560 550 540 530 520 510

DESIGN AGENCY

CTL
ENGINEERING, INC.
2860 FISHER ROAD
COLUMBUS, OHIO 43204
PHONE: (614) 276-8123
FAX: (614) 276-6377

DESIGNER
N.K.S

REVIEWER
JG   09-26-23

PROJECT ID
115994

SUBSET	TOTAL
2	11

SHEET	TOTAL
P.35	44

PROP. GUARDRAIL
TYPE MGS

EX. GUARDRAIL
PROP. CONSTRUCTION
LIMITS (TYP.)

B-002-1-22

B-002-0-22

INTERSECTION
STA. 0+00.00 ℄ CONST. DRIVEWAY
STA. 1179+75.00 ℄ CONST. S.R. 52 & ☐ EXIST. R/W

℄ CONST. SR. 52

1180

0+00

570

565

560

570

565

+00

B-002-2-22

EX. GUARD RAIL

565

℄ CONST. DRIVEWAY

PROP. DRILLED SHAFT WALL

PROP. GUARDRAIL
TYPE MGS

PROPOSED GRADE

B-002-2-22
58' RT.
ASPHALT = 0.17'
AGGREGATE BASE = 0.83'

EXISTING GRADE

580

570

560

550

540

530

520

510

6
12
10
20
24
45
17
23
37
9
17
17
35
52
9/36/50/3" 50/1"
37
50/1" 68
46/50/1"

8
7
9
18
24
29
16
26 W
29
31
15
19
22 21

19
21 22 TR
12

N₆₀   WC

572.46 569.39 566.94 564.98 562.33 559.32 556.66

0+00   1+00

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STA. 1180+50.00

590 — 590
580 — 580
570 — 570
560 — 560
550 — 550
540 — 540
530 — 530
520 — 520

B-002-1-22
STA. 1180+41.73
ASPHALT=1.33'

B-002-0-22
STA. 1180+41.11
ASPHALT=3.5'

B-002-2-22
STA. 1180+42
ASPHALT = 0.17'
AGGREGATE BASE = 0.83'

B-002-1-22:
4 6
3 20
26 16
43 15
11/36/50/4" 12
114 10
40/57/6" 10
26/50/4" 9 W
TR

N_60   WC

B-002-0-22:
22 6
17 22 W
27 7
134 6
17 22
123 19
59 9
87 16
30/57/6" 15 14 TR

N_60   WC

B-002-2-22:
6 8
12 9
10 18
22 24
45 29
17 16 W
23 25
37 29
9 29
17 31
10 15
35 19
52 22 21
9/36/50/3" 50/1"
37 19
50/1" 68 21 22 TR
46/50/1" 12

N_60   WC

80 70 60 50 40 30 20 10 0 10 20 30 40 50 60 70 80

STA. 1179+00.00

590 — 590
580 — 580
570 — 570
560 — 560
550 — 550
540 — 540
530 — 530
520 — 520

B-001-0-22
STA. 1178+96.4
ASPHALT=1.5'
CONCRETE=0.83'

27 12
49 10
68 13
52 11
39 15
56 15
55 14
78 13 11
37/53/6" 10
TR

N_60   WC

80 70 60 50 40 30 20 10 0 10 20 30 40 50 60 70 80

GEOTECHNICAL PROFILE - LANDSLIDE
CROSS SECTIONS STA. 1179+00.00 AND STA. 1180+50.00

DESIGN AGENCY

CTL
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FAX: (614)276-6377

DESIGNER
N.K.S

REVIEWER
JG 09-26-23

PROJECT ID
115994

SUBSET	TOTAL
4	11

SHEET	TOTAL
P.37	44

MODEL: BRO-52 - 1181+50.00   PAPERSIZE: 17x11 (in.)   DATE: 26-09-2023   TIME: 14:38:34   USER: hp
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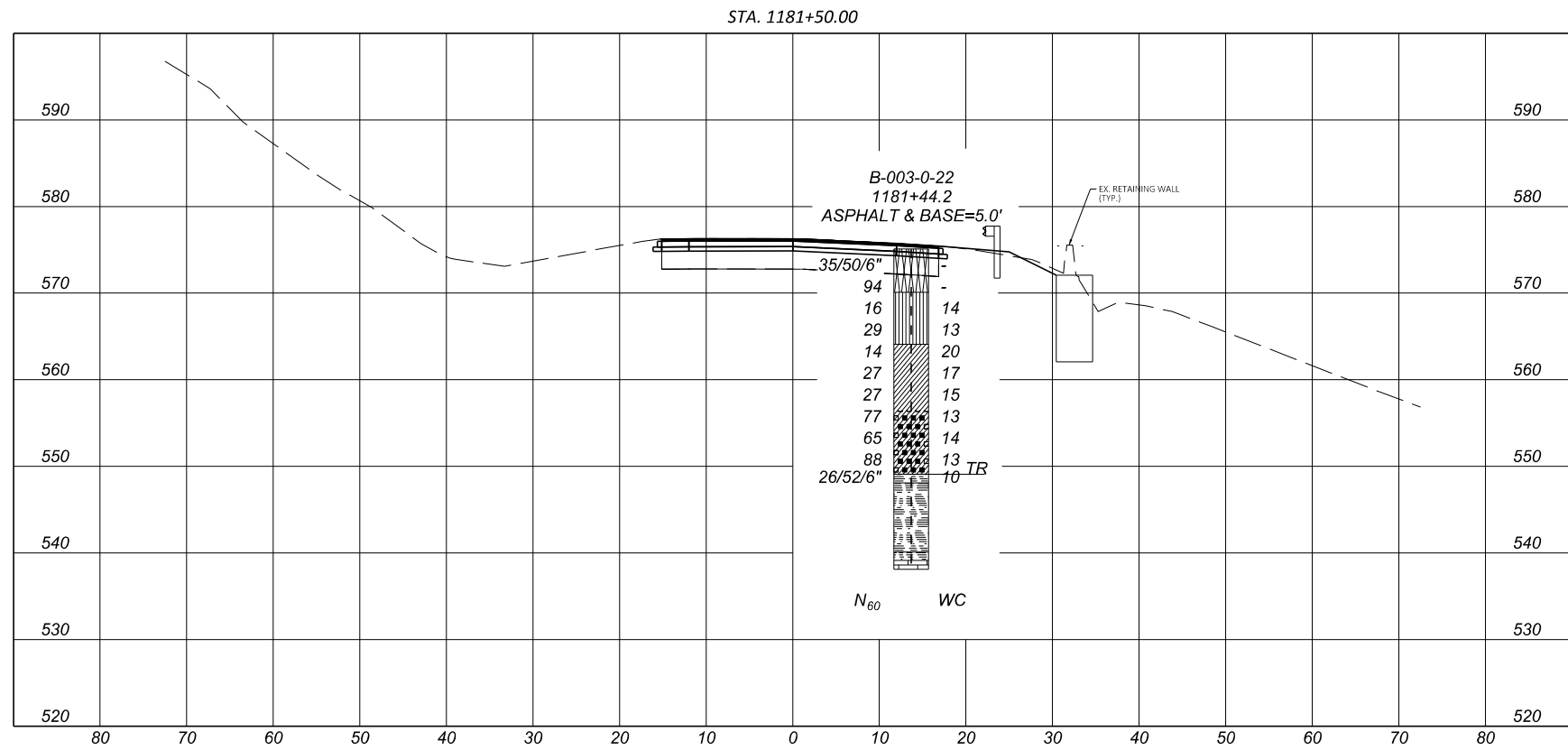
GEOTECHNICAL PROFILE - LANDSLIDE
CROSS SECTIONS STA. 1181+50.00

STA. 1181+50.00

590 — 590

580 — 580

B-003-0-22
1181+44.2
ASPHALT & BASE=5.0'

EX. RETAINING WALL
(TYP.)

570 — 570

35/50/6"

94   -
16   14
29   13
14   20

560 — 560

27   17
27   15
77   13

550 — 550

65   14
88   13 TR
26/52/6"   10

540 — 540

530 — 530

N_{60} WC

520 — 520

80 70 60 50 40 30 20 10 0 10 20 30 40 50 60 70 80

DESIGN AGENCY

CTL
ENGINEERING INC
2860 FISHER ROAD
COLUMBUS, OHIO 43204
PHONE: (614)276-8123
FAX: (614)276-6377
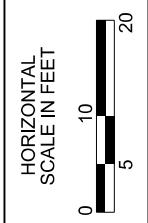
DESIGNER
N.K.S

REVIEWER
JG   09-26-23

PROJECT ID
115994

SUBSET	TOTAL
5	11

SHEET	TOTAL
P.38	44

BRO-52-22.27

MODEL: Sheet PAPERSIZE: 17x11 (in.)   DATE: 26-09-2023 TIME: 14:48:46 USER: hp
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PROJECT:	BRO-52-22.27	DRILLING FIRM / OPERATOR:	ODOT / CAREY	DRILL RIG:	CME 55 TRUCK	STATION / OFFSET:	1178+96, 6' RT.	EXPLORATION ID
TYPE:	LANDSLIDE	SAMPLING FIRM / LOGGER:	ODOT / MCLEISH	HAMMER:	CME AUTOMATIC	ALIGNMENT:	CL SR 52	B-001-0-22
PID: 115994	SFN:	DRILLING METHOD:	3.25" HSA / NQ2	CALIBRATION DATE:	4-18-22	ELEVATION:	570.0 (ft) EOB: 35.5 ft.	PAGE
START: 6-15-22	END: 6-29-22	SAMPLING METHOD:	SPT / NQ2	ENERGY RATIO (%):	86.7	LAT / LONG:	38.648977, -83.731759	1 OF 1

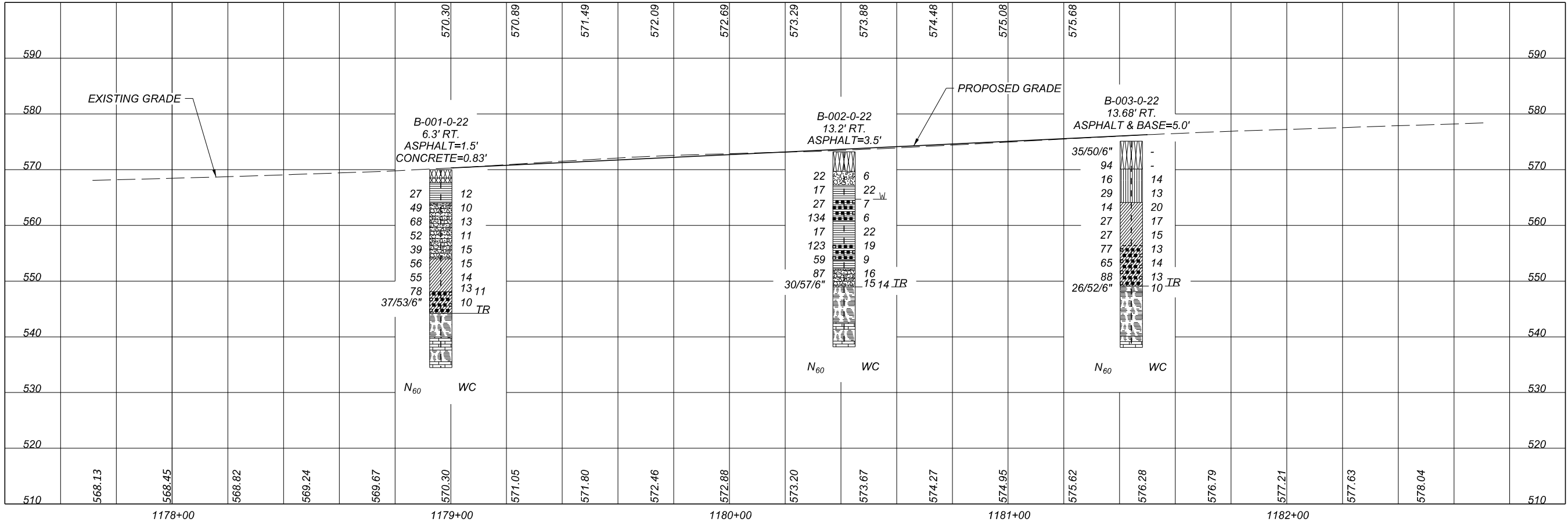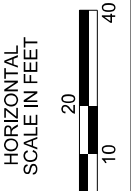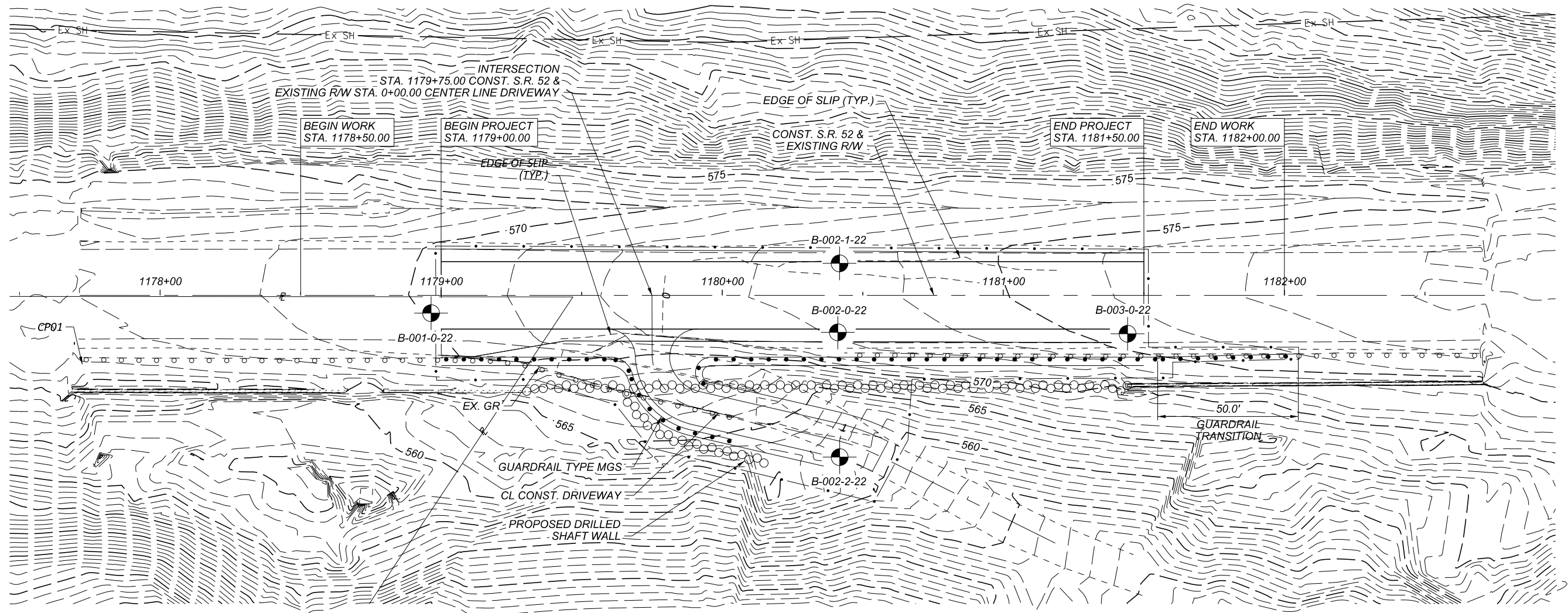| MATERIAL DESCRIPTION AND NOTES	ELEV. 570.0	DEPTHS	SPT/ RQD	N60	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG				ODOT CLASS (GI)	SO4 ppm	BACK FILL
								GR	CS	FS	SI	CL	LL	PL	PI	WC			
ASPHALT (18") & CONCRETE (10")	567.6	1–2																	
VERY STIFF, BROWN AND DARK GRAY, **SILTY CLAY**, SOME GRAVEL AND STONE FRAGMENTS, LITTLE SAND, MODERATELY ORGANIC (LOI = 5.1%), DAMP	564.0	3–5	5 / 9 10	27	67	SS-1	3.00	26	5	6	27	36	39	23	16	12	A-6b (8)	-	
DENSE, BROWN, **STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, DAMP		6–8	24 / 24 10	49	56	SS-2	-	45	13	9	17	16	29	18	11	10	A-2-6 (0)	-	
@8.5'; VERY DENSE		9–10	17 / 30 17	68	28	SS-3	-	-	-	-	-	-	-	-	-	13	A-2-6 (V)	-	
@11.0'; USED 3" SPLITSPOON FOR SAMPLE		11–12	17 / 16 20	52	44	SS-4	-	52	8	5	18	17	30	17	13	11	A-2-6 (1)	-	
DENSE, NO RECOVERY; AUGER CUTTINGS TAKEN @13.5'; NO RECOVERY TOOK AUGER SAMPLE	554.0	14–15	7 / 12 15	39	0	SS-5	-	-	-	-	-	-	-	-	-	15	A-2-6 (V)	-	
VERY STIFF, BROWN, **SILT AND CLAY**, LITTLE STONE FRAGMENTS, TRACE SAND, DAMP		16–17	11 / 21 18	56	61	SS-6	3.50	13	3	3	38	43	34	21	13	15	A-6a (9)	-	
@18.5'; HARD		19–20	10 / 16 22	55	83	SS-7	4.50	-	-	-	-	-	-	-	-	14	A-6a (V)	-	
@21.9' - 25.8'; ENCOUNTERED BOULDERS/COBBLES		21–22	27 / 23 31	78	89	SS-8A	4.50	-	-	-	-	-	-	-	-	13	A-6a (V)	-	
						SS-8B	-	-	-	-	-	-	-	-	-	11	A-6a (V)	-	
@23.5'; BROWN AND GRAY	544.2	24–25	37 / 53	-	100	SS-9	-	-	-	-	-	-	-	-	-	10	A-6a (V)	-	
SHALE, DARK GRAY, MODERATELY WEATHERED, WEAK, LAMINATED, CALCAREOUS, FOSSILIFEROUS; RQD 74%, REC 100%. @28.0' - 29.5'; HIGHLY WEATHERED	540.0	26–30		70	100	NQ2-1											CORE		
INTERBEDDED SHALE (70%) AND LIMESTONE (30%), BLOCKY, FAIR, RQD 50%, REC. 85%; **SHALE**, DARK GRAY WITH GRAY, MODERATELY WEATHERED, VERY WEAK TO WEAK, LAMINATED, CALCAREOUS, FOSSILIFEROUS, RANGES IN THICKNESS 2" TO 5"; **LIMESTONE**, BLUISH GRAY, MODERATELY WEATHERED, STRONG, VERY THIN TO THIN BEDDED, FOSSILIFEROUS, RANGES IN THICKNESS 1" TO 10". @30.5' - 31.8'; HIGHLY WEATHERED WITH LOSS	534.5	31–35		47	83	NQ2-2											CORE		

TR (at ~25.5)
EOB (at ~35.5)

OHIO DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING

Office of Geotechnical Engineering

B-001-0-22

BR: NQ2-1 25.5'
ER: NQ2-1 30.5'
BR: NQ2-2 30.5'
ER: NQ2-2 35.5'

Run #:	Depth		Recovery		RQD	
NQ2-1	25.5'	30.5'	60/60	100%	42/60	70%
NQ2-2	30.5'	35.5'	50/60	83%	28/60	47%
BRO-52-22.27 PID 115994						

GEOTECHNICAL PROFILE – LANDSLIDE

BORING LOG AND ROCK CORE PHOTO FOR B-001-0-22

BRO-52-22.27

PROJECT: BRO-52-22.27	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 1180+41, 31' RT.	EXPLORATION ID B-002-0-22
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / SPROUSE	HAMMER: CME AUTOMATIC	ALIGNMENT: CL SR 52	
PID: 115994 SFN:	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 4-18-22	ELEVATION: 573.2 (ft) EOB: 35.0 ft.	PAGE 1 OF 1
START: 6-29-22 END: 7-6-22	SAMPLING METHOD: SPT / NQ2	ENERGY RATIO (%): 86.7	LAT / LONG: 38.648947, -83.731259	

MATERIAL DESCRIPTION AND NOTES / Core Log

MATERIAL DESCRIPTION AND NOTES	ELEV. 573.2	DEPTHS	SPT/ RQD	N60	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
ASPHALT (42")		1-3																	
	569.7																		
MEDIUM DENSE, BROWNISH GRAY, **STONE FRAGMENTS WITH SAND**, LITTLE SAND, TRACE CLAY, DAMP		4-5	12 10 5	22	56	SS-1	2.00	46	23	9	17	5	17	16	1	6	A-1-b (0)	-	
	567.2	6																	
VERY STIFF, GRAY AND BROWN, **SILTY CLAY**, LITTLE STONE FRAGMENTS, LITTLE SAND, MOIST		7	4 5 7	17	56	SS-2	4.00	18	7	6	29	40	38	22	16	22	A-6b (9)	-	
	564.7 ▼	8																	
@8.5' - 12.5'; ENCOUNTERED BOULDERS/COBBLES		9-10	13 11 8	27	47	SS-3	3.00	-	-	-	-	-	-	-	-	7	A-6b (V)	-	
@11.0'; HARD		11-12	8 45 48	134	50	SS-4	5.00	-	-	-	-	-	-	-	-	6	A-6b (V)	-	
@13.5'; VERY STIFF, BROWN, "AND" STONE FRAGMENTS		13-14	4 6 6	17	44	SS-5	3.25	37	7	4	25	27	39	22	17	22	A-6b (6)	-	
@16.0'; HARD, TRACE SAND, DAMP @16.5' - 19.5'; ENCOUNTERED BOULDERS/COBBLES		15-17	14 57 28	123	56	SS-6	4.50	42	2	2	24	30	36	20	16	19	A-6b (6)	-	
		18-19	25 22 19	59	56	SS-7	4.5+	-	-	-	-	-	-	-	-	9	A-6b (V)	-	
	552.2	20																	
VERY DENSE, BROWN AND GRAY, **STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, DAMP		21-22	9 25 35	87	50	SS-8	-	13	43	19	17	8	36	21	15	16	A-2-6 (1)	-	
	549.0	23																	
		24 TR	30 57	-	100	SS-9A	-	-	-	-	-	-	-	-	-	15	A-2-6 (V)	-	
SHALE, DARK GRAY AND BROWN, HIGHLY WEATHERED, WEAK, LAMINATED, CALCAREOUS, BLOCKY, POOR; RQD 63%, REC 100%.						SS-9B	-	-	-	-	-	-	-	-	-	14	Rock (V)	-	
		25-29		60	100	NQ2-1											CORE		
	542.6	30																	
INTERBEDDED SHALE (70%) AND LIMESTONE (30%), BLOCKY, GOOD, RQD 32%, REC. 96%; **SHALE**, DARK GRAY, MODERATELY WEATHERED, WEAK, LAMINATED, CALCAREOUS, RANGES IN THICKNESS 1" TO 19"; **LIMESTONE**, BLUISH GRAY, MODERATELY WEATHERED, STRONG, VERY THIN TO THIN BEDDED, FOSSILIFEROUS, RANGES IN THICKNESS 0.5" TO 3.5".		31-34		38	97	NQ2-2											CORE		
	538.2	35 EOB																	

(Left margin vertical text: FOR SACHINAI93050002COL_ODOT20000COL 9.22.23 FOR SACHINAI600976.GPJ)

OHIO DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING

Office of Geotechnical Engineering

B-002-0-22

BR: NQ2-1 25.0'
30.0'
ER: NQ2-2 35.0'

Run #:	Depth		Recovery		RQD	
NQ2-1	25.0'	30.0'	60/60	100%	36/60	60%
NQ2-2	30.0'	35.0'	57/60	98%	23/60	38%
BRO-52-22.27 PID 115994						

CTL ENGINEERING, INC. COLUMBUS, OHIO 43204 PHONE (614) 276-8123 FAX (614) 276-6377

DESIGN AGENCY

GEOTECHNICAL PROFILE - LANDSLIDE
BORING LOG AND ROCK CORE PHOTO FOR B-002-0-22

BRO-52-22.27

MODEL: Sheet PAPERSIZE: 17x11 (in.)   DATE: 26-09-2023 TIME: 14:44:55 USER: hp
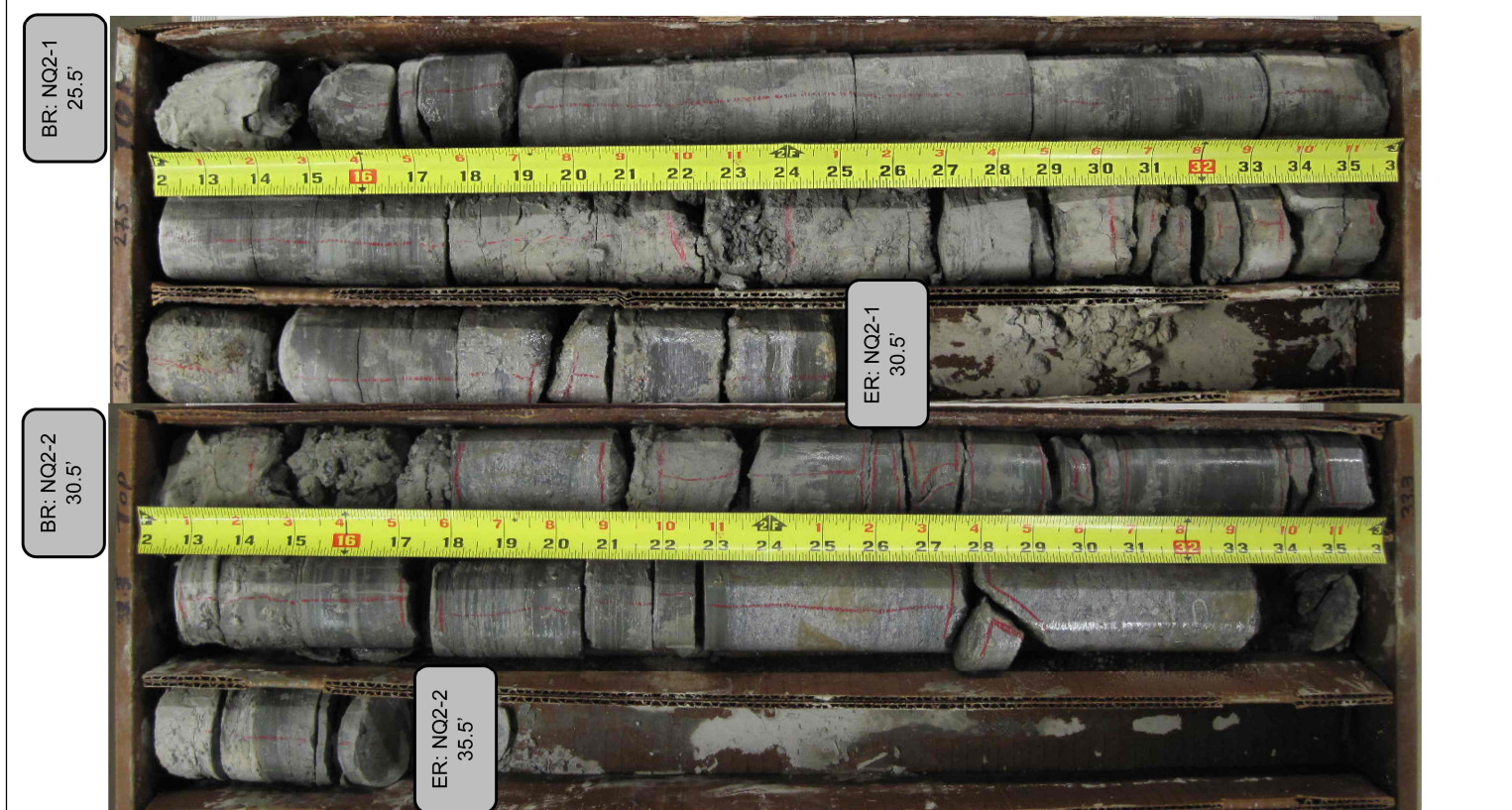D:\Drop Box\CTL 2023\September\Dept 05\COL\Evan\23050002COL_ODOT\MOD_25.09.23\93830ZL003.dgn

PROJECT: BRO-52-22.27	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 1180+41, 12' LT.	EXPLORATION ID
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / MCLEISH	HAMMER: CME AUTOMATIC	ALIGNMENT: CL SR 52	B-002-1-22
PID: 115994 SFN:	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 4-18-22	ELEVATION: 573.2 (ft) EOB: 30.5 ft.	PAGE
START: 7-6-22 END: 7-6-22	SAMPLING METHOD: SPT / NQ2	ENERGY RATIO (%): 86.7	LAT / LONG: 38.649000, -83.731230	1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 573.2	DEPTHS	SPT/ RQD	N60	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
ASPHALT (16")	571.8	1																	
VERY LOOSE, BROWN AND DARK BROWN, **SANDY SILT**, "AND" STONE FRAGMENTS, SOME CLAY, DAMP	569.7	2 / 3	4 2 1	4	33	SS-1	-	50	3	2	23	22	NP	NP	NP	6	A-4a (2)	-	
MEDIUM STIFF, BROWN, **SILTY CLAY**, LITTLE STONE FRAGMENTS, TRACE SAND, DAMP	567.2	4 / 5	4 1 1	3	33	SS-2	1.00	15	2	2	33	48	37	21	16	20	A-6b (10)	-	
HARD, BROWN, **CLAY**, "AND" SILT, LITTLE SAND, TRACE STONE FRAGMENTS, DAMP		6 / 7 / 8	3 7 11	26	67	SS-3	4.50	10	8	7	41	34	40	24	16	16	A-6b (10)	-	
	562.2	9 / 10	6 15 15	43	89	SS-4	4.50	-	-	-	-	-	-	-	-	15	A-6b (V)	-	
HARD, BROWN, **SILT AND CLAY**, SOME SAND, LITTLE STONE FRAGMENTS, DAMP	559.7	11 / 12 / 13	11 36 50/4"	-	100	SS-5	4.5+	19	16	15	32	18	32	20	12	12	A-6a (4)	-	
VERY DENSE, BROWN AND GRAY, **STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, DAMP @13.5' - 23.5'; ENCOUNTERED BOULDERS/COBBLES		14 / 15	32 24 55	114	100	SS-6	-	-	-	-	-	-	-	-	-	10	A-2-4 (V)	-	
		16 / 17	40 57	-	100	SS-7	-	-	-	-	-	-	-	-	-	10	A-2-4 (V)	-	
		18 / 19	26 50/4"	-	100	SS-8	-	-	-	-	-	-	-	-	-	9	A-2-4 (V)	-	
		W 553.3 20																	
	549.6	21 / 22 / 23	37		90	NQ2-1											CORE		
SHALE, DARK GRAY, MODERATELY WEATHERED, WEAK, LAMINATED, CALCAREOUS, BLOCKY, FAIR; RQD 61%, REC 100%.	TR 24 / 25																	
@27.0'; 1" LIMESTONE LAYER		26 / 27 / 28	48		100	NQ2-2											CORE		
@ 28.5'; 2" LIMESTONE LAYER WITH HIGH ANGLE FRACTURE	542.7	29 / 30 EOB																	

CR SACHINA\COL\20050\COL_9 22 23 FOR SACHINA\600976.GPJ

OHIO DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING

Office of Geotechnical Engineering

B-002-1-22

BR: NQ2-1 20.5'

25.5'

ER: NQ2-2 30.5'

Run #:	Depth		Recovery		RQD	
NQ2-1	20.5'	25.5'	54/60	90%	22/60	37%
NQ2-2	25.5'	30.5'	60/60	100%	29/60	48%
BRO-52-22.27 PID 115994						

GEOTECHNICAL PROFILE – LANDSLIDE

BORING LOG AND ROCK CORE PHOTO FOR B-002-1-22

SUBSET TOTAL 8   11
PROJECT ID 115994
REVIEWER JG 09-26-23
DESIGNER N.K.S

CTL ENGINEERING INC.
2860 FISHER ROAD
COLUMBUS, OHIO 43204
PHONE (614) 276-8123
FAX (614) 276-6377

DESIGN AGENCY

BRO-52-22.27

PROJECT:	BRO-52-22.27	DRILLING FIRM / OPERATOR:	CTL / CTL	DRILL RIG: MOBILE B-57 TRACK	STATION / OFFSET: 1180+42, 58' RT.	EXPLORATION ID B-002-2-22
TYPE:	LANDSLIDE	SAMPLING FIRM / LOGGER:	CTL / CTL	HAMMER: MOBILE AUTOMATIC	ALIGNMENT: US 52	
PID: 115994	SFN:	DRILLING METHOD:	3.25" HSA / NQ2	CALIBRATION DATE: 8-7-20	ELEVATION: 562.1 (MSL) EOB: 40.0 ft.	PAGE 1 OF 1
START: 1-23-23	END: 1-24-23	SAMPLING METHOD:	SPT / NQ2	ENERGY RATIO (%): 76.4	COORD: Not Recorded	

