Technical Design Memo

Client:	Ohio Department of Transportation, District 10
Project:	**ATH-690-4.21 (Task Order 10-X)** **PID 114592**
HDR Project No:	10361025
Rev:	0
Calculation No:	1
Page:	1 of 116
Title:	Landslide Remediation Analyses and Design
Purpose:	Prepare slope stability analyses and wall calculations for the design of a repair to a landslide affecting southbound travel on State Route 690 (SR 690) in Athens County, Ohio.
Originator:	DCM
Date:	2/12/2023
Checked by:	AKB
Date:	2/13/2023
QC Review by:	DMV
Date:	2/15/2023

Summary

1. A landslide has occurred on the slope below SR 690 near mile marker 4.21 in Athens County, Ohio. The project location is shown on the attached Site Vicinity and Topographic Map. Based on observations gathered during the site reconnaissance performed on December 1, 2022, coupled with the findings from the geotechnical explorations performed from January 9 through 11, 2023 and on February 6, 2023, a soldier pile and lagging retaining wall is recommended to stabilize the landslide and repair SR 690. Presented herein are the discussion and evaluation of a soldier pile and lagging wall for mitigation of the continued slope movement. This design assumes that the topography and slope geometry as presented in the surveyed cross sections are representative of the current field conditions.

2. The recent geotechnical exploration program consisted of a series of 3 test borings and 1 dynamic cone penetration (DCP) test to characterize the soil profile in the vicinity of the existing landslide and develop the repair. The 3 test borings (designated as B-001-0-23, B-002-0-23, and B-003-0-23) were drilled within the southbound lane (right of the centerline) of SR 690. The DCP test (designated as D-002-1-23) was performed on the embankment slope below SR 690. The

approximate locations are shown on the attached Boring Plan. Typed boring logs and the DCP test report are also included in the attached calculations.

3. As the 3 test borings were drilled within the roadway, the surficial materials consisted of asphalt pavement ranging from 18 inches to 42 inches in thickness. An approximately 6-inch layer of granular base comprised of Gravel with Sand (A-1-b) was encountered beneath the asphalt in Borings B-002-0-23 and B-003-0-23.

Below the surficial materials, the soil profile generally consisted of a layer of stiff to very stiff cohesive Silty Clay (A-6b) and Clay (A-7-6) transitioning to hard residual soils consisting of Silty Clay (A-6b) and Clay (A-7-6) and exhibiting relic rock structure. The underlying bedrock consisted of shale underlain by sandstone with a thin intermediary layer of limestone.

As no samples were obtained from the DCP test (D-002-1-23) performed on the slope below the roadway, the subsurface soils were assumed to be cohesive material similar to those encountered in the borings for calculation and analysis purposes. The correlated SPT N-values indicate a soft material from the ground surface to a depth of approximately 7 feet. Below 7 feet, the SPT N-values indicate a stiff consistency to a depth of approximately 14 feet, before the blow counts sharply increase prior to encountering DCP refusal at a depth of 14.8 feet below the existing ground surface.

The generalized soil profile developed for the design section at Sta. 235+50 is primarily based on the findings from Borings B-001-0-23, B-002-0-23, and D-002-1-23. The soil profile is assumed to be depicted as shown graphically on the attached SLOPE/W output plots based on the generalized soil conditions as encountered in the explorations.

4. Central Athens County is located within the Marietta Plateau region of the Allegheny (Kanawha) Plateaus section of the unglaciated and dissected Appalachian Plateaus province, described as dissected, high-relief terrain prone to landslide activity and mainly composed of fine-grained rocks, red shales, and red residual soils. The site is located near the western edge of the Marietta Plateau, close to its boundary with the Muskingum-Pittsburgh Plateau. Soils in the Marietta Plateau region are identified as Pleistocene (Teays)-age Minford clays and/or red and brown colluvial silty-clay loam landslide deposits. The county is comprised of hills, narrow ridgetops, and stream valleys, with the southern portion characterized by more rolling slopes, wider ridgetops, and fewer steep hillsides than the northern portion. These land-features were originally formed by the pre-glacial Teays River system. This river system was eventually dammed by glacial advance, forming an extensive lake system that eventually spilled westward over old stream divides, forming what is now the Ohio River system. The project site is directly drained by Mush Run, located along the toe of the slope to the west of the alignment. Mush Run is a south-to-north flowing tributary that drains through a series of creeks and streams, including McDougall Branch and Federal Creek, before eventually draining into the Hocking River at a point approximately 7 miles southeast of the project site.

The surficial materials within Athens County largely consist of colluvium and residuum derived from local sedimentary bedrock, with lesser amounts of alluvium found within stream and river valleys. The bedrock mapped within the project site consists of the Pennsylvanian-age Conemaugh Group up to approximately El. 790 to El. 800, with the Pennsylvanian-age Monongahela Group mapped along the ridge tops above this approximate elevation as shown on the attached Bedrock Geology Map. These bedrock groups consist of shale, siltstone, and sandstone, with minor amounts of limestone and coal. The main coal seam of note within the Conemaugh Group is the Mahoning No. 7a.

Mine maps from the Ohio Department of Natural Resources (ODNR) indicate no surficial or deep mining has occurred within the area of project site. Deep mining associated with the Middle Kittanning No. 6 coal seam of the Pennsylvanian-age Allegheny-Pottsville Group was performed approximately 4.5 miles west and 2.5 miles south of the project site, and deep mining of the Pittsburgh No. 8 coal seam of the Pennsylvanian-age Monongahela was performed approximately 5 miles east and northeast of the project site.

5. HDR is unaware of any prior geotechnical explorations at the ATH-690-4.21 project site. A search of available records on ODOT's Transportation Information Mapping System (TIMS) reveals only the geographical locations of known landslide activity in the project area. The closest geotechnical explorations were for a bridge crossing Mush Run along SR 690 approximately 0.3 mile north of the project site.

6. In accordance with ODOT Geotechnical Design Manual (GDM) recommendations, an initial set of soil strength parameters were selected based on laboratory tests and published correlations of soil strength with SPT N_{60} values. A statistical basis for selecting the initial soil parameters was performed and is in the attached printed spreadsheets entitled "SOIL STRENGTH PARAMETER DETERMINATION". These values were then entered into the SLOPE/W slope stability modeling software to re-create the landslide observed in the field by simulating a series of optimized trial searches to determine the critical mode of failure based on a Morgenstern-Price stability model. In addition, the SLOPE/W optimization feature was utilized, which generates a hybrid circular and translational failure shape. Recognizing that a landslide had already occurred, soil strength parameters within the encountered soil profile were adjusted to generate a reasonable slip surface (FS < 1.0) that is consistent with the field observations and engineering judgment. Based on the topographic survey provided, toe bulges and hummocky terrain are located below the existing SR 690 alignment. As such, the existing slope was reconstructed to model previous slope configuration based on the adjacent slopes. This resulted in a 2H:1V slope immediately below the existing roadway alignment, which sharply transitioned to an approximately 5H:1V below about El. 660. Both SLOPE/W analyses are included in the attachments for comparison.

Bedrock depths along the slope below SR 690 were estimated based on the slope of the existing terrain, exposed bedrock outcrops in the cuts east of the project site, the limited data available on published bedrock topography maps, and the overburden soil thicknesses as encountered in the soil borings and DCP test. Analyses were performed with an approximately 2-foot thick "Weak Rock" layer modeled along the bedrock interface. Once the soil parameters and failure surface

were established, they were entered into the UA SLOPE Version 2.3 software program and a model was developed based on the current slope configuration (See attached UA SLOPE screen shot). The UA Slope analysis was initially run without the drilled shaft, so the Factor of Safety for the existing site conditions could be correlated with the Factor of Safety from the slope stability performed in SLOPE/W. This required some adjustment of the Weak Rock strength parameters.

The project site is located along a hillside cut aligned parallel to the Mush Run. Groundwater was only encountered in Boring B-001-0-22 at approximately El 640.7. Based on a review of FEMA flood maps, there is no designated base flood elevation at the project site and flood waters are not anticipated or mapped in the area. As such, groundwater was modeled from the existing drainage ditch to the right of the roadway, along the bedrock surface to the encountered groundwater elevation at El 640.7, and extended horizontally to the face of the slope and then continued near the ground surface.

7. After the soil profile and parameters between SLOPE/W and UA SLOPE were confirmed and finalized, a drilled shaft and lagging wall was selected and analyzed at 22 feet right of the SR 690 centerline. This allows for an approximately 12-foot travel lane, 2-foot shoulder, 1.5 feet for guardrail and post, and at a minimum, a 5-foot clearance between the existing pile and lagging wall located behind the surveyed guardrail and the back of the proposed 3-foot diameter drilled shaft. Once the wall location was established, the "Manually Determined Load Transfer Factor" was selected in the UA Slope program and the load transfer factor (η) was set to zero in order to determine the horizontal forces acting on the wall. It should be noted that the analyses also assume that up to two feet of Item 203 Embankment Fill will be placed at the project site to eliminate an existing dip in the vertical profile. The computed unfactored force per shaft is **Ps = 169,359** pounds based on 36-inch diameter drilled shafts spaced at approximate 6-foot centers. (See attached UA SLOPE computer screen shots of the post-construction condition of these calculations.) The numbering of soil layers for the UA Slope profile is listed as follows:

a. Layer 1 = Surcharge Load
b. Layer 2 = Item 203 Embankment Fill
c. Layer 3 = Soft Cohesive
d. Layer 4 = Stiff to Very Stiff Cohesive
e. Layer 5 = Very Stiff to Hard Colluvium
f. Layer 6 = Hard Residuum
g. Layer 7 = Weak Rock Layer
h. Layer 8 = Bedrock

8. In accordance with ODOT design requirements, LPILE software was used to determine the pile response to the applied lateral loading from the failure wedge determined by the Slope/W and UA Slope analyses performed at the design section at Sta. 235+50. Relative to the LPILE analyses, the following were considered:

(a) Factored Distributed Load (per GDM, 903.1)

- Convert concentrated load from UA SLOPE to distributed load
  - $½(D_L)(H_T)$ = 169,359 lbs.

D_L = distributed load
H_T = 24.7 feet (top/wall to slip surface, see attached)

- D_L = [(169,359 lbs)(2)]/[(24.7')(12"/ft)] = Resolution of Triangular Area
  D_L = **1143 lbs/in** (Service Load)
- (1143 lbs/in)(γ_{EH}) = (1143 lbs/in)(1.5) = **1714 lbs/in** (Strength Load for Moment/Shear Analysis).

Loading due to conventional earth pressures for a 5.5-foot exposed wall height was calculated for comparison purposes.

- Calculate conventional earth pressure wall loading.
  - Equivalent Fluid Weight (G_H) = (γ_m) * (K) = **42 pcf**
    Ym = soil moist unit weight (see attached calculations)
    Ka = active earth pressure (see attached calculations)
  - Lateral Thrust (P) = 1/2 * G_H * H^2 = P = **1174 lbs/ft**
    H = Wall Height
  - Horizontal Force Per Shaft (P_{SH}) = P*(S_{cc}) = **7042 lbs/shaft**
    S_{cc} = Center-to-Center Shaft Spacing = 6 ft
  - Resolve Horizontal Earth Pressure to Distributed Triangular Load
    (2* P_{SH}/H) / (12 in/ft)
    = **156 lbs/in per shaft (Service Load)**
    (117 lbs/in) (γ_{EH}) = (117 lbs/in) (1.5)
    = **235 lbs/in per shaft (Strength Load)**

As the conventional loading for an exposed height of 7.5 feet is less than the landslide loading, the landslide loading from UA SLOPE was applied to the proposed wall.

(b) Traffic Surcharge (per GDM, 903.7)

As the horizontal distance between the drilled shafts and traffic loading (11.4 feet) is approximately half the depth to the shear surface at the location of the drilled shafts (24.7 feet), traffic surcharge loading was included in the distributed load acting on the shaft for conservatism (see attached calculations).

(c) Modification of p-y curves

Since the center-to-center spacing is < 3.5 shaft diameters, a reduction in soil resistance (p) should be applied from the ground surface to the bottom of shaft or bedrock (whichever is shallower).

- $\beta_a = 0.64(S/D)^{0.34}$ = $\beta_a = 0.64(6/3)^{0.34}$
- β_a = **0.81**

(d) Lowering of the Ground Surface

The downslope stability was determined to be stable. (See the SLOPE/W output plot included in the attached calculations exhibiting a Factor of Safety greater than 1.3.) As such, the GDM recommendation of artificially lowering the ground surface in the LPILE analysis was not applied.

(e) Pile Length (per GDM, 903.4)

*Minimum 10 feet below slip plane
*Slip Plane = 24.7 ft below top of wall
+10.0 ft
34.7 ft minimum pile length

- **Bottom of Drilled Shaft = 35.0 ft > 34.7 ft** **OK**

ODOT GDM requires using a minimum rock socket depth based on the minimum drilled shaft depth of 10 feet below the failure surface (903.4) and review of the "Top Deflection Versus Length" plot produced by the LPILE software (903.9.1). Based on the encountered bedrock and our experience with such local bedrock types, **a minimum rock socket length of 10 feet** is recommended.

(f) Pile Head Deflection

As noted in ODOT GDM (903.8), for the unfactored Service Limit State analysis, pile head deflection shall be limited 1% or less of the drilled shaft length above bedrock (or the total shaft length when bedrock is not encountered). If the drilled shafts are within 10 feet of the edge of pavement, the deflection must be limited to 2 inches. The centerline of the drilled shafts is anticipated to be located less than 10 feet from the edge of pavement. As such, a limited pile head deflection of 2 inches or less was adopted.

Computed Pile Head Deflection (W 24 x 146) = **1.88 inches** < 2.0 inches OK
(See attached calculations)

(g) Steel Reinforcement and Pile Cross Section Character

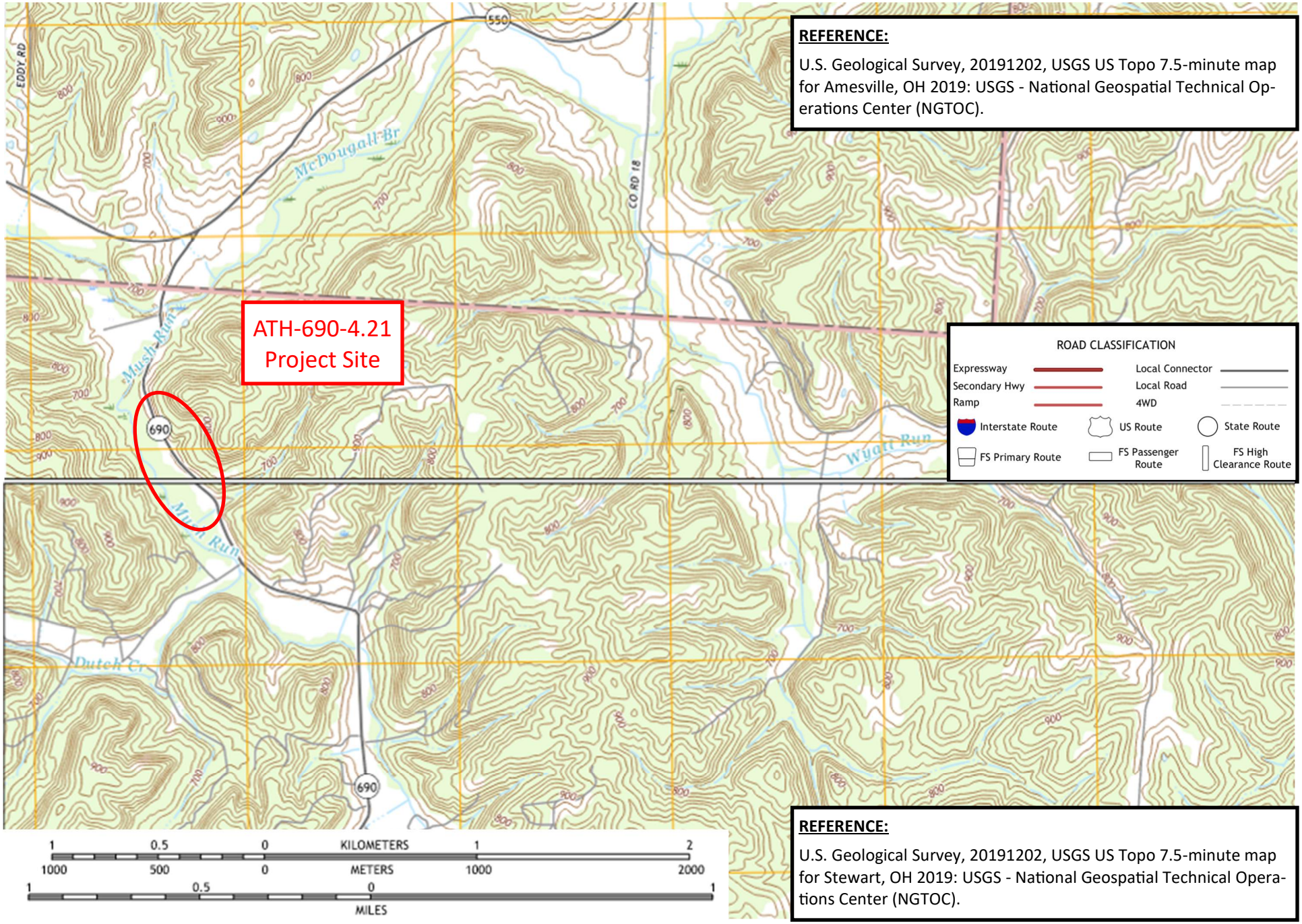
Use W 24 x 146 shaft reinforcement

A_s = Area of Steel = 24.7 in^2
I_x = Moment of Inertia around strong axis =4580 in^4
T_w = Web Thickness = 0.65 in
E = Modulus of Elasticity of Steel = 29,000,000 psi
F_y = yield strength of steel = 50,000 psi
B_f = Flange Width = 12.9 in

9. It is recommended that 36” diameter plug piles be utilized to the top of bedrock to prevent loss of material and undermining of the concrete lagging should the slope below the retaining wall become unstable as a result of elevated groundwater conditions.

Site Vicinity and Topographic Map

Site Vicinity and Topographic Map



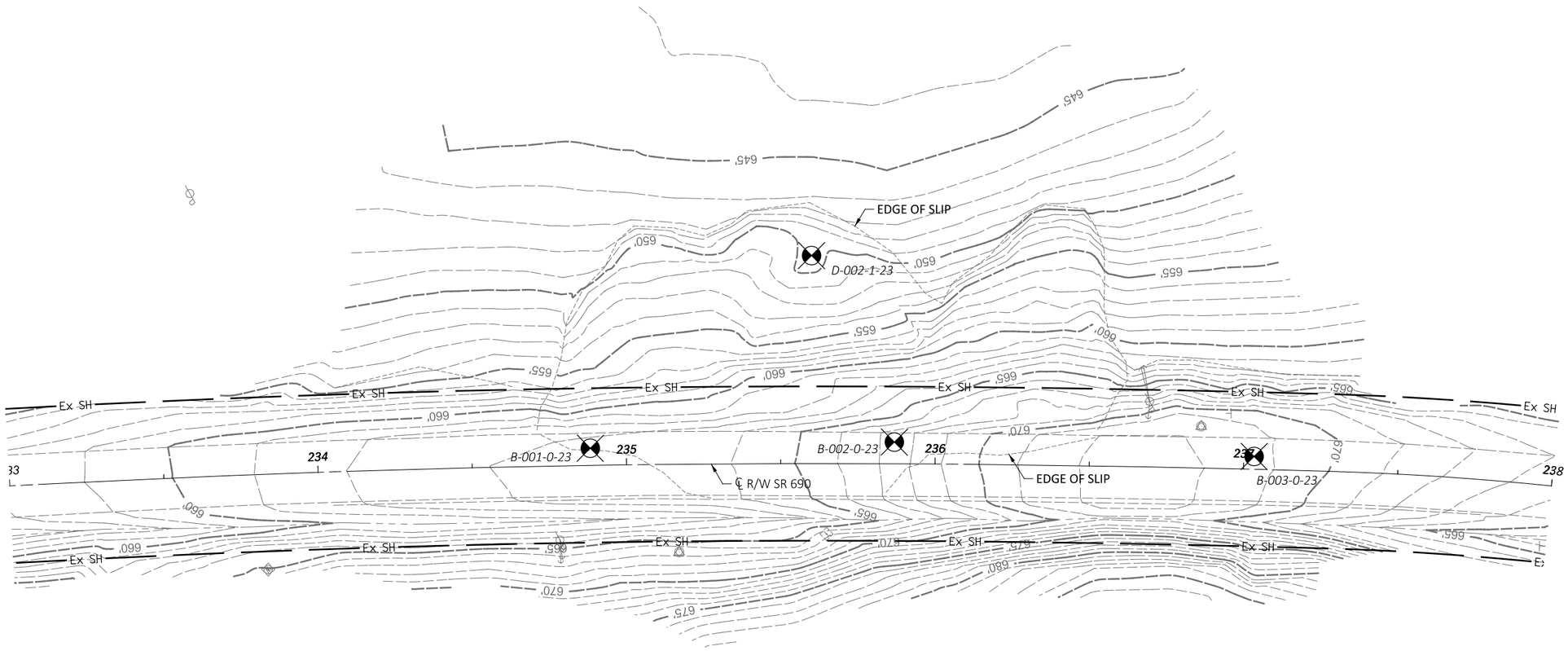
REFERENCE:

U.S. Geological Survey, 20191202, USGS US Topo 7.5-minute map for Amesville, OH 2019: USGS - National Geospatial Technical Operations Center (NGTOC).

REFERENCE:

U.S. Geological Survey, 20191202, USGS US Topo 7.5-minute map for Stewart, OH 2019: USGS - National Geospatial Technical Operations Center (NGTOC).

Boring Plan



HORIZONTAL SCALE IN FEET
0 10 20 40

BORING LOCATION PLAN

ATH-690-4.21

MODEL: CLX_RW_SR690 - Plan 1 [Sheet] PAPERSIZE: 34x22 (in.) DATE: 2/15/2023 TIME: 9:27:13 AM USER: CWAHLBRI
pw:\\ohiodot-pw.bentley.com:ohiodot-pw-02\Documents\01 Active Projects\District 10\Athens\114592\d02-Engineering_HDR\Geotechnical\Sheets\114592_YP900.dgn

DESIGN AGENCY
HDR

DESIGNER
DCM

REVIEWER
DMV 02/15/23

PROJECT ID
114592

SHEET 1 | TOTAL 0

Boring Logs
and
Rock Core Photos

PROJECT: ATH-690-04.21	DRILLING FIRM / OPERATOR: CENTRAL STAR / TS	DRILL RIG: DIEDRICH D-50 (SN 481)	STATION / OFFSET: 234+88, 6' LT.	EXPLORATION ID B-001-0-23
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: HDR / DM	HAMMER: AUTOMATIC HAMMER	ALIGNMENT: SR 690	
PID: 114592 SFN:	DRILLING METHOD: 2.25 HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 663.2 (MSL) EOB: 49.5 ft.	PAGE 1 OF 2
START: 1/9/23 END: 1/9/23	SAMPLING METHOD: SPT / ST / NQ2	ENERGY RATIO (%): 86.8	LAT / LONG: 39.375147, -81.989717	

MATERIAL DESCRIPTION AND NOTES	ELEV. 663.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
18 inches of Asphalt	661.7	1	8 4 4	12	44	SS-1	3.00	-	-	-	-	-	-	-	-	20	A-7-6 (V)	
STIFF TO VERY STIFF, BROWN TRACE MOTTLED GRAY, **CLAY**, SOME SILT, LITTLE SAND, TRACE STONE FRAGMENTS, MOIST		2 3 4 5 6	3 4 3	10	67	SS-2	1.50	2	7	10	31	50	53	23	30	25	A-7-6 (19)	
			3 5 7	17	100	SS-3	2.50	-	-	-	-	-	-	-	-	27	A-7-6 (V)	
	655.7	7																
STIFF TO VERY STIFF, BROWN TO RED-BROWN MOTTLED GRAY, **CLAY**, SOME SILT, LITTLE SAND, TRACE STONE FRAGMENTS, DAMP		8 9 10	4 5 8	19	83	SS-4	3.00	-	-	-	-	-	-	-	-	23	A-7-6 (V)	
Below 11.5' : Orange-Brown @ 11.6' - 12.1' : qu = 2005 psf		11 12 13 14			100	ST-5	3.00	1	4	8	28	59	58	23	35	21	A-7-6 (20)	
			4 4 9	19	100	SS-6	3.50	1	6	7	29	57	58	25	33	21	A-7-6 (20)	
	648.2	15																
STIFF TO VERY STIFF, ORANGE-BROWN AND LIGHT BROWN, **CLAY**, "AND" SILT, LITTLE SAND, TRACE STONE FRAGMENTS, DAMP		16 17 18 19	4 4 4	12	89	SS-7	3.00	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
			4 5 8	19	89	SS-8	2.50	4	4	8	36	48	46	23	23	19	A-7-6 (14)	
@ 21.0' - 21.5' : Trace Red-Brown		20 21	5 6 11	25	89	SS-9	3.50	-	-	-	-	-	-	-	-	16	A-7-6 (V)	
	640.7	22 W 640.7																
VERY STIFF, RED-BROWN AND LIGHT BROWN, **CLAY**, "AND" SAND, SOME SILT, LITTLE STONE FRAGMENTS, (RELIC ROCK STRUCTURE), DAMP		23 24	4 5 10	22	100	SS-10	-	13	27	10	28	22	43	24	19	18	A-7-6 (6)	
	638.2	TR 25																
SHALE, RED-BROWN AND LIGHT BROWN, HIGHLY WEATHERED, VERY WEAK, FRIABLE.		26 27 28	12 18 46	93	100	SS-11	-	-	-	-	-	-	-	-	-	12	Rock (V)	
			50/6"	-	102	SS-12	-	-	-	-	-	-	-	-	-	20	Rock (V)	
	633.7	29																

PID: 114592	SFN:	PROJECT: ATH-690-04.21	STATION / OFFSET: 234+88, 6' LT.	START: 1/9/23	END: 1/9/23	PG 2 OF 2	B-001-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
SHALE, RED-BROWN AND GRAY, HIGHLY WEATHERED, VERY WEAK, VERY THIN TO THIN BEDDED, FRIABLE, JOINT AND BEDDING DISCONTINUITIES, FRACTURED TO MODERATELY FRACTURED, TIGHT APERTURE, SLICKENSIDED, LAMINATED, VERY POOR TO POOR SURFACE CONDITIONS; RQD 54%, REC 83%. *(continued)* @ 33.0' - 34.0' : Highly Fractured, Calcareous @ 33.0' - 34.9' : Transition to Brownish Gray then Gray	633.2	31 32 33 34 35	48		77	NQ2-1											CORE	
LIMESTONE, GRAY, SLIGHTLY WEATHERED, STRONG, THICK BEDDED, CRYSTALLINE, BEDDING DISCONTINUITIES, SLIGHTLY FRACTURED, TIGHT APERTURE, ROUGH SURFACE, BLOCKY, GOOD SURFACE CONDITIONS; RQD 100%, REC 100%.	628.3 626.5	36 37	92		100	NQ2-2											CORE	
SHALE, GRAY, MODERATELY TO HIGHLY WEATHERED, VERY WEAK, MEDIUM BEDDED, BEDDING DISCONTINUITIES, MODERATELY FRACTURED, TIGHT APERTURE, LAMINATED, SLICKENSIDED, POOR SURFACE CONDITIONS; RQD 100%, REC 100%.	625.3	38 39 40 41 42 43 44	94		100	NQ2-3											CORE	
SANDSTONE, GRAY, UNWEATHERED TO SLIGHTLY WEATHERED, MODERATELY STRONG, FINE TO MEDIUM GRAINED, THICK TO VERY THICK BEDDED, JOINT AND BEDDING DISCONTINUITIES, SLIGHTLY FRACTURED TO INTACT, TIGHT TO OPEN APERTURE, SLIGHTY ROUGH, BLOCKY, VERY GOOD SURFACE CONDITIONS; RQD 96%, REC 100%. @ 43.9' - 44.3' : Qu = 5983 psi @ 48.5' - 49.5' : Dark Gray, Carbonaceous	613.7	45 46 47 48 49 EOB	97		100	NQ2-4											CORE	

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 20 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

B-001-0-23

Run #	Depth (ft)		Recovery		RQD	
NQ2-1	29.5	33.5	37 in. / 48 in.	77%	23 in. / 48 in.	48%
NQ2-2	33.5	37.5	48 in. / 48 in.	100%	44 in. / 48 in.	92%
NQ2-3	37.5	44.5	84 in. / 84 in.	100%	79 in. / 84 in.	94%

ATH-690-4.21 PID 114592

B-001-0-23

Run #	Depth (ft)		Recovery		RQD	
NQ2-3	37.5	44.5	84 in. / 84 in.	100%	79 in. / 84 in.	94%
NQ2-4	44.5	49.5	60 in. / 60 in.	100%	58 in. / 60 in.	97%

ATH-690-4.21 PID 114592

PROJECT: ATH-690-04.21	DRILLING FIRM / OPERATOR: CENTRAL STAR / TS	DRILL RIG: DIEDRICH D-50 (SN 481)	STATION / OFFSET: 235+87, 7' LT.	EXPLORATION ID B-002-0-23
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: HDR / DM	HAMMER: AUTOMATIC HAMMER	ALIGNMENT: SR 690	
PID: 114592 SFN:	DRILLING METHOD: 2.25 HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 667.4 (MSL) EOB: 44.8 ft.	PAGE 1 OF 2
START: 1/10/23 END: 1/11/23	SAMPLING METHOD: SPT / NQ2	ENERGY RATIO (%): 86.8	LAT / LONG: 39.375334, -81.989969	

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
42 inches of Asphalt	667.4																	
	663.4	1	16 6 5	16	78	SS-1	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	
MEDIUM DENSE, LIGHT BROWN, **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP	662.9	2	2 1 2	4	67	SS-2	1.00	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
STIFF TO VERY STIFF, BROWN AND GRAY, **CLAY**, SOME SAND, SOME SILT, DAMP		3	3 4 7	16	100	SS-3	1.50	0	0	1	21	78	60	28	32	28	A-7-6 (20)	
	658.4	4	5 8 14	32	78	SS-4	3.00	-	-	-	-	-	-	-	-	25	A-7-6 (V)	
@ 9.0' - Auger Grinding Prior to SPT Sampling		5	6 12 18	43	83	SS-5	3.50	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
VERY STIFF TO HARD, LIGHT BROWN TRACE RED-BROWN AND GRAY, **CLAY**, SOME SILT, LITTLE SAND, LITTLE STONE FRAGMENTS, DAMP	655.4	6	9 17 16	48	100	SS-6	4.00	14	12	7	29	38	46	25	21	13	A-7-6 (12)	
HARD, RED-BROWN, **SILTY CLAY**, SOME SAND, TRACE STONE FRAGMENTS, DAMP (Colluvium)		7	9 12 17	42	56	SS-7	4.50	-	-	-	-	-	-	-	-	19	A-6b (V)	
	652.4	8	11 40 50/5"	-	94	SS-8	4.50	8	10	11	40	31	38	22	16	9	A-6b (10)	
HARD, RED-BROWN, GRAY AND LIGHT BROWN, **SILTY CLAY**, TRACE SAND, DAMP (Possible Colluvium)		9	35 28 40	98	89	SS-9	4.50	-	-	-	-	-	-	-	-	10	A-6b (V)	
	649.4	10	22 26 30	81	100	SS-10	4.50	0	1	5	46	48	40	22	18	10	A-6b (11)	
HARD, RED-BROWN, GRAY AND LIGHT BROWN, **CLAY**, "AND" SILT, TRACE SAND, TRACE STONE FRAGMENTS, (RELIC ROCK STRUCTURE), DAMP (Residuum)		11	27 50/5"	-	91	SS-11	4.50	-	-	-	-	-	-	-	-	11	A-7-6 (V)	
	646.4	12	18 31 31	90	100	SS-12	4.50	3	2	5	49	41	44	23	21	11	A-7-6 (13)	
SHALE, GRAY TO BROWN-GRAY, MODERATELY TO HIGHLY WEATHERED, VERY WEAK.	644.9	TR 13	26 43 50/4"	-	100	SS-13	-	-	-	-	-	-	-	-	-	9	Rock (V)	
SHALE, GRAY, MODERATELY WEATHERED, VERY WEAK.		14	47 50/3"	-	100	SS-14	-	-	-	-	-	-	-	-	-	6	Rock (V)	
@ 24.0' - 24.5' : Gray and Red-Brown	641.4	15	50/6"	-	102	SS-15	-	-	-	-	-	-	-	-	-	7	Rock (V)	
SHALE, RED-BROWN AND GRAY, MODERATELY TO HIGHLY WEATHERED, WEAK, MEDIUM BEDDED, JOINT AND BEDDING DISCONTINUITIES, FRACTURED TO SLIGHTLY FRACTURED, NARROW TO OPEN APERTURE, SLICKENSIDED TO SLIGHTLY ROUGH, BLOCKY, FAIR SURFACE CONDITION; RQD 34%, REC 97%. @ 28.2' - 29.1' : Gray		16 17 18 19 20 21 22 23 24 25 26 27 28 29	27		100	NQ2-1											CORE	

