Final Structure Foundation Exploration Report

PER-CR25-2.00

Perry County, OH
January 20, 2023

Prepared for:
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By:

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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. PER-CR25-2.00 (SFN 6430899) on Toll Gate Road, County Route 25 (CR 25), over Center Branch Rush Creek in Perry County, Ohio.

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

Based on HDR's assessment of the borings, the generalized soil profile consists of existing fill material over granular and cohesive alluvial and glacial till soils that generally increase in strength with depth. Further discussion on the encountered subsurface conditions is located in Section 4.

Given the relatively shallow depth to competent sandstone bedrock (approximately 30 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, with the proximity of the Center Branch Rush Creek, shallow groundwater, and 15 to 20 feet of soft and/or loose alluvium within the soil profile, pile foundations are anticipated to be the preferred foundation option. The recommended design parameters for the foundation analyses 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. PER-CR25-2.00 (SFN 6430899) carrying Toll Gate Road, (CR 25) over Center Branch Rush Creek. The PER-CR25-2.00 project is located in west-central Perry County, approximately 2.4 miles from the border of Fairfield County, as shown on the Site Vicinity Map (Exhibit No. 1) in Appendix A. The work includes the removal of the existing deck and superstructure of the current bridge structure and its replacement with a simply-supported redundant bridge structure. The structure is to be stepped back from the existing bridge abutments, which are to remain in place, with minimal approach work expected. The total project length is 300 feet, from Station 8+50.00 to 11+50.00. The work length is to be determined by the selected design build team (DBT).

This geotechnical study was authorized by the Ohio Department of Transportation (ODOT) on August 31, 2022, under the VAR-STW Geotechnical Engineering Services CEAO 2023-2 contract. The geotechnical services performed under this modification 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 development of the plans and design of the bridge structure by the DBT.

2 GEOLOGY AND OBSERVATIONS

2.1 Project Setting

This project is located within the west-central portion of Perry County, Ohio in a rural setting surrounded by wooded and agricultural parcels. Elevations along the project site range from about El. 835 outside the bridge limits to approximately El. 820 at the stream crossing.

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 Illinoian Glaciated Allegheny Plateau region of the

Glaciated Allegheny Plateaus section of the Appalachian Plateaus province (Exhibit No. 2 in Appendix A). The Illinoian Glaciated Allegheny Plateau region is characterized by dissected, rugged hills, covered with loess and older drift on ridgetops. Elevations in this region generally range from 600 to 1,400 feet above sea level. Soils in the Illinoian Glaciated Allegheny Plateau consist of clayey, Illinoian-age till over deeply buried, soft Devonian-age shales and near-surface Mississippian-age sandstones and shales.

Drainage in the western part of the county is accommodated by Center Branch Rush Creek and its tributaries, which drains into Rush Creek approximately 2 1/2 miles downstream of the project site and two miles west of Junction City. The project site is directly drained by the Center Branch Rush Creek.

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 Illinoian-aged loam till deposits (Ti) and Holocene-aged alluvial deposits (a) with underlying Mississippian and Pennsylvanian bedrock including sandstone, shale, siltstone, clay, limestone, and coal (P, SsSh). The alluvium develops in floodplains of modern streams with soils ranging from silt to clay to boulders, commonly including organic materials. The loam till is composed of till deposits overlain by loess that becomes thicker along bluffs bordering major rivers. The till deposits consist of an unsorted mix of silt, clay, sand, gravel, and boulders deposited directly from several separate ice advances. The thicknesses of the alluvium and loam till deposits at the project site are approximately 25 feet.

2.2.1 Project Soils

The USDA Soil Survey of Perry County indicates the most prevalent surficial soil types within the project limits are the silt loams of the Newark (Ne) and Homewood-Westmoreland (HaE2) units as shown in Exhibit No. 4a.

Soils of the Newark silt loam (0 to 3 percent slopes) consist of 85 percent Newark soils, and 15 percent minor components. The frequently flooded Newark soils generally consist of silt and silty clay loams derived from fine, silty alluvium derived from sedimentary rock. The somewhat poorly drained soils are typically located in flood plains with a moderately high to high water capacity.

Soils of the Homewood-Westmoreland silt loam (25 to 40 percent slopes) consist of 45 percent Homewood and similar soils, 35 percent Westmoreland and similar soils, and 20 percent minor components. Homewood-Westmoreland soils generally consist of silt loam and clay loam derived from Illinoian loamy till and loamy colluvium derived from sedimentary rock. The soils are typically located along hills, including back and side slopes with a moderately 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 high risk of corrosion to steel, low to moderate risk of corrosion to concrete, and have pH levels of 5.5 and 6.7.

2.2.2 Bedrock Geology

As shown on Exhibit No. 5 (Bedrock Geology Map), the bedrock geology mapped within the project area is the Mississippian-age Logan and Cuyahoga Formations Undivided (Mlc). The Pennsylvanian-age Allegheny and Pottsville Groups, Undivided (IPap) may also be found along the northern and southern extents and/or in areas adjacent to the project site along CR 25. The Logan and Cuyahoga Formations, Undivided generally consist of locally fossiliferous shale, siltstone, and silty to granular sandstone, which are often interbedded, with minor amounts of conglomerate and thin- to thick-bedded limestone. The Allegheny and Pottsville Groups, Undivided generally consist of locally fossiliferous and partially calcareous shale and thin- to medium-bedded, locally fossiliferous siltstone, with minor amounts of thin- to medium-bedded limestone and very fine to medium-grained sandstone. Coal beds of note within the Allegheny and Pottsville Group include the Upper and Lower Freeport, Middle and Lower Kittanning, Clarion, and Newland-Brookville seams. Perry County was heavily mined in the central and eastern portions of the county, but not at the project site itself. Based on review of the ODNR Mine Maps as shown in Exhibit No. 6 (Mines of Ohio Map), surface coal mining of the Middle Kittanning coal seam was performed approximately 1.5 to 2.0 miles east of the project site. Bedrock elevations in the project area, as shown on Exhibit No. 7 (Bedrock Topography Map), range between about 800 to 850 feet. The contours appear to form a generally northeast-southwest trending channel at the bridge structure.

3 EXPLORATION

3.1 Site Reconnaissance

A visual reconnaissance of the project site and surrounding area was performed by an HDR geotechnical engineer on August 4, 2022 to mark the preliminary boring locations and during the drilling activities on October 19, 2022. The project site is located within a wooded, relatively narrow valley, with the existing bridge located within the low point of a sag curve. The existing bridge is a two-lane structure carrying CR 25 over Center Branch Rush Creek. The bridge is supported by nine approximately 24-inch deep by 9-inch wide steel sections spanning between the two bridge abutments. Each abutment is constructed of seven evenly spaced 12-inch deep by 12-inch wide piles with lagging placed behind piles. The lagging consists of guardrail at the north abutment and concrete panels at the south abutment. The bridge deck consists of corrugated steel decking with an asphaltic concrete overlay.

3.2 Subsurface Exploration

Two borings were drilled as part of the geotechnical exploration program to assess the subsurface conditions within the PER-CR25-2.00 project limits. The locations of the test borings are shown on the Boring Location Plan (Exhibit No. 8) in Appendix A. The test borings were located and marked in the field during the initial visual reconnaissance on August 4, 2022. These as-drilled locations are reflected on the boring plan, the boring logs in Appendix B, 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	CR 25	9+74	6 ft Lt	830.8	785.8
B-002-0-22	E1	CR 25	10+31	5 ft Lt	831.3	786.3

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

The borings were drilled by Central Star Drilling under the supervision of an HDR geotechnical engineer on October 19, 2022, with a Diedrich D-50 track rig. The rig was calibrated on March 7, 2022 and has 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 explored depths. 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. An undisturbed soil sample was collected in Boring B-002-0-22 in accordance with the *Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes*, ASTM D 1587. The depth of this sample was determined by the HDR geotechnical engineer after review of the encountered subsurface conditions above the undisturbed sample. The collection of two additional undisturbed samples were attempted during the drilling activities. However, the recovery in both instances was minimal.

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.

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 24 natural moisture content tests (per ASTM D 2216), 14 Atterberg limit determinations (per ASTM D 4318), and 14 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 soil unconfined compression test (per ASTM D 2166) and 1 one-dimensional consolidation test (per ASTM D 2435) were performed on the collected undisturbed Shelby tube sample from Boring B-002-0-22, and 2 unconfined compression tests (ASTM D 7012 – Method C) 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 two test borings consists of embankment fill, as found behind the existing abutments, over alluvium and glacial till soils. Bedrock encountered beneath the soil overburden consists of shale and sandstone.

As Borings B-001-0-22 and B-002-0-22 were located within the existing limits of the roadway, the surficial materials consisted of 12 inches of asphalt pavement. Beneath the pavement, approximately 5 to 5.5 feet of fill material was encountered. The overlying fill material was granular, consisting of 3 feet of medium dense to dense Gravel with Sand and Silt (A-2-4) in Boring B-001-0-22 and 1.5 feet of loose Gravel with Sand (A-1-b) in Boring B-002-0-22. The underlying fill material was cohesive in nature. In Boring B-001-0-22, medium stiff to stiff Silt and Clay (A-6a) was encountered, whereas at B-002-0-22, medium stiff to stiff Sandy Silt (A-4a) was encountered. The thickness of the cohesive fill as encountered was 2 feet and 4 feet, respectively.

Alluvial soils were encountered beneath the fill material. The alluvium generally consisted of cohesive layers of very soft to medium stiff gray Sandy Silt (A-4a) and Silt (A-4b); however, roughly 6.5 feet of granular alluvium was also encountered in Boring B-001-0-22. Pocket penetrometer readings in the cohesive alluvium ranged from 0.25 to 2.0 tsf, with N_{60}-values from 1 to 7 blows per foot (bpf). The 18 inches of Gravel with Sand, Silt, and Clay (A-2-6) encountered from El. 817.3 to El. 815.8 and 5 feet of Sandy Silt (A-4a) from El 815.8 to El 810.8 in Boring B-002-0-22 generally exhibited a loose relative density, with N_{60}-values of 4 to 7 bpf.

Glacial till was encountered in the borings starting at a depth of 16.5 (El 814.8) to 20 feet (El 810.8) below the existing ground surface (bgs) and extending to the top of bedrock. The till consisted of medium to very dense Gravel with Sand (A-1-b) and hard Silt and Clay (A-6a).

Shale and sandstone bedrock was encountered beneath the till deposits to the boring termination depths of 45 feet. A thin layer of shale was encountered from a depth of 30 to 30.5 feet (El. 800.8 to El. 800.3) in Boring B-001-0-22, and 30 to 30.5 ft (El. 801.3 to El. 800.8) in Boring B-002-0-22, respectively. The shale was able to be sampled utilizing the split-barrel sampling procedure, with split spoon refusal obtained (N > 50/6"). Sandstone was encountered underlying the shale at a depth of 30.5 to the termination depth (El. 800.3 to El. 785.8 and El. 800.8 to El. 786.3) in both borings. The sandstone was characterized as slightly weathered and strong to very strong, with a stratum rock quality (SRQD) of 55% to 65%.