MATERIAL DESCRIPTION AND NOTES	ELEV. 562.1	DEPTHS	SPT/RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
ASPHALT (2")	561.9																		
AGGREGATE BASE (10")	561.1	1	2																
LOOSE, GRAY, **GRAVEL AND STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, (FILL), DAMP	559.6	2	2 3	6	78	SS-1	-	47	19	12	15	7	NP	NP	NP	8	A-1-b (0)	-	
MEDIUM DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, (FILL), DAMP		3	3 5 4	11	67	SS-2	-	-	-	-	-	-	-	-	-	7	A-2-7 (V)	-	
@4.0'; LOOSE	556.6	4 5	4 4	10	72	SS-3	2.25	-	-	-	-	-	-	-	-	9	A-2-7 (V)	-	
VERY STIFF, BROWN, **CLAY**, "AND" SILT, TRACE GRAVEL, TRACE SAND, DAMP		6	5 8 8	20	89	SS-4	2.25	-	-	-	-	-	-	-	-	18	A-7-6 (V)	-	
@7.0'; STIFF, GRAY		7 8	6 8 9	22	100	SS-5	1.75	7	2	2	48	41	44	24	20	24	A-7-6 (13)	-	
@8.5'; MOIST		9	3 32	45	78	SS-6	1.50	-	-	-	-	-	-	-	-	29	A-7-6 (V)	-	
@10.0'; SOME SILT, LITTLE SAND, DAMP		10 11	5 6 7	17	100	SS-7	1.75	10	4	13	34	39	44	23	21	16	A-7-6 (13)	-	
@11.5'; MOIST		12	7 9 9	23	83	SS-8	1.25	-	-	-	-	-	-	-	-	26	A-7-6 (V)	-	
	W 549.1	13 14	7 21 8	37	89	SS-9	1.50	-	-	-	-	-	-	-	-	25	A-7-6 (V)	-	
@14.5'; GRAY AND BROWN		15	3 3	9	67	SS-10	1.25	-	-	-	-	-	-	-	-	29	A-7-6 (V)	-	
@16.0'; VERY STIFF, "AND" SILT, LITTLE GRAVEL, TRACE SAND		16 17	4 6 7	17	100	SS-11	3.00	11	3	2	37	47	58	27	31	29	A-7-6 (20)	-	
@17.5'; STIFF		18	4 4 4	10	100	SS-12	1.50	-	-	-	-	-	-	-	-	31	A-7-6 (V)	-	
@19.0'; VERY STIFF, BROWN, DAMP		19 20	7 10 17	34	100	SS-13	3.15	-	-	-	-	-	-	-	-	15	A-7-6 (V)	-	
@20.5'; HARD		21	13 19 22	52	100	SS-14	4.25	-	-	-	-	-	-	-	-	19	A-7-6 (V)	-	
@22.0'; STIFF		22 23	9 36 50/3"	-	100	SS-15	1.50	-	-	-	-	-	-	-	-	21	A-7-6 (V)	-	
@23.5'; VERY STIFF		24	50/1"	-	100	SS-16	3.50	-	-	-	-	-	-	-	-	22	A-7-6 (V)	-	
		25 26	9 11 18	37	100	SS-17	2.75	-	-	-	-	-	-	-	-	19	A-7-6 (V)	-	
@26.5'; HARD		27	12 25 28	67	100	SS-18	4.50	-	-	-	-	-	-	-	-	22	A-7-6 (V)	-	
VERY DENSE, GRAY, **GRAVEL AND/OR STONE FRAGMENTS**, (WEATHERED LIMESTONE), WET	534.1 TR	28 29	50/1"	-	100	SS-19	-	-	-	-	-	-	-	-	-	21	Rock (V)	-	
INTERBEDDED SHALE (55%) AND LIMESTONE (45%), REC. 100%; SHALE, GRAY, HIGHLY WEATHERED, WEAK; LIMESTONE, LIGHT GRAY, MODERATELY WEATHERED, MODERATELY STRONG TO STRONG, FINE GRAINED.	532.1	30	46 50/1"	-	100	SS-20	-	-	-	-	-	-	-	-	-	12	Rock (V)	-	
		31 32 33 34	22		100	NQ-1											CORE		
INTERBEDDED SHALE (85%) AND LIMESTONE (15%); SHALE, GRAY, HIGHLY WEATHERED, WEAK; LIMESTONE, LIGHT GRAY, MODERATELY WEATHERED, MODERATELY STRONG TO STRONG, FINE GRAINED. @35.6' - 36.1'; Shale; Unit Weight = 150 pcf; Qu = 1,180 psi	527.1	35 36 37 38 39	45		100	NQ-2											CORE		
	522.1 EOB	40																	

B-002-2-22

BR: NQ2-1 30.0'
BR: NQ2-2 35.0'
ER: NQ2-2 40.0'

Run #	Depth (ft)		Recovery (in)		RQD (in)	
NQ2-1	30.0	35.0	60/60	100%	13/60	22%
NQ2-2	35.0	40.0	60/60	100%	27/60	45%
BRO-52-22.27 PID 115994						

CTL ENGINEERING INC.
COLUMBUS, OHIO 43204
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GEOTECHNICAL PROFILE – LANDSLIDE

BORING LOG AND ROCK CORE PHOTO FOR B-002-2-22
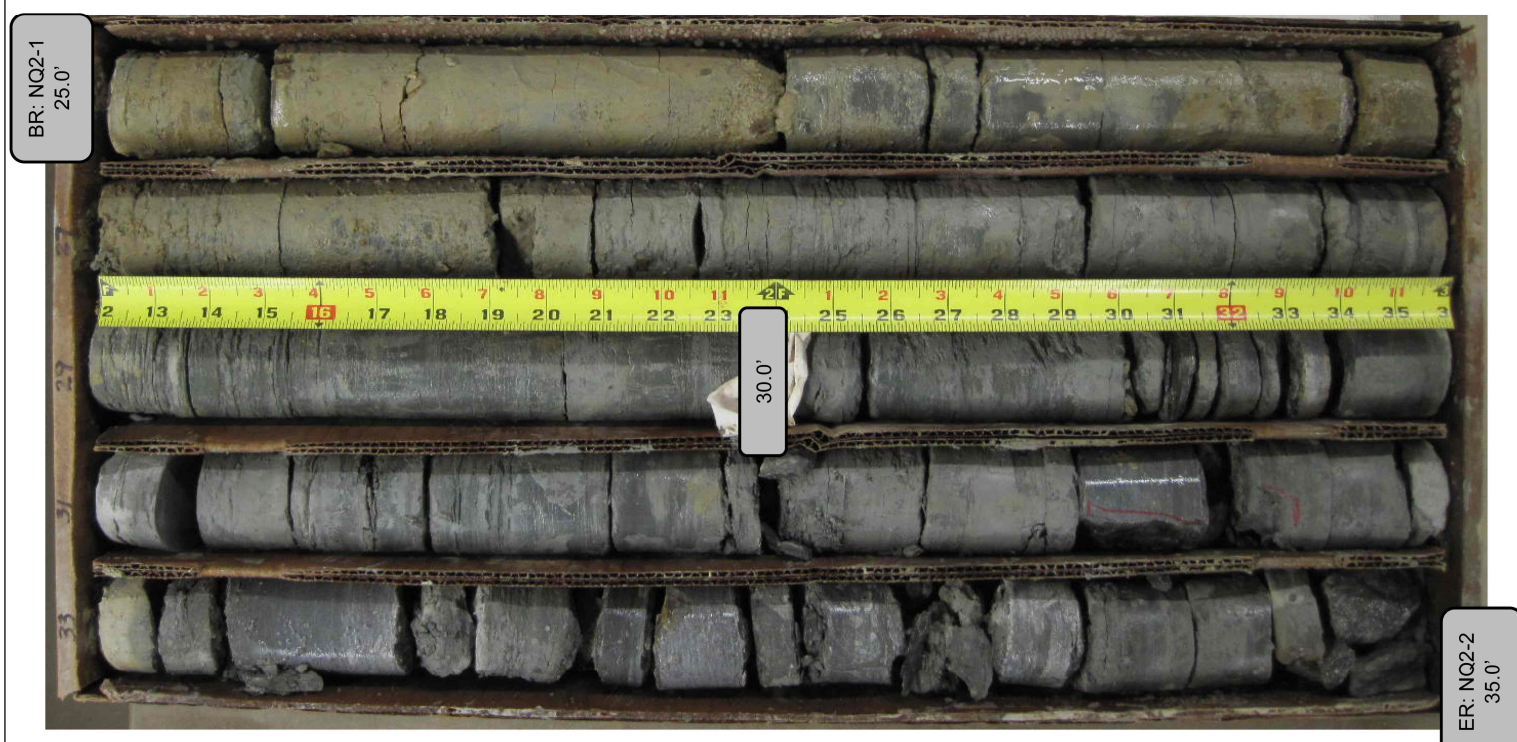
BRO-52-22.27

PROJECT:	BRO-52-22.27	DRILLING FIRM / OPERATOR:	ODOT / CAREY	DRILL RIG:	CME 55 TRUCK	STATION / OFFSET:	1181+44, 14' RT.	EXPLORATION ID
TYPE:	LANDSLIDE	SAMPLING FIRM / LOGGER:	ODOT / MCLEISH	HAMMER:	CME AUTOMATIC	ALIGNMENT:	CL SR 52	B-003-0-22
PID: 115994	SFN:	DRILLING METHOD:	3.25" HSA / NQ2	CALIBRATION DATE:	4-18-22	ELEVATION:	575.1 (ft) EOB: 37.0 ft.	PAGE
START: 7-5-22	END: 7-6-22	SAMPLING METHOD:	SPT / NQ2	ENERGY RATIO (%):	86.7	LAT / LONG:	38.648907, -83.730921	1 OF 1

MATERIAL DESCRIPTION AND NOTES

Description	ELEV.	Depth	SPT/RQD	N60	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm
ASPHALT & BASE (60")	575.1	1																
		2	35/50	-	100	SS-1	-	-	-	-	-	-	-	-	-	-		
		3																
	570.1	4–5	31/44/21	94	100	SS-2	-	-	-	-	-	-	-	-	-	-		
VERY STIFF, BROWN AND GRAY, **SANDY SILT**, SOME CLAY, LITTLE STONE FRAGMENTS		6–7	6/5/6	16	61	SS-3	2.00	14	13	8	36	29	25	17	8	14	A-4a (6)	-
@8.5'; BROWN, POOR RECOVERY, AUGER SAMPLE TAKEN		9–10	7/10/10	29	0	SS-4	-	-	-	-	-	-	-	-	-	13	A-4a (V)	-
	564.1	11–12	5/5	14	56	SS-5	2.50	33	3	4	28	32	35	21	14	20	A-6a (7)	-
VERY STIFF, BROWN, **SILT AND CLAY**, SOME STONE FRAGMENTS, TRACE SAND, USED 3" SPLITSPOON FOR SAMPLE, DAMP		14–15	9/9/10	27	11	SS-6	-	-	-	-	-	-	-	-	-	17	A-6a (V)	-
@16.0'; TRACE STONE FRAGMENTS, POOR RECOVERY, AUGER SAMPLE		16–17	8/8/11	27	27	SS-7	3.00	10	1	3	50	36	34	21	13	15	A-6a (9)	-
@18.5'; USED 3" SPLITSPOON FOR SAMPLE @18.6' - 26.0'; ENCOUNTERED BOULDERS/COBBLES		19–20	38/22/31	77	56	SS-8	4.5+	-	-	-	-	-	-	-	-	13	A-6a (V)	-
@21.0'; HARD		21–22	18/19/26	65	100	SS-9	4.50	9	3	2	45	41	32	21	11	14	A-6a (8)	-
@23.5'; SOME STONE FRAGMENTS, DAMP		24–25	42/30/31	88	100	SS-10	4.50	-	-	-	-	-	-	-	-	13	A-6a (V)	-
SHALE, GRAY AND BROWN, HIGHLY WEATHERED, VERY WEAK, LAMINATED.	549.1 TR 548.1	26–27	26/52	-	100	SS-11	-	-	-	-	-	-	-	-	-	10	Rock (V)	-
SHALE, DARK GRAY WITH BROWN, HIGHLY WEATHERED, WEAK, LAMINATED, CALCAREOUS, BLOCKY, POOR; RQD 73%, REC 100%.		28–31	73		100	NQ2-1											CORE	
@29.6'; 1" LIMESTONE LAYER																		
@30.9' - 31.0'; HIGHLY FRACTURED																		
@32.7'; MODERATELY WEATHERED.	540.1	32–35	60		100	NQ2-2											CORE	
INTERBEDDED SHALE (70%) AND LIMESTONE (30%), BLOCKY, GOOD, RQD 42%, REC. 100%;	538.1 EOB	36–37																
SHALE, DARK GRAY, MODERATELY WEATHERED, WEAK, LAMINATED, CALCAREOUS, RANGES IN THICKNESS 0.5" TO 4";																		
LIMESTONE, BLUISH GRAY, MODERATELY WEATHERED, STRONG, VERY THIN TO THIN BEDDED, FOSSILIFEROUS, RANGES IN THICKNESS 0.5" TO 3".																		
@36.2' - 36.6'; HIGH ANGLE FRACTURE																		

2COL\23050002COL_9.22.23 FOR SACHINA\60097/6 GPJ

OHIO DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING

Office of Geotechnical Engineering

B-003-0-22

BR: NQ2-1 27.0'   32.0'   ER: NQ2-2 37.0'

Run #:	Depth		Recovery		RQD	
NQ2-1	27.0'	32.0'	60/60	100%	44/60	73%
NQ2-2	32.0'	37.0'	60/60	100%	36/60	60%
BRO-52-22.27 PID 115994						

P_43 | SHEET 10 | SUBSET TOTAL 11 | PROJECT ID 115994 | JG REVIEWER 09-26-23 | DESIGNER N.K.S | REVIEWER N.K.S

CTL ENGINEERING INC.
2860 FISHER ROAD
COLUMBUS, OHIO 43204
PHONE (614) 276-8123
FAX (614) 276-6377

DESIGN AGENCY

GEOTECHNICAL PROFILE - LANDSLIDE
BORING LOG AND ROCK CORE PHOTO FOR B-003-0-22

44

BRO-52-22.27

![CTL ENGINEERING logo]

UNIAXIAL COMPRESSIVE STRENGTH OF
INTACT ROCK CORE - ASTM D 7012
Method C

PROJECT NO: 2305002COL
DATE: 7/26/2023

BORING NUMBER	B-02-2-22	TOP DEPTH(FT)	35.6	BOTTOM DEPTH(FT)	36.1
SAMPLE NUMBER	NQ-2	DISTRICT	9	PID NO.	115994
COUNTY	BRO	ROUTE	52	SECTION	22.27

FORMATION	Ordovician Age
DESCRIPTION	Shale, Gray, Highly Weathered, Weak
MOISTURE CONDITION	As Received

MEASUREMENT	LENGTH(INCHES)	DIAMETER(INCHES)
1	4.043	1.953
2	4.045	1.952
3	4.042	1.927
AVERAGE	4.043	1.944

LENGTH/DIAMETER	2.1
CORRECTION FACTOR	1
AREA(IN²)	3.0
MASS (GRAMS)	472.6
UNIT WEIGHT(LBS/FT³)	150

RATE OF LOADING (in/min)	0.09
COMPRESSIVE STRENGTH (PSI)	1,180
Equip. ID - 68897	
NON-CONFORMANCES - None	
TIME OF TEST (MINUTES)	2.63
LOADING DIRECTION	
PERP. TO BEDDING	
TECHNICIAN - MW	
TEMPERATURE - Room	

Stress (psi) vs Strain(%)

BEFORE TESTING

AFTER TESTING

GEOTECHNICAL PROFILE - LANDSLIDE
COMPRESSIVE STRENGTH TEST RESULT
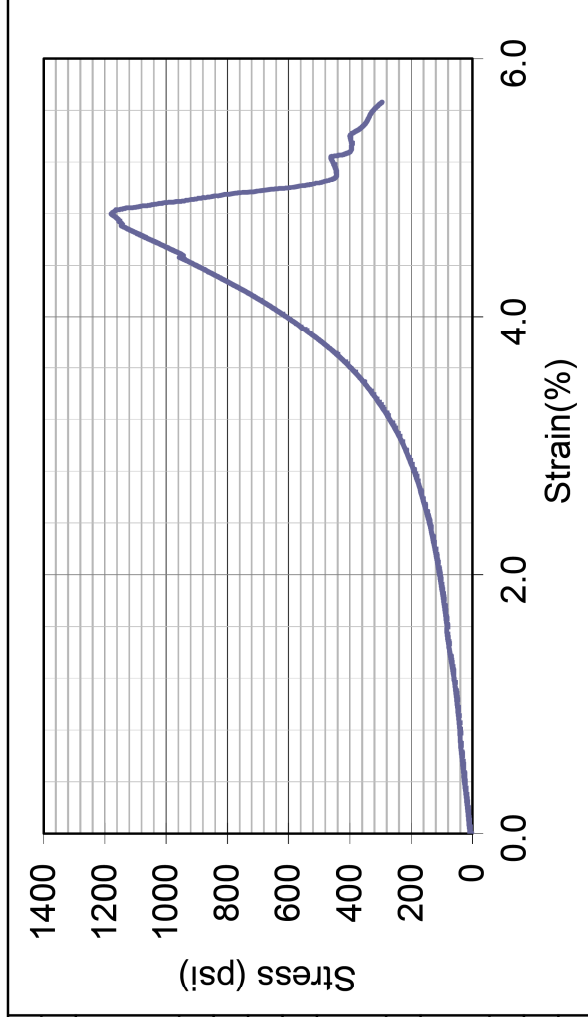
APPENDIX B
TEST BORING RECORDS

PROJECT:	BRO-52-22.27	DRILLING FIRM / OPERATOR:	ODOT / CAREY	DRILL RIG:	CME 55 TRUCK	STATION / OFFSET:	1178+96, 6' RT.	EXPLORATION ID
TYPE:	LANDSLIDE	SAMPLING FIRM / LOGGER:	ODOT / MCLEISH	HAMMER:	CME AUTOMATIC	ALIGNMENT:	CL SR 52	B-001-0-22
PID: 115994 SFN:		DRILLING METHOD:	3.25" HSA / NQ2	CALIBRATION DATE:	4/18/22	ELEVATION: 570.0 (ft) EOB: 35.5 ft.		PAGE
START: 6/15/22 END: 6/29/22		SAMPLING METHOD:	SPT / NQ2	ENERGY RATIO (%):	86.7	LAT / LONG:	38.648977, -83.731759	1 OF 2

MATERIAL DESCRIPTION AND NOTES	ELEV. 570.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL
								GR	CS	FS	SI	CL	LL	PL	PI			
ASPHALT (18") & CONCRETE (10")		1																
	567.6	2																
VERY STIFF, BROWN AND DARK GRAY, **SILTY CLAY**, SOME GRAVEL AND STONE FRAGMENTS, LITTLE SAND, MODERATELY ORGANIC (LOI = 5.1%), DAMP		3																
		4	5 / 9 / 10	27	67	SS-1	3.00	26	5	6	27	36	39	23	16	12	A-6b (8)	
	564.0	5																
DENSE, BROWN, **STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, DAMP		6	24 / 24 / 10	49	56	SS-2	-	45	13	9	17	16	29	18	11	10	A-2-6 (0)	
		7																
		8																
@8.5'; VERY DENSE		9	17 / 30 / 17	68	28	SS-3	-	-	-	-	-	-	-	-	-	13	A-2-6 (V)	
		10																
@11.0'; USED 3" SPLITSPOON FOR SAMPLE		11	17 / 16 / 20	52	44	SS-4	-	52	8	5	18	17	30	17	13	11	A-2-6 (1)	
		12																
		13																
DENSE, NO RECOVERY; AUGER CUTTINGS TAKEN @13.5'; NO RECOVERY TOOK AUGER SAMPLE		14	7 / 12 / 15	39	0	SS-5	-	-	-	-	-	-	-	-	-	15	A-2-6 (V)	
	554.0	15																
VERY STIFF, BROWN, **SILT AND CLAY**, LITTLE STONE FRAGMENTS, TRACE SAND, DAMP		16	11 / 21 / 18	56	61	SS-6	3.50	13	3	3	38	43	34	21	13	15	A-6a (9)	
		17																
		18																
@18.5'; HARD		19	10 / 16 / 22	55	83	SS-7	4.50	-	-	-	-	-	-	-	-	14	A-6a (V)	
		20																
		21	27 / 23 / 31	78	89	SS-8A	4.50	-	-	-	-	-	-	-	-	13	A-6a (V)	
@21.9' - 25.8'; ENCOUNTERED BOULDERS/COBBLES		22				SS-8B	-	-	-	-	-	-	-	-	-	11	A-6a (V)	
		23																
@23.5'; BROWN AND GRAY		24	37 / 53	-	100	SS-9	-	-	-	-	-	-	-	-	-	10	A-6a (V)	
	544.2	25																
SHALE, DARK GRAY, MODERATELY WEATHERED, WEAK, LAMINATED, CALCAREOUS, FOSSILIFEROUS; RQD 74%, REC 100%.	TR	26																
		27																
@28.0' - 29.5'; HIGHLY WEATHERED		28	70		100	NQ2-1											CORE	
	540.0	29																

MATERIAL DESCRIPTION AND NOTES	ELEV. 540.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL
								GR	CS	FS	SI	CL	LL	PL	PI			
INTERBEDDED SHALE (70%) AND LIMESTONE (30%), BLOCKY, FAIR, RQD 50%, REC. 85%; **SHALE**, DARK GRAY WITH GRAY, MODERATELY WEATHERED, VERY WEAK TO WEAK, LAMINATED, CALCAREOUS, FOSSILIFEROUS, RANGES IN THICKNESS 2" TO 5"; **LIMESTONE**, BLUISH GRAY, MODERATELY WEATHERED, STRONG, VERY THIN TO THIN BEDDED, FOSSILIFEROUS, RANGES IN THICKNESS 1" TO 10". @30.5' - 31.8'; HIGHLY WEATHERED WITH LOSS	534.5	31 32 33 34 35 EOB	47		83	NQ2-2												CORE	

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

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 25 LB. BENTONITE CHIPS

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 9/28/23 09:26 - O:\PROJECT\2023\COL-05\23050002COL\DESIGN\TO SACHINA\9.22.23\23050002COL 9.22.23 FOR SACHINA\6009

PROJECT: BRO-52-22.27	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 1180+41, 13' RT.	EXPLORATION ID B-002-0-22
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / SPROUSE	HAMMER: CME AUTOMATIC	ALIGNMENT: CL SR 52	
PID: 115994 SFN:	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 4/18/22	ELEVATION: 573.2 (ft) EOB: 35.0 ft.	PAGE 1 OF 2
START: 6/29/22 END: 7/6/22	SAMPLING METHOD: SPT / NQ2	ENERGY RATIO (%): 86.7	LAT / LONG: 38.648947, -83.731259	

MATERIAL DESCRIPTION AND NOTES	ELEV. 573.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
ASPHALT (42")	569.7	1–3																
MEDIUM DENSE, BROWNISH GRAY, **STONE FRAGMENTS WITH SAND**, LITTLE SAND, TRACE CLAY, DAMP	567.2	4–5	12 / 10 / 5	22	56	SS-1	2.00	46	23	9	17	5	17	16	1	6	A-1-b (0)	
VERY STIFF, GRAY AND BROWN, **SILTY CLAY**, LITTLE STONE FRAGMENTS, LITTLE SAND, MOIST		6–7 W 564.7	4 / 5 / 7	17	56	SS-2	4.00	18	7	6	29	40	38	22	16	22	A-6b (9)	
@8.5' - 12.5'; ENCOUNTERED BOULDERS/COBBLES		9–10	13 / 11 / 8	27	47	SS-3	3.00	-	-	-	-	-	-	-	-	7	A-6b (V)	
@11.0'; HARD		11–12	8 / 45 / 48	134	50	SS-4	5.00	-	-	-	-	-	-	-	-	6	A-6b (V)	
@13.5'; VERY STIFF, BROWN, "AND" STONE FRAGMENTS		14–15	4 / 6 / 6	17	44	SS-5	3.25	37	7	4	25	27	39	22	17	22	A-6b (6)	
@16.0'; HARD, TRACE SAND, DAMP @16.5' - 19.5'; ENCOUNTERED BOULDERS/COBBLES		16–17	14 / 57 / 28	123	56	SS-6	4.50	42	2	2	24	30	36	20	16	19	A-6b (6)	
	552.2	19–20	25 / 22 / 19	59	56	SS-7	4.5+	-	-	-	-	-	-	-	-	9	A-6b (V)	
VERY DENSE, BROWN AND GRAY, **STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, DAMP	549.0	21–22	9 / 25 / 35	87	50	SS-8	-	13	43	19	17	8	36	21	15	16	A-2-6 (1)	
		24 TR	30 / 57	-	100	SS-9A	-	-	-	-	-	-	-	-	-	15	A-2-6 (V)	
SHALE, DARK GRAY AND BROWN, HIGHLY WEATHERED, WEAK, LAMINATED, CALCAREOUS, BLOCKY, POOR; RQD 63%, REC 100%.		25				SS-9B	-	-	-	-	-	-	-	-	-	14	Rock (V)	
		27–28	60		100	NQ2-1											CORE	

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 9/28/23 09:26 - O:\PROJECT\2023\COL-05\23050002COL\DESIGN\TO SACHINA\9.22.23\23050002COL 9.22.23 FOR SACHINA\6009

MATERIAL DESCRIPTION AND NOTES	ELEV. 543.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL
								GR	CS	FS	SI	CL	LL	PL	PI			
INTERBEDDED SHALE (70%) AND LIMESTONE (30%), BLOCKY, GOOD, RQD 32%, REC. 96%; **SHALE**, DARK GRAY, MODERATELY WEATHERED, WEAK, LAMINATED, CALCAREOUS, RANGES IN THICKNESS 1" TO 19"; **LIMESTONE**, BLUISH GRAY, MODERATELY WEATHERED, STRONG, VERY THIN TO THIN BEDDED, FOSSILIFEROUS, RANGES IN THICKNESS 0.5" TO 3.5".	542.6 538.2	31 32 33 34 35 EOB	38		97	NQ2-2												CORE	

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

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 25 LB. BENTONITE CHIPS

PROJECT: BRO-52-22.27	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 1180+42, 12' LT.	EXPLORATION ID
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / MCLEISH	HAMMER: CME AUTOMATIC	ALIGNMENT: CL SR 52	B-002-1-22
PID: 115994 SFN:	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 4/18/22	ELEVATION: 573.2 (ft) EOB: 30.5 ft.	PAGE 1 OF 2
START: 7/6/22 END: 7/6/22	SAMPLING METHOD: SPT / NQ2	ENERGY RATIO (%): 86.7	LAT / LONG: 38.649000, -83.731230	

MATERIAL DESCRIPTION AND NOTES	ELEV. 573.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL
								GR	CS	FS	SI	CL	LL	PL	PI			
ASPHALT (16")	571.8	1																
VERY LOOSE, BROWN AND DARK BROWN, **SANDY SILT**, "AND" STONE FRAGMENTS, SOME CLAY, DAMP	569.7	2–3	4 / 2 / 1	4	33	SS-1	-	50	3	2	23	22	NP	NP	NP	6	A-4a (2)	
MEDIUM STIFF, BROWN, **SILTY CLAY**, LITTLE STONE FRAGMENTS, TRACE SAND, DAMP	567.2	4–5	4 / 1 / 1	3	33	SS-2	1.00	15	2	2	33	48	37	21	16	20	A-6b (10)	
HARD, BROWN, **CLAY**, "AND" SILT, LITTLE SAND, TRACE STONE FRAGMENTS, DAMP		6–7	3 / 7 / 11	26	67	SS-3	4.50	10	8	7	41	34	40	24	16	16	A-6b (10)	
	562.2	9–10	6 / 15 / 15	43	89	SS-4	4.50	-	-	-	-	-	-	-	-	15	A-6b (V)	
HARD, BROWN, **SILT AND CLAY**, SOME SAND, LITTLE STONE FRAGMENTS, DAMP	559.7	11–12	11 / 36 / 50/4"	-	100	SS-5	4.5+	19	16	15	32	18	32	20	12	12	A-6a (4)	
VERY DENSE, BROWN AND GRAY, **STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, DAMP @13.5' - 23.5'; ENCOUNTERED BOULDERS/COBBLES		14–15	32 / 24 / 55	114	100	SS-6	-	-	-	-	-	-	-	-	-	10	A-2-4 (V)	
		16–17	40 / 57	-	100	SS-7	-	-	-	-	-	-	-	-	-	10	A-2-4 (V)	
		19	26 / 50/4"	-	100	SS-8	-	-	-	-	-	-	-	-	-	9	A-2-4 (V)	
	549.6	23	37		90	NQ2-1											CORE	
SHALE, DARK GRAY, MODERATELY WEATHERED, WEAK, LAMINATED, CALCAREOUS, BLOCKY, FAIR; RQD 61%, REC 100%. @27.0'; 1" LIMESTONE LAYER @ 28.5'; 2" LIMESTONE LAYER WITH HIGH ANGLE FRACTURE		28	48		100	NQ2-2											CORE	

W 553.3
TR

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 9/28/23 09:26 - O:\PROJECT\2023\COL-05\230500002\COLDESIGN\TO SACHINA\9.22.23\230500002\COL 9.22.23 FOR SACHINA\6009

MATERIAL DESCRIPTION AND NOTES	ELEV. 543.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL
								GR	CS	FS	SI	CL	LL	PL	PI			
	542.7	EOB																

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

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 25 LB. BENTONITE CHIPS

PROJECT:	BRO-52-22.27	DRILLING FIRM / OPERATOR:	CTL / CTL	DRILL RIG: MOBILE B-57 TRACK	STATION / OFFSET: 1180+42, 58' RT.
TYPE:	LANDSLIDE	SAMPLING FIRM / LOGGER:	CTL / CTL	HAMMER: MOBILE AUTOMATIC	ALIGNMENT: US 52
PID: 115994 SFN:		DRILLING METHOD:	3.25" HSA / NQ2	CALIBRATION DATE: 8/7/20	ELEVATION: 562.1 (MSL) EOB: 40.0 ft.
START: 1/23/23 END: 1/24/23		SAMPLING METHOD:	SPT / NQ2	ENERGY RATIO (%): 76.4	COORD: Not Recorded

Left vertical margin text: STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 9/28/23 08:47 - O:\PROJECT\2023\COL-05\230500002COL DESIGN\INTO SACHIN\9.22.23\2205002\COL.GPJ