PID: 114592	SFN:	PROJECT: ATH-690-04.21	STATION / OFFSET: 235+87, 7' LT.	START: 1/10/23	END: 1/11/23	PG 2 OF 2	B-002-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
SHALE, RED-BROWN AND GRAY, MODERATELY TO HIGHLY WEATHERED, WEAK, MEDIUM BEDDED, JOINT AND BEDDING DISCONTINUITIES, FRACTURED TO SLIGHTLY FRACTURED, NARROW TO OPEN APERTURE, SLICKENSIDED TO SLIGHTLY ROUGH, BLOCKY, FAIR SURFACE CONDITION; RQD 34%, REC 97%. *(continued)* @ 32.8' - 36.9' : Gray and Dark Gray @ 33.1' - 33.5' : Qu = 824 psi @ 34.8' - 35.8' : Highly Fractured	637.4	31 32 33 34	43		100	NQ2-2											CORE	
LIMESTONE, GRAY AND BROWN, HIGHLY WEATHERED, MODERATELY STRONG, THIN BEDDED, CRYSTALLINE, JOINT AND BEDDING DISCONTINUITIES, FRACTURED TO HIGHLY FRACTURED, OPEN APERTURE, VERY ROUGH, VERY BLOCKY, FAIR TO POOR SURFACE CONDITIONS; RQD 0%, REC 100%.	630.2 629.1	35 36 37 38 39 40	62		97	NQ2-3											CORE	
SANDSTONE, GRAY, UNWEATHERED TO SLIGHTLY WEATHERED, SLIGHTLY STRONG, FINE TO MEDIUM GRAINED, THICK TO VERY THICK BEDDED, JOINT AND BEDDING DISCONTINUITIES, SLIGHTLY FRACTURED TO INTACT, TIGHT APERTURE, SLIGHTLY ROUGH, BLOCKY, VERY GOOD SURFACE CONDITIONS; RQD 91%, REC 100%. @ 38.3' - 38.5' : Gray Shale, Argillaceous	622.6	41 42 43 44 EOB																

NOTES: NONE

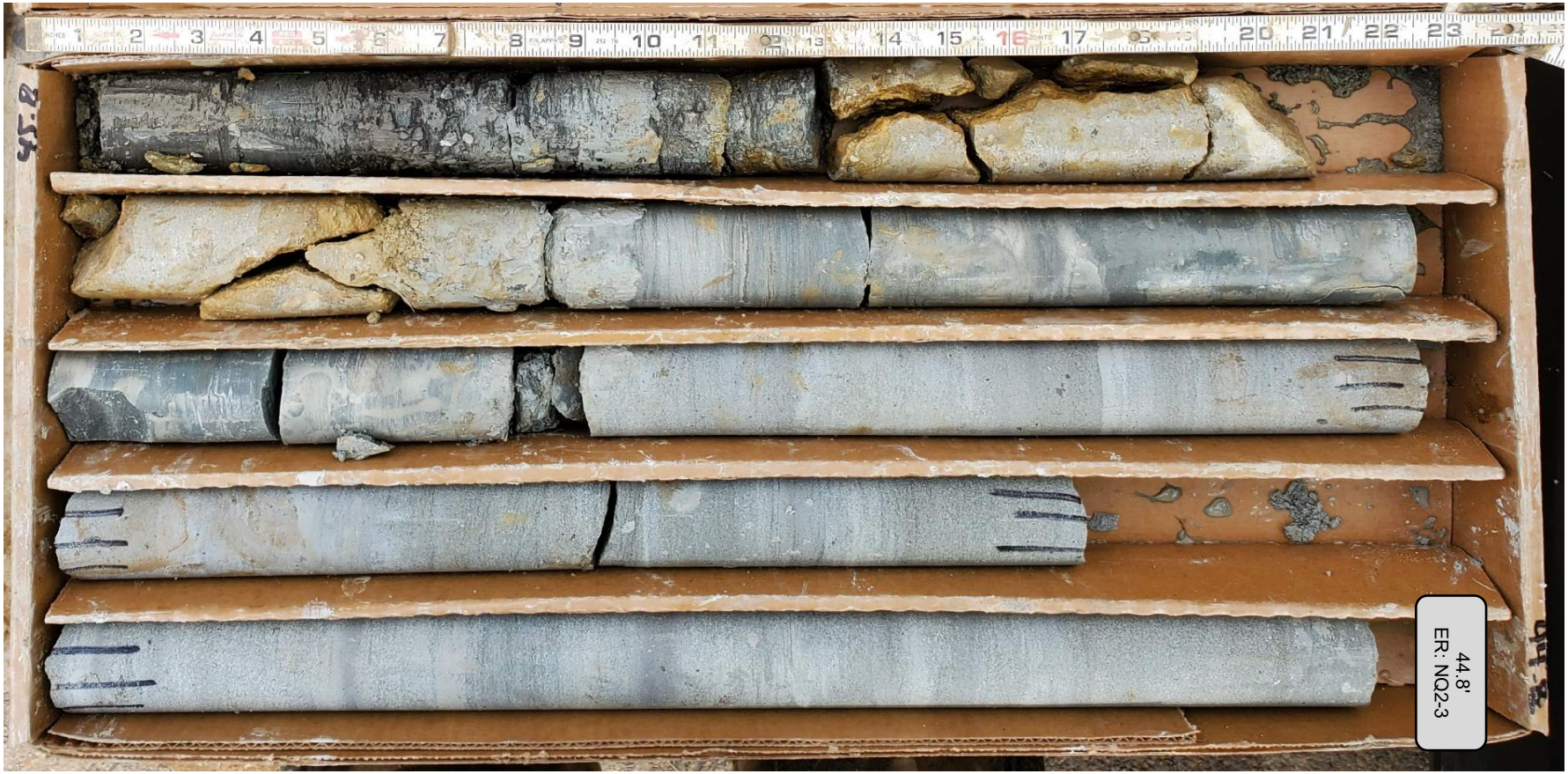
ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 20 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

B-002-0-23

Run #	Depth (ft)		Recovery		RQD	
NQ2-1	26.0	29.8	45 in. / 45 in.	100%	12 in. / 45 in.	27%
NQ2-2	29.8	34.8	60 in. / 60 in.	100%	26 in. / 60 in.	43%
NQ2-3	34.8	44.8	116 in. / 120 in.	97%	74 in. / 120 in.	62%

ATH-690-4.21 PID 114592

B-002-0-23



Run #	Depth (ft)		Recovery		RQD	
NQ2-3	34.8	44.8	116 in. / 120 in.	97%	74 in. / 120 in.	62%

ATH-690-4.21 PID 114592

PROJECT: ATH-690-04.21	DRILLING FIRM / OPERATOR: CENTRAL STAR / TS	DRILL RIG: DIEDRICH D-50 (SN 481)	STATION / OFFSET: 237+03, 4' LT.	EXPLORATION ID B-003-0-23
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: HDR / DM	HAMMER: AUTOMATIC HAMMER	ALIGNMENT: SR 690	
PID: 114592 SFN:	DRILLING METHOD: 2.25 HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 671.4 (MSL) EOB: 50.0 ft.	PAGE 1 OF 2
START: 1/10/23 END: 1/10/23	SAMPLING METHOD: SPT / ST / NQ2	ENERGY RATIO (%): 86.8	LAT / LONG: 39.375569, -81.990250	

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
24 inches of Asphalt	671.4																	
DENSE, LIGHT BROWN, **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP	669.4	2	16 13 11	35	67	SS-1	-	0	52	26	14	8	NP	NP	NP	6	A-1-b (0)	
STIFF TO VERY STIFF, ORANGE-BROWN MOTTLED GRAY, **SILTY CLAY**, TRACE SAND, DARK BROWN CONCRETION NODULES, DAMP	668.9	3 4	5 4 5	13	78	SS-2	1.50	-	-	-	-	-	-	-	-	20	A-6b (V)	
		5 6	4 5 5	14	100	SS-3	2.00	0	3	5	53	39	40	22	18	21	A-6b (11)	
	663.4	8	4 6 7	19	67	SS-4	2.50	-	-	-	-	-	-	-	-	24	A-7-6 (V)	
VERY STIFF, LIGHT ORANGE-BROWN MOTTLED GRAY, **CLAY**, "AND" SILT, TRACE SAND, TRACE STONE FRAGMENTS, DAMP		11			100	ST-5	4.00	1	1	6	44	48	56	28	28	23	A-7-6 (18)	
@11.8' - 12.3' : Qu = 1889 psf	657.4	13	5 9 12	30	78	SS-6	2.50	-	-	-	-	-	-	-	-	20	A-7-6 (V)	
HARD, RED-BROWN, **CLAY**, "AND" SILT, LITTLE SAND, (RELIC ROCK STRUCTURE), DAMP		16	17 16 23	56	100	SS-7	4.00	0	3	8	42	47	42	23	19	11	A-7-6 (12)	
	653.9	18	16 17 34	74	100	SS-8	4.00	0	3	4	49	44	47	24	23	12	A-7-6 (15)	
HARD, LIGHT BROWN TO OLIVE, **CLAY**, "AND" SILT, TRACE SAND, NOTED MICA (RELIC ROCK STRUCTURE), DAMP	651.4	TR 20																
SHALE, RED-BROWN, LIGHT-BROWN AND OLIVE, HIGHLY WEATHERED, VERY WEAK.		21	22 33 45	113	100	SS-9	-	-	-	-	-	-	-	-	-	11	Rock (V)	
		23	25 32 45	111	100	SS-10	-	-	-	-	-	-	-	-	-	11	Rock (V)	
		25	18 50/5"	-	100	SS-11	-	-	-	-	-	-	-	-	-	10	Rock (V)	
@ 27.5' : Red-Brown and Gray		28	50/5"	-	100	SS-12	-	-	-	-	-	-	-	-	-	9	Rock (V)	

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 2/15/23 16:11 - C:\PWWORKING\EAST01\D3052771\20230109_ATH-690-4.21_10-X_BORING LOGS.GPJ

PID: 114592	SFN:	PROJECT: ATH-690-04.21	STATION / OFFSET: 237+03, 4' LT.	START: 1/10/23	END: 1/10/23	PG 2 OF 2	B-003-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
	641.4																	
	640.9		50/4"	-	100	SS-13	-	-	-	-	-	-	-	-	-	6	Rock (V)	
SHALE, RED-BROWN AND DARK GRAY, MODERATELY WEATHERED, VERY WEAK, THIN TO MEDIUM BEDDED, JOINT AND BEDDING DISCONTINUITIES, MODERATELY TO SLIGHTLY FRACTURED, NARROW APERTURE, SLIGHTLY ROUGH, BLOCKY, FAIR SURFACE CONDITIONS; RQD 60%, REC 100%. @ 32.9' - 33.3' : Qu = 457 psi		31	75		100	NQ2-1											CORE	
	633.9	32 33 34 35																
LIMESTONE, GRAY, SLIGHTLY WEATHERED, STRONG, THICK BEDDED, CRYSTALLINE, BEDDING DISCONTINUITIES, SLIGHT FRACTURE, TIGHT APERTURE, ROUGH, BLOCKY, GOOD SURFACE CONDITIONS; RQD 100%, REC 100%.	632.0	36 37 38 39	75		100	NQ2-2											CORE	
SHALE, GRAY, MODERATELY TO HIGHLY WEATHERED, VERY WEAK, MEDIUM BEDDED, BEDDING DISCONTINUITIES, MODERATELY FRACTURED, TIGHT APERTURE, LAMINATED, SLICKENSIDED, POOR SURFACE CONDITIONS; RQD 100%, REC 100%.	631.1	40 41 42 43 44																
SANDSTONE, GRAY, UNWEATHERED TO SLIGHTLY WEATHERED, SLIGHTLY STRONG, FINE TO MEDIUM GRAINED, THICK TO VERY THICK BEDDED, JOINT AND BEDDING DISCONTINUITIES, SLIGHTLY FRACTURED TO INTACT, TIGHT TO NARROW APERTURE, SLIGHTLY ROUGH, BLOCKY, VERY GOOD SURFACE CONDITIONS; RQD 94%, REC 100%.		45 46 47 48 49	100		100	NQ2-3											CORE	
	621.4	EOB 50																

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 20 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

B-003-0-23

Run #	Depth (ft)		Recovery		RQD	
NQ2-1	30.5	34.8	52 in. / 52 in.	100%	39 in. / 52 in.	75%
NQ2-2	34.8	44.8	120 in. / 120 in.	100%	90 in. / 120 in.	75%

ATH-690-4.21 PID 114592

B-003-0-23

Run #	Depth (ft)		Recovery		RQD	
NQ2-2	34.8	44.8	120 in. / 120 in.	100%	90 in. / 120 in.	75%
NQ2-3	44.8	50.0	62 in. / 62 in.	100%	62 in. / 62 in.	100%

ATH-690-4.21 PID 114592

Dynamic Cone Penetration Test
Log

9999 Carver Road, Suite 210, Blue Ash, OH 45242-5583 **hdrinc.com**
(513) 984-7500

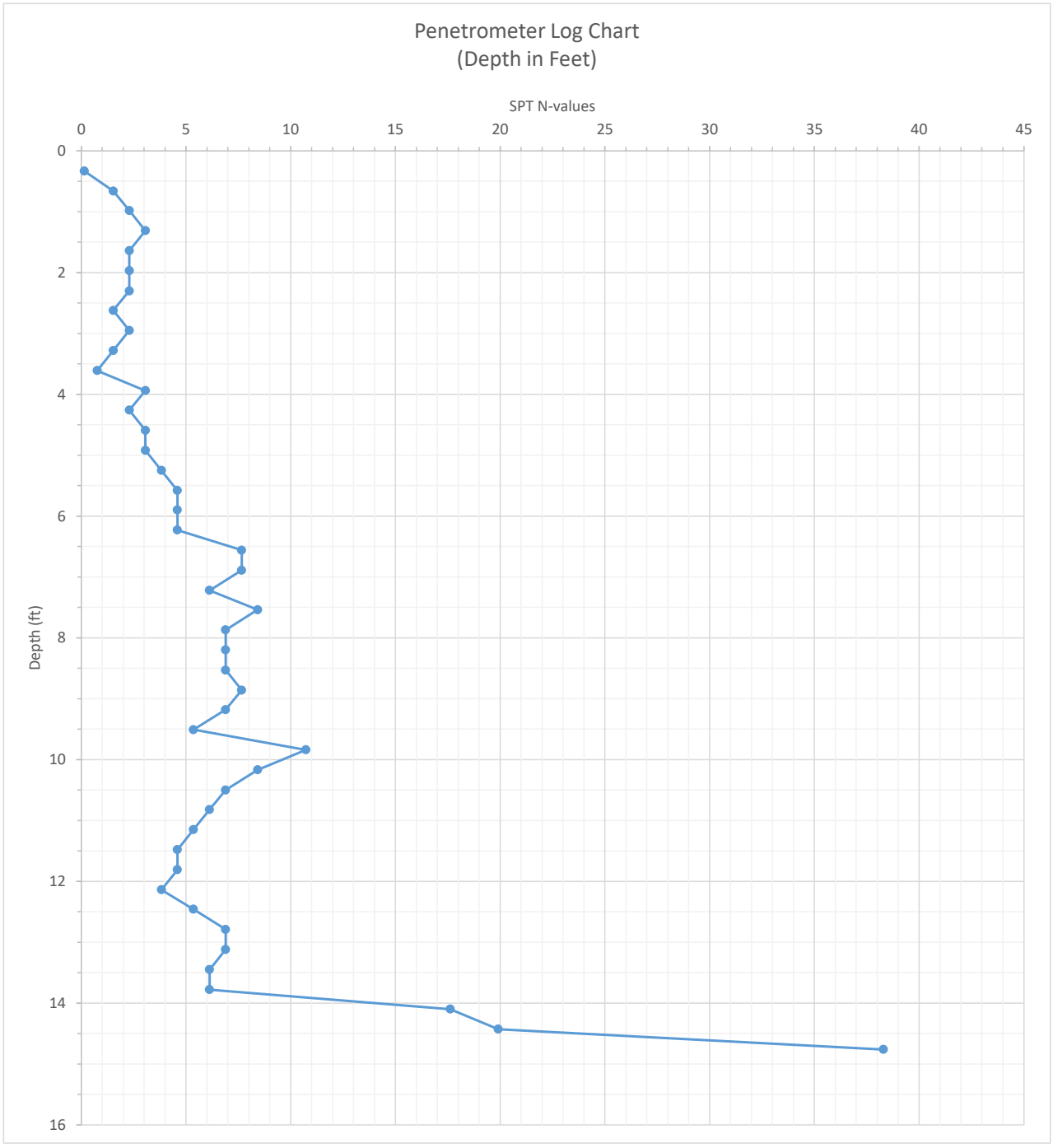
Dynamic Cone Penetration Test Log

Client:	ODOT District 10	**Operator Name / Company:**	JK / Advanced Materials, LLC
Project Name:	ATH-690-4.21 (10-X)	**Lat / Long:**	
Location:	D-002-1-23	**North / East:**	
Station, Offset:	Sta. 235+50, 75 LT (approx.)	**Date:**	2/6/2023
Elevation:	649.5 (approx)	**Sheet:**	1 of 2
Notes:	Staked Location		

Depth (in)	Depth (ft)	Depth (cm)	Pre Blows	SPT N-Value	Depth (in)	Depth (ft)	Depth (cm)	Pre Blows	SPT N-Value
3.94	0.33	10	0.2	0.1532					
7.87	0.66	20	2	1.532					
11.81	0.98	30	3	2.298					
15.75	1.31	40	4	3.064					
19.69	1.64	50	3	2.298					
23.62	1.97	60	3	2.298					
27.56	2.3	70	3	2.298					
31.5	2.62	80	2	1.532					
35.43	2.95	90	3	2.298					
39.37	3.28	100	2	1.532					
43.31	3.61	110	1	0.766					
47.24	3.94	120	4	3.064					
51.18	4.26	130	3	2.298					
55.12	4.59	140	4	3.064					
59.06	4.92	150	4	3.064					
62.99	5.25	160	5	3.83					
66.93	5.58	170	6	4.596					
70.87	5.9	180	6	4.596					
74.8	6.23	190	6	4.596					
78.74	6.56	200	10	7.66					
82.68	6.89	210	10	7.66					
86.61	7.22	220	8	6.128					
90.55	7.54	230	11	8.426					
94.49	7.87	240	9	6.894					
98.43	8.2	250	9	6.894					
102.36	8.53	260	9	6.894					
106.3	8.86	270	10	7.66					
110.24	9.18	280	9	6.894					
114.17	9.51	290	7	5.362					
118.11	9.84	300	14	10.724					
122.05	10.17	310	11	8.426					
125.98	10.5	320	9	6.894					
129.92	10.82	330	8	6.128					
133.86	11.15	340	7	5.362					
137.8	11.48	350	6	4.596					
141.73	11.81	360	6	4.596					
145.67	12.14	370	5	3.83					
149.61	12.46	380	7	5.4					
153.54	12.79	390	9	6.9					
157.48	13.12	400	9	6.9					
161.42	13.45	410	8	6.1					
165.35	13.78	420	8	6.1					
169.29	14.1	430	23	17.6					
173.23	14.43	440	26	19.9					
177.17	14.76	450	50	38.3					

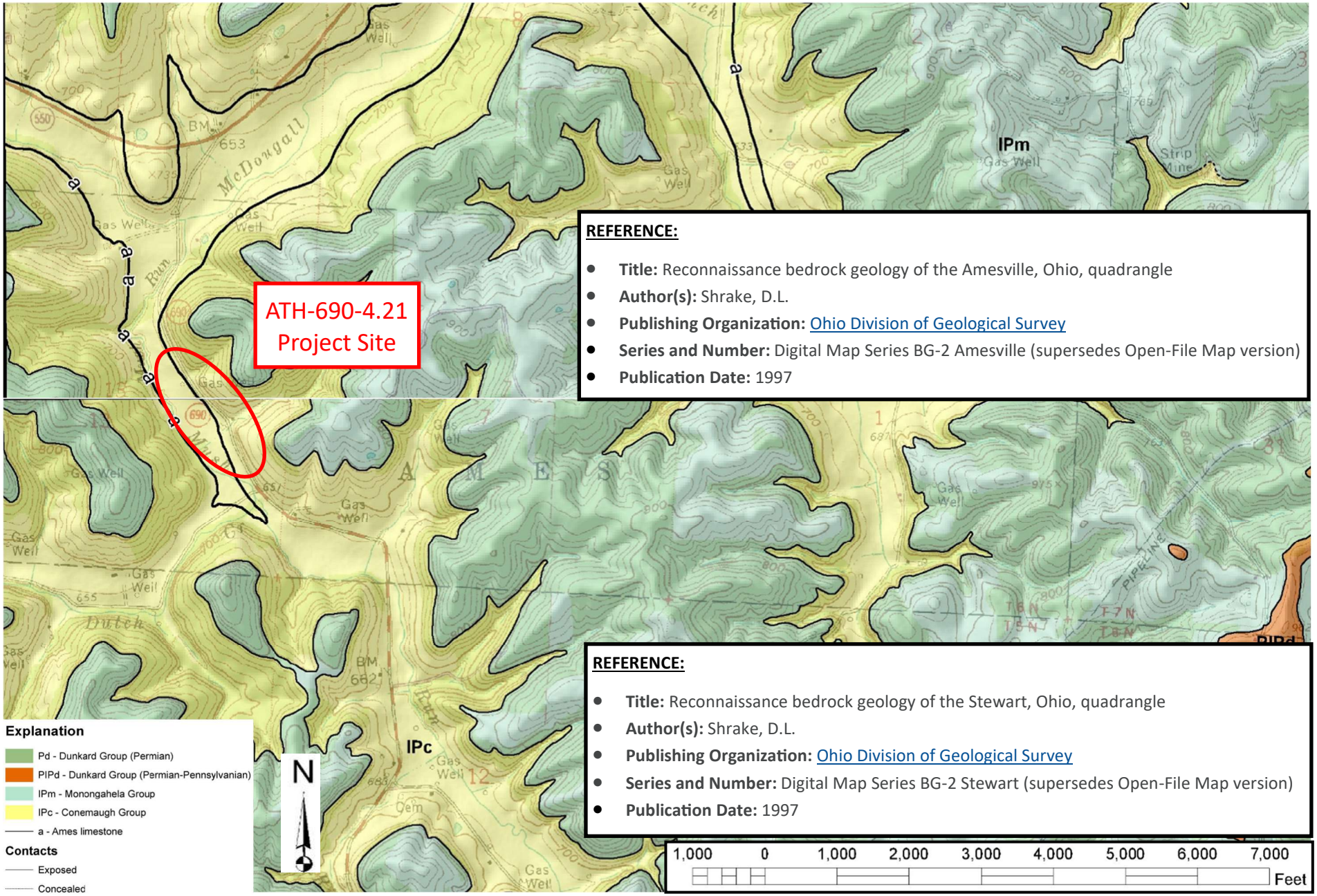
Dynamic Cone Penetration Test Log

Client:	ODOT District 10	**Operator Name / Company:**	JK / Advanced Materials, LLC
Project Name:	ATH-690-4.21 (10-X)	**Lat / Long:**	
Location:	D-002-1-23	**North / East:**	
Station, Offset:	Sta. 235+50, 75 LT (approx.)	**Date:**	2/6/2023
Elevation:	649.5 (approx)	**Sheet:**	2 of 2
Notes:	Staked Location		



Bedrock Geology Map

Bedrock Geology Map



REFERENCE:

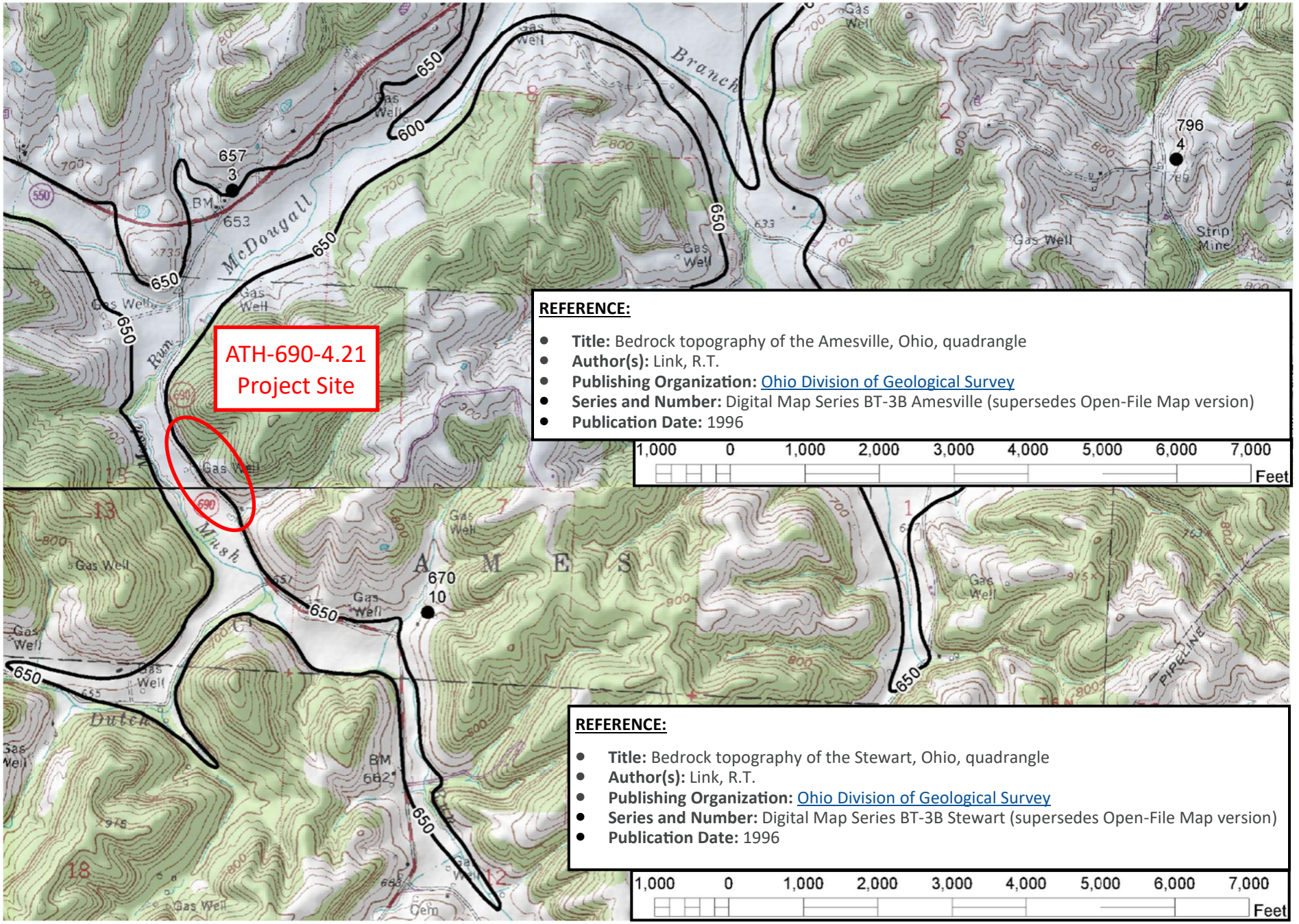
- **Title:** Reconnaissance bedrock geology of the Amesville, Ohio, quadrangle
- **Author(s):** Shrake, D.L.
- **Publishing Organization:** Ohio Division of Geological Survey
- **Series and Number:** Digital Map Series BG-2 Amesville (supersedes Open-File Map version)
- **Publication Date:** 1997

REFERENCE:

- **Title:** Reconnaissance bedrock geology of the Stewart, Ohio, quadrangle
- **Author(s):** Shrake, D.L.
- **Publishing Organization:** Ohio Division of Geological Survey
- **Series and Number:** Digital Map Series BG-2 Stewart (supersedes Open-File Map version)
- **Publication Date:** 1997

Bedrock Topography Map

Bedrock Topography Map



REFERENCE:

- **Title:** Bedrock topography of the Amesville, Ohio, quadrangle
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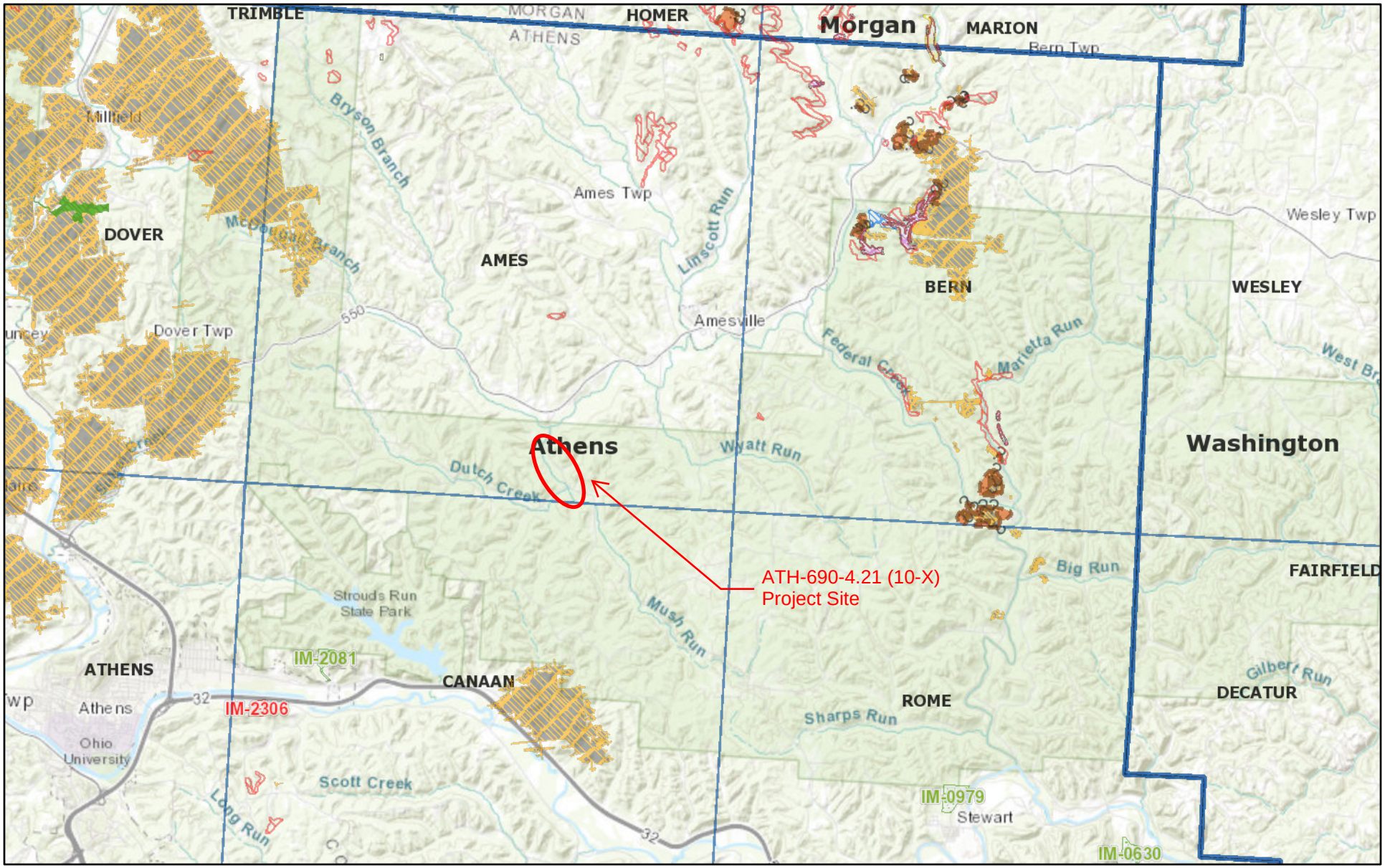
- **Series and Number:** Digital Map Series BT-3B Stewart (supersedes Open-File Map version)
- **Publication Date:** 1996

ODNR Mine Maps

ATH-690-4.21: Mines of Ohio



January 13, 2023

1:144,448

0 0.75 1.5 3 mi

0 1.5 3 6 km

Abandoned before 1977

Past

Current

Proposed

Original Application

Adjacent Area Application

Historic - From Geology Maps

Past

Current

Proposed

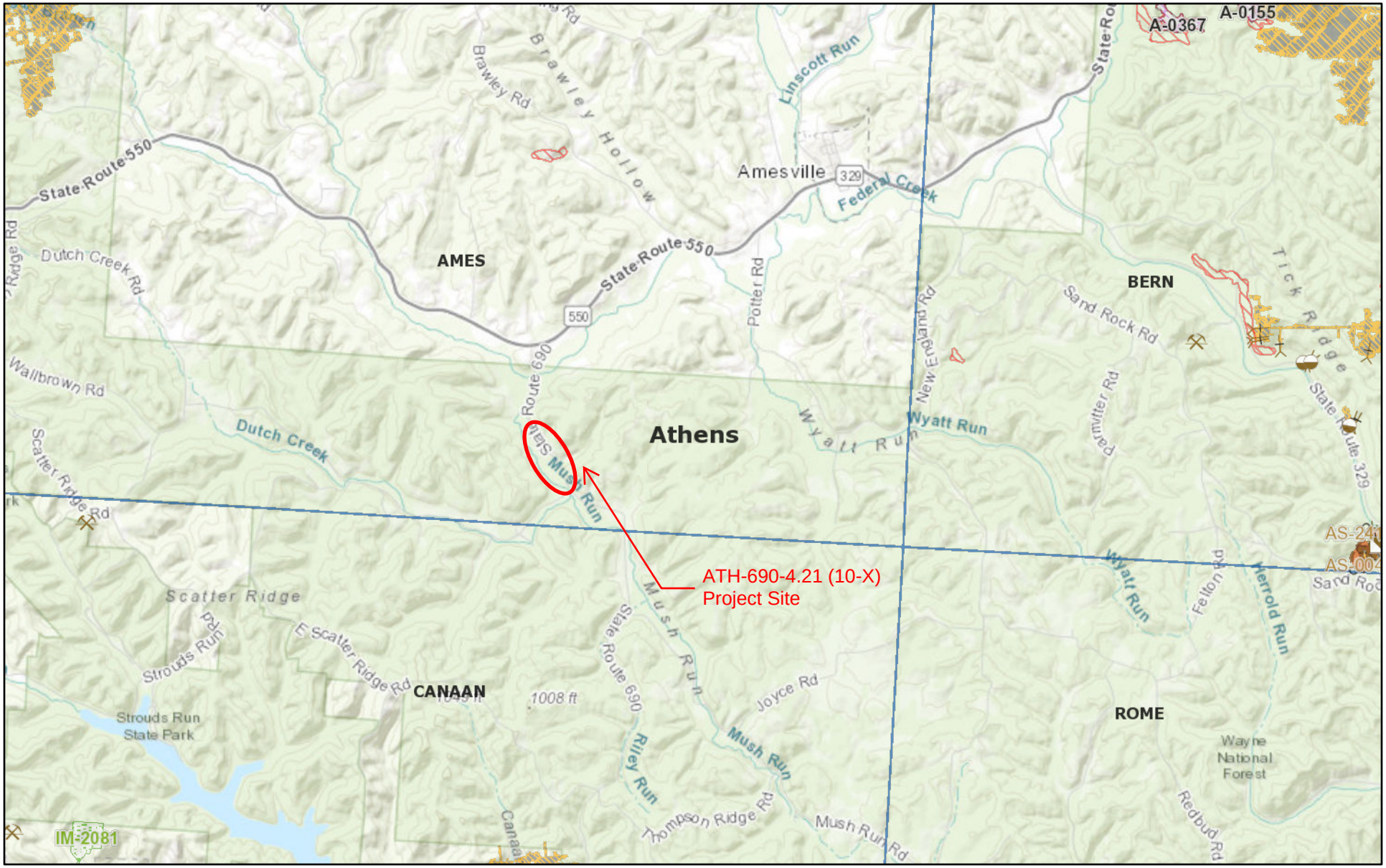
Original Application

Adjacent Area Application

VITA, West Virginia GIS, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS

Ohio Dept. of Natural Resources

ATH-690-4.21: Mines of Ohio



January 13, 2023

1:72,224

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0 0.75 1.5 3 km

VITA, West Virginia GIS, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS

Abandoned before 1977

Past

Current

Proposed

Original Application

Adjacent Area Application

Historic - From Geology Maps

Past

Current

Proposed

Original Application

Adjacent Area Application

Ohio Dept. of Natural Resources

FEMA Flood Map

National Flood Hazard Layer FIRMette

FEMA

81°59'41"W 39°22'44"N

81°59'4"W 39°22'17"N

0 250 500 1,000 1,500 2,000 Feet

1:6,000

Basemap: USGS National Map: Orthoimagery: Data refreshed October, 2020

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 Cross Sections with 1% Annual Chance
- 17.5 Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