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 within the CR 25 travel lanes, and delayed water readings were not obtained. Groundwater depths and elevations as 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 Drilling (ft)	Notes
B-001-0-22	13.5/El. 817.3	Water added at 30.5 ft. Boring completed the same day.
B-002-1-22	17.5/El. 813.8	Water added at 30.5 ft. 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, recorded pocket penetrometer readings, 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)	γ_{eff} (pcf)	S_u (psf)	ϕ' (°)	c' (psf)	ϕ' (°)
831.0	827.0	Granular Fill	120	120	0	32	0	32
827.0	825.0	Cohesive Fill	110	110	900	0	90	22
825.0	815.0	Very Soft to Soft Cohesive	120	120	500	0	25	16
815.0	811.0	Loose Granular	120	57.6	0	25	0	25
811.0	806.0	Medium Dense to Dense Granular	135	72.6	0	33	0	34
806.0	801.0	Hard Cohesive	140	77.6	4000	0	200	27

1. Effective unit weights to be used below groundwater (assumed at El 815 in recommended design soil profile).

5.2 Bridge Foundations

The project involves the replacement of an existing single-span structure carrying Toll Gate Road (CR 25) over Center Branch Rush Creek. As this will be a design-build project, providing a recommended foundation type is outside the scope of this study. However, given the 15 feet to 20 feet of soft and/or loose soils overlying the site, and the relatively shallow depth to competent sandstone (approximately 30 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 layers 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 DBT 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)		
831.0	827.0	Granular Fill	120	120	-	90
827.0	825.0	Cohesive Fill	110	110	0.01	-
825.0	815.0	Very Soft to Soft Cohesive	120	120	0.02	-
815.0	811.0	Loose Granular	120	57.6	-	20
811.0	806.0	Medium Dense to Dense Granular	135	72.6	-	60
806.0	801.0	Hard Cohesive	140	77.6	0.005	N/A

1 Effective unit weights to be used below Groundwater (assumed at El 815 in 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 Center Branch Rush Creek 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 DBT in determining the predicted scour depth.

Table 5-3: Scour Analysis Parameters

Boring	Sample	Depth	D50 Value (mm)	Critical Shear Stress, Tc (psf)	Erosion Category, EC (dim)
B-001-0-22	SS-5	820.8	0.0259	0.154	3.91
	SS-6	818.7	0.0329	0.180	3.87
	SS-7	817.3	0.9635	0.020	2.18
	SS-8	815.8	0.1258	0.003	1.12
B-002-0-22	SS-5	821.8	0.0133	0.108	3.67
	SS-6	820.3	0.0253	0.157	3.67
	SS-7	818.8	0.0282	0.167	3.67
	SS-8	817.3	0.0266	0.151	3.61

5.4 Additional 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 the pavement removal, removal of the existing bridge structure, and possible relocation of existing utilities.

5.4.2 Settlement

- As modifications to the vertical roadway alignment are expected to be minor, minimal settlement is anticipated. However, should the vertical alignment be raised as the project moves forward and settlement analyses required, the results of a consolidation test performed on a relatively undisturbed cohesive soil sample collected from Boring B-002-0-22 are located within Appendix C.
- It is anticipated that the bridge foundations will bear on the underlying competent sandstone encountered at approximately 30 feet below the existing ground surface. This will limit any anticipated settlement of the bridge structure itself. However, additional analyses 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 may need to be conducted if the roadway profile is raised.

6 LIMITATIONS

This report documents the findings and conclusions of HDR Engineering, Inc., for the geotechnical aspects related to the planning and design of the PER-CR25-2.00 project in Perry County, Ohio. The report has been prepared for the use of the Perry County Engineer's Office 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 variations 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/"

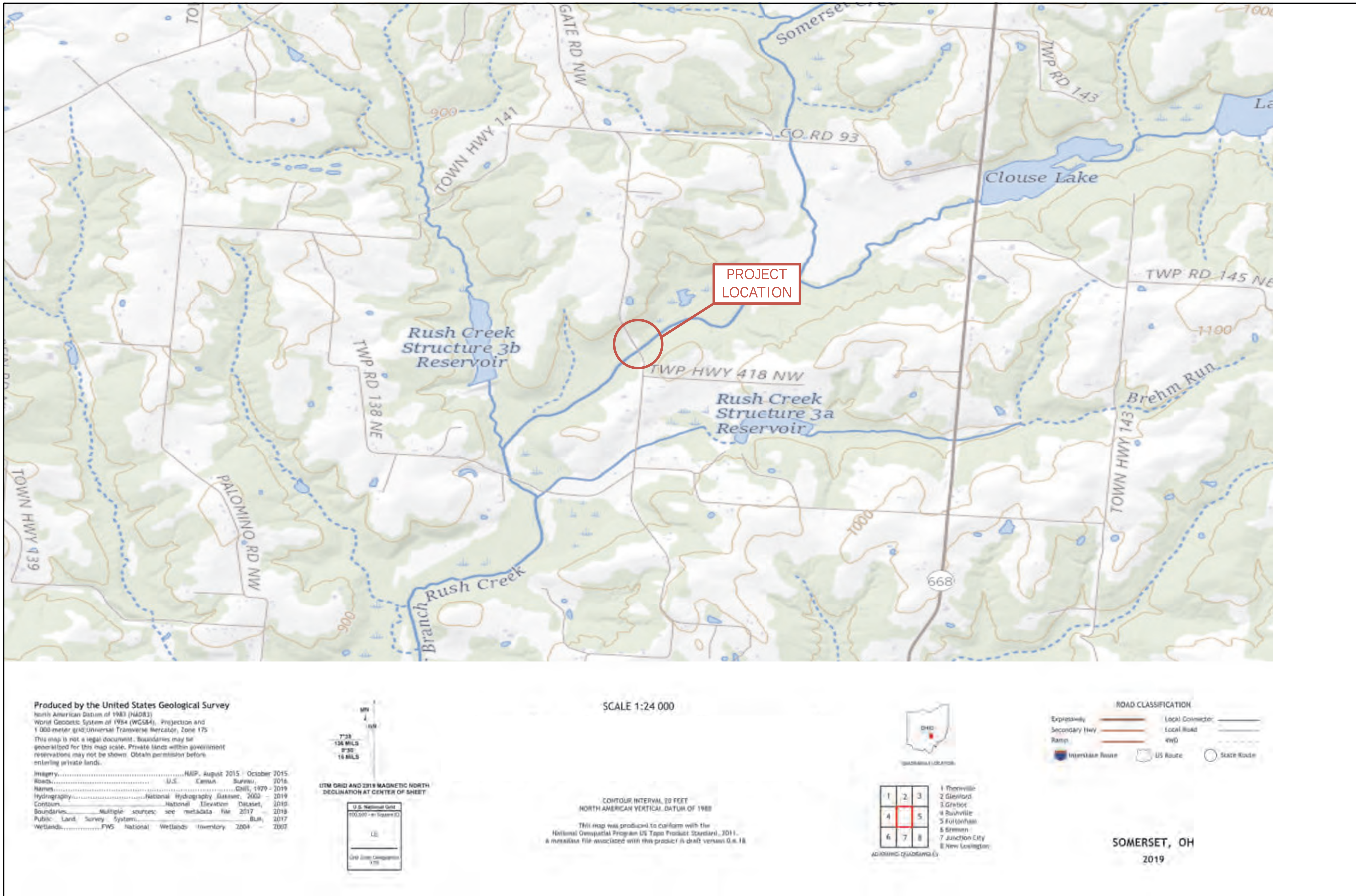
Ohio Department of Natural Resources, Division of Geologic Survey, Pavey, R.R. et. al. (2002); *"Surficial geology of the Canton 30x60-Minute quadrangle".*

Ohio Department of Natural Resources, Division of Geologic Survey, Swinford, E.M. and Schumacher, G.A., (2001); *"Reconnaissance bedrock geology of the Wilmot, Ohio, quadrangle".*

Ohio Department of Natural Resources, Division of Geologic Survey, Swinford, E.M., Vorbau, K.E., and Schumacher, G.A., (2001); *"Bedrock topography of the Wilmot, Ohio, quadrangle".*

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



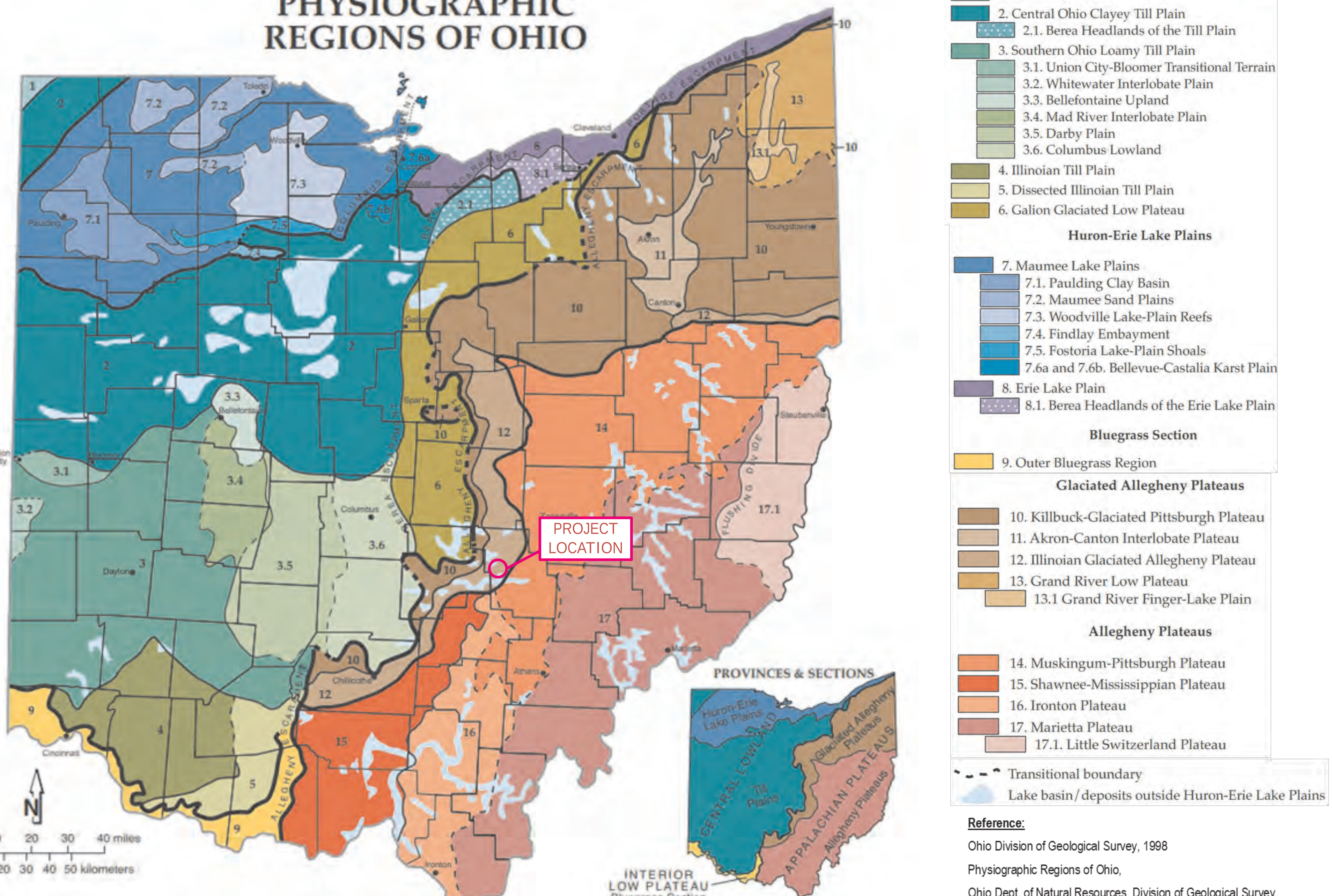
Calculated: LSH
Checked: DMV

Exhibit No. 1: Site Vicinity and Topographic Map

Project: PER-CR25-2.00
PID: 117332

STATE OF OHIO • DEPARTMENT OF NATURAL RESOURCES • DIVISION OF GEOLOGICAL SURVEY

PHYSIOGRAPHIC REGIONS OF OHIO



Reference:

Ohio Division of Geological Survey, 1998

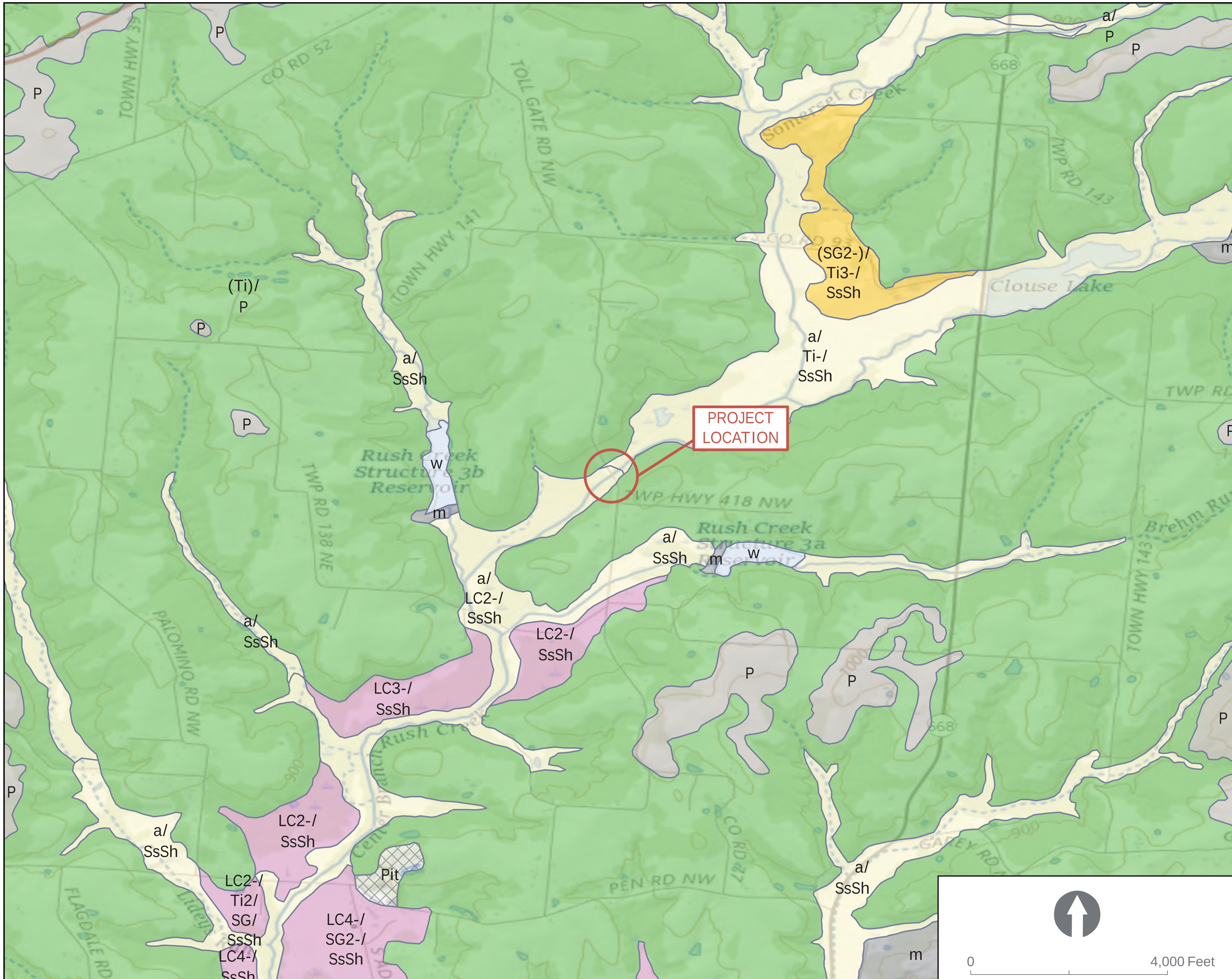
Physiographic Regions of Ohio,

Ohio Dept. of Natural Resources, Division of Geological Survey

Calculated: LSH
Checked: DMV

Exhibit No. 2: Physiographic Regions of Ohio

Project: PER-CR25-2.00
PID: 117332



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.
- LC — Silt and clay w/ occas. sand/gravel interbeds - present as deltaic deposits, outwash, deposits in upland depressions, intermorainal lake deposits, and backwater lake deposits.
- 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.
- SsSh — Sandstone and shale - interbedded shale, siltstone, and sandstone and associated colluvium, with common vertical and horizontal changes in rock type.
- T — Till - (predominantly Wisconsinan) - Unsorted mix of silt, clay, sand, gravel, and boulders; variable carbonate content, generally grey to light brown when unweathered. Fractures common. May contain silt, sand, and gravel lenses. Deposited directly from several separate ice advances. Undifferentiated and nonspecified age in buried valleys or where separated by intervening nontill units from an overlying till. Surface may be wave-planed or modified by lacustrine erosion and deposition.
- Ti — Loam till - (predominantly Illinoian) - Properties similar to unit T. Generally, overlain by loess that becomes thicker along bluffs bordering major rivers.
- m — 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.
- w — Water

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

Calculated: LSH
Checked: DMV

Exhibit No. 3: Surficial Geology

Project: PER-CR25-2.00
PID: 117332

G:\OHIO\ODOT\ODT-OCEA STATEWIDE CONTRACT PROJECTS\PER-CR25-2.00_10354468_ARCGISPRO\7.2_WIP\MAP_DOCS\HDR_PROJECT.APRX DATE: 11/21/2022

Map Unit Legend

- HaE2 - Homewood-Westmoreland silt loams, 25 to 40 percent slopes, eroded
- Ne - Newark silt loam, 0 to 3 percent slopes, frequently flooded

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: PER-CR25-2.00
PID: 117332

Corrosion of Concrete

Map Unit Legend

- HaE2 - Homewood-Westmoreland silt loams -Moderate rating
- Ne - Newark silt loam - Low 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: PER-CR25-2.00
PID: 117332

G:\OHIO\ODOT\ODT-OCEA STATEWIDE CONTRACT PROJECTS\PER-CR25-2.00_10354468_ARCGISPRO\7.2_WIP\MAP_DOCS\HDR_PROJECT.APRX DATE: 11/21/2022

Corrosion of Steel

Map Unit Legend

- HaE2 - Homewood-Westmoreland silt loams - High Rating
- Ne - Newark 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: PER-CR25-2.00
PID: 117332

pH (1 to 1 Water)

Map Unit Legend

- HaE2 - Homewood-Westmoreland silt loams - pH rating 5.5
- Ne - Newark silt loam - pH rating 6.7

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

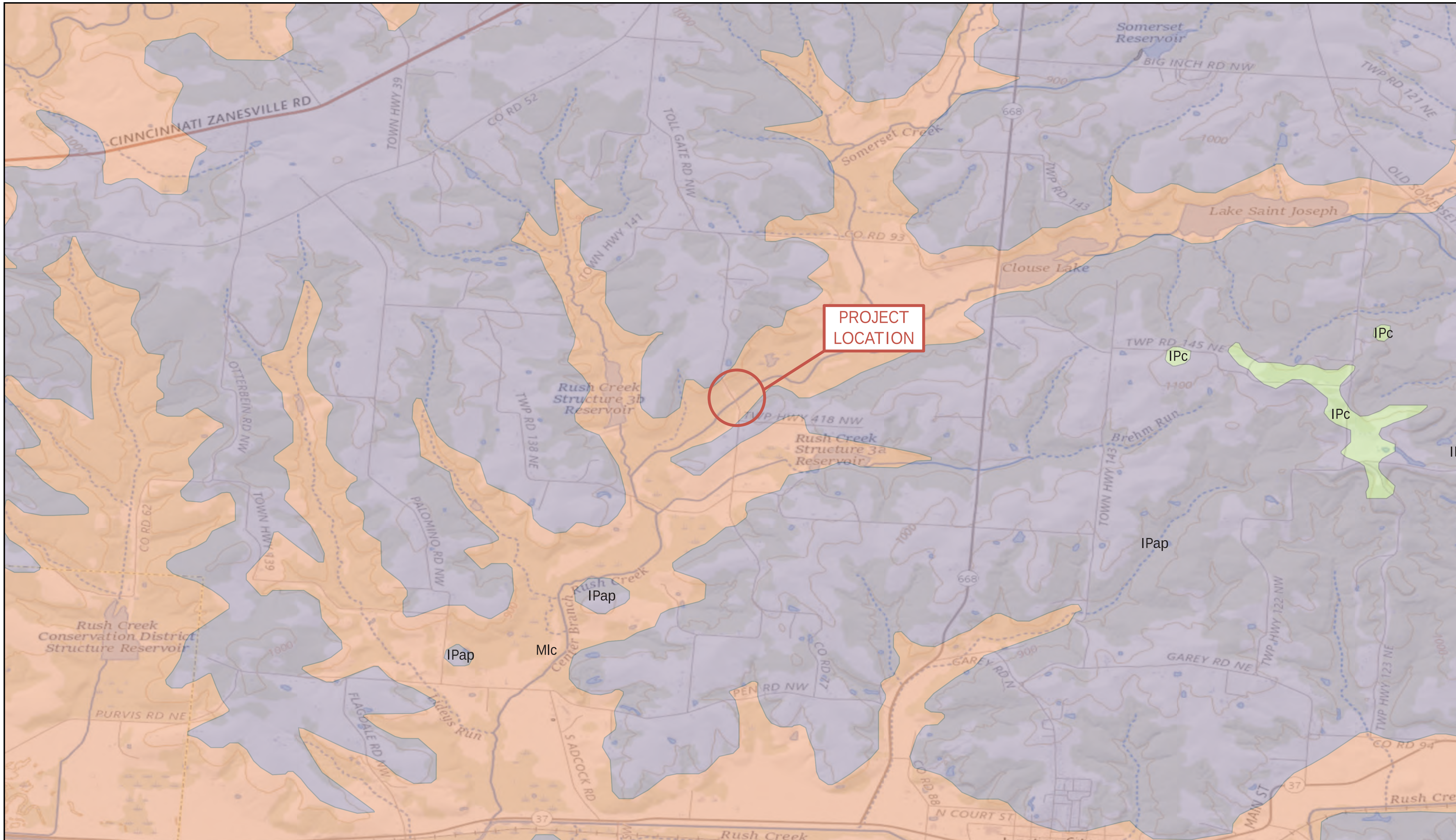
The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