MATERIAL DESCRIPTION AND NOTES	ELEV. 562.1	DEPTHS	SPT/ RQD	N60	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
ASPHALT (2")	561.9																	
AGGREGATE BASE (10")	561.1	1	2 2 3	6	78	SS-1	-	47	19	12	15	7	NP	NP	NP	8	A-1-b (0)	
LOOSE, GRAY, GRAVEL AND STONE FRAGMENTS WITH SAND, LITTLE SILT, TRACE CLAY, (FILL), DAMP	559.6	2																
MEDIUM DENSE, BROWN, GRAVEL AND STONE FRAGMENTS WITH SAND, SILT, AND CLAY, (FILL), DAMP		3 4	3 5 4	11	67	SS-2	-	-	-	-	-	-	-	-	-	7	A-2-7 (V)	
@4.0'; LOOSE	556.6	5	3 4 4	10	72	SS-3	2.25	-	-	-	-	-	-	-	-	9	A-2-7 (V)	
VERY STIFF, BROWN, CLAY, "AND" SILT, TRACE GRAVEL, TRACE SAND, DAMP		6 7	5 8 8	20	89	SS-4	2.25	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
@7.0'; STIFF, GRAY		8	6 8 9	22	100	SS-5	1.75	7	2	2	48	41	44	24	20	24	A-7-6 (13)	
@8.5'; MOIST		9 10	3 3 32	45	78	SS-6	1.50	-	-	-	-	-	-	-	-	29	A-7-6 (V)	
@10.0'; SOME SILT, LITTLE SAND, DAMP		11	5 6 7	17	100	SS-7	1.75	10	4	13	34	39	44	23	21	16	A-7-6 (13)	
@11.5'; MOIST		12 13	7 9 9	23	83	SS-8	1.25	-	-	-	-	-	-	-	-	26	A-7-6 (V)	
	W 549.1	14	7 21 8	37	89	SS-9	1.50	-	-	-	-	-	-	-	-	25	A-7-6 (V)	
@14.5'; GRAY AND BROWN		15 16	3 3 4	9	67	SS-10	1.25	-	-	-	-	-	-	-	-	29	A-7-6 (V)	
@16.0'; VERY STIFF, "AND" SILT, LITTLE GRAVEL, TRACE SAND		17	4 6 7	17	100	SS-11	3.00	11	3	2	37	47	58	27	31	29	A-7-6 (20)	
@17.5'; STIFF		18 19	4 4 4	10	100	SS-12	1.50	-	-	-	-	-	-	-	-	31	A-7-6 (V)	
@19.0'; VERY STIFF, BROWN, DAMP		20	7 10 17	34	100	SS-13	3.15	-	-	-	-	-	-	-	-	15	A-7-6 (V)	
@20.5'; HARD		21 22	13 19 22	52	100	SS-14	4.25	-	-	-	-	-	-	-	-	19	A-7-6 (V)	
@22.0'; STIFF		23	9 36 50/3"	-	100	SS-15	1.50	-	-	-	-	-	-	-	-	21	A-7-6 (V)	
@23.5'; VERY STIFF		24	50/1"	-	100	SS-16	3.50	-	-	-	-	-	-	-	-	22	A-7-6 (V)	
		25 26	9 11 18	37	100	SS-17	2.75	-	-	-	-	-	-	-	-	19	A-7-6 (V)	
@26.5'; HARD	534.1	27 28	12 25 28	67	100	SS-18	4.50	-	-	-	-	-	-	-	-	22	A-7-6 (V)	
VERY DENSE, GRAY, GRAVEL AND/OR STONE FRAGMENTS, (WEATHERED LIMESTONE), WET		28 29	50/1"	-	100	SS-19	-	-	-	-	-	-	-	-	-	21	Rock (V)	
	532.1		46	-	100	SS-20	-	-	-	-	-	-	-	-	-	12	Rock (V)	

TR (at 28)

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 9/28/23 08:47 - O:\PROJECT\2023\COL-05\23050002COL\DESIGN\TO SACHINA\9.22.23\23050002COL.GPJ

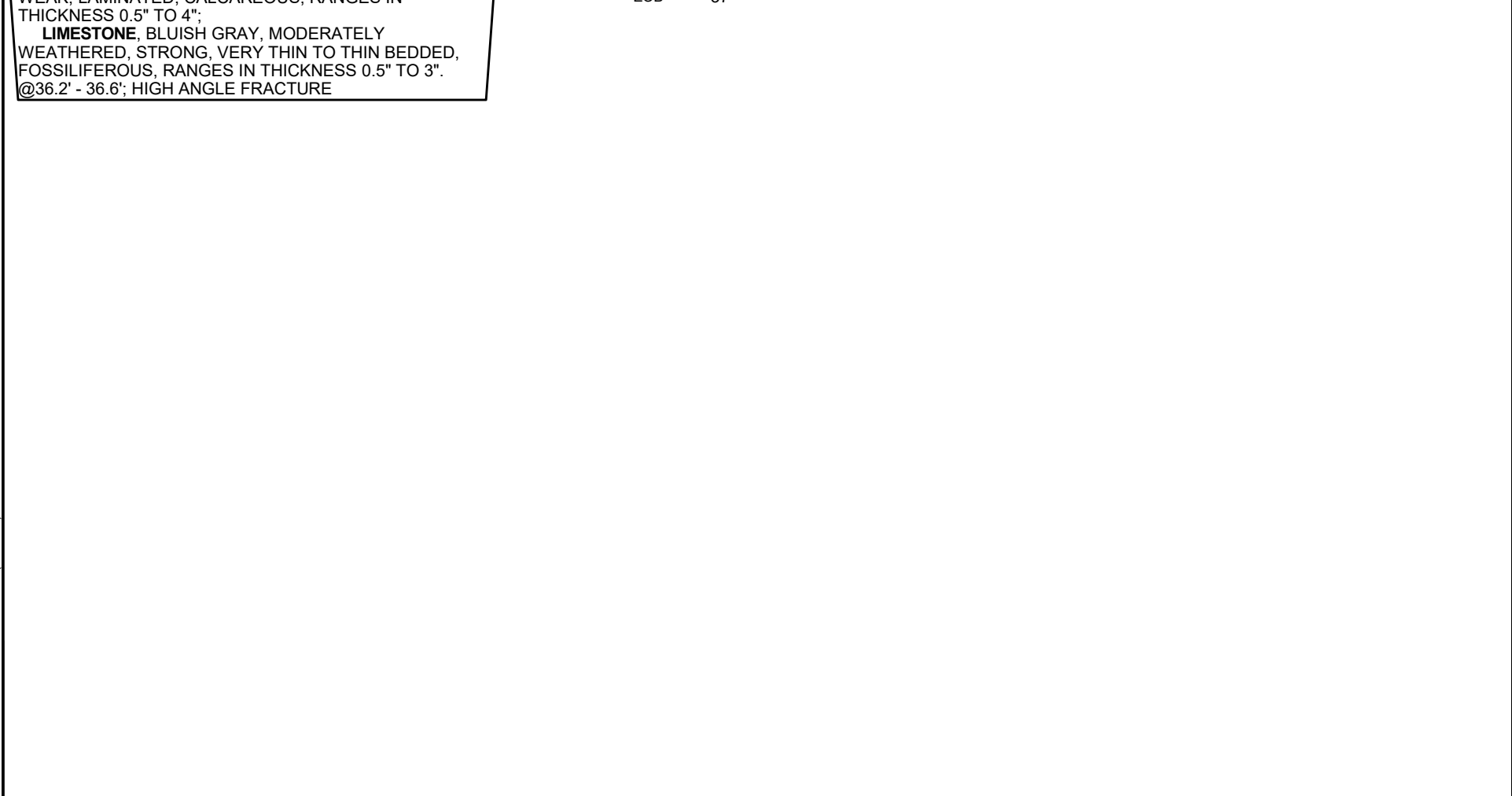| MATERIAL DESCRIPTION AND NOTES	ELEV. 532.1	DEPTHS	SPT/ RQD	N$_{60}$	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL
								GR	CS	FS	SI	CL	LL	PL	PI			
INTERBEDDED SHALE (55%) AND LIMESTONE (45%), REC. 100%; **SHALE**, GRAY, HIGHLY WEATHERED, WEAK; **LIMESTONE**, LIGHT GRAY, MODERATELY WEATHERED, MODERATELY STRONG TO STRONG, FINE GRAINED.	527.1	31 32 33 34 35	50/1" 22		100	NQ-1												CORE
INTERBEDDED SHALE (85%) AND LIMESTONE (15%); **SHALE**, GRAY, HIGHLY WEATHERED, WEAK; **LIMESTONE**, LIGHT GRAY, MODERATELY WEATHERED, MODERATELY STRONG TO STRONG, FINE GRAINED. @35.6' - 36.1'; Shale; Unit Weight = 150 pcf; Qu = 1,180 psi	522.1	36 37 38 39 40 EOB	45		100	NQ-2												CORE

NOTES: CAVED AT 28.6'. WATER LEVEL AT COMPLETION OF DRILLING UNABLE TO BE MEASURED DUE TO INTRODUCTION OF WATER DURING ROCK CORING

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED ASPHALT PATCH; TREMIED BENTONITE GROUT

PROJECT: BRO-52-22.27	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 1181+44, 14' RT.	EXPLORATION ID B-003-0-22
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / MCLEISH	HAMMER: CME AUTOMATIC	ALIGNMENT: CL SR 52	
PID: 115994 SFN:	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 4/18/22	ELEVATION: 575.1 (ft) EOB: 37.0 ft.	PAGE 1 OF 2
START: 7/5/22 END: 7/6/22	SAMPLING METHOD: SPT / NQ2	ENERGY RATIO (%): 86.7	LAT / LONG: 38.648907, -83.730921	

MATERIAL DESCRIPTION AND NOTES	ELEV. 575.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL
								GR	CS	FS	SI	CL	LL	PL	PI			
ASPHALT & BASE (60")		1																
		2	35 50	-	100	SS-1	-	-	-	-	-	-	-	-	-	-		
		3																
		4	31 44 21	94	100	SS-2	-	-	-	-	-	-	-	-	-	-		
	570.1	5																
VERY STIFF, BROWN AND GRAY, **SANDY SILT**, SOME CLAY, LITTLE STONE FRAGMENTS		6																
		7	6 5 6	16	61	SS-3	2.00	14	13	8	36	29	25	17	8	14	A-4a (6)	
		8																
@8.5'; BROWN, POOR RECOVERY, AUGER SAMPLE TAKEN		9	7 10 10	29	0	SS-4	-	-	-	-	-	-	-	-	-	13	A-4a (V)	
	564.1	10																
VERY STIFF, BROWN, **SILT AND CLAY**, SOME STONE FRAGMENTS, TRACE SAND, USED 3" SPLITSPOON FOR SAMPLE, DAMP		11																
		12	7 5 5	14	56	SS-5	2.50	33	3	4	28	32	35	21	14	20	A-6a (7)	
		13																
		14	9 9 10	27	11	SS-6	-	-	-	-	-	-	-	-	-	17	A-6a (V)	
		15																
@16.0'; TRACE STONE FRAGMENTS, POOR RECOVERY, AUGER SAMPLE		16																
		17	8 8 11	27	100	SS-7	3.00	10	1	3	50	36	34	21	13	15	A-6a (9)	
		18																
@18.5'; USED 3" SPLITSPOON FOR SAMPLE @18.6' - 26.0'; ENCOUNTERED BOULDERS/COBBLES		19	38 22 31	77	56	SS-8	4.5+	-	-	-	-	-	-	-	-	13	A-6a (V)	
		20																
@21.0'; HARD		21	18 19 26	65	100	SS-9	4.50	9	3	2	45	41	32	21	11	14	A-6a (8)	
		22																
		23																
@23.5'; SOME STONE FRAGMENTS, DAMP		24	42 30 31	88	100	SS-10	4.50	-	-	-	-	-	-	-	-	13	A-6a (V)	
	549.1	25																
SHALE, GRAY AND BROWN, HIGHLY WEATHERED, VERY WEAK, LAMINATED.	548.1	26 TR	26 52	-	100	SS-11	-	-	-	-	-	-	-	-	-	10	Rock (V)	
		27																
SHALE, DARK GRAY WITH BROWN, HIGHLY WEATHERED, WEAK, LAMINATED, CALCAREOUS, BLOCKY, POOR; RQD 73%, REC 100%.		28																
		29	73		100	NQ2-1											CORE	

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT .GDT - 9/28/23 09:26 - O:\PROJECT\2023\COL-05\23050002COLIDESIGNTO SACHINA9.22.23\23050002COL 9.22.23 FOR SACHINA16009

MATERIAL DESCRIPTION AND NOTES	ELEV. 545.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL
								GR	CS	FS	SI	CL	LL	PL	PI			
@29.6'; 1" LIMESTONE LAYER **SHALE**, DARK GRAY WITH BROWN, HIGHLY WEATHERED, WEAK, LAMINATED, CALCAREOUS, BLOCKY, POOR; RQD 73%, REC 100%. *(continued)* @30.9' - 31.0'; HIGHLY FRACTURED @32.7'; MODERATELY WEATHERED.		31 32 33 34																
	540.1	35	60		100	NQ2-2											CORE	
INTERBEDDED SHALE (70%) AND LIMESTONE (30%), BLOCKY, GOOD, RQD 42%, REC. 100%; **SHALE**, DARK GRAY, MODERATELY WEATHERED, WEAK, LAMINATED, CALCAREOUS, RANGES IN THICKNESS 0.5" TO 4"; **LIMESTONE**, BLUISH GRAY, MODERATELY WEATHERED, STRONG, VERY THIN TO THIN BEDDED, FOSSILIFEROUS, RANGES IN THICKNESS 0.5" TO 3". @36.2' - 36.6'; HIGH ANGLE FRACTURE	538.1	36 EOB 37																

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

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 25 LB. BENTONITE CHIPS

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 9/28/23 09:26 - O:\PROJECT\2023\COL-05\23050002COL\DESIGN\TO SACHINA\9.22.23\23050002COL 9.22.23 FOR SACHINA\6009

APPENDIX C
GLOBAL STABILITY AND DRILLED SHAFT ANALYSES

SLIDE, UA SLOPE AND LPILE RESULTS FOR U.S. 52 WALL AT 1180+50

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Pavement		145	Mohr-Coulomb	50	0
Embankment Fill		120	Mohr-Coulomb	125	19
Driveway Fill		122	Mohr-Coulomb	150	25
A-6-b, A-7-6		128	Mohr-Coulomb	200	27
A-2-4, A-2-6 with Boulders/Cobbles		135	Mohr-Coulomb	50	34
Soft Rock		140	Mohr-Coulomb	0	18
Firm Rock		145	Mohr-Coulomb	2000	40

1.0

250.00 lbs/ft2

250.00 lbs/ft2

W

W

BRO-52-22.27 LANDSLIDE REPAIR

Location	Station 1180+50	Analysis	Long Term - Effective Stress Conditions
Drawn By	CTL Engineering, Inc.	Company	CTL Engineering Inc.
Date	8/4/2023 3:14:00 PM	Client	Ohio Department of Transportation

SLIDEINTERPRETG.SLG

BRO-52-22.27 LANDSLIDE REPAIR STATION 1180+50 UASLOPE OUTPUT EXISTING CONDITIONS

File   Run   Options   Help

Calculated Results

Factor of Safety:	1.00	
Force per Shaft:	0.000	lb
Acting Point X:	33.130	ft Y: 0.000 ft

Analysis Unit System
◉ English   ○ Metric

Number of Vertical Sections and Soil Layers
Vertical Section Num: 22   Soil Layer Num: 7

Analysis Method
○ Total Stress   ◉ Effective Stress

Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
▶ Layer1	50.0	0.0	145.0
Layer2	125.0	19.0	120.0
Layer3	150.0	25.0	122.0
Layer4	200.0	27.0	128.0
Layer5	50.0	34.0	135.0
Layer6	0.0	16.0	140.0
Layer7	2000.0	40.0	145.0

Chart (Double-Click for More Options)
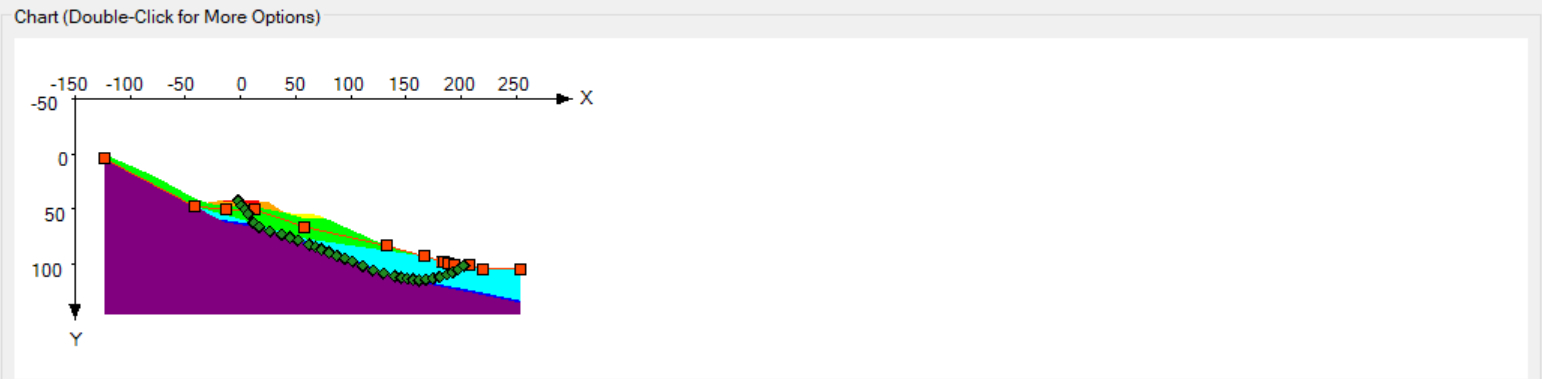
Slope Profile Vertical Sections

	Section 5	Section 6	Section 7	Section 8	Section 9	Section 10	Section 11	Section 12	Section 13	Section 14	Section 15	Section 16	Section 17	Secti
X (ft)	-18.00	-16.01	-16.00	-13.37	13.20	16.00	16.01	25.00	40.00	57.61	70.00	77.50	132.00	166.00
Y1 (ft)	42.00	42.00	42.00	42.00	42.40	42.50	42.50	43.50	53.00	54.10	55.00	58.40	83.00	92.50
Y2 (ft)	42.00	42.00	43.20	43.20	45.30	45.30	42.50	43.50	53.00	54.10	55.00	58.40	83.00	92.50
Y3 (ft)	46.70	47.20	47.20	47.80	47.80	48.30	48.30	50.10	53.00	54.10	55.00	58.40	83.00	92.50
Y4 (ft)	46.70	47.20	47.20	47.80	47.80	47.80	48.30	50.10	53.00	58.40	58.40	58.40	83.00	92.50
Y5 (ft)	54.00	54.70	54.70	55.20	62.70	63.80	63.80	66.50	71.20	76.30	78.30	79.40	87.50	92.50
▶ Y6 (ft)	59.90	59.90	59.90	59.90	64.00	65.00	65.00	67.70	73.00	78.90	83.60	86.60	108.00	115.00
Y7 (ft)	59.90	60.90	60.90	61.90	66.00	67.00	67.00	69.70	75.00	80.90	85.60	88.60	110.00	117.00
Y8 (ft)	145.00	145.00	145.00	145.00	145.00	145.00	145.00	145.00	145.00	145.00	145.00	145.00	145.00	145.00

Coordinates of Crest   X: 42.20 ft   Y: -2.30 ft   Coordinates of Toe   X: 202.00 ft   Y: 101.00 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 Save Data

[▷ Run]

Auto	○ On ◉ Off	0.303 (n)
Xmin	0.00	Diameter: 3.00 ft
Xmax	0.00	CTC Spacing: 5.50 ft
XDelta	0.00	X Coordinate: 33.13 ft

Pore Water Pressure

Pore Pressure Options: ○ No Pore Pressure   ○ Constant Ratio   ◉ Specified phreatic surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7	Point 8	Point 9	Point 10	Point 11	Point 12	Point 13	Point 14
▶ X (ft)	-124.00	-41.80	-13.40	13.20	57.60	132.00	166.10	182.00	184.30	188.10	193.00	207.00	219.00	253.00
Y (ft)	4.00	47.30	50.30	50.30	65.90	83.00	92.60	97.00	97.80	99.20	101.00	101.00	104.00	104.00

Slip Surface

	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7	Point 8	Point 9	Point 10	Point 11	Point 12	Point 13	Point 14	Point 15	Point 16	Point 17	Point 18	P
X (ft)	0.70	3.80	6.90	11.40	16.50	26.50	37.10	44.60	51.90	62.10	67.70	73.10	80.10	87.10	94.10	101.10	110.50	11
▶ Y (ft)	46.40	50.00	54.00	62.00	66.00	70.00	73.00	75.50	78.00	82.00	84.00	86.50	89.00	92.00	94.50	97.00	101.60	10

BRO-52-22.27 LANDSLIDE REPAIR STATION 1180+50 UASLOPE OUTPUT WITH DRILLED SHAFT WALL

File   Run   Options   Help

Calculated Results

Factor of Safety: 1.14
Force per Shaft: 120635.879 lb
Acting Point X: 33.130 ft   Y: 63.007 ft

Analysis Unit System
(●) English   ( ) Metric

Number of Vertical Sections and Soil Layers
Vertical Section Num: 25   Soil Layer Num: 8

Analysis Method
( ) Total Stress   (●) Effective Stress

Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
▶ Layer1	50.0	0.0	145.0
Layer2	250.0	28.0	125.0
Layer3	125.0	19.0	120.0
Layer4	150.0	25.0	122.0
Layer5	200.0	27.0	128.0
Layer6	50.0	34.0	135.0
Layer7	0.0	16.0	140.0
Layer8	2000.0	40.0	145.0

Chart (Double-Click for More Options)
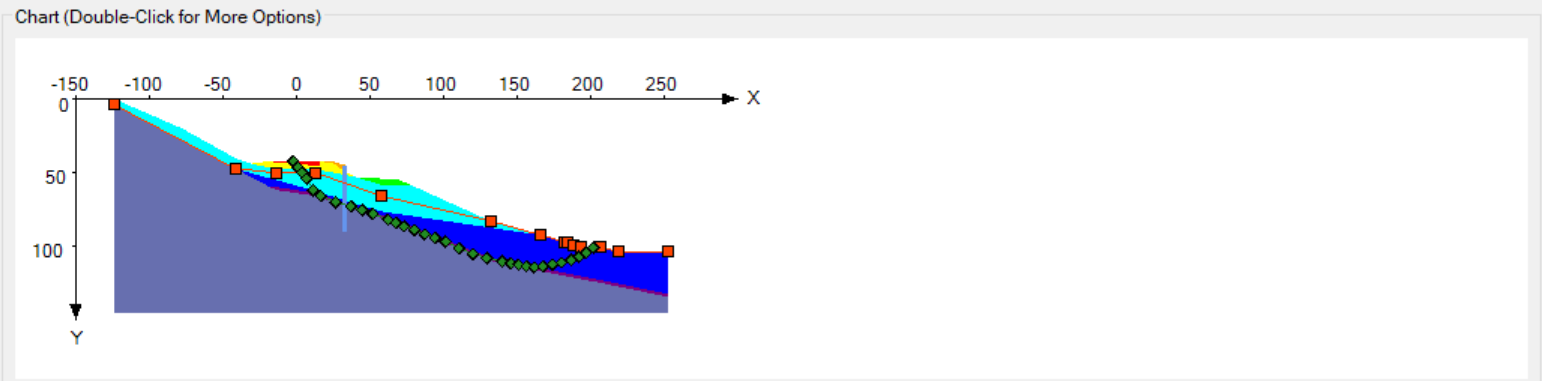
Slope Profile Vertical Sections

	Section 13	Section 14	Section 15	Section 16	Section 17	Section 18	Section 19	Section 20	Section 21	Section 22	Section 23	Section 24	Section 25
X (ft)	25.00	33.13	33.14	40.00	57.61	70.00	77.50	132.00	166.00	193.00	207.00	219.00	253.00
Y1 (ft)	42.50	45.00	49.60	53.00	54.10	55.00	58.40	83.00	92.50	101.00	101.00	104.00	104.00
Y2 (ft)	42.50	45.00	49.60	53.00	54.10	55.00	58.40	83.00	92.50	101.00	101.00	104.00	104.00
Y3 (ft)	43.50	49.60	49.60	53.00	54.10	55.00	58.40	83.00	92.50	101.00	101.00	104.00	104.00
Y4 (ft)	50.00	51.60	51.60	53.00	54.10	55.00	58.40	83.00	92.50	101.00	101.00	104.00	104.00
Y5 (ft)	50.00	51.60	51.60	53.00	58.40	58.40	58.40	83.00	92.50	101.00	101.00	104.00	104.00
Y6 (ft)	66.40	68.90	68.90	71.20	76.30	78.30	79.40	87.50	92.50	101.00	101.00	104.00	104.00
Y7 (ft)	67.90	70.60	70.60	73.00	78.90	83.60	86.60	108.00	115.00	120.40	123.00	125.50	132.60
▶ Y8 (ft)	69.90	72.60	72.60	75.00	80.90	85.60	88.60	110.00	117.00	122.40	125.00	127.50	134.60
Y9 (ft)	145.00	145.00	145.00	145.00	145.00	145.00	145.00	145.00	145.00	145.00	145.00	145.00	145.00

Coordinates of Crest   X: -17.80 ft   Y: 42.00 ft   Coordinates of Toe   X: 207.50 ft   Y: 101.10 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:	3.00 ft
Xmax	0.00	CTC Spacing:	5.50 ft
XDelta	0.00	X Coordinate:	33.13 ft

[ ] Auto Save Data

▷ Run

Pore Water Pressure

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

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7	Point 8	Point 9	Point 10	Point 11	Point 12	Point 13	Point 14
▶ X (ft)	-124.00	-41.80	-13.40	13.20	57.60	132.00	166.00	182.00	184.30	188.10	193.00	207.00	219.00	253.00
Y (ft)	4.00	47.30	50.30	50.30	65.90	83.00	92.60	97.00	97.80	99.20	101.00	101.00	104.00	104.00

Slip Surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7	Point 8	Point 9	Point 10	Point 11	Point 12	Point 13	Point 14	Point 15	Point 16	Point 17	Po
▶ X (ft)	-2.30	0.70	3.80	6.90	11.40	16.50	26.50	37.10	44.60	51.90	62.10	67.70	73.10	80.10	87.10	94.10	101.10	110
Y (ft)	42.20	46.40	50.00	54.00	62.00	66.00	70.00	73.00	75.50	78.00	82.00	84.00	86.50	89.00	92.00	94.50	97.00	101

L-PILE Soil Parameters (Station 1180+50)

Artificial Lowering of Ground Surface

The passive resistance from the downhill side soil mass should be ignored. In order to include this in the L-pile soil model, the ground level should be artificially lowered.

To do this, first determine the angle of steepness of the slope - downhill of the drilled shafts - from horizontal (β_{dh}), and then determine the depth to the shear surface at the location of the drilled shafts (d_τ). For slopes of steepness from $\beta=0°$ to 45°, lower the ground surface by an amount equal to $d_\tau TAN(\beta_{dh})$.

For the current project, β_{dh} = 32 degrees (From cross section at Sta. 1180+50)

Proposed top of pile elevation = 570.2 (Top of wall elevation from plans)
Existing grade at pile location = 565.1 (From cross section at Sta. 1180+50)
Estimated shear surface elevation at pile location = 542.3

Depth of shear surface beneath existing ground surface at pile location
d_τ = 565.1 – 542.3 = 22.8 feet

Therefore, $d_\tau TAN(\beta_{dh})$ = 14.2 feet.

The first soil layer should start at elevation 565.1 – 14.2 = 550.9

Which is at a depth of 570.2 – 550.9 = 19.3 feet along the shaft

Depth of shear surface beneath top of wall at pile location
  d_p = 570.2 – 542.3 = 27.9 feet

From 19.3' to 24.1'
Use soil type – *Stiff Clay with Free Water (Reese)*
Effective Unit Weight (pcf) = 120 pcf – 62.4 pcf = 57.6 pcf
N_{60} = 22 bpf (Average blow count in cohesive soils below fill, B-002-2-22 and B-003-0-22)
Undrained Cohesion (psf) = $N_{60}/8$ = 22/8 = 2,750 psf
Use Strain Factor K_{rm} = 0.005 (From L-pile Technical Manual Table 3-4, stiff to very stiff clay)
Use Subgrade Modulus K_{static} = 1,000 pci (From L-pile Technical Manual Table 3-3)

From 24.1' to 27.9'
Use soil type – *Sand (Reese)*
Effective Unit Weight (pcf) = 135 pcf – 62.4 pcf = 72.6 pcf
Friction Angle (deg) = 34 (AASHTO LRFD Table 10.4.6.2.4-1)
Use Subgrade Modulus K_{static} = 125 pci (From L-pile Technical Manual Table 3-3)

Project: BRO-52-22.27
Project No: 23050002OL
September 26, 2023

Below 27.9'

Use soil type – *Weak Rock (Reese)*

Effective Unit Weight (pcf) = 145 pcf – 62.4 pcf = 82.6 pcf

Compressive strength (q_u) = 1,180 psi (B-002-2-22, NQ-2 Compressive Strength Test Result of Shale)

Initial Rock Modulus (E_r) = 100,000 psi (Per ODOT GDM, Weak to Slightly Strong)

RQD = 22% (Lowest RQD from Borings B-002-2-22 and B-003-0-22)

Use Strain Factor K_{rm} = 0.0005 (From L-pile Technical Manual Equation 3-136)

P-y Modification Factors

If the drilled shafts are at a center-to-center spacing closer than about 3½ diameters, a reduction in the soil resistance p, for the p-y curve behavior of the soil, must be considered.

P- modification factor $\beta_a = 0.64(S/D)^{0.34}$

In which S= Center to Center Spacing between the Piles

       D= Diameter of the Shaft

For 36- inch shafts with reinforced shafts placed at 5.5 feet center to center

$\beta_a = 0.64(5.5/3.0)^{0.34} = 0.79$

No P-Y modification factors are applied to the bedrock layers

BRO-52-22.27 Slide Repair

From AASHTO 3.11.5.3, Active Earth Pressure

$$K_a = Sin^2(\Theta+\emptyset'_f)/\Gamma[Sin^2(\Theta)*Sin(\Theta-\delta)]$$

in which $\quad \Gamma= [1+\sqrt{\{(Sin(\emptyset'f+\delta)*Sin(\emptyset'f-\beta))/(Sin(\Theta-\delta)*Sin(\Theta+\beta))\}}]^2$

Where

Angle of back face of the wall to the horizontal (Degrees), Θ=	90	
Effective angle of internal friction (degrees), $\emptyset'f$=	30	(Assumed)
Friction angle between fill and wall (degrees), δ=	20	(2/3 $\emptyset'f$)
Angle of fill to the horizontal , β=	0	Assumed)

Calculation

$Sin(\Theta-\delta)$=	0.94
$Sin^2(\Theta)$=	1.00
$Sin(\Theta+\emptyset'_f)$=	0.87
$Sin^2(\Theta+\emptyset'_f)$=	0.75
$Sin(\emptyset'_f-\beta)$=	0.50
$Sin(\Theta+\beta)$=	1.00
$Sin(\emptyset'_f+\delta)$=	0.77
Γ=	2.68
K_a=	0.30

γ_{Ls}=	125 pcf	(GB7, Section E.7)

Case 1

Diameter of Shaft=	36	inches
C/C Spacing (CC)=	5.5	feet

Therefore for a 36-inch Shaft placed at 5.5 feet center to center

Surcharge Load q_{LS},   0.0 lb/in $\gamma_{LS}*2*K_a*CC/12$

Per 903.7 of GDM - If the horizontal distance (H) between the drilled shafts and traffic loading is less than or equal to one half of the half the depth to the shear surface at the location of the drilled shafts (d_t), also apply a (unfactored) vehicular live load surcharge (LS) to the drilled shafts equal to two feet of soil with a unit weight of 125 pcf.

$d_t/2 =$	11.4	feet
$H =$	15	feet
	No Surcharge Load	

BRO-52-22.27 Slide Repair

Conversion of force per Shaft to Distributed Load

The UA Slope 2.3 program calculates the unfactored earth pressure (EH), resultant load per shaft, however, for proper structural analysis of pile reaction, we need to convert this to a realistic load.