N

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 1/13/2023 at 2:31 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

Soil Strength Parameter Determination
and
Laboratory Testing

9999 Carver Road, Suite 210, Blue Ash, OH 45242-5583 **hdrinc.com**
(513) 984-7500

ODOT District 10
ATH-690-4.21 (10-X)

Soil Strength Parameter Determination

Computed By = DCM
Checked By = AKB

Layer		Undrained Shear Strength (Su) (psf)				Dry Unit Weight (pcf)		Moist Unit Wt. (pcf)		Adopted Short Term Parameters		Long-Term Strength Values					Adopted Long Term Strength Parameters (Back-Calculated from SlopeW)	
		PPR	N-values		Tested	Correlation	Tested	Correlation	Tested			N_{60} Value	ODOT GB-7 Correlations		Tested			
			Sowers	T and P	Values								Cohesion (psf)	phi (deg)	Cohesion (psf)	phi (deg)		
Layer 1 1 - STIFF TO VERY STIFF COHESIVE	Max	4000	4000	4000	1003	120	105	130	127	S_u= 950 psf		Max	32	200	26		c' = 70 psf	
	Min	1000	700	532	945	90	103	105	126	Φ = 0 deg		Min	4	50	20		Φ' = 22 deg	
	Average	2464	1921	1382	974	100	104	121	127			Average	10	106	22			
	Std Dev	865	1186	889	41	8	1	5	1	Y_{dry} = 105 pcf		Std Dev	7	41	2		Y_{dry} = 105 pcf	
	Avg + Std	3330	3107	2271	1015	108	105	126	128	Y_{moist} = 125 pcf		Avg + Std	17	148	24		Y_{moist} = 125 pcf	
	Avg - Std	1599	734	493	932	92	103	117	126			Avg - Std	4	65	21			
Layer 2 2 - VERY STIFF TO HARD COLLUVIUM	Max	4500	4000	4000		125		135		S_u = 2250 psf		Max	48	250	28		c' = 160 psf	
	Min	2500	3000	1596		110		125		Φ = 0 deg		Min	12	129	23		Φ' = 24 deg	
	Average	3643	3833	3241		119		132				Average	32	211	26			
	Std Dev	748	408	995		6		4		Y_{dry} = 120 pcf		Std Dev	15	51	2		Y_{dry} = 120 pcf	
	Avg + Std	4391	4242	4236		125		136		Y_{moist} = 130 pcf		Avg + Std	46	262	28		Y_{moist} = 130 pcf	
	Avg - Std	2895	3425	2246		113		128				Avg - Std	17	159	24			
Layer 3 3 - HARD RESIDUUM	Max	4500	4000	4000		125		135		S_u = 3400 psf		Max	98	250	28		c' = 180 psf	
	Min	4000	4000	2926		120		135		Φ = 0 deg		Min	22	173	25		Φ' = 25 deg	
	Average	4333	4000	3821		124		135				Average	70	239	28			
	Std Dev	258	0	438		2		0		Y_{dry} = 125 pcf		Std Dev	28	29	1		Y_{dry} = 125 pcf	
	Avg + Std	4592	4000	4259		126		135		Y_{moist} = 135 pcf		Avg + Std	98	268	29		Y_{moist} = 135 pcf	
	Avg - Std	4075	4000	3383		122		135				Avg - Std	43	210	26			
Layer 4 BEDROCK	Max	N/A	N/A	N/A		N/A		N/A		S_u = 4000 psf		Max	113	250	28		c' = 250 psf	
	Min	N/A	N/A	N/A		N/A		N/A		Φ = 0 deg		Min	93	250	28		Φ' = 28 deg	
	Average	N/A	N/A	N/A		N/A		N/A				Average	106	250	28			
	Std Dev	N/A	N/A	N/A		N/A		N/A		Y_{dry} = 150 pcf		Std Dev	11	0	0		Y_{dry} = 150 pcf	
	Avg + Std	N/A	N/A	N/A		N/A		N/A		Y_{moist} = 155 pcf		Avg + Std	117	250	28		Y_{moist} = 155 pcf	
	Avg - Std	N/A	N/A	N/A		N/A		N/A				Avg - Std	95	250	28			
Layer 5 5 - SOFT COHESIVE	Max	N/A	875	665		N/A		N/A		S_u = 350 psf		Max	5	63	21		c' = 35 psf	
	Min	N/A	0	0		N/A		N/A		Φ = 0 deg		Min	0	15	15		Φ' = 18 deg	
	Average	N/A	461	350		N/A		N/A				Average	3	34	18			
	Std Dev	N/A	235	178		N/A		N/A		Y_{dry} = 120 pcf		Std Dev	1	15	2		Y_{dry} = 120 pcf	
	Avg + Std	N/A	695	528		N/A		N/A		Y_{moist} = 125 pcf		Avg + Std	4	49	20		Y_{moist} = 125 pcf	
	Avg - Std	N/A	226	172		N/A		N/A				Avg - Std	1	19	17			

ODOT District 10
ATH-690-4.21 (10-X)

Soil Strength Parameter Determination

Computed By = DCM
Checked By = AKB

Values for Soil Strength Correlation	
Reference	Value
HI PI (Sowers)	0.25
MD PI (Sowers)	0.175
LO PI (Sowers)	0.075
T&P	0.133

A-XY Assumed Classification for Calculation purposes

NOTE: Granular Soils in SS-1 in Boring B-001-0-23 and B-002-0-23 omitted

NOTE: SPT Values for DCP D-002-1-23 not adjusted to N60

Layer 1

	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)	Strength Testing Dry Unit Wt (pcf)	Moist Unit Wt (pcf)	Qu/UU Su (psf)
Max	32	100	4.0	2	7	10	53	78	60	28	35	28	4000	4000	4000	200	26	14.0	667.4	120	130	0.450	2.72	0.837	105	127	1003
Min	4	44	1.0	0	0	1	21	39	40	22	18	18	1000	700	532	50	20	2.0	635.5	90	105	0.270	2.65	0.378	103	126	945
Average	10	83	2.5	1	4	6	34	55	54	25	29	23	2464	1921	1382	106	22	9.3	646.7	100	121	0.398	2.70	0.558	104	127	974
Std Dev	7	18	0.9	1	3	3	12	13	7	3	6	3	865	1186	889	41	2	3.1	10.4	8	5	0.066	0.03	0.131	1	1	41
Avg + Std	17	101	3.3	2	6	9	46	68	61	27	35	25	3330	3107	2271	148	24	12.3	657.0	108	126	0.463	2.73	0.689	105	128	1015
Avg - Std	4	65	1.6	0	1	3	23	42	47	22	23	20	1599	734	493	65	21	6.2	636.3	92	117	0.332	2.66	0.428	103	126	932

Alignment	Surface Elevation	Exploration ID	From		To	Sample ID	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	ODOT Class.	Soil Type	Layer	Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)	Strength Testing Dry Unit Wt (pcf)	Moist Unit Wt (pcf)	Qu/UU Su (psf)
SR 690	671.4	B-003-0-23	3	-	4.5	SS-2	13	78	1.5	-	-	-	-	-	-	-	-	20	A-6b	Cohesive	1	1500	2275	1729	136	23	4.0	667.4	100	120		2.70	0.685			
SR 690	671.4	B-003-0-23	5	-	6.5	SS-3	14	100	2	0	3	5	53	39	40	22	18	21	A-6b	Cohesive	1	2000	2450	1862	143	24	6.0	665.4	105	125	0.27	2.70	0.605			
SR 690	671.4	B-003-0-23	7.5	-	9	SS-4	19	67	2.5	-	-	-	-	-	-	-	-	24	A-7-6	Cohesive	1	2500	4000	2527	163	25	8.0	663.4	110	125		2.65	0.503			
SR 690	671.4	B-003-0-23	10.5	-	12.5	ST-5	ST	100	4	1	1	6	44	48	56	28	28	23	A-7-6	Cohesive	1	4000	N/A	N/A			12.0	659.4			0.414	2.65		103.1	126.2	944.5
SR 690	671.4	B-003-0-23	12.5	-	14	SS-6	30	78	2.5	-	-	-	-	-	-	-	-	20	A-7-6	Cohesive	1	2500	4000	3990	200	26	13.0	658.4	115	130		2.65	0.438			
SR 690	667.4	B-002-0-23	4.5	-	6	SS-2	4	67	1	-	-	-	-	-	-	-	-	18	A-7-6	Cohesive	1	1000	1000	532	50	20	5.0	662.4	90	105		2.65	0.837			
SR 690	667.4	B-002-0-23	6	-	7.5	SS-3	16	100	1.5	0	0	1	21	78	60	28	32	28	A-7-6	Cohesive	1	1500	4000	2128	153	24	7.0	660.4	110	125	0.45	2.65	0.503			
SR 690	667.4	B-002-0-23	7.5	-	9	SS-4	32	78	3	-	-	-	-	-	-	-	-	25	A-7-6	Cohesive	1	3000	4000	4000	200	26	8.0	659.4	120	130		2.65	0.378			
SR 690	663.2	B-001-0-23	1	-	2.5	SS-1	12	44	3	-	-	-	-	-	-	-	-	20	A-7-6	Cohesive	1	3000	3000	1596	129	23	2.0	661.2	100	120		2.65	0.654			
SR 690	663.2	B-001-0-23	3.5	-	5	SS-2	10	67	1.5	2	7	10	31	50	53	23	30	25	A-7-6	Cohesive	1	1500	2500	1330	114	23	4.0	659.2	100	120	0.387	2.65	0.654			
SR 690	663.2	B-001-0-23	5	-	6.5	SS-3	17	100	2.5	-	-	-	-	-	-	-	-	27	A-7-6	Cohesive	1	2500	4000	2261	157	24	6.0	657.2	110	125		2.65	0.503			
SR 690	663.2	B-001-0-23	7.5	-	9	SS-4	19	83	3	-	-	-	-	-	-	-	-	23	A-7-6	Cohesive	1	3000	4000	2527	163	25	8.0	655.2	110	125		2.65	0.503			
SR 690	663.2	B-001-0-23	10.5	-	12.5	ST-5	ST	100	3	1	4	8	28	59	58	23	35	21	A-7-6	Cohesive	1	3000	N/A	N/A			12.0	651.2			0.432	2.65		105	127.4	1002.5
SR 690	663.2	B-001-0-23	12.5	-	14	SS-6	19	100	3.5	1	6	7	29	57	58	25	33	21	A-7-6	Cohesive	1	3500	4000	2527	163	25	13.0	650.2	115	130	0.432	2.65	0.438			
SR 690	649.5	D-002-1-23	6.2	-	6.6		8	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	1400	1064	100	22	6	644	95	120		2.72				
SR 690	649.5	D-002-1-23	6.6	-	6.9		8	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	1400	1064	100	22	7	643	95	120		2.72				
SR 690	649.5	D-002-1-23	6.9	-	7.2		6	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	1050	798	75	21	7	643	95	120		2.72				
SR 690	649.5	D-002-1-23	7.2	-	7.5		8	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	1400	1064	100	22	7	643	95	120		2.72				
SR 690	649.5	D-002-1-23	7.5	-	7.9		7	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	1225	931	88	22	8	642	95	120		2.72				
SR 690	649.5	D-002-1-23	7.9	-	8.2		7	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	1225	931	88	22	8	642	95	120		2.72				
SR 690	649.5	D-002-1-23	8.2	-	8.5		7	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	1225	931	88	22	8	642	95	120		2.72				
SR 690	649.5	D-002-1-23	8.5	-	8.9		8	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	1400	1064	100	22	9	641	95	120		2.72				
SR 690	649.5	D-002-1-23	8.9	-	9.2		7	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	1225	931	88	22	9	641	95	120		2.72				
SR 690	649.5	D-002-1-23	9.2	-	9.5		5	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	875	665	63	21	9	641	95	120		2.72				
SR 690	649.5	D-002-1-23	9.5	-	9.8		11	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	1925	1463	121	23	10	640	105	125		2.72				
SR 690	649.5	D-002-1-23	9.8	-	10.2		8	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	1400	1064	100	22	10	640	95	120		2.72				
SR 690	649.5	D-002-1-23	10.2	-	10.5		7	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	1225	931	88	22	10	640	95	120		2.72				
SR 690	649.5	D-002-1-23	10.5	-	10.8		6	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	1050	798	75	21	11	639	95	120		2.72				
SR 690	649.5	D-002-1-23	10.8	-	11.2		5	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	875	665	63	21	11	639	95	120		2.72				
SR 690	649.5	D-002-1-23	11.2	-	11.5		5	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	875	665	63	21	11	639	95	120		2.72				
SR 690	649.5	D-002-1-23	11.5	-	11.8		5	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	875	665	63	21	12	638	95	120		2.72				
SR 690	649.5	D-002-1-23	11.8	-	12.1		4	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	700	532	50	20	12	638	95	115		2.72				
SR 690	649.5	D-002-1-23	12.1	-	12.5		5	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	875	665	63	21	12	638	95	120		2.72				
SR 690	649.5	D-002-1-23	12.5	-	12.8		7	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	1225	931	88	22	13	637	95	120		2.72				
SR 690	649.5	D-002-1-23	12.8	-	13.1		7	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	1225	931	88	22	13	637	95	120		2.72				
SR 690	649.5	D-002-1-23	13.1	-	13.5		6	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	1050	798	75	21	13	637	95	120		2.72				
SR 690	649.5	D-002-1-23	13.5	-	13.8		6	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	1050	798	75	21	14	636	95	120		2.72				
SR 690	649.5	D-002-1-23	13.8	-	14.1		18	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	1	N/A	3150	2394	160	24	14	636	115	130		2.72				

Values for Soil Strength Correlation	
Reference	Value
HI PI (Sowers)	0.25
MD PI (Sowers)	0.175
LO PI (Sowers)	0.075
T&P	0.133

Layer 2

	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC		Short-Term Cohesion (psf) PPR	N-values Sowers	N-values T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)
Max	48	100	4.5	14	12	11	40	48	46	25	23	19	Max	4500	4000	4000	250	28	21.0	657.4	125	135	0.324	2.70	0.503
Min	12	56	2.5	4	4	7	29	31	38	22	16	9	Min	2500	3000	1596	129	23	10.0	642.2	110	125	0.252	2.65	0.323
Average	32	86	3.6	9	9	9	35	39	43	23	20	16	Average	3643	3833	3241	211	26	14.7	650.9	119	132	0.300	2.66	0.395
Std Dev	15	14	0.7	5	4	2	6	9	5	2	4	4	Std Dev	748	408	995	51	2	3.9	6.0	6	4	0.042	0.02	0.066
Avg + Std	46	100	4.4	14	13	11	41	48	48	25	24	20	Avg + Std	4391	4242	4236	262	28	18.6	656.8	125	136	0.342	2.69	0.460
Avg - Std	17	72	2.9	4	5	7	29	30	39	22	16	12	Avg - Std	2895	3425	2246	159	24	10.8	644.9	113	128	0.258	2.64	0.329

Alignment	Surface Elevation	Exploration ID	From		To	Sample ID	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	ODOT Class.	Soil Type	Layer	Short-Term Cohesion (psf) PPR	N-values Sowers	N-values T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)
SR 690	667.4	B-002-0-23	9	-	10.5	SS-5	43	83	3.5	-	-	-	-	-	-	-	-	18	A-7-6	Cohesive	2	3500	4000	4000	250	28	10.0	657.4	120	130		2.65	0.378
SR 690	667.4	B-002-0-23	10.5	-	12	SS-6	48	100	4	14	12	7	29	38	46	25	21	13	A-7-6	Cohesive	2	4000	4000	4000	250	28	11.0	656.4	125	135	0.324	2.65	0.323
SR 690	667.4	B-002-0-23	12	-	13.5	SS-7	42	56	4.5	-	-	-	-	-	-	-	-	19	A-6b	Cohesive	2	4500	4000	4000	250	28	13.0	654.4	125	135		2.70	0.348
SR 690	667.4	B-002-0-23	13.5	-	14.92	SS-8	REFUSAL	94	4.5	8	10	11	40	31	38	22	16	9	A-6b	Cohesive	2	4500	N/A	N/A	250	28	14.0	653.4			0.252	2.70	
SR 690	663.2	B-001-0-23	15	-	16.5	SS-7	12	89	3	-	-	-	-	-	-	-	-	18	A-7-6	Cohesive	2	3000	3000	1596	129	23	16.0	647.2	110	125		2.65	0.503
SR 690	663.2	B-001-0-23	17.5	-	19	SS-8	19	89	2.5	4	4	8	36	48	46	23	23	19	A-7-6	Cohesive	2	2500	4000	2527	163	25	18.0	645.2	115	130	0.324	2.65	0.438
SR 690	663.2	B-001-0-23	20	-	21.5	SS-9	25	89	3.5	-	-	-	-	-	-	-	-	16	A-7-6	Cohesive	2	3500	4000	3325	183	25	21.0	642.2	120	135		2.65	0.378

Values for Soil Strength Correlation	
Reference	Value
HI PI (Sowers)	0.25
MD PI (Sowers)	0.175
LO PI (Sowers)	0.075
T&P	0.133

Layer 3

	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC		Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)
Max	98	100	4.5	13	27	10	49	48	47	24	23	18	Max	4500	4000	4000	250	28	23.0	655.4	125	135	0.333	2.70	0.378
Min	22	89	4.0	0	1	4	28	22	40	22	18	10	Min	4000	4000	2926	173	25	16.0	640.2	120	135	0.270	2.65	0.323
Average	70	97	4.3	3	7	6	43	40	43	23	20	12	Average	4333	4000	3821	239	28	18.3	649.7	124	135	0.299	2.66	0.340
Std Dev	28	5	0.3	6	11	3	9	11	3	1	2	3	Std Dev	258	0	438	29	1	2.5	4.9	2	0	0.023	0.02	0.022
Avg + Std	98	102	4.6	9	18	9	52	51	46	24	22	15	Avg + Std	4592	4000	4259	268	29	20.8	654.6	126	135	0.322	2.69	0.363
Avg - Std	43	92	4.1	-2	-4	4	34	30	41	22	18	9	Avg - Std	4075	4000	3383	210	26	15.8	644.7	122	135	0.276	2.64	0.318

Alignment	Surface Elevation	Exploration ID	From		To	Sample ID	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	ODOT Class.	Soil Type	Layer	Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)
SR 690	671.4	B-003-0-23	15	-	16.5	SS-7	56	100	4	0	3	8	42	47	42	23	19	11	A-7-6	Cohesive	3	4000	4000	4000	250	28	16.0	655.4	125	135	0.288	2.65	0.323
SR 690	671.4	B-003-0-23	17.5	-	19	SS-8	74	100	4	0	3	4	49	44	47	24	23	12	A-7-6	Cohesive	3	4000	4000	4000	250	28	18.0	653.4	125	135	0.333	2.65	0.323
SR 690	667.4	B-002-0-23	15	-	16.5	SS-9	98	89	4.5	-	-	-	-	-	-	-	-	10	A-6b	Cohesive	3	4500	4000	4000	250	28	16.0	651.4	125	135		2.70	0.348
SR 690	667.4	B-002-0-23	16.5	-	18	SS-10	81	100	4.5	0	1	5	46	48	40	22	18	10	A-6b	Cohesive	3	4500	4000	4000	250	28	17.0	650.4	125	135	0.27	2.70	0.348
SR 690	667.4	B-002-0-23	18	-	18.92	SS-11	REFUSAL	91	4.5	-	-	-	-	-	-	-	-	11	A-7-6	Cohesive	3	4500	N/A	N/A	250	28	18.0	649.4				2.65	
SR 690	667.4	B-002-0-23	19.5	-	21	SS-12	90	100	4.5	3	2	5	49	41	44	23	21	11	A-7-6	Cohesive	3	4500	4000	4000	250	28	20.0	647.4	125	135	0.306	2.65	0.323
SR 690	663.2	B-001-0-23	22.5	-	24	SS-10	22	100	-	13	27	10	28	22	43	24	19	18	A-7-6	Cohesive	3	N/A	4000	2926	173	25	23.0	640.2	120	135	0.297	2.65	0.378

Values for Soil Strength Correlation	
Reference	Value
HI PI (Sowers)	0.25
MD PI (Sowers)	0.175
LO PI (Sowers)	0.075
T&P	0.133

Layer 4

	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC		Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)
Max	113	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	20	Max	N/A	N/A	N/A	250	28	30.0	650.4	N/A	N/A	N/A	N/A	N/A
Min	93	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6	Min	N/A	N/A	N/A	250	28	21.0	635.2	N/A	N/A	N/A	N/A	N/A
Average	106	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	10	Average	N/A	N/A	N/A	250	28	25.0	643.6	N/A	N/A	N/A	N/A	N/A
Std Dev	11	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4	Std Dev	N/A	N/A	N/A	0	0	2.9	4.7	N/A	N/A	N/A	N/A	N/A
Avg + Std	117	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	14	Avg + Std	N/A	N/A	N/A	250	28	27.9	648.2	N/A	N/A	N/A	N/A	N/A
Avg - Std	95	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6	Avg - Std	N/A	N/A	N/A	250	28	22.1	638.9	N/A	N/A	N/A	N/A	N/A

Alignment	Surface Elevation	Exploration ID	From		To	Sample ID	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	ODOT Class.	Soil Type	Layer	Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)
SR 690	671.4	B-003-0-23	20	-	21.5	SS-9	113	100	-	-	-	-	-	-	-	-	-	11	Rock		4	N/A	N/A	N/A	250	28	21.0	650.4				
SR 690	671.4	B-003-0-23	22.5	-	24	SS-10	111	100	-	-	-	-	-	-	-	-	-	11	Rock		4	N/A	N/A	N/A	250	28	23.0	648.4				
SR 690	671.4	B-003-0-23	25	-	25.92	SS-11	REFUSAL	100	-	-	-	-	-	-	-	-	-	10	Rock		4	N/A	N/A	N/A	250	28	25.0	646.4				
SR 690	671.4	B-003-0-23	27.5	-	27.92	SS-12	REFUSAL	100	-	-	-	-	-	-	-	-	-	9	Rock		4	N/A	N/A	N/A	250	28	28.0	643.4				
SR 690	671.4	B-003-0-23	30	-	30.33	SS-13	REFUSAL	100	-	-	-	-	-	-	-	-	-	6	Rock		4	N/A	N/A	N/A	250	28	30.0	641.4				
SR 690	667.4	B-002-0-23	21	-	22.3	SS-13	REFUSAL	100	-	-	-	-	-	-	-	-	-	9	Rock		4	N/A	N/A	N/A	250	28	22.0	645.4				
SR 690	667.4	B-002-0-23	22.5	-	23.25	SS-14	REFUSAL	100	-	-	-	-	-	-	-	-	-	6	Rock		4	N/A	N/A	N/A	250	28	23.0	644.4				
SR 690	667.4	B-002-0-23	24	-	24.5	SS-15	REFUSAL	100	-	-	-	-	-	-	-	-	-	7	Rock		4	N/A	N/A	N/A	250	28	24.0	643.4				
SR 690	663.2	B-001-0-23	25	-	26.5	SS-11	93	100	-	-	-	-	-	-	-	-	-	12	Rock		4	N/A	N/A	N/A	250	28	26.0	637.2				
SR 690	663.2	B-001-0-23	27.5	-	28	SS-12	REFUSAL	100	-	-	-	-	-	-	-	-	-	20	Rock		4	N/A	N/A	N/A	250	28	28.0	635.2				

Values for Soil Strength Correlation	
Reference	Value
HI PI (Sowers)	0.25
MD PI (Sowers)	0.175
LO PI (Sowers)	0.075
T&P	0.133

A-XY Assumed Classification for Calculation purposes

NOTE: SPT Values for DCP D-002-1-23 not adjusted to N60

Layer 5

	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC		Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)
Max	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Max	N/A	875	665	63	21	6.0	649.5	N/A	N/A	N/A	2.72	N/A
Min	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Min	N/A	0	0	15	15	0.0	643.5	N/A	N/A	N/A	2.72	N/A
Average	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Average	N/A	461	350	34	18	3.0	646.5	N/A	N/A	N/A	2.72	N/A
Std Dev	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Std Dev	N/A	235	178	15	2	1.9	1.9	N/A	N/A	N/A	0.00	N/A
Avg + Std	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Avg + Std	N/A	695	528	49	20	4.9	648.4	N/A	N/A	N/A	2.72	N/A
Avg - Std	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Avg - Std	N/A	226	172	19	17	1.1	644.6	N/A	N/A	N/A	2.72	N/A

Alignment	Surface Elevation	Exploration ID	From		To	Sample ID	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	ODOT Class.	Soil Type	Layer	Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)
SR 690	649.5	D-002-1-23	0.0	-	0.3		0	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	5	N/A	0	0	15	15	0.0	649.5	#N/A	#N/A		2.72	#N/A
SR 690	649.5	D-002-1-23	0.3	-	0.7		2	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	5	N/A	350	266	25	18	0.0	649.5	#N/A	#N/A		2.72	#N/A
SR 690	649.5	D-002-1-23	0.7	-	1.0		2	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	5	N/A	350	266	25	18	1.0	648.5	85	105		2.72	0.997
SR 690	649.5	D-002-1-23	1.0	-	1.3		3	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	5	N/A	525	399	38	19	1.0	648.5	90	105		2.72	0.886
SR 690	649.5	D-002-1-23	1.3	-	1.6		2	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	5	N/A	350	266	25	18	1.0	648.5	85	105		2.72	0.997
SR 690	649.5	D-002-1-23	1.6	-	2.0		2	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	5	N/A	350	266	25	18	2.0	647.5	85	105		2.72	0.997
SR 690	649.5	D-002-1-23	2.0	-	2.3		2	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	5	N/A	350	266	25	18	2.0	647.5	85	105		2.72	0.997
SR 690	649.5	D-002-1-23	2.3	-	2.6		2	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	5	N/A	350	266	25	18	2.0	647.5	85	105		2.72	0.997
SR 690	649.5	D-002-1-23	2.6	-	3.0		2	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	5	N/A	350	266	25	18	3.0	646.5	85	105		2.72	0.997
SR 690	649.5	D-002-1-23	3.0	-	3.3		2	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	5	N/A	350	266	25	18	3.0	646.5	85	105		2.72	0.997
SR 690	649.5	D-002-1-23	3.3	-	3.6		1	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	5	N/A	175	133	15	15	3.0	646.5	85	105		2.72	0.997
SR 690	649.5	D-002-1-23	3.6	-	3.9		3	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	5	N/A	525	399	38	19	4.0	645.5	90	105		2.72	0.886
SR 690	649.5	D-002-1-23	3.9	-	4.3		2	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	5	N/A	350	266	25	18	4.0	645.5	85	105		2.72	0.997
SR 690	649.5	D-002-1-23	4.3	-	4.6		3	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	5	N/A	525	399	38	19	4.0	645.5	90	105		2.72	0.886
SR 690	649.5	D-002-1-23	4.6	-	4.9		3	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	5	N/A	525	399	38	19	5.0	644.5	90	105		2.72	0.886
SR 690	649.5	D-002-1-23	4.9	-	5.3		4	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	5	N/A	700	532	50	20	5.0	644.5	90	105		2.72	0.886
SR 690	649.5	D-002-1-23	5.3	-	5.6		5	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	5	N/A	875	665	63	21	5.0	644.5	95	110		2.72	0.787
SR 690	649.5	D-002-1-23	5.6	-	5.9		5	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	5	N/A	875	665	63	21	6.0	643.5	95	120		2.72	0.787
SR 690	649.5	D-002-1-23	5.9	-	6.2		5	-	-	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	5	N/A	875	665	63	21	6.0	643.5	95	120		2.72	0.787

National Engineering & Architectural Services Inc.
5710 Westbourne Avenue
Columbus, OH 43213
614-892-0162

Unconfined Compressive Strength of Cohesive Soil (ASTM D2166)

(Project: ATH-690-4.21, Boring Location: B-001-0-23, ST-5, Depth: 11.8 - 12.3ft)

Tested Date: 1/16/2023

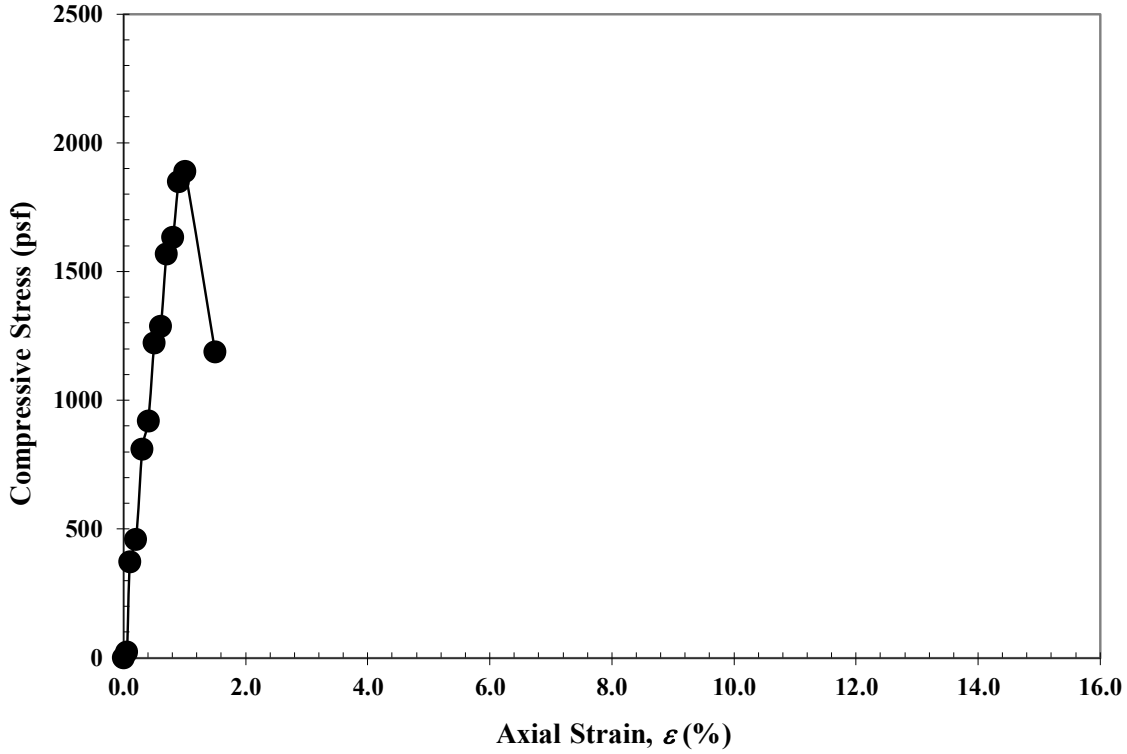
Specimen Properties

Average Dia., D_{avg} (in):	2.89
Average Height, H_{avg} (in):	5.75
Area, A (in^2):	6.57
Volume, V (in^3):	37.74
Wet Mass of Specimen (lb):	2.8
Moisture Content (%):	22.4
Dry Mass of Specimen (lb):	2.3
Wet Unit Weight, γ (lb/ft^3):	126.2
Dry Unit Weight, γ_d (lb/ft^3):	103.1

Final Specimen Figure

Results

Unconfined Compressive Strength (psf):	**1889**
Strain (%):	**1.0**



Notes: Medium stiff, brown and maroonish brown, CLAY, "and" silt, trace sand, trace gravel, damp. Specimen mode of failure was a distinct diagonal shear along what appears to be a pre-existing slickenslide.