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: PER-CR25-2.00
PID: 117332



Geologic Unit

- IPap - Allegheny and Pottsville Groups Undifferentiated
- IPc - Conemaugh Group
- Mlc - Logan and Cuyahoga Formations, Undivided
- <all other values>

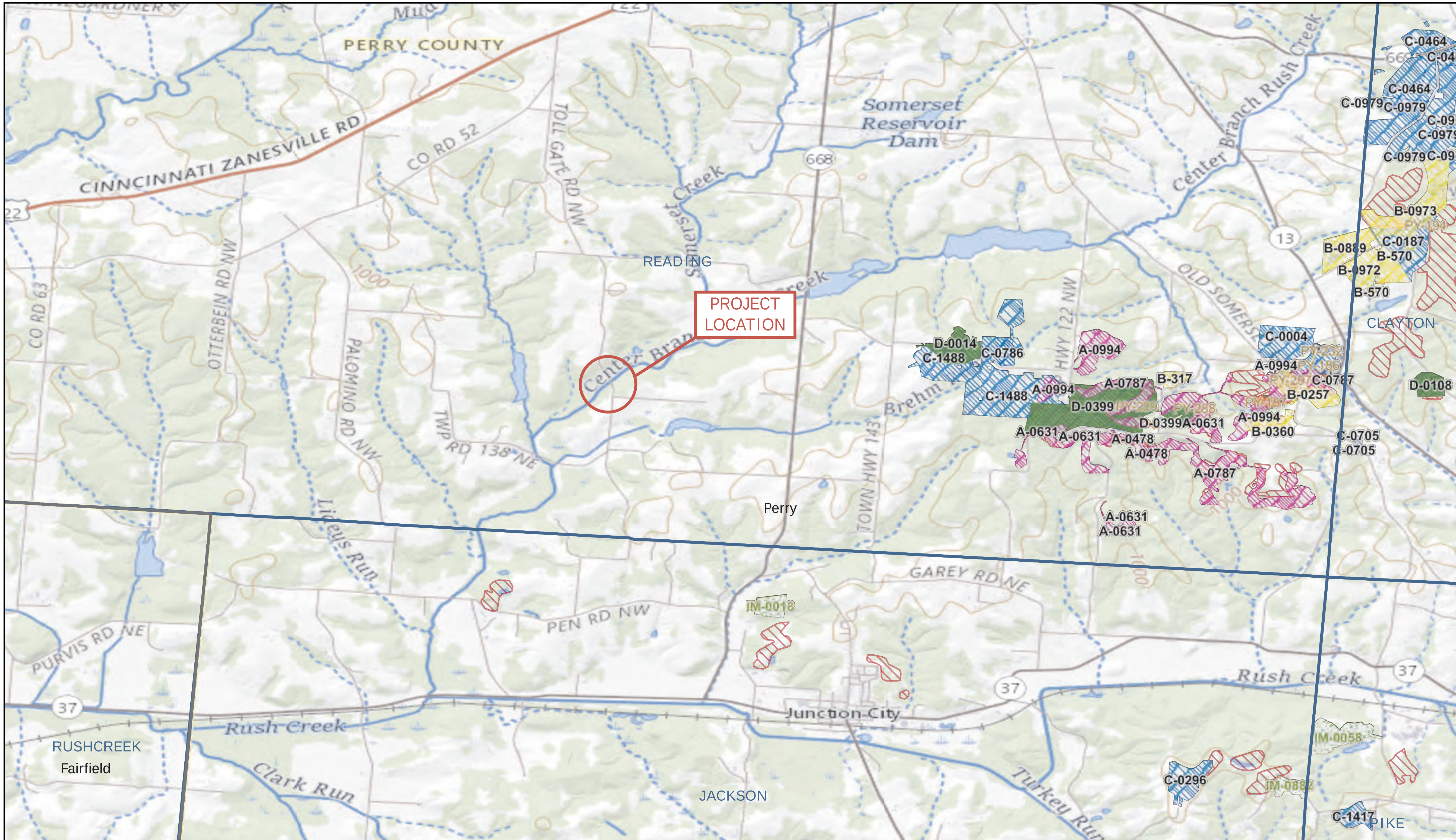
0 6,000 Feet

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

Calculated: LSH
Checked: DMV

Exhibit No. 5: Bedrock Geology Map

Project: PER-CR25-2.00
PID: 117332



County Boundary

Township Boundary

Proposed

- Original Application
- Adjacent Area Application
- Current

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

0 8,000 Feet

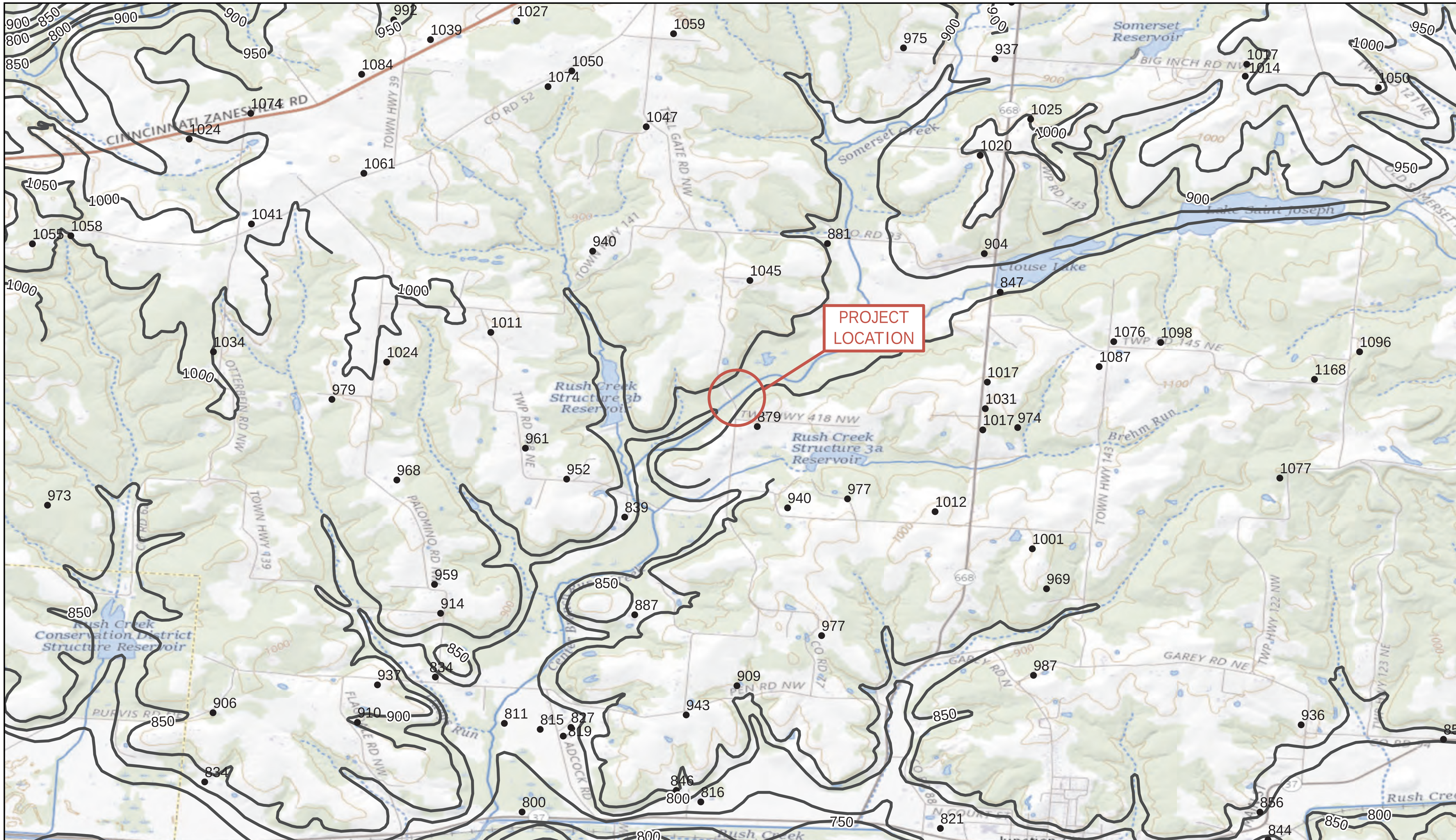
Source: ODNR Division of Geological Survey, Mines of Ohio Interactive Map
https://gis.ohiodnr.gov/portal/home/item.html?id=3aa9227986ea49f2b93532b9341f718b

Exhibit No. 6: Mines of Ohio Map

Calculated: LSH
Checked: DMV

Project: PER-CR25-2.00
PID: 117332

G:\OHIO\ODOT\ODT-OCEA STATEWIDE CONTRACT PROJECTS\PER-CR25-2.00_10354468_ARCGISPRO\7.2_WIP\MAP_DOCS\HDR_PROJECT.APRX DATE: 11/28/2022



Bedrock contour (ft)

Bedrock Elevation (ft)

0 6,000 Feet

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

Exhibit No. 7: Bedrock Topography Map

Calculated: LSH
Checked: DMV

Project: PER-CR25-2.00
PID: 117332

HORIZONTAL
SCALE IN FEET

0 10 20 40

EXHIBIT NO. 8 : BORING LOCATION PLAN

DESIGN AGENCY

HDR

DESIGNER
DCM

REVIEWER
DMV 11-23-22

PROJECT ID
117322

PER-CR25-2.00

MODEL: CLX_RW_CR25 - Plan 1 [Sheet] PAPERSIZE: 17x11 (in.) DATE: 11/28/2022 TIME: 2:07:53 PM USER: CWAHLBRI

Appendix B. Boring Logs

PROJECT: PER-CR25-02.00	DRILLING FIRM / OPERATOR: CENTRAL STAR / TS	DRILL RIG: DIEDRICH D-50 TRACK	STATION / OFFSET: 9+74, 6' LT.	EXPLORATION ID B-001-0-22
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: HDR / DCM	HAMMER: AUTOMATIC HAMMER	ALIGNMENT: CR-25	
PID: 117332 SFN: 6430899	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 830.8 (MSL) EOB: 45.0 ft.	PAGE 1 OF 2
START: 10/19/22 END: 10/19/22	SAMPLING METHOD: SPT / ST / NQ2	ENERGY RATIO (%): 86.8	LAT / LONG: 39.756322, -82.324129	