The triangular load distribution is a close enough approximation of the actual
condition to develop a realistic calculation of distributed shear, moment and displacement in the drilled shaft

Case 1
Diameter of Shaft=   36 inches
C/C Spacing (CC)=   5.5 feet
For a 36-inch shaft at 5.5 feet center to center spacing

Load on Shaft (F_{SW})=	120,636	lbs
Depth of Shear plane at Shaft Location(D_S)=	27.9	feet
The Distributed Load (F_D)=	720.6	lbs/in

BRO-52-22.27 Slide Repair

a) **_Following cases were evaluated:_**

    Case1

    Diameter of Shaft =   36 inches

    Center to Center Spacing =   5.5 feet

b) **_Unfactored Loads_**

Case	Surchage Loads(lbs/in)	Distributed Load(lbs/in)	Total Unfactored Load (lbs/in)
1	0.0	720.6	720.6

c) **_Load Factor per AASHTO Table 3.4.1.1 and 3.4.1.2_**

Load Factor for Surcharge Load (LS) = 1.75
Load Factor for Distributed Load (EH) = 1.5

d) **_Factored Distributed loads_**

Case	Factored Surcharge Load (lbs/in)	Factored Distributed Loads(lbs/in)	Total Factored Load(lbs/in)
1	0.0	1081.0	1081.0

e) **_Limit State Checks_**

1   Use Factored Loads for Strength Limit State and check Moment capacity
      and Nominal Shear per AASHTO 6.10.8 and 6.10.9

2   Use Unfactored Loads for Service Limit State for deflection

f)   *L-pile Analysis*

Note: It is assumed that 50 Ksi steel will be used.
Section Used=   W24x229

Case1: 36 inch diameter Shafts with 5.5 feet center to center spacing

Checks:

Structural Strength Limit State Checks (W24x229 Section)

Calculated Factored Moment(in-lbs)	Factored Nominal Moment Resistance(in-lbs)	Acceptable Or Unacceptable
16,792,563	29,400,000	Acceptable

Calculated Factored Shear (Kips)	Factored Nominal Shear resistance (Kips)	Acceptable Or Unacceptable
565.1	628.1	Acceptable

and for nominal shear resistance calculation Per AASHTO 6.10.9

Service Limit State Checks (W24x229 Section)
Drilled Shaft Length above bedrock=   27.9 feet
For the unfactored Service Limit State analysis, the maximum Pilehead deflection must be limited to 1% or less
of the drilled shaft length above bedrock (27.9'), or 2 inches if the wall is within 10 feet of the proposed pavement.

Calculated Deflection(in)	Allowable Deflection(in) Per ODOT Recommendations	Acceptable Or Unacceptable
1.6	3.3	Acceptable

BRO-52-22.27 Slide Repair

W24x229

Thickness of Flange (t_f) =   1.73 in

Depth (d) =   26.02 in

Yield Strength of Steel (F_y) =   50 Ksi

$D = d - 2t_f =$ 22.56 in

thickness of Web (t_w) =   0.96 in

$V_p =$ $0.58\ F_y D t_w =$ 628.1 Kips

Young's Modulus (E) =   29000 Ksi

Assume Unstiffened Web

Shear Buckling Coefficient (K) =   5.0

$Sqrt(EK/F_y) =$ 53.9 Equation 1

$1.12*Sqrt(EK/F_y) =$ 60.3 Equation 2

$1.4*Sqrt(EK/F_y) =$ 75.4 Equation 3

$D/t_w =$ 23.5

Since, $D/t_w \leq$ Equation1, C =   1.0

Therefore,

Nominal Shear Resistance (V_n) = CV_p 628.1 Kips

$\phi_v =$ 1.0

Factored Shear Resistance (V_u) = $\phi_v V_n$ 628.1 Kips

W24x229

Per AASHTO, 6.10.8

For Continously Braced Flanges in Tension or Compression

$f_{bu} \leq \phi_f R_h F_{yf}$ Equation 1

Where f_{bu} =   Factored Bending Moment Obtained in Strength Limit State

ϕ_f =   Flexural Resistance Factor

R_h =   Hybrid Factor

F_{yf} = $f_y * S_{x-x}$

f_y =   Yield Strength of Steel

S_{x-x} =   Section Modulus of Steel Section

ϕ_f =	1.0	Per AASHTO 6.5.4.2
R_h =	1.0	Per AASHTO 6.10.1.10.1
S_{x-x} =	588.0	In^3
f_y =	50.0	ksi
F_{yf} =	29,400,000	lb-in

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

                    LPile for Windows, Version 2022-12.008

                   Analysis of Individual Piles and Drilled Shafts
                   Subjected to Lateral Loading Using the p-y Method
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================================================================================

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

Path to file locations:
\PROJECT\2023\COL-05\23050002COL\Design\Station 1180+50\LPILE\REVISED ANALYSES\US 52 Wall\9.22.23 REVISED ANALYSIS\

Name of input data file:
23.09.26 Lpile.lp12d

Name of output report file:
23.09.26 Lpile.lp12o

Name of plot output file:
23.09.26 Lpile.lp12p

Name of runtime message file:
23.09.26 Lpile.lp12r




--------------------------------------------------------------------------------
                             Date and Time of Analysis
--------------------------------------------------------------------------------

            Date:  September 26, 2023      Time:  18:35:36




--------------------------------------------------------------------------------
                                 Problem Title
--------------------------------------------------------------------------------
```

```
Project Name: BRO-52-22.27 SLIDE REPAIR

Job Number: 23050002COL

Client: OHIO DEPARTMENT OF TRANSPORTATION

Engineer: CTL ENGINEERING, INC

Description: US 52 STATION 1180+50 DRILLED SHAFT RETAINING WALL ANALYSIS




-------------------------------------------------------------------------------
                        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

 - Analysis uses p-y modification factors for p-y curves
 - 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                    =           1
Total length of pile                               =      42.900 ft
Depth of ground surface below top of pile          =      19.3000 ft
```

Pile diameters used for p-y curve computations are defined using 2 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	36.0000
2	42.900	36.0000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

    Section 1 is an elastic pile
    Cross-sectional Shape   =   Circular Pile
    Length of section   =   42.900000 ft
    Width of top of section   =   36.000000 in
    Width of bottom of section   =   36.000000 in
    Top Area   =   64.200000 sq. in
    Bottom Area   =   64.200000 sq. in
    Moment of Inertia at Top   =   7650. in^4
    Moment of Inertia at Bottom   =   7650. in^4
    Elastic Modulus   =   29000000. psi

                     Soil and Rock Layering Information

The soil profile is modelled using 3 layers

Layer 1 is stiff clay with water-induced erosion

    Distance from top of pile to top of layer   =   19.300000 ft
    Distance from top of pile to bottom of layer   =   24.100000 ft
    Effective unit weight at top of layer   =   57.600000 pcf
    Effective unit weight at bottom of layer   =   57.600000 pcf
    Undrained cohesion at top of layer   =   2750. psf
    Undrained cohesion at bottom of layer   =   2750. psf
    Epsilon-50 at top of layer   =   0.005000
    Epsilon-50 at bottom of layer   =   0.005000
    Subgrade k at top of layer   =   1000.000000 pci
    Subgrade k at bottom of layer   =   1000.000000 pci

Layer 2 is sand, p-y criteria by Reese et al., 1974

    Distance from top of pile to top of layer   =   24.100000 ft
    Distance from top of pile to bottom of layer   =   27.900000 ft
    Effective unit weight at top of layer   =   72.600000 pcf
    Effective unit weight at bottom of layer   =   72.600000 pcf
    Friction angle at top of layer   =   34.000000 deg.
    Friction angle at bottom of layer   =   34.000000 deg.
    Subgrade k at top of layer   =   125.000000 pci

```
    Subgrade k at bottom of layer              =     125.000000 pci


Layer 3 is weak rock, p-y criteria by Reese, 1997

    Distance from top of pile to top of layer        =     27.900000 ft
    Distance from top of pile to bottom of layer     =     65.000000 ft
    Effective unit weight at top of layer            =     82.600000 pcf
    Effective unit weight at bottom of layer         =     82.600000 pcf
    Uniaxial compressive strength at top of layer    =        1180. psi
    Uniaxial compressive strength at bottom of layer =        1180. psi
    Initial modulus of rock at top of layer          =      100000. psi
    Initial modulus of rock at bottom of layer       =      100000. psi
    RQD of rock at top of layer                      =     22.000000 %
    RQD of rock at bottom of layer                   =     22.000000 %
    k rm of rock at top of layer                     =     0.0005000
    k rm of rock at bottom of layer                  =     0.0005000


 (Depth of the lowest soil layer extends 22.100 ft below the pile tip)



-------------------------------------------------------------------------------
                      Summary of Input Soil Properties
-------------------------------------------------------------------------------

Layer        Soil Type        Layer     Effective   Cohesion   Angle of   Uniaxial                             E50            Rock
Mass
 Num.          Name           Depth     Unit Wt.                Friction      qu        RQD %       or          kpy
Modulus
          (p-y Curve Type)     ft         pcf         psf        deg.        psi                    krm          pci
psi
-----   -------------------  ----------  ----------  ----------  ----------  ----------  ----------  ----------  ----------
----------
  1         Stiff Clay        19.3000    57.6000     2750.        --          --          --         0.00500    1000.0000     --

          with Free Water     24.1000    57.6000     2750.        --          --          --         0.00500    1000.0000     --

  2            Sand           24.1000    72.6000      --         34.0000      --          --          --         125.0000      --

          (Reese, et al.)     27.9000    72.6000      --         34.0000      --          --          --         125.0000      --

  3           Weak            27.9000    82.6000      --          --         1180.       22.0000     5.00E-04     --
100000.
             Rock             65.0000    82.6000      --          --         1180.       22.0000     5.00E-04     --
100000.



-------------------------------------------------------------------------------
                     Modification Factors for p-y Curves
-------------------------------------------------------------------------------

Distribution of p-y modifiers with depth defined using 3 points

Point      Depth X         p-mult          y-mult
 No.         ft
-----    ----------      ----------      ----------
  1         19.300         0.7900          1.0000
  2         27.900         0.7900          1.0000
```

```
   3            27.900          1.0000          1.0000




-------------------------------------------------------------------------------
                              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           Depth X             Dist. Load
 No.              ft                   lb/in
-----          ----------           ----------
  1              0.000                0.000
  2             27.900              720.600


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

Point           Depth X             Dist. Load
 No.              ft                   lb/in
-----          ----------           ----------
  1              0.000                0.000
  2             27.900             1081.000




-------------------------------------------------------------------------------
              Pile-head Loading and Pile-head Fixity Conditions
-------------------------------------------------------------------------------

Number of loads specified = 2

Load   Load          Condition                Condition           Axial Thrust      Compute Top y      Run Analysis
 No.   Type              1                        2               Force, lbs        vs. Pile Length
-----  ----     --------------------     --------------------     ----------------  ---------------    ------------
  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 = 1

Pile Section No. 1:
-------------------
Moment-curvature properties were derived from elastic section properties




--------------------------------------------------------------------------------
            Layering Correction Equivalent Depths of Soil & Rock Layers
--------------------------------------------------------------------------------


           Top of    Equivalent
            Layer    Top Depth  Same Layer  Layer is       F0         F1
Layer       Below      Below     Type As    Rock or     Integral   Integral
  No.     Pile Head  Grnd Surf    Layer     is Below    for Layer  for Layer
            ft          ft        Above    Rock Layer     lbs        lbs
-----    ----------  ----------  ----------  ----------  ----------  ----------
   1       19.3000       0.00      N.A.         No          0.00      11511.
   2       24.1000       3.3571     No          No        11511.      47053.
   3       27.9000       8.6000     No          Yes        N.A.        N.A.

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals
       for Layer n. Layering correction equivalent depths are computed only
       for soil types with both shallow-depth and deep-depth expressions for
       peak lateral load transfer. These soil types are soft and stiff clays,
       non-liquefied sands, and cemented c-phi soil.




--------------------------------------------------------------------------------
             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    Deflect.   Bending     Shear      Slope     Total     Bending   Soil Res.  Soil Spr.  Distrib.
    X         y       Moment      Force        S       Stress   Stiffness      p        Es*H     Lat. Load
  feet     inches     in-lbs       lbs      radians    psi*     lb-in^2    lb/inch    lb/inch    lb/inch
---------- ---------- ---------- ---------- ---------- ---------- ---------- ---------- ---------- ----------
      0.00     1.5954   3.72E-06   1.81E-07   -0.00569   8.75E-09   2.22E+11      0.00       0.00     2.7700
    0.4290     1.5662    36.7057    35.6505   -0.00569    0.08637   2.22E+11      0.00       0.00    11.0802
    0.8580     1.5369   367.0577   121.2118   -0.00569    0.8637    2.22E+11      0.00       0.00    22.1604
    1.2870     1.5076     1285.    263.8139   -0.00569    3.0228    2.22E+11      0.00       0.00    33.2406
    1.7160     1.4783     3083.    463.4568   -0.00569    7.2548    2.22E+11      0.00       0.00    44.3208
    2.1450     1.4490     6056.    720.1406   -0.00569   14.2505    2.22E+11      0.00       0.00    55.4010
    2.5740     1.4198    10498.      1034.    -0.00569   24.7008    2.22E+11      0.00       0.00    66.4812
```

3.0030	1.3905	16701.	1405.	−0.00569	39.2968	2.22E+11	0.00	0.00	77.5614
3.4320	1.3612	24960.	1832.	−0.00569	58.7292	2.22E+11	0.00	0.00	88.6415
3.8610	1.3320	35568.	2317.	−0.00569	83.6892	2.22E+11	0.00	0.00	99.7217
4.2900	1.3027	48819.	2859.	−0.00568	114.8675	2.22E+11	0.00	0.00	110.8019
4.7190	1.2734	65006.	3458.	−0.00568	152.9551	2.22E+11	0.00	0.00	121.8821
5.1480	1.2442	84423.	4114.	−0.00568	198.6430	2.22E+11	0.00	0.00	132.9623
5.5770	1.2149	107364.	4827.	−0.00568	252.6221	2.22E+11	0.00	0.00	144.0425
6.0060	1.1857	134123.	5597.	−0.00568	315.5833	2.22E+11	0.00	0.00	155.1227
6.4350	1.1565	164992.	6424.	−0.00567	388.2176	2.22E+11	0.00	0.00	166.2029
6.8640	1.1273	200267.	7308.	−0.00567	471.2158	2.22E+11	0.00	0.00	177.2831
7.2930	1.0981	240239.	8250.	−0.00566	565.2690	2.22E+11	0.00	0.00	188.3633
7.7220	1.0690	285204.	9248.	−0.00566	671.0680	2.22E+11	0.00	0.00	199.4435
8.1510	1.0399	335454.	10303.	−0.00565	789.3038	2.22E+11	0.00	0.00	210.5237
8.5800	1.0108	391284.	11415.	−0.00564	920.6673	2.22E+11	0.00	0.00	221.6039
9.0090	0.9818	452986.	12585.	−0.00563	1066.	2.22E+11	0.00	0.00	232.6841
9.4380	0.9528	520855.	13811.	−0.00562	1226.	2.22E+11	0.00	0.00	243.7643
9.8670	0.9239	595184.	15094.	−0.00561	1400.	2.22E+11	0.00	0.00	254.8445
10.2960	0.8951	676267.	16435.	−0.00559	1591.	2.22E+11	0.00	0.00	265.9246
10.7250	0.8663	764398.	17832.	−0.00558	1799.	2.22E+11	0.00	0.00	277.0048
11.1540	0.8377	859870.	19287.	−0.00556	2023.	2.22E+11	0.00	0.00	288.0850
11.5830	0.8091	962976.	20799.	−0.00554	2266.	2.22E+11	0.00	0.00	299.1652
12.0120	0.7807	1074011.	22367.	−0.00551	2527.	2.22E+11	0.00	0.00	310.2454
12.4410	0.7524	1193268.	23993.	−0.00549	2808.	2.22E+11	0.00	0.00	321.3256
12.8700	0.7242	1321041.	25676.	−0.00546	3108.	2.22E+11	0.00	0.00	332.4058
13.2990	0.6962	1457623.	27415.	−0.00542	3430.	2.22E+11	0.00	0.00	343.4860
13.7280	0.6683	1603308.	29212.	−0.00539	3772.	2.22E+11	0.00	0.00	354.5662
14.1570	0.6407	1758390.	31066.	−0.00535	4137.	2.22E+11	0.00	0.00	365.6464
14.5860	0.6132	1923163.	32977.	−0.00531	4525.	2.22E+11	0.00	0.00	376.7266
15.0150	0.5860	2097919.	34945.	−0.00526	4936.	2.22E+11	0.00	0.00	387.8068
15.4440	0.5591	2282953.	36970.	−0.00521	5372.	2.22E+11	0.00	0.00	398.8870
15.8730	0.5324	2478558.	39052.	−0.00515	5832.	2.22E+11	0.00	0.00	409.9672
16.3020	0.5060	2685028.	41191.	−0.00510	6318.	2.22E+11	0.00	0.00	421.0474
16.7310	0.4799	2902656.	43387.	−0.00503	6830.	2.22E+11	0.00	0.00	432.1275
17.1600	0.4542	3131737.	45640.	−0.00496	7369.	2.22E+11	0.00	0.00	443.2077
17.5890	0.4289	3372564.	47950.	−0.00488	7935.	2.22E+11	0.00	0.00	454.2879
18.0180	0.4039	3625430.	50317.	−0.00480	8530.	2.22E+11	0.00	0.00	465.3681
18.4470	0.3794	3890629.	52741.	−0.00472	9154.	2.22E+11	0.00	0.00	476.4483
18.8760	0.3554	4168455.	55223.	−0.00462	9808.	2.22E+11	0.00	0.00	487.5285
19.3050	0.3318	4459201.	57720.	−0.00452	10492.	2.22E+11	−15.728	244.0152	498.6087
19.7340	0.3088	4762745.	59504.	−0.00442	11206.	2.22E+11	−299.776	4998.	509.6889
20.1630	0.2863	5071852.	60150.	−0.00430	11934.	2.22E+11	−479.791	8626.	520.7691
20.5920	0.2645	5382045.	59952.	−0.00418	12664.	2.22E+11	−649.664	12645.	531.8493
21.0210	0.2433	5689115.	58983.	−0.00405	13386.	2.22E+11	−801.389	16957.	542.9295
21.4500	0.2228	5989336.	57335.	−0.00392	14093.	2.22E+11	−936.075	21631.	554.0097
21.8790	0.2030	6279432.	55092.	−0.00377	14775.	2.22E+11	−1054.	26741.	565.0899
22.3080	0.1839	6556561.	52339.	−0.00363	15427.	2.22E+11	−1156.	32326.	576.1701
22.7370	0.1657	6818312.	49159.	−0.00347	16043.	2.22E+11	−1242.	38612.	587.2503
23.1660	0.1482	7062699.	45635.	−0.00331	16618.	2.22E+11	−1312.	45582.	598.3305
23.5950	0.1316	7288167.	41852.	−0.00314	17149.	2.22E+11	−1365.	53410.	609.4106
24.0240	0.1158	7493606.	37899.	−0.00297	17632.	2.22E+11	−1400.	62236.	620.4908
24.4530	0.1010	7678374.	36913.	−0.00279	18067.	2.22E+11	−234.665	11961.	631.5710
24.8820	0.08707	7873660.	38937.	−0.00261	18526.	2.22E+11	−253.326	14978.	642.6512
25.3110	0.07408	8079265.	40934.	−0.00243	19010.	2.22E+11	−266.867	18546.	653.7314
25.7400	0.06206	8295122.	42929.	−0.00224	19518.	2.22E+11	−276.981	22978.	664.8116
26.1690	0.05102	8521257.	44944.	−0.00204	20050.	2.22E+11	−280.832	28335.	675.8918
26.5980	0.04101	8757862.	47013.	−0.00184	20607.	2.22E+11	−277.926	34890.	686.9720
27.0270	0.03204	9005308.	49166.	−0.00164	21189.	2.22E+11	−270.913	43529.	698.0522
27.4560	0.02415	9264074.	51490.	−0.00143	21798.	2.22E+11	−233.379	49755.	709.1324
27.8850	0.01736	9535448.	53248.	−0.00121	22436.	2.22E+11	−176.620	52372.	383.9103
28.3140	0.01171	9812315.	3782.	−9.83E−04	23088.	2.22E+11	−19425.	8536390.	0.00

```
28.7430    0.00724    9574386.     -97988.    -7.58E-04      22528.    2.22E+11    -20113.    1.43E+07    0.00
29.1720    0.00391    8803428.    -200513.    -5.45E-04      20714.    2.22E+11    -19718.    2.60E+07    0.00
29.6010    0.00163    7509903.    -297175.    -3.56E-04      17670.    2.22E+11    -17835.    5.63E+07    0.00
30.0300    2.47E-04   5743711.    -355484.    -2.02E-04      13515.    2.22E+11     -4818.    1.00E+08    0.00
30.4590   -4.49E-04   3849841.    -343209.    -9.05E-05       9058.    2.22E+11      9586.    1.10E+08    0.00
30.8880   -6.85E-04   2210031.    -277508.    -2.02E-05       5200.    2.22E+11     15938.    1.20E+08    0.00
31.3170   -6.57E-04    992617.    -193906.     1.69E-05       2336.    2.22E+11     16541.    1.30E+08    0.00
31.7460   -5.10E-04    213576.    -115743.     3.09E-05    502.5324    2.22E+11     13825.    1.39E+08    0.00
32.1750   -3.38E-04   -199077.     -54906.     3.11E-05    468.4170    2.22E+11      9810.    1.49E+08    0.00
32.6040   -1.90E-04   -351739.     -14533.     2.47E-05    827.6212    2.22E+11      5875.    1.59E+08    0.00
33.0330   -8.39E-05   -348707.       7675.     1.66E-05    820.4864    2.22E+11      2753.    1.69E+08    0.00
33.4620   -1.94E-05   -272716.      16492.     9.37E-06    641.6841    2.22E+11   672.4710    1.79E+08    0.00
33.8910    1.26E-05   -178903.      17037.     4.13E-06    420.9483    2.22E+11   -460.856    1.89E+08    0.00
34.3200    2.32E-05    -97304.      13553.     9.26E-07    228.9502    2.22E+11   -892.507    1.98E+08    0.00
34.7490    2.21E-05    -39358.       8954.    -6.60E-07     92.6066    2.22E+11   -894.435    2.08E+08    0.00
35.1780    1.64E-05     -5116.       4867.    -1.18E-06     12.0376    2.22E+11   -693.282    2.18E+08    0.00
35.6070    1.00E-05     10753.       1942.    -1.11E-06     25.3001    2.22E+11   -443.172    2.28E+08    0.00
36.0360    4.94E-06     14876.    213.8562    -8.13E-07     35.0028    2.22E+11   -228.112    2.38E+08    0.00
36.4650    1.65E-06     12954.    -576.977    -4.90E-07     30.4810    2.22E+11    -79.127    2.47E+08    0.00
36.8940   -1.02E-07      8936.    -767.548    -2.36E-07     21.0250    2.22E+11     5.0903    2.57E+08    0.00
37.3230   -7.82E-07      5052.    -653.741    -7.36E-08     11.8864    2.22E+11    39.1239    2.57E+08    0.00
37.7520   -8.60E-07      2205.    -442.403     1.06E-08      5.1876    2.22E+11    42.9810    2.57E+08    0.00
38.1810   -6.73E-07   496.7607    -245.104     4.19E-08      1.1688    2.22E+11    33.6696    2.57E+08    0.00
38.6100   -4.28E-07   -318.882    -103.378     4.40E-08      0.7503    2.22E+11    21.3910    2.57E+08    0.00
39.0390   -2.20E-07   -567.622     -19.960     3.37E-08      1.3356    2.22E+11    11.0171    2.57E+08    0.00
39.4680   -8.07E-08   -524.387     18.7808     2.10E-08      1.2339    2.22E+11     4.0336    2.57E+08    0.00
39.8970   -3.64E-09   -374.255     29.6323     1.06E-08      0.8806    2.22E+11     0.1822    2.57E+08    0.00
40.3260    2.87E-08   -219.293     26.4106     3.73E-09      0.5160    2.22E+11     -1.434    2.57E+08    0.00
40.7550    3.48E-08   -102.331     18.2413     2.21E-12      0.2408    2.22E+11     -1.740    2.57E+08    0.00
41.1840    2.87E-08    -31.481     10.0691    -1.55E-09     0.07407    2.22E+11     -1.435    2.57E+08    0.00
41.6130    1.88E-08     1.3403      3.9511    -1.90E-09     0.00315    2.22E+11     -0.942    2.57E+08    0.00
42.0420    9.14E-09     9.2001      0.3510    -1.78E-09     0.02165    2.22E+11     -0.457    2.57E+08    0.00
42.4710    5.34E-10     4.9537      -0.894    -1.61E-09     0.01166    2.22E+11   -0.02669    2.57E+08    0.00
42.9000   -7.48E-09       0.00        0.00    -1.56E-09       0.00     2.22E+11     0.3738    1.29E+08    0.00
```

* The above values of total stress are combined axial and bending stresses.

Output Summary for Load Case No. 1:

```
Pile-head deflection             =       1.59543704 inches
Computed slope at pile head      =      -0.0056872 radians
Maximum bending moment           =         9812315. inch-lbs
Maximum shear force              =         -355484. lbs
Depth of maximum bending moment  =      28.31400000 feet below pile head
Depth of maximum shear force     =      30.03000000 feet below pile head
Number of iterations             =              18
Number of zero deflection points =               5
Pile deflection at ground        =       0.33207876 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        Pile Head      Maximum       Maximum
   Length       Deflection     Moment         Shear
    feet          inches       ln-lbs          lbs
 -----------   ------------   ------------   ------------
   42.90000     1.59543704     9812315.      -355484.
   40.75500     1.56292655     9675938.      -351417.
   38.61000     1.58356192     9810240.      -364483.
   36.46500     1.55984500     9655993.      -351587.
   34.32000     1.57451558     9723113.      -355643.
   32.17500     1.56896091     9794332.      -361618.



-------------------------------------------------------------------------------
                 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    Deflect.   Bending     Shear      Slope      Total      Bending    Soil Res.  Soil Spr.  Distrib.
     X        y        Moment      Force        S        Stress     Stiffness     p         Es*H      Lat. Load
    feet     inches    in-lbs       lbs       radians     psi*      lb-in^2    lb/inch     lb/inch    lb/inch
 ---------- ---------- ---------- ---------- ---------- ---------- ---------- ---------- ---------- ----------
     0.00     2.7085   -1.23E-04      0.00   -0.00945   2.89E-07   2.22E+11      0.00       0.00       4.1555
     0.4290    2.6598     55.0637    53.4807  -0.00945    0.1296    2.22E+11      0.00       0.00      16.6218
     0.8580    2.6112    550.6376   181.8345  -0.00945    1.2956    2.22E+11      0.00       0.00      33.2437
     1.2870    2.5625      1927.    395.7574  -0.00945    4.5347    2.22E+11      0.00       0.00      49.8655
     1.7160    2.5138      4625.    695.2495  -0.00945   10.8832    2.22E+11      0.00       0.00      66.4873
     2.1450    2.4652      9086.      1080.   -0.00945   21.3777    2.22E+11      0.00       0.00      83.1091
     2.5740    2.4165     15748.      1551.   -0.00945   37.0547    2.22E+11      0.00       0.00      99.7310
     3.0030    2.3678     25054.      2107.   -0.00945   58.9506    2.22E+11      0.00       0.00     116.3528
     3.4320    2.3192     37443.      2749.   -0.00945   88.1020    2.22E+11      0.00       0.00     132.9746
     3.8610    2.2705     53357.      3476.   -0.00945  125.5454    2.22E+11      0.00       0.00     149.5965
     4.2900    2.2219     73235.      4289.   -0.00945  172.3172    2.22E+11      0.00       0.00     166.2183
     4.7190    2.1732     97518.      5188.   -0.00945  229.4539    2.22E+11      0.00       0.00     182.8401
     5.1480    2.1246    126647.      6172.   -0.00944  297.9921    2.22E+11      0.00       0.00     199.4619
     5.5770    2.0760    161062.      7241.   -0.00944  378.9682    2.22E+11      0.00       0.00     216.0838
     6.0060    2.0274    201203.      8396.   -0.00944  473.4188    2.22E+11      0.00       0.00     232.7056
     6.4350    1.9788    247512.      9637.   -0.00943  582.3803    2.22E+11      0.00       0.00     249.3274
     6.8640    1.9303    300428.     10964.   -0.00943  706.8891    2.22E+11      0.00       0.00     265.9492
     7.2930    1.8818    360392.     12375.   -0.00942  847.9819    2.22E+11      0.00       0.00     282.5711
     7.7220    1.8333    427845.     13873.   -0.00941     1007.    2.22E+11      0.00       0.00     299.1929
     8.1510    1.7849    503228.     15456.   -0.00940     1184.    2.22E+11      0.00       0.00     315.8147
     8.5800    1.7365    586980.     17125.   -0.00939     1381.    2.22E+11      0.00       0.00     332.4366
     9.0090    1.6883    679542.     18879.   -0.00937     1599.    2.22E+11      0.00       0.00     349.0584
     9.4380    1.6401    781355.     20718.   -0.00935     1838.    2.22E+11      0.00       0.00     365.6802
     9.8670    1.5920    892859.     22644.   -0.00933     2101.    2.22E+11      0.00       0.00     382.3020
    10.2960    1.5439   1014495.     24655.   -0.00931     2387.    2.22E+11      0.00       0.00     398.9239
    10.7250    1.4961   1146703.     26751.   -0.00929     2698.    2.22E+11      0.00       0.00     415.5457
    11.1540    1.4483   1289924.     28933.   -0.00926     3035.    2.22E+11      0.00       0.00     432.1675
    11.5830    1.4007   1444598.     31201.   -0.00923     3399.    2.22E+11      0.00       0.00     448.7894
    12.0120    1.3533   1611166.     33554.   -0.00919     3791.    2.22E+11      0.00       0.00     465.4112
    12.4410    1.3061   1790068.     35993.   -0.00915     4212.    2.22E+11      0.00       0.00     482.0330
```

12.8700	1.2591	1981745.	38517.	-0.00911	4663.	2.22E+11	0.00	0.00	498.6548
13.2990	1.2123	2186637.	41127.	-0.00906	5145.	2.22E+11	0.00	0.00	515.2767
13.7280	1.1658	2405185.	43822.	-0.00901	5659.	2.22E+11	0.00	0.00	531.8985
14.1570	1.1196	2637829.	46603.	-0.00895	6207.	2.22E+11	0.00	0.00	548.5203
14.5860	1.0737	2885011.	49470.	-0.00888	6788.	2.22E+11	0.00	0.00	565.1422
15.0150	1.0281	3147169.	52422.	-0.00881	7405.	2.22E+11	0.00	0.00	581.7640
15.4440	0.9829	3424746.	55460.	-0.00874	8058.	2.22E+11	0.00	0.00	598.3858
15.8730	0.9381	3718180.	58583.	-0.00866	8749.	2.22E+11	0.00	0.00	615.0076
16.3020	0.8938	4027914.	61792.	-0.00857	9477.	2.22E+11	0.00	0.00	631.6295
16.7310	0.8499	4354387.	65086.	-0.00847	10246.	2.22E+11	0.00	0.00	648.2513
17.1600	0.8066	4698040.	68466.	-0.00836	11054.	2.22E+11	0.00	0.00	664.8731
17.5890	0.7638	5059313.	71932.	-0.00825	11904.	2.22E+11	0.00	0.00	681.4949
18.0180	0.7217	5438648.	75483.	-0.00813	12797.	2.22E+11	0.00	0.00	698.1168
18.4470	0.6802	5836483.	79119.	-0.00800	13733.	2.22E+11	0.00	0.00	714.7386
18.8760	0.6393	6253261.	82842.	-0.00786	14714.	2.22E+11	0.00	0.00	731.3604
19.3050	0.5993	6689421.	86576.	-0.00771	15740.	2.22E+11	-28.405	244.0152	747.9823
19.7340	0.5600	7144651.	89920.	-0.00755	16811.	2.22E+11	-185.208	1703.	764.6041
20.1630	0.5216	7615237.	92587.	-0.00738	17918.	2.22E+11	-324.385	3202.	781.2259
20.5920	0.4840	8097929.	94574.	-0.00719	19054.	2.22E+11	-482.646	5133.	797.8477
21.0210	0.4475	8588975.	95791.	-0.00700	20209.	2.22E+11	-657.191	7560.	814.4696
21.4500	0.4120	9084189.	96137.	-0.00679	21375.	2.22E+11	-853.751	10668.	831.0914
21.8790	0.3775	9578803.	95561.	-0.00658	22538.	2.22E+11	-1049.	14301.	847.7132
22.3080	0.3443	1.01E+07	94122.	-0.00635	23690.	2.22E+11	-1222.	18277.	864.3351
22.7370	0.3122	1.05E+07	91931.	-0.00611	24819.	2.22E+11	-1374.	22665.	880.9569
23.1660	0.2813	1.10E+07	89096.	-0.00586	25917.	2.22E+11	-1505.	27546.	897.5787
23.5950	0.2518	1.15E+07	85727.	-0.00560	26977.	2.22E+11	-1615.	33020.	914.2005
24.0240	0.2237	1.19E+07	81933.	-0.00533	27994.	2.22E+11	-1704.	39209.	930.8224
24.4530	0.1970	1.23E+07	81643.	-0.00505	28962.	2.22E+11	-287.009	7501.	947.4442
24.8820	0.1717	1.27E+07	85023.	-0.00476	29971.	2.22E+11	-311.671	9343.	964.0660
25.3110	0.1480	1.32E+07	88375.	-0.00446	31022.	2.22E+11	-330.580	11499.	980.6878
25.7400	0.1258	1.36E+07	91725.	-0.00414	32112.	2.22E+11	-345.869	14149.	997.3097
26.1690	0.1053	1.41E+07	95101.	-0.00382	33244.	2.22E+11	-353.999	17304.	1014.
26.5980	0.08648	1.46E+07	98540.	-0.00349	34416.	2.22E+11	-354.316	21091.	1031.
27.0270	0.06939	1.51E+07	102076.	-0.00314	35631.	2.22E+11	-349.688	25941.	1047.
27.4560	0.05412	1.57E+07	105737.	-0.00279	36889.	2.22E+11	-338.844	32234.	1064.
27.8850	0.04071	1.62E+07	108262.	-0.00242	38193.	2.22E+11	-320.016	40468.	575.9187
28.3140	0.02924	1.68E+07	46074.	-0.00203	39512.	2.22E+11	-24416.	4298234.	0.00
28.7430	0.01978	1.67E+07	-83334.	-0.00164	39309.	2.22E+11	-25859.	6729184.	0.00
29.1720	0.01232	1.59E+07	-217515.	-0.00127	37493.	2.22E+11	-26271.	1.10E+07	0.00
29.6010	0.00676	1.45E+07	-350638.	-9.12E-04	34039.	2.22E+11	-25448.	1.94E+07	0.00
30.0300	0.00292	1.23E+07	-475194.	-6.02E-04	28999.	2.22E+11	-22942.	4.04E+07	0.00
30.4590	5.61E-04	9574087.	-565119.	-3.48E-04	22527.	2.22E+11	-11995.	1.10E+08	0.00
30.8880	-6.56E-04	6505913.	-556667.	-1.61E-04	15308.	2.22E+11	15278.	1.20E+08	0.00
31.3170	-0.00110	3842640.	-457205.	-4.09E-05	9042.	2.22E+11	23363.	1.10E+08	0.00
31.7460	-0.00108	1798534.	-332569.	2.45E-05	4232.	2.22E+11	25058.	1.20E+08	0.00
32.1750	-8.44E-04	418505.	-205055.	5.02E-05	984.7173	2.22E+11	24482.	1.49E+08	0.00
32.6040	-5.61E-04	-312708.	-97440.	5.15E-05	735.7840	2.22E+11	17326.	1.59E+08	0.00
33.0330	-3.14E-04	-584739.	-26291.	4.10E-05	1376.	2.22E+11	10315.	1.69E+08	0.00
33.4620	-1.38E-04	-583397.	12591.	2.75E-05	1373.	2.22E+11	4790.	1.79E+08	0.00
33.8910	-3.13E-05	-455104.	27869.	1.54E-05	1071.	2.22E+11	1145.	1.89E+08	0.00
34.3200	2.11E-05	-296456.	28728.	6.73E-06	697.5445	2.22E+11	-811.619	1.98E+08	0.00
34.7490	3.80E-05	-159319.	22685.	1.44E-06	374.8678	2.22E+11	-1536.	2.08E+08	0.00
35.1780	3.59E-05	-62887.	14822.	-1.14E-06	147.9703	2.22E+11	-1519.	2.18E+08	0.00
35.6070	2.62E-05	-6710.	7923.	-1.95E-06	15.7877	2.22E+11	-1161.	2.28E+08	0.00
36.0360	1.58E-05	18691.	3055.	-1.81E-06	43.9780	2.22E+11	-730.036	2.38E+08	0.00
36.4650	7.62E-06	24744.	232.9294	-1.30E-06	58.2205	2.22E+11	-366.309	2.47E+08	0.00
36.8940	2.38E-06	21089.	-1016.	-7.73E-07	49.6209	2.22E+11	-119.048	2.57E+08	0.00
37.3230	-3.37E-07	14279.	-1279.	-3.63E-07	33.5978	2.22E+11	16.8580	2.57E+08	0.00
37.7520	-1.35E-06	7916.	-1062.	-1.05E-07	18.6260	2.22E+11	67.5392	2.57E+08	0.00
38.1810	-1.42E-06	3343.	-705.734	2.56E-08	7.8657	2.22E+11	70.9383	2.57E+08	0.00