National Engineering & Architectural Services Inc.
5710 Westbourne Avenue
Columbus, OH 43213
614-892-0162

Unconfined Compressive Strength of Cohesive Soil (ASTM D2166)

(Project: ATH-690-4.21, Boring Location: B-003-0-23, ST-5, Depth: 11.6 - 12.1ft)

Tested Date: 1/16/2023

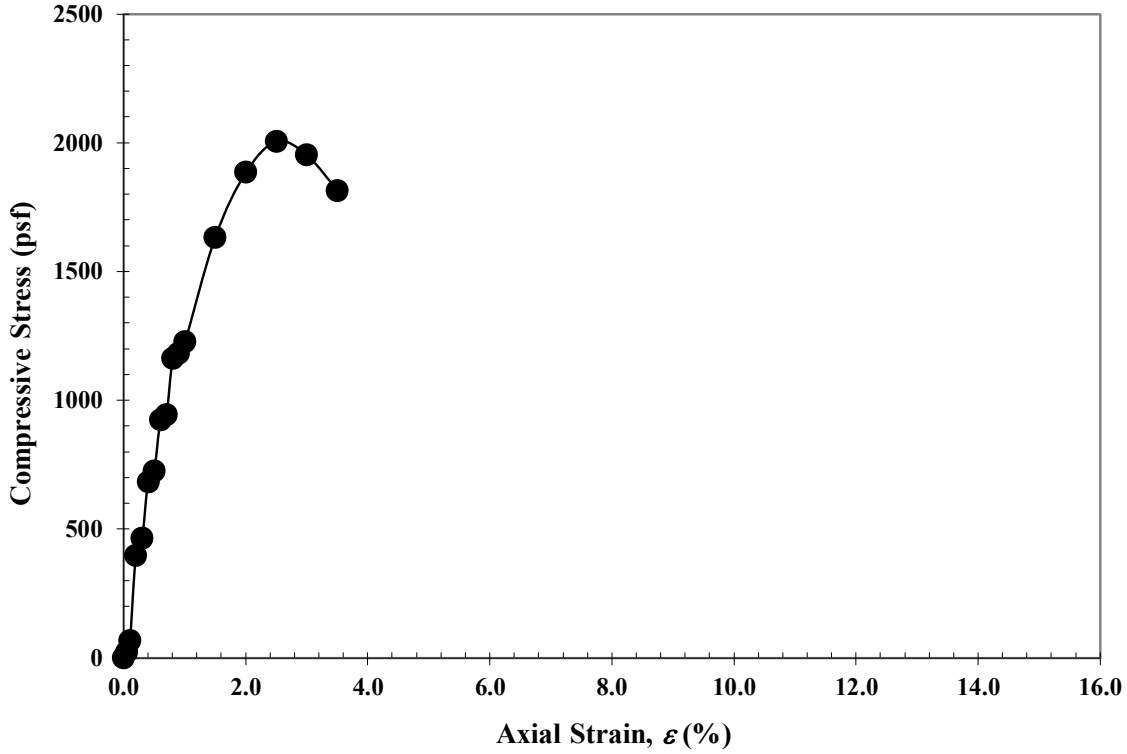
Specimen Properties

Average Dia., D_{avg} (in):	2.88
Average Height, H_{avg} (in):	5.74
Area, A (in^2):	6.51
Volume, V (in^3):	37.41
Wet Mass of Specimen (lb):	2.8
Moisture Content (%):	21.3
Dry Mass of Specimen (lb):	2.3
Wet Unit Weight, γ (lb/ft^3):	127.4
Dry Unit Weight, γ_d (lb/ft^3):	105.0

Final Specimen Figure

Results

Unconfined Compressive Strength (psf):	**2005**
Strain (%):	**2.5**



Notes: Stiff, brown, CLAY, some silt, little sand, trace gravel, damp.

PROJECT: ATH-690-04.21	DRILLING FIRM / OPERATOR: CENTRAL STAR / TS	DRILL RIG: DIEDRICH D-50 (SN 481)	STATION / OFFSET: 234+88, 6' LT.	EXPLORATION ID B-001-0-23
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: HDR / DM	HAMMER: AUTOMATIC HAMMER	ALIGNMENT: SR 690	
PID: 114592 SFN:	DRILLING METHOD: 2.25 HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 663.2 (MSL) EOB: 49.5 ft.	PAGE 1 OF 2
START: 1/9/23 END: 1/9/23	SAMPLING METHOD: SPT / ST / NQ2	ENERGY RATIO (%): 86.8	LAT / LONG: 39.375147, -81.989717	

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
18 inches of Asphalt	663.2																	
	661.7		8 4 4	12	44	SS-1	3.00	-	-	-	-	-	-	-	-	20	A-7-6 (V)	
STIFF TO VERY STIFF, BROWN TRACE MOTTLED GRAY, **CLAY**, SOME SILT, LITTLE SAND, TRACE STONE FRAGMENTS, MOIST			3 4 3	10	67	SS-2	1.50	2	7	10	31	50	53	23	30	25	A-7-6 (19)	
			3 5 7	17	100	SS-3	2.50	-	-	-	-	-	-	-	-	27	A-7-6 (V)	
	655.7																	
STIFF TO VERY STIFF, BROWN TO RED-BROWN MOTTLED GRAY, **CLAY**, SOME SILT, LITTLE SAND, TRACE STONE FRAGMENTS, DAMP			4 5 8	19	83	SS-4	3.00	-	-	-	-	-	-	-	-	23	A-7-6 (V)	
1 - Stiff to Very Stiff Cohesive					100	ST-5	3.00	1	4	8	28	59	58	23	35	21	A-7-6 (20)	
Below 11.5' : Orange-Brown @ 11.6' - 12.1' : qu = 2005 psf			4 4 9	19	100	SS-6	3.50	1	6	7	29	57	58	25	33	21	A-7-6 (20)	
	648.2																	
STIFF TO VERY STIFF, ORANGE-BROWN AND LIGHT BROWN, **CLAY**, "AND" SILT, LITTLE SAND, TRACE STONE FRAGMENTS, DAMP			4 4 4	12	89	SS-7	3.00	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
2 - Very Stiff to Hard Colluvium			4 5 8	19	89	SS-8	2.50	4	4	8	36	48	46	23	23	19	A-7-6 (14)	
@ 21.0' - 21.5' : Trace Red-Brown			5 6 11	25	89	SS-9	3.50	-	-	-	-	-	-	-	-	16	A-7-6 (V)	
	640.7	W 640.7																
VERY STIFF, RED-BROWN AND LIGHT BROWN, **CLAY**, "AND" SAND, SOME SILT, LITTLE STONE FRAGMENTS, (RELIC ROCK STRUCTURE), DAMP			4 5 10	22	100	SS-10	-	13	27	10	28	22	43	24	19	18	A-7-6 (6)	
3 - Hard Residuum	638.2	TR																
SHALE, RED-BROWN AND LIGHT BROWN, HIGHLY WEATHERED, VERY WEAK, FRIABLE.			12 18 46	93	100	SS-11	-	-	-	-	-	-	-	-	-	12	Rock (V)	
			50/6"	-	102	SS-12	-	-	-	-	-	-	-	-	-	20	Rock (V)	
	633.7																	

PID: 114592	SFN:	PROJECT: ATH-690-04.21	STATION / OFFSET: 234+88, 6' LT.	START: 1/9/23	END: 1/9/23	PG 2 OF 2	B-001-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
SHALE, RED-BROWN AND GRAY, HIGHLY WEATHERED, VERY WEAK, VERY THIN TO THIN BEDDED, FRIABLE, JOINT AND BEDDING DISCONTINUITIES, FRACTURED TO MODERATELY FRACTURED, TIGHT APERTURE, SLICKENSIDED, LAMINATED, VERY POOR TO POOR SURFACE CONDITIONS; RQD 54%, REC 83%. *(continued)* @ 33.0' - 34.0' : Highly Fractured, Calcareous @ 33.0' - 34.9' : Transition to Brownish Gray then Gray	633.2	31 32 33 34 35	48		77	NQ2-1											CORE	
LIMESTONE, GRAY, SLIGHTLY WEATHERED, STRONG, THICK BEDDED, CRYSTALLINE, BEDDING DISCONTINUITIES, SLIGHTLY FRACTURED, TIGHT APERTURE, ROUGH SURFACE, BLOCKY, GOOD SURFACE CONDITIONS; RQD 100%, REC 100%.	628.3 626.5	36 37	92		100	NQ2-2											CORE	
SHALE, GRAY, MODERATELY TO HIGHLY WEATHERED, VERY WEAK, MEDIUM BEDDED, BEDDING DISCONTINUITIES, MODERATELY FRACTURED, TIGHT APERTURE, LAMINATED, SLICKENSIDED, POOR SURFACE CONDITIONS; RQD 100%, REC 100%.	625.3	38 39 40 41 42 43 44	94		100	NQ2-3											CORE	
SANDSTONE, GRAY, UNWEATHERED TO SLIGHTLY WEATHERED, MODERATELY STRONG, FINE TO MEDIUM GRAINED, THICK TO VERY THICK BEDDED, JOINT AND BEDDING DISCONTINUITIES, SLIGHTLY FRACTURED TO INTACT, TIGHT TO OPEN APERTURE, SLIGHTY ROUGH, BLOCKY, VERY GOOD SURFACE CONDITIONS; RQD 96%, REC 100%. @ 43.9' - 44.3' : Qu = 5983 psi @ 48.5' - 49.5' : Dark Gray, Carbonaceous	613.7	45 46 47 48 49 EOB	97		100	NQ2-4											CORE	

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 20 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

PROJECT: ATH-690-04.21	DRILLING FIRM / OPERATOR: CENTRAL STAR / TS	DRILL RIG: DIEDRICH D-50 (SN 481)	STATION / OFFSET: 235+87, 7' LT.	EXPLORATION ID B-002-0-23
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: HDR / DM	HAMMER: AUTOMATIC HAMMER	ALIGNMENT: SR 690	
PID: 114592 SFN:	DRILLING METHOD: 2.25 HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 667.4 (MSL) EOB: 44.8 ft.	PAGE 1 OF 2
START: 1/10/23 END: 1/11/23	SAMPLING METHOD: SPT / NQ2	ENERGY RATIO (%): 86.8	LAT / LONG: 39.375334, -81.989969	

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
42 inches of Asphalt	667.4																	
	663.4		16 6 5	16	78	SS-1	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	
MEDIUM DENSE, LIGHT BROWN, **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP	662.9		2 1 2	4	67	SS-2	1.00	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
STIFF TO VERY STIFF, BROWN AND GRAY, **CLAY**, SOME SAND, SOME SILT, DAMP			3 4 7	16	100	SS-3	1.50	0	0	1	21	78	60	28	32	28	A-7-6 (20)	
1 - Stiff to Very Stiff Cohesive			5 8 14	32	78	SS-4	3.00	-	-	-	-	-	-	-	-	25	A-7-6 (V)	
	658.4																	
@ 9.0' - Auger Grinding Prior to SPT Sampling			6 12 18	43	83	SS-5	3.50	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
VERY STIFF TO HARD, LIGHT BROWN TRACE RED-BROWN AND GRAY, **CLAY**, SOME SILT, LITTLE SAND, LITTLE STONE FRAGMENTS, DAMP	655.4		9 17 16	48	100	SS-6	4.00	14	12	7	29	38	46	25	21	13	A-7-6 (12)	
HARD, RED-BROWN, **SILTY CLAY**, SOME SAND, TRACE STONE FRAGMENTS, DAMP (Colluvium)			9 12 17	42	56	SS-7	4.50	-	-	-	-	-	-	-	-	19	A-6b (V)	
2 - Very Stiff to Hard Colluvium			11 40 50/5"	-	94	SS-8	4.50	8	10	11	40	31	38	22	16	9	A-6b (10)	
	652.4																	
HARD, RED-BROWN, GRAY AND LIGHT BROWN, **SILTY CLAY**, TRACE SAND, DAMP (Possible Colluvium)			35 28 40	98	89	SS-9	4.50	-	-	-	-	-	-	-	-	10	A-6b (V)	
3 - Hard Residuum			22 26 30	81	100	SS-10	4.50	0	1	5	46	48	40	22	18	10	A-6b (11)	
	649.4		27 50/5"	-	91	SS-11	4.50	-	-	-	-	-	-	-	-	11	A-7-6 (V)	
HARD, RED-BROWN, GRAY AND LIGHT BROWN, **CLAY**, "AND" SILT, TRACE SAND, TRACE STONE FRAGMENTS, (RELIC ROCK STRUCTURE), DAMP (Residuum)			18 31 31	90	100	SS-12	4.50	3	2	5	49	41	44	23	21	11	A-7-6 (13)	
	646.4	TR																
SHALE, GRAY TO BROWN-GRAY, MODERATELY TO HIGHLY WEATHERED, VERY WEAK.	644.9		26 43 50/4"	-	100	SS-13	-	-	-	-	-	-	-	-	-	9	Rock (V)	
SHALE, GRAY, MODERATELY WEATHERED, VERY WEAK.			47 50/3"	-	100	SS-14	-	-	-	-	-	-	-	-	-	6	Rock (V)	
@ 24.0' - 24.5' : Gray and Red-Brown			50/6"	-	102	SS-15	-	-	-	-	-	-	-	-	-	7	Rock (V)	
	641.4																	
SHALE, RED-BROWN AND GRAY, MODERATELY TO HIGHLY WEATHERED, WEAK, MEDIUM BEDDED, JOINT AND BEDDING DISCONTINUITIES, FRACTURED TO SLIGHTLY FRACTURED, NARROW TO OPEN APERTURE, SLICKENSIDED TO SLIGHTLY ROUGH, BLOCKY, FAIR SURFACE CONDITION; RQD 34%, REC 97%. @ 28.2' - 29.1' : Gray			27		100	NQ2-1											CORE	

PID: 114592	SFN:	PROJECT: ATH-690-04.21	STATION / OFFSET: 235+87, 7' LT.	START: 1/10/23	END: 1/11/23	PG 2 OF 2	B-002-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
SHALE, RED-BROWN AND GRAY, MODERATELY TO HIGHLY WEATHERED, WEAK, MEDIUM BEDDED, JOINT AND BEDDING DISCONTINUITIES, FRACTURED TO SLIGHTLY FRACTURED, NARROW TO OPEN APERTURE, SLICKENSIDED TO SLIGHTLY ROUGH, BLOCKY, FAIR SURFACE CONDITION; RQD 34%, REC 97%. *(continued)* @ 32.8' - 36.9' : Gray and Dark Gray @ 33.1' - 33.5' : Qu = 824 psi @ 34.8' - 35.8' : Highly Fractured	637.4	31 32 33 34	43		100	NQ2-2											CORE	
LIMESTONE, GRAY AND BROWN, HIGHLY WEATHERED, MODERATELY STRONG, THIN BEDDED, CRYSTALLINE, JOINT AND BEDDING DISCONTINUITIES, FRACTURED TO HIGHLY FRACTURED, OPEN APERTURE, VERY ROUGH, VERY BLOCKY, FAIR TO POOR SURFACE CONDITIONS; RQD 0%, REC 100%.	630.2 629.1	35 36 37 38 39 40	62		97	NQ2-3											CORE	
SANDSTONE, GRAY, UNWEATHERED TO SLIGHTLY WEATHERED, SLIGHTLY STRONG, FINE TO MEDIUM GRAINED, THICK TO VERY THICK BEDDED, JOINT AND BEDDING DISCONTINUITIES, SLIGHTLY FRACTURED TO INTACT, TIGHT APERTURE, SLIGHTLY ROUGH, BLOCKY, VERY GOOD SURFACE CONDITIONS; RQD 91%, REC 100%. @ 38.3' - 38.5' : Gray Shale, Argillaceous	622.6	41 42 43 44 EOB																

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 20 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

PROJECT: ATH-690-04.21	DRILLING FIRM / OPERATOR: CENTRAL STAR / TS	DRILL RIG: DIEDRICH D-50 (SN 481)	STATION / OFFSET: 237+03, 4' LT.	EXPLORATION ID B-003-0-23
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: HDR / DM	HAMMER: AUTOMATIC HAMMER	ALIGNMENT: SR 690	
PID: 114592 SFN:	DRILLING METHOD: 2.25 HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 671.4 (MSL) EOB: 50.0 ft.	PAGE 1 OF 2
START: 1/10/23 END: 1/10/23	SAMPLING METHOD: SPT / ST / NQ2	ENERGY RATIO (%): 86.8	LAT / LONG: 39.375569, -81.990250	

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
24 inches of Asphalt	671.4																	
DENSE, LIGHT BROWN, **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP	669.4	1	16 13 11	35	67	SS-1	-	0	52	26	14	8	NP	NP	NP	6	A-1-b (0)	
STIFF TO VERY STIFF, ORANGE-BROWN MOTTLED GRAY, **SILTY CLAY**, TRACE SAND, DARK BROWN CONCRETION NODULES, DAMP	668.9	2	5 4 5	13	78	SS-2	1.50	-	-	-	-	-	-	-	-	20	A-6b (V)	
1 - Stiff to Very Stiff Cohesive		3																
		4																
		5	4 5 5	14	100	SS-3	2.00	0	3	5	53	39	40	22	18	21	A-6b (11)	
		6																
		7																
	663.4	8	4 6 7	19	67	SS-4	2.50	-	-	-	-	-	-	-	-	24	A-7-6 (V)	
VERY STIFF, LIGHT ORANGE-BROWN MOTTLED GRAY, **CLAY**, "AND" SILT, TRACE SAND, TRACE STONE FRAGMENTS, DAMP		9																
		10																
		11			100	ST-5	4.00	1	1	6	44	48	56	28	28	23	A-7-6 (18)	
@11.8' - 12.3' : Qu = 1889 psf		12																
		13	5 9 12	30	78	SS-6	2.50	-	-	-	-	-	-	-	-	20	A-7-6 (V)	
	657.4	14																
HARD, RED-BROWN, **CLAY**, "AND" SILT, LITTLE SAND, (RELIC ROCK STRUCTURE), DAMP		15																
3 - Hard Residuum		16	17 16 23	56	100	SS-7	4.00	0	3	8	42	47	42	23	19	11	A-7-6 (12)	
	653.9	17																
HARD, LIGHT BROWN TO OLIVE, **CLAY**, "AND" SILT, TRACE SAND, NOTED MICA (RELIC ROCK STRUCTURE), DAMP		18	16 17 34	74	100	SS-8	4.00	0	3	4	49	44	47	24	23	12	A-7-6 (15)	
	651.4	19																
SHALE, RED-BROWN, LIGHT-BROWN AND OLIVE, HIGHLY WEATHERED, VERY WEAK.		TR 20	22 33 45	113	100	SS-9	-	-	-	-	-	-	-	-	-	11	Rock (V)	
		21																
		22																
		23	25 32 45	111	100	SS-10	-	-	-	-	-	-	-	-	-	11	Rock (V)	
		24																
		25																
		26	18 50/5"	-	100	SS-11	-	-	-	-	-	-	-	-	-	10	Rock (V)	
		27																
@ 27.5' : Red-Brown and Gray		28	50/5"	-	100	SS-12	-	-	-	-	-	-	-	-	-	9	Rock (V)	
		29																

PID: 114592	SFN:	PROJECT: ATH-690-04.21	STATION / OFFSET: 237+03, 4' LT.	START: 1/10/23	END: 1/10/23	PG 2 OF 2	B-003-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
	641.4																	
	640.9		50/4"	-	100	SS-13	-	-	-	-	-	-	-	-	-	6	Rock (V)	
SHALE, RED-BROWN AND DARK GRAY, MODERATELY WEATHERED, VERY WEAK, THIN TO MEDIUM BEDDED, JOINT AND BEDDING DISCONTINUITIES, MODERATELY TO SLIGHTLY FRACTURED, NARROW APERTURE, SLIGHTLY ROUGH, BLOCKY, FAIR SURFACE CONDITIONS; RQD 60%, REC 100%. @ 32.9' - 33.3' : Qu = 457 psi		31	75		100	NQ2-1											CORE	
	633.9	32 33 34 35																
LIMESTONE, GRAY, SLIGHTLY WEATHERED, STRONG, THICK BEDDED, CRYSTALLINE, BEDDING DISCONTINUITIES, SLIGHT FRACTURE, TIGHT APERTURE, ROUGH, BLOCKY, GOOD SURFACE CONDITIONS; RQD 100%, REC 100%.	632.0	36 37 38 39	75		100	NQ2-2											CORE	
SHALE, GRAY, MODERATELY TO HIGHLY WEATHERED, VERY WEAK, MEDIUM BEDDED, BEDDING DISCONTINUITIES, MODERATELY FRACTURED, TIGHT APERTURE, LAMINATED, SLICKENSIDED, POOR SURFACE CONDITIONS; RQD 100%, REC 100%.	631.1	40 41 42 43 44																
SANDSTONE, GRAY, UNWEATHERED TO SLIGHTLY WEATHERED, SLIGHTLY STRONG, FINE TO MEDIUM GRAINED, THICK TO VERY THICK BEDDED, JOINT AND BEDDING DISCONTINUITIES, SLIGHTLY FRACTURED TO INTACT, TIGHT TO NARROW APERTURE, SLIGHTLY ROUGH, BLOCKY, VERY GOOD SURFACE CONDITIONS; RQD 94%, REC 100%.		45 46 47 48 49	100		100	NQ2-3											CORE	
	621.4	EOB 50																

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 20 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

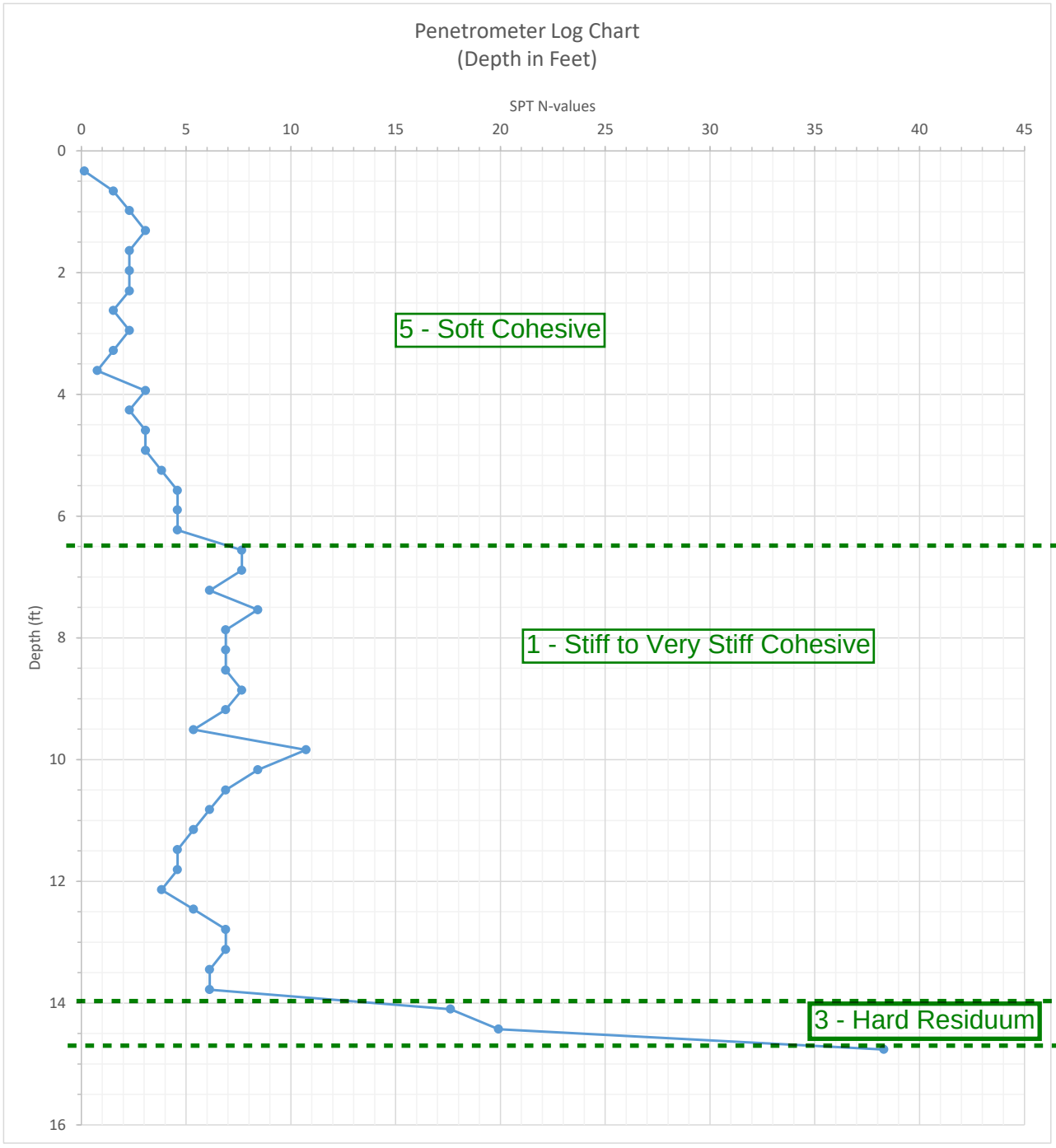
Dynamic Cone Penetration Test Log

Client:	ODOT District 10	**Operator Name / Company:**	JK / Advanced Materials, LLC
Project Name:	ATH-690-4.21 (10-X)	**Lat / Long:**	
Location:	D-002-1-23	**North / East:**	
Station, Offset:	Sta. 235+50, 75 LT (approx.)	**Date:**	2/6/2023
Elevation:	649.5 (approx)	**Sheet:**	1 of 2
Notes:	Staked Location		

Depth (in)	Depth (ft)	Depth (cm)	Pre Blows	SPT N-Value	Depth (in)	Depth (ft)	Depth (cm)	Pre Blows	SPT N-Value
3.94	0.33	10	0.2	0.1532					
7.87	0.66	20	2	1.532					
11.81	0.98	30	3	2.298					
15.75	1.31	40	4	3.064					
19.69	1.64	50	3	2.298					
23.62	1.97	60	3	2.298					
27.56	2.3	70	3	2.298					
31.5	2.62	80	2	1.532					
35.43	2.95	90	3	2.298					
39.37	3.28	100	2	1.532					
43.31	3.61	110	1	0.766					
47.24	3.94	120	4	3.064					
51.18	4.26	130	3	2.298					
55.12	4.59	140	4	3.064					
59.06	4.92	150	4	3.064					
62.99	5.25	160	5	3.83					
66.93	5.58	170	6	4.596					
70.87	5.9	180	6	4.596					
74.8	6.23	190	6	4.596					
78.74	6.56	200	10	7.66					
82.68	6.89	210	10	7.66					
86.61	7.22	220	8	6.128					
90.55	7.54	230	11	8.426					
94.49	7.87	240	9	6.894					
98.43	8.2	250	9	6.894					
102.36	8.53	260	9	6.894					
106.3	8.86	270	10	7.66					
110.24	9.18	280	9	6.894					
114.17	9.51	290	7	5.362					
118.11	9.84	300	14	10.724					
122.05	10.17	310	11	8.426					
125.98	10.5	320	9	6.894					
129.92	10.82	330	8	6.128					
133.86	11.15	340	7	5.362					
137.8	11.48	350	6	4.596					
141.73	11.81	360	6	4.596					
145.67	12.14	370	5	3.83					
149.61	12.46	380	7	5.4					
153.54	12.79	390	9	6.9					
157.48	13.12	400	9	6.9					
161.42	13.45	410	8	6.1					
165.35	13.78	420	8	6.1					
169.29	14.1	430	23	17.6					
173.23	14.43	440	26	19.9					
177.17	14.76	450	50	38.3					

Dynamic Cone Penetration Test Log

Client:	ODOT District 10	**Operator Name / Company:**	JK / Advanced Materials, LLC
Project Name:	ATH-690-4.21 (10-X)	**Lat / Long:**	
Location:	D-002-1-23	**North / East:**	
Station, Offset:	Sta. 235+50, 75 LT (approx.)	**Date:**	2/6/2023
Elevation:	649.5 (approx)	**Sheet:**	2 of 2
Notes:	Staked Location		



Rock Strength Parameter Determination
and
Laboratory Testing

9999 Carver Road, Suite 210, Blue Ash, OH 45242-5583 **hdrinc.com**
(513) 984-7500

ODOT District 10
ATH-690-4.21 (10-X)

Rock Strength Parameter Determination

Computed By = DCM
Checked By = AKB

BEDROCK TESTING

Project	Exploration ID	Sample Depth (ft)	Sample ID	Rock Type	Color	Moist Unit Weight (pcf)	Compressive Strength (psi)	(MPa)	Er Modulus (psi)	(MPa)	GSI Range	USE	Em (Hoek & Brown) Modulus (GPa)	(psi)	Lesser of Er vs Em (psi)	Em (Yang) Modulus (MPa)	(psi)
ATH-690-4.20	B-001-0-23	32.9	NQ2-1	Shale	Red-Brown	158	457	3.2	9,864	68	20-30	25	0.4	61052	9864	2.2	312
ATH-690-4.20	B-002-0-23	33.1	NQ2-1	Shale	Gray	160.3	824	5.7	20,098	139	20-30	25	0.6	81979	20098	4.4	636
				Shale	Maximum	160.3	824						Shale	Maximum	20098		
					Minimum	158	457							Minimum	9864		
					Average	159	641							Average	14981		
					Std Dev	2	260							Std Dev	7237		
					Adopted Value	160	600							Adopted Value	14900		

Project	Exploration ID	Sample Depth (ft)	Sample ID	Rock Type	Color	Moist Unit Weight (pcf)	Compressive Strength (psi)	(MPa)	Er Modulus (psi)	(MPa)	GSI Range	USE	Em (Hoek & Brown) Modulus (GPa)	(psi)	Lesser of Er vs Em (psi)	Em (Yang) Modulus (MPa)	(psi)
								0.0		0			0.0	0	0	0.0	0
					Maximum	0	0							Maximum	0		
					Minimum	0	0							Minimum	0		
					Average	#DIV/0!	#DIV/0!							Average	0		
					Std Dev	N/A	N/A							Std Dev	N/A		
					Adopted Value									Adopted Value			

Project	Exploration ID	Sample Depth (ft)	Sample ID	Rock Type	Color	Moist Unit Weight (pcf)	Compressive Strength (psi)	(MPa)	Er Modulus (psi)	(MPa)	GSI Range	USE	Em (Hoek & Brown) Modulus (GPa)	(psi)	Lesser of Er vs Em (psi)	Em (Yang) Modulus (MPa)	(psi)
ATH-690-4.20	B-003-0-23	18.9	NQ2-1	Sandstone	Gray	155.9	5983	41.3	747,875	5156	55-65	60	11.4	1656533	747875	818.5	118719
				Sandstone	Maximum	155.9	5983							Maximum	747875		
					Minimum	155.9	5983							Minimum	747875		
					Average	156	5983							Average	747875		
					Std Dev	N/A	N/A							Std Dev	N/A		
					Adopted Value	155	5900							Adopted Value	747000		

BEDROCK QUALITY

Project	Exploration ID	Rock Type	Depth Range (ft.) From	To	Thickness (ft)	Layer RQD (%)	Weighted RQD*(Length / Total Length)
ATH-690-4.20	B-001-0-23	SHALE	30.5	37.5	7	60	16.3
ATH-690-4.20	B-001-0-23	SHALE	39.4	40.3	0.9	100	3.5
ATH-690-4.20	B-002-0-23	SHALE	26	37.2	11.2	34	14.8
ATH-690-4.20	B-003-0-23	SHALE	29.5	34.9	5.4	54	11.3
ATH-690-4.20	B-003-0-23	SHALE	36.7	37.9	1.2	100	4.7
				SHALE	25.7	RQD SUM	51
				Maximum	11.2	100	
				Minimum	0.9	34	
				Average	5.1	69.6	
				Adopted Value			51

Project	Exploration ID	Rock Type	Depth Range (ft.) From	To	Thickness (ft)	Layer RQD (%)	Weighted RQD*(Length / Total Length)
ATH-690-4.20	B-001-0-23	LIMESTONE	37.5	39.4	1.9	100	39.6
ATH-690-4.20	B-002-0-23	LIMESTONE	37.2	38.3	1.1	0	0.0
ATH-690-4.20	B-003-0-23	LIMESTONE	34.9	36.7	1.8	100	37.5
				LIMESTONE	4.8	RQD SUM	77
				Maximum	1.9	100	
				Minimum	1.1	0	
				Average	1.6	66.7	
				Adopted Value			77

Project	Exploration ID	Rock Type	Depth Range (ft.) From	To	Thickness (ft)	Layer RQD (%)	Weighted RQD*(Length / Total Length)
ATH-690-4.20	B-001-0-23	SANDSTONE	40.3	50	9.7	94	32.8
ATH-690-4.20	B-002-0-23	SANDSTONE	38.3	44.8	6.5	91	21.3
ATH-690-4.20	B-003-0-23	SANDSTONE	37.9	49.5	11.6	96	40.1
				SANDSTONE	27.8	RQD SUM	94
				Maximum	11.6	96	
				Minimum	6.5	91	
				Average	9.3	93.7	
				Adopted Value			94

Table 10.4.6.5-1—Estimation of E_m Based on GSI

Expression	Notes/Remarks	Reference
$E_m\left(GPa\right)=\sqrt{\frac{q_u}{100}}10^{\frac{GSI-10}{40}}$ for $q_u \le 100$ MPa $E_m\left(GPa\right)=10^{\frac{GSI-10}{40}}$ for $q_u \le 100$ MPa	Accounts for rocks with $q_u < 100$ MPa; notes q_u in MPa	Hoek and Brown (1997); Hoek et al. (2002)
$E_m=\frac{E_R}{100}e^{GSI/21.7}$	Reduction factor on intact modulus, based on *GSI*	Yang (2006)

Notes: E_r = modulus of intact rock, E_m = equivalent rock mass modulus, *GSI* = geological strength index, q_u = uniaxial compressive strength, and 1 MPa = 2.09 ksf.

