Final Structure Foundation Exploration Report

MOE-TR183-0.13

Monroe County, OH
March 7, 2023

Prepared for:
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By:

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Appendices

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EXECUTIVE SUMMARY

This report summarizes the results of the structure foundation exploration program performed in support of the replacement of Bridge No. MOE-TR183-0.13 (SFN 5634504) carrying Paines Run Road, Township Road 183 (TR 183), over Paines Run in Salem Township in eastern Monroe County, just to the northeast of the unincorporated community of Cameron, Ohio.

The report includes the geotechnical information obtained from borings and laboratory testing performed under this study. The exploration, along with the laboratory test results are presented in more detail in Section 3 and Appendices B and C of this report.

Based on HDR's assessment of the borings, the generalized soil profile consists of alluvial sand and gravel deposits overlying shale, claystone, and sandstone bedrock. Further discussion on the encountered subsurface conditions is located in Section 4.

Given the relatively shallow depth to bedrock (approximately 25 feet), it is anticipated that deep foundations will be utilized to support the new bridge structure. The selected design build team will determine the appropriate foundation type. However, given the proximity of Paines Run, the shallow groundwater, and interbedded loose to medium dense sands and gravel deposits within the soil profile, pile foundations are anticipated to be the preferred foundation option. The recommended design parameters for the foundation analyses to be performed by the design build team are provided in Section 5 and in Appendix D.

1 INTRODUCTION

This report summarizes the results of the structure foundation exploration program performed in support of the replacement of Bridge No. MOE-TR183-0.13 (SFN 5634504) carrying Paines Run Road (TR 183) over Paines Run. The MOE-TR183-0.13 project is located in Salem Township in eastern Monroe County, just to the northeast of the unincorporated community of Cameron, Ohio as shown on the Site Vicinity Map (Exhibit No. 1) in Appendix A. The work includes the removal of the existing 49-foot bridge structure and its replacement with a presumed single span box beam structure using the design-build contracting method. Minimal approach work is expected, with a total project length of 200 feet, starting at Straight Line Mileage (SLM) 0.13 and extending to approximate SLM 0.17.

This geotechnical study was authorized by the Ohio Department of Transportation (ODOT) on October 12, 2022, under the VAR-STW Geotechnical Engineering Services CEAO 2023-2 contract. The geotechnical services performed under this task order were carried out in general accordance with ODOT's *Specifications for Geotechnical Explorations* (SGE) *Geotechnical Design Manual* (GDM), *Bridge Design Manual* (BDM), and the *Location and Design Manual, Volume 2*. All four documents are dated July 2022. The scope of work relative to this exploration report included:

- a visual reconnaissance of the project site,
- review of available soil and geologic information within the project area,
- the development and performance of a subsurface exploration program to evaluate the existing subsurface conditions at the bridge location,
- laboratory testing on selected soil and rock samples in accordance with the requirements of the SGE,
- characterization of a generalized soil profile along with recommended design strength parameters, and
- preparation of this Structure Foundation Exploration report.

This report presents the descriptions and interpretations of the encountered subsurface conditions at the site and provides general geotechnical recommendations to assist in the design of the replacement bridge structure by the selected design build team.

2 GEOLOGY AND OBSERVATIONS

2.1 Project Setting

This project is located within a valley flood plain the northeast portion of Monroe County, Ohio. The rural setting surrounded by wooded hillsides and agricultural parcels. A residential structure, as well as an existing farm equipment supplier and boneyard are located adjacent to the project site. Elevations along the project site range from about El. 690 outside the bridge limits to approximately El. 680 at the stream crossing itself.

2.2 Soil and Geologic Setting

A review of the Physiographic Regions of Ohio map (Ohio Division of Geological Survey, 1998) indicates that the project site is located within the Little Switzerland Plateau region of the Allegheny Plateaus section of the Appalachian Plateaus province (Exhibit No. 2 in Appendix A). The Little Switzerland Plateau region is characterized by highly dissected, high relief valleys of generally 450 ft to 750 feet along the Ohio River. Elevations in this region generally range from 450 to 1,400 feet above sea level. Soils in the Little Switzerland Plateau typically consist of red and brown silty-clay loam colluvium over Pennsylvanian-age upper Conemaugh group through Permian-age Dunkard group cyclic sequences of red and gray shales, and siltstones, sandstones, limestones, and coals.

The project site is directly drained by Paines Run, with the confluence of Paines Run and Sunfish Creek located approximately 900 feet downstream of the project site. Sunfish Creek and its tributaries drain much of the northern part of Monroe County, and eventually drains into the Ohio River, approximately 5 miles east of the project site.

According to the Surficial Geology data from the Ohio Department of Natural Resources (ODNR) Division of Geological Survey (Exhibit No. 3 in Appendix A), surficial soils at the site consist of primarily Holocene-aged alluvial deposits (a) with underlying Wisconsinan-aged sand and gravel (SG). These surficial deposits are underlain by Pennsylvanian bedrock including sandstone, shale, siltstone, clay, limestone, and coal (P). The alluvium develops in floodplains of modern streams with soils ranging from silt to clay to boulders, commonly including organic materials. The sand and gravel deposits consist of intermixed and interbedded sand and gravel, commonly containing thin, discontinuous layers of silt and clay. The deposits may be finely stratified to massive, as well as cross bedded. The thickness of the sand and gravel deposits at the project site is approximately 25 feet.

2.2.1 Project Soils

The USDA Soil Survey of Monroe County indicates the most prevalent surficial soil types within the project limits are the Chagrin (Chg1AF) and Hartshorn (He) silt loams as shown in Exhibit No. 4a.

Soils of the Chagrin silt loam (0 to 3 percent slopes) consist of 95 percent Chagrin soils, and 5 percent minor components. The Chagrin soils generally consist of silt loam and loam overlying stratified gravelly fine sandy loam to silt loam derived from fine loamy alluvium. The well drained soils are typically located in flood plains with a moderately high to high water capacity.

Soils of the Hartshorn silt loam (0 to 2 percent slopes) consist of 100 percent Hartshorn and similar soils. Hartshorn soils generally consist of silt loam, gravelly silt loam, sand and gravel overlying unweathered bedrock derived from alluvium. The well drained soils are typically located in floodplains with a very low to moderately high water capacity.

As shown on Exhibit Nos. 4b through 4d in Appendix A, the soil survey indicates the soils within the project area are considered to have low to moderate risk of corrosion to concrete, high risk of corrosion to steel, and have pH levels of 6.1 to 6.5.

2.2.2 Bedrock Geology

As shown on Exhibit No. 5 (Bedrock Geology Map), the bedrock geology mapped within the project area is the Pennsylvanian age Monongahela Group (IPm). The Permian-Pennsylvanian age Dunkard Group (PIPd) is located at higher elevations on the valley walls and ridges outside of the project area. Bedrock elevations in the project area are less than 700 feet within the Sunfish Creek valley as shown on Exhibit No. 6 (Bedrock Topography Map), and quickly climbs upon the valley walls to El 750 or higher.

The Upper Pennsylvanian-age Monongahela Group generally consists of shale, siltstone, limestone, sandstone, and coal with laterally extensive nonmarine limestone and coal beds. General features include lenticular, planar, nodular, irregular, and cross bedding, with thin to massive bedding. The sandstones are described as fine to coarse grained, locally calcareous and conglomeratic, thin to massive to cross bedded, and micaceous. Limestone is described as micritic to coarse grained, thin to medium bedding including nodular to irregular bedding. Coals are banded, bituminous, thin to thick bedded with local to regional distribution.

No previous surface or deep mining was mapped at the project site itself. However as shown on the ODNR Mines of Ohio Map (Exhibit No. 7), significant deep mining of the Pittsburgh No. 8 coal seam of the Monongahela group has been performed approximately 0.75 mile northeast of the project site. Additional information provided by ODNR indicates this coal seam to be near El. 450 to El. 500. Several abandoned mine entrances are also located within approximately 0.75 mile to 1.0 mile south and west of the project site. These mine openings are associated with the Meigs Creek No. 9 and Uniontown No. 10 coal seams, also of the Monongahela group. These seams ranged from roughly El. 700 to El. 755 based on available historic mining information provided by the ODNR.

3 EXPLORATION

3.1 Site Reconnaissance

A visual reconnaissance of the project site and surrounding area was performed by an HDR geotechnical engineer during the drilling activities on October 17 and 18, 2022. The project site is located within a relatively wide valley containing Sunfish Creek, near the toe of the valley wall. The existing bridge is a one lane structure carrying TR 183 over Paines Run. This single span structure is supported by two approximately 23-inch deep by 9-inch wide, steel sections spanning between the two bridge abutments. The abutments appear to have been previously constructed of 15-inch by 15-inch by 36-inch stacked stone blocks, which have since been braced and strengthened with a soldier pile and lagging wall along the face of the masonry abutment. The lagging consists of corrugated steel sheeting at the north abutment, and guardrail at the south abutment. Measured from the creek bed to the bridge deck surface, the abutment walls are approximately 9 feet in height along the south abutment and approximately 4.5 feet at the north abutment.

The existing bridge deck consists of approximately 2.5-inch by 3.5-inch wood planks, placed perpendicular to the alignment, supported on six evenly spaced 3-inch wide by 5-inch deep steel sections positioned parallel to the alignment. Multiple gaps and holes were noted near the middle bridge span from apparent rot and decay of the planks. The bridge deck is supported by 10 approximately 6.5-inch wide and 8-inch deep steel sections spanning perpendicular to the alignment and connected to the two 23-inch deep by 9-inch wide steel sections running along the sides of the bridge. The exceptions are the southern and northern most 6.5-inch by 8-inch steel sections. As the bridge is set slightly askew to the creek, these steel sections do not span the entire width of the bridge, but rather intersect their respective abutment. Multiple 6.5-inch by 8-inch steel sections exhibited severe rust and corrosion resulting in section loss of the webbing at several locations.

An approximately 12-inch diameter rubber pipe with a 24-inch diameter corrugated plastic pipe serving as outer casing was observed to be traversing beneath the bridge structure along the south abutment wall. No details on this overland pipe were available at the time of the reconnaissance.

3.2 Subsurface Exploration

Two borings were drilled as part of the geotechnical exploration program to assess the subsurface conditions within the MOE-TR183-0.13 project limits. The locations of the test borings, are shown on the Boring Location Plan (Exhibit No. 8) in Appendix A. These as-drilled locations are reflected on the boring plan, boring logs and Table 3-1.

Table 3-1. Summary of Bridge Structure Borings

Boring Number	Boring Type[1]	Alignment	Station	Offset	Surface (El., feet)	Bottom of Borehole (El., feet)
B-001-0-22	E1	TR 183	9+85	12 LT	687.1	647.1
B-002-0-22	E1	TR 183	10+30	7 RT	688.7	648.8

[1] ODOT Boring Designations: Bridge Structure (E1)

The borings were drilled by Central Star Drilling under the supervision of an HDR geotechnical engineer between October 17 and October 18, 2022, with a Diedrich D-50 track rig. The rig was calibrated on March 7, 2022, with an energy ratio of 86.8%. All borings were drilled in general accordance with the *Specifications for Geotechnical Explorations* (ODOT revised July 2022) utilizing 3.25-inch internal diameter hollow stem augers to advance the borings to the top of bedrock. The sampling of the soils was accomplished in accordance with the *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils*, ASTM D 1586. In the split-barrel sampling procedure, a standard 2-inch outside diameter split-barrel sampling spoon is driven into the ground with a 140-pound hammer falling a distance of 30 inches. The number of blows required to advance the sampling spoon the last 12 inches of a typical 18-inch penetration is recorded as the standard penetration test (SPT) resistance or N_{SPT}-value. The N_{SPT}-value is then corrected to an energy ratio of 60%, termed N_{60}, which is used for design. Sampling of the underlying bedrock was performed in accordance with the *Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation*, ASTM D 2113, using an NQ2-size double tube-swivel barrel with a diamond bit. Boring logs and photographs of the recovered rock core samples are provided in Appendix B.

3.3 Laboratory Testing

The obtained soil and rock samples were visually examined by an HDR geotechnical engineer, and representative soil samples selected for laboratory testing to confirm the field classification and to assess the various engineering properties of the soils. Soil index testing performed by HDR included 25 natural moisture content tests (per ASTM D 2216), 13 Atterberg limit determinations (per ASTM D 4318), and 13 grain size analyses (per ASTM D 422). The results of the soil index tests are presented on the final boring logs located in Appendix B. In addition to the soil index testing, 1 unconfined compression test (ASTM D 7012 – Method C) and 3 Point Load Strength Index of Rock (ASTM D 5731) tests were performed on bedrock samples. Results of these tests are presented on the individual laboratory sheets included in Appendix C.

4 FINDINGS

The generalized soil profile as encountered in the borings consists of alluvial sand and gravel deposits overlying shale, claystone, and sandstone bedrock. The upper layers of the granular deposits consisted primarily of loose to medium dense Sandy Silt (A-4a), Gravel with Sand, Silt, and Clay (A-2-6), and Gravel with Sand and Silt (A-2-4). These soils were encountered to a depth of 16 feet below ground surface (bgs) (El. 671.1) in Boring B-001-0-22 and 20 feet bgs (El. 668.7) in Boring B-002-0-22. A thin layer of medium dense Gravel with Sand (A-1-b) was also encountered in Boring B-002-0-22, from 11.5 to 13 feet bgs. The N_{60}-values in the upper soil layers ranged from 4 to 23 blows per foot (bpf).

A significant increase in the relative density of the granular deposits was noted beneath these upper layers, with dense to very dense Gravel and Stone Fragments with Sand (A-1-b) and very dense Gravel and Stone Fragments with Sand, Silt and Clay (A-2-6) encountered. This layer extended to the top of rock at 23.5 feet bgs (El 663.6) in Boring B-001-0-22 and to a very dense Sandy Silt (A-4a) exhibiting relic rock structure at 22.5 feet bgs (El. 666.2) in Boring B-002-0-22. This residual soil extended to the top of rock at 25 feet bgs (El. 663.7). The N_{60}-values in these lower layers ranged from 35 to 91 bpf.

Shale, claystone, and sandstone bedrock was encountered underlying the sand and gravel deposits to the boring termination depths of approximately 40 feet. Shale was encountered from a depth of 23.5 to 29.5 feet bgs (El. 663.6 to El. 657.6) in Boring B-001-0-22 and 25 to 28 feet bgs (El. 663.7 to El. 660.7) in Boring B-002-0-22. The shale was characterized as slightly weathered, very weak to slightly strong with a stratum rock quality designation (SRQD) of 52% to 67%. Claystone was encountered underlying the shale from a depth of 29.5 feet (El 657.6) to 34.7 feet bgs (El. 652.4) in Boring B-001-0-22 and 28 feet bgs (El 660.7) to 36.9 feet bgs (El. 651.8) in Boring B-002-0-22. The claystone was characterized as moderately to slightly weathered and weak to very weak with a SRQD ranging from 49% to 73%. Sandstone was encountered underlying the claystone at depths of 34.7 feet bgs (El 652.4) and 36.9 feet bgs (El 651.8) in Borings B-001-0-22 and B-002-0-22, respectively, to termination. The sandstone was characterized as unweathered to slightly weathered and slightly to moderately strong with a SRQD of 97% to 100%.

Groundwater was encountered in both borings during drilling. As water was introduced during drilling activities to perform rock coring, water levels upon completion were not obtained. Furthermore, the borings were sealed immediately upon completion as the borings were performed in close proximity to the traveled lane, and delayed water readings were not obtained. Groundwater depths and elevations encountered in the borings are tabulated in Table 4-1 and included on the boring logs in Appendix B.

Table 4-1. Summary of Groundwater Levels

Boring	Depth/Elevation During (ft)	Notes
B-001-0-22	12/675.1	Water added at 25.0 feet. Boring completed the same day
B-002-1-22	10/678.7	Water added at 25.5 feet. Boring completed the same day

5 ANALYSES AND RECOMMENDATIONS

5.1 Determination of Soil Parameters

Soil parameters were developed primarily from laboratory tests, supplemented by published correlations with SPT data and plasticity indices and our engineering experience and judgement. A summary of the recommended strength parameters and design profile elevations are provided in Table 5-1. Details of the parameter development are located in Appendix D.