```
38.6100   -1.09E-06    649.7950   -383.190    7.19E-08    1.5289    2.22E+11    54.3705   2.57E+08    0.00
39.0390   -6.78E-07   -602.405   -155.926    7.25E-08    1.4174    2.22E+11    33.9214   2.57E+08    0.00
39.4680   -3.41E-07   -955.624    -24.673    5.44E-08    2.2485    2.22E+11    17.0705   2.57E+08    0.00
39.8970   -1.19E-07   -856.441    34.5236    3.34E-08    2.0152    2.22E+11     5.9275   2.57E+08    0.00
40.3260    2.00E-09   -600.169    49.5232    1.65E-08    1.4122    2.22E+11    -0.100    2.57E+08    0.00
40.7550    5.09E-08   -346.550    42.7201    5.47E-09    0.8154    2.22E+11    -2.543    2.57E+08    0.00
41.1840    5.83E-08   -160.322    28.6695   -4.11E-10    0.3772    2.22E+11    -2.916    2.57E+08    0.00
41.6130    4.66E-08    -51.369    15.1641   -2.87E-09    0.1209    2.22E+11    -2.331    2.57E+08    0.00
42.0420    2.88E-08     -4.193     5.4586   -3.51E-09    0.00986   2.22E+11    -1.440    2.57E+08    0.00
42.4710    1.05E-08      4.8334    0.4072   -3.50E-09    0.01137   2.22E+11    -0.523    2.57E+08    0.00
42.9000   -7.30E-09      0.00      0.00    -3.45E-09    0.00      2.22E+11     0.3648   1.29E+08    0.00
```

* The above values of total stress are combined axial and bending stresses.

Output Summary for Load Case No. 2:

```
Pile-head deflection              =      2.70851638 inches
Computed slope at pile head       =     -0.0094539 radians
Maximum bending moment            =      16792563. inch-lbs
Maximum shear force               =       -565119. lbs
Depth of maximum bending moment   =      28.31400000 feet below pile head
Depth of maximum shear force      =      30.45900000 feet below pile head
Number of iterations              =             20
Number of zero deflection points  =              5
Pile deflection at ground         =      0.59972226 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 Length feet	Pile Head Deflection inches	Maximum Moment ln-lbs	Maximum Shear lbs
42.90000	2.70851638	16792563.	-565119.
40.75500	2.65332471	16519044.	-565750.
38.61000	2.68647601	16723325.	-571541.
36.46500	2.64396192	16493208.	-563052.
34.32000	2.67372226	16659248.	-574227.
32.17500	2.73250080	16696905.	-614593.

              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 Load                    Load                Axial    Pile-head Pile-head Max Shear Max Moment
Case Type  Pile-head   Type       Pile-head  Loading  Deflection Rotation  in Pile   in Pile
 No.  1     Load 1      2          Load 2     lbs      inches     radians   lbs       in-lbs
---- ----- ---------- ---------- ---------- ---------- ---------- ---------- ---------- ----------
   1  V, lb      0.00  M, in-lb       0.00       0.00     1.5954   -0.00569  -355484.   9812315.
   2  V, lb      0.00  M, in-lb       0.00       0.00     2.7085   -0.00945  -565119.   1.68E+07


Maximum pile-head deflection = 2.7085163757 inches
Maximum pile-head rotation   = -0.0094538596 radians = -0.541666 deg.

--------------------------------------------------------------------------------
                        Summary of Warning Messages
--------------------------------------------------------------------------------

The following warning was reported 4226 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.
```

SLIDE, UA SLOPE AND LPILE RESULTS FOR U.S. 52 WALL AT 1181+50

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Pavement		145	Mohr-Coulomb	100	0
Embankment Fill		120	Mohr-Coulomb	150	22
Driveway Fill		122	Mohr-Coulomb	150	25
A-6a, A-7-6 with Cobbles/Boulders		120	Mohr-Coulomb	200	27
A-24,A-26 with Boulders/Cobbles		135	Mohr-Coulomb	50	34
Soft Rock		140	Mohr-Coulomb	0	13
Firm Rock		145	Mohr-Coulomb	2000	40
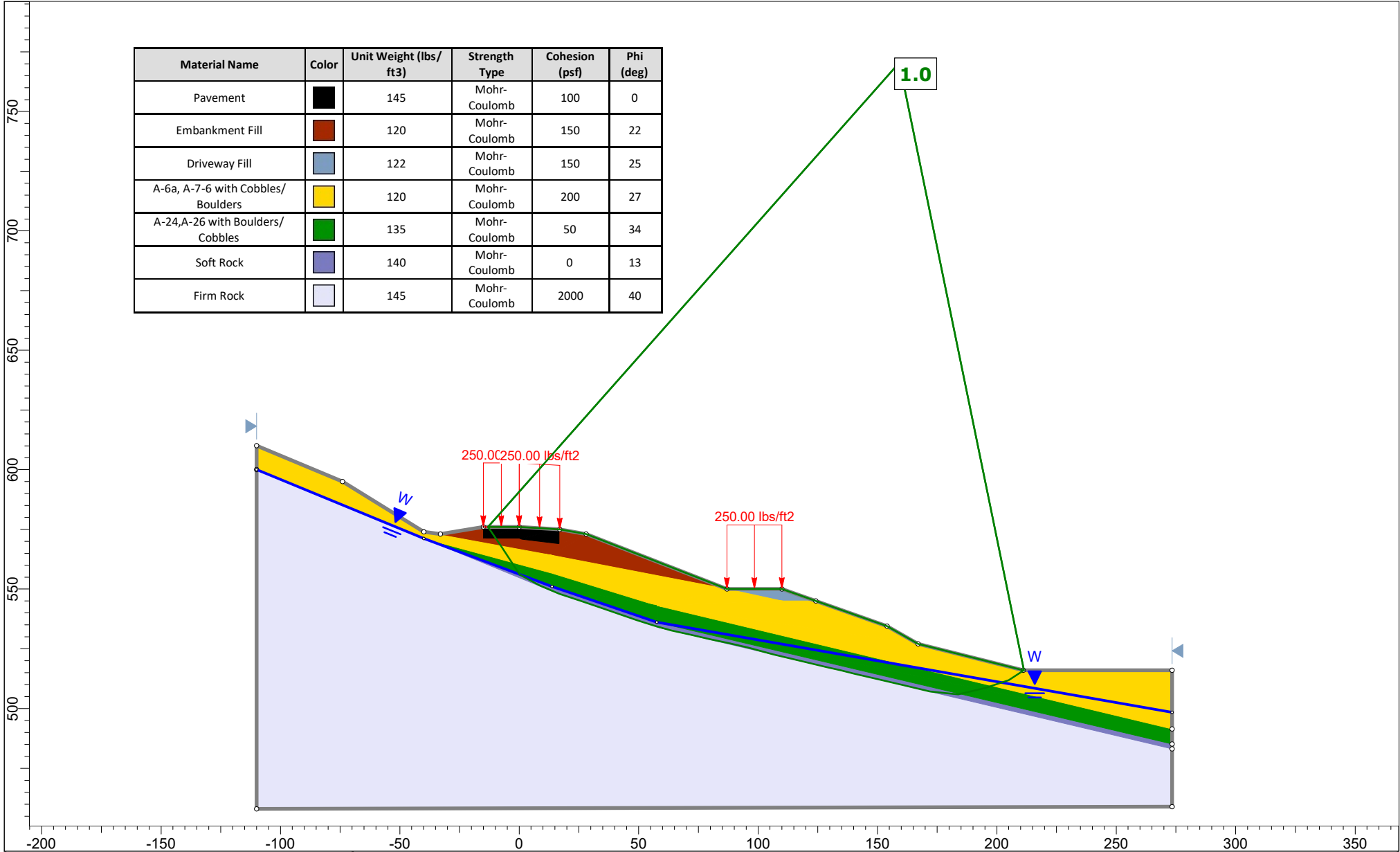
BRO-52-22.27 LANDSLIDE REPAIR

Location	Station 1181+50	Analysis	Long Term - Effective Stress Conditions
Drawn By	CTL Engineering, Inc.	Company	CTL Engineering Inc.
Date	8/4/2023 10:35:03 AM	Client	Ohio Department of Transportation

BRO-52-22.27 LANDSLIDE REPAIR STATION 1181+50 UASLOPE OUTPUT EXISTING CONDITIONS

File   Run   Options   Help

Calculated Results

Factor of Safety: 1.00
Force per Shaft: 0.000   lb
Acting Point X: 33.130   ft   Y: 0.000   ft

Analysis Unit System
◉ English   ○ Metric

Number of Vertical Sections and Soil Layers
Vertical Section Num: 19   Soil Layer Num: 7

Analysis Method
○ Total Stress   ◉ Effective Stress

Chart (Double-Click for More Options)

Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
▸ Layer1	100.0	0.0	145.0
Layer2	150.0	22.0	120.0
Layer3	150.0	25.0	122.0
Layer4	200.0	27.0	120.0
Layer5	50.0	34.0	135.0
Layer6	0.0	13.2	140.0
Layer7	2000.0	40.0	145.0
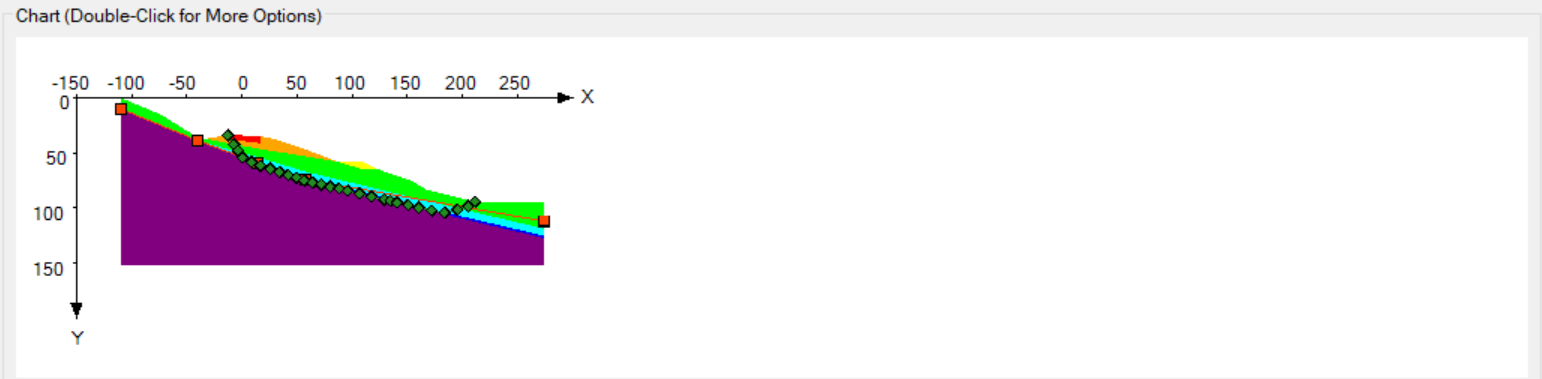
Slope Profile Vertical Sections

	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)	-110.00	-74.00	-40.00	-33.00	-15.01	-15.00	0.00	13.70	17.00	17.01	28.00	57.61	87.00	110.00
Y1 (ft)	0.00	15.00	36.00	37.00	34.00	34.00	34.00	34.80	35.00	35.00	37.00	46.70	58.00	58.00
Y2 (ft)	0.00	15.00	36.00	37.00	34.00	39.00	39.00	40.70	41.00	35.00	37.00	46.70	58.00	58.00
Y3 (ft)	0.00	15.00	38.80	37.00	40.60	40.60	43.30	45.90	46.40	46.40	48.30	53.10	58.00	58.00
Y4 (ft)	0.00	15.00	38.80	37.00	40.60	40.60	43.30	45.90	46.40	46.40	48.30	53.10	58.00	65.00
Y5 (ft)	10.00	24.90	38.80	40.70	45.80	45.80	49.80	53.40	54.60	54.60	57.90	66.90	74.00	79.40
Y6 (ft)	10.00	24.90	38.80	41.40	48.10	48.10	53.90	58.90	60.10	60.10	63.70	73.90	80.90	86.20
Y7 (ft)	10.00	24.90	38.80	41.70	48.70	48.70	55.30	60.90	62.10	62.10	65.70	75.90	82.90	88.20
Y8 (ft)	152.00	152.00	152.00	152.00	152.00	152.00	152.00	152.00	152.00	152.00	152.00	152.00	152.00	152.00

Coordinates of Crest   X: -13.10 ft   Y: 34.00 ft   Coordinates of Toe   X: 211.30 ft   Y: 94.00 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 Save Data

Auto   ○ On   ◉ Off   0.000 (n)
Xmin   0.00   Diameter: 3.00 ft
Xmax   0.00   CTC Spacing: 5.50 ft
XDelta 0.00   X Coordinate: 33.13 ft

[▷ Run]

Pore Water Pressure

Pore Pressure Options: ○ No Pore Pressure   ○ Constant Ratio   ◉ Specified phreatic surface

	Point 1	Point 2	Point 3	Point 4	Point 5
▸ X (ft)	-110.00	-40.00	13.70	57.60	273.40
Y (ft)	10.00	38.80	58.90	73.90	111.60

Slip Surface

12	Point 13	Point 14	Point 15	Point 16	Point 17	Point 18	Point 19	Point 20	Point 21	Point 22	Point 23	Point 24	Point 25	Point 26	Point 27	Point 28
▸ X (ft)	71.90	79.90	87.90	95.90	106.50	117.10	128.70	134.50	140.30	150.40	160.30	172.00	183.70	195.10	204.90	211.30
Y (ft)	78.60	80.40	82.00	84.00	86.80	89.40	92.20	93.40	94.80	97.10	99.50	102.30	104.10	101.50	98.20	94.00

UA Slope Program Version 2.3 - O:\PROJECT\2023\COL-05\23050002COL\Design\Station 1181+50\Station 1181+50 UASLOPE Model\REVISED ANALYSES\9.22.23 REVISED ANALYSIS\1181+50 US 52 with Shafts 9.22.23.ua3

File   Run   Options   Help

Calculated Results

Factor of Safety: 1.20

Force per Shaft: 151321.281 lb

Acting Point 33.130 ft   Y 56.527 ft

Analysis Unit System

◉ English   ○ Metric

Number of Vertical Sections and Soil Layers

Vertical Section 21   Soil Layer 8

Analysis Method

○ Total Stress   ◉ Effective Stress

Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
Layer1	100.0	0.0	145.0
Layer2	250.0	28.0	125.0
Layer3	150.0	22.0	120.0
Layer4	150.0	25.0	122.0
Layer5	200.0	27.0	120.0
Layer6	50.0	34.0	135.0
Layer7	0.0	13.2	140.0
Layer8	2000.0	40.0	145.0
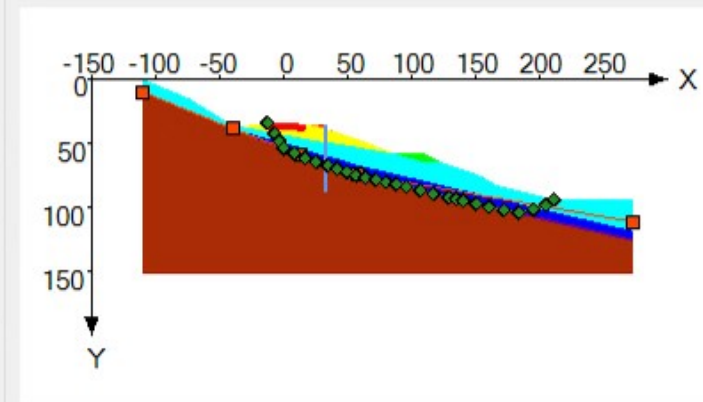
Chart (Double-Click for More Options)

Slope Profile Vertical Sections

	on 6	Section 7	Section 8	Section 9	Section 10	Section 11	Section 12	Section 13	Section 14	Section 15	Section 16	Sec
X (ft)		0.00	13.70	17.00	17.01	25.00	33.13	33.14	57.61	87.00	110.00	124.
Y1 (ft)		34.00	34.80	35.00	35.00	35.20	35.20	38.50	46.70	58.00	58.00	65.0
Y2 (ft)		39.00	40.60	40.00	35.00	35.20	37.80	38.50	46.70	58.00	58.00	65.0
Y3 (ft)		39.00	40.60	40.00	35.00	37.00	38.90	38.90	46.70	58.00	58.00	65.0
Y4 (ft)		43.30	45.90	46.40	46.40	48.30	48.90	48.90	53.10	58.00	58.00	65.0
Y5 (ft)		43.30	45.90	46.40	46.40	48.30	48.90	48.90	53.10	58.00	65.00	65.0
Y6 (ft)		49.70	53.40	54.60	54.60	57.90	59.40	59.40	66.90	74.00	79.40	83.0
Y7 (ft)		53.80	58.90	60.10	60.10	63.70	65.50	65.50	73.90	80.90	86.20	89.6
Y8 (ft)		55.30	60.90	62.10	62.10	65.70	67.50	67.50	75.90	82.90	88.20	91.6
Y9 (ft)	0	152.00	152.00	152.00	152.00	152.00	152.00	152.00	152.00	152.00	152.00	152.

Coordinates of Crest   X: -13.10 ft   Y: 34.00 ft   Coordinates of Toe   X: 211.30 ft   Y: 94.00 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 (η)
Xmin 0.00   Diameter: 3.00 ft
Xmax 0.00   CTC Spacing: 5.50 ft
XDelta 0.00   X Coordinate: 33.13 ft

☐ Auto Save Data

▷ Run

Pore Water Pressure

Pore Pressure Options: ○ No Pore Pressure   ○ Constant Ratio   ◉ Specified phreatic surface

	Point 1	Point 2	Point 3	Point 4	Point 5
X (ft)	-110.00	-40.00	13.70	57.60	273.40
Y (ft)	10.00	38.80	58.90	73.90	111.60

Slip Surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7	Point 8	Point 9	Point 10	Point 11	Point 12	Point 13	Point 14
X (ft)	-13.10	-7.40	-3.60	0.20	8.50	16.80	25.50	34.20	41.70	49.20	56.60	63.90	71.90	79.90

Project: BRO-52-22.27
Project No: 23050002OL
September 26, 2023

L-PILE Soil Parameters (Station 1181+50)

Artificial Lowering of Ground Surface

The passive resistance from the downhill side soil mass should be ignored. In order to include this in the L-pile soil model, the ground level should be artificially lowered.

To do this, first determine the angle of steepness of the slope - downhill of the drilled shafts - from horizontal (β_{dh}), and then determine the depth to the shear surface at the location of the drilled shafts (d_τ). For slopes of steepness from $\beta=0°$ to $45°$, lower the ground surface by an amount equal to $d_\tau TAN(\beta_{dh})$.

For the current project, $\beta_{dh} = 23$ degrees (From plan contours near Sta. 1181+50)

Proposed top of pile elevation = 575.5 (Top of wall elevation from plans)
Existing grade at pile location = 572.2 (From cross section at Sta. 1181+50)
Estimated shear surface elevation at pile location = 542.5

Depth of shear surface beneath existing ground surface at pile location
$d_\tau = 572.2 - 542.5 = 29.7$ feet

Therefore, $d_\tau TAN(\beta_{dh}) = 12.6$ feet.

The first soil layer should start at elevation $572.2 - 12.6 = 559.6$

Which is at a depth of $575.5 - 559.6 = 15.9$ feet along the shaft

Depth of shear surface beneath top of wall at pile location
  $d_p = 575.5 - 542.5 = 33.0$ feet

From 15.9' to 24.9'
Use soil type – *Stiff Clay with Free Water (Reese)*
Effective Unit Weight (pcf) = 120 pcf – 62.4 pcf = 57.6 pcf
N_{60} = 22 bpf (Average blow count in cohesive soils below fill, B-002-2-22 and B-003-0-22)
Undrained Cohesion (psf) = $N_{60}/8$ = 22/8 = 2,750 psf
Use Strain Factor K_{rm} = 0.005 (From L-pile Technical Manual Table 3-4, stiff to very stiff clay)
Use Subgrade Modulus K_{static} = 1,000 pci (From L-pile Technical Manual Table 3-3)

From 24.9' to 33.0'
Use soil type – *Sand (Reese)*
Effective Unit Weight (pcf) = 135 pcf – 62.4 pcf = 72.6 pcf
Friction Angle (deg) = 34 (AASHTO LRFD Table 10.4.6.2.4-1)
Use Subgrade Modulus K_{static} = 125 pci (From L-pile Technical Manual Table 3-3)

Project: BRO-52-22.27
Project No: 23050002OL
September 26, 2023

Below 33.0'

Use soil type – *Weak Rock (Reese)*

Effective Unit Weight (pcf) = 145 pcf – 62.4 pcf = 82.6 pcf

Compressive strength (q_u) = 1,180 psi (B-002-2-22, NQ-2 Compressive Strength Test - Shale)

Initial Rock Modulus (E_r) = 100,000 psi (Per ODOT GDM, Weak to Slightly Strong)

RQD = 22% (Lowest RQD from Borings B-002-2-22 and B-003-0-22)

Use Strain Factor K_{rm} = 0.0005 (From L-pile Technical Manual Equation 3-136)

P-y Modification Factors

If the drilled shafts are at a center-to-center spacing closer than about 3½ diameters, a reduction in the soil resistance p, for the p-y curve behavior of the soil, must be considered.

P- modification factor $\beta_a = 0.64(S/D)^{0.34}$

In which S= Center to Center Spacing between the Piles

D= Diameter of the Shaft

For 36- inch shafts with reinforced shafts placed at 5.5 feet center to center

$\beta_a = 0.64(5.5/3.0)^{0.34} = 0.79$

No P-Y modification factors are applied to the bedrock layers

BRO-52-22.27 Slide Repair

From AASHTO 3.11.5.3, Active Earth Pressure

$$K_a = Sin^2(\Theta + \emptyset'_f)/\Gamma[Sin^2(\Theta)*Sin(\Theta - \delta)]$$

in which

$$\Gamma = [1 + \sqrt{\{(Sin(\emptyset'f + \delta)*Sin(\emptyset'f - \beta))/(Sin(\Theta - \delta)*Sin(\Theta + \beta))\}]^2$$

Where

Angle of back face of the wall to the horizontal (Degrees), Θ=	90
Effective angle of internal friction (degrees), $\emptyset'f$=	30 (Assumed)
Friction angle between fill and wall (degrees), δ=	20 (2/3 $\emptyset'f$)
Angle of fill to the horizontal , β=	0 Assumed)

Calculation

$Sin(\Theta - \delta)$=	0.94
$Sin^2(\Theta)$=	1.00
$Sin(\Theta + \emptyset'_f)$=	0.87
$Sin^2(\Theta + \emptyset'_f)$=	0.75
$Sin(\emptyset'_f - \beta)$=	0.50
$Sin(\Theta + \beta)$=	1.00
$Sin(\emptyset'_f + \delta)$=	0.77
Γ=	2.68
K_a=	0.30

γ_{Ls}=	125 pcf	(GB7, Section E.7)

Case 1

Diameter of Shaft=	36 inches
C/C Spacing (CC)=	5.5 feet

Therefore for a 36-inch Shaft placed at 5.5 feet center to center

Surcharge Load q_{LS},   0.0 lb/in $\gamma_{LS}*2*K_a*CC/12$

Per 903.7 of GDM - If the horizontal distance (H) between the drilled shafts and traffic loading is less than or equal to one half of the half the depth to the shear surface at the location of the drilled shafts (d_t), also apply a (unfactored) vehicular live load surcharge (LS) to the drilled shafts equal to two feet of soil with a unit weight of 125 pcf.

$d_t/2$ =	14.85	feet
H =	15	feet

No Surcharge Load

BRO-52-22.27 Slide Repair

Conversion of force per Shaft to Distributed Load

The UA Slope 2.3 program calculates the unfactored earth pressure (EH), resultant load per shaft, however, for proper structural analysis of pile reaction, we need to convert this to a realistic load.

The triangular load distribution is a close enough approximation of the actual
condition to develop a realistic calculation of distributed shear, moment and displacement in the drilled shaft

Case 1

Diameter of Shaft=　　36 inches
C/C Spacing (CC)=　　5.5 feet
For a 36-inch shaft at 5.5 feet center to center spacing

Load on Shaft (F_{SW})=　151,322 lbs
Depth of Shear plane at Shaft Location(D_S)=　33.0 feet
The Distibuted Load (F_D)=　764.3 lbs/in

a) **Following cases were evaluated:**

        Case1

        Diameter of Shaft =   36 inches

        Center to Center Spacing =   5.5 feet

b) **Unfactored Loads**

Case	Surchage Loads(lbs/in)	Distributed Load(lbs/in)	Total Unfactored Load (lbs/in)
1	0.0	764.3	764.3

c) **Load Factor per AASHTO Table 3.4.1.1 and 3.4.1.2**

$$\text{Load Factor for Surcharge Load (LS)} = 1.75$$
$$\text{Load Factor for Distributed Load (EH)} = 1.5$$

d) **Factored Distributed loads**

Case	Factored Surcharge Load (lbs/in)	Factored Distributed Loads(lbs/in)	Total Factored Load(lbs/in)
1	0.0	1146.4	1146.4

e) **Limit State Checks**

    1   Use Factored Loads for Strength Limit State and check Moment capacity
          and Nominal Shear per AASHTO 6.10.8 and 6.10.9

    2   Use Unfactored Loads for Service Limit State for deflection

f) *L-pile Analysis*

Note: **It is assumed that 50 Ksi steel will be used.**
Section Used=   W24x162

Case1: 36 inch diameter Shafts with 5.5 feet center to center spacing

Checks:

Structural Strength Limit State Checks (W24x162 Section)

Calculated Factored Moment(in-lbs)	Factored Nominal Moment Resistance(in-lbs)	Acceptable Or Unacceptable
7,980,560	20,700,000	Acceptable

Calculated Factored Shear (Kips)	Factored Nominal Shear resistance (Kips)	Acceptable Or Unacceptable
281.2	461.2	Acceptable

Note - The next smaller pile size (W24x146) fails in shear
and for nominal shear resistance calculation Per AASHTO 6.10.9

Service Limit State Checks (W24x162 Section)
Drilled Shaft Length above bedrock=   33 feet
For the unfactored Service Limit State analysis, the maximum Pilehead deflection must be limited to 1% or less
of the drilled shaft length above bedrock (33'), or 2 inches if the wall is within 10 feet of the proposed pavement.

Calculated Deflection(in)	Allowable Deflection(in) Per ODOT Recommendations	Acceptable Or Unacceptable
1.0	4.0	Acceptable

BRO-52-22.27 Slide Repair

<u>W24x162</u>

Thickness of Flange (t_f) =	1.22 in
Depth (d) =	25.00 in
Yield Strength of Steel (F_y) =	50 Ksi
D = d-2t_f =	22.56 in
thickness of Web (t_w) =	0.705 in

V_p = 0.58 $F_y D t_w$ = 461.2 Kips

Young's Modulus (E) = 29000 Ksi

Assume Unstiffened Web

Shear Buckling Coefficient (K) = 5.0

Sqrt(EK/F_y) = 53.9 Equation 1

1.12*Sqrt(EK/F_y) = 60.3 Equation 2

1.4*Sqrt(EK/F_y) = 75.4 Equation 3

D/t_w = 32.0

Since, D/$t_w \leq$ Equation 1, C = 1.0

Therefore,

Nominal Shear Resistance (V_n) = CV_p 461.2 Kips

ϕ_v = 1.0

Factored Shear Resistance (V_u) = $\phi_v V_n$ 461.2 Kips

W24x162

Per AASHTO, 6.10.8

   For Continously Braced Flanges in Tension or Compression

   $f_{bu} \leq \phi_f R_h F_{yf}$ Equation 1

Where f_{bu} =   Factored Bending Moment Obtained in Strength Limit State

   ϕ_f =   Flexural Resistance Factor

   R_h =   Hybrid Factor

   F_{yf} = $f_y * S_{x-x}$

   f_y =   Yield Strength of Steel

   S_{x-x} =   Section Modulus of Steel Section

   ϕ_f =   1.0   Per AASHTO 6.5.4.2

   R_h =   1.0   Per AASHTO 6.10.1.10.1

   S_{x-x} =   414.0 In^3

   f_y =   50.0   ksi

   F_{yf} =   20,700,000   lb-in

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

                       LPile for Windows, Version 2022-12.008

                      Analysis of Individual Piles and Drilled Shafts
                      Subjected to Lateral Loading Using the p-y Method
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================================================================================

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

Path to file locations:
\PROJECT\2023\COL-05\23050002COL\Design\Station 1181+50\Station 1181+50 LPILE Model\REVISED ANALYSES\9.22.23 REVISED ANALYSIS\

Name of input data file:
23.09.26 Lpile.lp12d

Name of output report file:
23.09.26 Lpile.lp12o

Name of plot output file:
23.09.26 Lpile.lp12p

Name of runtime message file:
23.09.26 Lpile.lp12r



--------------------------------------------------------------------------------
                              Date and Time of Analysis
--------------------------------------------------------------------------------

              Date:  September 26, 2023      Time:  20:36:49



--------------------------------------------------------------------------------
                                  Problem Title
--------------------------------------------------------------------------------
```

```
Project Name: BRO-52-22.27 SLIDE REPAIR

Job Number: 23050002COL

Client: OHIO DEPARTMENT OF TRANSPORTATION

Engineer: CTL ENGINEERING, INC

Description: US 52 STATION 1181+50 DRILLED SHAFT RETAINING WALL ANALYSIS




-------------------------------------------------------------------------------
                        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

 - Analysis uses p-y modification factors for p-y curves
 - 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                    =           1
Total length of pile                               =      48.000 ft
Depth of ground surface below top of pile          =      15.9000 ft
```