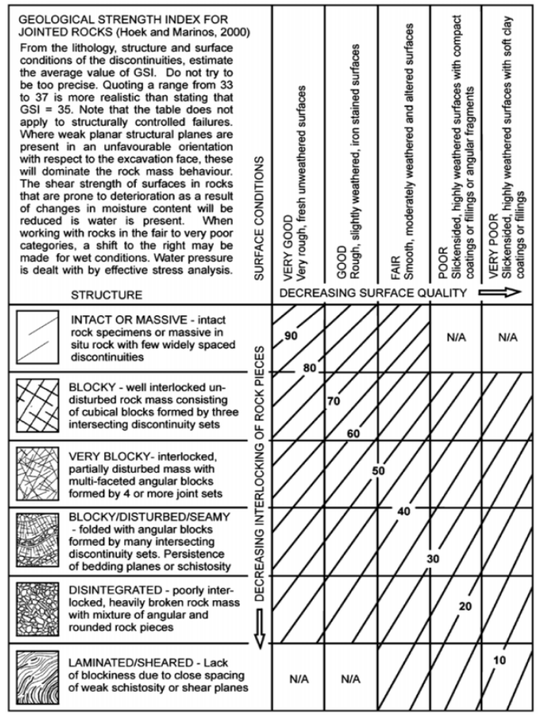


Figure 10.4.6.4-1—Determination of *GSI* for Jointed Rock Mass (Hoek and Marinos, 2000)

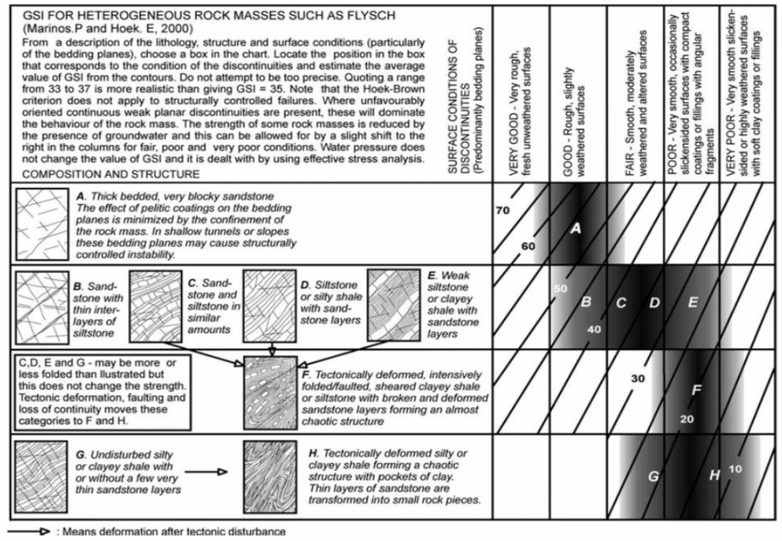


Figure 10.4.6.4-2—Determination of *GSI* for Tectonically Deformed Heterogeneous Rock Masses (Marinos and Hoek 2000)

NEAS
National Engineering & Architectural Services Inc.

5710 Westbourne Avenue
Columbus, OH 43213
614-892-0162

Unconfined Compressive Strength of Rock Core (ASTM D7012 Method C)

(Project: ATH-690-4.21, Boring Location: B-001-0-23, NQ2-1, Depth: 32.9 - 33.3ft)

Tested Date: 1/17/2023

Specimen Properties

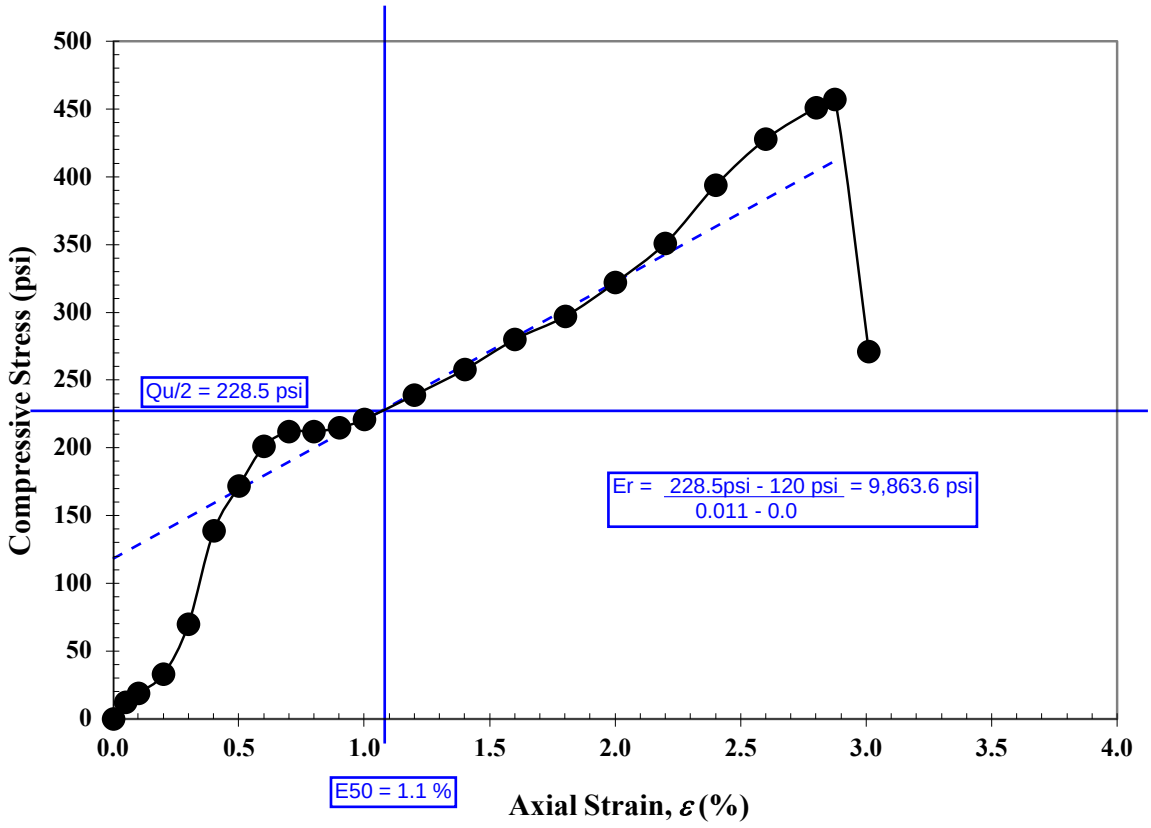
Average Dia., D_{avg} (in):	1.97
Average Height, H_{avg} (in):	4.42
Length to Diameter Ratio:	2.24
Area, A (in^2):	3.05
Volume, V (in^3):	13.48
Wet Mass of Specimen (lb):	1.2
Moisture Content (%):	6.3
Dry Mass of Specimen (lb):	1.2
Wet Unit Weight, γ (lb/ft^3):	158.0
Dry Unit Weight, γ_d (lb/ft^3):	148.7

Final Specimen Figure

Results

Unconfined Compressive Strength (psi): **457** **3** (MPa)

Strain (%): **2.9**



Notes: Shale, maroonish brown and dark gray, moderately weathered, very weak.

Sample trimming procedure does not conform to ASTM D4543 and the results reported may differ from the results obtained from a test specimen that meets the requirements of Practice D4543.

NEAS
National Engineering & Architectural Services Inc.

5710 Westbourne Avenue
Columbus, OH 43213
614-892-0162

Unconfined Compressive Strength of Rock Core (ASTM D7012 Method C)

(Project: ATH-690-4.21, Boring Location: B-002-0-23, NQ2-1, Depth: 33.1 - 33.5ft)

Tested Date: 1/17/2023

Specimen Properties

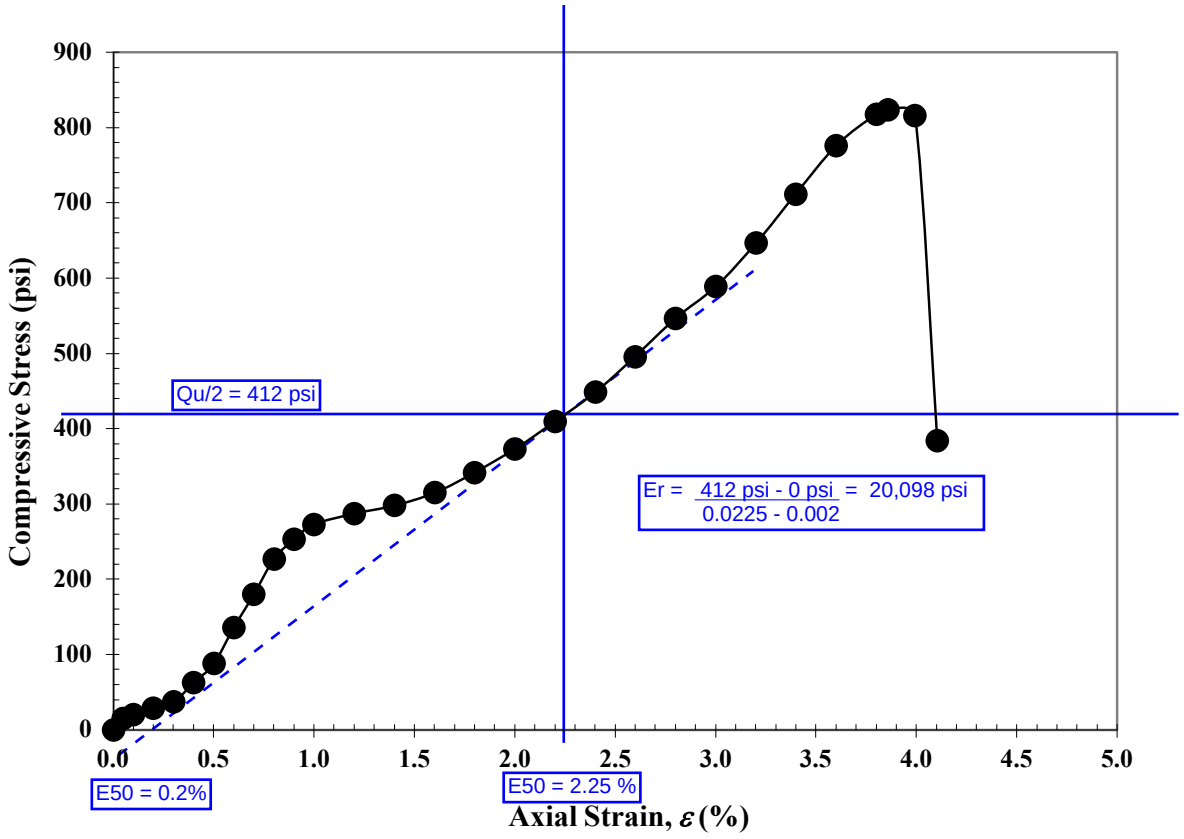
Average Dia., D_{avg} (in):	2.00
Average Height, H_{avg} (in):	4.46
Length to Diameter Ratio:	2.23
Area, A (in^2):	3.13
Volume, V (in^3):	13.95
Wet Mass of Specimen (lb):	1.3
Moisture Content (%):	5.3
Dry Mass of Specimen (lb):	1.2
Wet Unit Weight, γ (lb/ft^3):	160.3
Dry Unit Weight, γ_d (lb/ft^3):	152.2

Final Specimen Figure

Results

Unconfined Compressive Strength (psi): **824** **6** (MPa)

Strain (%): **3.9**



Notes: Shale, gray, moderately weathered, weak.

Sample trimming procedure does not conform to ASTM D4543 and the results reported may differ from the results obtained from a test specimen that meets the requirements of Practice D4543.

NEAS
National Engineering & Architectural Services Inc.

5710 Westbourne Avenue
Columbus, OH 43213
614-892-0162

Unconfined Compressive Strength of Rock Core (ASTM D7012 Method C)

(Project: ATH-690-4.21, Boring Location: B-003-0-23, NQ2-1, Depth: 43.9 - 44.3ft)

Tested Date: 1/17/2023

Specimen Properties

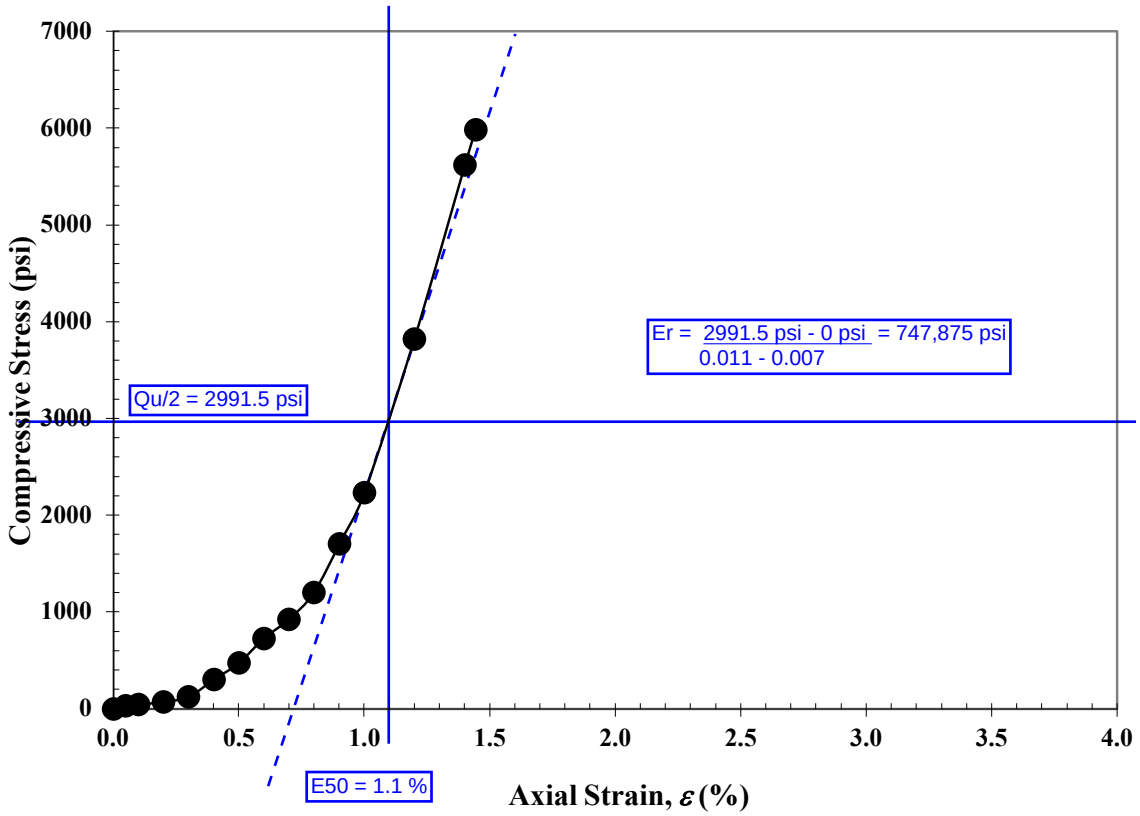
Average Dia., D_{avg} (in):	1.99
Average Height, H_{avg} (in):	4.44
Length to Diameter Ratio:	2.23
Area, A (in^2):	3.10
Volume, V (in^3):	13.77
Wet Mass of Specimen (lb):	1.2
Moisture Content (%):	4.8
Dry Mass of Specimen (lb):	1.2
Wet Unit Weight, γ (lb/ft^3):	155.9
Dry Unit Weight, γ_d (lb/ft^3):	148.7

Final Specimen Figure

Results

Unconfined Compressive Strength (psi): **5983** **41** (MPa)

Strain (%): **1.4**



Notes: Sandstone, gray, unweathered, moderately strong, fine to medium grained.

Sample trimming procedure does not conform to ASTM D4543 and the results reported may differ from the results obtained from a test specimen that meets the requirements of Practice D4543.

Plan and Subsurface Profile

B-003
LOCATED 1-25-2023

CONTROL POINT SV11

B-002
LOCATED 1-25-2023

D-002-1-23
(APPROXIMATE)

B-001
LOCATED 1-25-2023

CONTROL POINT SV12

PCC 236+12.36

236+50
236+25
236+00
235+75
235+50
235+25
235+00

665'
660'
670'
675'
650'
655'
645'

5H:1V
35.00 ft
2H:1V
11.00 ft
25.00 ft
15.00 ft

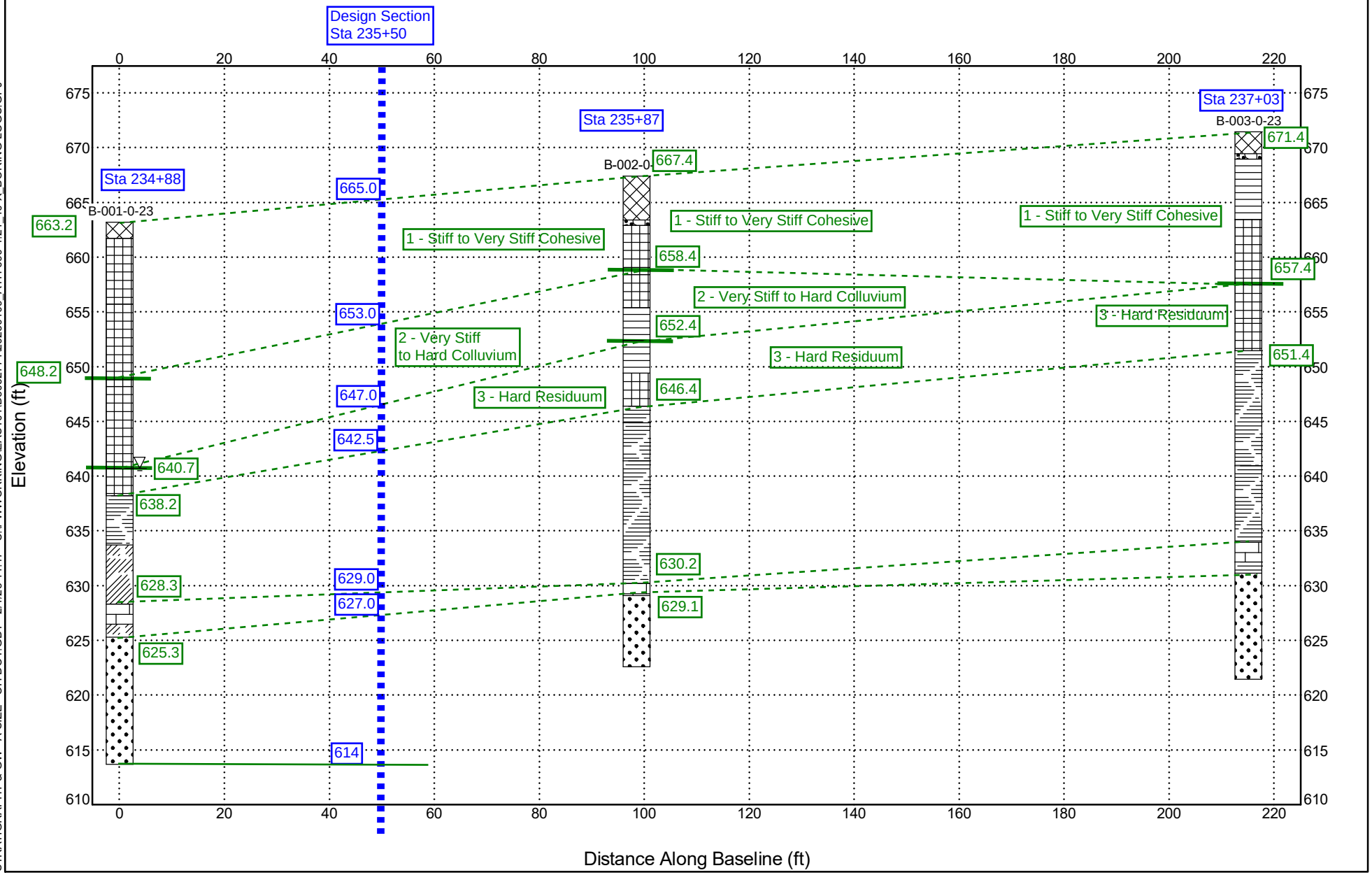
OH-E
HS X-1

SUBSURFACE DIAGRAM

PROJECT NUMBER 114592

PROJECT NAME ATH-690-4.21 (10-X)

PROJECT LOCATION Athens County, OH



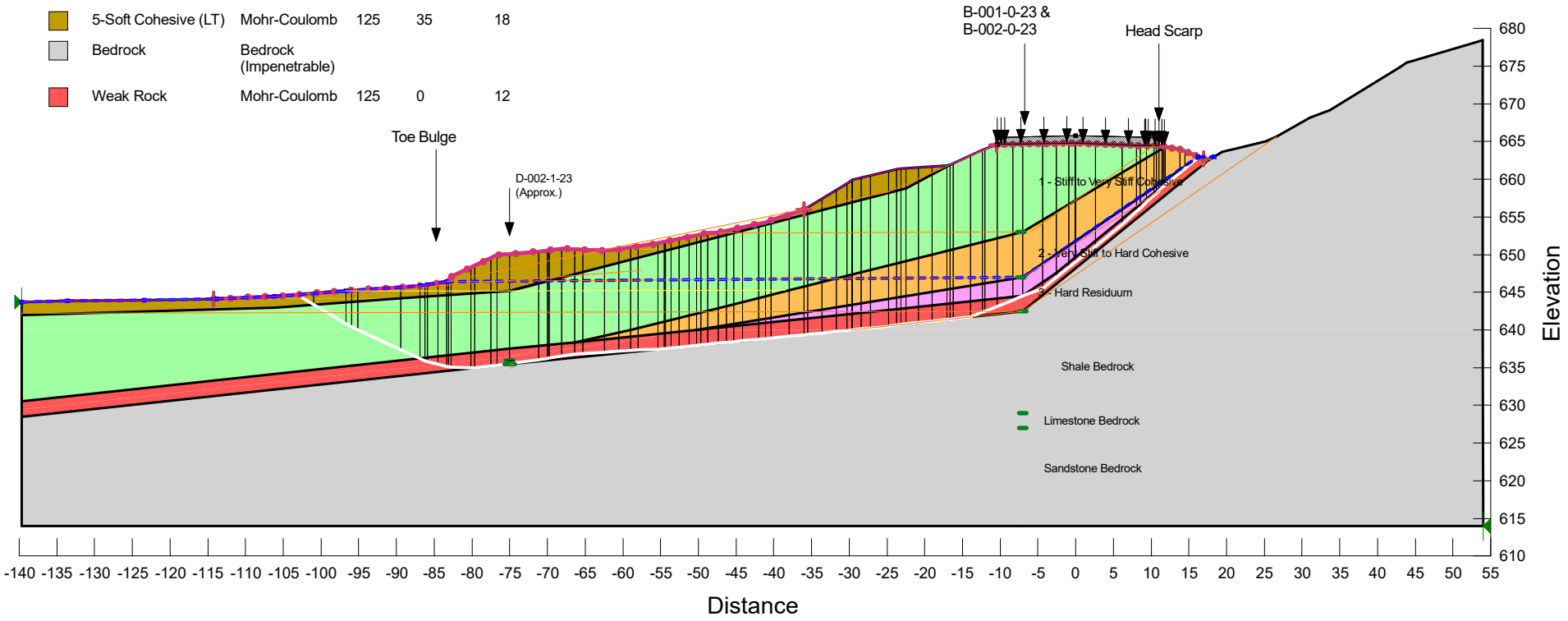
Slope Stability Analyses

Station 235+50
Existing Conditions

Color	Name	Slope Stability Material Model	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	1-Stiff to Very Stiff Cohesive (LT)	Mohr-Coulomb	125	70	22
	2-Very Stiff to Hard Coluvium (LT)	Mohr-Coulomb	130	160	24
	3-Hard Residuum (LT)	Mohr-Coulomb	135	180	25
	5-Soft Cohesive (LT)	Mohr-Coulomb	125	35	18
	Bedrock	Bedrock (Impenetrable)			
	Weak Rock	Mohr-Coulomb	125	0	12

1.01

Title: ATH-690-4.21 (10-X)
Name: Existing Conditions - Sta 235+50
Description: Existing Slope Conditions
Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Optimize Critical Slip Surface Location: Yes
Surcharge (Unit Weight): 250 pcf



Station 235+50
Reconstructed Slope Conditions

The existing slope was reconstructed to assumed, pre-landslide slope geometries based on the adjacent slopes to the north and south of the project limits.

B-003
LOCATED 1-25-2023

CONTROL POINT SV11

15.00 ft
2H:1V
5H:1V
35.00 ft

25.00 ft

236+50
236+25
236+00
235+75
235+50
235+25
235+00

PGC 236+12.36

665'
660'
675'
670'
655'
650'
645'

B-002
LOCATED 1-25-2023

D-002-1-23
(APPROXIMATE)

B-001
LOCATED 1-25-2023

11.00 ft

CONTROL POINT SV12

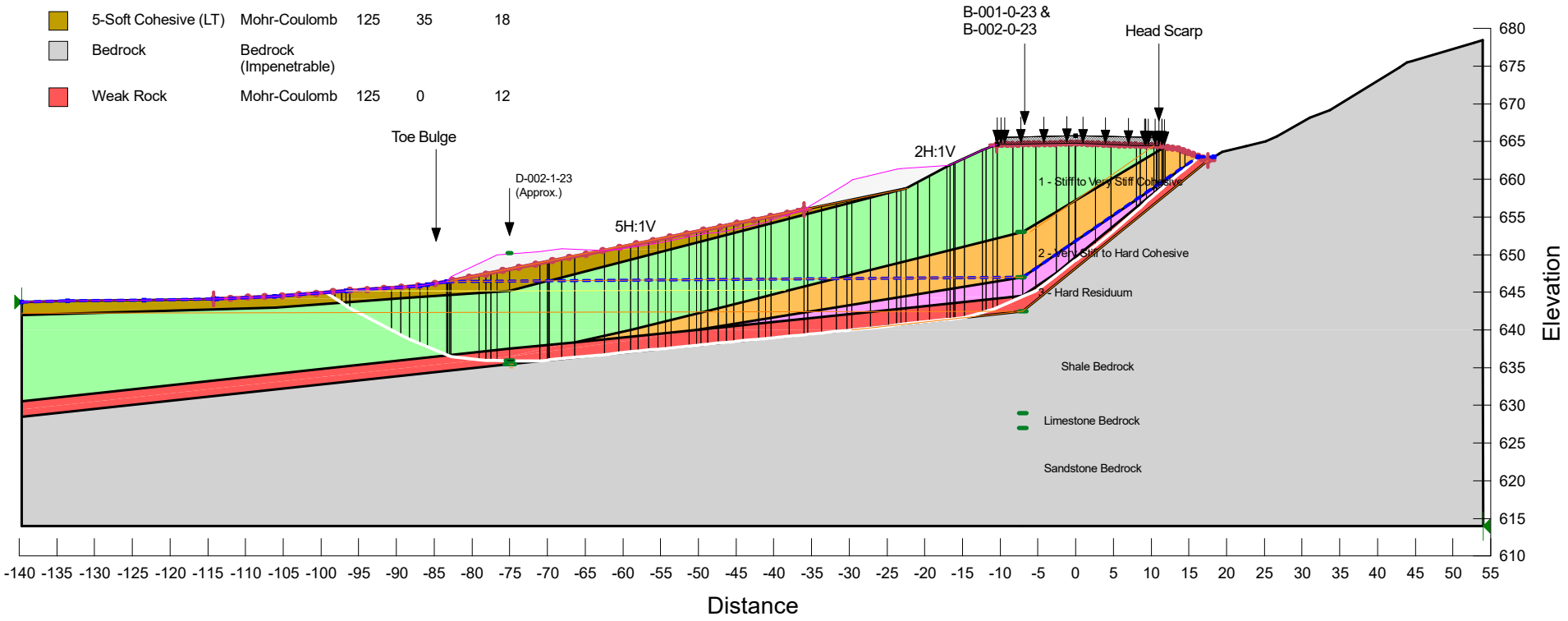
Assumed,
Pre-Landslide
Slope Geometry

Assumed,
Pre-Landslide
Slope Geometry

Color	Name	Slope Stability Material Model	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	1-Stiff to Very Stiff Cohesive (LT)	Mohr-Coulomb	125	70	22
	2-Very Stiff to Hard Coluvium (LT)	Mohr-Coulomb	130	160	24
	3-Hard Residuum (LT)	Mohr-Coulomb	135	180	25
	5-Soft Cohesive (LT)	Mohr-Coulomb	125	35	18
	Bedrock	Bedrock (Impenetrable)			
	Weak Rock	Mohr-Coulomb	125	0	12

0.99

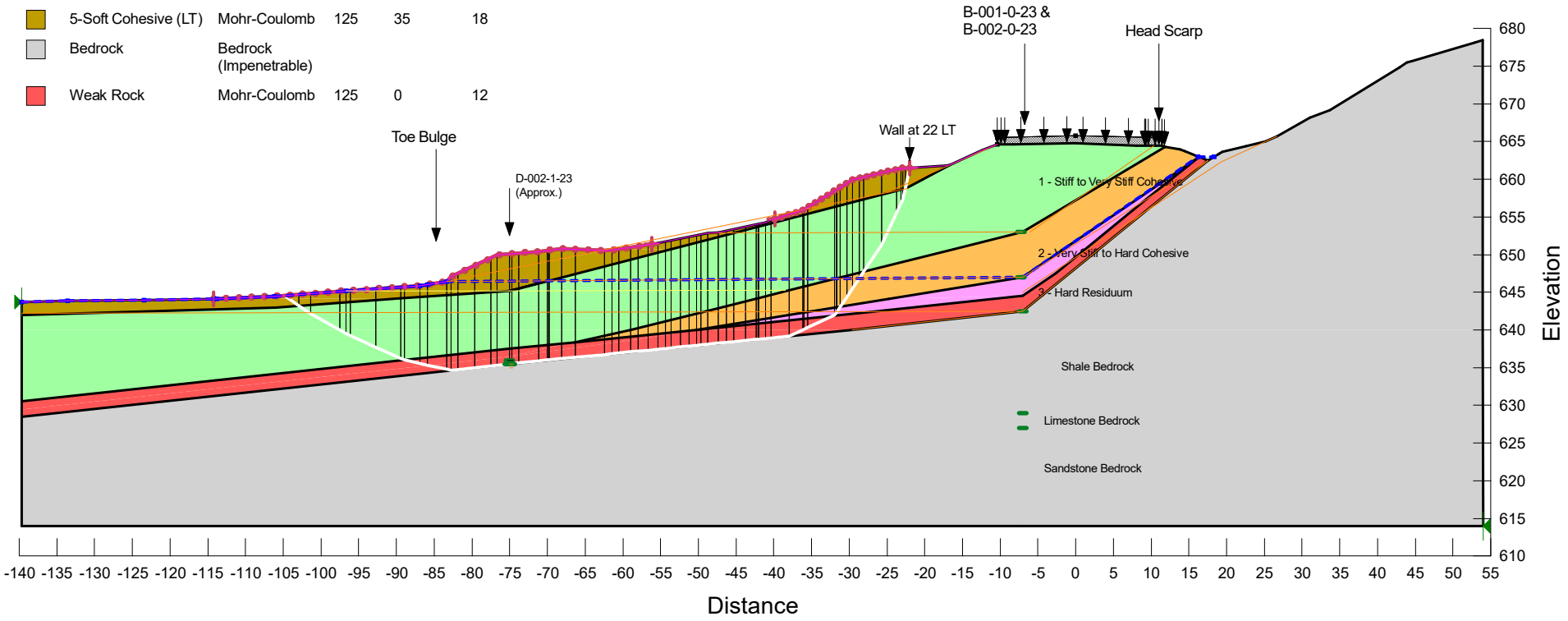
Title: ATH-690-4.21 (10-X)
Name: Reconstructed Existing Conditions - Sta 235+50 (3)-DCP
Description: Reconstructed to pre-landslide geometry based on adjacent slopes
Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Optimize Critical Slip Surface Location: Yes
Surcharge (Unit Weight): 250 pcf



Station 235+50
Downslope Stability

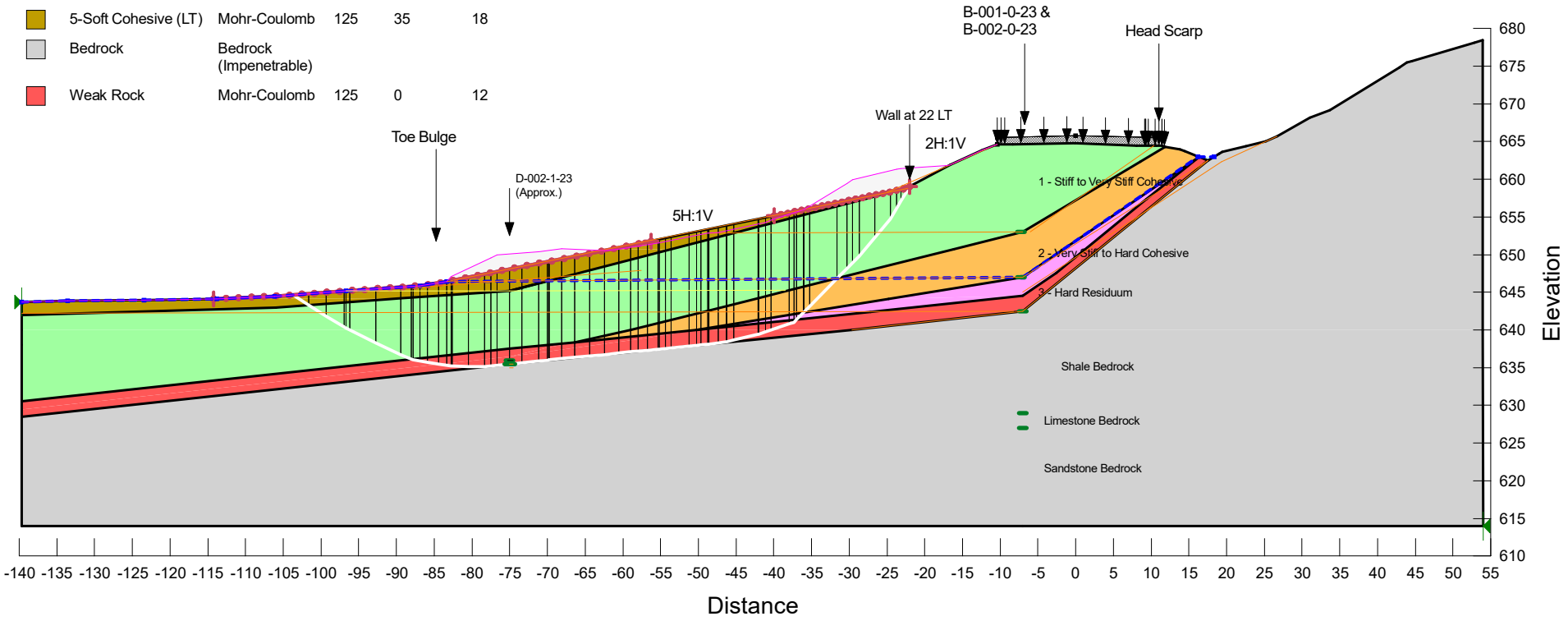
Color	Name	Slope Stability Material Model	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	1-Stiff to Very Stiff Cohesive (LT)	Mohr-Coulomb	125	70	22
	2-Very Stiff to Hard Coluvium (LT)	Mohr-Coulomb	130	160	24
	3-Hard Residuum (LT)	Mohr-Coulomb	135	180	25
	5-Soft Cohesive (LT)	Mohr-Coulomb	125	35	18
	Bedrock	Bedrock (Impenetrable)			
	Weak Rock	Mohr-Coulomb	125	0	12