Table 5-1. Recommended Soil Strength Parameters

Recommended Design Profile		Material	Unit Wt.[1]	Undrained Shear Strength		Drained Shear Strength	
Top Elevation (ft)	Bottom Elevation (ft)		γ_T (pcf)	S_u (psf)	ϕ' (°)	c' (psf)	ϕ' (°)
688	686	Medium Dense	125	0	31	0	31
686	682	Loose Granular	120	0	28	0	28
682	676	Medium Dense	125	0	31	0	31
676	669	Medium Dense (submerged)	125	0	31	0	31
669	635.5	Dense to Very Dense Granular	135	0	37	0	37

1. Effective unit weights to be used below groundwater (assumed at El 676 in recommended design soil profile).

5.2 Bridge Foundations

The project involves the replacement of an existing single-span structure carrying Paines Run Road (TR 183) over Paines Run. As this will be a design-build project, providing a recommended foundation type is outside the scope of this study. However, given the interbedded layers of loose and medium dense granular soils overlying the site, and the relatively shallow depth to competent bedrock (approximately 25 feet bgs), it is anticipated that deep foundations will be utilized to support the bridge abutments. With the adjacent creek, shallow groundwater, and granular soil encountered within the soil profile, driven or cast-in-place pile foundations rather than drilled shafts are anticipated to be the preferred foundation type to avoid potential complications related to seepage and potential caving of the shaft walls during excavation. As such, Table 5-2 below provides a summary of recommended design parameters for use by the selected design build team for axial and lateral pile analyses using both APILE and LPILE software programs by Ensoft. Any piles spaced closer than five (5) pile widths must also consider group effects.

Table 5-2. Recommended Axial and Lateral Pile Design Parameters

Recommended Design Profile		Material	Unit Wt.[1]		E50	k (pci)
Top Elevation (ft)	Bottom Elevation (ft)		γ_T (pcf)	γ_{Eff} (pcf)		
688	686	Medium Dense	125	125	-	90
686	682	Loose Granular	120	120	-	25
682	676	Medium Dense	125	125	-	90
676	669	Medium Dense (submerged)	125	62.6	-	60
669	635.5	Dense to Very Dense Granular	135	72.6	-	125

[1] Effective unit weights to be used below groundwater (assumed at El 676 in the recommended design soil profile).

5.3 Scour Evaluation Parameters

Continuous sampling of the soils was conducted within each boring for a length of 6 feet beginning from the approximate elevation of the stream bed for Paines Run to assist with the determination of the scour analysis parameters per Section 1302 of the GDM. Table 5-3 below summarizes the sampling depths and respective scour analysis parameters to be utilized by the selected design build team in determining the predicted scour depth.

Table 5-3: Scour Analysis Parameters

Boring	Sample	Top Elevation (ft)	D50 Value (mm)	Critical Shear Stress, Tc (psf)	Erosion Category, EC (dim)
B-001-0-22	SS-5	677.6	4.8348	0.101	3.02
	SS-6	676.1	3.0327	0.063	2.78
	SS-7	674.6	2.4802	0.052	2.67
	SS-8	673.1	5.3393	0.112	3.07
B-002-0-22	SS-5	678.7	4.2471	0.089	2.95
	SS-6	677.2	1.3939	0.029	2.37
	SS-7	675.7	2.6654	0.056	2.71
	SS-8	674.2	3.0839	0.064	2.79

5.4 Recommendations

5.4.1 Site Preparation

- Site preparation activities at the bridge should be performed in accordance with Item 201 and Item 202 of the current edition of the CMS. These activities are anticipated to include removal of the existing bridge structure and possible relocation of existing utilities.

5.4.2 Settlement

- Modifications to the vertical roadway alignment within the project area are expected to be minor and as such, minimal settlement is anticipated to occur. This settlement, within the predominantly granular profile, is anticipated to be immediate and to occur during construction. In addition, any settlement of the bridge structure itself would be limited should the vertical alignment of TR 183 be raised as it is anticipated that the bridge foundations will bear on the underlying competent bedrock encountered at approximately 25 feet below the existing ground surface. However, analyses may need to be conducted if the roadway profile is raised to estimate the magnitude of any drag forces acting on the piles as outlined in section 305.3.2.2 of the ODOT BDM using the neutral plane method considering 100% tip resistance mobilization.

6 LIMITATIONS

This report documents the preliminary findings and conclusions of HDR Engineering, Inc., for the geotechnical aspects related to the planning and design of the MOE-TR183-0.13 project in Monroe County, Ohio. The report has been prepared for the use of the Office of the Monroe County Engineer for specific application to this project, in accordance with generally accepted engineering practice. No warranty, expressed or implied, is made. Any analyses or recommendations submitted are based on the field explorations performed at the locations indicated, on specific laboratory tests on individual samples taken during this exploration, and information obtained from outside sources. The report and analyses do not reflect variation that could occur between borings or at other points in time. Variations in conditions, if any, may become evident during the construction period, at which time, a re-evaluation of the recommendations may become necessary. In the event of such changes, the recommendations and changes should be reviewed by HDR's geotechnical staff.

7 REFERENCES

State of Ohio Department of Transportation (Updated July 2022); "*Specifications for Geotechnical Explorations."*

State of Ohio Department of Transportation (Updated July 2022); "*Geotechnical Design Manual."*

State of Ohio Department of Transportation (Updated July 2022); "*Bridge Design Manual."*

State of Ohio Department of Transportation (July 2022); "*Location and Design Manual, Volume 2 – Drainage Design."*

United States Department of Agriculture: Natural Resources Conservation Service (2022); "Web Soil Survey". http://websoilsurvey.nrcs.usda.gov/app/"

Ohio Department of Natural Resources, Division of Geologic Survey (2022); "*Ohio Geology Interactive Map*". https://ohiodnr.gov/business-and-industry/services-to-business-industry/gis-mapping-services/ohio-geology-interactive-map

Ohio Division of Geological Survey (1998); *Physiographic regions of Ohio: Ohio Department of National Resources*, Division of Geological Survey, scale 1:2,100,000.

Ohio Department of Natural Resources Division of Geological Survey (2013); "*Ohio's Geology in Core and Outcrop: A Field Guide for Citizens and Environmental and Geotechnical Investigators*", Information circular 63.

United States Geological Survey Topographic Map, (2019); "*Cameron Quadrangle, Ohio."*

Ohio Department of Natural Resources, Division of Geologic Survey and Division of Mineral Resources (2022); *"Mines of Ohio"*. https://gis.ohiodnr.gov/MapViewer/?config=OhioMines#

Appendix A. Exhibits

Exhibit No. 1: Site Vicinity and Topographic Map

Project: MOE-TR183-0.13
PID: 117574

Calculated: LSH
Checked: DMV

Produced by the United States Geological Survey
North American Datum of 1983 (NAD83)
World Geodetic System of 1984 (WGS84). Projection and
1 000-meter grid:Universal Transverse Mercator, Zone 17S

This map is not a legal document. Boundaries may be generalized for this map scale. Private lands within government reservations may not be shown. Obtain permission before entering private lands.

Imagery........NAIP, August 2015 - October 2015
Roads........U.S. Census Bureau, 2016
Names........GNIS, 1979 - 2019
Hydrography........National Hydrography Dataset, 1899 - 2019
Contours........National Elevation Dataset, 2010
Boundaries........Multiple sources; see metadata file 2017 - 2018
Public Land Survey System........BLM, 2017
Wetlands........FWS National Wetlands Inventory 2004 - 2007

UTM GRID AND 2019 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

U.S. National Grid
100,000 - m Square ID
NE
Grid Zone Designation
17S

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NORTH AMERICAN VERTICAL DATUM OF 1988

This map was produced to conform with the
National Geospatial Program US Topo Product Standard, 2011.
A metadata file associated with this product is draft version 0.6.18

QUADRANGLE LOCATION

1 Hunter
2 Armstrongs Mills
3 Businessburg
4 Woodsfield
5 Powhatan Point
6 Antioch
7 Round Bottom
8 New Martinsville

ADJOINING QUADRANGLES

ROAD CLASSIFICATION

Expressway	Local Connector
Secondary Hwy	Local Road
Ramp	4WD
Interstate Route	US Route
State Route	

CAMERON, OH
2019

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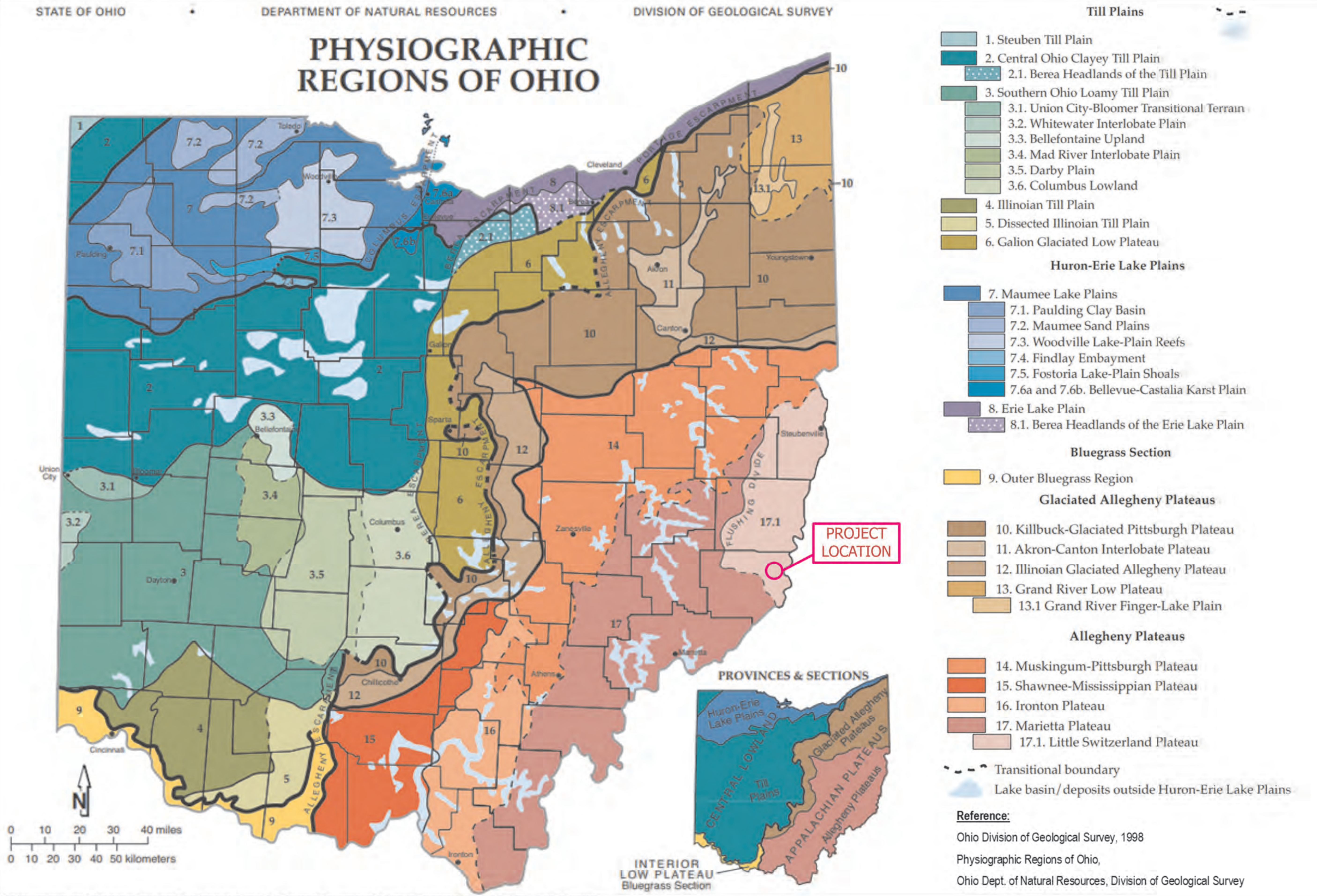
Exhibit No. 2: Physiographic Regions of Ohio

Calculated: LSH
Checked: DMV

Project: MOE-TR183-0.13
PID: 117574



Reference:

Ohio Division of Geological Survey, 1998

Physiographic Regions of Ohio,

Ohio Dept. of Natural Resources, Division of Geological Survey

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Geologic Mapping Unit Descriptions
Surficial Units

▨	Quarry
☒	Pit
a	Alluvium (Holocene) -Includes a wide variety of textures from silt to clay to boulders. Commonly includes organic material; generally, not compact. Occurs in floodplains of modern streams and mapped only where areal extent and thickness are noteworthy. Also includes alluvial terraces, old floodplain remnants that are positioned tens of feet above modern floodplains.
E	Eolian silt (loess) and fine sand - Deposited by wind, generally on bedrock and Illinoian till-capped ridges. Mapped where thickness and areal extent noteworthy.
SG	Sand and gravel (predominantly Wisconsinan) - Intermixed and interbedded sand and gravel commonly containing thin, discontinuous layers or silt, clay, and till. Grains well to moderately sorted, moderately to well rounded; finely stratified to massive, may be cross bedded; locally, may contain organic material. Widespread fluvial deposits in terraces and buried valleys. May be older in deep buried valleys.
L	Silt (predominantly Wisconsinan) - Massive or laminated, commonly contains thin sand partings. May contain localized clay, sand, or gravel layers. Clay content commonly increases with depth. Frequently occurs in lowland surface deposits, in terraces, and as deposits of glacial lakes.
Lk	Silt and clay (Minford silt) (predominantly pre-Illinoian). Present on high terraces or as eroded remnants of lacustrine clays and silts. Finely laminated. Often covered with loess and/or colluvium; sometimes underlain by sand and gravel.
P	Sandstone, Siltstone, shale, clay, limestone, and coal- Sandstone nonbedded to massive, medium to coarse grained with abundant rounded quartz pebbles; quartz pebble conglomerate present. Interbeds of shale, sandstone, siltstone, clay, coal, and limestone common in upper portions of unit. Common horizontal and vertical changes in rock type.
Pd	Sandstone, siltstone, shale, and clay (predominantly Permian). Sandstone fine grained to conglomeratic; thin to massive, crossbedding present. Limestone and coal beds present in lower part of unit.