Pile diameters used for p-y curve computations are defined using 2 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	36.0000
2	48.000	36.0000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

    Section 1 is an elastic pile
    Cross-sectional Shape   =   Circular Pile
    Length of section   =   48.000000 ft
    Width of top of section   =   36.000000 in
    Width of bottom of section   =   36.000000 in
    Top Area   =   47.700000 sq. in
    Bottom Area   =   47.700000 sq. in
    Moment of Inertia at Top   =   5170. in^4
    Moment of Inertia at Bottom   =   5170. in^4
    Elastic Modulus   =   29000000. psi

                     Soil and Rock Layering Information

The soil profile is modelled using 3 layers

Layer 1 is stiff clay with water-induced erosion

    Distance from top of pile to top of layer   =   15.900000 ft
    Distance from top of pile to bottom of layer   =   24.900000 ft
    Effective unit weight at top of layer   =   57.600000 pcf
    Effective unit weight at bottom of layer   =   57.600000 pcf
    Undrained cohesion at top of layer   =   2750. psf
    Undrained cohesion at bottom of layer   =   2750. psf
    Epsilon-50 at top of layer   =   0.005000
    Epsilon-50 at bottom of layer   =   0.005000
    Subgrade k at top of layer   =   1000.000000 pci
    Subgrade k at bottom of layer   =   1000.000000 pci

Layer 2 is sand, p-y criteria by Reese et al., 1974

    Distance from top of pile to top of layer   =   24.900000 ft
    Distance from top of pile to bottom of layer   =   33.000000 ft
    Effective unit weight at top of layer   =   72.600000 pcf
    Effective unit weight at bottom of layer   =   72.600000 pcf
    Friction angle at top of layer   =   34.000000 deg.
    Friction angle at bottom of layer   =   34.000000 deg.
    Subgrade k at top of layer   =   125.000000 pci

```
    Subgrade k at bottom of layer               =     125.000000 pci


Layer 3 is weak rock, p-y criteria by Reese, 1997

    Distance from top of pile to top of layer        =     33.000000 ft
    Distance from top of pile to bottom of layer     =     65.000000 ft
    Effective unit weight at top of layer            =     82.600000 pcf
    Effective unit weight at bottom of layer         =     82.600000 pcf
    Uniaxial compressive strength at top of layer    =        1180. psi
    Uniaxial compressive strength at bottom of layer =        1180. psi
    Initial modulus of rock at top of layer          =      100000. psi
    Initial modulus of rock at bottom of layer       =      100000. psi
    RQD of rock at top of layer                      =     22.000000 %
    RQD of rock at bottom of layer                   =     22.000000 %
    k rm of rock at top of layer                     =     0.0005000
    k rm of rock at bottom of layer                  =     0.0005000


 (Depth of the lowest soil layer extends 17.000 ft below the pile tip)



-------------------------------------------------------------------------------
                     Summary of Input Soil Properties
-------------------------------------------------------------------------------

Layer         Soil Type        Layer     Effective  Cohesion   Angle of   Uniaxial                              E50                     Rock
Mass
 Num.           Name           Depth     Unit Wt.              Friction      qu        RQD %           or         kpy
Modulus
           (p-y Curve Type)      ft        pcf        psf        deg.       psi                       krm         pci
psi
-----    -------------------  ----------  ----------  ----------  ----------  ----------  ----------  ----------  ----------
----------
  1          Stiff Clay        15.9000     57.6000     2750.       --          --          --         0.00500    1000.0000       --

           with Free Water     24.9000     57.6000     2750.       --          --          --         0.00500    1000.0000       --

  2            Sand            24.9000     72.6000      --        34.0000      --          --           --        125.0000        --

           (Reese, et al.)     33.0000     72.6000      --        34.0000      --          --           --        125.0000        --

  3            Weak            33.0000     82.6000      --         --         1180.      22.0000     5.00E-04       --
100000.
              Rock             65.0000     82.6000      --         --         1180.      22.0000     5.00E-04       --
100000.



-------------------------------------------------------------------------------
                   Modification Factors for p-y Curves
-------------------------------------------------------------------------------

Distribution of p-y modifiers with depth defined using 3 points

Point      Depth X        p-mult         y-mult
 No.          ft
-----     ----------     ----------     ----------
  1         15.900         0.7900         1.0000
  2         33.000         0.7900         1.0000
```

```
   3          33.000          1.0000          1.0000




-------------------------------------------------------------------------------
                            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          Depth X               Dist. Load
 No.             ft                     lb/in
-----          ----------            ----------
  1              0.000                   0.000
  2             33.000                 764.300


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

Point          Depth X               Dist. Load
 No.             ft                     lb/in
-----          ----------            ----------
  1              0.000                   0.000
  2             33.000                1146.400




-------------------------------------------------------------------------------
             Pile-head Loading and Pile-head Fixity Conditions
-------------------------------------------------------------------------------

Number of loads specified = 2

Load   Load         Condition              Condition          Axial Thrust    Compute Top y    Run Analysis
 No.   Type             1                      2               Force, lbs      vs. Pile Length
-----  ----    --------------------    --------------------   -------------   ---------------   ------------
   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 = 1


Pile Section No. 1:
-------------------
Moment-curvature properties were derived from elastic section properties




-------------------------------------------------------------------------------
           Layering Correction Equivalent Depths of Soil & Rock Layers
-------------------------------------------------------------------------------


           Top of     Equivalent
           Layer      Top Depth  Same Layer  Layer is       F0          F1
Layer      Below        Below     Type As    Rock or     Integral    Integral
 No.     Pile Head    Grnd Surf    Layer     is Below    for Layer   for Layer
            ft           ft        Above    Rock Layer     lbs         lbs
-----    ----------   ----------  ----------  ----------  ----------  ----------
  1       15.9000        0.00       N.A.        No           0.00      37491.
  2       24.9000        5.9048      No         No         37491.     188536.
  3       33.0000       17.1000      No         Yes         N.A.         N.A.


Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals
       for Layer n. Layering correction equivalent depths are computed only
       for soil types with both shallow-depth and deep-depth expressions for
       peak lateral load transfer. These soil types are soft and stiff clays,
       non-liquefied sands, and cemented c-phi soil.






-------------------------------------------------------------------------------
             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   Deflect.   Bending     Shear      Slope     Total     Bending    Soil Res.  Soil Spr.  Distrib.
    X         y       Moment      Force        S       Stress   Stiffness      p         Es*H     Lat. Load
   feet    inches     in-lbs       lbs       radians    psi*     lb-in^2    lb/inch    lb/inch    lb/inch
---------- ---------- ---------- ---------- ---------- ---------- ---------- ---------- ---------- ----------
      0.00     1.0464   1.30E-05  -8.71E-08   -0.00412   4.54E-08   1.50E+11       0.00       0.00     2.7793
     0.4800     1.0226    46.1048    40.0215   -0.00412     0.1605   1.50E+11       0.00       0.00    11.1171
     0.9600     0.9989   461.0480   136.0732   -0.00412     1.6052   1.50E+11       0.00       0.00    22.2342
     1.4400     0.9752     1614.    296.1593   -0.00412     5.6182   1.50E+11       0.00       0.00    33.3513
     1.9200     0.9515     3873.    520.2799   -0.00412    13.4836   1.50E+11       0.00       0.00    44.4684
     2.4000     0.9278     7607.    808.4349   -0.00412    26.4857   1.50E+11       0.00       0.00    55.5855
     2.8800     0.9041    13186.      1161.    -0.00412    45.9086   1.50E+11       0.00       0.00    66.7025
```

3.3600	0.8804	20978.	1577.	-0.00411	73.0364	1.50E+11	0.00	0.00	77.8196
3.8400	0.8567	31351.	2057.	-0.00411	109.1533	1.50E+11	0.00	0.00	88.9367
4.3200	0.8330	44676.	2601.	-0.00411	155.5435	1.50E+11	0.00	0.00	100.0538
4.8000	0.8093	61319.	3210.	-0.00411	213.4911	1.50E+11	0.00	0.00	111.1709
5.2800	0.7857	81652.	3882.	-0.00411	284.2802	1.50E+11	0.00	0.00	122.2880
5.7600	0.7620	106041.	4618.	-0.00410	369.1951	1.50E+11	0.00	0.00	133.4051
6.2400	0.7384	134857.	5419.	-0.00410	469.5199	1.50E+11	0.00	0.00	144.5222
6.7200	0.7148	168467.	6283.	-0.00409	586.5387	1.50E+11	0.00	0.00	155.6393
7.2000	0.6912	207241.	7212.	-0.00409	721.5357	1.50E+11	0.00	0.00	166.7564
7.6800	0.6677	251548.	8204.	-0.00408	875.7950	1.50E+11	0.00	0.00	177.8735
8.1600	0.6443	301756.	9261.	-0.00407	1051.	1.50E+11	0.00	0.00	188.9905
8.6400	0.6209	358234.	10382.	-0.00405	1247.	1.50E+11	0.00	0.00	200.1076
9.1200	0.5976	421352.	11566.	-0.00404	1467.	1.50E+11	0.00	0.00	211.2247
9.6000	0.5744	491477.	12815.	-0.00402	1711.	1.50E+11	0.00	0.00	222.3418
10.0800	0.5512	568979.	14128.	-0.00400	1981.	1.50E+11	0.00	0.00	233.4589
10.5600	0.5283	654227.	15504.	-0.00398	2278.	1.50E+11	0.00	0.00	244.5760
11.0400	0.5054	747589.	16945.	-0.00395	2603.	1.50E+11	0.00	0.00	255.6931
11.5200	0.4828	849435.	18450.	-0.00392	2957.	1.50E+11	0.00	0.00	266.8102
12.0000	0.4603	960132.	20019.	-0.00389	3343.	1.50E+11	0.00	0.00	277.9273
12.4800	0.4380	1080051.	21652.	-0.00385	3760.	1.50E+11	0.00	0.00	289.0444
12.9600	0.4160	1209559.	23349.	-0.00380	4211.	1.50E+11	0.00	0.00	300.1615
13.4400	0.3942	1349026.	25110.	-0.00375	4697.	1.50E+11	0.00	0.00	311.2785
13.9200	0.3727	1498821.	26934.	-0.00370	5218.	1.50E+11	0.00	0.00	322.3956
14.4000	0.3516	1659312.	28824.	-0.00364	5777.	1.50E+11	0.00	0.00	333.5127
14.8800	0.3308	1830868.	30777.	-0.00357	6374.	1.50E+11	0.00	0.00	344.6298
15.3600	0.3105	2013858.	32794.	-0.00350	7011.	1.50E+11	0.00	0.00	355.7469
15.8400	0.2905	2208650.	34875.	-0.00342	7690.	1.50E+11	0.00	0.00	366.8640
16.3200	0.2711	2415615.	36063.	-0.00333	8410.	1.50E+11	-332.120	7056.	377.9811
16.8000	0.2522	2624101.	35812.	-0.00323	9136.	1.50E+11	-522.159	11925.	389.0982
17.2800	0.2339	2828172.	34587.	-0.00313	9847.	1.50E+11	-692.429	17051.	400.2153
17.7600	0.2162	3022549.	32496.	-0.00301	10523.	1.50E+11	-845.177	22515.	411.3324
18.2400	0.1992	3202531.	29636.	-0.00289	11150.	1.50E+11	-981.744	28388.	422.4495
18.7200	0.1829	3363957.	26097.	-0.00277	11712.	1.50E+11	-1103.	34738.	433.5665
19.2000	0.1673	3503174.	21967.	-0.00264	12197.	1.50E+11	-1210.	41637.	444.6836
19.6800	0.1525	3617014.	17328.	-0.00250	12593.	1.50E+11	-1302.	49158.	455.8007
20.1600	0.1385	3702787.	12261.	-0.00236	12892.	1.50E+11	-1380.	57374.	466.9178
20.6400	0.1254	3758265.	6849.	-0.00221	13085.	1.50E+11	-1444.	66358.	478.0349
21.1200	0.1130	3781684.	1170.	-0.00207	13166.	1.50E+11	-1495.	76159.	489.1520
21.6000	0.1015	3771745.	-4687.	-0.00192	13132.	1.50E+11	-1528.	86713.	500.2691
22.0800	0.09086	3727692.	-10598.	-0.00178	12978.	1.50E+11	-1536.	97350.	511.3862
22.5600	0.08102	3649655.	-16463.	-0.00164	12707.	1.50E+11	-1534.	109089.	522.5033
23.0400	0.07199	3538043.	-22235.	-0.00150	12318.	1.50E+11	-1526.	122093.	533.6204
23.5200	0.06373	3393511.	-27874.	-0.00137	11815.	1.50E+11	-1511.	136516.	544.7375
24.0000	0.05623	3216935.	-33343.	-0.00124	11200.	1.50E+11	-1489.	152533.	555.8545
24.4800	0.04944	3009396.	-38609.	-0.00112	10478.	1.50E+11	-1462.	170343.	566.9716
24.9600	0.04332	2772155.	-40280.	-0.00101	9652.	1.50E+11	-263.019	34972.	578.0887
25.4400	0.03781	2545366.	-38450.	-9.08E-04	8862.	1.50E+11	-268.746	40941.	589.2058
25.9200	0.03286	2329210.	-36576.	-8.14E-04	8109.	1.50E+11	-270.207	47360.	600.3229
26.4000	0.02843	2124006.	-34634.	-7.29E-04	7395.	1.50E+11	-266.948	54081.	611.4400
26.8800	0.02447	1930232.	-32590.	-6.51E-04	6720.	1.50E+11	-257.537	60620.	622.5571
27.3600	0.02094	1748568.	-30413.	-5.80E-04	6088.	1.50E+11	-242.826	66806.	633.6742
27.8400	0.01779	1579872.	-28074.	-5.16E-04	5501.	1.50E+11	-223.484	72363.	644.7913
28.3200	0.01499	1425153.	-25559.	-4.58E-04	4962.	1.50E+11	-204.029	78392.	655.9084
28.8000	0.01251	1285427.	-22865.	-4.06E-04	4475.	1.50E+11	-183.335	84420.	667.0255
29.2800	0.01031	1161749.	-19981.	-3.59E-04	4045.	1.50E+11	-160.285	89537.	678.1425
29.7600	0.00837	1055251.	-16895.	-3.17E-04	3674.	1.50E+11	-135.728	93400.	689.2596
30.2400	0.00666	967119.	-13602.	-2.78E-04	3367.	1.50E+11	-110.638	95641.	700.3767
30.7200	0.00517	898553.	-10103.	-2.42E-04	3128.	1.50E+11	-86.072	95896.	711.4938
31.2000	0.00388	850736.	-6417.	-2.08E-04	2962.	1.50E+11	-68.445	101728.	722.6109
31.6800	0.00277	824624.	-2569.	-1.76E-04	2871.	1.50E+11	-51.785	107708.	733.7280

```
32.1600    0.00185    821136.      1437.   -1.45E-04      2859.   1.50E+11    -35.562    110984.   744.8451
32.6400    0.00110    841181.      5594.   -1.13E-04      2929.   1.50E+11    -21.894    114261.   755.9622
33.1200    5.48E-04   885581.     -8362.   -7.95E-05      3083.   1.50E+11     -5771.   6.07E+07   190.7276
33.6000    1.88E-04   744852.    -31290.   -4.82E-05      2593.   1.50E+11     -2381.   7.30E+07     0.00
34.0800   -7.06E-06   525125.    -37846.   -2.38E-05      1828.   1.50E+11   104.4919   8.52E+07     0.00
34.5600   -8.59E-05   308865.    -33356.   -7.75E-06      1075.   1.50E+11     1455.   9.75E+07     0.00
35.0400   -9.64E-05   140862.    -23874.    8.85E-07   490.4299   1.50E+11     1838.   1.10E+08     0.00
35.5200   -7.57E-05    33831.    -13960.    4.24E-06   117.7877   1.50E+11     1605.   1.22E+08     0.00
36.0000   -4.75E-05   -19954.     -6143.    4.51E-06    69.4712   1.50E+11     1109.   1.34E+08     0.00
36.4800   -2.38E-05   -36941.     -1205.    3.41E-06   128.6156   1.50E+11   605.5788   1.47E+08     0.00
36.9600   -8.20E-06   -33837.      1191.    2.05E-06   117.8084   1.50E+11   226.3268   1.59E+08     0.00
37.4400   -1.09E-07   -23224.      1852.    9.59E-07    80.8578   1.50E+11     3.2398   1.71E+08     0.00
37.9200    2.84E-06   -12504.      1600.    2.72E-07    43.5329   1.50E+11    -90.600   1.84E+08     0.00
38.4000    3.03E-06    -4789.      1043.   -5.98E-08    16.6735   1.50E+11  -102.962   1.96E+08     0.00
38.8800    2.15E-06  -490.388   522.1587   -1.61E-07     1.7073   1.50E+11   -77.822   2.08E+08     0.00
39.3600    1.17E-06     1226.   169.0171   -1.47E-07     4.2694   1.50E+11   -44.797   2.20E+08     0.00
39.8400    4.59E-07     1457.    -13.397   -9.56E-08     5.0716   1.50E+11   -18.541   2.33E+08     0.00
40.3200    6.96E-08     1072.    -75.317   -4.70E-08     3.7321   1.50E+11    -2.959   2.45E+08     0.00
40.8000   -8.26E-08   589.0348   -73.214   -1.51E-08     2.0508   1.50E+11     3.6892   2.57E+08     0.00
41.2800   -1.04E-07   228.5197   -48.517    6.02E-10     0.7956   1.50E+11     4.8864   2.70E+08     0.00
41.7600   -7.57E-08    30.1222   -23.782    5.57E-09     0.1049   1.50E+11     3.7021   2.82E+08     0.00
42.2400   -4.02E-08   -45.447     -7.325    5.28E-09     0.1582   1.50E+11     2.0119   2.88E+08     0.00
42.7200   -1.49E-08   -54.266     0.6113    3.36E-09     0.1889   1.50E+11     0.7439   2.88E+08     0.00
43.2000   -1.52E-09   -38.405     2.9731    1.58E-09     0.1337   1.50E+11   0.07621   2.88E+08     0.00
43.6800    3.33E-09   -20.016     2.7131    4.58E-10    0.06969   1.50E+11    -0.166   2.88E+08     0.00
44.1600    3.75E-09    -7.151     1.6928   -6.36E-11    0.02490   1.50E+11    -0.188   2.88E+08     0.00
44.6400    2.60E-09    -0.515     0.7781   -2.11E-10    0.00179   1.50E+11    -0.130   2.88E+08     0.00
45.1200    1.33E-09     1.8126    0.2131   -1.86E-10    0.00631   1.50E+11   -0.06631   2.88E+08     0.00
45.6000    4.56E-10     1.9400   -0.04353  -1.14E-10    0.00675   1.50E+11   -0.02279   2.88E+08     0.00
46.0800    1.49E-11     1.3112     -0.111  -5.14E-11    0.00456   1.50E+11  -7.47E-04   2.88E+08     0.00
46.5600   -1.36E-10     0.6575   -0.09391  -1.36E-11    0.00229   1.50E+11   0.00679   2.88E+08     0.00
47.0400   -1.41E-10     0.2293   -0.05402   3.48E-12   7.98E-04   1.50E+11   0.00706   2.88E+08     0.00
47.5200   -9.57E-11    0.03525   -0.01990   8.57E-12   1.23E-04   1.50E+11   0.00479   2.88E+08     0.00
48.0000   -4.25E-11      0.00       0.00    9.24E-12      0.00    1.50E+11   0.00212   1.44E+08     0.00
```

* The above values of total stress are combined axial and bending stresses.

Output Summary for Load Case No. 1:

```
Pile-head deflection              =      1.04635484 inches
Computed slope at pile head       =     -0.0041160 radians
Maximum bending moment            =       3781684. inch-lbs
Maximum shear force               =        -40280. lbs
Depth of maximum bending moment   =     21.12000000 feet below pile head
Depth of maximum shear force      =     24.96000000 feet below pile head
Number of iterations              =             23
Number of zero deflection points  =              6
Pile deflection at ground         =      0.28811604 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        Pile Head      Maximum        Maximum
    Length       Deflection     Moment         Shear
     feet         inches        ln-lbs          lbs
 ------------  ------------  ------------  ------------
   48.00000     1.04635484     3781684.       -40280.
   45.60000     1.03045188     3746535.       -40710.
   43.20000     1.02739136     3738927.       -40645.
   40.80000     1.03250552     3782291.       -41440.
   38.40000     1.03770562     3760723.       -40439.
   36.00000     1.03253148     3774927.       -41397.
   33.60000     1.03078874     3761716.       -45836.
   31.20000     1.28569335     3778420.       -53197.


--------------------------------------------------------------------------------
                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    Deflect.   Bending     Shear      Slope     Total     Bending    Soil Res.  Soil Spr.  Distrib.
     X         y       Moment      Force        S       Stress    Stiffness      p        Es*H     Lat. Load
    feet     inches    in-lbs       lbs      radians    psi*      lb-in^2     lb/inch    lb/inch    lb/inch
 ---------- ---------- ---------- ---------- ---------- ---------- ---------- ---------- ---------- ----------
      0.00     3.3502   4.01E-06       0.00   -0.01131   1.40E-08   1.50E+11       0.00       0.00     4.1687
      0.4800   3.2851    69.1542    60.0297   -0.01131    0.2408    1.50E+11       0.00       0.00    16.6749
      0.9600   3.2199   691.5418   204.1009   -0.01131    2.4077    1.50E+11       0.00       0.00    33.3498
      1.4400   3.1548     2420.    444.2196   -0.01131    8.4269    1.50E+11       0.00       0.00    50.0247
      1.9200   3.0897     5809.    780.3857   -0.01131   20.2246    1.50E+11       0.00       0.00    66.6996
      2.4000   3.0245    11410.      1213.    -0.01131   39.7269    1.50E+11       0.00       0.00    83.3745
      2.8800   2.9594    19778.      1741.    -0.01131   68.8599    1.50E+11       0.00       0.00   100.0495
      3.3600   2.8942    31465.      2365.    -0.01131  109.5499    1.50E+11       0.00       0.00   116.7244
      3.8400   2.8291    47025.      3086.    -0.01131  163.7229    1.50E+11       0.00       0.00   133.3993
      4.3200   2.7640    67010.      3902.    -0.01130  233.3051    1.50E+11       0.00       0.00   150.0742
      4.8000   2.6989    91975.      4814.    -0.01130  320.2227    1.50E+11       0.00       0.00   166.7491
      5.2800   2.6338   122472.      5823.    -0.01130  426.4017    1.50E+11       0.00       0.00   183.4240
      5.7600   2.5688   159055.      6927.    -0.01129  553.7685    1.50E+11       0.00       0.00   200.0989
      6.2400   2.5037   202276.      8128.    -0.01128  704.2491    1.50E+11       0.00       0.00   216.7738
      6.7200   2.4388   252689.      9425.    -0.01128  879.7696    1.50E+11       0.00       0.00   233.4487
      7.2000   2.3739   310848.     10817.    -0.01126     1082.    1.50E+11       0.00       0.00   250.1236
      7.6800   2.3090   377305.     12306.    -0.01125     1314.    1.50E+11       0.00       0.00   266.7985
      8.1600   2.2442   452614.     13891.    -0.01124     1576.    1.50E+11       0.00       0.00   283.4735
      8.6400   2.1796   537328.     15572.    -0.01122     1871.    1.50E+11       0.00       0.00   300.1484
      9.1200   2.1150   632000.     17349.    -0.01119     2200.    1.50E+11       0.00       0.00   316.8233
      9.6000   2.0506   737184.     19222.    -0.01117     2567.    1.50E+11       0.00       0.00   333.4982
     10.0800   1.9864   853432.     21190.    -0.01114     2971.    1.50E+11       0.00       0.00   350.1731
     10.5600   1.9223   981298.     23255.    -0.01110     3417.    1.50E+11       0.00       0.00   366.8480
     11.0400   1.8585  1121335.     25417.    -0.01106     3904.    1.50E+11       0.00       0.00   383.5229
     11.5200   1.7949  1274097.     27674.    -0.01102     4436.    1.50E+11       0.00       0.00   400.1978
     12.0000   1.7316  1440136.     30027.    -0.01096     5014.    1.50E+11       0.00       0.00   416.8727
     12.4800   1.6686  1620006.     32476.    -0.01090     5640.    1.50E+11       0.00       0.00   433.5476
     12.9600   1.6060  1814260.     35021.    -0.01084     6317.    1.50E+11       0.00       0.00   450.2225
```

13.4400	1.5437	2023451.	37663.	-0.01076	7045.	1.50E+11	0.00	0.00	466.8975
13.9200	1.4820	2248133.	40400.	-0.01068	7827.	1.50E+11	0.00	0.00	483.5724
14.4000	1.4207	2488859.	43233.	-0.01059	8665.	1.50E+11	0.00	0.00	500.2473
14.8800	1.3599	2746182.	46163.	-0.01049	9561.	1.50E+11	0.00	0.00	516.9222
15.3600	1.2998	3020655.	49188.	-0.01038	10517.	1.50E+11	0.00	0.00	533.5971
15.8400	1.2404	3312831.	52310.	-0.01026	11534.	1.50E+11	0.00	0.00	550.2720
16.3200	1.1816	3623264.	55434.	-0.01013	12615.	1.50E+11	-32.343	157.6623	566.9469
16.8000	1.1237	3951434.	58473.	-0.00998	13757.	1.50E+11	-63.245	324.1856	583.6218
17.2800	1.0667	4296869.	61278.	-0.00982	14960.	1.50E+11	-146.497	791.0871	600.2967
17.7600	1.0106	4657360.	63482.	-0.00965	16215.	1.50E+11	-305.683	1742.	616.9716
18.2400	0.9555	5028179.	64809.	-0.00946	17506.	1.50E+11	-484.141	2919.	633.6465
18.7200	0.9015	5403958.	65157.	-0.00926	18815.	1.50E+11	-678.921	4338.	650.3215
19.2000	0.8488	5778788.	64440.	-0.00905	20120.	1.50E+11	-887.371	6022.	666.9964
19.6800	0.7973	6146306.	62586.	-0.00882	21399.	1.50E+11	-1107.	7998.	683.6713
20.1600	0.7472	6499777.	59536.	-0.00858	22630.	1.50E+11	-1336.	10298.	700.3462
20.6400	0.6985	6832162.	55244.	-0.00832	23787.	1.50E+11	-1572.	12961.	717.0211
21.1200	0.6513	7136189.	49674.	-0.00805	24846.	1.50E+11	-1813.	16033.	733.6960
21.6000	0.6057	7404408.	42800.	-0.00777	25779.	1.50E+11	-2058.	19568.	750.3709
22.0800	0.5618	7629249.	34695.	-0.00748	26562.	1.50E+11	-2274.	23313.	767.0458
22.5600	0.5195	7804100.	25498.	-0.00719	27171.	1.50E+11	-2471.	27392.	783.7207
23.0400	0.4790	7922982.	15318.	-0.00689	27585.	1.50E+11	-2648.	31845.	800.3956
23.5200	0.4402	7980560.	4267.	-0.00658	27785.	1.50E+11	-2807.	36722.	817.0705
24.0000	0.4032	7972132.	-7546.	-0.00627	27756.	1.50E+11	-2946.	42084.	833.7455
24.4800	0.3679	7893630.	-20011.	-0.00597	27483.	1.50E+11	-3066.	48001.	850.4204
24.9600	0.3344	7741610.	-25373.	-0.00567	26953.	1.50E+11	-513.229	8839.	867.0953
25.4400	0.3026	7601331.	-23352.	-0.00537	26465.	1.50E+11	-535.953	10200.	883.7702
25.9200	0.2725	7472591.	-21345.	-0.00508	26017.	1.50E+11	-551.228	11650.	900.4451
26.4000	0.2441	7355438.	-19305.	-0.00480	25609.	1.50E+11	-557.976	13168.	917.1200
26.8800	0.2173	7250200.	-17192.	-0.00452	25242.	1.50E+11	-559.477	14834.	933.7949
27.3600	0.1920	7157381.	-14967.	-0.00424	24919.	1.50E+11	-552.221	16564.	950.4698
27.8400	0.1684	7077775.	-12575.	-0.00397	24642.	1.50E+11	-534.804	18294.	967.1447
28.3200	0.1463	7012513.	-9985.	-0.00370	24415.	1.50E+11	-516.869	20348.	983.8196
28.8000	0.1258	6962743.	-7182.	-0.00343	24242.	1.50E+11	-494.206	22631.	1000.
29.2800	0.1068	6929771.	-4127.	-0.00316	24127.	1.50E+11	-462.422	24939.	1017.
29.7600	0.08936	6915204.	-766.939	-0.00290	24076.	1.50E+11	-422.017	27204.	1034.
30.2400	0.07344	6920936.	2944.	-0.00263	24096.	1.50E+11	-373.970	29332.	1051.
30.7200	0.05905	6949114.	7044.	-0.00236	24194.	1.50E+11	-319.818	31197.	1067.
31.2000	0.04620	7002088.	11525.	-0.00210	24379.	1.50E+11	-275.359	34330.	1084.
31.6800	0.03490	7081887.	16317.	-0.00183	24656.	1.50E+11	-245.302	40485.	1101.
32.1600	0.02517	7190061.	21390.	-0.00155	25033.	1.50E+11	-211.187	48333.	1117.
32.6400	0.01703	7328294.	26764.	-0.00127	25514.	1.50E+11	-173.746	58779.	1134.
33.1200	0.01051	7498383.	-17827.	-9.88E-04	26107.	1.50E+11	-16729.	9172051.	286.0789
33.6000	0.00565	7122922.	-115186.	-7.07E-04	24799.	1.50E+11	-17362.	1.77E+07	0.00
34.0800	0.00236	6171445.	-212433.	-4.52E-04	21487.	1.50E+11	-16405.	4.00E+07	0.00
34.5600	4.42E-04	4675697.	-281230.	-2.43E-04	16279.	1.50E+11	-7483.	9.75E+07	0.00
35.0400	-4.42E-04	2931674.	-278497.	-9.72E-05	10207.	1.50E+11	8432.	1.10E+08	0.00
35.5200	-6.78E-04	1467412.	-212836.	-1.27E-05	5109.	1.50E+11	14367.	1.22E+08	0.00
36.0000	-5.88E-04	479806.	-131920.	2.47E-05	1671.	1.50E+11	13729.	1.34E+08	0.00
36.4800	-3.93E-04	-52303.	-63562.	3.29E-05	182.0989	1.50E+11	10006.	1.47E+08	0.00
36.9600	-2.09E-04	-252423.	-18128.	2.71E-05	878.8416	1.50E+11	5769.	1.59E+08	0.00
37.4400	-8.10E-05	-261133.	5424.	1.72E-05	909.1673	1.50E+11	2408.	1.71E+08	0.00
37.9200	-1.07E-05	-189941.	13346.	8.55E-06	661.3045	1.50E+11	342.5237	1.84E+08	0.00
38.4000	1.75E-05	-107386.	12622.	2.84E-06	373.8761	1.50E+11	-593.914	1.96E+08	0.00
38.8800	2.19E-05	-44534.	8630.	-8.23E-08	155.0518	1.50E+11	-792.105	2.08E+08	0.00
39.3600	1.65E-05	-7963.	4528.	-1.09E-06	27.7251	1.50E+11	-632.184	2.20E+08	0.00
39.8400	9.36E-06	7633.	1619.	-1.10E-06	26.5768	1.50E+11	-378.027	2.33E+08	0.00
40.3200	3.88E-06	10688.	54.6845	-7.45E-07	37.2120	1.50E+11	-165.153	2.45E+08	0.00
40.8000	7.74E-07	8263.	-520.504	-3.81E-07	28.7701	1.50E+11	-34.565	2.57E+08	0.00
41.2800	-5.07E-07	4692.	-551.768	-1.32E-07	16.3355	1.50E+11	23.7098	2.70E+08	0.00
41.7600	-7.49E-07	1907.	-377.953	-5.42E-09	6.6396	1.50E+11	36.6426	2.82E+08	0.00

```
   42.2400  -5.69E-07    337.8956   -190.482    3.77E-08     1.1764   1.50E+11    28.4515   2.88E+08         0.00
   42.7200  -3.14E-07   -287.305    -63.260     3.87E-08     1.0003   1.50E+11    15.7230   2.88E+08         0.00
   43.2000  -1.23E-07   -390.854     -0.198     2.57E-08     1.3608   1.50E+11     6.1734   2.88E+08         0.00
   43.6800  -1.90E-08   -289.586     20.3124    1.26E-08     1.0082   1.50E+11     0.9483   2.88E+08         0.00
   44.1600   2.15E-08   -156.855     19.9541    4.00E-09     0.5461   1.50E+11    -1.073    2.88E+08         0.00
   44.6400   2.72E-08    -59.715     12.9531   -1.56E-10     0.2079   1.50E+11    -1.358    2.88E+08         0.00
   45.1200   1.97E-08     -7.635      6.2105   -1.45E-09     0.02658  1.50E+11    -0.983    2.88E+08         0.00
   45.6000   1.05E-08     11.8304     1.8724   -1.37E-09     0.04119  1.50E+11    -0.523    2.88E+08         0.00
   46.0800   3.89E-09     13.9347    -0.195    -8.74E-10     0.04852  1.50E+11    -0.194    2.88E+08         0.00
   46.5600   3.98E-10      9.5859    -0.812    -4.22E-10     0.03337  1.50E+11    -0.01988  2.88E+08         0.00
   47.0400  -9.74E-10      4.5776    -0.729    -1.50E-10     0.01594  1.50E+11     0.04868  2.88E+08         0.00
   47.5200  -1.33E-09      1.1843    -0.397    -3.94E-11     0.00412  1.50E+11     0.06658  2.88E+08         0.00
   48.0000  -1.43E-09      0.00       0.00     -1.67E-11     0.00     1.50E+11     0.07139  1.44E+08         0.00
```

* The above values of total stress are combined axial and bending stresses.