Title: ATH-690-4.21 (10-X)
Name: Down Slope Stability - Sta 235+50 (3)
Description: Reconstructed to pre-landslide geometry based on adjacent slopes
Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Optimize Critical Slip Surface Location: Yes
Surcharge (Unit Weight): 250 pcf



Color	Name	Slope Stability Material Model	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	1-Stiff to Very Stiff Cohesive (LT)	Mohr-Coulomb	125	70	22
	2-Very Stiff to Hard Coluvium (LT)	Mohr-Coulomb	130	160	24
	3-Hard Residuum (LT)	Mohr-Coulomb	135	180	25
	5-Soft Cohesive (LT)	Mohr-Coulomb	125	35	18
	Bedrock	Bedrock (Impenetrable)			
	Weak Rock	Mohr-Coulomb	125	0	12

Title: ATH-690-4.21 (10-X)
Name: Reconstructed Down Slope Stability - Sta 235+50 (4)
Description: Reconstructed Slope geometry
Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Optimize Critical Slip Surface Location: Yes
Surcharge (Unit Weight): 250 pcf

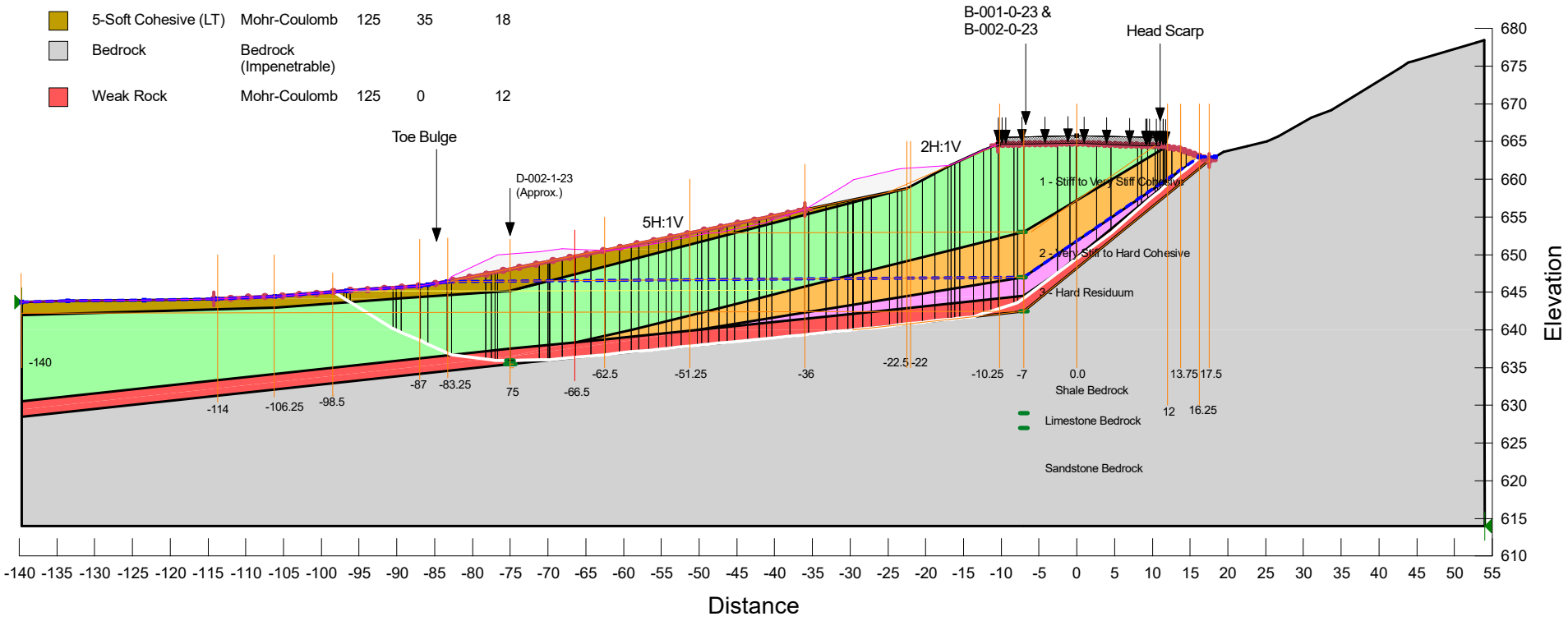


UA SLOPE Analyses

Color	Name	Slope Stability Material Model	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	1-Stiff to Very Stiff Cohesive (LT)	Mohr-Coulomb	125	70	22
	2-Very Stiff to Hard Coluvium (LT)	Mohr-Coulomb	130	160	24
	3-Hard Residuum (LT)	Mohr-Coulomb	135	180	25
	5-Soft Cohesive (LT)	Mohr-Coulomb	125	35	18
	Bedrock	Bedrock (Impenetrable)			
	Weak Rock	Mohr-Coulomb	125	0	12

0.99

Title: ATH-690-4.21 (10-X)
Name: Reconstructed Conditions (UA Slope) - Sta 235+50 (3) DCP
Description: UA Slope Coordinates
Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Optimize Critical Slip Surface Location: Yes
Surcharge (Unit Weight): 250 pcf



Station 235+50
Existing Conditions

UA Slope Program Version 2.3 - J:\ODOT-District 5-10_GES\2021\Task Order 10-X ATH-690-4.21\20230202_ATH-690-4.21_10-X_UASlope.ua3*

File Run Options Help

Calculated Results

Factor of Safety: 0.99

Force per Shaft: 0.000 lb

Acting Point X: 22.000 ft Y: 0.000 ft

Analysis Unit System

(•) English ( ) Metric

Number of Vertical Sections and Soil Layers

Vertical Section Num: 20 Soil Layer Num: 8

Analysis Method

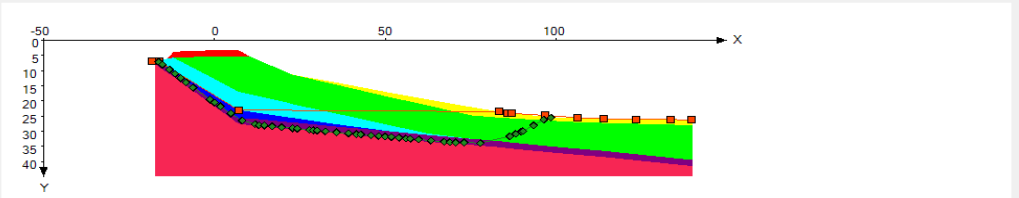
( ) Total Stress (•) Effective Stress

Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
Layer1	0.1	0.0	125.0
Layer2	200.0	28.0	125.0
Layer3	35.0	18.0	125.0
Layer4	70.0	22.0	125.0
Layer5	160.0	24.0	130.0
Layer6	180.0	25.0	135.0
▸ Layer7	0.0	11.0	120.0
Layer8	4000.0	40.0	155.0

Parameters modified to recreate the Factor of Safety calculated in SLOPE/W.

Chart (Double-Click for More Options)



Slope Profile Vertical Sections

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Section 10	Section 11	Section 12	Section 13	Se
X (ft)	-17.50	-16.25	-13.75	-12.00	0.00	7.00	10.25	22.00	22.00	22.50	36.00	51.25	62.50	75.0
▸ Y1 (ft)	7.50	7.00	6.00	3.75	3.25	3.25	5.25	11.00	11.00	11.25	14.00	17.25	19.50	22.0
Y2 (ft)	7.50	7.00	6.00	5.75	5.25	5.25	5.25	11.00	11.00	11.25	14.00	17.25	19.50	22.0
Y3 (ft)	7.50	7.00	6.00	5.75	5.25	5.25	5.25	11.00	11.00	11.25	14.00	17.25	19.50	22.0
Y4 (ft)	7.50	7.00	6.00	5.75	5.25	5.25	5.25	11.00	11.00	11.25	14.75	18.75	21.50	24.7
Y5 (ft)	7.50	7.00	6.00	5.75	12.75	17.00	17.75	20.75	20.75	21.00	24.25	28.00	30.75	32.5
Y6 (ft)	7.50	7.00	8.75	10.00	18.25	23.00	23.50	25.50	25.50	25.50	27.75	30.00	31.25	32.5
Y7 (ft)	8.75	7.00	9.00	10.50	20.25	26.00	25.75	27.00	27.00	27.00	28.50	30.00	31.25	32.5
Y8 (ft)	7.50	8.75	10.75	12.00	21.75	27.50	28.00	29.25	29.25	29.25	30.75	32.25	33.50	34.5
Y9 (ft)	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.0

Coordinates of Crest X: 40.30 ft Y: 5.30 ft Coordinates of Toe X: 83.30 ft Y: 23.50 ft

Drilled Shaft Information

(•) Calculate without Drilled Shaft

( ) Automatic Load Transfer Factor

( ) Manually Defined Load Transfer Factor

[ ] Anchor (On/Off)

Anchor force: 50000.0 lb

Anchor angle: 30.00

Anchor spacing: 8.00 ft

Auto ( ) On (•) Off 0.000 (n)

[ ] Auto Save Data

Xmin 10.00 Diameter: 3.00 ft

Xmax 20.00 CTC Spacing: 6.00 ft

XDelta 2.00 X Coordinate: 22.00 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	Point 6	Point 7	Point 8	Point 9	Point 10	Point 11	Point 12
▸ X (ft)	-18.35	-16.25	7.00	83.33	85.90	86.92	96.65	106.17	113.86	123.47	133.61	139.67
Y (ft)	7.00	7.00	23.00	23.56	24.00	24.14	24.79	25.52	25.85	26.03	26.12	26.26

Slip Surface

	nt 34	Point 35	Point 36	Point 37	Point 38	Point 39	Point 40	Point 41	Point 42	Point 43	Point 44	Point 45	Point 46	Point 47	Point 48	Point 49
X (ft)	00	57.33	59.77	63.38	67.22	68.90	70.59	73.08	77.85	86.41	88.17	89.76	90.30	93.37	96.44	98.50
▸ Y (ft)	36	32.50	32.74	33.10	33.48	33.64	33.74	33.74	33.90	31.65	30.86	30.15	29.91	28.06	26.18	25.50

Station 235+50
Post-Construction Conditions

9999 Carver Road, Suite 210, Blue Ash, OH 45242-5583 **hdrinc.com**
(513) 984-7500

ODOT intends on raising the profile to remove an existing dip in the vertical alignment (Per November 11, 2022 email from ODOT District 10). As such, 2 feet of additional fill was incorporated into the analyses.

UA Slope Program Version 2.3 - J:\ODOT-District 5-10_GES\2021\Task Order 10-X ATH-690-4.21\20230202_ATH-690-4.21_10-X_UASlope.ua3*

File Run Options Help

Calculated Results

Factor of Safety: 5.01

Force per Shaft: 169358.585 lb

Acting Point X: 22.000 ft Y: 20.440 ft

Analysis Unit System

(•) English ( ) Metric

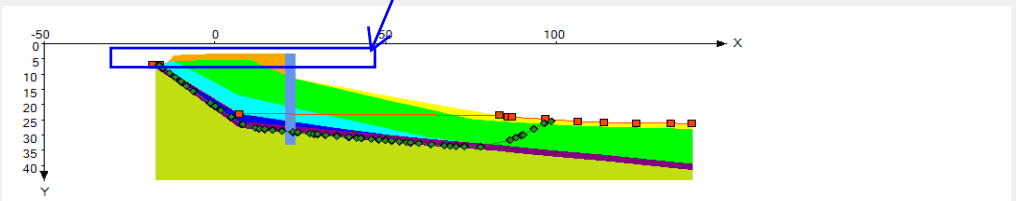
Number of Vertical Sections and Soil Layers

Vertical Section Num: 20 Soil Layer Num: 8

Analysis Method

( ) Total Stress (•) Effective Stress

Chart (Double-Click for More Options)



Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
Layer1	0.1	0.0	125.0
Layer2	200.0	28.0	125.0
Layer3	35.0	18.0	125.0
Layer4	70.0	22.0	125.0
Layer5	160.0	24.0	130.0
Layer6	180.0	25.0	135.0
▸ Layer7	0.0	11.0	120.0
Layer8	4000.0	40.0	155.0

Parameters modified to recreate the Factor of Safety calculated in SLOPE/W.

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	Se
X (ft)	-17.50	-16.25	-13.75	-12.00	0.00	7.00	10.25	22.00	22.00	22.50	36.00	51.25	62.50	75.0
Y1 (ft)	7.50	7.00	6.00	3.75	3.25	3.25	3.25	3.25	11.00	11.25	14.00	17.25	19.50	22.0
▸ Y2 (ft)	7.50	7.00	6.00	3.75	3.25	3.25	3.25	3.25	11.00	11.25	14.00	17.25	19.50	22.0
Y3 (ft)	7.50	7.00	6.00	5.75	5.25	5.25	5.25	11.00	11.00	11.25	14.00	17.25	19.50	22.0
Y4 (ft)	7.50	7.00	6.00	5.75	5.25	5.25	5.25	11.00	11.00	11.25	14.75	18.75	21.50	24.7
Y5 (ft)	7.50	7.00	6.00	5.75	12.75	17.00	17.75	20.75	20.75	21.00	24.25	28.00	30.75	32.5
Y6 (ft)	7.50	7.00	8.75	10.00	18.25	23.00	23.50	25.50	25.50	25.50	27.75	30.00	31.25	32.5
Y7 (ft)	8.75	7.00	9.00	10.50	20.25	26.00	25.75	27.00	27.00	27.00	28.50	30.00	31.25	32.5
Y8 (ft)	7.50	8.75	10.75	12.00	21.75	27.50	28.00	29.25	29.25	29.25	30.75	32.25	33.50	34.5
Y9 (ft)	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.0

Coordinates of Crest X: 40.30 ft Y: 5.30 ft Coordinates of Toe X: 83.30 ft Y: 23.50 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: 6.00 ft

XDelta 0.00 X Coordinate: 22.00 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
▸ X (ft)	-18.35	-16.25	7.00	83.33	85.90	86.92	96.65	106.17	113.86	123.47	133.61	139.67
Y (ft)	7.00	7.00	23.00	23.56	24.00	24.14	24.79	25.52	25.85	26.03	26.12	26.26

Slip Surface

	nt 34	Point 35	Point 36	Point 37	Point 38	Point 39	Point 40	Point 41	Point 42	Point 43	Point 44	Point 45	Point 46	Point 47	Point 48	Point 49
X (ft)	00	57.33	59.77	63.38	67.22	68.90	70.59	73.08	77.85	86.41	88.17	89.76	90.30	93.37	96.44	98.50
▸ Y (ft)	96	32.50	32.74	33.10	33.48	33.64	33.74	33.74	33.90	31.65	30.86	30.15	29.91	28.06	26.18	25.50

Wall Calculations

Geometry

	Elevation (ft)	
Top of Backfill =	666.5	*at Outside Edge of Shoulder*
Top of Wall =	665.5	*at C/L of Wall*
Existing Ground Surface =	659.0	*at C/L of Wall*
Maintenance Bench =	658.0	*at C/L of Wall*
Slip Plane =	640.8	*at C/L of Wall*

	Horiz. Distance from C/L (ft)	
Start of Wall Backfill =	10.4	*at Outside Edge of Shoulder*
Wall =	22.0	*at C/L of Wall*
Backfill Slope Angle =	12.0	H:1V

Wall Loading Profile

	Top Elev.	Thickness (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)
Item 203	665.5	6.5	200	28	120
Stiff to Very Stiff Cohesive	659.0	1.0	70	22	125
Bottom of Wall/Maintenance Bench	658.0				
Weighted Value		7.5	185	27	120

Earth Pressure Coefficients

	Deg		
Shear Resistance, Φ =	30		
Wall Friction , δ^A =	0.0		
Wall Slope, θ =	90		
Backfill Slope, β =	4.76		
Revised Backfill Slope, β =	4.76		
Backfill Condition	INFINITE		
Horz. Backslope Dist.	11.6	feet	*(C/L of Wall - Edge of Shoulder)*
Wall Height (H)	7.5	feet	*(Top of Wall - Maintenance Bench)*
Slope Height (h)	1.0	feet	*(Top of Backfill - Top of Wall)*
I =	3.81	degrees	

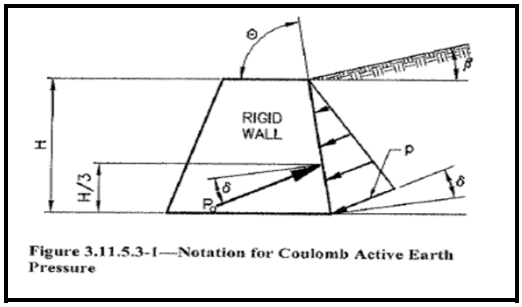


Figure 3.11.5.3-1—Notation for Coulomb Active Earth Pressure

Active Earth Coefficient

$$K_a = \frac{\sin^2(\theta+\Phi)}{(\sin^2(\theta)*\sin(\theta-\delta)*[1+\sqrt{(\sin(\Phi+\delta)*\sin(\Phi-\beta))/(\sin(\theta-\delta)*\sin(\theta+\beta))}]^2)}$$

K_a = **0.348**

At-Rest Earth Coefficient

$K_o = (1-\sin(\phi))*(1+\sin(\beta))$

K_o = **0.538**

Notes:

A. *Wall friction neglected*

B. *Figure and Equation for Active Earth Pressure from AASHTO 3.11.5.3 (LRFD Design Manual).*

C. *The wall backfill will consist of proposed fill and cohesive overburden. Using the soil layer thicknesses and respective soil parameters as determined by backcalculation in SlopeW, a weighted average was determined and assumed for the entire backfill (c' = 185 psf and φ' = 27°, per backcalculated UA Slope Values). The parameters were converted to equivalent soil strength parameters c' = 0 psf and φ'= 30° for computing earth pressures based on a 1 degree increase in friction angle for every 50 psf decrease in cohesion up to 150 psf (Ref: Hall's Thesis).*

Soil Lateral Design Profile

	Top Elev	Depth (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)	ε50	k
1 - Stiff to Very Stiff Cohesive	658.0	7.5	950	0	125	0.01	N/A
2 - Very Stiff to Hard Cohesive	649.3	16.2	2250	0	130	0.005	N/A
2 - Very Stiff to Hard Cohesive	647	18.5	2250	0	67.6	0.005	N/A
3 - Hard Residuum	644.5	21.0	3400	0	72.6	0.005	N/A
Shale Bedrock	640.8	24.7	N/A	N/A	N/A	N/A	N/A
Sandstone Bedrock	629.0	36.5	N/A	N/A	N/A	N/A	N/A

Depths referenced below the top of wall, starting at the lowered ground surface. ε50 and k values per LPile Technical Manual.

Wall Loading Computations

Earth Pressure Model = CONVENTIONAL *(Conventional or UA SLOPE)* UA SLOPE

1) Soil Unit Weight = 120 pcf *Weighted Average Along Cantilevered Wall Height*

2) Determine Coefficient of Earth Pressure (K)

Restraint Condition = ACTIVE *(Active or At-Rest)*

Ka = 0.348

3) Determine Equivalent Fluid Weight (G_H)

G_H = $(\gamma_m) * (K_a)$

G_H = 42 *For application to CONVENTIONAL Earth Pressure Model*

4) Artificially Lowered Ground Surface (ODOT GDM Section 903.3.2, pg. 9-14) for FS_{dh} < 1.30

Lower Ground Surface? NO

Lowered Ground Surface (ft) = 0.0 = dt (tan(β_{dh})

β_{dh} = 11.6 = steepness of the slope downhill of the drilled shaft

FS_{dh} = 1.32 = Factor of Safety down slope of the proposed wall

d_t = 17.2 = depth below bench to the shear surface at the location of the drilled shaft

5) Modification of p-y curves (ODOT GDM Section 903.2, pg. 9-13]

P_m = $0.64*(S/D)^{0.34}$ *(Ref: Reese, Isenhower, & Wang - 2006)*

D = 3 feet *(shaft diameter or pile flange width)*

Assumed Shaft Spacing = 6 feet *(center-to-center pile spacing)*

P_m = 0.81 *For retaining wall, applies from top of wall to top of rock/bottom of drilled shafts*

For a row of drilled shafts, applies below shear plane to top of rock/bottom of drilled shafts

Reduce p-multiplier? NO *For application above shear plane if using a row of spaced drilled shafts instead of a retaining wall*

FS_{UAS} = - = Factor of Safety from UASlope including shafts

p-multipler = 0.81 = (P_m - P_m/FS_{UAS}) *From top of wall to bottom of shear plane*

6) Determine Lateral Thrust

Conventional Earth Pressure Theory *UA SLOPE*

Exposed Wall Height (H) = 7.5 feet Depth from T/Wall to Slip Plane = 24.7 feet

Wall Height (H) + GS_{AL} = 7.5

P = $1/2 * G_H * H^2$

P = 1174 lbs/foot

P_{SH} = P*(Shaft Spacing) *(earth loading)*

P_{SH} = 7042 lbs/shaft Force Per Shaft = 169359 lbs/shaft

7) Resolve horizontal earth force to distributed triangular load (for LPILE)

w = $2*P_{SH}/H$

w = 1878 lbs/foot per shaft (Earth - Service Limit) 13713 lbs/foot per shaft

w = 156 lbs/inch per shaft (Earth - Service Limit) 1143 lbs/inch per shaft

γ_E = 1.5 *Earth Load Factor*

w = $(2*P_{SH}/H)*\gamma_E$

w = 235 lbs/inch per shaft (Earth - Strength Limit) 1714 lbs/inch per shaft

8) Determine live-load traffic surcharge force (P_s)

Include traffic surcharge? YES

Surcharge Pressure (q_s) = 250 psf

P_s = Ka * qs * H

P_s = 652 lbs/foot *(surcharge resolved to distributed load)* 2147 lbs/foot

P_s = 3912 lbs/shaft 12884 lbs/shaft

9) Resolve surcharge to distributed rectangular load (for LPILE)

w = P_S/H

w = 522 lbs/foot per shaft (surcharge - unfactored) 522 lbs/foot per shaft

w = 43 lbs/inch per shaft (surcharge - unfactored) 43 lbs/inch per shaft

γ_S = 1.75 *Surcharge Load Factor - Strength I*

w = $(P_S/L)*\gamma_S$

w = 76 lbs/inch per shaft (Surcharge - Strength I) 76 lbs/inch per shaft

Distributed Lateral Loads for LPILE

CONVENTIONAL		
Depth (ft.)	**Service (psi)**	**Strength-I (psi)**
0	43	76
7.5	200	311

Distributed Lateral Loads for LPILE

UA SLOPE		
Depth (ft.)	**Service (psi)**	**Strength-I (psi)**
0	43	76
24.7	1186	1790

Steel Beam and Cross-Section Properties

Assumed Pile Shape W 24x146

Pile Availability

AISC Member Producers	3	
Non-Member Producers	1	

Shaft Geometry

Shaft Diameter	36	in
Longest Beam Dimension	27.86575	in
Clear Distance	4.0671252	in

Steel Beam Geometry

Beam Depth (D)	24.7	in
Web Thickness (t_w)	0.65	in
Flange Width (B_f)	12.9	in
Flange Thickness (t_f)	1.09	in
Area of Steel (A_s)	43	in^2

Steel Properties

Yield Strength of Steel	50	ksi
Moment of Inertia (I_{xx}) of Steel	4580	in^4
Modulus of Elasticity of Steel (E)	29000	ksi
Modulus of Elasticity of Steel (E)	29000000	psi
EI (Steel Only)	1.328E+11	$lb*in^2$
Section Modulus (S_x)	371	in^3
Section Modulus (Z_x)	418	in^3
Shear-Buckling Coefficient (k)	5	
Ratio of Shear-Buckling Resistance (C)	1	
D/t_w	38	
$1.12\sqrt{E/F_{yw}}$	60.313846	
$1.40\sqrt{E/F_{yw}}$	75.392307	

Determined by AASHTO LRFD Bridge Specifications Eqn's 6.10.9.3.2-4, 6.10.9.3.2-5, and 6.10.9.3.2-6

Shear Capacity Calculation

$V_u \le \phi V_{cr}$

$\phi_v =$ 1 *AASHTO LRFD Bridge Design Spec's 6.5.4.2*

$V_u =$ *shear in web due to factored permanent and construction loads applied to noncompact section (kips)*

$V_{cr} =$ *shear buckling resistance determined from Equation 6.10.9.3.3-1 (AASHTO LRFD Bridge Design Spec's)*

$V_n = V_{cr} = CV_p$

$V_p = 0.58F_{yw}Dt_w$

$V_p =$ *plastic shear force (kips)*

$C =$ *ratio of shear-buckling resistance to shear yield strength determined by AASHTO Eqn's 6.10.9.3.2-4, 6.10.9.3.2-5, 6.10.9.3.2-5, or 6.10.9.3.2-6*

$V_p =$ 0.58 * 50 * 24.7 * 0.65

$V_p =$ 465.6 kips

$\phi V_{cr} = \phi * C * V_p$

$\phi V_{cr} =$ 1 * 1 * 465.6

$\phi V_{cr} =$ 465.6 kips

$V_u =$ 404.46 kips *(from LPILE)*

kips *(from PYWALL)*

$V_u < \phi V_{cr}$ **OK**

Flexure Capacity Calculation

$M_u \le \phi M_n$

$\phi_b =$ 1 *AASHTO LRFD Bridge Design Spec's 6.5.4.2*

$M_u =$ *Moment due to the factored loads*

$M_n =$ *Nominal flexural resistance of a section*

$S_x =$ *Elastic section modulus about the x-axis*

$\phi M_n = \phi * F_y * S_x$

$\phi M_n =$ 1 * 50 * 371

$\phi M_n =$ 18550 in*kips

$M_u =$ 15205 in*kips *(from LPILE)*

$M_u =$ in*kips *(from PYWALL)*

$M_u < \phi M_n$ **OK**

Minimum Pile Length

Top of Wall to Slip Plane =	24.7	ft	
Minimum Pile Length Below Slip Plane =	10	ft	*ODOT Minimum Required Length*
Minimum Required Pile Length =	34.7	ft	

Deflection Criteria

Pile Length Above Rock =	22.7	ft	Exposed Wall Height =	7.5	ft
Pile Length Above Rock =	272.4	in	Exposed Wall Height =	90	in

1.) *Per the ODOT GDM, pile-head deflection in the service limit state limited to 1% or less of the shaft length above bedrock, or 1% of total drilled shaft length if not embedded in bedrock.*

2.) *Following industry acceptance criteria, limit wall deflection to 1% of exposed wall height where ODOT landslide criteria does not govern. Alternatively, limit wall deflection to 1.5% of the exposed wall height in accordance with NCDOT guidelines. Use 1.5% wall deflection for PYWALL software.*

ODOT Landslide Criteria Governs YES

Drilled Shafts Located Within 10 feet of Edge of Pavement YES

1% Wall Height **OR** 2 inches- LPILE	2	in	$\delta =$	1.88 in	*(from LPILE)*
1.5% Wall Height - PYWALL		in	$\delta =$	in	*(from PYWALL)*

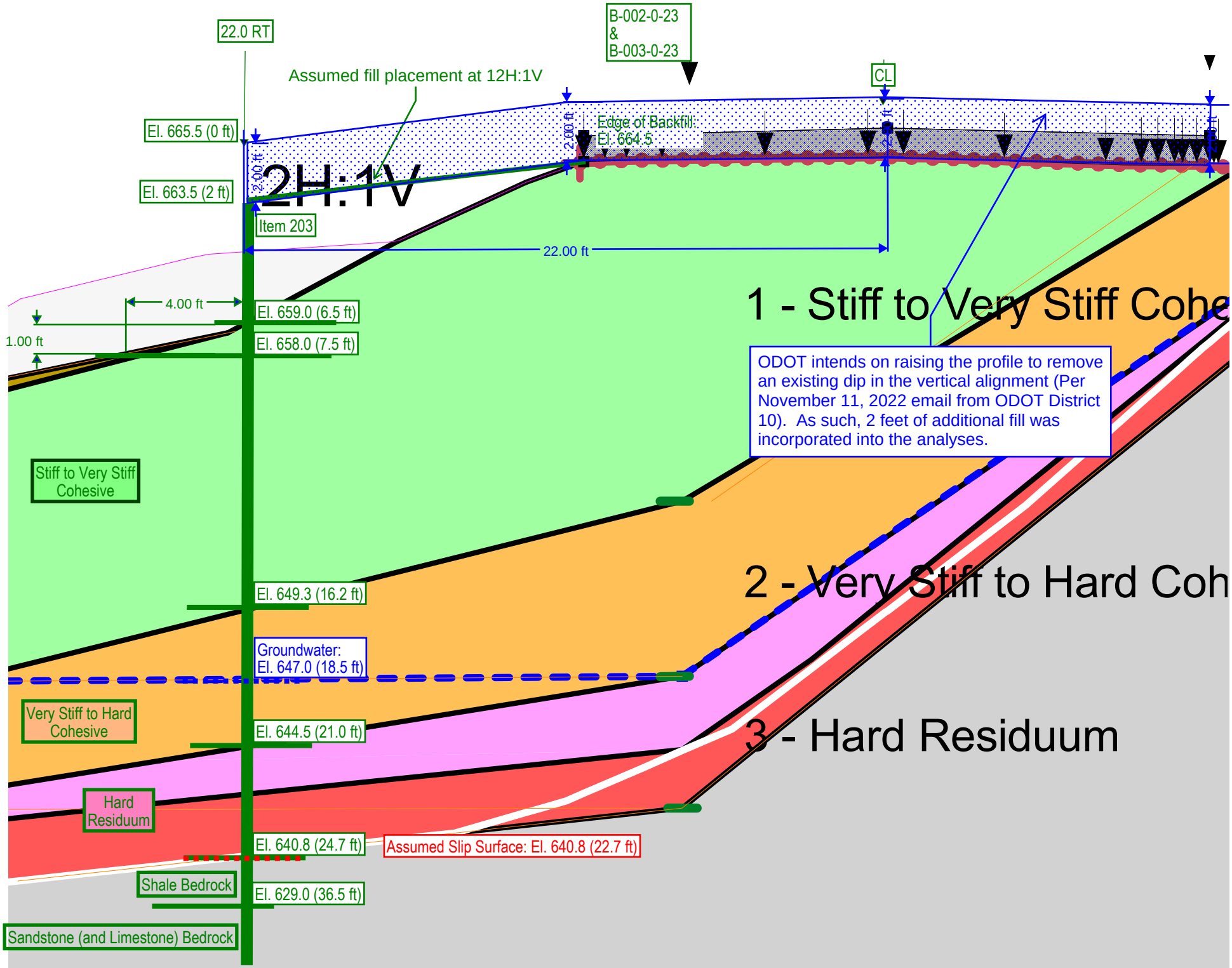
LPILE Analyses
(W 24 x 146)

Service Limit State

Strength Limit State

9999 Carver Road, Suite 210, Blue Ash, OH 45242-5583 **hdrinc.com**
(513) 984-7500

LPILE Design Profile


22.0 RT
B-002-0-23
&
B-003-0-23
Assumed fill placement at 12H:1V
CL
El. 665.5 (0 ft)
2.00 ft
2.00 ft
Edge of Backfill
El. 664.5
2.00 ft
2H:1V
El. 663.5 (2 ft)
Item 203
22.00 ft
4.00 ft
1.00 ft
El. 659.0 (6.5 ft)
El. 658.0 (7.5 ft)
1 - Stiff to Very Stiff Cohe
ODOT intends on raising the profile to remove an existing dip in the vertical alignment (Per November 11, 2022 email from ODOT District 10). As such, 2 feet of additional fill was incorporated into the analyses.
Stiff to Very Stiff Cohesive
2 - Very Stiff to Hard Coh
El. 649.3 (16.2 ft)
Groundwater:
El. 647.0 (18.5 ft)
Very Stiff to Hard Cohesive
El. 644.5 (21.0 ft)
3 - Hard Residuum
Hard Residuum
El. 640.8 (24.7 ft)
Assumed Slip Surface: El. 640.8 (22.7 ft)
Shale Bedrock
El. 629.0 (36.5 ft)
Sandstone (and Limestone) Bedrock

Service Limit Analyses

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

                    LPile for Windows, Version 2019-11.002

                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:
\ODOT-District 5-10_GES\2021\Task Order 10-X ATH-690-4.21\

Name of input data file:
20230202_ATH-690-4.21_10-X_LPILE_Service Limit State - Additional Fill Placement.lp11

Name of output report file:
20230202_ATH-690-4.21_10-X_LPILE_Service Limit State - Additional Fill Placement.lp11

Name of plot output file:
20230202_ATH-690-4.21_10-X_LPILE_Service Limit State - Additional Fill Placement.lp11

Name of runtime message file:
20230202_ATH-690-4.21_10-X_LPILE_Service Limit State - Additional Fill Placement.lp11



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

Date: February 15, 2023 Time: 15:32:16

Problem Title

Project Name:ATH-690-4.21

PID: 114592

Client: ODOT D-10

Engineer: HDR

Description: ATH-690-4.21_Sta. 235+50_Service Limit State

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 one distributed lateral load 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 = 35.000 ft
Depth of ground surface below top of pile = 7.5000 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	35.000	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 = 35.000000 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 = 4580. in^4
Moment of Inertia at Bottom = 4580. in^4
Elastic Modulus = 29000000. psi

```
--------------------------------------------------------------------------------
                     Ground Slope and Pile Batter Angles
--------------------------------------------------------------------------------

Ground Slope Angle                                  =        0.000 degrees
                                                    =        0.000 radians

Pile Batter Angle                                   =        0.000 degrees
                                                    =        0.000 radians


--------------------------------------------------------------------------------
                     Soil and Rock Layering Information
--------------------------------------------------------------------------------

The soil profile is modelled using 6 layers

Layer 1 is stiff clay without free water

   Distance from top of pile to top of layer          =     7.500000 ft
   Distance from top of pile to bottom of layer       =    16.200000 ft
   Effective unit weight at top of layer              =   125.000000 pcf
   Effective unit weight at bottom of layer           =   125.000000 pcf
   Undrained cohesion at top of layer                 =   950.000000 psf
   Undrained cohesion at bottom of layer              =   950.000000 psf
   Epsilon-50 at top of layer                         =     0.010000
   Epsilon-50 at bottom of layer                      =     0.010000


Layer 2 is stiff clay without free water

   Distance from top of pile to top of layer          =    16.200000 ft
   Distance from top of pile to bottom of layer       =    18.500000 ft
   Effective unit weight at top of layer              =   130.000000 pcf
   Effective unit weight at bottom of layer           =   130.000000 pcf
   Undrained cohesion at top of layer                 =        2250. psf
   Undrained cohesion at bottom of layer              =        2250. psf
   Epsilon-50 at top of layer                         =     0.005000
   Epsilon-50 at bottom of layer                      =     0.005000


Layer 3 is stiff clay without free water

   Distance from top of pile to top of layer          =    18.500000 ft
   Distance from top of pile to bottom of layer       =    21.000000 ft
   Effective unit weight at top of layer              =    67.600000 pcf
   Effective unit weight at bottom of layer           =    67.600000 pcf
   Undrained cohesion at top of layer                 =        2250. psf
   Undrained cohesion at bottom of layer              =        2250. psf
   Epsilon-50 at top of layer                         =     0.005000
```

```
   Epsilon-50 at bottom of layer                      =     0.005000


Layer 4 is stiff clay without free water

   Distance from top of pile to top of layer          =    21.000000 ft
   Distance from top of pile to bottom of layer       =    24.700000 ft
   Effective unit weight at top of layer              =    72.600000 pcf
   Effective unit weight at bottom of layer           =    72.600000 pcf
   Undrained cohesion at top of layer                 =        3400. psf
   Undrained cohesion at bottom of layer              =        3400. psf
   Epsilon-50 at top of layer                         =     0.005000
   Epsilon-50 at bottom of layer                      =     0.005000


Layer 5 is weak rock, p-y criteria by Reese, 1997

   Distance from top of pile to top of layer          =    24.700000 ft
   Distance from top of pile to bottom of layer       =    36.500000 ft
   Effective unit weight at top of layer              =   160.000000 pcf
   Effective unit weight at bottom of layer           =   160.000000 pcf
   Uniaxial compressive strength at top of layer      =   600.000000 psi
   Uniaxial compressive strength at bottom of layer   =   600.000000 psi
   Initial modulus of rock at top of layer            =       14900. psi
   Initial modulus of rock at bottom of layer         =       14900. psi
   RQD of rock at top of layer                        =    51.000000 %
   RQD of rock at bottom of layer                     =    51.000000 %
   k rm of rock at top of layer                       =    0.0005000
   k rm of rock at bottom of layer                    =    0.0005000


Layer 6 is weak rock, p-y criteria by Reese, 1997

   Distance from top of pile to top of layer          =    36.500000 ft
   Distance from top of pile to bottom of layer       =    55.000000 ft
   Effective unit weight at top of layer              =   155.000000 pcf
   Effective unit weight at bottom of layer           =   155.000000 pcf
   Uniaxial compressive strength at top of layer      =        5900. psi
   Uniaxial compressive strength at bottom of layer   =        5900. psi
   Initial modulus of rock at top of layer            =      747000. psi
   Initial modulus of rock at bottom of layer         =      747000. psi
   RQD of rock at top of layer                        =    94.000000 %
   RQD of rock at bottom of layer                     =    94.000000 %
   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 20.000 ft below the pile tip)
```

**** Warning - Possible Input Data Error ****

Values entered for effective unit weight of rock were outside the limits of
50 pcf to 150 pcf.