Source: ODNR Division of Geological Survey
https://gis.ohiodnr.gov/website/dgs/geologyviewer/#

Calculated: LSH
Checked: DMV

Exhibit No. 3: Surficial Geology

Project: MOE-TR183-0.13
PID: 117574

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Map Unit Legend

- 🟩 Chg1AF - Chagrin silt loam, 0 to 3 percent slopes, frequently flooded
- 🟪 He - Hartshorn silt loam

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:15,800.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Perry County, Ohio
Survey Area Data: Version 19, Sep 9, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Oct 8, 2020—Nov 7, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Source:Web Soil Survey 11/2022
https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

Calculated: LSH
Checked: DMV

Exhibit No. 4a: Soil Survey Map
Soil Types

Project: MOE-TR183-0.13
PID: 117574

G:\OHIO\ODOT\ODT-OCEA STATEWIDE CONTRACT PROJECTS\MOE-TR183-0.13_10356687_ARCGISPRO\7.2_WIP\MAP_DOCS\MOE-TR183-0.13.APRX DATE: 12/1/2022

Corrosion of Concrete

Map Unit Legend

🟩 Chg1AF - Chagrin silt loam, 0 to 3 percent slopes, frequently flooded, Low rating

🟨 He - Hartshorn silt loam, Moderate rating

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:15,800.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Perry County, Ohio
Survey Area Data: Version 19, Sep 9, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Oct 8, 2020—Nov 7, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Source:Web Soil Survey 11/2022
https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

Calculated: LSH
Checked: DMV

Exhibit No. 4b: Soil Survey Map
Corrosion of Concrete

Project: MOE-TR183-0.13
PID: 117574

G:\OHIO\ODOT\ODT-OCEA STATEWIDE CONTRACT PROJECTS\MOE-TR183-0.13_10356687_ARCGISPRO\7.2_WIP\MAP_DOCS\MOE-TR183-0.13.APRX DATE: 12/1/2022

Corrosion of Steel

Map Unit Legend

🟥	Chg1AF - Chagrin silt loam, 0 to 3 percent slopes, frequently flooded, High rating
🟥	He - Hartshorn silt loam, High rating

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:15,800.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Perry County, Ohio
Survey Area Data: Version 19, Sep 9, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Oct 8, 2020—Nov 7, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Source:Web Soil Survey 11/2022
https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

Calculated: LSH
Checked: DMV

Exhibit No. 4c: Soil Survey Map
Corrosion of Steel

Project: MOE-TR183-0.13
PID: 117574

pH (1 to 1 Water)

Map Unit Legend

- 🟩 Chg1AF - Chagrin silt loam, 0 to 3 percent slopes, frequently flooded, pH rating 6.5
- 🟩 He - Hartshorn silt loam, pH rating 6.4

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:15,800.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Perry County, Ohio
Survey Area Data: Version 19, Sep 9, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Oct 8, 2020—Nov 7, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Source:Web Soil Survey 11/2022
https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

Calculated: LSH
Checked: DMV

Exhibit No. 4d: Soil Survey Map
pH Levels

Project: MOE-TR183-0.13
PID: 117574

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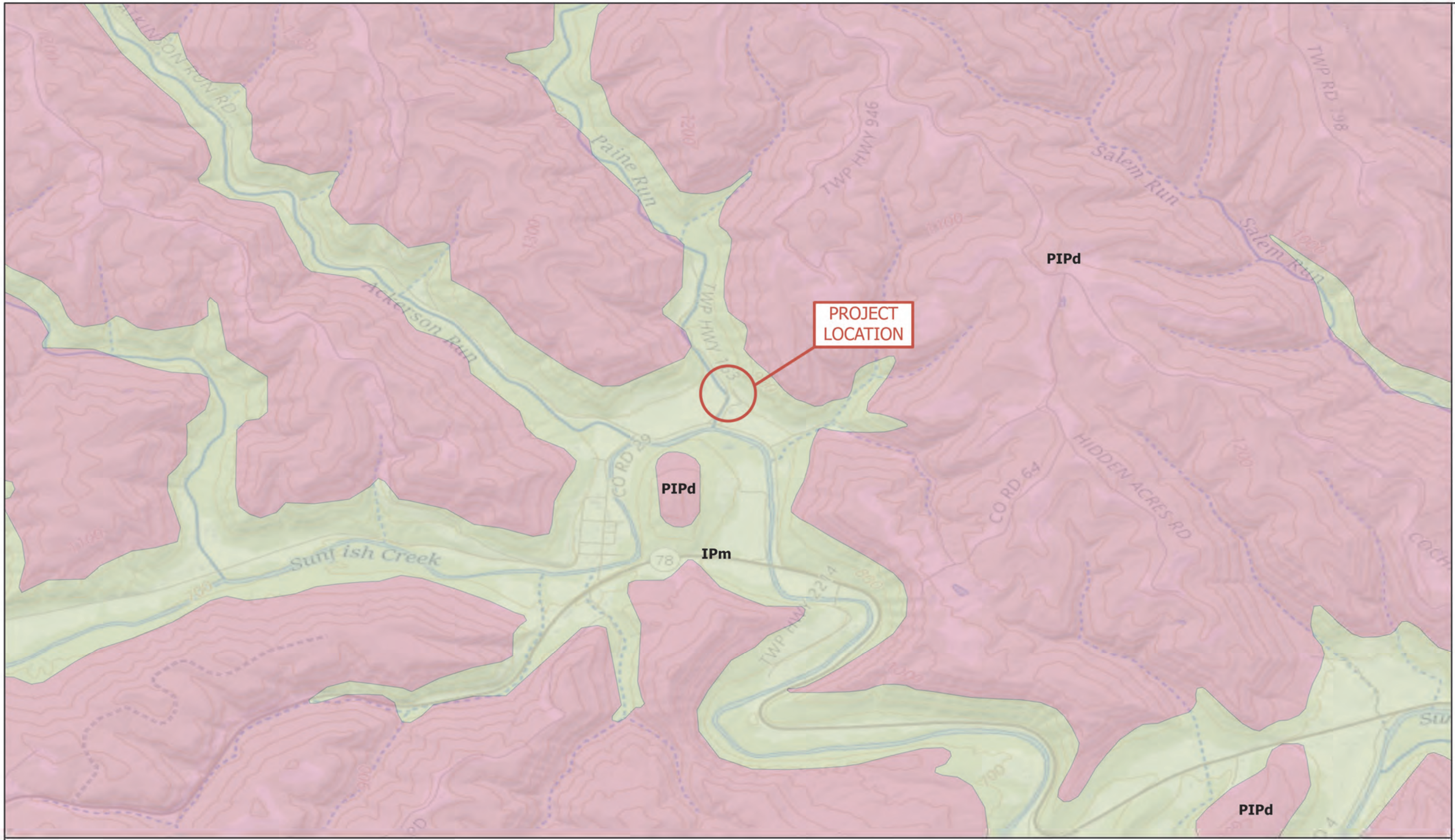
Exhibit No. 5: Bedrock Geology Map



UNIT_CODE

- 🟩 IPm - Monongahela Group, Pennsylvanian
- 🟥 PIPd - Dunkard Group, Permian-Pennsylvanian

0 4,000 Feet

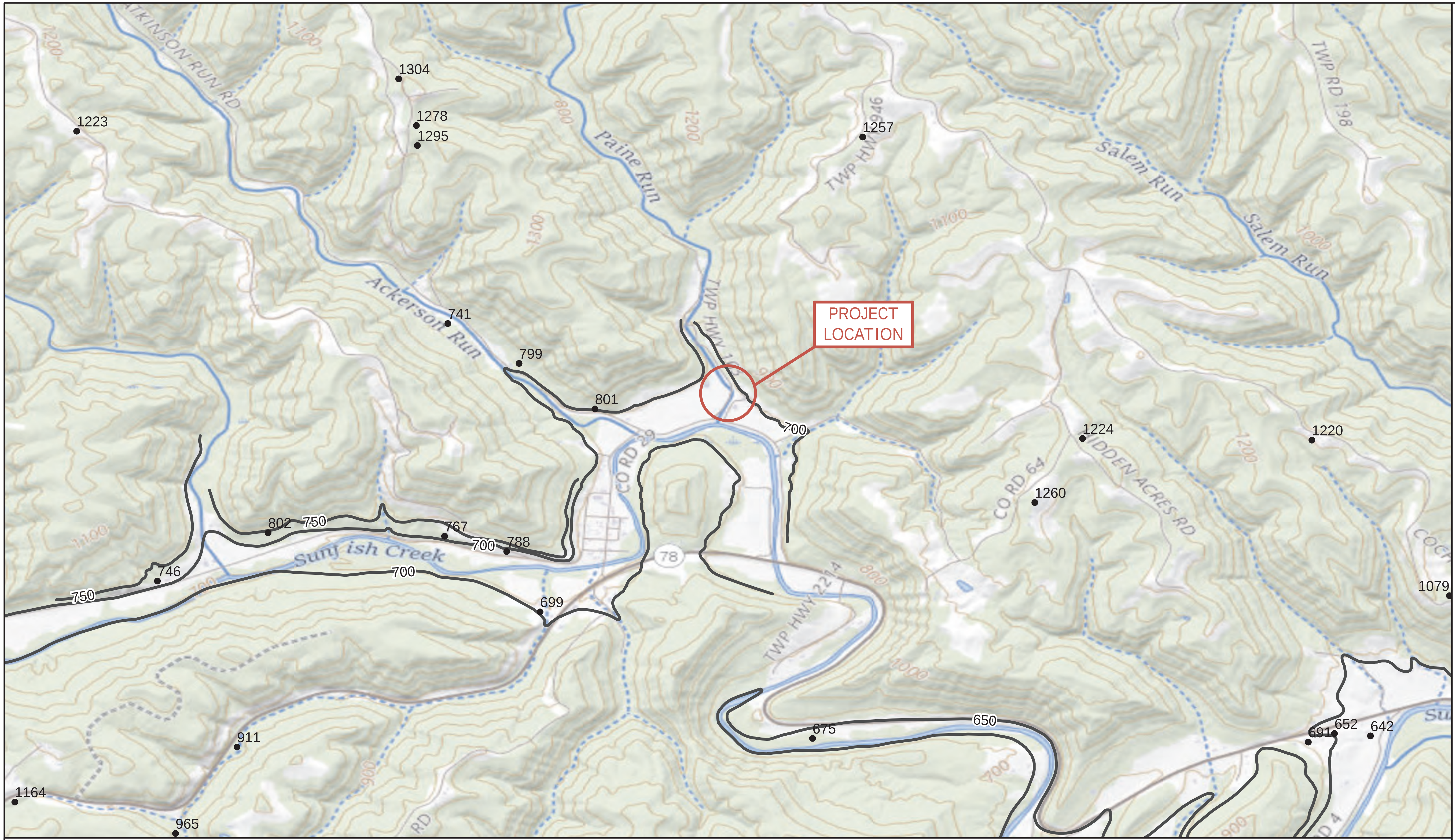
Source: ODNR Division of Geological Survey, 500K Generalized bedrock map of Ohio.
https://gis.ohiodnr.gov/website/dgs/geologyviewer/#

Calculated: LSH
Checked: DMV

Project: MOE-TR183-0.13
PID: 117574

G:\OHIO\ODOT\ODT-OCEA STATEWIDE CONTRACT PROJECTS\MOE-TR183-0.13_10356687_ARCGISPRO\7.2_WIP\MAP_DOCS\MOE-TR183-0.13.APRX DATE: 11/29/2022

Exhibit No. 6: Bedrock Topography Map



— Bedrock contour (ft)

● Bedrock Elevation (ft)

0 4,000 Feet

Source: ODNR Division of Geological Survey, Bedrock Topography 24K
https://gis.ohiodnr.gov/website/dgs/geologyviewer/#

Calculated: LSH
Checked: DMV

Project: MOE-TR183-0.13
PID: 117574

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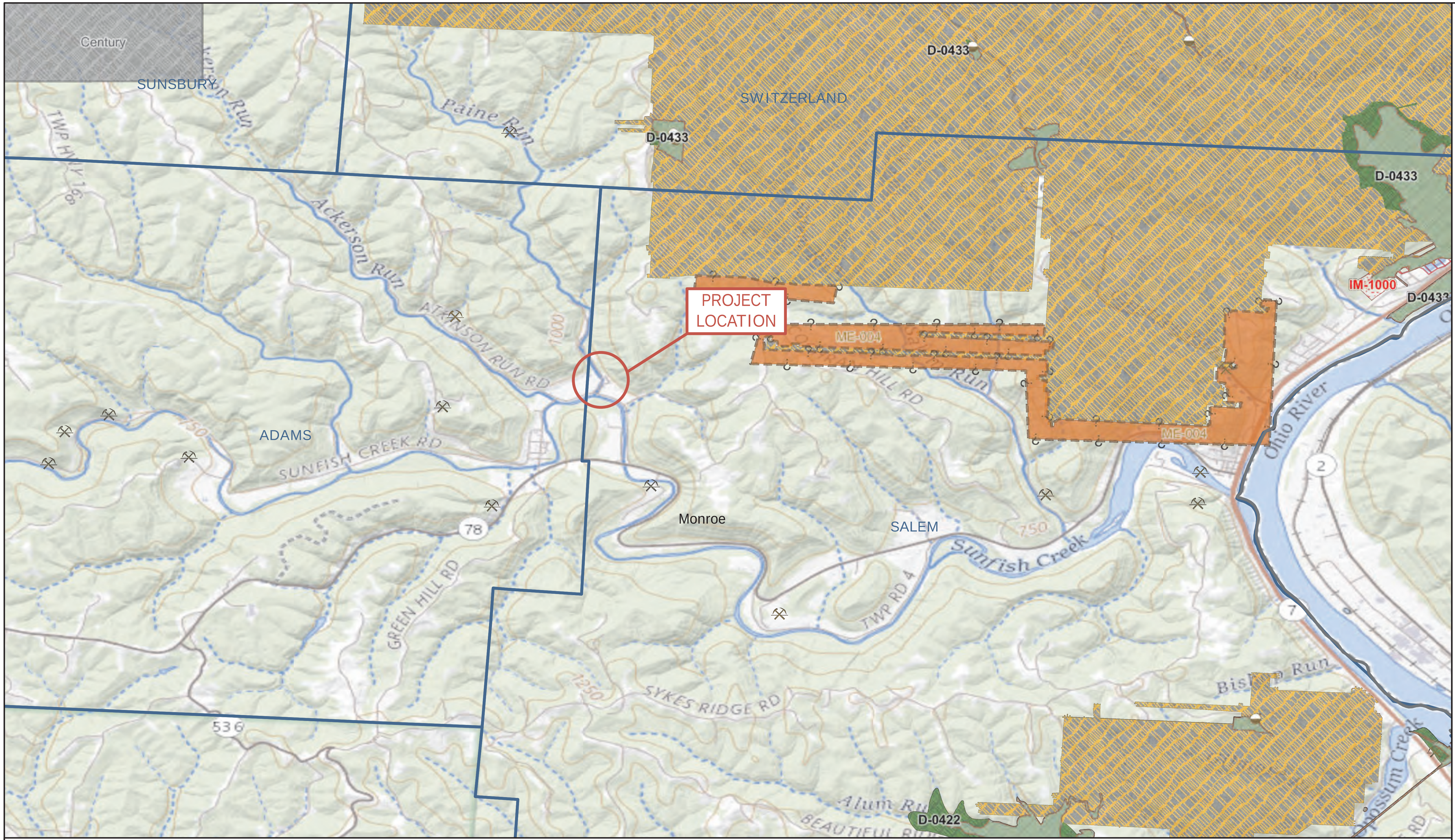
Exhibit No. 7: Mines of Ohio Map



▭ County Boundary

▭ Township Boundary

Past

- ▨ A Law (1965 - 1972)
- ▨ B Law (1972 - 1975)
- ▨ C Law (1976 - 1981)
- ▨ D Law (1982 - Present)
- ▨ Historic - From Topo Maps
- ▨ Historic - From Geology Maps

Proposed

- ▨ Original Application
- ▨ Adjacent Area Application
- ▨ Permitted
- ▨ Current
- ▨ Past
- ▨ Partially Known
- ▨ Known

0 8,000 Feet

Source: ODNR Division of Geological Survey, Mines of Ohio Interactive Map
https://gis.ohiodnr.gov/portal/home/item.html?id=3aa9227986ea49f2b93532b9341f718b