MATERIAL DESCRIPTION AND NOTES	ELEV. 830.8	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
12 inches Asphalt	829.8																	
MEDIUM DENSE TO DENSE, BROWN, **GRAVEL WITH SAND AND SILT**, TRACE CLAY, MOIST (FILL)		1–2	11 11 12	33	67	SS-1	-	-	-	-	-	-	-	-	-	8	A-2-4 (V)	
	826.8	4	24 7 5	17	78	SS-2A	-	56	10	7	22	5	25	18	7	17	A-2-4 (0)	
MEDIUM STIFF TO STIFF, DARK BROWN, **SILT AND CLAY**, LITTLE SAND, MOIST (FILL)	824.8	4–5				SS-2B	0.50	-	-	-	-	-	-	-	-	-	A-6a (V)	
SOFT, GRAY, **SILT**, SOME SAND, LITTLE CLAY, WET		6–7	2 1 2	4	67	SS-3	0.25	-	-	-	-	-	-	-	-	22	A-4b (V)	
@ 8' - 10' (ST-4) : Minimal shavings from inside the shelby tube were jarred for moisture testing and visual classification.		8–10			4	ST-4	-	-	-	-	-	-	-	-	-	24	A-4b (V)	
@ 11.0' - 12.0' : Final hammer blow drove spoon from 11.0' - 12.0'	818.8	10–11	1 0 1	1	100	SS-5	0.25	0	1	26	54	19	24	17	7	29	A-4b (8)	
SOFT, GRAY, **SILT**, SOME SAND, LITTLE CLAY, TRACE GRAVEL, WET	817.3	12–13 W 817.3	WOH 3 2	7	11	SS-6	0.25	8	2	20	57	13	23	18	5	25	A-4b (7)	
LOOSE, GRAY, **GRAVEL WITH SAND, SILT, AND CLAY**, WET	815.8	13.5–15	5 3 2	7	67	SS-7	-	44	13	33	7	3	31	18	13	22	A-2-6 (0)	
LOOSE, GRAY, **SANDY SILT**, TRACE GRAVEL, TRACE CLAY, WET		15–16	1 1 2	4	89	SS-8	-	6	10	48	29	7	16	15	1	28	A-4a (0)	
@ 18.5' - 18.9' : Gray Clay	810.8	17.5–19	WOH 1 2	4	100	SS-9	-	-	-	-	-	-	-	-	-	29	A-4a (V)	
VERY DENSE, GRAY, **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, WET	805.8	20–21	10 13 22	51	67	SS-10	-	49	14	14	17	6	18	NP	NP	15	A-1-b (0)	
HARD, GRAY, **SILT AND CLAY**, TRACE SAND, DAMP	800.8	25–26	7 9 14	33	100	SS-11	4.00	0	3	2	60	35	30	19	11	17	A-6a (8)	

PID: 117332	SFN: 6430899	PROJECT: PER-CR25-02.00	STATION / OFFSET: 9+74, 6' LT.	START: 10/19/22	END: 10/19/22	PG 2 OF 2	B-001-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 800.8	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, GRAY, SLIGHTLY WEATHERED, WEAK.	800.3	TR	50/3"	-	100	SS-12	-	-	-	-	-	-	-	-	-	6	Rock (V)	
SANDSTONE, GRAY, SLIGHTLY WEATHERED, VERY STRONG, FINE TO MEDIUM GRAINED, THIN TO MEDIUM BEDDED, JOINT AND BEDDING DISCONTINUITIES, MODERATELY FRACTURED TO FRACTURED, TIGHT TO OPEN, SLIGHTLY ROUGH, VERY BLOCKY, GOOD SURFACE CONDITIONS; RQD 55%, REC 100%. @ 31.1' - 31.5' : Interbedded Shale @ 33.8' - 34.3' : Interbedded Shale @ 35.0' - 35.7' : 15,571 psi		31–35	22		100	NQ2-1											CORE	
		35–40	65		100	NQ2-2											CORE	
	785.8	40–45 EOB	73		100	NQ2-3											CORE	

NOTES: QUICKCRETE CONCRETE USED TO PATCH PAVEMENT. UNSUCCESSFULLY ATTEMPTED TO RECOVER ST-4 SAMPLE WITH SPT SAMPLER.

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 - 11/29/22 11:46 - C:\PWWORKING\EAST01\D2962083\20221019_PER-CR25-2.00_BORINGLOGS.GPJ

PROJECT: PER-CR25-02.00	DRILLING FIRM / OPERATOR: CENTRAL STAR / TS	DRILL RIG: DIEDRICH D-50 TRACK	STATION / OFFSET: 10+31, 5' LT.	EXPLORATION ID B-002-0-22
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: HDR / DCM	HAMMER: AUTOMATIC HAMMER	ALIGNMENT: CR-25	
PID: 117332 SFN: 6430899	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 831.3 (MSL) EOB: 45.0 ft.	PAGE
START: 10/19/22 END: 10/19/22	SAMPLING METHOD: SPT / ST / NQ2	ENERGY RATIO (%): 86.8	LAT / LONG: 39.756463, -82.324220	1 OF 2

MATERIAL DESCRIPTION AND NOTES	ELEV. 831.3	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
12 inches Asphalt	830.3																	
LOOSE, BROWN AND GRAY, **GRAVEL WITH SAND**, TRACE SILT, DRY (FILL)	828.8		6-3-3	9	33	SS-1	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
MEDIUM STIFF TO STIFF, GRAY, **SANDY SILT**, SOME CLAY, LITTLE GRAVEL, DAMP (FILL)	824.8		1-1-4	7	89	SS-2	1.00	12	6	16	45	21	24	19	5	14	A-4a (6)	
SOFT TO MEDIUM STIFF, GRAY, **SILT**, "AND" CLAY, TRACE TO LITTLE SAND, WET			2-1-2	4	100	SS-3	0.50	-	-	-	-	-	-	-	-	31	A-4b (V)	
@ 8.5' - 9.0' : qu = 1000 psf					75	ST-4	1.00	0	1	9	54	36	29	19	10	29	A-4b (8)	
	820.3		1-1-1	3	100	SS-5	1.00	1	2	16	50	31	26	19	7	33	A-4b (8)	
VERY SOFT, GRAY, **SILT**, SOME SAND, LITTLE CLAY, WET	818.8		WOH-WOH-1	1	33	SS-6	1.00	0	8	21	51	20	20	19	1	24	A-4b (7)	
SOFT TO MEDIUM STIFF, BROWN AND GRAY, **SANDY SILT**, SOME CLAY, MOIST			2-2-2	6	100	SS-7	2.00	0	10	23	44	23	25	19	6	22	A-4a (6)	
	814.8		2-2-1	4	100	SS-8	1.50	0	5	29	42	24	25	18	7	22	A-4a (6)	
MEDIUM DENSE, BROWN AND GRAY, **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, WET		W 813.8																
@ 17.5' - 19.5' : Zero recovery in ST-9. Split-Spoon sampler driven to recover sample.					0	ST-9	-	-	-	-	-	-	-	-	-	21	A-1-b (V)	
			6-7-7	20	100	SS-10	-	36	21	19	18	6	20	20	NP	16	A-1-b (0)	
	801.3		5-10-8	26	56	SS-11	-	-	-	-	-	-	-	-	-	14	A-1-b (V)	

MATERIAL DESCRIPTION AND NOTES	ELEV. 801.3	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, GRAY, SLIGHTLY WEATHERED, WEAK, ARENACEOUS.	800.8	TR	50/1"	-	100	SS-12	-	-	-	-	-	-	-	-	-	10	Rock (V)	
SANDSTONE, GRAY, SLIGHTLY WEATHERED, STRONG, FINE TO MEDIUM GRAINED, THIN TO MEDIUM BEDDED, JOINT AND BEDDING DISCONTINUITIES, FRACTURED TO MODERATELY FRCTURED, OPEN TO TIGHT APERTURE, SLIGHTLY ROUGH, VERY BLOCK, GOOD TO FAIR SURFACE; RQD 65%, REC 100%.		31–35	22		100	NQ2-1											CORE	
@ 40.2' - 41.0' : 14,247 psi	786.3	35–45 EOB	85		100	NQ2-2											CORE	

NOTES: QUICKCRETE CONCRETE USED TO PATCH PAVEMENT.

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

Appendix C. Laboratory Testing

Unconfined Compressive Strength of Cohesive Soils (ASTM D2166)

UNCONFINED COMPRESSION TEST

Project Name	: PER-CR25-2.0		
Project #	: 10354468	Sample #	: ST-4
Project County	: Perry	Sample Loc.	: Boring No. B-002-0-22
Project State	: Ohio	Sample Depth	: 8.5' to 9.0'
Laboratory #	: 10354468	Date Tested	: 10/31/2022
Submitted By	: HDR	Date Reported	: 11/2/2022

Soil Type :	A-4(8)				
Wet Density :	125.4	pcf	Initial Height :	5.75	in
Dry Density :	97.4	pcf	Initial Diameter :	2.84	in
Moisture :	28.7	%	Proving Ring :	#22734	

RESULTS:

#	Axial Load lbs	Corrected Area sf	Unit Strain %	Stress Ksf
1	0.0	0.04	0.0	0.00
2	1.9	0.04	0.3	0.04
3	2.9	0.04	0.5	0.07
4	3.9	0.04	0.8	0.09
5	6.8	0.04	1.0	0.15
6	7.8	0.04	1.3	0.17
7	8.7	0.04	1.6	0.20
8	10.7	0.04	1.8	0.24
9	11.6	0.04	2.1	0.26
10	14.6	0.04	2.4	0.32
11	16.5	0.05	2.8	0.37
12	19.4	0.05	3.1	0.43
13	21.3	0.05	3.5	0.47
14	23.3	0.05	3.8	0.51
15	25.2	0.05	4.2	0.55
16	27.2	0.05	4.5	0.59
17	30.1	0.05	4.9	0.65
18	31.0	0.05	5.2	0.67
19	33.0	0.05	5.7	0.71
20	34.9	0.05	6.1	0.75
21	36.9	0.05	6.5	0.78
22	38.8	0.05	7.0	0.82
23	39.8	0.05	7.4	0.84
24	41.7	0.05	7.8	0.88
25	42.7	0.05	8.3	0.89
26	44.6	0.05	8.7	0.93
27	46.6	0.05	9.6	0.96
28	48.5	0.05	10.4	0.99
29	49.5	0.05	11.3	1.00
30	48.5	0.05	12.2	0.97
31	44.6	0.05	13.0	0.00

hdrinc.com

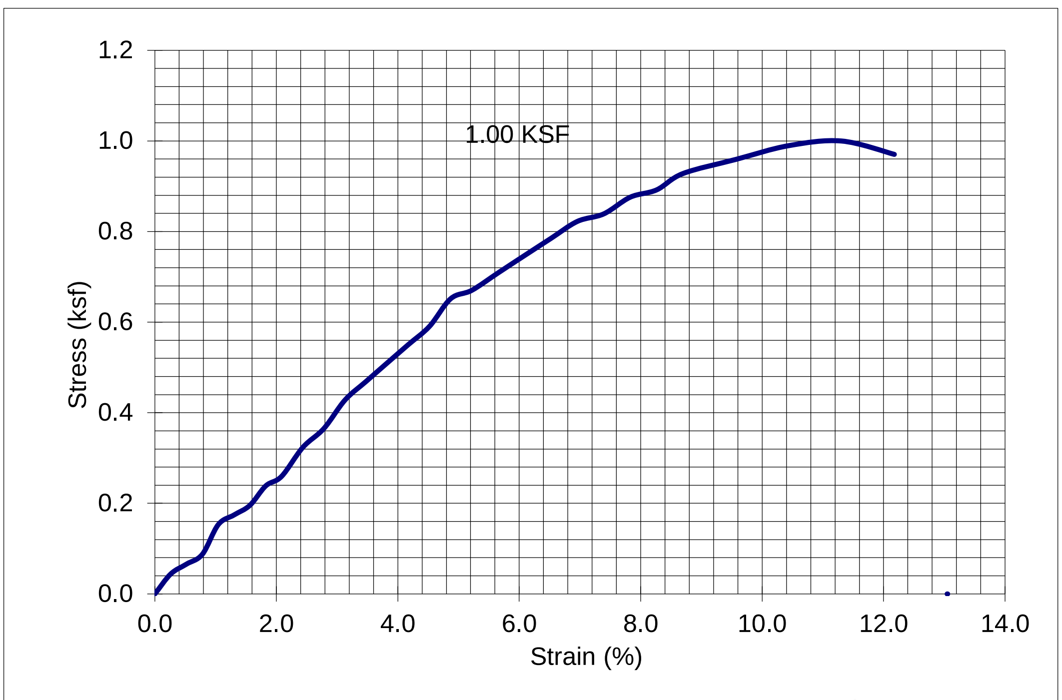
4645 Village Square Drive, Suite F, Paducah, KY 42001
T 270.444.9691 F 270.538.1599