The maximum input value, in layer 6, for effective unit weight = 160.00 pcf

This data may be erroneous. Please check your data.

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Undrained Cohesion psf	Uniaxial qu psi	RQD %	E50 or krm	Rock Mass Modulus psi
1	Stiff Clay w/o Free Water	7.5000 16.2000	125.0000 125.0000	950.0000 950.0000	-- --	-- --	0.01000 0.01000	-- --
2	Stiff Clay w/o Free Water	16.2000 18.5000	130.0000 130.0000	2250. 2250.	-- --	-- --	0.00500 0.00500	-- --
3	Stiff Clay w/o Free Water	18.5000 21.0000	67.6000 67.6000	2250. 2250.	-- --	-- --	0.00500 0.00500	-- --
4	Stiff Clay w/o Free Water	21.0000 24.7000	72.6000 72.6000	3400. 3400.	-- --	-- --	0.00500 0.00500	-- --
5	Weak Rock	24.7000 36.5000	160.0000 160.0000	-- --	600.0000 600.0000	51.0000 51.0000	5.00E-04 5.00E-04	14900. 14900.
6	Weak Rock	36.5000 55.0000	155.0000 155.0000	-- --	5900. 5900.	94.0000 94.0000	5.00E-04 5.00E-04	747000. 747000.

---

p-y Modification Factors for Group Action

Distribution of p-y modifiers with depth defined using 2 points

Point No.	Depth X ft	p-mult	y-mult
1	7.500	0.8100	1.0000
2	24.700	0.8100	1.0000

Static Loading Type

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

Distributed Lateral Loading Used For All Load Cases

Distributed lateral load intensity defined using 2 points

Point No.	Depth X in	Dist. Load lb/in
1	0.000	43.000
2	296.400	1186.000

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

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

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

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	7.5000	0.00	N.A.	No	0.00	106805.
2	16.2000	4.5182	Yes	No	106805.	66098.
3	18.5000	6.8148	Yes	No	172903.	80630.
4	21.0000	6.7586	Yes	No	253533.	185367.
5	24.7000	17.2000	No	Yes	N.A.	N.A.
6	36.5000	29.0000	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 in-lb^2	Soil Res. p lb/inch	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0.00	1.8847	-9.70E-05	1.99E-07	-0.00770	3.81E-07	1.33E+11	0.00	0.00	47.0491
0.3500	1.8524	414.9729	223.1154	-0.00770	1.6309	1.33E+11	0.00	0.00	59.1964

0.7000	1.8201	1874.	505.7525	-0.00770	7.3657	1.33E+11	0.00	0.00	75.3927
1.0500	1.7878	4663.	856.4142	-0.00770	18.3274	1.33E+11	0.00	0.00	91.5891
1.4000	1.7554	9068.	1275.	-0.00770	35.6386	1.33E+11	0.00	0.00	107.7854
1.7500	1.7231	15374.	1762.	-0.00769	60.4224	1.33E+11	0.00	0.00	123.9818
2.1000	1.6908	23867.	2317.	-0.00769	93.8015	1.33E+11	0.00	0.00	140.1781
2.4500	1.6585	34833.	2939.	-0.00769	136.8988	1.33E+11	0.00	0.00	156.3745
2.8000	1.6262	48557.	3630.	-0.00769	190.8372	1.33E+11	0.00	0.00	172.5709
3.1500	1.5939	65326.	4389.	-0.00769	256.7394	1.33E+11	0.00	0.00	188.7672
3.5000	1.5616	85424.	5216.	-0.00769	335.7285	1.33E+11	0.00	0.00	204.9636
3.8500	1.5293	109138.	6111.	-0.00768	428.9271	1.33E+11	0.00	0.00	221.1599
4.2000	1.4970	136753.	7073.	-0.00768	537.4582	1.33E+11	0.00	0.00	237.3563
4.5500	1.4648	168555.	8104.	-0.00768	662.4447	1.33E+11	0.00	0.00	253.5526
4.9000	1.4326	204830.	9203.	-0.00767	805.0093	1.33E+11	0.00	0.00	269.7490
5.2500	1.4004	245863.	10370.	-0.00766	966.2749	1.33E+11	0.00	0.00	285.9453
5.6000	1.3682	291941.	11605.	-0.00765	1147.	1.33E+11	0.00	0.00	302.1417
5.9500	1.3361	343347.	12908.	-0.00764	1349.	1.33E+11	0.00	0.00	318.3381
6.3000	1.3040	400370.	14279.	-0.00763	1574.	1.33E+11	0.00	0.00	334.5344
6.6500	1.2719	463294.	15718.	-0.00762	1821.	1.33E+11	0.00	0.00	350.7308
7.0000	1.2400	532404.	17225.	-0.00760	2092.	1.33E+11	0.00	0.00	366.9271
7.3500	1.2081	607987.	18801.	-0.00759	2389.	1.33E+11	0.00	0.00	383.1235
7.7000	1.1763	690329.	19783.	-0.00756	2713.	1.33E+11	-314.6714	1124.	399.3198
8.0500	1.1445	774163.	20155.	-0.00754	3043.	1.33E+11	-323.1903	1186.	415.5162
8.4000	1.1129	859627.	20559.	-0.00752	3378.	1.33E+11	-331.5224	1251.	431.7126
8.7500	1.0814	946857.	20997.	-0.00749	3721.	1.33E+11	-339.6629	1319.	447.9089
9.1000	1.0500	1035997.	21468.	-0.00746	4072.	1.33E+11	-347.6065	1390.	464.1053
9.4500	1.0188	1127193.	21976.	-0.00742	4430.	1.33E+11	-355.3479	1465.	480.3016
9.8000	0.9877	1220592.	22519.	-0.00738	4797.	1.33E+11	-362.8815	1543.	496.4980
10.1500	0.9567	1316348.	23098.	-0.00734	5173.	1.33E+11	-370.2015	1625.	512.6943
10.5000	0.9260	1414618.	23716.	-0.00730	5560.	1.33E+11	-377.3018	1711.	528.8907
10.8500	0.8954	1515562.	24372.	-0.00725	5956.	1.33E+11	-384.1762	1802.	545.0870
11.2000	0.8650	1619344.	25068.	-0.00721	6364.	1.33E+11	-390.8181	1898.	561.2834
11.5500	0.8349	1726134.	25805.	-0.00715	6784.	1.33E+11	-397.2207	1998.	577.4798
11.9000	0.8050	1836103.	26583.	-0.00710	7216.	1.33E+11	-403.3768	2105.	593.6761
12.2500	0.7753	1949429.	27404.	-0.00704	7662.	1.33E+11	-409.2789	2217.	609.8725
12.6000	0.7459	2066294.	28268.	-0.00697	8121.	1.33E+11	-414.9193	2336.	626.0688
12.9500	0.7167	2186883.	29178.	-0.00691	8595.	1.33E+11	-420.2897	2463.	642.2652
13.3000	0.6879	2311388.	30133.	-0.00683	9084.	1.33E+11	-425.3817	2597.	658.4615
13.6500	0.6593	2440004.	31136.	-0.00676	9590.	1.33E+11	-430.1862	2740.	674.6579
14.0000	0.6311	2572933.	32188.	-0.00668	10112.	1.33E+11	-434.6940	2893.	690.8543
14.3500	0.6032	2710380.	33289.	-0.00660	10652.	1.33E+11	-438.8952	3056.	707.0506
14.7000	0.5757	2852558.	34441.	-0.00651	11211.	1.33E+11	-442.7795	3230.	723.2470
15.0500	0.5485	2999683.	35645.	-0.00642	11789.	1.33E+11	-446.3362	3418.	739.4433
15.4000	0.5218	3151979.	36904.	-0.00632	12388.	1.33E+11	-449.5538	3619.	755.6397
15.7500	0.4954	3309674.	38217.	-0.00622	13007.	1.33E+11	-452.4206	3835.	771.8360
16.1000	0.4695	3473003.	39587.	-0.00611	13649.	1.33E+11	-454.9242	4069.	788.0324
16.4500	0.4441	3642209.	40040.	-0.00600	14314.	1.33E+11	-921.8654	8718.	804.2287
16.8000	0.4192	3809339.	39571.	-0.00588	14971.	1.33E+11	-926.1443	9280.	820.4251
17.1500	0.3947	3974605.	39154.	-0.00576	15621.	1.33E+11	-929.5895	9891.	836.6215
17.5000	0.3708	4138230.	38792.	-0.00563	16264.	1.33E+11	-932.1679	10558.	852.8178
17.8500	0.3475	4300456.	38489.	-0.00549	16901.	1.33E+11	-933.8440	11288.	869.0142

18.2000	0.3247	4461538.	38249.	-0.00536	17534.	1.33E+11	-934.5796	12090.	885.2105
18.5500	0.3025	4621750.	38077.	-0.00521	18164.	1.33E+11	-933.9969	12969.	901.4069
18.9000	0.2809	4781386.	37980.	-0.00506	18791.	1.33E+11	-931.4841	13928.	917.6032
19.2500	0.2599	4940778.	37963.	-0.00491	19418.	1.33E+11	-927.9033	14992.	933.7996
19.6000	0.2397	5100273.	38031.	-0.00475	20045.	1.33E+11	-923.2103	16180.	949.9960
19.9500	0.2200	5260241.	38190.	-0.00459	20673.	1.33E+11	-917.3554	17510.	966.1923
20.3000	0.2011	5421071.	38444.	-0.00442	21306.	1.33E+11	-910.2832	19010.	982.3887
20.6500	0.1829	5583172.	38799.	-0.00424	21943.	1.33E+11	-901.9317	20709.	998.5850
21.0000	0.1655	5746979.	39074.	-0.00407	22586.	1.33E+11	-980.5051	24888.	1015.
21.3500	0.1488	5911390.	38886.	-0.00388	23233.	1.33E+11	-1155.	32597.	1031.
21.7000	0.1329	6073619.	38432.	-0.00369	23870.	1.33E+11	-1140.	36027.	1047.
22.0500	0.1178	6234215.	38113.	-0.00350	24501.	1.33E+11	-1123.	40033.	1063.
22.4000	0.1035	6393768.	37940.	-0.00330	25128.	1.33E+11	-1103.	44761.	1080.
22.7500	0.09007	6552908.	37922.	-0.00309	25754.	1.33E+11	-1081.	50401.	1096.
23.1000	0.07752	6712310.	38070.	-0.00288	26380.	1.33E+11	-1056.	57217.	1112.
23.4500	0.06586	6872698.	38397.	-0.00267	27011.	1.33E+11	-1028.	65574.	1128.
23.8000	0.05511	7034848.	38916.	-0.00245	27648.	1.33E+11	-997.1576	75995.	1144.
24.1500	0.04530	7199595.	39641.	-0.00222	28295.	1.33E+11	-962.4934	89246.	1161.
24.5000	0.03644	7367836.	40588.	-0.00199	28957.	1.33E+11	-923.8754	106491.	1177.
24.8500	0.02856	7540537.	23321.	-0.00176	29635.	1.33E+11	-8560.	1258901.	84.6730
25.2000	0.02168	7563734.	-13818.	-0.00152	29726.	1.33E+11	-9210.	1784186.	0.00
25.5500	0.01581	7424469.	-53397.	-0.00128	29179.	1.33E+11	-9637.	2560765.	0.00
25.9000	0.01092	7115199.	-94245.	-0.00105	27964.	1.33E+11	-9814.	3774752.	0.00
26.2500	0.00698	6632815.	-135208.	-8.34E-04	26068.	1.33E+11	-9693.	5834944.	0.00
26.6000	0.00392	5979450.	-174850.	-6.34E-04	23500.	1.33E+11	-9185.	9852249.	0.00
26.9500	0.00165	5164071.	-204451.	-4.58E-04	20295.	1.33E+11	-4911.	1.25E+07	0.00
27.3000	6.64E-05	4262063.	-215212.	-3.09E-04	16750.	1.33E+11	-213.3457	1.35E+07	0.00
27.6500	-9.49E-04	3356292.	-208797.	-1.89E-04	13191.	1.33E+11	3268.	1.45E+07	0.00
28.0000	-0.00152	2508170.	-190211.	-9.60E-05	9857.	1.33E+11	5582.	1.54E+07	0.00
28.3500	-0.00176	1758517.	-164086.	-2.85E-05	6911.	1.33E+11	6859.	1.64E+07	0.00
28.7000	-0.00176	1129848.	-134399.	1.71E-05	4440.	1.33E+11	7278.	1.74E+07	0.00
29.0500	-0.00161	629566.	-104324.	4.50E-05	2474.	1.33E+11	7043.	1.84E+07	0.00
29.4000	-0.00138	253526.	-76187.	5.89E-05	996.3923	1.33E+11	6355.	1.93E+07	0.00
29.7500	-0.00112	-10403.	-51505.	6.28E-05	40.8845	1.33E+11	5398.	2.03E+07	0.00
30.1000	-8.54E-04	-179113.	-31087.	5.98E-05	703.9363	1.33E+11	4325.	2.13E+07	0.00
30.4500	-6.15E-04	-271531.	-15167.	5.26E-05	1067.	1.33E+11	3256.	2.23E+07	0.00
30.8000	-4.12E-04	-306512.	-3550.	4.35E-05	1205.	1.33E+11	2276.	2.32E+07	0.00
31.1500	-2.49E-04	-301348.	4245.	3.39E-05	1184.	1.33E+11	1436.	2.42E+07	0.00
31.5000	-1.27E-04	-270855.	8858.	2.48E-05	1064.	1.33E+11	760.6650	2.52E+07	0.00
31.8500	-4.06E-05	-226943.	10986.	1.70E-05	891.9163	1.33E+11	252.6335	2.61E+07	0.00
32.2000	1.56E-05	-178575.	11305.	1.06E-05	701.8234	1.33E+11	-100.8129	2.71E+07	0.00
32.5500	4.81E-05	-131985.	10417.	5.65E-06	518.7196	1.33E+11	-321.6819	2.81E+07	0.00
32.9000	6.30E-05	-91070.	8825.	2.12E-06	357.9172	1.33E+11	-436.3022	2.91E+07	0.00
33.2500	6.59E-05	-57851.	6919.	-2.34E-07	227.3626	1.33E+11	-471.3493	3.00E+07	0.00
33.6000	6.11E-05	-32947.	4983.	-1.67E-06	129.4854	1.33E+11	-450.9891	3.10E+07	0.00
33.9500	5.19E-05	-15998.	3224.	-2.44E-06	62.8742	1.33E+11	-386.4798	3.13E+07	0.00
34.3000	4.05E-05	-5867.	1778.	-2.79E-06	23.0567	1.33E+11	-302.0967	3.13E+07	0.00
34.6500	2.84E-05	-1064.	698.4110	-2.90E-06	4.1828	1.33E+11	-211.9088	3.13E+07	0.00
35.0000	1.62E-05	0.00	0.00	-2.92E-06	0.00	1.33E+11	-120.6679	1.56E+07	0.00

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

Output Summary for Load Case No. 1:

```
Pile-head deflection             =     1.88473102 inches
Computed slope at pile head      =    -0.00769561 radians
Maximum bending moment           =       7563734. inch-lbs
Maximum shear force              =       -215212. lbs
Depth of maximum bending moment  =    25.20000000 feet below pile head
Depth of maximum shear force     =    27.30000000 feet below pile head
Number of iterations             =             24
Number of zero deflection points =              2
```

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
35.00000	1.88473102	7563734.	-215212.
33.25000	1.87604284	7489365.	-213616.
31.50000	1.86462818	7468594.	-212311.
29.75000	1.91137898	7546518.	-228738.
28.00000	2.65800140	5626218.	-261637.
26.25000	7.09606581	2941644.	-130162.
24.50000	14.73728920	2120402.	-44875.
22.75000	22.30884847	1678898.	-38627.
21.00000	76.09172600	1502506.	-42249.

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

```
Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
```

Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	0.00	M, in-lb	0.00	0.00	1.8847	-0.00770	-215212.	7563734.

Maximum pile-head deflection = 1.8847310186 inches
Maximum pile-head rotation = -0.0076956126 radians = -0.440926 deg.

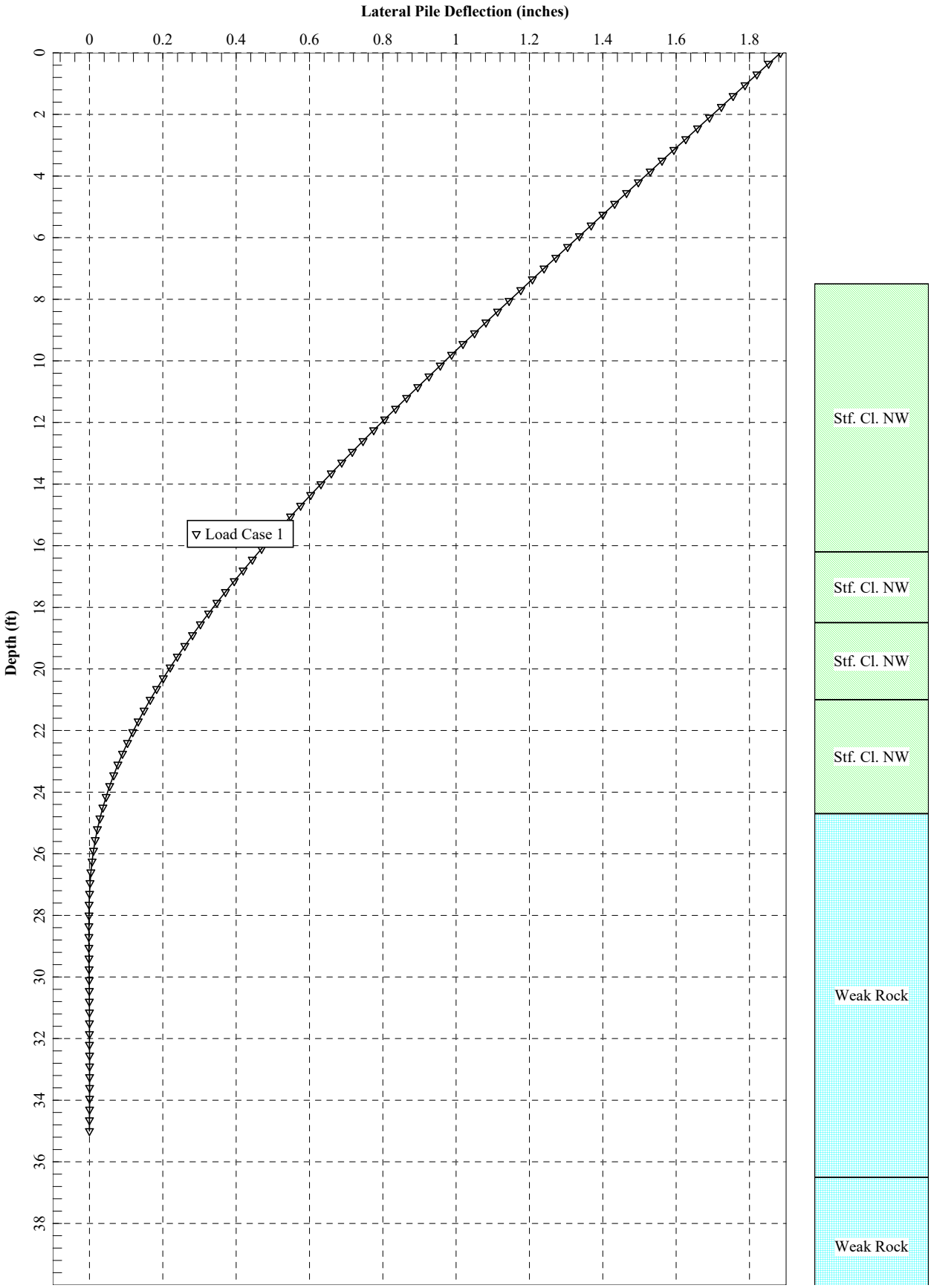
Summary of Warning Messages

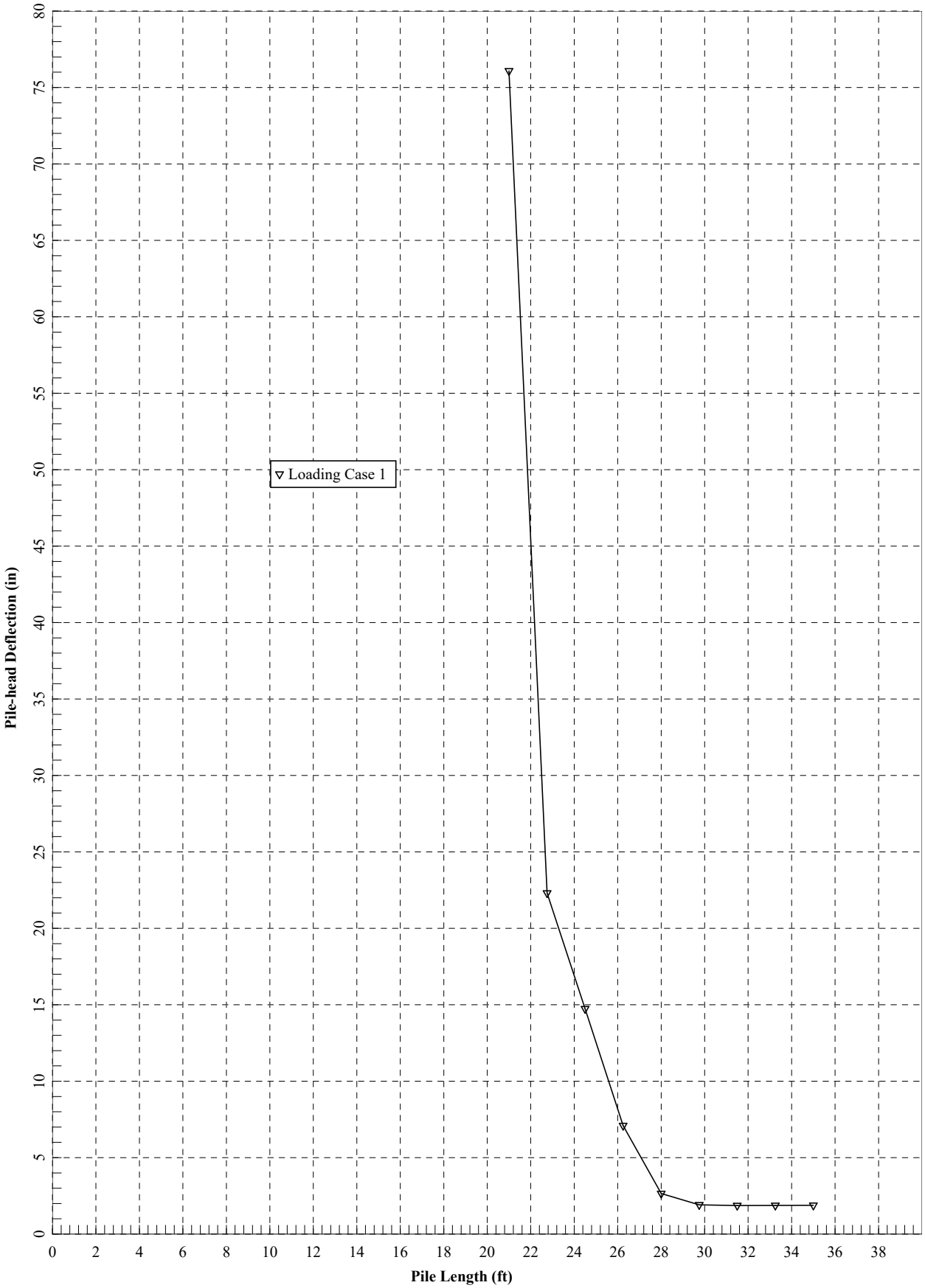
The following warning was reported 3880 times

**** 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.


Lateral Pile Deflection (inches)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Depth (ft)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
Load Case 1
Stf. Cl. NW
Stf. Cl. NW
Stf. Cl. NW
Stf. Cl. NW
Weak Rock
Weak Rock


Loading Case 1
Pile-head Deflection (in)
Pile Length (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38

Strength Limit Analyses

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

                    LPile for Windows, Version 2019-11.002

                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:
\ODOT-District 5-10_GES\2021\Task Order 10-X ATH-690-4.21\

Name of input data file:
20230202_ATH-690-4.21_10-X_LPILE_Strength Limit State - Additional Fill Placement.lp11

Name of output report file:
20230202_ATH-690-4.21_10-X_LPILE_Strength Limit State - Additional Fill Placement.lp11

Name of plot output file:
20230202_ATH-690-4.21_10-X_LPILE_Strength Limit State - Additional Fill Placement.lp11

Name of runtime message file:
20230202_ATH-690-4.21_10-X_LPILE_Strength Limit State - Additional Fill Placement.lp11



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

               Date:  February 15, 2023          Time:  15:28:17
```

Problem Title

Project Name:ATH-690-4.21

PID: 114592

Client: ODOT D-10

Engineer: HDR

Description: ATH-690-4.21_Sta. 235+50_Strength Limit State

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 one distributed lateral load 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 = 35.000 ft
Depth of ground surface below top of pile = 7.5000 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	35.000	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 = 35.000000 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 = 4580. in^4
Moment of Inertia at Bottom = 4580. in^4
Elastic Modulus = 29000000. psi

Ground Slope and Pile Batter Angles

Ground Slope Angle = 0.000 degrees
= 0.000 radians

Pile Batter Angle = 0.000 degrees
= 0.000 radians

Soil and Rock Layering Information

The soil profile is modelled using 6 layers

Layer 1 is stiff clay without free water

Distance from top of pile to top of layer	=	7.500000 ft
Distance from top of pile to bottom of layer	=	16.200000 ft
Effective unit weight at top of layer	=	125.000000 pcf
Effective unit weight at bottom of layer	=	125.000000 pcf
Undrained cohesion at top of layer	=	950.000000 psf
Undrained cohesion at bottom of layer	=	950.000000 psf
Epsilon-50 at top of layer	=	0.010000
Epsilon-50 at bottom of layer	=	0.010000

Layer 2 is stiff clay without free water

Distance from top of pile to top of layer	=	16.200000 ft
Distance from top of pile to bottom of layer	=	18.500000 ft
Effective unit weight at top of layer	=	130.000000 pcf
Effective unit weight at bottom of layer	=	130.000000 pcf
Undrained cohesion at top of layer	=	2250. psf
Undrained cohesion at bottom of layer	=	2250. psf
Epsilon-50 at top of layer	=	0.005000
Epsilon-50 at bottom of layer	=	0.005000

Layer 3 is stiff clay without free water

Distance from top of pile to top of layer	=	18.500000 ft
Distance from top of pile to bottom of layer	=	21.000000 ft
Effective unit weight at top of layer	=	67.600000 pcf
Effective unit weight at bottom of layer	=	67.600000 pcf
Undrained cohesion at top of layer	=	2250. psf
Undrained cohesion at bottom of layer	=	2250. psf
Epsilon-50 at top of layer	=	0.005000
Epsilon-50 at bottom of layer	=	0.005000

Layer 4 is stiff clay without free water

Distance from top of pile to top of layer	=	21.000000 ft
Distance from top of pile to bottom of layer	=	24.700000 ft
Effective unit weight at top of layer	=	72.600000 pcf
Effective unit weight at bottom of layer	=	72.600000 pcf
Undrained cohesion at top of layer	=	3400. psf
Undrained cohesion at bottom of layer	=	3400. psf
Epsilon-50 at top of layer	=	0.005000
Epsilon-50 at bottom of layer	=	0.005000

Layer 5 is weak rock, p-y criteria by Reese, 1997

```
   Distance from top of pile to top of layer           =    24.700000 ft
   Distance from top of pile to bottom of layer        =    36.500000 ft
   Effective unit weight at top of layer               =   160.000000 pcf
   Effective unit weight at bottom of layer            =   160.000000 pcf
   Uniaxial compressive strength at top of layer       =   600.000000 psi
   Uniaxial compressive strength at bottom of layer    =   600.000000 psi
   Initial modulus of rock at top of layer             =       14900. psi
   Initial modulus of rock at bottom of layer          =       14900. psi
   RQD of rock at top of layer                         =    51.000000 %
   RQD of rock at bottom of layer                      =    51.000000 %
   k rm of rock at top of layer                        =    0.0005000
   k rm of rock at bottom of layer                     =    0.0005000


Layer 6 is weak rock, p-y criteria by Reese, 1997

   Distance from top of pile to top of layer           =    36.500000 ft
   Distance from top of pile to bottom of layer        =    55.000000 ft
   Effective unit weight at top of layer               =   155.000000 pcf
   Effective unit weight at bottom of layer            =   155.000000 pcf
   Uniaxial compressive strength at top of layer       =        5900. psi
   Uniaxial compressive strength at bottom of layer    =        5900. psi
   Initial modulus of rock at top of layer             =      747000. psi
   Initial modulus of rock at bottom of layer          =      747000. psi
   RQD of rock at top of layer                         =    94.000000 %
   RQD of rock at bottom of layer                      =    94.000000 %
   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 20.000 ft below the pile tip)


**** Warning - Possible Input Data Error ****

Values entered for effective unit weight of rock were outside the limits of
50 pcf to 150 pcf.