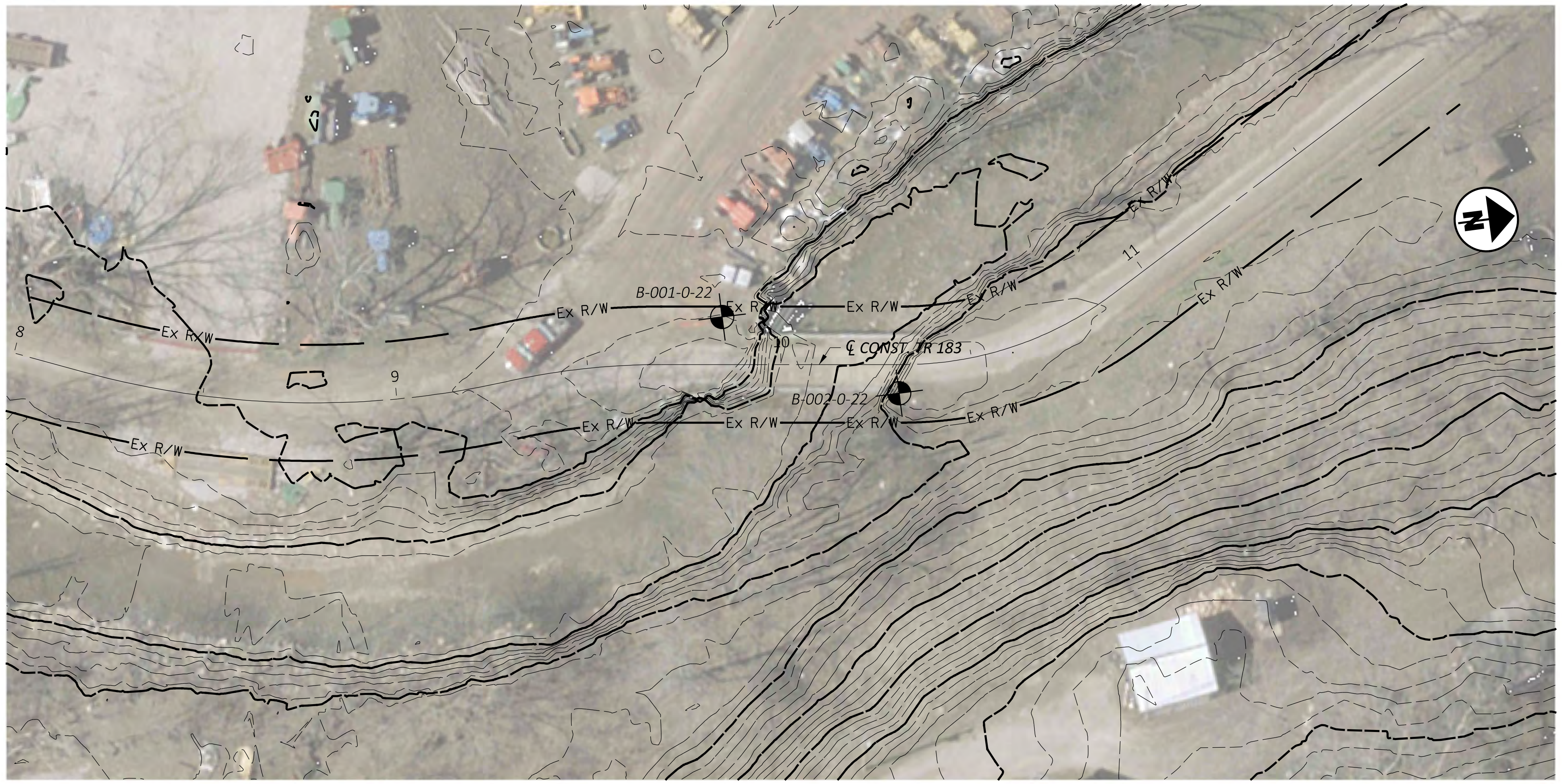
Calculated: LSH
Checked: DMV

Project: MOE-TR183-0.13
PID: 117574

G:\OHIO\ODOT\ODT-OCEA STATEWIDE CONTRACT PROJECTS\PER-CR25-2.00_10354468_ARCGISPRO\7.2_WIP\MAP_DOCS\HDR_PROJECT.APRX DATE: 12/1/2022

MOE-TR183-0.13

MODEL: CLX_RW_TR183 - Plan 1 [Sheet] PAPERSIZE: 17x11 (in.) DATE: 12/2/2022 TIME: 10:49:12 AM USER: CWAHLBRI



HORIZONTAL SCALE IN FEET
0 10 20 40

EXHIBIT NO. 8: BORING LOCATION PLAN

DESIGN AGENCY

HDR

DESIGNER
DCM

REVIEWER
DMV 12-02-22

PROJECT ID
117574

SHEET	TOTAL
1	1

Appendix B. Boring Logs and Rock Core Photos

PROJECT: MOE-TR183-00.13
TYPE: BRIDGE
PID: 117574 SFN: 5634504
START: 10/17/22 END: 10/17/22

DRILLING FIRM / OPERATOR: CENTRAL STAR / TS
SAMPLING FIRM / LOGGER: HDR / DCM
DRILLING METHOD: 2.25" HSA / NQ2
SAMPLING METHOD: SPT / NQ2

DRILL RIG: DIEDRICH D-50 TRACK
HAMMER: AUTOMATIC HAMMER
CALIBRATION DATE: 3/7/22
ENERGY RATIO (%): 86.8

STATION / OFFSET: 9+85, 12' LT.
ALIGNMENT: TR183
ELEVATION: 687.1 (MSL) EOB: 40.0 ft.
LAT / LONG: 39.775803, -80.937953

EXPLORATION ID
B-001-0-22

PAGE
1 OF 2

MATERIAL DESCRIPTION AND NOTES	ELEV. 687.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	HOLE SEALED
								GR	CS	FS	SI	CL	LL	PL	PI			
MEDIUM DENSE, BROWN, **GRAVEL WITH SAND AND SILT**, DAMP	685.6	1	4 4 5	13	17	SS-1	-	-	-	-	-	-	-	-	-	13	A-2-4 (V)	
LOOSE TO MEDIUM DENSE, BROWN, **SANDY SILT**, SOME GRAVEL, TRACE CLAY, DAMP		2																
		3	3 2 2	6	67	SS-2	-	-	-	-	-	-	-	-	-	15	A-4a (V)	
		4																
		5 6	2 7 7	20	78	SS-3	-	25	21	16	28	10	23	16	7	15	A-4a (1)	
	679.6	7																
MEDIUM DENSE, BROWN, **GRAVEL WITH SAND AND SILT**, TRACE CLAY, MOIST		8 9	7 10 6	23	100	SS-4	-	-	-	-	-	-	-	-	-	12	A-2-4 (V)	
	676.1	10	5 4 6	14	78	SS-5	-	63	7	20	2	8	31	24	7	16	A-2-4 (0)	
LOOSE TO MEDIUM DENSE, BROWN, **GRAVEL WITH SAND, SILT, AND CLAY**, MOIST TO WET		W 675.1 11 12	4 2 3	7	100	SS-6	-	60	11	8	9	12	40	22	18	27	A-2-6 (0)	
		13 14	2 2 7	13	39	SS-7	-	54	16	11	10	9	29	17	12	20	A-2-6 (0)	
	671.1	15	5 4 4	12	50	SS-8	-	62	12	11	7	8	27	13	14	15	A-2-6 (0)	
DENSE TO VERY DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND**, TRACE SILT, TRACE CLAY, MOIST		16 17	10 11 13	35	67	SS-9	-	-	-	-	-	-	-	-	-	15	A-1-b (V)	
		18																
		19 20	7 9 17	38	78	SS-10	-	59	12	12	9	8	19	15	4	12	A-1-b (0)	
		21 22	9 15 21	52	44	SS-11	-	-	-	-	-	-	-	-	-	18	A-1-b (V)	
	663.6	23 TR																
SHALE, GRAY, MODERATELY WEATHERED, VERY WEAK.	662.1	24	50/6"	-	100	SS-12	-	-	-	-	-	-	-	-	-	11	Rock (V)	
		25																
SHALE, GRAY TO DARK GRAY, SLIGHTLY WEATHERED, WEAK, MEDIUM BEDDED, ARENACEOUS, PYRITIC, JOINT AND BEDDING DISCONTINUITIES, FRACTURED TO MODERATELY FRACTURED, NARROW APERTURE, SLIGHTLY ROUGH, MASSIVE TO BLOCKY, FAIR SURFACE CONDITIONS; RQD 67%, REC 100%. @ 27.3' - 29.0' : Qu = 1,313 psi (Point Load Test)	657.6	26 27 28 29	75		100	NQ2-1											CORE	

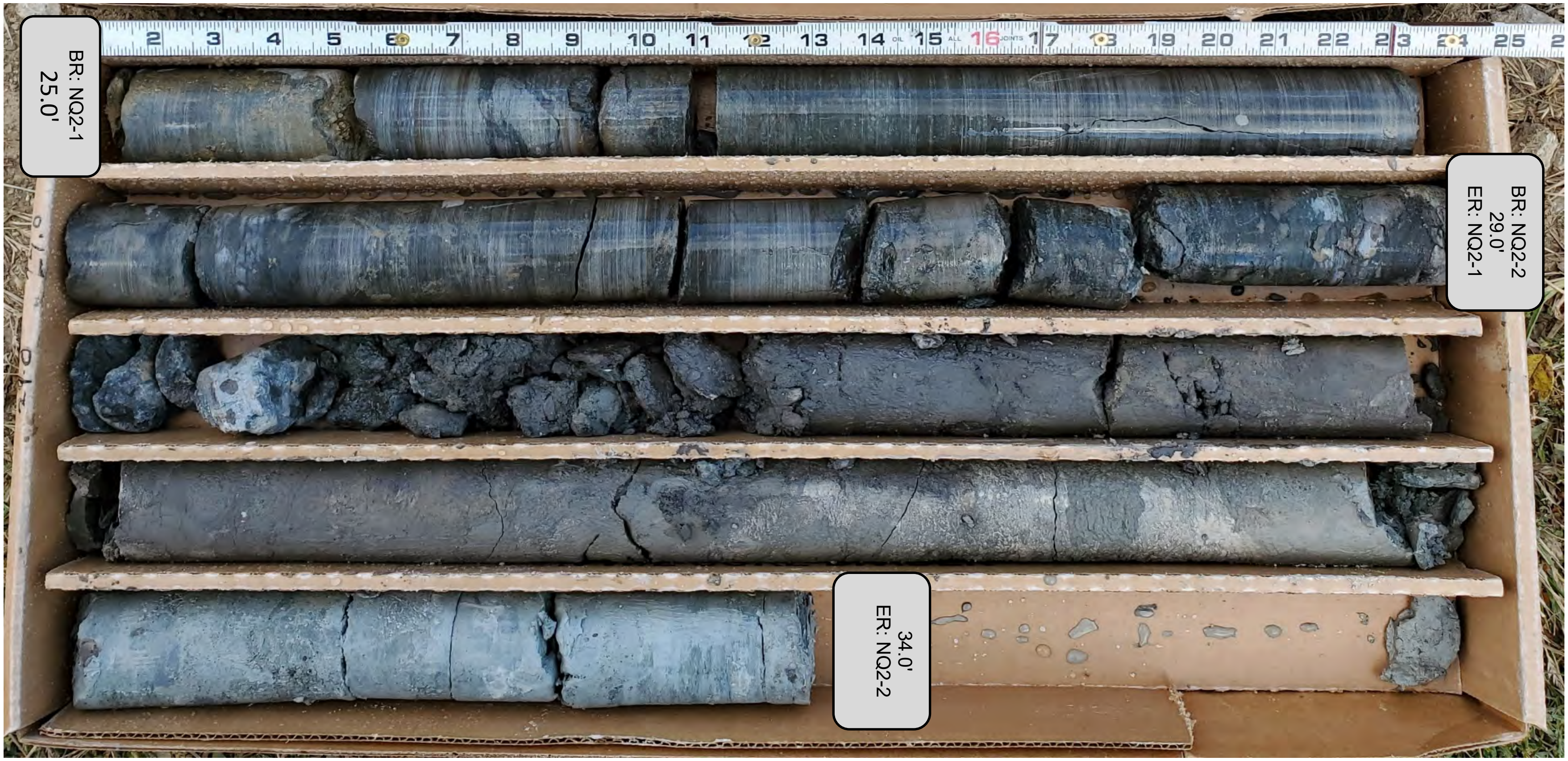
PID: 117574 | SFN: 5634504 | PROJECT: MOE-TR183-00.13 | STATION / OFFSET: 9+85, 12' LT. | START: 10/17/22 | END: 10/17/22 | PG 2 OF 2 | B-001-0-22

MATERIAL DESCRIPTION AND NOTES		ELEV. 657.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
@ 28.3' - 29.3' : Interbedded Limestone Nodules. Irregular Bedding. **CLAYSTONE**, DARK GRAY TO GRAY, MODERATELY WEATHERED, VERY WEAK, THIN BEDDED, FRIABLE, BEDDING DISCONTINUITIES, SLIGHTLY TO MODERATELY FRACTURED,TIGHT APERTURE, SLICKENSIDED, LAMINATED, POOR SURFACE CONDITIONS; RQD 73%, REC 100%. *(continued)*	▨	652.4	31 32 33 34	75		100	NQ2-2											CORE	
@ 32.5' - 33.4' : Qu = 266 psi (Point Load Test) @ 33.0' - 34.0' : Light Gray **SANDSTONE**, GRAY, UNWEATHERED TO SLIGHTLY WEATHERED, SLIGHTLY TO MODERATELY STRONG, FINE TO MEDIUM GRAINED, THICK BEDDED, BEDDING AND JOINT DISCONTINUITIES, SLIGHTLY FRACTURED, TIGHT APERTURE, SLIGHTLY ROUGH, MASSIVE, GOOD SURFACE CONDITIONS; RQD 100%, REC 100%.	⁘	647.1	35 36 37 38 39 EOB 40	89		100	NQ2-3											CORE	

NOTES: QUICKRETE CONCRETE USED TO PATCH PAVEMENT

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 25 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

B-001-0-22



Run #	Depth (ft)		Recovery		RQD	
NQ2-1	25	29	48 in. / 48 in.	100%	36 in. / 48 in.	75%
NQ2-2	29	34	60 in. / 60 in.	100%	45 in. / 60 in.	75%

MOE-TR183-0.13, PID 117574

B-001-0-22

Run #	Depth (ft)		Recovery		RQD	
NQ2-3	34	40	72 in. / 72 in.	100%	64 in. / 72 in.	89%

MOE-TR183-0.13, PID 117574

PROJECT: MOE-TR183-00.13	DRILLING FIRM / OPERATOR: CENTRAL STAR / TS	DRILL RIG: DIEDRICH D-50 TRACK	STATION / OFFSET: 10+30, 7' RT.	EXPLORATION ID B-002-0-22
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: HDR / DCM	HAMMER: AUTOMATIC HAMMER	ALIGNMENT: TR183	
PID: 117574 SFN: 5634504	DRILLING METHOD: 2.25" HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 688.7 (MSL) EOB: 39.9 ft.	PAGE 1 OF 2
START: 10/18/22 END: 10/18/22	SAMPLING METHOD: SPT / NQ2	ENERGY RATIO (%): 86.8	LAT / LONG: 39.775919, -80.937860	

MATERIAL DESCRIPTION AND NOTES	ELEV. 688.7
LOOSE TO MEDIUM DENSE, BROWN, **GRAVEL WITH SAND, SILT, AND CLAY**, DAMP	683.7
LOOSE, BROWN, **GRAVEL WITH SAND AND SILT**, TRACE CLAY, DAMP	680.2
VERY LOOSE, DARK GRAY, **SANDY SILT**, TRACE CLAY, WET @ 8.5' - 9.5' : Final SS-4 hammer blow drove sampler 1 foot (to 9.5 feet) @ 9.0' - 10.0' : auger drilled	678.7
LOOSE, BROWN, **GRAVEL WITH SAND AND SILT**, TRACE CLAY, WET	677.2
MEDIUM DENSE, BROWN, **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, WET	675.7
MEDIUM DENSE, BROWN, **GRAVEL WITH SAND AND SILT**, TRACE CLAY, WET @ 14.5' - 16.0' : Damp	668.7
VERY DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, MOIST	666.2
VERY DENSE, GRAY TO LIGHT GRAY, **SANDY SILT**, LITTLE CLAY, DAMP (Relic Rock Structure) @ 23.0' - 23.2' : gray stone fragments	663.7
SHALE, GRAY, MODERATELY TO SLIGHTLY WEATHERED, VERY WEAK.	663.2
SHALE, GRAY TO DARK GRAY, SLIGHTLY WEATHERED, WEAK TO SLIGHTLY STRONG, THIN TO MEDIUM BEDDED, JOINT AND BEDDING DISCONTINUITIES, FRACTURED TO MODERATELY FRACTURED, TIGHT TO NARROW APERTURE, SLIGHTLY ROUGH, VERY BLOCKY, FAIR SURFACE CONDITION; RQD 52%, REC 100%.	660.7

DEPTHS: W 678.7 (at 9.5'); TR (at 25', 663.7)

DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	HOLE SEALED
						GR	CS	FS	SI	CL	LL	PL	PI			
0 - 1.5	3 6 7	19	67	SS-1	-	-	-	-	-	-	-	-	-	9	A-2-6 (V)	▨
2.5 - 4.0	5 4 3	10	67	SS-2	-	57	16	12	- 15 -		-	-	-	8	A-2-6 (V)	
5.0 - 6.5	3 2 3	7	67	SS-3	-	69	14	8	5	4	24	17	7	8	A-2-4 (0)	
7.5 - 9.0	2 2 1	4	83	SS-4A	-	-	-	-	-	-	-	-	-	17	A-2-4 (V)	
				SS-4B	-	-	-	-	-	-	-	-	-	53	A-4a (V)	
10.0 - 11.5	2 3 3	9	33	SS-5	-	60	14	12	8	6	29	19	10	22	A-2-4 (0)	
11.5 - 13.0	2 2 7	13	78	SS-6	-	46	20	16	9	9	23	17	6	19	A-1-b (0)	
13.0 - 14.5	7 8 5	19	50	SS-7	-	54	15	15	9	7	28	20	8	18	A-2-4 (0)	
14.5 - 16.0	5 6 6	17	56	SS-8	-	56	15	12	11	6	25	17	8	14	A-2-4 (0)	
17.5 - 19.0	6 6 8	20	17	SS-9	-	-	-	-	-	-	-	-	-	20	A-2-4 (V)	
20.0 - 21.5	11 24 13	54	67	SS-10	-	62	14	9	9	6	29	18	11	16	A-2-6 (0)	
22.5 - 24.0	14 30 33	91	89	SS-11	-	-	-	-	-	-	-	-	-	15	A-4a (V)	
25	50/1"	-	100	SS-12	-	9	17	14	34	26	29	14	15	12	Rock (V)	
25.5 - 30	64		100	NQ2-1											CORE	

PID: 117574	SFN: 5634504	PROJECT: MOE-TR183-00.13	STATION / OFFSET: 10+30, 7' RT.	START: 10/18/22	END: 10/18/22	PG 2 OF 2	B-002-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 658.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	HOLE SEALED
								GR	CS	FS	SI	CL	LL	PL	PI			
CLAYSTONE, GRAY TO DARK GRAY, MODERATELY WEATHERED, VERY WEAK, THIN BEDDED, FRIABLE, JOINT AND BEDDING DISCONTINUITIES, FRACTURED, SLICKENSIDED, LAMINATED, POOR SURFACE CONDITION; RQD 50%, REC 100%. *(continued)*	657.1	31	58		100	NQ2-2											CORE	
CLAYSTONE, GRAY TO LIGHT GRAY, SLIGHTLY WEATHERED, WEAK, THIN TO MEDIUM BEDDED, JOINT AND BEDDING DISCONTINUITIES, SLIGHT TO MODERATELY FRACTURED, TIGHT APERTURE, SLICKENSIDED, BLOCKY, FAIR TO POOR SURFACE CONDITION; RQD 49%, REC 100%. @ 33.2' - 34.0' : Qu = 282 psi (Point Load Test)	651.8	32 33 34 35 36	57		100	NQ2-3											CORE	
SANDSTONE, GRAY, UNWEATHERED TO SLIGHTLY WEATHERED, SLIGHTLY TO MODERATELY STRONG, FINE TO MEDIUM GRAINED, MEDIUM TO THICK BEDDED, JOINT DISCONTINUITIES, MODERATELY FRACTURED, TIGHT APERTURE, SLIGHTLY ROUGH, BLOCKY, FAIR TO GOOD SURFACE CONDITIONS; RQD 94%, REC 100%. @ 38.3' - 39.3' : Qu = 10,068 psi	648.8	37 38 39 EOB																

NOTES: QUICKRETE CONCRETE USED TO PATCH PAVEMENT. SAMPLE SS-2 (2.5' - 4.0'): INSUFFICIENT AMOUNT OF SAMPLE TO PERFORM HYDROMETER TEST

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 25 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

B-002-0-22

Run #	Depth (ft)		Recovery		RQD	
NQ2-1	25.5	29.9	53 in. / 53 in.	100%	34 in. / 53 in.	64%
NQ2-2	29.9	34.9	60 in. / 60 in.	100%	35 in. / 60 in.	58%

MOE-TR183-0.13, PID 117574

B-002-0-22

Run #	Depth (ft)		Recovery		RQD	
NQ2-3	34.9	39.9	60 in. / 60 in.	100%	34 in. / 60 in.	57%

MOE-TR183-0.13, PID 117574

Appendix C. Laboratory Testing

Unconfined Compressive Strength of Rock (ASTM D7012)

ASTM: D7012-Method C

UNCONFINED COMPRESSION TEST (ROCK CORE)

PROJECT NAME : MOE-TR183-0.13
PROJECT NO. : 10336687
PROJECT COUNTY : Monroe
PROJECT STATE : Ohio
LABORATORY NO. : 10336687
SUBMITTED BY : HDR

SAMPLE NO. : B-002-0-22
SAMPLE LOC. : RC-1
SAMPLE DEPTH : 38.3' to 39.3'
DATE TESTED : 11/9/2022
DATE REPORTED : 11/11/2022

ROCK DESCRIPTION : NA
Machine Used : ELE CT-7250
Diameter : 1.98 in
Height : 4.04 in
Area : 3.08 in²
Volume : 0.0072 ft³

RESULTS :

Air Dry Moisture:	0.6	%
Air-Dry Density :	158.1	lbs/ft.³
Maximum Stress :	10,068	psi
Elapsed Time :	6:23	min.
Rate of Loading :	90	lb/sec

Comments :

Approved By : Kevin E. Walker

Point Load Strength Index of Rock (ASTM D 5731)

HDR

ASTM D5731 Point Load Strength Index of Rock

Project Name: MOE-TR183-0.13	Sample No.: 27.3' to 29.0'
Project No.: 10356687	Date Sampled: 11/9/2022
Project County: Monroe	Date Tested: 11/14/2022
Project State: Ohio	Date Reported: 11/15/2022
Laboratory No.: 10356687	Sample Details:
Sample Loc.: B-001-0-22	

Sample Depth	Core Size	Test Type	Orientation	Width (w), in	Diameter (d), in	Length (L), in	Load (P), kip	Load (P), kN
27.3	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.126	0.56
27.4	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.148	0.66
27.5	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.182	0.81
27.6	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.229	1.02
27.7	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.382	1.7
27.8	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.292	1.3
27.9	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.209	0.93
28	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.191	0.85
28.1	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.225	1
28.2	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.247	1.1
33.5								

Note: min 10 samples required

Testing Machine Serial Number: HDR 1003

Point Load Strength Index	
Mean $I_{s(50)} \perp$	
Mean $I_{s(50)} //$	57.11
$I_{s(50)}$	54.73
$I_{a(50)}$	1.00

Uniaxial Compressive Strength (Bx) 1,313 psi

Average Uniaxial Compressive Strength: 1,313 psi

Sampled By: ____________

Tested By: Don Schmidt

Approved By: Kevin E. Walker

Note: ASTM D5731 applies to medium strength rock having a compresive strength over 2175 psi

ASTM D5731 Point Load Strength Index of Rock

Project Name: MOE-TR183-0.13
Project No.: 10356687
Project County: Monroe
Project State: Ohio
Laboratory No.: 10356687
Sample Loc.: B-001-0-22

Sample No.: 32.5' to 33.4'
Date Sampled: 11/9/2022
Date Tested: 11/14/2022
Date Reported: 11/15/2022
Sample Details:

Sample Depth	Core Size	Test Type	Orientation	Width (w), in	Diameter (d), in	Length (L), in	Load (P), kip	Load (P), kN
32.5	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.038	0.17
32.6	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.029	0.13
32.7	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.020	0.09
32.8	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.070	0.31
32.9	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.054	0.24
33	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.047	0.21
33.1	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.040	0.18
33.2	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.058	0.26
33.3	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.049	0.22
33.4	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.045	0.2
33.5								

Note: min 10 samples required
Testing Machine Serial Number: HDR 1003

Uniaxial Compressive Strength (Bx) 266 psi

Average Uniaxial Compressive Strength: 266 psi

Point Load Strength Index	
Mean $I_{s(50)} \perp$	
Mean $I_{s(50)}$ //	11.56
$I_{s(50)}$	11.69
$I_{a(50)}$	1.00

Sampled By:

Tested By: Don Schmidt

Approved By:

Note: ASTM D5731 applies to medium strength rock having a compresive strength over 2175 psi

ASTM D5731 Point Load Strength Index of Rock

Project Name: MOE-TR183-0.13		Sample No.:	33.2' to 34.0'
Project No.: 10356687		Date Sampled:	11/9/2022
Project County: Monroe		Date Tested:	11/14/2022
Project State: Ohio		Date Reported:	11/15/2022
Laboratory No.: 10356687		Sample Details:	
Sample Loc.: B-002-0-22			

Sample Depth	Core Size	Test Type	Orientation	Width (w), in	Diameter (d), in	Length (L), in	Load (P), kip	Load (P), kN
33.2	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.031	0.14
33.3	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.029	0.13
33.4	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.040	0.18
33.5	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.045	0.2
33.6	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.038	0.17
33.7	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.054	0.24
33.8	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.063	0.28
33.9	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.063	0.28
34	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.065	0.29
34.1	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.049	0.22
33.5								

Note: min 10 samples required

Testing Machine Serial Number: HDR 1003

Uniaxial Compressive Strength (Bx) 282 psi

Average Uniaxial Compressive Strength: 282 psi

Point Load Strength Index	
Mean $I_{s(50)}\perp$	
Mean $I_{s(50)}//$	12.25
$I_{s(50)}$	12.36
$I_{a(50)}$	1.00

Sampled By: ____________________

Tested By: Don Schmidt

Approved By: Kevin E. Walker

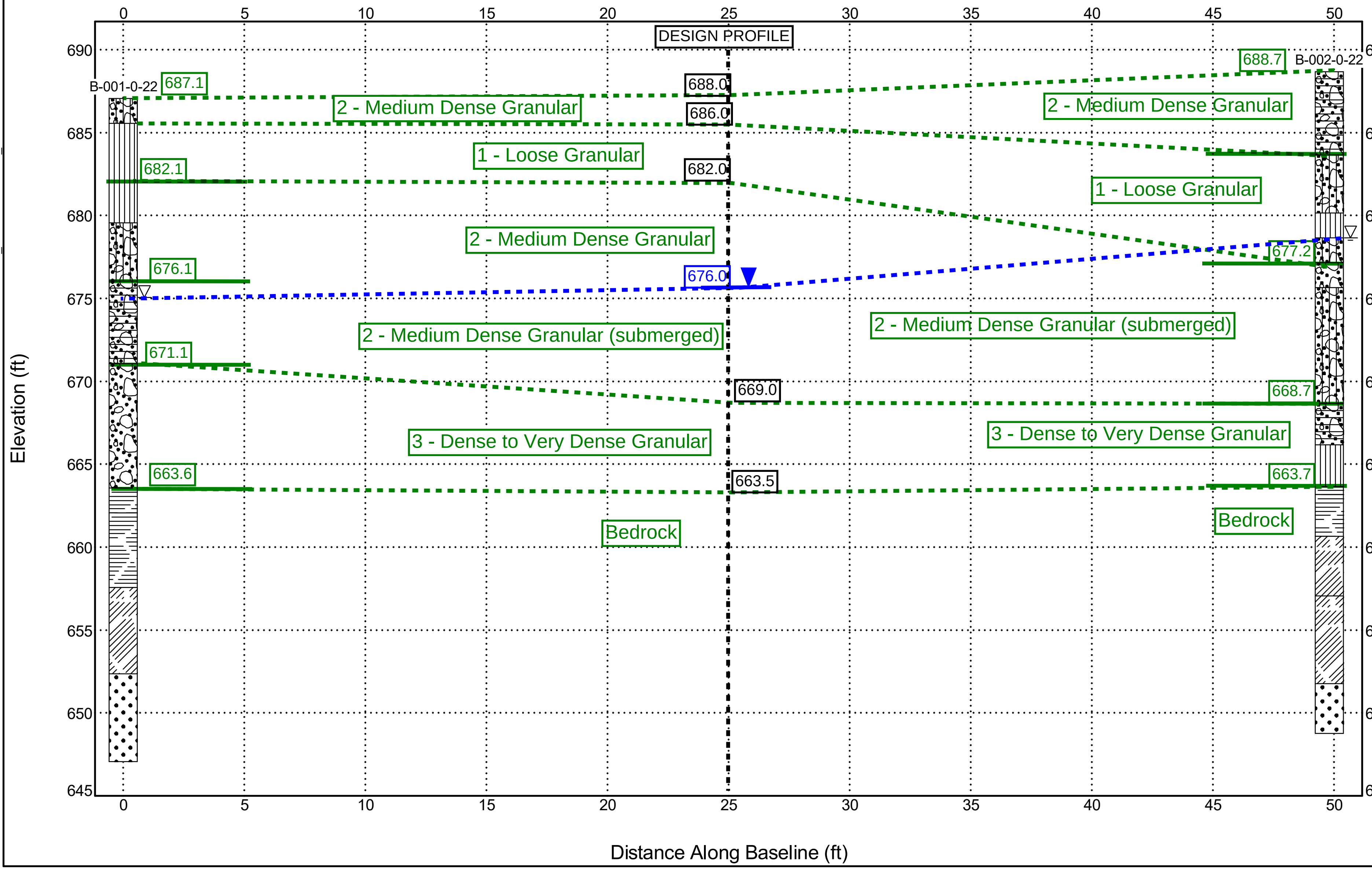
Note: ASTM D5731 applies to medium strength rock having a compresive strength over 2175 psi

Appendix D. Analyses

Soil Strength Parameter Determination

SUBSURFACE DIAGRAM

PROJECT NAME MOE - TR183 - 0.13
PROJECT NUMBER 117574
PROJECT LOCATION MONROE COUNTY, OH



STRATIGRAPHY & GW - A SIZE - OH DOT.GDT - 11/27/22 16:02 - C:\PWWORKING\EAST01\D2962262\20221114_MOE-TR183-0.13_BORINGLOGS.GPJ

PROJECT: MOE-TR183-00.13
TYPE: BRIDGE
PID: 117574 SFN: 5634504
START: 10/17/22 END: 10/17/22

DRILLING FIRM / OPERATOR: CENTRAL STAR / TS
SAMPLING FIRM / LOGGER: HDR / DCM
DRILLING METHOD: 2.25" HSA / NQ2
SAMPLING METHOD: SPT / NQ2