UNCONFINED COMPRESSION TEST

Project Name	: PER-CR25-2.0		
Project #	: 10354468	Sample #	: ST-4
Project County	: Perry	Sample Loc.	: Boring No. B-002-0-22
Project State	: Ohio	Sample Depth	: 8.5' to 9.0'
Laboratory #	: 10354468	Date Tested	: 10/31/2022
Submitted By	: HDR	Date Reported	: 11/2/2022

Soil Type :	A-4(8)		
Wet Density :	125.4 pcf	Initial Height :	5.75 in
Dry Density :	97.4 pcf	Initial Diameter :	2.84 in
Moisture :	28.7 %	Proving Ring :	#22734
Deg. of Sat. :	100.0 %	SPECIFIC GRAVITY :	2.690

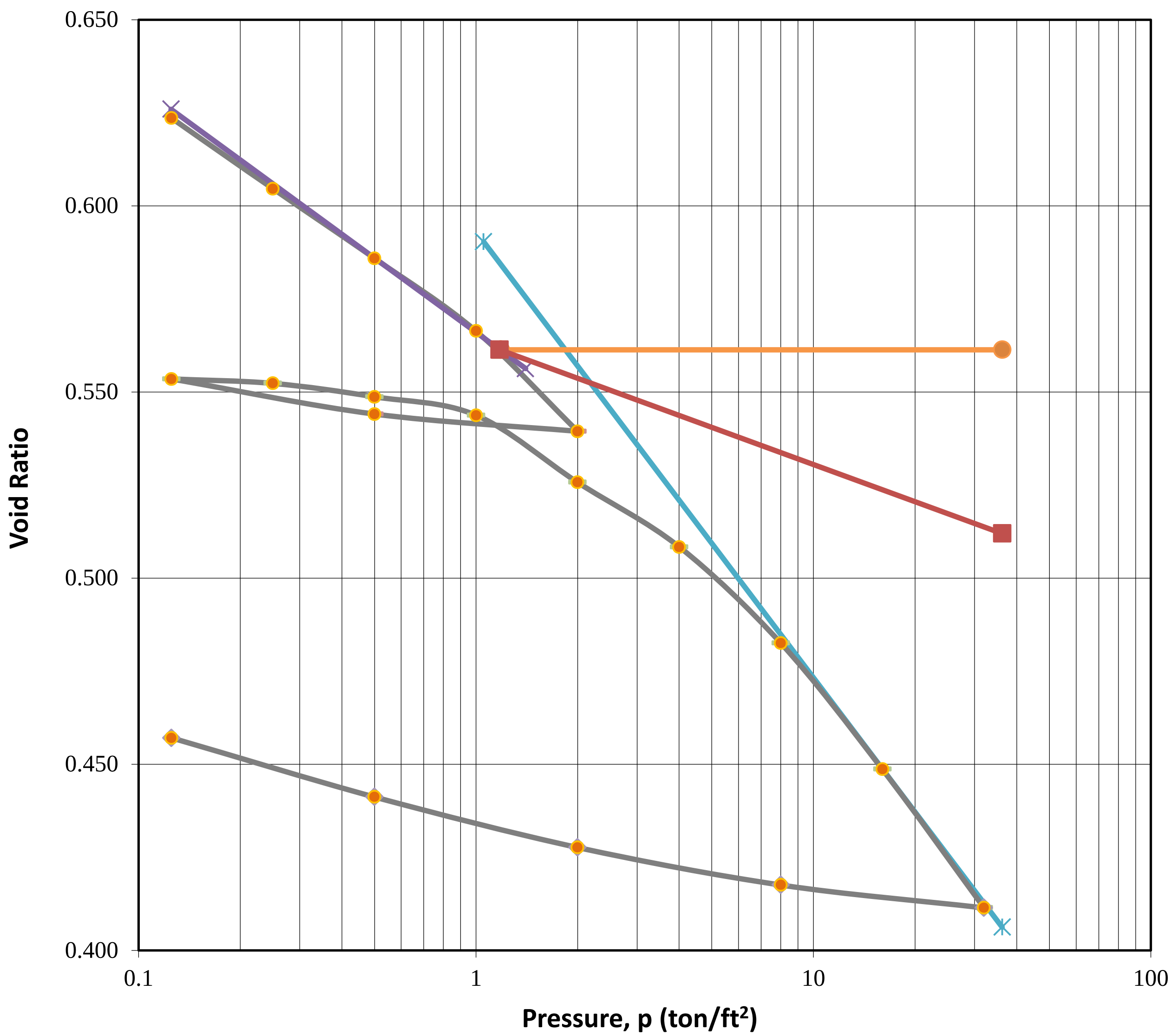
Comments : AASHTO: T-208



APPROVED BY: ____________

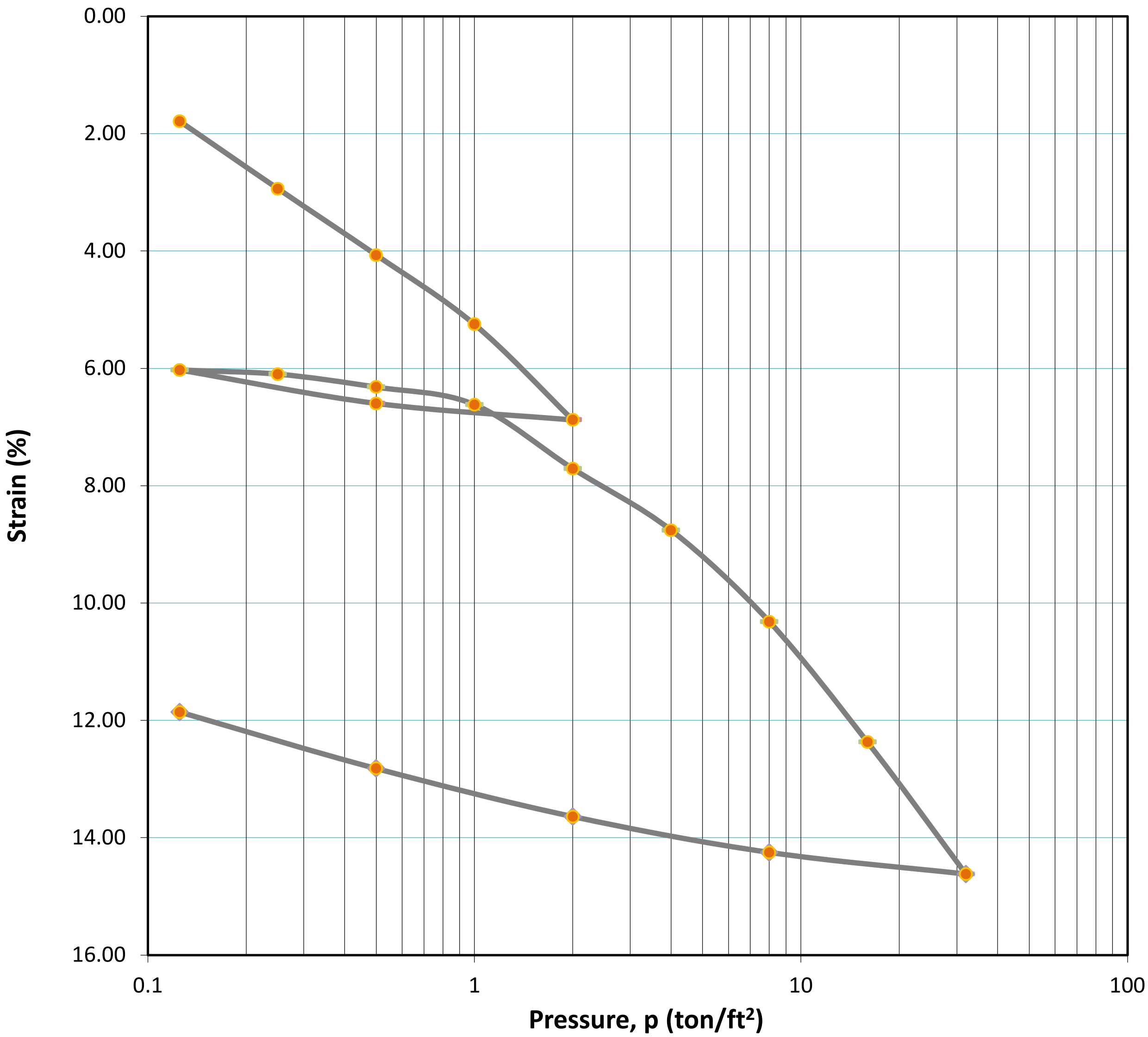
4645 Village Square Drive, Suite F, Paducah, KY 42001
T 270.444.9691 F 270.538.1599

1-D Consolidation Properties of Soils Using Incremental Loading (ASTM D2435)



			Test Date:	11/17/2022
Summary of Consolidation Test Results				
Overburden Press. (tsf)	**0.57**	**Compression Index, C_c**	**0.12**	
Preconsol. Press., P_c (tsf)	**2.18**	**Rebound Index, C_r**	**0.01**	
Over Consolidation Ratio	**3.83**			
Soil Description:	Gray Silty Clay			
Project Number:	10354468	**Depth:** 9.0-9.5	**Remarks:**	
Sample Number:	ST-4	**Boring Number:** B-002-0-22	ASTM D2435/D2435M-11	
Project:	PER-CR25-2.0			
Client:	ODOT			
Location:	Ohio			

CONSOLIDATION TEST



	Before	After	Liquid Limits:	29	Test Date:	11/17/2022
Moisture (%):	25.1	18.3	**Plastic Limits:**	19		
Dry Density (pcf):	101.4	115.2	**Plasticity Index (%):**	10		
Saturation (%):	100.0	100.0				
Void Ratio:	0.66	0.46	**Specific Gravity:**	2.690	MEASURED	