Output Summary for Load Case No. 2:

```
Pile-head deflection            =      3.35022585 inches
Computed slope at pile head     =     -0.0113095 radians
Maximum bending moment          =       7980560. inch-lbs
Maximum shear force             =      -281230. lbs
Depth of maximum bending moment =      23.52000000 feet below pile head
Depth of maximum shear force    =      34.56000000 feet below pile head
Number of iterations            =            125
Number of zero deflection points =             5
Pile deflection at ground       =      1.23301253 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 Length feet	Pile Head Deflection inches	Maximum Moment ln-lbs	Maximum Shear lbs
48.00000	3.35022585	7980560.	-281230.
45.60000	3.18590966	7824339.	-262344.
43.20000	3.19665651	7830289.	-265511.
40.80000	2.77989114	7435351.	-207107.
38.40000	3.20396238	7834491.	-272048.
36.00000	2.93429854	7583015.	-260970.

```
-------------------------------------------------------------------------------
        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 Load                   Load                 Axial   Pile-head Pile-head Max Shear Max Moment
Case Type  Pile-head        Type   Pile-head   Loading Deflection Rotation   in Pile   in Pile
 No.  1    Load 1            2      Load 2         lbs     inches   radians     lbs      in-lbs
---- ----- ---------- ---------- ---------- ---------- ---------- ---------- ---------- ----------
   1 V, lb       0.00 M, in-lb        0.00       0.00     1.0464  -0.00412    -40280.   3781684.
   2 V, lb       0.00 M, in-lb        0.00       0.00     3.3502  -0.01131   -281230.   7980560.


Maximum pile-head deflection = 3.3502258466 inches
Maximum pile-head rotation   = -0.0113094854 radians = -0.647986 deg.

--------------------------------------------------------------------------------
                         Summary of Warning Messages
--------------------------------------------------------------------------------

The following warning was reported 10000 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.
```

SLIDE, UA SLOPE AND LPILE RESULTS FOR DRIVEWAY WALL AT 1180+04.13
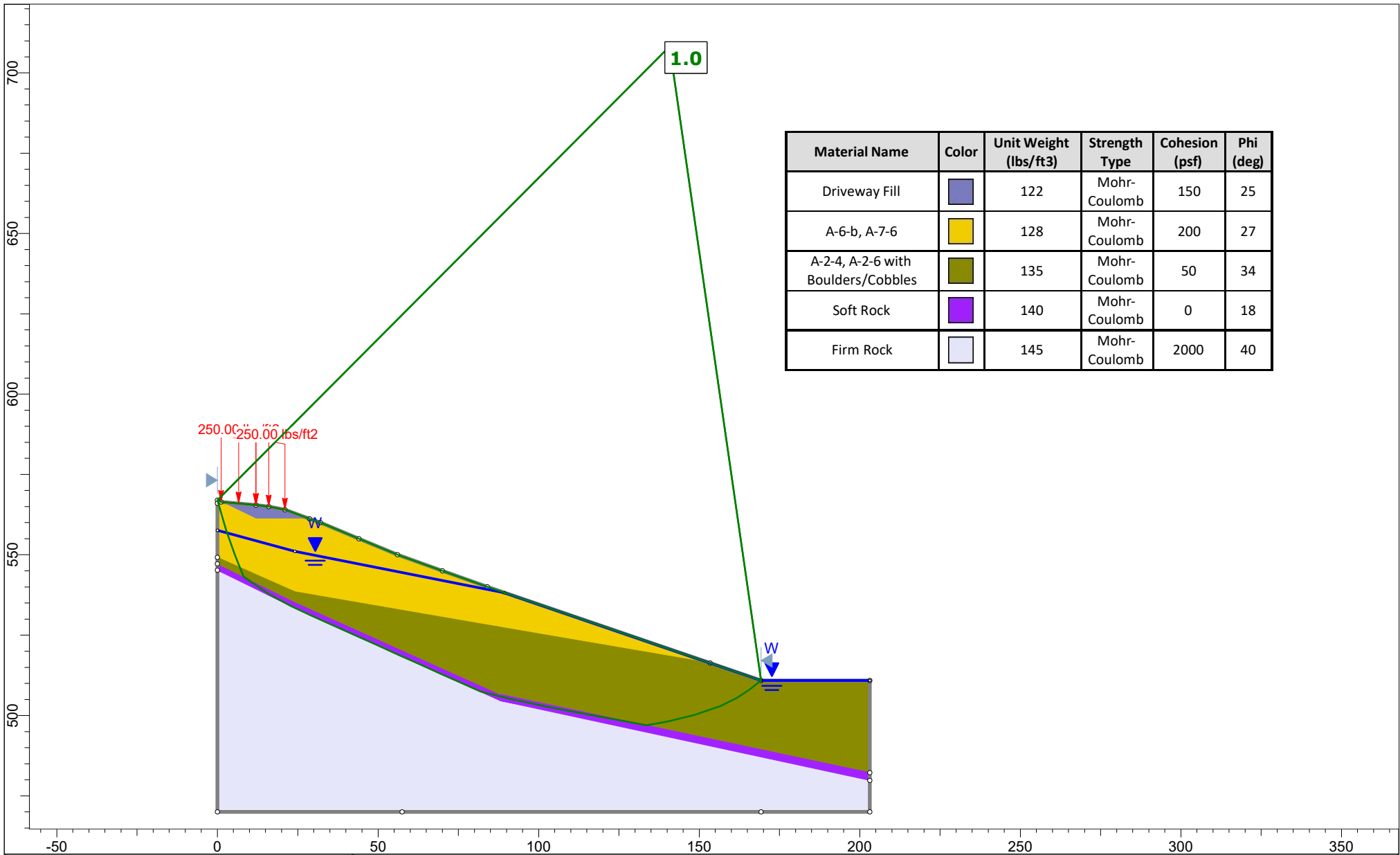
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Driveway Fill		122	Mohr-Coulomb	150	25
A-6-b, A-7-6		128	Mohr-Coulomb	200	27
A-2-4, A-2-6 with Boulders/Cobbles		135	Mohr-Coulomb	50	34
Soft Rock		140	Mohr-Coulomb	0	18
Firm Rock		145	Mohr-Coulomb	2000	40

BRO-52-22.27 LANDSLIDE REPAIR

Location	Station 1180+04.13	Analysis	Long Term - Effective Stress Conditions
Drawn By	CTL Engineering, Inc.	Company	CTL Engineering Inc.
Date	9/27/2023 1:31:30 PM	Client	Ohio Department of Transportation

BRO-52-22.27 LANDSLIDE REPAIR STATION 1180+04.13 UASLOPE OUTPUT EXISTING CONDITIONS DOWNSLOPE OF DRIVEWAY

File   Run   Options   Help

Calculated Results

Factor of Safety: 1.00

Force per Shaft: 0.000 lb

Acting Point X: 26.000 ft   Y: 0.000 ft

Analysis Unit System
- ( ) English
- ( ) Metric

Number of Vertical Sections and Soil Layers
Vertical Section Num: 14   Soil Layer Num: 5

Analysis Method
- ( ) Total Stress
- (•) Effective Stress

Chart (Double-Click for More Options)

Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
Layer1	150.0	25.0	122.0
Layer2	200.0	27.0	128.0
Layer3	50.0	34.0	135.0
Layer4	0.0	13.0	140.0
Layer5	2000.0	40.0	145.0

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)	0.00	1.20	12.00	16.00	21.00	24.00	26.00	26.01	28.60	56.00	88.00	153.40	169.20	203.10
Y1 (ft)	0.00	0.60	1.50	2.00	3.00	4.10	4.80	4.80	5.80	17.00	28.40	50.70	56.10	56.10
Y2 (ft)	0.00	0.60	5.80	5.80	5.80	5.80	5.80	5.80	5.80	17.00	28.40	50.70	56.10	56.10
Y3 (ft)	17.80	18.40	23.20	25.00	27.10	28.50	28.90	28.90	29.40	34.00	39.50	50.70	56.10	56.10
Y4 (ft)	19.80	20.30	25.20	27.00	29.30	30.60	31.60	31.60	32.80	45.60	60.40	74.30	77.70	84.80
Y5 (ft)	21.80	22.30	27.20	29.00	31.30	32.60	33.60	33.60	34.80	47.60	62.40	76.30	79.70	86.80
Y6 (ft)	97.00	97.00	97.00	97.00	97.00	97.00	97.00	97.00	97.00	97.00	97.00	97.00	97.00	97.00

Coordinates of Crest   X: 0.00 ft   Y: 0.00 ft   Coordinates of Toe   X: 169.20 ft   Y: 56.10 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 Save Data

Auto ( ) On (•) Off   0.000 (n)

Xmin: 0.00   Diameter: 3.00 ft
Xmax: 0.00   CTC Spacing: 5.50 ft
XDelta: 0.00   X Coordinate: 26.00 ft

[Run]

Pore Water Pressure

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

	Point 1	Point 2	Point 3	Point 4	Point 5
X (ft)	0.00	24.10	89.40	169.20	203.10
Y (ft)	9.40	15.90	28.50	56.10	56.10

Slip Surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
X (ft)	0.00	8.10	28.40	82.00	133.70	156.50	169.20
Y (ft)	0.00	23.80	34.00	59.00	65.50	64.20	56.10

BRO-52-22.27 LANDSLIDE REPAIR STATION 1180+04.13 UASLOPE OUTPUT WITH SHAFTS DOWNSLOPE OF DRIVEWAY

File   Run   Options   Help

Calculated Results

Factor of Safety: 1.22

Force per Shaft: 166700.350   lb

Acting Point X: 26.000   ft   Y: 22.104   ft

Analysis Unit System

◉ English   ○ Metric

Number of Vertical Sections and Soil Layers

Vertical Section Num: 14   Soil Layer Num: 6

Analysis Method

○ Total Stress   ◉ Effective Stress

Chart (Double-Click for More Options)

Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
▶ Layer1	250.0	28.0	125.0
Layer2	150.0	25.0	122.0
Layer3	200.0	27.0	128.0
Layer4	50.0	34.0	135.0
Layer5	0.0	13.0	140.0
Layer6	2000.0	40.0	145.0

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)	0.00	1.20	12.00	16.00	21.00	24.00	26.00	26.01	28.60	56.00	88.00	153.40	169.20	203.10
Y1 (ft)	0.00	0.40	0.40	0.40	0.40	0.40	0.40	4.80	5.80	17.00	28.40	50.70	56.10	56.10
Y2 (ft)	0.00	0.60	1.50	2.00	3.00	4.10	4.80	4.80	5.80	17.00	28.40	50.70	56.10	56.10
Y3 (ft)	0.00	0.60	5.80	5.80	5.80	5.80	5.80	5.80	5.80	17.00	28.40	50.70	56.10	56.10
Y4 (ft)	17.80	18.40	23.20	25.00	27.10	28.50	28.90	28.90	29.40	34.00	39.50	50.70	56.10	56.10
Y5 (ft)	19.80	20.30	25.20	27.00	29.30	30.60	31.60	31.60	32.80	45.60	60.40	74.30	77.70	84.80
Y6 (ft)	21.80	22.30	27.20	29.00	31.30	32.60	33.60	33.60	34.80	47.60	62.40	76.30	79.70	86.80
Y7 (ft)	97.00	97.00	97.00	97.00	97.00	97.00	97.00	97.00	97.00	97.00	97.00	97.00	97.00	97.00

Coordinates of Crest   X: 0.00 ft   Y: 0.00 ft   Coordinates of Toe   X: 169.20 ft   Y: 56.10 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)

☐ Auto Save Data

Xmin   0.00   Diameter: 3.00 ft

Xmax   0.00   CTC Spacing: 5.50 ft

XDelta   0.00   X Coordinate: 26.00 ft

[▷ Run]

Pore Water Pressure

Pore Pressure Options: ○ No Pore Pressure   ○ Constant Ratio   ◉ Specified phreatic surface

	Point 1	Point 2	Point 3	Point 4	Point 5
▶ X (ft)	0.00	24.10	89.40	169.20	203.10
Y (ft)	9.40	15.90	28.50	56.10	56.10

Slip Surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
▶ X (ft)	0.00	8.10	28.40	82.00	133.70	156.50	169.20
Y (ft)	0.00	23.80	34.00	59.00	65.50	64.20	56.10

Project: BRO-52-22.27
Project No: 23050002OL
September 27, 2023

L-PILE Soil Parameters (Station 1180+04.13 Downslope of Driveway)

Artificial Lowering of Ground Surface
The passive resistance from the downhill side soil mass should be ignored. In order to include this in the L-pile soil model, the ground level should be artificially lowered.

To do this, first determine the angle of steepness of the slope - downhill of the drilled shafts - from horizontal (β_{dh}), and then determine the depth to the shear surface at the location of the drilled shafts (d_τ). For slopes of steepness from $\beta=0°$ to $45°$, lower the ground surface by an amount equal to $d_\tau TAN(\beta_{dh})$.

For the current project, β_{dh} = 20 degrees (From cross section at Sta. 1180+04.13, average slope angle downslope of driveway to toe of slope)

Proposed top of pile elevation = 566.6 (Top of wall elevation from plans)
Existing grade at pile location = 562.2 (From cross section at Sta. 1180+04.13, downslope of driveway)

Estimated shear surface elevation at pile location = 533.4

Depth of shear surface beneath existing ground surface at pile location
   $d_\tau = 562.2 - 533.4 = 28.8$ feet

Depth of shear surface beneath top of wall at pile location
   $d_p = 566.6 - 533.4 = 33.2$ feet

Therefore, $d_\tau TAN(\beta_{dh}) = 10.5$ feet.

The first soil layer should start at elevation 562.2 – 10.5 = 551.7

Which is at a depth of 566.6 – 551.7 = 14.9 feet along the shaft

From 14.9' to 28.5'
Use soil type – *Stiff Clay with Free Water (Reese)*
Effective Unit Weight (pcf) = 128 pcf – 62.4 pcf = 65.6 pcf
N_{60} = 27 bpf (Average blow count in cohesive soils below fill, B-002-0-22, B-002-1-22 and B-002-2-22)
Undrained Cohesion (psf) = $N_{60}/8$ = 27/8 = 3,375 psf
Use Strain Factor K_{rm} = 0.005 (From L-pile Technical Manual Table 3-4, stiff to very stiff clay)
Use Subgrade Modulus K_{static} = 1,000 pci (From L-pile Technical Manual Table 3-3)

Project: BRO-52-22.27
Project No: 23050002OL
September 27, 2023

From 28.5' to 33.2'
Use soil type – *Sand (Reese)*
Effective Unit Weight (pcf) = 135 pcf – 62.4 pcf = 72.6 pcf
Friction Angle (deg) = 34 (AASHTO LRFD Table 10.4.6.2.4-1)
Use Subgrade Modulus K_{static} = 125 pci (From L-pile Technical Manual Table 3-3)

Below 33.2'
Use soil type – *Weak Rock (Reese)*
Effective Unit Weight (pcf) = 145 pcf – 62.4 pcf = 82.6 pcf
Compressive strength (q_u) = 1,180 psi (B-002-2-22, NQ-2 Compressive Strength Test Result of Shale)
Initial Rock Modulus (E_r) = 100,000 psi (Per ODOT GDM, Weak to Slightly Strong)
RQD = 22% (Lowest RQD from Borings B-002-2-22 and B-003-0-22)
Use Strain Factor K_{rm} = 0.0005 (From L-pile Technical Manual Equation 3-136)

P-y Modification Factors
If the drilled shafts are at a center-to-center spacing closer than about 3½ diameters, a reduction in the soil resistance p, for the p-y curve behavior of the soil, must be considered.
P- modification factor $\beta_a = 0.64(S/D)^{0.34}$
In which S= Center to Center Spacing between the Piles
           D= Diameter of the Shaft

For 36- inch shafts with reinforced shafts placed at 5.5 feet center to center
$\beta a = 0.64(5.5/3.0)^{0.34} = 0.79$

No P-Y modification factors are applied to the bedrock layers

BRO-52-22.27 Slide Repair

From AASHTO 3.11.5.3, Active Earth Pressure

$$K_a = \frac{Sin^2(\Theta+\emptyset'_f)}{\Gamma[Sin^2(\Theta)*Sin(\Theta-\delta)]}$$

in which $\quad \Gamma = \left[1+\sqrt{\frac{(Sin(\emptyset'f+\delta)*Sin(\emptyset'f-\beta))}{(Sin(\Theta-\delta)*Sin(\Theta+\beta))}}\right]^2$

Where

Angle of back face of the wall to the horizontal (Degrees), Θ=	90
Effective angle of internal friction (degrees), $\emptyset'f$=	30 (Assumed)
Friction angle between fill and wall (degrees), δ=	20 (2/3 $\emptyset'f$)
Angle of fill to the horizontal , β=	0 Assumed)

Calculation

$Sin(\Theta-\delta)$=	0.94
$Sin^2(\Theta)$=	1.00
$Sin(\Theta+\emptyset'_f)$=	0.87
$Sin^2(\Theta+\emptyset'_f)$=	0.75
$Sin(\emptyset'_f-\beta)$=	0.50
$Sin(\Theta+\beta)$=	1.00
$Sin(\emptyset'_f+\delta)$=	0.77
Γ=	2.68
K_a=	0.30

γ_{Ls}=	125 pcf	(GB7, Section E.7)

Case 1

Diameter of Shaft=	36	inches
C/C Spacing (CC)=	5.5	feet

Therefore for a 36-inch Shaft placed at 5.5 feet center to center

Surcharge Load q_{LS}, 34.1 lb/in $\gamma_{LS}*2*K_a*CC/12$

BRO-52-22.27 Slide Repair

Conversion of force per Shaft to Distributed Load

The UA Slope 2.3 program calculates the unfactored earth pressure (EH), resultant load per shaft, however, for proper structural analysis of pile reaction, we need to convert this to a realistic load.

The triangular load distribution is a close enough approximation of the actual
condition to develop a realistic calculation of distributed shear, moment and displacement in the drilled shaft

Case 1
Diameter of Shaft=   36 inches
C/C Spacing (CC)=   5.5 feet
For a 36-inch shaft at 5.5 feet center to center spacing

Load on Shaft (F_{SW})=   166,701 lbs
Depth of Shear plane at Shaft Location(D_S)=   33.2 feet
The Distibuted Load (F_D)=   802.8 lbs/in

BRO-52-22.27 Slide Repair

a) **Following cases were evaluated:**

Case1
Diameter of Shaft = 36 inches
Center to Center Spacing = 5.5 feet

b) **Unfactored Loads**

Case	Surchage Loads(lbs/in)	Distributed Load(lbs/in)	Total Unfactored Load (lbs/in)
1	34.1	802.8	836.9

c) **Load Factor per AASHTO Table 3.4.1.1 and 3.4.1.2**

Load Factor for Surcharge Load (LS) = 1.75
Load Factor for Distributed Load (EH) = 1.5

d) **Factored Distributed loads**

Case	Factored Surcharge Load (lbs/in)	Factored Distributed Loads(lbs/in)	Total Factored Load(lbs/in)
1	59.6	1204.2	1263.8

e) **Limit State Checks**

1 Use Factored Loads for Strength Limit State and check Moment capacity
   and Nominal Shear per AASHTO 6.10.8 and 6.10.9
2 Use Unfactored Loads for Service Limit State for deflection

f)   *L-pile Analysis*

Note: **It is assumed that 50 Ksi steel will be used.**
Section Used=   W24x84

Case1: 36 inch diameter Shafts with 5.5 feet center to center spacing

Checks:
Structural Strength Limit State Checks (W24x84 Section)

Calculated Factored Moment(in-lbs)	Factored Nominal Moment Resistance(in-lbs)	Acceptable Or Unacceptable
8,476,425	9,800,000	Acceptable

Calculated Factored Shear (Kips)	Factored Nominal Shear resistance (Kips)	Acceptable Or Unacceptable
100.1	307.5	Acceptable

and for nominal shear resistance calculation Per AASHTO 6.10.9

Service Limit State Checks (W24x84 Section)
Drilled Shaft Length above bedrock=   33.2 feet
For the unfactored Service Limit State analysis, the maximum Pilehead deflection must be limited to 1% or less
of the drilled shaft length above bedrock (33.2'), or 2 inches if wall is within 10 feet of proposed pavement.

Calculated Deflection(in)	Allowable Deflection(in) Per ODOT Recommendations	Acceptable Or Unacceptable
1.8	2.0	Acceptable

BRO-52-22.27 Slide Repair

<u>W24x84</u>

Thickness of Flange (t_f) =	0.77 in
Depth (d) =	24.10 in
Yield Strength of Steel (F_y) =	50 Ksi
D = d-2t_f=	22.56 in
thickness of Web (t_w) =	0.47 in

V_p = 0.58 $F_y D t_w$ =   307.5 Kips

Young's Modulus (E) =   29000 Ksi

Assume Unstiffened Web

Shear Buckling Coefficient (K) =	5.0
Sqrt(EK/F_y) =	53.9 Equation 1
1.12*Sqrt(EK/F_y) =	60.3 Equation 2
1.4*Sqrt(EK/F_y) =	75.4 Equation 3

D/t_w =	48.0
Since, D/$t_w \leq$ Equation1, C =	1.0

Therefore,

Nominal Shear Resistance (V_n) = CV_p 307.5 Kips

ϕ_v =   1.0

Factored Shear Resistance (V_u) = $\phi_v V_n$ 307.5 Kips

W24x84

Per AASHTO, 6.10.8

For Continously Braced Flanges in Tension or Compression

$$f_{bu} \leq \phi_f R_h F_{yf} \qquad \text{Equation 1}$$

Where f_{bu} = Factored Bending Moment Obtained in Strength Limit State

ϕ_f = Flexural Resistance Factor

R_h = Hybrid Factor

F_{yf} = $f_y * S_{x-x}$

f_y = Yield Strength of Steel

S_{x-x} = Section Modulus of Steel Section

ϕ_f =	1.0	Per AASHTO 6.5.4.2
R_h =	1.0	Per AASHTO 6.10.1.10.1
S_{x-x} =	196.0	In^3
f_y =	50.0	ksi
F_{yf} =	9,800,000	lb-in

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

                        LPile for Windows, Version 2022-12.007

                        Analysis of Individual Piles and Drilled Shafts
                        Subjected to Lateral Loading Using the p-y Method
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================================================================================

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

Path to file locations:
\PROJECT\2023\COL-05\23050002COL\Design\Station 1180+04.13 (Driveway\LPILE\

Name of input data file:
23.09.27 Lpile.lp12d

Name of output report file:
23.09.27 Lpile.lp12o

Name of plot output file:
23.09.27 Lpile.lp12p

Name of runtime message file:
23.09.27 Lpile.lp12r




--------------------------------------------------------------------------------
                              Date and Time of Analysis
--------------------------------------------------------------------------------

              Date:  September 27, 2023        Time:  17:43:13
```

```
--------------------------------------------------------------------------------
                                 Problem Title
--------------------------------------------------------------------------------

Project Name: BRO-52-22.27 LANDSLIDE REPAIR

Job Number: 23050002COL

Client: OHIO DEPARTMENT OF TRANSPORTATION

Engineer: CTL ENGINEERING, INC.

Description: STATION 1180+04.13 DRILLED SHAFT RETAINING WALL ANALYSIS




--------------------------------------------------------------------------------
                          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

 - Analysis uses p-y modification factors for p-y curves
 - 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   =   1
Total length of pile   =   48.200 ft
Depth of ground surface below top of pile   =   14.9000 ft

Pile diameters used for p-y curve computations are defined using 2 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.

            Depth Below   Pile
Point   Pile Head   Diameter
 No.   feet   inches
-----   ------------   ------------
  1   0.000   36.0000
  2   48.200   36.0000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

    Section 1 is an elastic pile
    Cross-sectional Shape   =   Circular Pile
    Length of section   =   48.200000 ft
    Width of top of section   =   36.000000 in
    Width of bottom of section   =   36.000000 in
    Top Area   =   24.700000 sq. in
    Bottom Area   =   24.700000 sq. in
    Moment of Inertia at Top   =   2370. in^4
    Moment of Inertia at Bottom   =   2370. in^4
    Elastic Modulus   =   29000000. psi

                      Soil and Rock Layering Information

The soil profile is modelled using 3 layers

Layer 1 is stiff clay with water-induced erosion

```
        Distance from top of pile to top of layer          =     14.900000 ft
        Distance from top of pile to bottom of layer       =     28.500000 ft
        Effective unit weight at top of layer              =     65.600000 pcf
        Effective unit weight at bottom of layer           =     65.600000 pcf
        Undrained cohesion at top of layer                 =         3375. psf
        Undrained cohesion at bottom of layer              =         3375. psf
        Epsilon-50 at top of layer                         =      0.005000
        Epsilon-50 at bottom of layer                      =      0.005000
        Subgrade k at top of layer                         =   1000.000000 pci
        Subgrade k at bottom of layer                      =   1000.000000 pci


Layer 2 is sand, p-y criteria by Reese et al., 1974

        Distance from top of pile to top of layer          =     28.500000 ft
        Distance from top of pile to bottom of layer       =     33.200000 ft
        Effective unit weight at top of layer              =     72.600000 pcf
        Effective unit weight at bottom of layer           =     72.600000 pcf
        Friction angle at top of layer                     =     34.000000 deg.
        Friction angle at bottom of layer                  =     34.000000 deg.
        Subgrade k at top of layer                         =    125.000000 pci
        Subgrade k at bottom of layer                      =    125.000000 pci


Layer 3 is weak rock, p-y criteria by Reese, 1997

        Distance from top of pile to top of layer          =     33.200000 ft
        Distance from top of pile to bottom of layer       =     60.000000 ft
        Effective unit weight at top of layer              =     82.600000 pcf
        Effective unit weight at bottom of layer           =     82.600000 pcf
        Uniaxial compressive strength at top of layer      =         1180. psi
        Uniaxial compressive strength at bottom of layer   =         1180. psi
        Initial modulus of rock at top of layer            =       100000. psi
        Initial modulus of rock at bottom of layer         =       100000. psi
        RQD of rock at top of layer                        =     22.000000 %
        RQD of rock at bottom of layer                     =     22.000000 %
        k rm of rock at top of layer                       =      0.0005000
        k rm of rock at bottom of layer                    =      0.0005000


 (Depth of the lowest soil layer extends 11.800 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	Cohesion psf	Angle of Friction deg.	Uniaxial qu psi	RQD %	E50 or krm	kpy pci	Rock Mass Modulus psi
1	Stiff Clay	14.9000	65.6000	3375.	--	--	--	0.00500	1000.0000	--

	with Free Water	28.5000	65.6000	3375.	--	--	--	0.00500	1000.0000	--
2	Sand	28.5000	72.6000	--	34.0000	--	--	--	125.0000	--
	(Reese, et al.)	33.2000	72.6000	--	34.0000	--	--	--	125.0000	--
3	Weak	33.2000	82.6000	--	--	1180.	22.0000	5.00E-04	--	100000.
	Rock	60.0000	82.6000	--	--	1180.	22.0000	5.00E-04	--	100000.

```
--------------------------------------------------------------------------------
                      Modification Factors for p-y Curves
--------------------------------------------------------------------------------
```

Distribution of p-y modifiers with depth defined using 3 points

Point No.	Depth X ft	p-mult	y-mult
1	14.900	0.7900	1.0000
2	33.200	0.7900	1.0000
3	33.200	1.0000	1.0000

```
--------------------------------------------------------------------------------
                              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	34.100
2	33.200	836.900

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

Point No.	Depth X ft	Dist. Load lb/in
1	0.000	59.600
2	33.200	1263.800

```
--------------------------------------------------------------------------------
               Pile-head Loading and Pile-head Fixity Conditions
--------------------------------------------------------------------------------


Number of loads specified = 2

Load   Load         Condition               Condition           Axial Thrust    Compute Top y    Run Analysis
No.    Type            1                        2               Force, lbs      vs. Pile Length
-----  ----   --------------------    -----------------------   ------------    ---------------   ------------
   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 = 1

Pile Section No. 1:
-------------------
Moment-curvature properties were derived from elastic section properties




--------------------------------------------------------------------------------
         Layering Correction Equivalent Depths of Soil & Rock Layers
--------------------------------------------------------------------------------