DRILL RIG: DIEDRICH D-50 TRACK
HAMMER: AUTOMATIC HAMMER
CALIBRATION DATE: 3/7/22
ENERGY RATIO (%): 86.8

STATION / OFFSET: 9+85, 12' LT.
ALIGNMENT: TR183
ELEVATION: 687.1 (MSL) EOB: 40.0 ft.
LAT / LONG: 39.775803, -80.937953

EXPLORATION ID B-001-0-22
PAGE 1 OF 2

MATERIAL DESCRIPTION AND NOTES	ELEV. 687.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
MEDIUM DENSE, BROWN, **GRAVEL WITH SAND AND SILT**, DAMP 2 - Medium Dense Granular	685.6	1 2	4 4 5	13	17	SS-1	-	-	-	-	-	-	-	-	-	13	A-2-4 (V)	▨
LOOSE TO MEDIUM DENSE, BROWN, **SANDY SILT**, SOME GRAVEL, TRACE CLAY, DAMP 1 - Loose Granular	682.1	3 4	3 2 2	6	67	SS-2	-	-	-	-	-	-	-	-	-	15	A-4a (V)	
	679.6	5 6 7	2 7 7	20	78	SS-3	-	25	21	16	28	10	23	16	7	15	A-4a (1)	
MEDIUM DENSE, BROWN, **GRAVEL WITH SAND AND SILT**, TRACE CLAY, MOIST 2 - Medium Dense Granular		8 9	7 10 6	23	100	SS-4	-	-	-	-	-	-	-	-	-	12	A-2-4 (V)	
	676.1	10	5 4 6	14	78	SS-5	-	63	7	20	2	8	31	24	7	16	A-2-4 (0)	
LOOSE TO MEDIUM DENSE, BROWN, **GRAVEL WITH SAND, SILT, AND CLAY**, MOIST TO WET		W 675.1 11 12	4 2 3	7	100	SS-6	-	60	11	8	9	12	40	22	18	27	A-2-6 (0)	
		13	2 2 7	13	39	SS-7	-	54	16	11	10	9	29	17	12	20	A-2-6 (0)	
	671.1	14 15	5 4 4	12	50	SS-8	-	62	12	11	7	8	27	13	14	15	A-2-6 (0)	
DENSE TO VERY DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND**, TRACE SILT, TRACE CLAY, MOIST 3 - Dense to Very Dense Granular		16 17 18	10 11 13	35	67	SS-9	-	-	-	-	-	-	-	-	-	15	A-1-b (V)	
		19 20	7 9 17	38	78	SS-10	-	59	12	12	9	8	19	15	4	12	A-1-b (0)	
	663.6	21 22 23	9 15 21	52	44	SS-11	-	-	-	-	-	-	-	-	-	18	A-1-b (V)	
SHALE, GRAY, MODERATELY WEATHERED, VERY WEAK.	662.1	TR 24	50/6"	-	100	SS-12	-	-	-	-	-	-	-	-	-	11	Rock (V)	
SHALE, GRAY TO DARK GRAY, SLIGHTLY WEATHERED, WEAK, MEDIUM BEDDED, ARENACEOUS, PYRITIC, JOINT AND BEDDING DISCONTINUITIES, FRACTURED TO MODERATELY FRACTURED, NARROW APERTURE, SLIGHTLY ROUGH, MASSIVE TO BLOCKY, FAIR SURFACE CONDITIONS; RQD 67%, REC 100%. @ 27.3' - 29.0' : Qu = 1,313 psi (Point Load Test)	657.6	25 26 27 28 29	75		100	NQ2-1											CORE	

PID: 117574	SFN: 5634504	PROJECT: MOE-TR183-00.13	STATION / OFFSET: 9+85, 12' LT.	START: 10/17/22	END: 10/17/22	PG 2 OF 2	B-001-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 657.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	HOLE SEALED
								GR	CS	FS	SI	CL	LL	PL	PI			
@ 28.3' - 29.3' : Interbedded Limestone Nodules. Irregular Bedding. **CLAYSTONE**, DARK GRAY TO GRAY, MODERATELY WEATHERED, VERY WEAK, THIN BEDDED, FRIABLE, BEDDING DISCONTINUITIES, SLIGHTLY TO MODERATELY FRACTURED,TIGHT APERTURE, SLICKENSIDED, LAMINATED, POOR SURFACE CONDITIONS; RQD 73%, REC 100%. *(continued)*	652.4	31 32 33 34	75		100	NQ2-2											CORE	
@ 32.5' - 33.4' : Qu = 266 psi (Point Load Test) @ 33.0' - 34.0' : Light Gray **SANDSTONE**, GRAY, UNWEATHERED TO SLIGHTLY WEATHERED, SLIGHTLY TO MODERATELY STRONG, FINE TO MEDIUM GRAINED, THICK BEDDED, BEDDING AND JOINT DISCONTINUITIES, SLIGHTLY FRACTURED, TIGHT APERTURE, SLIGHTLY ROUGH, MASSIVE, GOOD SURFACE CONDITIONS; RQD 100%, REC 100%.	647.1	35 36 37 38 39 EOB 40	89		100	NQ2-3											CORE	

NOTES: QUICKRETE CONCRETE USED TO PATCH PAVEMENT

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 25 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 11/21/22 14:52 - C:\PWWORKING\EAST01\D2962262\20221114_MOE-TR183-0.13_BORINGLOGS.GPJ

PROJECT: MOE-TR183-00.13
TYPE: BRIDGE
PID: 117574 SFN: 5634504
START: 10/18/22 END: 10/18/22

DRILLING FIRM / OPERATOR: CENTRAL STAR / TS
SAMPLING FIRM / LOGGER: HDR / DCM
DRILLING METHOD: 2.25" HSA / NQ2
SAMPLING METHOD: SPT / NQ2

DRILL RIG: DIEDRICH D-50 TRACK
HAMMER: AUTOMATIC HAMMER
CALIBRATION DATE: 3/7/22
ENERGY RATIO (%): 86.8

STATION / OFFSET: 10+30, 7' RT.
ALIGNMENT: TR183
ELEVATION: 688.7 (MSL) EOB: 39.9 ft.
LAT / LONG: 39.775919, -80.937860

EXPLORATION ID
B-002-0-22

PAGE
1 OF 2

MATERIAL DESCRIPTION AND NOTES	ELEV. 688.7	DEPTHS
LOOSE TO MEDIUM DENSE, BROWN, **GRAVEL WITH SAND, SILT, AND CLAY**, DAMP 2 - Medium Dense Granular	686.2 683.7	
LOOSE, BROWN, **GRAVEL WITH SAND AND SILT**, TRACE CLAY, DAMP 1 - Loose Granular	680.2	
VERY LOOSE, DARK GRAY, **SANDY SILT**, TRACE CLAY, WET @ 8.5' - 9.5' : Final SS-4 hammer blow drove sampler 1 foot (to 9.5 feet) @ 9.0' - 10.0' : auger drilled	678.7 677.2	W 678.7
LOOSE, BROWN, **GRAVEL WITH SAND AND SILT**, TRACE CLAY, WET	675.7	
MEDIUM DENSE, BROWN, **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, WET		
MEDIUM DENSE, BROWN, **GRAVEL WITH SAND AND SILT**, TRACE CLAY, WET @ 14.5' - 16.0' : Damp 2 - Medium Dense Granular	668.7	
VERY DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, MOIST 3 - Dense to Very Dense Granular	666.2	
VERY DENSE, GRAY TO LIGHT GRAY, **SANDY SILT**, LITTLE CLAY, DAMP (Relic Rock Structure) @ 23.0' - 23.2' : gray stone fragments	663.7	TR
SHALE, GRAY, MODERATELY TO SLIGHTLY WEATHERED, VERY WEAK.	663.2	
SHALE, GRAY TO DARK GRAY, SLIGHTLY WEATHERED, WEAK TO SLIGHTLY STRONG, THIN TO MEDIUM BEDDED, JOINT AND BEDDING DISCONTINUITIES, FRACTURED TO MODERATELY FRACTURED, TIGHT TO NARROW APERTURE, SLIGHTLY ROUGH, VERY BLOCKY, FAIR SURFACE CONDITION; RQD 52%, REC 100%.	660.7	

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
3 6 7	19	67	SS-1	-	-	-	-	-	-	-	-	-	9	A-2-6 (V)	
5 4 3	10	67	SS-2	-	57	16	12	- 15 -		-	-	-	8	A-2-6 (V)	
3 2 3	7	67	SS-3	-	69	14	8	5	4	24	17	7	8	A-2-4 (0)	
2 2 1	4	83	SS-4A	-	-	-	-	-	-	-	-	-	17	A-2-4 (V)	
			SS-4B	-	-	-	-	-	-	-	-	-	53	A-4a (V)	
2 3 3	9	33	SS-5	-	60	14	12	8	6	29	19	10	22	A-2-4 (0)	
2 2 7	13	78	SS-6	-	46	20	16	9	9	23	17	6	19	A-1-b (0)	
7 8 5	19	50	SS-7	-	54	15	15	9	7	28	20	8	18	A-2-4 (0)	
5 6 6	17	56	SS-8	-	56	15	12	11	6	25	17	8	14	A-2-4 (0)	
6 6 8	20	17	SS-9	-	-	-	-	-	-	-	-	-	20	A-2-4 (V)	
11 24 13	54	67	SS-10	-	62	14	9	9	6	29	18	11	16	A-2-6 (0)	
14 30 33	91	89	SS-11	-	-	-	-	-	-	-	-	-	15	A-4a (V)	
50/1"	-	100	SS-12	-	9	17	14	34	26	29	14	15	12	Rock (V)	
64		100	NQ2-1											CORE	

PID: 117574	SFN: 5634504	PROJECT: MOE-TR183-00.13	STATION / OFFSET: 10+30, 7' RT.	START: 10/18/22	END: 10/18/22	PG 2 OF 2	B-002-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 658.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	HOLE SEALED
								GR	CS	FS	SI	CL	LL	PL	PI			
CLAYSTONE, GRAY TO DARK GRAY, MODERATELY WEATHERED, VERY WEAK, THIN BEDDED, FRIABLE, JOINT AND BEDDING DISCONTINUITIES, FRACTURED, SLICKENSIDED, LAMINATED, POOR SURFACE CONDITION; RQD 50%, REC 100%. *(continued)*	657.1	31	58		100	NQ2-2											CORE	
CLAYSTONE, GRAY TO LIGHT GRAY, SLIGHTLY WEATHERED, WEAK, THIN TO MEDIUM BEDDED, JOINT AND BEDDING DISCONTINUITIES, SLIGHT TO MODERATELY FRACTURED, TIGHT APERTURE, SLICKENSIDED, BLOCKY, FAIR TO POOR SURFACE CONDITION; RQD 49%, REC 100%. @ 33.2' - 34.0' : Qu = 282 psi (Point Load Test)	651.8	32 33 34 35 36	57		100	NQ2-3											CORE	
SANDSTONE, GRAY, UNWEATHERED TO SLIGHTLY WEATHERED, SLIGHTLY TO MODERATELY STRONG, FINE TO MEDIUM GRAINED, MEDIUM TO THICK BEDDED, JOINT DISCONTINUITIES, MODERATELY FRACTURED, TIGHT APERTURE, SLIGHTLY ROUGH, BLOCKY, FAIR TO GOOD SURFACE CONDITIONS; RQD 94%, REC 100%. @ 38.3' - 39.3' : Qu = 10,068 psi	648.8	37 38 39 EOB																

NOTES: QUICKRETE CONCRETE USED TO PATCH PAVEMENT. SAMPLE SS-2 (2.5' - 4.0'): INSUFFICIENT AMOUNT OF SAMPLE TO PERFORM HYDROMETER TEST

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 25 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

Monroe County Engineer
MOE-TR183-0.13

Soil Strength Parameter Determination

Computed By = DCM
Checked By = DMV

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							N_{60} Value	ODOT GB-7 Correlations		
			Sowers	T and P	Values	Correlation	Tested	Correlation	Tested				Cohesion (psf)	phi (deg)	
Layer 1 LOOSE GRANULAR	**Max**	N/A	N/A	N/A		120		125			**Max**	10	N/A	30	
	Min	N/A	N/A	N/A		95		115		S_u= **0** psf	**Min**	4	N/A	28	c' = **0** psf
	Average	N/A	N/A	N/A		102		119		Φ = **28** deg	**Average**	7	N/A	29	Φ' = **28** deg
	Std Dev	N/A	N/A	N/A		9		5			**Std Dev**	2	N/A	1	
										Y_{dry} = 100 pcf					Y_{dry} = 100 pcf
	Avg + Std	N/A	N/A	N/A		111		124		Y_{moist} = **120** pcf	**Avg + Std**	9	N/A	30	Y_{moist} = **120** pcf
	Avg - Std	N/A	N/A	N/A		93		114			**Avg - Std**	5	N/A	28	
Layer 2 MEDIUM DENSE GRANULAR	**Max**	N/A	N/A	N/A		110		130			**Max**	23	N/A	33	
	Min	N/A	N/A	N/A		100		120		S_u = **0** psf	**Min**	12	N/A	30	c' = **0** psf
	Average	N/A	N/A	N/A		107		127		Φ = **31** deg	**Average**	17	N/A	31	Φ' = **31** deg
	Std Dev	N/A	N/A	N/A		4		4			**Std Dev**	4	N/A	1	
										Y_{dry} = 105 pcf					Y_{dry} = 105 pcf
	Avg + Std	N/A	N/A	N/A		111		131		Y_{moist} = **125** pcf	**Avg + Std**	20	N/A	32	Y_{moist} = **125** pcf
	Avg - Std	N/A	N/A	N/A		103		123			**Avg - Std**	13	N/A	31	
Layer 3 DENSE TO VERY DENSE GRANULAR	**Max**	N/A	N/A	N/A		125		140			**Max**	91	N/A	40	
	Min	N/A	N/A	N/A		120		135		S_u = **0** psf	**Min**	35	N/A	35	c' = **0** psf
	Average	N/A	N/A	N/A		123		138		Φ = **37** deg	**Average**	54	N/A	37	Φ' = **37** deg
	Std Dev	N/A	N/A	N/A		3		3			**Std Dev**	22	N/A	3	
										Y_{dry} = 125 pcf					Y_{dry} = 125 pcf
	Avg + Std	N/A	N/A	N/A		126		141		Y_{moist} = **135** pcf	**Avg + Std**	76	N/A	40	Y_{moist} = **135** pcf
	Avg - Std	N/A	N/A	N/A		120		135			**Avg - Std**	32	N/A	35	

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 1

	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC		Short-Term Cohesion (psf) N-values			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)
														PPR	Sowers	T & P									
Max	10	100	N/A	69	16	12	9	12	40	22	18	53	**Max**	N/A	N/A	N/A	N/A	30	12.0	685.7	120	125	0.270	2.72	0.787
Min	4	33	N/A	57	11	8	5	4	24	17	7	8	**Min**	N/A	N/A	N/A	N/A	28	3.0	675.1	95	115	0.126	2.71	0.414
Average	7	70	N/A	62	14	10	7	7	31	19	12	21	**Average**	N/A	N/A	N/A	N/A	29	7.4	680.8	102	119	0.189	2.71	0.668
Std Dev	2	22	N/A	5	2	2	2	4	8	3	6	16	**Std Dev**	N/A	N/A	N/A	N/A	1	3.6	3.7	9	5	0.074	0.00	0.136
Avg + Std	9	92	N/A	67	16	12	9	11	39	22	17	37	**Avg + Std**	N/A	N/A	N/A	N/A	30	11.0	684.5	111	124	0.263	2.72	0.803
Avg - Std	5	47	N/A	56	12	8	5	3	23	17	6	6	**Avg - Std**	N/A	N/A	N/A	N/A	28	3.8	677.1	93	114	0.115	2.71	0.532

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			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)
																						PPR	Sowers	T & P									
TR 183	687.1	B-001-0-22	2.5	-	4	SS-2	6	67	-	-	-	-	-	-	-	-	-	15	A-4a	Granular	1	N/A				29	3.0	684.1	95	115		2.72	0.787
TR 183	687.1	B-001-0-22	11	-	12.5	SS-6	7	100	-	60	11	8	9	12	40	22	18	27	A-2-6	Granular	1	N/A				29	12.0	675.1	105	125	0.27	2.71	0.611
TR 183	688.7	B-002-0-22	2.5	-	4	SS-2	10	67	-	57	16	12	-	-	-	-	-	8	A-2-6	Granular	1	N/A				30	3.0	685.7	95	115		2.71	0.780
TR 183	688.7	B-002-0-22	5	-	6.5	SS-3	7	67	-	69	14	8	5	4	24	17	7	8	A-2-4	Granular	1	N/A				29	6.0	682.7	100	120	0.126	2.71	0.691
TR 183	688.7	B-002-0-22	7.5	-	8.5	SS-4A	4	83	-	-	-	-	-	-	-	-	-	17	A-2-4	Granular	1	N/A				28	8.0	680.7	95	115		2.71	0.780
TR 183	688.7	B-002-0-22	8.5	-	9	SS-4B	-	-	-	-	-	-	-	-	-	-	-	53	A-4a	Granular	1	N/A					9.0	679.7	120			2.72	0.414
TR 183	688.7	B-002-0-22	10	-	11.5	SS-5	9	33	-	60	14	12	8	6	29	19	10	22	A-2-4	Granular	1	N/A				30	11.0	677.7	105	125	0.171	2.71	0.611