Sample Description:	Gray Silty Clay		
Project Number:	10354468	**Depth:** 9.0-9.5	**Remarks:**
Sample Number:	ST-4	**Boring Number:** B-002-0-22	ASTM D2435/D2435M-11
Project:	PER-CR25-2.0		
Client:	ODOT		
Location:	Ohio		

HDR

CONSOLIDATION TEST

Test Summary

Project: PER-CR25-2.0
Location: Ohio
Job Number: 10354468
Project Number: 10354468
Test Date: 11/17/2022

Sample Number: ST-4
Boring Number: B-002-0-22
Depth: 9.0-9.5
Sample Type: Undisturbed

Sample Description: Gray Silty Clay
Remarks:

Index	Load Sequence tsf	Change in Height in	Specimen Height in	Height of Void in	Vertical Strain	Void Ratio	t90 Fitting Time Min	t50 Fitting Time Min	t90 Cv ft²/Day	t50 Cv ft²/Day
0	0.000	0.0000	1.0000	0.0000	0.0000	0.6562	0.0000	0.0000	0.0000	0.0000
0	0.125	0.0179	0.9821	0.3772	1.7900	0.6236	46.6856	11.2210	0.0438	0.0416
1	0.250	0.0294	0.9706	0.3657	2.9400	0.6046	15.5269	3.5701	0.1286	0.1237
2	0.500	0.0407	0.9593	0.3544	4.0700	0.5859	7.9559	1.8388	0.2452	0.2288
3	1.000	0.0525	0.9475	0.3426	5.2500	0.5664	4.4916	1.0633	0.4237	0.3756
4	2.000	0.0688	0.9312	0.3263	6.8800	0.5394	2.9876	0.6668	0.6153	0.5580
5	0.500	0.0660	0.9340	0.3291	6.6000	0.5441	0.0000	0.0000	0.0000	0.0000
6	0.125	0.0603	0.9397	0.3348	6.0300	0.5535	0.0000	0.0000	0.0000	0.0000
7	0.250	0.0610	0.9390	0.3341	6.1000	0.5523	0.0000	0.0000	0.0000	0.0000
8	0.500	0.0632	0.9368	0.3319	6.3200	0.5487	2.2982	0.5821	0.8096	0.6470
9	1.000	0.0662	0.9338	0.3289	6.6200	0.5437	2.2940	0.6475	0.8058	0.5738
10	2.000	0.0771	0.9229	0.3180	7.7100	0.5257	2.2621	0.6050	0.7983	0.5918
11	4.000	0.0876	0.9124	0.3075	8.7600	0.5084	2.7537	0.6050	0.6409	0.5605
12	8.000	0.1032	0.8968	0.2919	10.3200	0.4826	1.4322	0.3308	1.1905	0.9541
13	16.000	0.1237	0.8763	0.2714	12.3700	0.4487	1.0582	0.2477	1.5383	1.1540
14	32.000	0.1462	0.8538	0.2489	14.6200	0.4115	0.8613	0.2025	1.7943	1.2529
15	8.000	0.1425	0.8575	0.2526	14.2500	0.4176	0.0000	0.0000	0.0000	0.0000
16	2.000	0.1364	0.8636	0.2587	13.6400	0.4277	0.0000	0.0000	0.0000	0.0000
17	0.500	0.1282	0.8718	0.2669	12.8200	0.4412	0.0000	0.0000	0.0000	0.0000
18	0.125	0.1186	0.8814	0.2765	11.8600	0.4571	0.0000	0.0000	0.0000	0.0000

Approved By: [signature]

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1-D Consolidation Properties of Soils Using Incremental Loading (ASTM D2435)

ASTM: D7012-Method C

UNCONFINED COMPRESSION TEST (ROCK CORE)

PROJECT NAME :	PER-CR25-2.0		
PROJECT NO. :	10354468	SAMPLE NO.	: B-001-0-22
PROJECT COUNTY :	Perry	SAMPLE LOC.	: RC-1
PROJECT STATE :	Ohio 10354468	SAMPLE DEPTH	: 35.0' to 35.7'
LABORATORY NO. :	HDR	DATE TESTED	: 11/9/2011
SUBMITTED BY :		DATE REPORTED	: 11/11/2022

ROCK DESCRIPTION : NA

Machine Used : ELE CT-7250

Diameter :	1.98 in	Area :	3.09 in^2
Height :	3.92 in	Volume :	0.0070 ft^3

RESULTS :

Air Dry Moisture:	1.5	%
Air-Dry Density :	158.1	$lbs/ft.^3$
Maximum Stress :	15,571	psi
Elapsed Time :	9:45	min.
Rate of Loading :	90	lb/sec

Comments :

Approved By : Kevin E. Walker

hdrinc.com

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ASTM: D7012-Method C

UNCONFINED COMPRESSION TEST (ROCK CORE)

PROJECT NAME :	PER-CR25-2.0		
PROJECT NO. :	10354468	SAMPLE NO.	: B-002-0-22
PROJECT COUNTY :	Perry	SAMPLE LOC.	: RC-2
PROJECT STATE :	Ohio 10354468	SAMPLE DEPTH	: 40.2' to 41.0'
LABORATORY NO. :	HDR	DATE TESTED	: 11/8/2022
SUBMITTED BY :		DATE REPORTED	: 11/11/2022

ROCK DESCRIPTION :	NA		
Machine Used :	ELE CT-7250		
Diameter :	1.98 in	Area :	3.09 in²
Height :	3.84 in	Volume :	0.0069 ft³

RESULTS :

Air Dry Moisture:	4.3	%
Air-Dry Density :	151.5	lbs/ft.³
Maximum Stress :	14,247	psi
Elapsed Time :	8:17	min.
Rate of Loading :	90	lb/sec

Comments :

Approved By : [signature]

Appendix D. Analyses

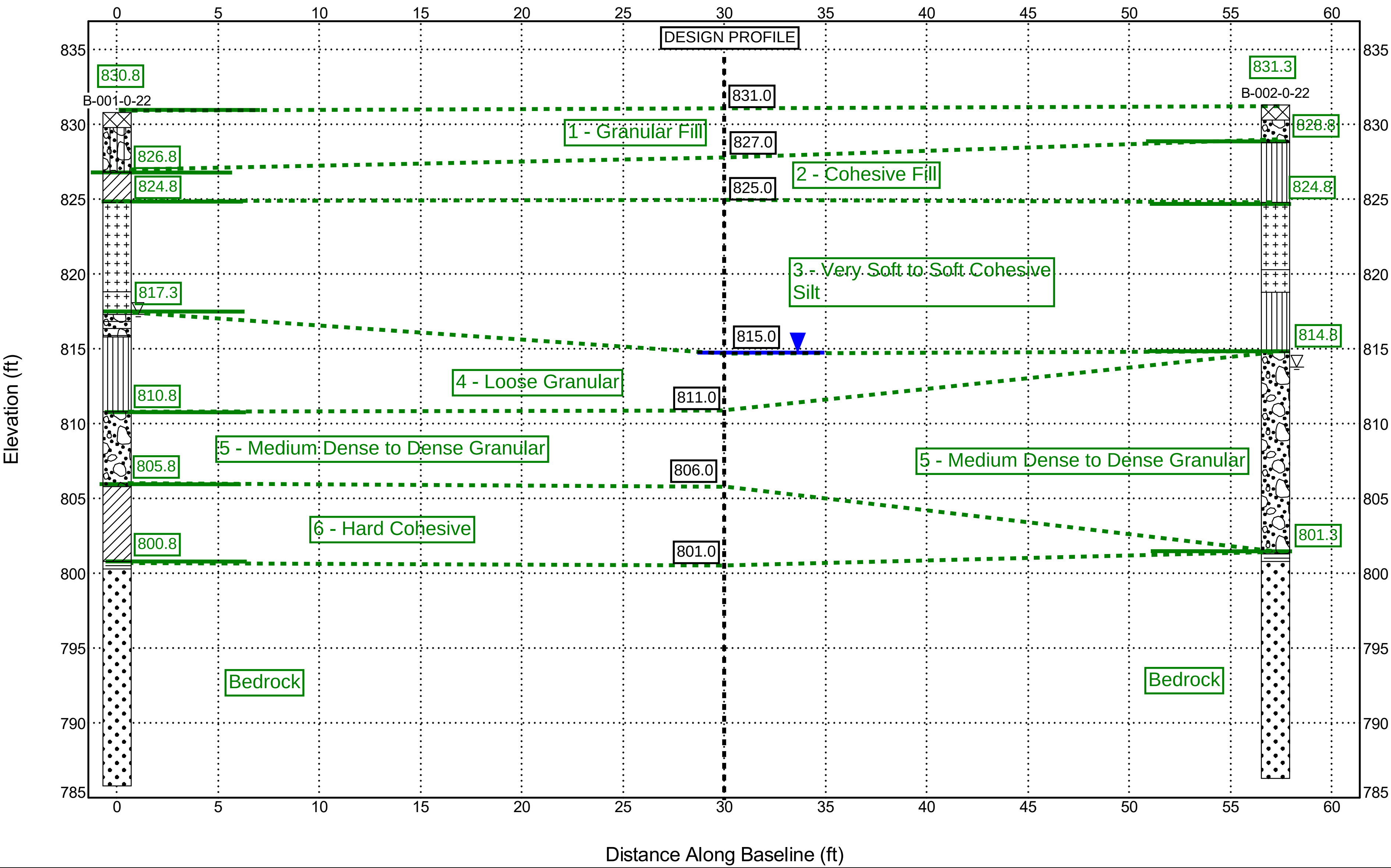
Design Profile

SUBSURFACE DIAGRAM

PROJECT NAME PER-CR25-2.00

PROJECT NUMBER 117332

PROJECT LOCATION PERRY COUNTY, OH



STRATIGRAPHY & GW - A SIZE - OH DOT.GDT - 11/22/22 14:18 - C:\PWWORKING\EAST01\D2962083\20221019_PER-CR25-2.00_BORINGLOGS.GPJ

PROJECT: PER-CR25-02.00	DRILLING FIRM / OPERATOR: CENTRAL STAR / TS	DRILL RIG: DIEDRICH D-50 TRACK	STATION / OFFSET: 9+74, 6' LT.
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: HDR / DCM	HAMMER: AUTOMATIC HAMMER	ALIGNMENT: CR-25
PID: 117332 SFN: 6430899	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 830.8 (MSL) EOB: 45.0 ft.
START: 10/19/22 END: 10/19/22	SAMPLING METHOD: SPT / ST / NQ2	ENERGY RATIO (%): 86.8	LAT / LONG: 39.756322, -82.324129