           Top of     Equivalent
           Layer      Top Depth   Same Layer  Layer is       F0          F1
Layer      Below       Below      Type As     Rock or     Integral    Integral
No.       Pile Head   Grnd Surf   Layer       is Below    for Layer   for Layer
            ft           ft       Above       Rock Layer    lbs         lbs
-----   ----------   ----------  ----------  ----------   ----------  ----------
   1      14.9000        0.00     N.A.          No            0.00       90832.
   2      28.5000        8.6230   No            No         90832.       126835.
   3      33.2000       18.3000   No            Yes        N.A.          N.A.
```

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals
       for Layer n. Layering correction equivalent depths are computed only
       for soil types with both shallow-depth and deep-depth expressions for
       peak lateral load transfer. These soil types are soft and stiff clays,
       non-liquefied sands, and cemented c-phi soil.

               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	1.7837	-9.12E-06	0.00	-0.00805	6.93E-08	6.87E+10	0.00	0.00	37.0138
0.4820	1.7371	619.1416	239.3676	-0.00805	4.7023	6.87E+10	0.00	0.00	45.7551
0.9640	1.6906	2769.	537.7217	-0.00805	21.0304	6.87E+10	0.00	0.00	57.4102
1.4460	1.6440	6840.	903.4890	-0.00805	51.9456	6.87E+10	0.00	0.00	69.0653
1.9280	1.5974	13221.	1337.	-0.00805	100.4094	6.87E+10	0.00	0.00	80.7204
2.4100	1.5509	22302.	1837.	-0.00805	169.3830	6.87E+10	0.00	0.00	92.3755
2.8920	1.5043	34474.	2405.	-0.00805	261.8280	6.87E+10	0.00	0.00	104.0307
3.3740	1.4578	50126.	3041.	-0.00804	380.7058	6.87E+10	0.00	0.00	115.6858
3.8560	1.4113	69649.	3744.	-0.00804	528.9776	6.87E+10	0.00	0.00	127.3409
4.3380	1.3648	93431.	4514.	-0.00803	709.6050	6.87E+10	0.00	0.00	138.9960
4.8200	1.3184	121864.	5351.	-0.00802	925.5493	6.87E+10	0.00	0.00	150.6511
5.3020	1.2720	155337.	6257.	-0.00801	1180.	6.87E+10	0.00	0.00	162.3062
5.7840	1.2257	194239.	7229.	-0.00799	1475.	6.87E+10	0.00	0.00	173.9613
6.2660	1.1795	238962.	8269.	-0.00798	1815.	6.87E+10	0.00	0.00	185.6164
6.7480	1.1335	289894.	9376.	-0.00795	2202.	6.87E+10	0.00	0.00	197.2715
7.2300	1.0875	347425.	10551.	-0.00793	2639.	6.87E+10	0.00	0.00	208.9266
7.7120	1.0418	411947.	11793.	-0.00790	3129.	6.87E+10	0.00	0.00	220.5817
8.1940	0.9962	483848.	13103.	-0.00786	3675.	6.87E+10	0.00	0.00	232.2368
8.6760	0.9509	563518.	14480.	-0.00781	4280.	6.87E+10	0.00	0.00	243.8920
9.1580	0.9058	651347.	15924.	-0.00776	4947.	6.87E+10	0.00	0.00	255.5471
9.6400	0.8611	747726.	17436.	-0.00770	5679.	6.87E+10	0.00	0.00	267.2022
10.1220	0.8167	853044.	19015.	-0.00764	6479.	6.87E+10	0.00	0.00	278.8573
10.6040	0.7727	967691.	20662.	-0.00756	7350.	6.87E+10	0.00	0.00	290.5124
11.0860	0.7292	1092057.	22376.	-0.00747	8294.	6.87E+10	0.00	0.00	302.1675
11.5680	0.6863	1226532.	24157.	-0.00738	9315.	6.87E+10	0.00	0.00	313.8226
12.0500	0.6439	1371506.	26006.	-0.00727	10416.	6.87E+10	0.00	0.00	325.4777
12.5320	0.6022	1527368.	27922.	-0.00714	11600.	6.87E+10	0.00	0.00	337.1328
13.0140	0.5613	1694509.	29906.	-0.00701	12870.	6.87E+10	0.00	0.00	348.7879

13.4960	0.5211	1873319.	31957.	-0.00686	14228.	6.87E+10	0.00	0.00	360.4430
13.9780	0.4819	2064187.	34075.	-0.00669	15677.	6.87E+10	0.00	0.00	372.0981
14.4600	0.4437	2267504.	36261.	-0.00651	17222.	6.87E+10	0.00	0.00	383.7533
14.9420	0.4066	2483659.	38047.	-0.00631	18863.	6.87E+10	-161.892	2303.	395.4084
15.4240	0.3707	2707626.	38841.	-0.00609	20564.	6.87E+10	-365.927	5709.	407.0635
15.9060	0.3361	2932969.	38464.	-0.00586	22276.	6.87E+10	-590.179	10156.	418.7186
16.3880	0.3030	3152576.	36750.	-0.00560	23944.	6.87E+10	-851.537	16257.	430.3737
16.8700	0.2714	3358094.	33694.	-0.00533	25505.	6.87E+10	-1077.	22966.	442.0288
17.3520	0.2414	3542354.	29496.	-0.00503	26904.	6.87E+10	-1270.	30436.	453.6839
17.8340	0.2131	3699301.	24342.	-0.00473	28096.	6.87E+10	-1431.	38840.	465.3390
18.3160	0.1867	3823940.	18414.	-0.00441	29043.	6.87E+10	-1561.	48374.	476.9941
18.7980	0.1621	3912312.	11889.	-0.00409	29714.	6.87E+10	-1661.	59274.	488.6492
19.2800	0.1394	3961471.	4942.	-0.00376	30087.	6.87E+10	-1730.	71810.	500.3043
19.7620	0.1186	3969482.	-2250.	-0.00342	30148.	6.87E+10	-1769.	86273.	511.9594
20.2440	0.09977	3935439.	-9497.	-0.00309	29889.	6.87E+10	-1772.	102757.	523.6146
20.7260	0.08285	3859616.	-16537.	-0.00276	29314.	6.87E+10	-1721.	120112.	535.2697
21.2080	0.06781	3744141.	-23159.	-0.00244	28437.	6.87E+10	-1652.	140860.	546.9248
21.6900	0.05460	3591712.	-29270.	-0.00213	27279.	6.87E+10	-1567.	166008.	558.5799
22.1720	0.04313	3405544.	-34785.	-0.00184	25865.	6.87E+10	-1469.	196928.	570.2350
22.6540	0.03332	3189324.	-39625.	-0.00156	24223.	6.87E+10	-1357.	235596.	581.8901
23.1360	0.02507	2947162.	-43723.	-0.00130	22384.	6.87E+10	-1235.	284960.	593.5452
23.6180	0.01824	2683542.	-47017.	-0.00107	20381.	6.87E+10	-1103.	349627.	605.2003
24.1000	0.01273	2403275.	-49454.	-8.53E-04	18253.	6.87E+10	-962.254	437277.	616.8554
24.5820	0.00838	2111453.	-50861.	-6.63E-04	16036.	6.87E+10	-769.324	530887.	628.5105
25.0640	0.00506	1814920.	-50827.	-4.97E-04	13784.	6.87E+10	-487.871	557316.	640.1656
25.5460	0.00263	1523482.	-49269.	-3.57E-04	11571.	6.87E+10	-265.250	583745.	651.8207
26.0280	9.35E-04	1244976.	-46517.	-2.40E-04	9456.	6.87E+10	-98.605	610174.	663.4759
26.5100	-1.53E-04	985368.	-42883.	-1.47E-04	7484.	6.87E+10	16.8189	636603.	675.1310
26.9920	-7.61E-04	748909.	-38643.	-7.36E-05	5688.	6.87E+10	87.1997	663032.	686.7861
27.4740	-0.00100	538343.	-34039.	-1.94E-05	4089.	6.87E+10	119.6826	689462.	698.4412
27.9560	-9.85E-04	355148.	-29267.	1.82E-05	2697.	6.87E+10	121.9564	715891.	710.0963
28.4380	-7.94E-04	199788.	-24478.	4.15E-05	1517.	6.87E+10	101.8731	742320.	721.7514
28.9200	-5.05E-04	71982.	-19951.	5.30E-05	546.7023	6.87E+10	8.3892	96094.	733.4065
29.4020	-1.81E-04	-31007.	-15642.	5.47E-05	235.4924	6.87E+10	3.1123	99397.	745.0616
29.8840	1.28E-04	-108966.	-11297.	4.88E-05	827.5866	6.87E+10	-2.267	102701.	756.7167
30.3660	3.83E-04	-161685.	-6913.	3.74E-05	1228.	6.87E+10	-7.026	106005.	768.3718
30.8480	5.60E-04	-188933.	-2486.	2.27E-05	1435.	6.87E+10	-10.590	109308.	780.0269
31.3300	6.45E-04	-190441.	1993.	6.69E-06	1446.	6.87E+10	-12.567	112612.	791.6820
31.8120	6.38E-04	-165883.	6532.	-8.30E-06	1260.	6.87E+10	-12.782	115916.	803.3372
32.2940	5.49E-04	-114878.	11143.	-2.01E-05	872.4898	6.87E+10	-11.324	119219.	814.9923
32.7760	4.05E-04	-36986.	15833.	-2.65E-05	280.9064	6.87E+10	-8.581	122523.	826.6474
33.2580	2.43E-04	68274.	11912.	-2.52E-05	518.5360	6.87E+10	-2491.	5.93E+07	316.9042
33.7400	1.14E-04	100814.	1547.	-1.81E-05	765.6722	6.87E+10	-1410.	7.17E+07	0.00
34.2220	3.37E-05	86175.	-3949.	-1.02E-05	654.4962	6.87E+10	-490.391	8.41E+07	0.00
34.7040	-4.34E-06	55131.	-5158.	-4.26E-06	418.7187	6.87E+10	72.3426	9.65E+07	0.00
35.1860	-1.56E-05	26507.	-4102.	-8.25E-07	201.3226	6.87E+10	292.9106	1.09E+08	0.00
35.6680	-1.39E-05	7683.	-2413.	6.14E-07	58.3509	6.87E+10	291.0061	1.21E+08	0.00
36.1500	-8.46E-06	-1406.	-1006.	8.78E-07	10.6802	6.87E+10	195.4746	1.34E+08	0.00
36.6320	-3.72E-06	-3956.	-168.927	6.52E-07	30.0440	6.87E+10	94.0072	1.46E+08	0.00
37.1140	-9.13E-07	-3360.	175.2448	3.44E-07	25.5219	6.87E+10	25.0010	1.58E+08	0.00
37.5960	2.62E-07	-1929.	225.1929	1.22E-07	14.6473	6.87E+10	-7.730	1.71E+08	0.00
38.0780	4.97E-07	-755.345	157.2808	8.94E-09	5.7368	6.87E+10	-15.753	1.83E+08	0.00
38.5600	3.65E-07	-109.136	76.0084	-2.74E-08	0.8289	6.87E+10	-12.350	1.96E+08	0.00

```
39.0420   1.80E-07   123.9192    21.5821  -2.68E-08    0.9412  6.87E+10    -6.470  2.08E+08   0.00
39.5240   5.50E-08   140.5254    -3.188  -1.57E-08    1.0673  6.87E+10    -2.095  2.20E+08   0.00
40.0060  -1.54E-09    87.0414    -9.068  -6.11E-09    0.6611  6.87E+10   0.06190  2.33E+08   0.00
40.4880  -1.57E-08    35.6281    -6.966  -9.47E-10    0.2706  6.87E+10    0.6650  2.45E+08   0.00
40.9700  -1.25E-08     6.4620    -3.433   8.24E-10   0.04908  6.87E+10    0.5564  2.58E+08   0.00
41.4520  -6.16E-09    -4.090    -0.993   9.24E-10   0.03106  6.87E+10    0.2873  2.70E+08   0.00
41.9340  -1.81E-09    -5.029   0.09297   5.40E-10   0.03819  6.87E+10   0.08828  2.82E+08   0.00
42.4160   9.16E-11    -3.014    0.3350   2.02E-10   0.02289  6.87E+10  -0.00458  2.89E+08   0.00
42.8980   5.24E-10    -1.153    0.2460   2.63E-11   0.00876  6.87E+10  -0.02622  2.89E+08   0.00
43.3800   3.96E-10    -0.169    0.1129  -2.93E-11   0.00128  6.87E+10  -0.01980  2.89E+08   0.00
43.8620   1.85E-10    0.1528   0.02879  -3.00E-11   0.00116  6.87E+10  -0.00927  2.89E+08   0.00
44.3440   4.93E-11    0.1642  -0.00517  -1.66E-11   0.00125  6.87E+10  -0.00247  2.89E+08   0.00
44.8260  -6.87E-12   0.09302  -0.01131  -5.80E-12  7.06E-04  6.87E+10   3.43E-04  2.89E+08   0.00
45.3080  -1.78E-11   0.03333  -0.00775       0.00  2.53E-04  6.87E+10   8.90E-04  2.89E+08   0.00
45.7900  -1.25E-11   0.00341  -0.00336   1.06E-12  2.59E-05  6.87E+10   6.26E-04  2.89E+08   0.00
46.2720  -5.57E-12  -0.00557  -7.47E-04       0.00  4.23E-05  6.87E+10   2.79E-04  2.89E+08   0.00
46.7540  -1.33E-12  -0.00523   2.51E-04       0.00  3.97E-05  6.87E+10   6.66E-05  2.89E+08   0.00
47.2360       0.00  -0.00266   3.92E-04       0.00  2.02E-05  6.87E+10  -1.81E-05  2.89E+08   0.00
47.7180       0.00  -6.91E-04   2.30E-04       0.00  5.25E-06  6.87E+10  -3.81E-05  2.89E+08   0.00
48.2000       0.00      0.00      0.00       0.00      0.00  6.87E+10  -4.13E-05  1.45E+08   0.00
```

* The above values of total stress are combined axial and bending stresses.

Output Summary for Load Case No. 1:

```
Pile-head deflection          =      1.78369246 inches
Computed slope at pile head   =     -0.0080511 radians
Maximum bending moment        =       3969482. inch-lbs
Maximum shear force           =        -50861. lbs
Depth of maximum bending moment =   19.76200000 feet below pile head
Depth of maximum shear force  =    24.58200000 feet below pile head
Number of iterations          =             23
Number of zero deflection points =          8
Pile deflection at ground     =      0.40983373 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

```
48.20000    1.78369246     3969482.     -50861.
45.79000    1.78819971     3980417.     -51127.
43.38000    1.79384385     3990393.     -51280.
40.97000    1.79260328     3989626.     -51205.
38.56000    1.78671522     3977408.     -51076.
36.15000    1.79680340     3995389.     -51429.
33.74000    1.79589901     3997940.     -51337.
31.33000    1.78069164     3978006.     -48819.
28.92000    1.86018885     3992743.     -59077.
```

```
-------------------------------------------------------------------------------
                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	4.6455	-2.74E-05	-1.58E-07	-0.01886	2.08E-07	6.87E+10	0.00	0.00	63.9707
0.4820	4.5364	1070.	407.9262	-0.01886	8.1270	6.87E+10	0.00	0.00	77.0827
0.9640	4.4273	4719.	904.3322	-0.01886	35.8397	6.87E+10	0.00	0.00	94.5653
1.4460	4.3183	11531.	1502.	-0.01886	87.5801	6.87E+10	0.00	0.00	112.0480
1.9280	4.2092	22092.	2201.	-0.01885	167.7902	6.87E+10	0.00	0.00	129.5307
2.4100	4.1002	36987.	3000.	-0.01885	280.9124	6.87E+10	0.00	0.00	147.0133
2.8920	3.9911	56799.	3901.	-0.01885	431.3885	6.87E+10	0.00	0.00	164.4960
3.3740	3.8821	82115.	4903.	-0.01884	623.6608	6.87E+10	0.00	0.00	181.9786
3.8560	3.7732	113519.	6006.	-0.01883	862.1713	6.87E+10	0.00	0.00	199.4613
4.3380	3.6643	151596.	7211.	-0.01882	1151.	6.87E+10	0.00	0.00	216.9440
4.8200	3.5554	196931.	8516.	-0.01881	1496.	6.87E+10	0.00	0.00	234.4266
5.3020	3.4467	250108.	9922.	-0.01879	1900.	6.87E+10	0.00	0.00	251.9093
5.7840	3.3381	311713.	11430.	-0.01877	2367.	6.87E+10	0.00	0.00	269.3920
6.2660	3.2296	382330.	13039.	-0.01874	2904.	6.87E+10	0.00	0.00	286.8746
6.7480	3.1214	462544.	14749.	-0.01870	3513.	6.87E+10	0.00	0.00	304.3573
7.2300	3.0133	552941.	16560.	-0.01866	4200.	6.87E+10	0.00	0.00	321.8399
7.7120	2.9055	654105.	18472.	-0.01861	4968.	6.87E+10	0.00	0.00	339.3226
8.1940	2.7981	766620.	20485.	-0.01855	5822.	6.87E+10	0.00	0.00	356.8053
8.6760	2.6910	891073.	22599.	-0.01848	6768.	6.87E+10	0.00	0.00	374.2879
9.1580	2.5843	1028047.	24815.	-0.01840	7808.	6.87E+10	0.00	0.00	391.7706
9.6400	2.4782	1178127.	27131.	-0.01830	8948.	6.87E+10	0.00	0.00	409.2533
10.1220	2.3726	1341899.	29549.	-0.01820	10192.	6.87E+10	0.00	0.00	426.7359
10.6040	2.2676	1519948.	32068.	-0.01808	11544.	6.87E+10	0.00	0.00	444.2186
11.0860	2.1634	1712857.	34688.	-0.01794	13009.	6.87E+10	0.00	0.00	461.7012
11.5680	2.0601	1921213.	37409.	-0.01779	14591.	6.87E+10	0.00	0.00	479.1839
12.0500	1.9577	2145600.	40231.	-0.01762	16296.	6.87E+10	0.00	0.00	496.6666
12.5320	1.8563	2386602.	43154.	-0.01743	18126.	6.87E+10	0.00	0.00	514.1492

13.0140	1.7561	2644805.	46178.	-0.01721	20087.	6.87E+10	0.00	0.00	531.6319
13.4960	1.6572	2920793.	49304.	-0.01698	22183.	6.87E+10	0.00	0.00	549.1146
13.9780	1.5596	3215153.	52531.	-0.01672	24419.	6.87E+10	0.00	0.00	566.5972
14.4600	1.4637	3528467.	55858.	-0.01644	26798.	6.87E+10	0.00	0.00	584.0799
14.9420	1.3695	3861321.	59254.	-0.01613	29326.	6.87E+10	-11.304	47.7409	601.5625
15.4240	1.2771	4213923.	62614.	-0.01579	32004.	6.87E+10	-47.769	216.3399	619.0452
15.9060	1.1868	4585636.	65858.	-0.01542	34828.	6.87E+10	-86.088	419.5453	636.5279
16.3880	1.0988	4975764.	68804.	-0.01502	37791.	6.87E+10	-185.721	977.6336	654.0105
16.8700	1.0131	5381559.	70916.	-0.01458	40873.	6.87E+10	-409.276	2337.	671.4932
17.3520	0.9301	5796126.	71757.	-0.01411	44021.	6.87E+10	-660.528	4107.	688.9759
17.8340	0.8499	6211644.	71178.	-0.01360	47177.	6.87E+10	-935.275	6365.	706.4585
18.3160	0.7728	6619508.	69053.	-0.01306	50275.	6.87E+10	-1230.	9204.	723.9412
18.7980	0.6988	7010454.	65282.	-0.01249	53244.	6.87E+10	-1540.	12746.	741.4238
19.2800	0.6283	7374688.	59780.	-0.01189	56010.	6.87E+10	-1863.	17149.	758.9065
19.7620	0.5613	7701994.	52505.	-0.01125	58496.	6.87E+10	-2188.	22548.	776.3892
20.2440	0.4981	7982067.	43576.	-0.01059	60623.	6.87E+10	-2470.	28678.	793.8718
20.7260	0.4388	8206077.	33252.	-0.00991	62325.	6.87E+10	-2705.	35659.	811.3545
21.2080	0.3835	8366728.	21800.	-0.00921	63545.	6.87E+10	-2895.	43665.	828.8372
21.6900	0.3322	8458257.	9483.	-0.00850	64240.	6.87E+10	-3039.	52912.	846.3198
22.1720	0.2851	8476425.	-3436.	-0.00779	64378.	6.87E+10	-3138.	63665.	863.8025
22.6540	0.2421	8418509.	-16695.	-0.00708	63938.	6.87E+10	-3192.	76261.	881.2851
23.1360	0.2032	8283292.	-30036.	-0.00638	62911.	6.87E+10	-3201.	91123.	898.7678
23.6180	0.1683	8071057.	-43198.	-0.00569	61299.	6.87E+10	-3165.	108782.	916.2505
24.1000	0.1374	7783579.	-55918.	-0.00502	59116.	6.87E+10	-3083.	129820.	933.7331
24.5820	0.1102	7424202.	-67669.	-0.00438	56386.	6.87E+10	-2865.	150399.	951.2158
25.0640	0.08665	7000786.	-77759.	-0.00378	53171.	6.87E+10	-2544.	169789.	968.6985
25.5460	0.06651	6524681.	-85907.	-0.00321	49555.	6.87E+10	-2229.	193794.	986.1811
26.0280	0.04955	6007013.	-92160.	-0.00268	45623.	6.87E+10	-1924.	224525.	1004.
26.5100	0.03551	5458570.	-96577.	-0.00220	41457.	6.87E+10	-1628.	265212.	1021.
26.9920	0.02413	4889811.	-99212.	-0.00176	37138.	6.87E+10	-1342.	321724.	1039.
27.4740	0.01513	4310888.	-100110.	-0.00137	32741.	6.87E+10	-1063.	406283.	1056.
27.9560	0.00823	3731735.	-99293.	-0.00104	28342.	6.87E+10	-783.986	550889.	1074.
28.4380	0.00315	3162270.	-96467.	-7.46E-04	24017.	6.87E+10	-403.714	742320.	1091.
28.9200	-4.01E-04	2615801.	-91254.	-5.03E-04	19867.	6.87E+10	6.6591	96094.	1109.
29.4020	-0.00267	2106641.	-84640.	-3.04E-04	16000.	6.87E+10	45.9530	99397.	1126.
29.8840	-0.00392	1636689.	-77742.	-1.47E-04	12431.	6.87E+10	69.6364	102701.	1144.
30.3660	-0.00437	1207324.	-70644.	-2.72E-05	9170.	6.87E+10	80.1445	106005.	1161.
30.8480	-0.00424	819481.	-63415.	5.81E-05	6224.	6.87E+10	80.0620	109308.	1178.
31.3300	-0.00370	473742.	-56108.	1.13E-04	3598.	6.87E+10	72.0573	112612.	1196.
31.8120	-0.00294	170425.	-48761.	1.40E-04	1294.	6.87E+10	58.8197	115916.	1213.
32.2940	-0.00209	-90329.	-41398.	1.43E-04	686.0410	6.87E+10	42.9972	119219.	1231.
32.7760	-0.00128	-308463.	-34025.	1.26E-04	2343.	6.87E+10	27.1362	122523.	1248.
33.2580	-6.26E-04	-483924.	-10376.	9.29E-05	3675.	6.87E+10	6423.	5.93E+07	478.5644
33.7400	-2.07E-04	-428490.	17003.	5.45E-05	3254.	6.87E+10	2565.	7.17E+07	0.00
34.2220	3.86E-06	-287236.	24259.	2.43E-05	2182.	6.87E+10	-56.165	8.41E+07	0.00
34.7040	7.48E-05	-147862.	20488.	6.04E-06	1123.	6.87E+10	-1248.	9.65E+07	0.00
35.1860	7.37E-05	-50230.	12865.	-2.30E-06	381.4899	6.87E+10	-1388.	1.09E+08	0.00
35.6680	4.82E-05	962.4592	5926.	-4.37E-06	7.3098	6.87E+10	-1011.	1.21E+08	0.00
36.1500	2.32E-05	18318.	1450.	-3.56E-06	139.1274	6.87E+10	-536.217	1.34E+08	0.00
36.6320	7.09E-06	17735.	-618.351	-2.04E-06	134.6997	6.87E+10	-178.963	1.46E+08	0.00
37.1140	-3.95E-07	11165.	-1105.	-8.24E-07	84.8001	6.87E+10	10.8348	1.58E+08	0.00
37.5960	-2.44E-06	4958.	-864.563	-1.45E-07	37.6535	6.87E+10	72.1576	1.71E+08	0.00
38.0780	-2.08E-06	1164.	-465.582	1.12E-07	8.8412	6.87E+10	65.8025	1.83E+08	0.00

```
38.5600   -1.14E-06   -428.137   -163.316    1.43E-07   3.2517    6.87E+10    38.7155    1.96E+08    0.00
39.0420   -4.21E-07   -725.150     -7.599    9.47E-08   5.5075    6.87E+10    15.1286    2.08E+08    0.00
39.5240   -4.96E-08   -516.039     41.6197   4.24E-08   3.9193    6.87E+10     1.8902    2.20E+08    0.00
40.0060    7.03E-08   -243.693     38.9072   1.05E-08   1.8508    6.87E+10    -2.828     2.33E+08    0.00
40.4880    7.15E-08    -65.960     21.9607  -2.56E-09   0.5010    6.87E+10    -3.032     2.45E+08    0.00
40.9700    4.07E-08     10.3491     7.9567  -4.90E-09   0.07860   6.87E+10    -1.811     2.58E+08    0.00
41.4520    1.48E-08     26.0828     0.7170  -3.37E-09   0.1981    6.87E+10    -0.693     2.70E+08    0.00
41.9340    1.72E-09     18.6437    -1.529    -1.48E-09   0.1416    6.87E+10    -0.08380   2.82E+08    0.00
42.4160   -2.33E-09      8.4009    -1.434    -3.46E-10   0.06380   6.87E+10     0.1166    2.89E+08    0.00
42.8980   -2.29E-09      2.0585    -0.765     9.37E-11   0.01563   6.87E+10     0.1145    2.89E+08    0.00
43.3800   -1.25E-09     -0.452     -0.254     1.61E-10   0.00343   6.87E+10     0.06241   2.89E+08    0.00
43.8620   -4.25E-10     -0.875     -0.01158   1.05E-10   0.00664   6.87E+10     0.02127   2.89E+08    0.00
44.3440   -2.83E-11     -0.586      0.05402   4.40E-11   0.00445   6.87E+10     0.00142   2.89E+08    0.00
44.8260    8.35E-11     -0.250      0.04604   8.83E-12   0.00190   6.87E+10    -0.00418   2.89E+08    0.00
45.3080    7.38E-11     -0.05330    0.02329  -3.93E-12   4.05E-04  6.87E+10    -0.00369   2.89E+08    0.00
45.7900    3.81E-11      0.01972    0.00711  -5.34E-12   1.50E-04  6.87E+10    -0.00191   2.89E+08    0.00
46.2720    1.20E-11      0.02900   -1.35E-04 -3.29E-12   2.20E-04  6.87E+10    -6.01E-04  2.89E+08    0.00
46.7540        0.00      0.01816   -0.00188  -1.30E-12   1.38E-04  6.87E+10    -3.34E-06  2.89E+08    0.00
47.2360   -3.06E-12      0.00720   -0.00145       0.00   5.47E-05  6.87E+10     1.53E-04  2.89E+08    0.00
47.7180   -2.68E-12      0.00136   -6.23E-04      0.00   1.04E-05  6.87E+10     1.34E-04  2.89E+08    0.00
48.2000   -1.63E-12         0.00       0.00       0.00       0.00  6.87E+10     8.15E-05  1.45E+08    0.00
```

* The above values of total stress are combined axial and bending stresses.

Output Summary for Load Case No. 2:

```
Pile-head deflection           =      4.64546377 inches
Computed slope at pile head    =     -0.0188564 radians
Maximum bending moment         =        8476425. inch-lbs
Maximum shear force            =        -100110. lbs
Depth of maximum bending moment =   22.17200000 feet below pile head
Depth of maximum shear force   =    27.47400000 feet below pile head
Number of iterations           =             61
Number of zero deflection points =            7
Pile deflection at ground      =      1.37769213 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 Length feet	Pile Head Deflection inches	Maximum Moment ln-lbs	Maximum Shear lbs

```
 ------------   ------------   ------------   ------------
   48.20000     4.64546377      8476425.       -100110.
   45.79000     4.64671513      8478170.       -100024.
   43.38000     4.64918729      8480973.       -100161.
   40.97000     4.65048776      8480481.       -100008.
   38.56000     4.65467634      8486312.       -100284.
   36.15000     4.65087934      8484753.       -100554.
   33.74000     4.66657719      8489494.        -98478.
```

                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 Load                   Load                    Axial   Pile-head Pile-head Max Shear Max Moment
Case Type  Pile-head        Type    Pile-head     Loading Deflection Rotation   in Pile   in Pile
No.   1    Load 1            2      Load 2           lbs    inches    radians     lbs      in-lbs
---- ----- ----------    ---------- ----------   ---------- ---------- ---------- ---------- ----------
  1  V, lb      0.00 M, in-lb        0.00         0.00    1.7837   -0.00805    -50861.   3969482.
  2  V, lb      0.00 M, in-lb        0.00         0.00    4.6455   -0.01886   -100110.   8476425.
```

Maximum pile-head deflection = 4.6454637736 inches
Maximum pile-head rotation   = -0.0188564311 radians = -1.080394 deg.

                          Summary of Warning Messages

The following warning was reported 9663 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.

APPENDIX D
RESPONSES TO ODOT STAGE 3 SUBMISSION
COMMENTS

September 28, 2023

IBI Group
23 Triangle Park Drive
Cincinnati, Ohio 45246

Attention: Mr. Steven Butler, P.E.
               Associate – Manager, Transportation Engineering

Reference: Response to Stage 3 Comments
               BRO-52-22.27 Slide Repair
               PID No. 115994
               Brown County, Ohio
               CTL Project No. 23050002COL

Dear Mr. Butler:

This letter provides our responses to the comments prepared by ODOT OGE on the Stage 3 Submittals. These comments were provided to CTL via email by IBI Group personnel on 09/10/2023.

CTL Responses to Comments received from OGE on Deposition of Stage 3 Comments

ODOT General Comment 1:
         Update wall design per comments and finalize geotechnical report. Update Table on sheet 29.

CTL Response to ODOT General Comment 1:
         CTL revised the retaining wall analyses using the revised cross sections that include a 2:1 slope behind the guardrail.

         IBI Group will update the table on sheet 29.

ODOT General Comment 2:
         As we discussed, reduce the retaining wall height by following SCD MGS 1.1 by reducing slope 2:1 behind guardrail.

CTL Response to ODOT General Comment 2:
         CTL revised the retaining wall analyses using the revised cross sections that include a 2:1 slope behind the guardrail.

ODOT General Plan Comment 7.b:
         Decrease the plug pile length as we discussed.

CTL Response to ODOT General Plan Comment 7.b:

> The plug piles should extend a minimum of 3 feet below the "Artificially Lowered Ground Surface" as shown in Appendix C of the Geohazard Exploration Report. CTL recommends that the plug piles be extended to the depths stated below. These depths are measured from the top of the proposed wall.
>
> - For the US 52 Wall, the plug piles should extend to depths of 23 feet each.
> - For the Driveway Wall, the plug piles should extend to depths of 18 feet each.

ODOT Geotechnical Profile Comment 1:
Label contours with elevations per CADD standards on sheet 34.

CTL ODOT Geotechnical Profile Comment 1:
The sheet now contains elevation labels for the contours per the CADD standards.

ODOT Geotechnical Profile Comment 2:
Update cross sections per updated drawings.

CTL Response to ODOT Geotechnical Profile Comment 2:
The cross sections have been updated per the updated drawings.

ODOT Geotechnical Profile Comment 3:
Show station offset on boring logs.

CTL Response to ODOT Geotechnical Profile Comment 3:
The station and offset are now shown on the boring logs.

Closing

We appreciate the opportunity to be of service to you on this project. If you have any questions or need further information, please do not hesitate to contact us.

Respectfully submitted,

CTL ENGINEERING, INC.

Evan Holcombe, P.E
Geotechnical Engineer

Joe Grani, P.E.
Project Engineer