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) N-values PPR	Short-Term Cohesion (psf) N-values Sowers	Short-Term Cohesion (psf) 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	23	100	N/A	63	21	20	28	10	31	24	14	20	**Max**	N/A	N/A	N/A	N/A	33	18.0	687.7	110	130	0.189	2.72	0.691
Min	12	17	N/A	25	7	11	2	6	23	13	6	9	**Min**	N/A	N/A	N/A	N/A	30	1.0	670.7	100	120	0.117	2.71	0.537
Average	17	57	N/A	51	15	14	11	8	27	18	9	16	**Average**	N/A	N/A	N/A	N/A	31	10.4	677.5	107	127	0.149	2.71	0.586
Std Dev	4	26	N/A	13	5	3	8	1	3	3	3	4	**Std Dev**	N/A	N/A	N/A	N/A	1	5.7	5.5	4	4	0.027	0.00	0.062
Avg + Std	20	84	N/A	64	20	18	19	9	30	21	12	19	**Avg + Std**	N/A	N/A	N/A	N/A	32	16.0	683.0	111	131	0.177	2.71	0.648
Avg - Std	13	31	N/A	38	10	11	3	7	24	14	6	12	**Avg - Std**	N/A	N/A	N/A	N/A	31	4.7	672.0	103	123	0.122	2.71	0.524

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	Short-Term Cohesion (psf) N-values Sowers	Short-Term Cohesion (psf) 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)
TR 183	687.1	B-001-0-22	0	-	1.5	SS-1	13	17	-	-	-	-	-	-	-	-	-	13	A-2-4	Granular	2	N/A				31	1.0	686.1	100	120		2.71	0.691
TR 183	687.1	B-001-0-22	5	-	6.5	SS-3	20	78	-	25	21	16	28	10	23	16	7	15	A-4a	Granular	2	N/A				32	6.0	681.1	105	125	0.117	2.72	0.616
TR 183	687.1	B-001-0-22	8	-	9.5	SS-4	23	100	-	-	-	-	-	-	-	-	-	12	A-2-4	Granular	2	N/A				33	9.0	678.1	105	125		2.71	0.611
TR 183	687.1	B-001-0-22	9.5	-	11	SS-5	14	78	-	63	7	20	2	8	31	24	7	16	A-2-4	Granular	2	N/A				31	10.0	677.1	105	125	0.189	2.71	0.611
TR 183	687.1	B-001-0-22	12.5	-	14	SS-7	13	39	-	54	16	11	10	9	29	17	12	20	A-2-6	Granular	2	N/A				31	13.0	674.1	110	130	0.171	2.71	0.537
TR 183	687.1	B-001-0-22	14	-	15.5	SS-8	12	50	-	62	12	11	7	8	27	13	14	15	A-2-6	Granular	2	N/A				30	15.0	672.1	110	130	0.153	2.71	0.537
TR 183	688.7	B-002-0-22	0	-	1.5	SS-1	19	67	-	-	-	-	-	-	-	-	-	9	A-2-6	Granular	2	N/A				32	1.0	687.7	100	120		2.71	0.691
TR 183	688.7	B-002-0-22	11.5	-	13	SS-6	13	78	-	46	20	16	9	9	23	17	6	19	A-1-b	Granular	2	N/A				31	12.0	676.7	110	130	0.117	2.71	0.537
TR 183	688.7	B-002-0-22	13	-	14.5	SS-7	19	50	-	54	15	15	9	7	28	20	8	18	A-2-4	Granular	2	N/A				32	14.0	674.7	110	130	0.162	2.71	0.537
TR 183	688.7	B-002-0-22	14.5	-	16	SS-8	17	56	-	56	15	12	11	6	25	17	8	14	A-2-4	Granular	2	N/A				31	15.0	673.7	110	130	0.135	2.71	0.537
TR 183	688.7	B-002-0-22	17.5	-	19	SS-9	20	17	-	-	-	-	-	-	-	-	-	20	A-2-4	Granular	2	N/A				32	18.0	670.7	110	130		2.71	0.537

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			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)
														PPR	Sowers	T & P									
Max	91	89	N/A	62	14	12	9	8	29	18	11	18	**Max**	N/A	N/A	N/A	N/A	40	23.0	670.1	125	140	0.171	2.72	0.409
Min	35	44	N/A	59	12	9	9	6	19	15	4	12	**Min**	N/A	N/A	N/A	N/A	35	17.0	665.1	120	135	0.081	2.71	0.353
Average	54	69	N/A	61	13	11	9	7	24	17	8	15	**Average**	N/A	N/A	N/A	N/A	37	20.4	667.3	123	138	0.126	2.71	0.376
Std Dev	22	17	N/A	2	1	2	0	1	7	2	5	2	**Std Dev**	N/A	N/A	N/A	N/A	3	2.4	2.0	3	3	0.064	0.00	0.030
Avg + Std	76	86	N/A	63	14	13	9	8	31	19	12	17	**Avg + Std**	N/A	N/A	N/A	N/A	40	22.8	669.3	126	141	0.190	2.72	0.406
Avg - Std	32	52	N/A	58	12	8	9	6	17	14	3	13	**Avg - Std**	N/A	N/A	N/A	N/A	35	18.0	665.3	120	135	0.062	2.71	0.346

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			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)
																						PPR	Sowers	T & P									
TR 183	687.1	B-001-0-22	16	-	17.5	SS-9	35	67	-	-	-	-	-	-	-	-	-	15	A-1-b	Granular	3	N/A				35	17.0	670.1	120	135		2.71	0.409
TR 183	687.1	B-001-0-22	18.5	-	20	SS-10	38	78	-	59	12	12	9	8	19	15	4	12	A-1-b	Granular	3	N/A				35	19.0	668.1	120	135	0.081	2.71	0.409
TR 183	687.1	B-001-0-22	21	-	22.5	SS-11	52	44	-	-	-	-	-	-	-	-	-	18	A-1-b	Granular	3	N/A				39	22.0	665.1	125	140		2.71	0.353
TR 183	688.7	B-002-0-22	20	-	21.5	SS-10	54	67	-	62	14	9	9	6	29	18	11	16	A-2-6	Granular	3	N/A				39	21.0	667.7	125	140	0.171	2.71	0.353
TR 183	688.7	B-002-0-22	22.5	-	24	SS-11	91	89	-	-	-	-	-	-	-	-	-	15	A-4a	Granular	3	N/A				40	23.0	665.7	125	140		2.72	0.358

BEDROCK TESTING

Project	Exploration ID	Sample Depth (ft)	Sample ID	Rock Type	Color	Moist Unit Weight (pcf)	Compressive Strength (psi)	Compressive Strength (MPa)	Er Modulus (psi)	Er Modulus (MPa)	GSI Range	GSI USE	Em (Hoek & Brown) Modulus (GPa)	Em (Hoek & Brown) Modulus (psi)	Lesser of Er vs Em (psi)
MOE-TR183-0.13	B-001-0-22	27.3		Shale	Gray		1,313	9.1	NA	-	15-25	20	0.5	77602	77602
				Shale	Maximum	-	1313		NA = Not Available				Shale	Maximum	77602
					Minimum	-	1313							Minimum	77602
					Average	-	1313							Average	77602
					Std Dev	-	-							Std Dev	-
					Recommended Value:	150	1300							Recommended Value:	77500

Project	Exploration ID	Sample Depth (ft)	Sample ID	Rock Type	Color	Moist Unit Weight (pcf)	Compressive Strength (psi)	Compressive Strength (MPa)	Er Modulus (psi)	Er Modulus (MPa)	GSI Range	GSI USE	Em (Hoek & Brown) Modulus (GPa)	Em (Hoek & Brown) Modulus (psi)	Lesser of Er vs Em (psi)
MOE-TR183-0.13	B-001-0-22	32.5		Claystone	Gray		266	1.8	NA	-	10-20	15	0.2	26193	26193
MOE-TR183-0.13	B-002-0-22	33.2		Claystone	Gray		282	1.9	NA	-	10-20	15	0.2	26969	26969
				Claystone	Maximum	-	282		NA = Not Available				Claystone	Maximum	26969
					Minimum	-	266							Minimum	26193
					Average	-	274							Average	26581
					Std Dev	-	11							Std Dev	549
					Recommended Value:	150	275							Recommended Value:	26000

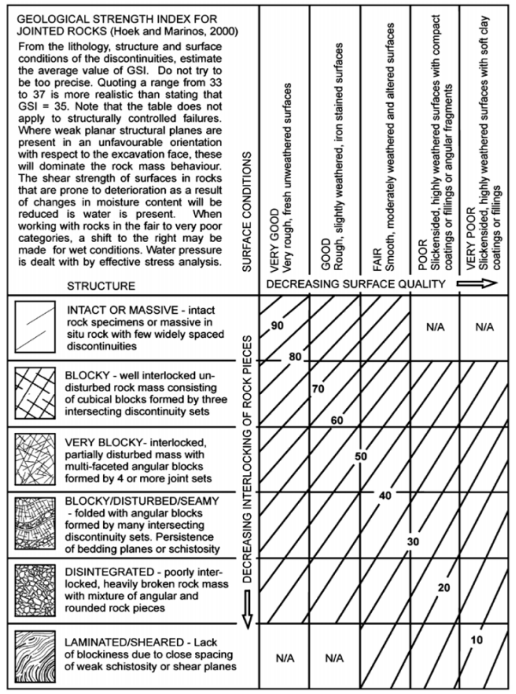
Project	Exploration ID	Sample Depth (ft)	Sample ID	Rock Type	Color	Moist Unit Weight (pcf)	Compressive Strength (psi)	Compressive Strength (MPa)	Er Modulus (psi)	Er Modulus (MPa)	GSI Range	GSI USE	Em (Hoek & Brown) Modulus (GPa)	Em (Hoek & Brown) Modulus (psi)	Lesser of Er vs Em (psi)
MOE-TR183-0.13	B-002-0-22	38.3		Sandstone	Gray	159.0	10,068	69.4	NA	-	45-55	50	8.3	1208404	1208404
				Sandstone	Maximum	159.0	10068		NA = Not Available				Sandstone	Maximum	1208404
					Minimum	159.0	10068							Minimum	1208404
					Average	159	10068							Average	1208404
					Std Dev	-	-							Std Dev	-
					Recommended Value:	160	10000							Recommended Value:	1208000

BEDROCK QUALITY

Project	Exploration ID	Rock Type	Depth Range (ft.) From	Depth Range (ft.) To	Thickness (ft)	Layer RQD (%)	Weighted RQD*(Length / Total Length)
MOE-TR183-0.13	B-001-0-22	Shale	25	29	4	67	41.2
MOE-TR183-0.13	B-002-0-22	Shale	25.5	28	2.5	52	20.0
				Shale	6.5	RQD SUM	61
				Maximum	4	67	
				Minimum	2.5	52	
				Average	3.3	59.5	
						Recommended Value:	61

Project	Exploration ID	Rock Type	Depth Range (ft.) From	Depth Range (ft.) To	Thickness (ft)	Layer RQD (%)	Weighted RQD*(Length / Total Length)
MOE-TR183-0.13	B-001-0-22	Claystone	29.5	34.7	5.2	73	26.9
MOE-TR183-0.13	B-002-0-22	Claystone	28	31.6	3.6	50	12.8
MOE-TR183-0.13	B-002-0-22	Claystone	31.6	36.9	5.3	49	18.4
				Claystone	14.1	RQD SUM	58
				Maximum	5.3	73	
				Minimum	3.6	49	
				Average	4.7	57.3	
						Recommended Value:	58

Project	Exploration ID	Rock Type	Depth Range (ft.) From	Depth Range (ft.) To	Thickness (ft)	Layer RQD (%)	Weighted RQD*(Length / Total Length)
MOE-TR183-0.13	B-001-0-22	Sandstone	34.7	40	5.3	100	63.9
MOE-TR183-0.13	B-002-0-22	Sandstone	36.9	39.9	3	94	34.0
				Sandstone	8.3	RQD SUM	98
				Maximum	5.3	100	
				Minimum	3	94	
				Average	4.2	97.0	
						Recommended Value:	98



GEOLOGICAL STRENGTH INDEX FOR JOINTED ROCKS (Hoek and Marinos, 2000)

From the lithology, structure and surface conditions of the discontinuities, estimate the average value of GSI. Do not try to be too precise. Quoting a range from 33 to 37 is more realistic than stating that GSI = 35. Note that the table does not apply to structurally controlled failures. Where weak planar structural planes are present in an unfavourable orientation with respect to the excavation face, these will dominate the rock mass behaviour. The shear strength of surfaces in rocks that are prone to deterioration as a result of changes in moisture content will be reduced is water is present. When working with rocks in the fair to very poor categories, a shift to the right may be made for wet conditions. Water pressure is dealt with by effective stress analysis.

INTACT OR MASSIVE - intact rock specimens or massive in situ rock with few widely spaced discontinuities

BLOCKY - well interlocked un-disturbed rock mass consisting of cubical blocks formed by three intersecting discontinuity sets

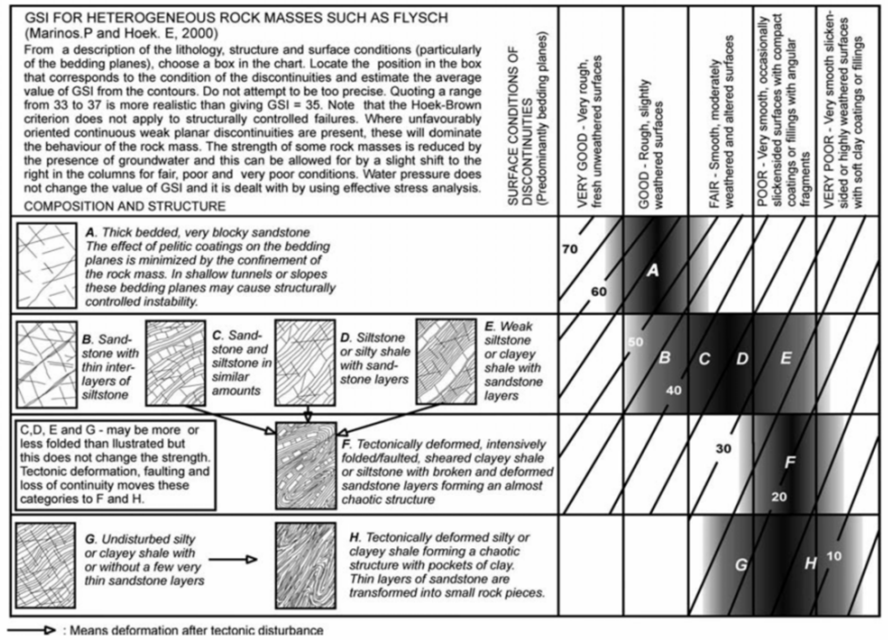
VERY BLOCKY- interlocked, partially disturbed mass with multi-faceted angular blocks formed by 4 or more joint sets

BLOCKY/DISTURBED/SEAMY - folded with angular blocks formed by many intersecting discontinuity sets. Persistence of bedding planes or schistosity

DISINTEGRATED - poorly inter-locked, heavily broken rock mass with mixture of angular and rounded rock pieces

LAMINATED/SHEARED - Lack of blockiness due to close spacing of weak schistosity or shear planes

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



GSI FOR HETEROGENEOUS ROCK MASSES SUCH AS FLYSCH (Marinos.P and Hoek. E, 2000)

From a description of the lithology, structure and surface conditions (particularly of the bedding planes), choose a box in the chart. Locate the position in the box that corresponds to the condition of the discontinuities and estimate the average value of GSI from the contours. Do not attempt to be too precise. Quoting a range from 33 to 37 is more realistic than giving GSI = 35. Note that the Hoek-Brown criterion does not apply to structurally controlled failures. Where unfavourably oriented continuous weak planar discontinuities are present, these will dominate the behaviour of the rock mass. The strength of some rock masses is reduced by the presence of groundwater and this can be allowed for by a slight shift to the right in the columns for fair, poor and very poor conditions. Water pressure does not change the value of GSI and it is dealt with by using effective stress analysis.

A. Thick bedded, very blocky sandstone The effect of pelitic coatings on the bedding planes is minimized by the confinement of the rock mass. In shallow tunnels or slopes these bedding planes may cause structurally controlled instability.