The maximum input value, in layer   6, for effective unit weight = 160.00 pcf

This data may be erroneous. Please check your data.
```

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Undrained Cohesion psf	Uniaxial qu psi	RQD %	E50 or krm	Rock Mass Modulus psi
1	Stiff Clay	7.5000	125.0000	950.0000	--	--	0.01000	--

	w/o Free Water	16.2000	125.0000	950.0000	--	--	0.01000	--
2	Stiff Clay	16.2000	130.0000	2250.	--	--	0.00500	--
	w/o Free Water	18.5000	130.0000	2250.	--	--	0.00500	--
3	Stiff Clay	18.5000	67.6000	2250.	--	--	0.00500	--
	w/o Free Water	21.0000	67.6000	2250.	--	--	0.00500	--
4	Stiff Clay	21.0000	72.6000	3400.	--	--	0.00500	--
	w/o Free Water	24.7000	72.6000	3400.	--	--	0.00500	--
5	Weak	24.7000	160.0000	--	600.0000	51.0000	5.00E-04	14900.
	Rock	36.5000	160.0000	--	600.0000	51.0000	5.00E-04	14900.
6	Weak	36.5000	155.0000	--	5900.	94.0000	5.00E-04	747000.
	Rock	55.0000	155.0000	--	5900.	94.0000	5.00E-04	747000.

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p-y Modification Factors for Group Action

Distribution of p-y modifiers with depth defined using 2 points

Point No.	Depth X ft	p-mult	y-mult
1	7.500	0.8100	1.0000
2	24.700	0.8100	1.0000

Static Loading Type

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

Distributed Lateral Loading Used For All Load Cases

Distributed lateral load intensity defined using 2 points

Point No.	Depth X in	Dist. Load lb/in
1	0.000	76.000
2	296.400	1790.000

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

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

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

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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

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Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	7.5000	0.00	N.A.	No	0.00	106805.
2	16.2000	4.5182	Yes	No	106805.	66098.
3	18.5000	6.8148	Yes	No	172903.	80630.
4	21.0000	6.7586	Yes	No	253533.	185367.
5	24.7000	17.2000	No	Yes	N.A.	N.A.
6	36.5000	29.0000	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 in-lb^2	Soil Res. p lb/inch	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0.00	3.8573	-7.69E-05	0.00	-0.01516	3.02E-07	1.33E+11	0.00	0.00	82.0719
0.3500	3.7936	723.8739	382.9546	-0.01516	2.8449	1.33E+11	0.00	0.00	100.2874
0.7000	3.7299	3217.	855.1655	-0.01516	12.6425	1.33E+11	0.00	0.00	124.5749
1.0500	3.6662	7907.	1429.	-0.01516	31.0766	1.33E+11	0.00	0.00	148.8623
1.4000	3.6025	15224.	2106.	-0.01516	59.8309	1.33E+11	0.00	0.00	173.1498
1.7500	3.5389	25594.	2884.	-0.01516	100.5893	1.33E+11	0.00	0.00	197.4372
2.1000	3.4752	39448.	3764.	-0.01516	155.0355	1.33E+11	0.00	0.00	221.7247
2.4500	3.4115	57213.	4746.	-0.01516	224.8533	1.33E+11	0.00	0.00	246.0121
2.8000	3.3479	79317.	5831.	-0.01516	311.7265	1.33E+11	0.00	0.00	270.2996
3.1500	3.2842	106190.	7017.	-0.01515	417.3389	1.33E+11	0.00	0.00	294.5870
3.5000	3.2206	138259.	8305.	-0.01515	543.3744	1.33E+11	0.00	0.00	318.8745
3.8500	3.1570	175953.	9695.	-0.01514	691.5166	1.33E+11	0.00	0.00	343.1619
4.2000	3.0934	219700.	11188.	-0.01514	863.4493	1.33E+11	0.00	0.00	367.4494
4.5500	3.0298	269929.	12782.	-0.01513	1061.	1.33E+11	0.00	0.00	391.7368
4.9000	2.9663	327068.	14478.	-0.01512	1285.	1.33E+11	0.00	0.00	416.0243
5.2500	2.9028	391546.	16277.	-0.01511	1539.	1.33E+11	0.00	0.00	440.3117
5.6000	2.8393	463792.	18177.	-0.01510	1823.	1.33E+11	0.00	0.00	464.5992
5.9500	2.7760	544232.	20179.	-0.01508	2139.	1.33E+11	0.00	0.00	488.8866
6.3000	2.7127	633297.	22284.	-0.01506	2489.	1.33E+11	0.00	0.00	513.1741
6.6500	2.6495	731414.	24490.	-0.01504	2875.	1.33E+11	0.00	0.00	537.4615
7.0000	2.5863	839012.	26798.	-0.01502	3297.	1.33E+11	0.00	0.00	561.7490
7.3500	2.5233	956519.	29209.	-0.01499	3759.	1.33E+11	0.00	0.00	586.0364
7.7000	2.4604	1084364.	30926.	-0.01495	4262.	1.33E+11	-378.4283	645.9802	610.3239
8.0500	2.3977	1216299.	31929.	-0.01492	4780.	1.33E+11	-388.8203	681.0859	634.6113
8.4000	2.3351	1352570.	32991.	-0.01488	5316.	1.33E+11	-399.0015	717.6491	658.8988
8.7500	2.2727	1493426.	34113.	-0.01483	5869.	1.33E+11	-408.9662	755.7660	683.1862
9.1000	2.2105	1639119.	35295.	-0.01478	6442.	1.33E+11	-418.7087	795.5414	707.4737
9.4500	2.1486	1789906.	36539.	-0.01473	7035.	1.33E+11	-428.2231	837.0890	731.7611
9.8000	2.0868	1946047.	37845.	-0.01467	7648.	1.33E+11	-437.5030	880.5326	756.0486
10.1500	2.0253	2107807.	39215.	-0.01461	8284.	1.33E+11	-446.5420	926.0074	780.3360
10.5000	1.9641	2275456.	40650.	-0.01454	8943.	1.33E+11	-455.3333	973.6612	804.6235
10.8500	1.9032	2449266.	42150.	-0.01446	9626.	1.33E+11	-463.8700	1024.	828.9109
11.2000	1.8427	2629515.	43717.	-0.01438	10334.	1.33E+11	-472.1446	1076.	853.1984
11.5500	1.7824	2816486.	45351.	-0.01430	11069.	1.33E+11	-480.1496	1131.	877.4858

11.9000	1.7226	3010466.	47055.	-0.01420	11832.	1.33E+11	-487.8770	1190.	901.7733
12.2500	1.6631	3211748.	48829.	-0.01410	12623.	1.33E+11	-495.3184	1251.	926.0607
12.6000	1.6041	3420627.	50674.	-0.01400	13444.	1.33E+11	-502.4651	1316.	950.3482
12.9500	1.5455	3637407.	52592.	-0.01389	14295.	1.33E+11	-509.3082	1384.	974.6356
13.3000	1.4874	3862396.	54583.	-0.01377	15180.	1.33E+11	-515.8380	1457.	998.9231
13.6500	1.4299	4095906.	56650.	-0.01364	16097.	1.33E+11	-522.0448	1533.	1023.
14.0000	1.3728	4338257.	58794.	-0.01351	17050.	1.33E+11	-527.9179	1615.	1047.
14.3500	1.3164	4589773.	61015.	-0.01337	18038.	1.33E+11	-533.4466	1702.	1072.
14.7000	1.2605	4850785.	63316.	-0.01322	19064.	1.33E+11	-538.6195	1795.	1096.
15.0500	1.2053	5121631.	65699.	-0.01306	20129.	1.33E+11	-543.4246	1894.	1120.
15.4000	1.1508	5402654.	68164.	-0.01290	21233.	1.33E+11	-547.8492	1999.	1145.
15.7500	1.0970	5694205.	70713.	-0.01272	22379.	1.33E+11	-551.8804	2113.	1169.
16.1000	1.0440	5996640.	73348.	-0.01254	23568.	1.33E+11	-555.5041	2235.	1193.
16.4500	0.9917	6310325.	74877.	-0.01234	24800.	1.33E+11	-1127.	4773.	1218.
16.8000	0.9403	6625608.	75295.	-0.01214	26040.	1.33E+11	-1133.	5063.	1242.
17.1500	0.8898	6942803.	75789.	-0.01192	27286.	1.33E+11	-1139.	5377.	1266.
17.5000	0.8401	7262239.	76364.	-0.01170	28542.	1.33E+11	-1144.	5717.	1290.
17.8500	0.7915	7584264.	77024.	-0.01146	29807.	1.33E+11	-1147.	6088.	1315.
18.2000	0.7439	7909242.	77773.	-0.01122	31084.	1.33E+11	-1150.	6492.	1339.
18.5500	0.6973	8237556.	78616.	-0.01096	32375.	1.33E+11	-1151.	6932.	1363.
18.9000	0.6518	8569617.	79562.	-0.01070	33680.	1.33E+11	-1150.	7408.	1388.
19.2500	0.6074	8905874.	80617.	-0.01042	35001.	1.33E+11	-1147.	7933.	1412.
19.6000	0.5642	9246798.	81787.	-0.01013	36341.	1.33E+11	-1144.	8512.	1436.
19.9500	0.5223	9592882.	83077.	-0.00984	37701.	1.33E+11	-1139.	9156.	1460.
20.3000	0.4816	9944641.	84492.	-0.00953	39084.	1.33E+11	-1132.	9875.	1485.
20.6500	0.4423	1.03E+07	86039.	-0.00921	40491.	1.33E+11	-1125.	10680.	1509.
21.0000	0.4043	1.07E+07	87491.	-0.00887	41924.	1.33E+11	-1226.	12735.	1533.
21.3500	0.3677	1.10E+07	88367.	-0.00853	43379.	1.33E+11	-1448.	16536.	1558.
21.7000	0.3326	1.14E+07	88909.	-0.00818	44841.	1.33E+11	-1434.	18102.	1582.
22.0500	0.2990	1.18E+07	89617.	-0.00781	46314.	1.33E+11	-1417.	19902.	1606.
22.4000	0.2670	1.22E+07	90503.	-0.00743	47800.	1.33E+11	-1398.	21988.	1630.
22.7500	0.2366	1.25E+07	91576.	-0.00704	49302.	1.33E+11	-1376.	24426.	1655.
23.1000	0.2079	1.29E+07	92849.	-0.00664	50823.	1.33E+11	-1351.	27304.	1679.
23.4500	0.1809	1.33E+07	94334.	-0.00622	52367.	1.33E+11	-1324.	30739.	1703.
23.8000	0.1556	1.37E+07	96045.	-0.00580	53937.	1.33E+11	-1293.	34889.	1728.
24.1500	0.1322	1.41E+07	97995.	-0.00535	55538.	1.33E+11	-1258.	39973.	1752.
24.5000	0.1106	1.45E+07	100201.	-0.00490	57173.	1.33E+11	-1220.	46301.	1776.
24.8500	0.09100	1.50E+07	77622.	-0.00443	58846.	1.33E+11	-11437.	527829.	127.7952
25.2000	0.07337	1.52E+07	27641.	-0.00396	59735.	1.33E+11	-12491.	715048.	0.00
25.5500	0.05776	1.52E+07	-26573.	-0.00348	59758.	1.33E+11	-13324.	968899.	0.00
25.9000	0.04417	1.50E+07	-83780.	-0.00300	58858.	1.33E+11	-13917.	1323458.	0.00
26.2500	0.03256	1.45E+07	-142923.	-0.00253	56993.	1.33E+11	-14246.	1837552.	0.00
26.6000	0.02288	1.38E+07	-202828.	-0.00209	54140.	1.33E+11	-14280.	2620919.	0.00
26.9500	0.01504	1.28E+07	-262152.	-0.00167	50297.	1.33E+11	-13970.	3902378.	0.00
27.3000	0.00889	1.16E+07	-319260.	-0.00128	45485.	1.33E+11	-13225.	6250577.	0.00
27.6500	0.00427	1.01E+07	-371867.	-9.38E-04	39757.	1.33E+11	-11826.	1.16E+07	0.00
28.0000	0.00101	8449747.	-404464.	-6.45E-04	33209.	1.33E+11	-3697.	1.54E+07	0.00
28.3500	-0.00114	6718391.	-402871.	-4.05E-04	26404.	1.33E+11	4455.	1.64E+07	0.00
28.7000	-0.00239	5065631.	-372705.	-2.18E-04	19909.	1.33E+11	9909.	1.74E+07	0.00
29.0500	-0.00298	3587673.	-324586.	-8.16E-05	14100.	1.33E+11	13004.	1.84E+07	0.00
29.4000	-0.00308	2339110.	-267509.	1.21E-05	9193.	1.33E+11	14175.	1.93E+07	0.00
29.7500	-0.00287	1340601.	-208565.	7.03E-05	5269.	1.33E+11	13893.	2.03E+07	0.00
30.1000	-0.00249	587167.	-152900.	1.01E-04	2308.	1.33E+11	12614.	2.13E+07	0.00
30.4500	-0.00203	56237.	-103852.	1.11E-04	221.0188	1.33E+11	10743.	2.23E+07	0.00

30.8000	-0.00156	-285192.	-63198.	1.07E-04	1121.	1.33E+11	8616.	2.32E+07	0.00
31.1500	-0.00113	-474627.	-31473.	9.53E-05	1865.	1.33E+11	6491.	2.42E+07	0.00
31.5000	-7.58E-04	-549568.	-8304.	7.91E-05	2160.	1.33E+11	4543.	2.52E+07	0.00
31.8500	-4.62E-04	-544379.	7279.	6.18E-05	2139.	1.33E+11	2878.	2.61E+07	0.00
32.2000	-2.39E-04	-488422.	16564.	4.55E-05	1920.	1.33E+11	1543.	2.71E+07	0.00
32.5500	-8.05E-05	-405245.	20935.	3.13E-05	1593.	1.33E+11	538.6153	2.81E+07	0.00
32.9000	2.41E-05	-312566.	21716.	2.00E-05	1228.	1.33E+11	-166.8852	2.91E+07	0.00
33.2500	8.72E-05	-222832.	20055.	1.15E-05	875.7582	1.33E+11	-623.9980	3.00E+07	0.00
33.6000	1.21E-04	-144105.	16872.	5.71E-06	566.3500	1.33E+11	-891.8563	3.10E+07	0.00
33.9500	1.35E-04	-81110.	12884.	2.15E-06	318.7720	1.33E+11	-1007.	3.13E+07	0.00
34.3000	1.39E-04	-35881.	8597.	2.96E-07	141.0157	1.33E+11	-1034.	3.13E+07	0.00
34.6500	1.38E-04	-8894.	4272.	-4.12E-07	34.9544	1.33E+11	-1026.	3.13E+07	0.00
35.0000	1.35E-04	0.00	0.00	-5.52E-07	0.00	1.33E+11	-1008.	1.56E+07	0.00

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

Output Summary for Load Case No. 1:

Pile-head deflection = 3.85726037 inches
Computed slope at pile head = -0.01516213 radians
Maximum bending moment = 15205186. inch-lbs
Maximum shear force = -404464. lbs
Depth of maximum bending moment = 25.55000000 feet below pile head
Depth of maximum shear force = 28.00000000 feet below pile head
Number of iterations = 26
Number of zero deflection points = 2

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
35.00000	3.85726037	15205186.	-404464.
33.25000	3.85327849	15143379.	-407202.
31.50000	3.83212203	15105414.	-403554.
29.75000	4.41338014	14424360.	-486458.
28.00000	11.89630479	8635134.	-410436.

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

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

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	0.00	M, in-lb	0.00	0.00	3.8573	-0.01516	-404464.	1.52E+07

Maximum pile-head deflection = 3.8572603663 inches
Maximum pile-head rotation = -0.0151621286 radians = -0.868726 deg.

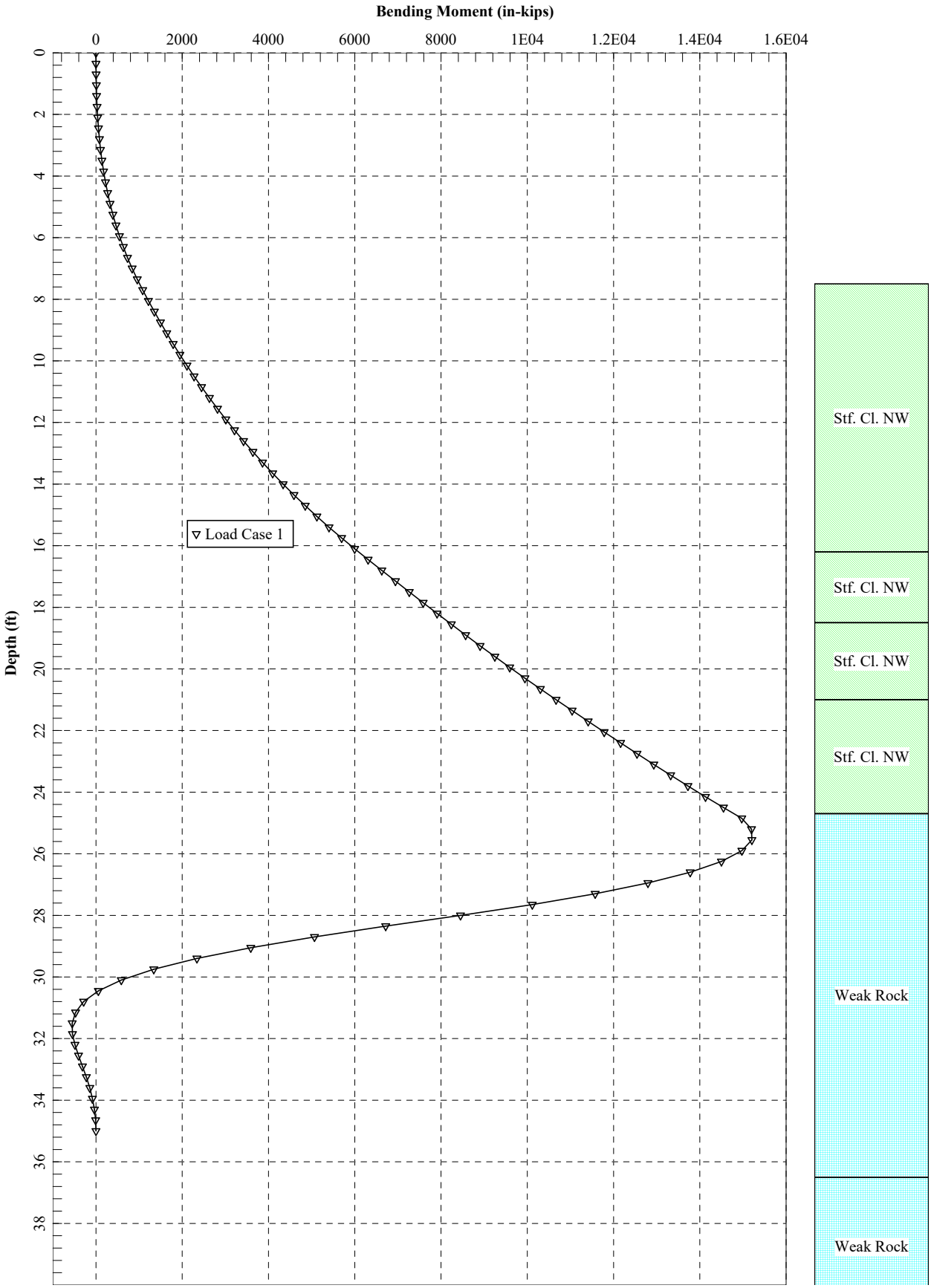
Summary of Warning Messages

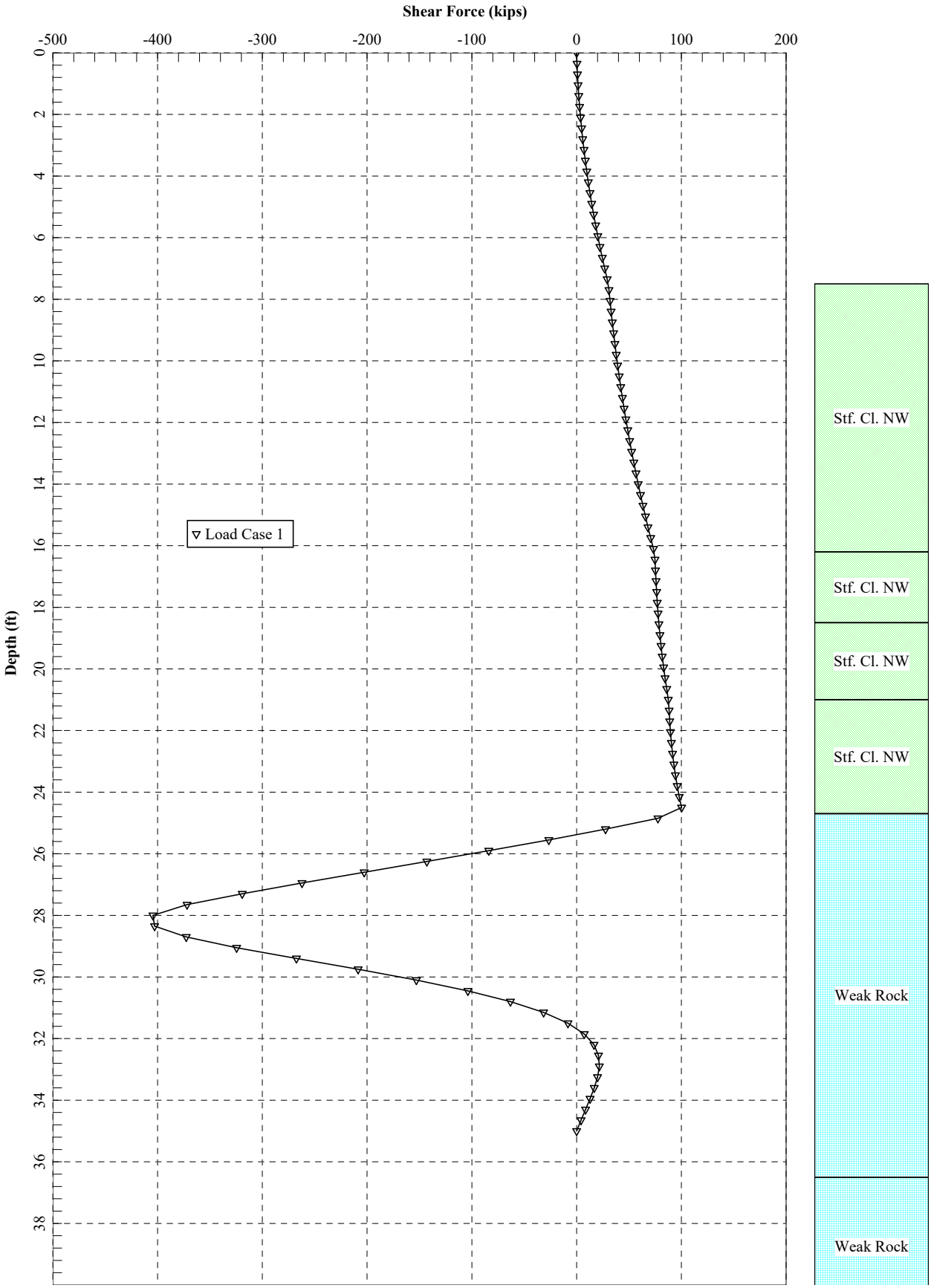
The following warning was reported 4507 times

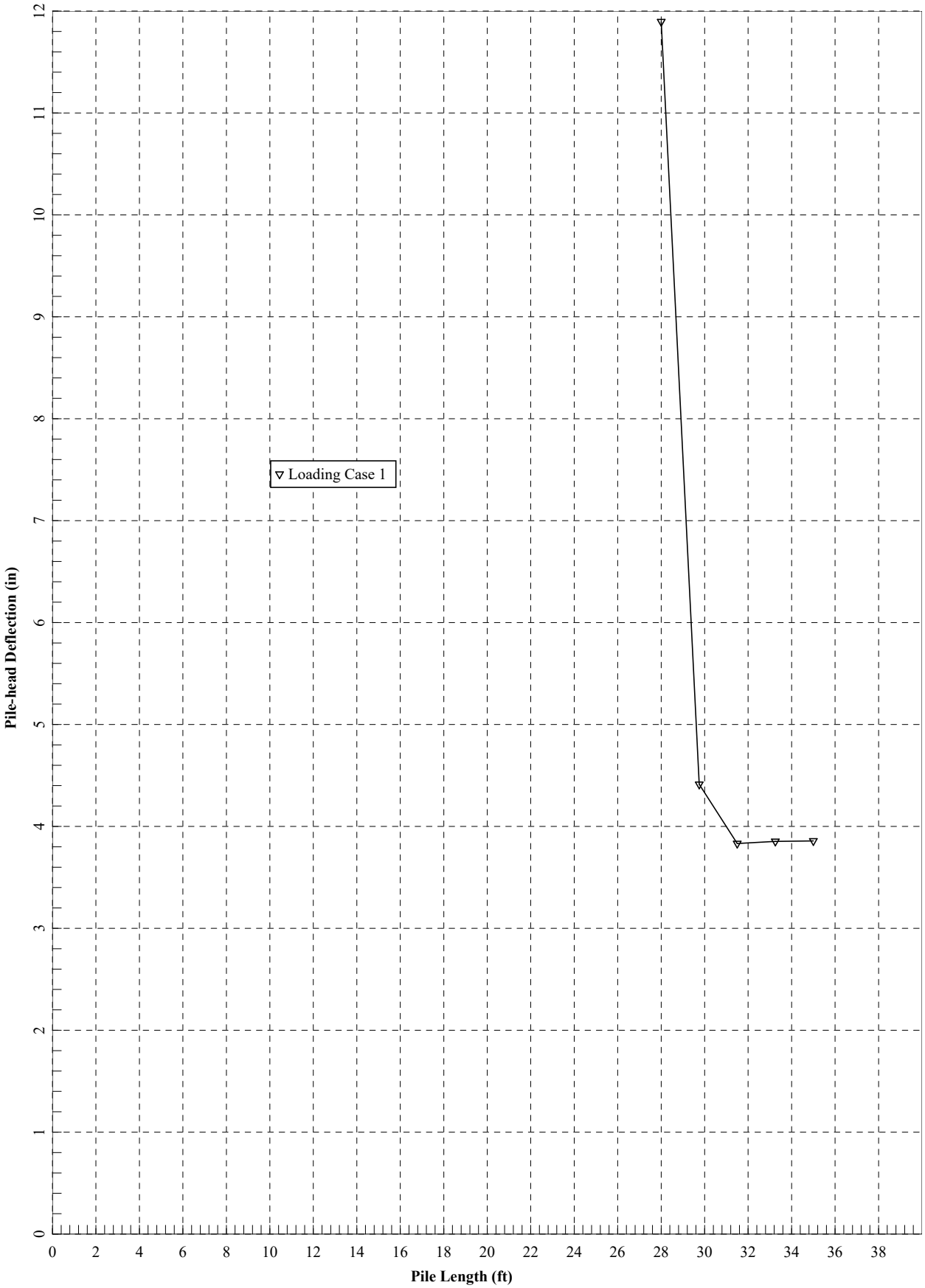
**** Warning ****

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.

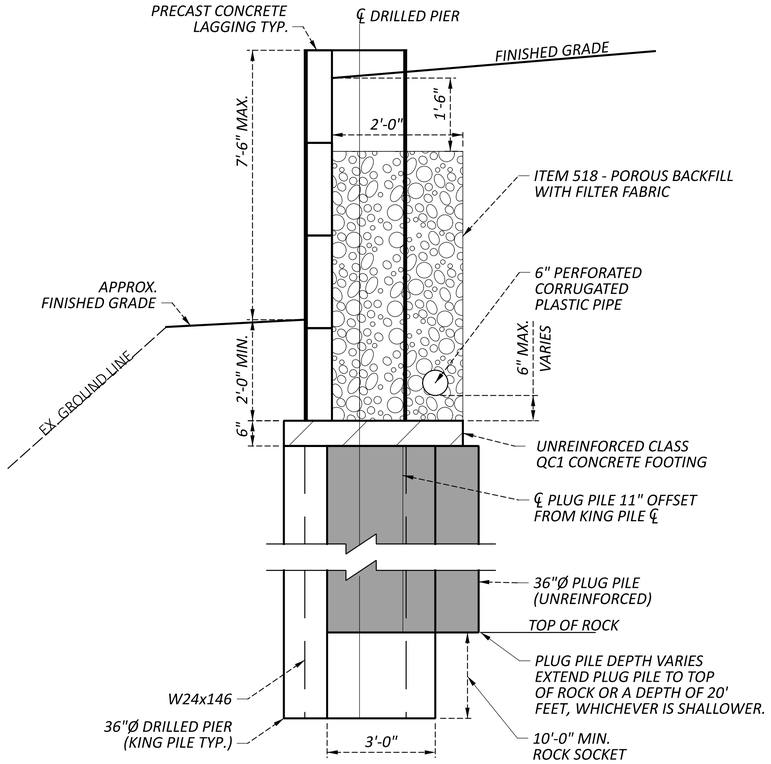
The analysis ended normally.


Bending Moment (in-kips)
0
2000
4000
6000
8000
1E04
1.2E04
1.4E04
1.6E04
Depth (ft)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
Load Case 1
Stf. Cl. NW
Stf. Cl. NW
Stf. Cl. NW
Stf. Cl. NW
Weak Rock
Weak Rock

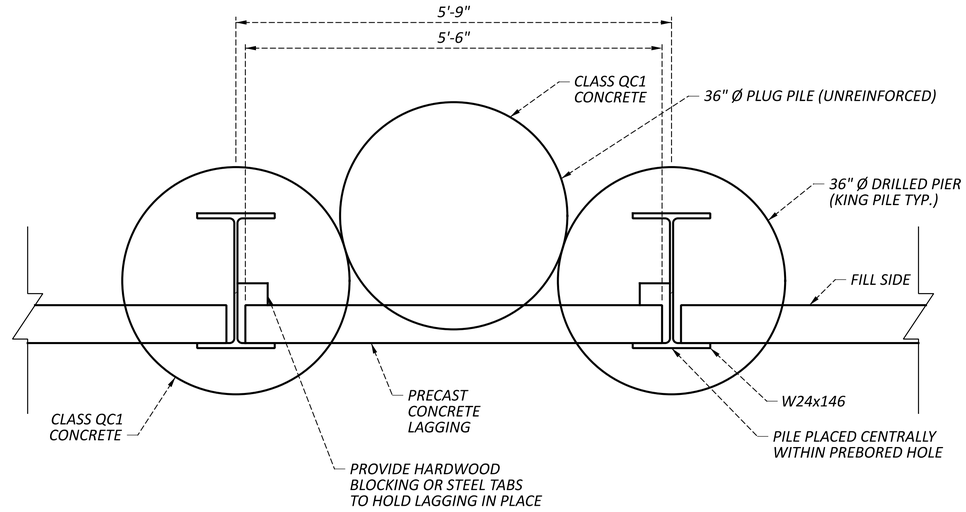

Shear Force (kips)
-500
-400
-300
-200
-100
0
100
200
Depth (ft)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
Load Case 1
Stf. Cl. NW
Stf. Cl. NW
Stf. Cl. NW
Stf. Cl. NW
Weak Rock
Weak Rock


Pile-head Deflection (in)
0
1
2
3
4
5
6
7
8
9
10
11
12
Loading Case 1
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
Pile Length (ft)

Soldier Pile and Lagging Wall Detail

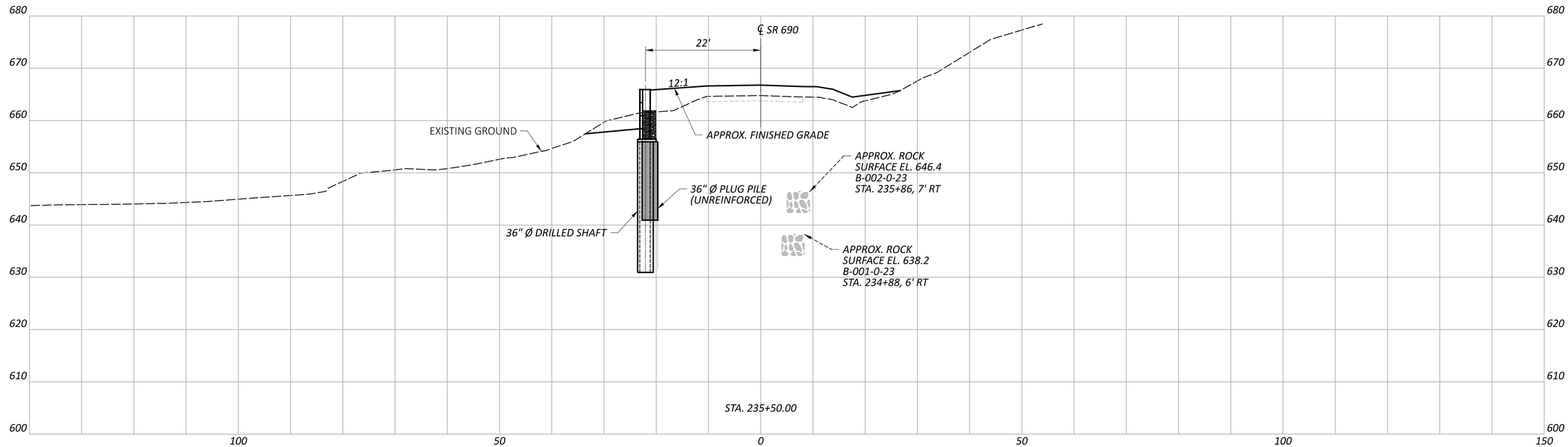


TYPICAL SECTION
NOT TO SCALE



PLAN - RETAINING WALL
NOT TO SCALE

BORING	STATION	OFFSET	APPROX. SURFACE ELEVATION	APPROX. ROCK SURFACE ELEVATION
B-001-0-22	234+88	6' LT	663.2	638.2
B-002-0-22	235+87	7' LT	667.4	646.4
B-003-0-22	237+03	4' LT	671.4	651.4



HORIZONTAL SCALE IN FEET
0 5 10 20

SOLDIER PILE AND LAGGING WALL DETAIL
CRITICAL SECTION STA. 235+50

DESIGN AGENCY
HDR

DESIGNER DCM
REVIEWER DMV 02/15/23
PROJECT ID 114592
SHEET 1 TOTAL 1

ATH-690-4.21

MODEL: Sheet PAPERSIZE: 34x22 (in.) DATE: 2/15/2023 TIME: 6:50:12 PM USER: DVOEGELE
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