B. Sand-stone with thin inter-layers of siltstone

C. Sand-stone and siltstone in similar amounts

D. Siltstone or silty shale with sand-stone layers

E. Weak siltstone or clayey shale with sandstone layers

C,D, E and G - may be more or less folded than Illustrated but this does not change the strength. Tectonic deformation, faulting and loss of continuity moves these categories to F and H.

F. Tectonically deformed, intensively folded/faulted, sheared clayey shale or siltstone with broken and deformed sandstone layers forming an almost chaotic structure

G. Undisturbed silty or clayey shale with or without a few very thin sandstone layers

H. Tectonically deformed silty or clayey shale forming a chaotic structure with pockets of clay. Thin layers of sandstone are transformed into small rock pieces.

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

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.

Scour Analysis Parameters

HDR

Project: MOE-TR183-0.13
Client: Monroe County Engineer
Task: **Scour Analysis**

Calculated By: DCM **Date:** 11/25/2022
Checked By: DMV **Date:** 12/1/2022

Reference

ODOT Geotechnical Design Manual (GDM)

Critical Shear Stress (Tc)

Cohesive Soils (GDM 1302.1)

$T_c = {}^{-2.0}(PI/100)^{1.3}(qu)^{0.4}$

Tc (Pa) = Critical Shear Stress
w (dim) = Water Content
F (dim) = Fraction of Fine Particles (< 75 um)
PI (dim) = Plasticity Index (use min PI = 4)
qu (psf) = Unconfined Compressiive Test
c (psf) = 1/2 qu cohesion
a = 0.01 unit conversion
0.01 = U.S. Customary units
0.1 = S.I.

Granular Soils (GDM1302.2)

Tc (Pa) = D50 (mm)
Tc (psf) = Critical Shear Stress (Pa)
D50 mean particle grain size (mm), > or = 0.2 mm

Reference

Location and Design Manual - Volume 2 : Drainage Design (LDv2)

Erosion Category (EC)

Cohesive Soils (LDv2 C1008.10.4)

$EC = 4.5 - (3 / 1.07^{PI})$ where $1.5 \leq EC < 4.5$
PI = Plasticity index (dim)

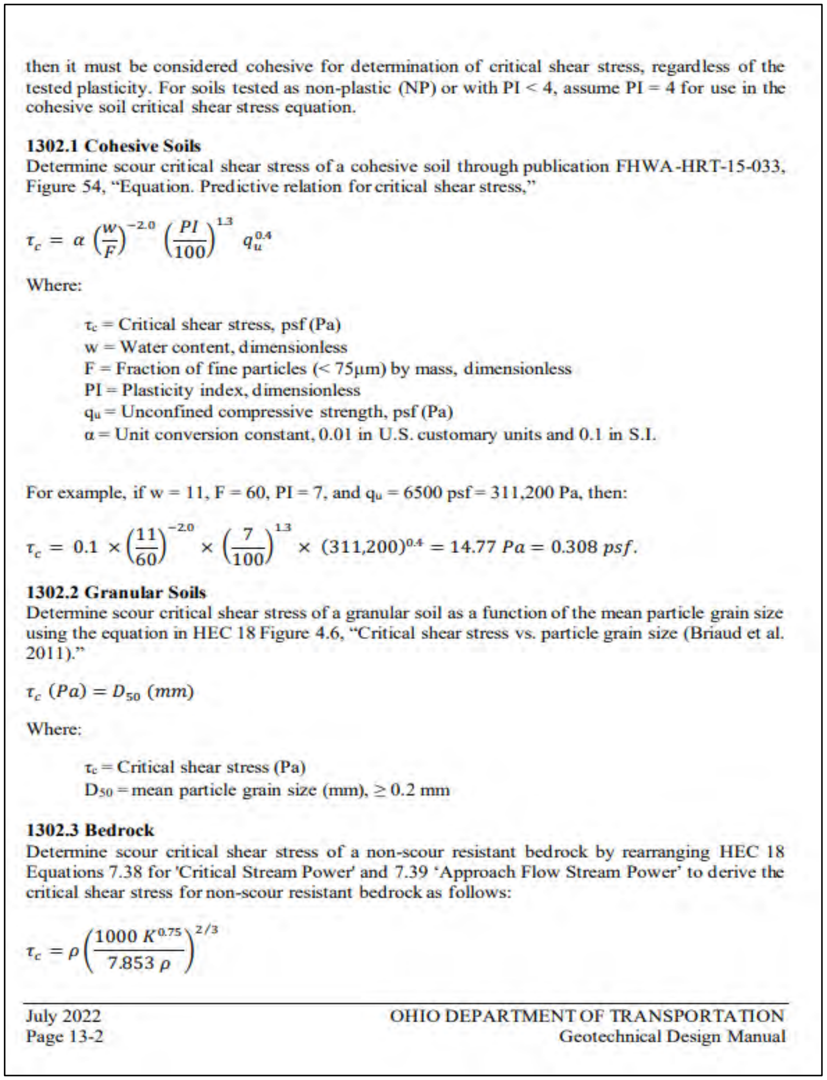
Granular Soils (LDv2 C1008.10.4)

$EC = 1.2\,[1.83333+\log(D50)]$

where $1 \leq EC \leq 6$

Boring No.	Sample	Elevation (ft)			D50	Moisture	Fines (< 75um)	Plasticiy	Unconfined Compressive Strength, Qu		Unit conversion	Tc (Pa)	Tc (psf)	EC (dim)
		Top		Bottom	(mm)	w (dim)	F (dim)	PI (dim)	Qu (psf)[1]	Qu (Pa)	a (dim)			
B-001-0-22	SS-5	677.56	-	676.06	4.8348	16	10	7	GRANULAR	Granular	0.1	4.835	0.101	3.02
	SS-6	676.06	-	674.56	3.0327	27	21	18	GRANULAR	Granular	0.1	3.033	0.063	2.78
	SS-7	674.56	-	673.06	2.4802	20	19	12	GRANULAR	Granular	0.1	2.480	0.052	2.67
	SS-8	673.06	-	671.56	5.3393	15	15	14	GRANULAR	Granular	0.1	5.339	0.112	3.07
B-002-0-22	SS-5	678.66	-	677.16	4.2471	22	14	10	GRANULAR	Granular	0.1	4.247	0.089	2.95
	SS-6	677.16	-	675.66	1.3939	19	18	6	GRANULAR	Granular	0.1	1.394	0.029	2.37
	SS-7	675.66	-	674.16	2.6654	18	16	8	GRANULAR	Granular	0.1	2.665	0.056	2.71
	SS-8	674.16	-	672.66	3.0839	14	17	8	GRANULAR	Granular	0.1	3.084	0.064	2.79

1. See soil parameter determination sheet summary
2. 1 Pa = 0.0208854 psf
3. dim = dimensionless



then it must be considered cohesive for determination of critical shear stress, regardless of the tested plasticity. For soils tested as non-plastic (NP) or with PI < 4, assume PI = 4 for use in the cohesive soil critical shear stress equation.

1302.1 Cohesive Soils

Determine scour critical shear stress of a cohesive soil through publication FHWA-HRT-15-033, Figure 54, "Equation. Predictive relation for critical shear stress,"

$$\tau_c = \alpha \left(\frac{w}{F}\right)^{-2.0} \left(\frac{PI}{100}\right)^{1.3} q_u^{0.4}$$

Where:

τ_c = Critical shear stress, psf (Pa)
w = Water content, dimensionless
F = Fraction of fine particles (< 75μm) by mass, dimensionless
PI = Plasticity index, dimensionless
q_u = Unconfined compressive strength, psf (Pa)
α = Unit conversion constant, 0.01 in U.S. customary units and 0.1 in S.I.

For example, if w = 11, F = 60, PI = 7, and q_u = 6500 psf = 311,200 Pa, then:

$$\tau_c = 0.1 \times \left(\frac{11}{60}\right)^{-2.0} \times \left(\frac{7}{100}\right)^{1.3} \times (311{,}200)^{0.4} = 14.77\ Pa = 0.308\ psf.$$

1302.2 Granular Soils

Determine scour critical shear stress of a granular soil as a function of the mean particle grain size using the equation in HEC 18 Figure 4.6, "Critical shear stress vs. particle grain size (Briaud et al. 2011)."

$$\tau_c\ (Pa) = D_{50}\ (mm)$$

Where:

τ_c = Critical shear stress (Pa)
D_{50} = mean particle grain size (mm), ≥ 0.2 mm

1302.3 Bedrock

Determine scour critical shear stress of a non-scour resistant bedrock by rearranging HEC 18 Equations 7.38 for 'Critical Stream Power' and 7.39 'Approach Flow Stream Power' to derive the critical shear stress for non-scour resistant bedrock as follows:

$$\tau_c = \rho \left(\frac{1000\ K^{0.75}}{7.853\ \rho}\right)^{2/3}$$

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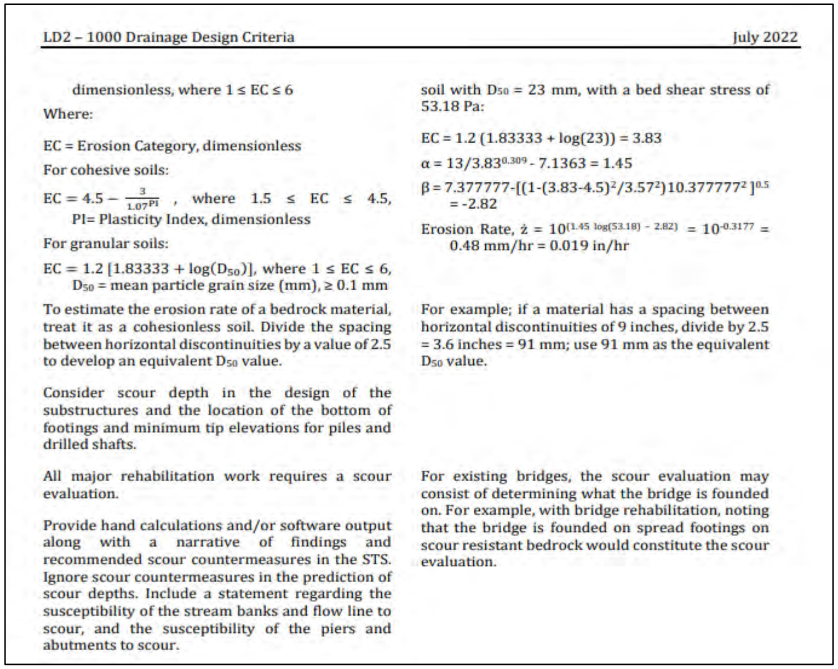

LD2 – 1000 Drainage Design Criteria July 2022

dimensionless, where 1 ≤ EC ≤ 6

Where:

EC = Erosion Category, dimensionless

For cohesive soils:

$EC = 4.5 - \frac{3}{1.07^{PI}}$, where 1.5 ≤ EC ≤ 4.5,
PI= Plasticity Index, dimensionless

For granular soils:

$EC = 1.2\ [1.83333 + \log(D_{50})]$, where 1 ≤ EC ≤ 6,
D_{50} = mean particle grain size (mm), ≥ 0.1 mm

To estimate the erosion rate of a bedrock material, treat it as a cohesionless soil. Divide the spacing between horizontal discontinuities by a value of 2.5 to develop an equivalent D_{50} value.

Consider scour depth in the design of the substructures and the location of the bottom of footings and minimum tip elevations for piles and drilled shafts.

All major rehabilitation work requires a scour evaluation.

Provide hand calculations and/or software output along with a narrative of findings and recommended scour countermeasures in the STS. Ignore scour countermeasures in the prediction of scour depths. Include a statement regarding the susceptibility of the stream banks and flow line to scour, and the susceptibility of the piers and abutments to scour.

soil with D_{50} = 23 mm, with a bed shear stress of 53.18 Pa:

$EC = 1.2\ (1.83333 + \log(23)) = 3.83$

$\alpha = 13/3.83^{0.309} - 7.1363 = 1.45$

$\beta = 7.377777\text{-}[(1\text{-}(3.83\text{-}4.5)^2/3.57^2)10.377777^2\ ]^{0.5}$
$= -2.82$

Erosion Rate, $\dot{z} = 10^{(1.45\ \log(53.18)\ -\ 2.82)} = 10^{-0.3177} =$
0.48 mm/hr = 0.019 in/hr

For example; if a material has a spacing between horizontal discontinuities of 9 inches, divide by 2.5 = 3.6 inches = 91 mm; use 91 mm as the equivalent D_{50} value.

For existing bridges, the scour evaluation may consist of determining what the bridge is founded on. For example, with bridge rehabilitation, noting that the bridge is founded on spread footings on scour resistant bedrock would constitute the scour evaluation.

Axial and Lateral Pile Design Parameter Determination

Project: MOE-TR183-0.13
Client: Monroe County Engineer
Task: **Generalized LPILE Parameters**

Calculated By: DCM **Date:** 11/22/2022
Checked By: DMV **Date:** 12/1/2022

Soil Lateral Design Profile

Soil Type	Elevation				Unit Wt (pcf)			
	Top (ft)	Bottom (ft)	Cohesion (psf)	Phi (deg)	Total	Effective[1]	ε50	k (pci)
2 - Medium Dense	688	686	0	31	125	125	N/A	90
1 - Loose Granular	686	682	0	28	120	120	N/A	25
2 - Medium Dense	682	676	0	31	125	125	N/A	90
2 - Medium Dense (submerged)	676	669	0	31	125	62.6	N/A	60
3 - Dense to Very Dense Granular	669	635.5	0	37	135	72.6	N/A	125

1. Effective unit weights to be applied below groundwater table (assumed at El 676 in recommended design profile)

ε50 tables from LPile Technical Manual

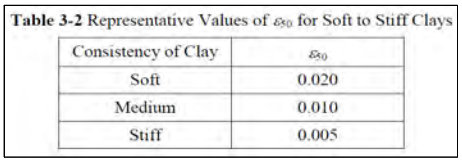

Table 3-2 Representative Values of ε_{50} for Soft to Stiff Clays

Consistency of Clay	ε_{50}
Soft	0.020
Medium	0.010
Stiff	0.005

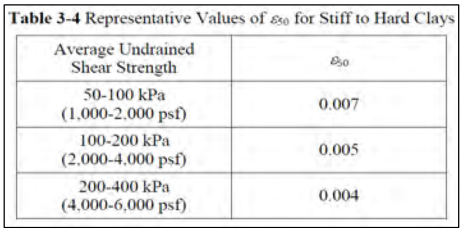

Table 3-4 Representative Values of ε_{50} for Stiff to Hard Clays

Average Undrained Shear Strength	ε_{50}
50-100 kPa (1,000-2,000 psf)	0.007
100-200 kPa (2,000-4,000 psf)	0.005
200-400 kPa (4,000-6,000 psf)	0.004

k tables from LPile Technical Manual

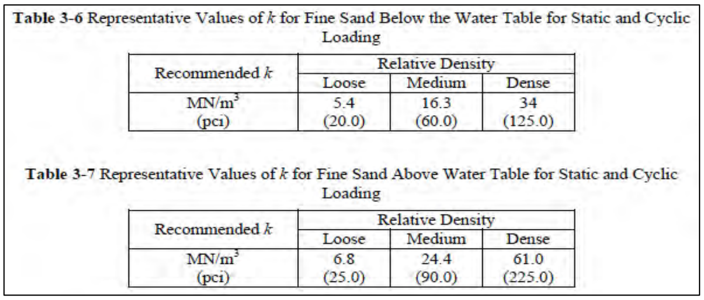

Table 3-6 Representative Values of *k* for Fine Sand Below the Water Table for Static and Cyclic Loading

Recommended *k*	Relative Density		
	Loose	Medium	Dense
MN/m^3 (pci)	5.4 (20.0)	16.3 (60.0)	34 (125.0)

Table 3-7 Representative Values of *k* for Fine Sand Above Water Table for Static and Cyclic Loading

Recommended *k*	Relative Density		
	Loose	Medium	Dense
MN/m^3 (pci)	6.8 (25.0)	24.4 (90.0)	61.0 (225.0)