EXPLORATION ID B-001-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 830.8	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
12 inches Asphalt	829.8																	
MEDIUM DENSE TO DENSE, BROWN, **GRAVEL WITH SAND AND SILT**, TRACE CLAY, MOIST (FILL) 1 - Granular Fill		1 - 2	11 11 12	33	67	SS-1	-	-	-	-	-	-	-	-	-	8	A-2-4 (V)	
	826.8	3 - 4	24			SS-2A	-	56	10	7	22	5	25	18	7	17	A-2-4 (0)	
MEDIUM STIFF TO STIFF, DARK BROWN, **SILT AND CLAY**, LITTLE SAND, MOIST (FILL) 2 - Cohesive Fill	824.8	4 - 5	7 5	17	78	SS-2B	0.50	-	-	-	-	-	-	-	-	-	A-6a (V)	
SOFT, GRAY, **SILT**, SOME SAND, LITTLE CLAY, WET 3 - Very Soft to Soft Cohesive Silt		6 - 7	2 1 2	4	67	SS-3	0.25	-	-	-	-	-	-	-	-	22	A-4b (V)	
@ 8' - 10' (ST-4) : Minimal shavings from inside the shelby tube were jarred for moisture testing and visual classification.		8 - 10			4	ST-4	-	-	-	-	-	-	-	-	-	24	A-4b (V)	
@ 11.0' - 12.0' : Final hammer blow drove spoon from 11.0' - 12.0'	818.8	10 - 11	1 0 1	1	100	SS-5	0.25	0	1	26	54	19	24	17	7	29	A-4b (8)	
SOFT, GRAY, **SILT**, SOME SAND, LITTLE CLAY, TRACE GRAVEL, WET	817.3	12 - 13 (W 817.3)	WOH 3 2	7	11	SS-6	0.25	8	2	20	57	13	23	18	5	25	A-4b (7)	
LOOSE, GRAY, **GRAVEL WITH SAND, SILT, AND CLAY**, WET	815.8	13.5 - 15	5 3 2	7	67	SS-7	-	44	13	33	7	3	31	18	13	22	A-2-6 (0)	
LOOSE, GRAY, **SANDY SILT**, TRACE GRAVEL, TRACE CLAY, WET 4 - Loose Granular		15 - 16	1 1 2	4	89	SS-8	-	6	10	48	29	7	16	15	1	28	A-4a (0)	
@ 18.5' - 18.9' : Gray Clay	810.8	18 - 19	WOH 1 2	4	100	SS-9	-	-	-	-	-	-	-	-	-	29	A-4a (V)	
VERY DENSE, GRAY, **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, WET 5 - Medium Dense to Dense Granular	805.8	20 - 21	10 13 22	51	67	SS-10	-	49	14	14	17	6	18	NP	NP	15	A-1-b (0)	
HARD, GRAY, **SILT AND CLAY**, TRACE SAND, DAMP 6 - Hard Cohesive	800.8	25 - 26	7 9 14	33	100	SS-11	4.00	0	3	2	60	35	30	19	11	17	A-6a (8)	

PID: 117332	SFN: 6430899	PROJECT: PER-CR25-02.00	STATION / OFFSET: 9+74, 6' LT.	START: 10/19/22	END: 10/19/22	PG 2 OF 2	B-001-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 800.8	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, GRAY, SLIGHTLY WEATHERED, WEAK.	800.3	TR	50/3"	-	100	SS-12	-	-	-	-	-	-	-	-	-	6	Rock (V)	
SANDSTONE, GRAY, SLIGHTLY WEATHERED, VERY STRONG, FINE TO MEDIUM GRAINED, THIN TO MEDIUM BEDDED, JOINT AND BEDDING DISCONTINUITIES, MODERATELY FRACTURED TO FRACTURED, TIGHT TO OPEN, SLIGHTLY ROUGH, VERY BLOCKY, GOOD SURFACE CONDITIONS; RQD 55%, REC 100%. @ 31.1' - 31.5' : Interbedded Shale @ 33.8' - 34.3' : Interbedded Shale @ 35.0' - 35.7' : 15,571 psi		31–35	22		100	NQ2-1											CORE	
		35–40	65		100	NQ2-2											CORE	
	785.8	40–45 EOB	73		100	NQ2-3											CORE	

NOTES: QUICKCRETE CONCRETE USED TO PATCH PAVEMENT. UNSUCCESSFULLY ATTEMPTED TO RECOVER ST-4 SAMPLE WITH SPT SAMPLER.

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

PROJECT: PER-CR25-02.00	DRILLING FIRM / OPERATOR: CENTRAL STAR / TS	DRILL RIG: DIEDRICH D-50 TRACK	STATION / OFFSET: 10+31, 5' LT.	EXPLORATION ID B-002-0-22
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: HDR / DCM	HAMMER: AUTOMATIC HAMMER	ALIGNMENT: CR-25	
PID: 117332 SFN: 6430899	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 831.3 (MSL) EOB: 45.0 ft.	PAGE 1 OF 2
START: 10/19/22 END: 10/19/22	SAMPLING METHOD: SPT / ST / NQ2	ENERGY RATIO (%): 86.8	LAT / LONG: 39.756463, -82.324220	

MATERIAL DESCRIPTION AND NOTES	ELEV. 831.3	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
12 inches Asphalt	830.3																	
LOOSE, BROWN AND GRAY, **GRAVEL WITH SAND**, TRACE SILT, DRY (FILL) — 1- Granular Fill	828.8	1–2	6-3-3	9	33	SS-1	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
MEDIUM STIFF TO STIFF, GRAY, **SANDY SILT**, SOME CLAY, LITTLE GRAVEL, DAMP (FILL) — 2 - Cohesive Fill	824.8	4–5	1-1-4	7	89	SS-2	1.00	12	6	16	45	21	24	19	5	14	A-4a (6)	
SOFT TO MEDIUM STIFF, GRAY, **SILT**, "AND" CLAY, TRACE TO LITTLE SAND, WET		6–7	2-1-2	4	100	SS-3	0.50	-	-	-	-	-	-	-	-	31	A-4b (V)	
@ 8.5' - 9.0' : qu = 1000 psf		8–9			75	ST-4	1.00	0	1	9	54	36	29	19	10	29	A-4b (8)	
3 - Very Soft to Soft Cohesive Silt	820.3	10–11	1-1-1	3	100	SS-5	1.00	1	2	16	50	31	26	19	7	33	A-4b (8)	
VERY SOFT, GRAY, **SILT**, SOME SAND, LITTLE CLAY, WET	818.8	11–12	WOH-WOH-1	1	33	SS-6	1.00	0	8	21	51	20	20	19	1	24	A-4b (7)	
SOFT TO MEDIUM STIFF, BROWN AND GRAY, **SANDY SILT**, SOME CLAY, MOIST		13	2-2-2	6	100	SS-7	2.00	0	10	23	44	23	25	19	6	22	A-4a (6)	
	814.8	14–15	2-2-1	4	100	SS-8	1.50	0	5	29	42	24	25	18	7	22	A-4a (6)	
MEDIUM DENSE, BROWN AND GRAY, **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, WET @ 17.5' - 19.5' : Zero recovery in ST-9. Split-Spoon sampler driven to recover sample.		W 813.8; 18–19			0	ST-9	-	-	-	-	-	-	-	-	-	21	A-1-b (V)	
		20–21	6-7-7	20	100	SS-10	-	36	21	19	18	6	20	20	NP	16	A-1-b (0)	
5 - Medium Dense to Dense Granular	801.3	25–26	5-10-8	26	56	SS-11	-	-	-	-	-	-	-	-	-	14	A-1-b (V)	

PID: 117332	SFN: 6430899	PROJECT: PER-CR25-02.00	STATION / OFFSET: 10+31, 5' LT.	START: 10/19/22	END: 10/19/22	PG 2 OF 2	B-002-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 801.3	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, GRAY, SLIGHTLY WEATHERED, WEAK, ARENACEOUS.	800.8	TR	50/1"	-	100	SS-12	-	-	-	-	-	-	-	-	-	10	Rock (V)	
SANDSTONE, GRAY, SLIGHTLY WEATHERED, STRONG, FINE TO MEDIUM GRAINED, THIN TO MEDIUM BEDDED, JOINT AND BEDDING DISCONTINUITIES, FRACTURED TO MODERATELY FRCTURED, OPEN TO TIGHT APERTURE, SLIGHTLY ROUGH, VERY BLOCK, GOOD TO FAIR SURFACE; RQD 65%, REC 100%.		31–35	22		100	NQ2-1											CORE	
@ 40.2' - 41.0' : 14,247 psi	786.3	35–45 EOB	85		100	NQ2-2											CORE	

NOTES: QUICKCRETE 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 - 11/20/22 15:53 - C:\PWWORKING\EAST01\D2962083\20221019_PER-CR25-2.00_BORINGLOGS.GPJ

Soil Strength Parameter Determination

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
		PPR	N-values		Tested							N_{60} Value	ODOT GB-7 Correlations		
			Sowers	T and P	Values	Correlation	Tested	Correlation	Tested				Cohesion (psf)	phi (deg)	
	Max	N/A	N/A	N/A		110		125			Max	33	N/A	34	
	Min	N/A	N/A	N/A		95		115		S_u = 0 psf	Min	9	N/A	30	c' = 0 psf
Layer 1	Average	N/A	N/A	N/A		102		120		Φ = 32 deg	Average	20	N/A	32	Φ' = 32 deg
	Std Dev	N/A	N/A	N/A		8		5			Std Dev	12	N/A	2	
GRANULAR FILL										γ_{dry} = 100 pcf					γ_{dry} = 100 pcf
	Avg + Std	N/A	N/A	N/A		109		125		γ_{moist} = 120 pcf	Avg + Std	32	N/A	34	γ_{moist} = 120 pcf
	Avg - Std	N/A	N/A	N/A		94		115			Avg - Std	7	N/A	29	
	Max	1000	525	931		115		110			Max	7	88	22	
	Min	500	525	931		95		110		S_u = 900 psf	Min	7	88	22	c' = 90 psf
Layer 2	Average	750	525	931		105		110		Φ = 0 deg	Average	7	88	22	Φ' = 22 deg
	Std Dev	354	N/A	N/A		14		N/A			Std Dev	N/A	N/A	N/A	
COHESIVE FILL										γ_{dry} = 105 pcf					γ_{dry} = 105 pcf
	Avg + Std	1104	N/A	N/A		119		N/A		γ_{moist} = 110 pcf	Avg + Std	N/A	N/A	N/A	γ_{moist} = 110 pcf
	Avg - Std	396	N/A	N/A		91		N/A			Avg - Std	N/A	N/A	N/A	
	Max	2000	525	931	500	95	97	120	125		Max	7	88	22	
	Min	250	75	133	500	90	97	110	125	S_u = 500 psf	Min	1	15	15	c' = 25 psf
Layer 3	Average	861	281	499	500	92	97	113	125	Φ = 0 deg	Average	4	48	19	Φ' = 16 deg
	Std Dev	614	159	282		3		5			Std Dev	2	26	3	
VERY SOFT TO SOFT COHESIVE										γ_{dry} = 100 pcf					γ_{dry} = 100 pcf
	Avg + Std	1475	440	781		94		118		γ_{moist} = 120 pcf	Avg + Std	6	73	21	γ_{moist} = 120 pcf
	Avg - Std	247	122	217		89		109			Avg - Std	2	22	16	
	Max	N/A	N/A	N/A		105		125			Max	7	N/A	29	
	Min	N/A	N/A	N/A		100		120		S_u = 0 psf	Min	4	N/A	23	c' = 0 psf
Layer 4	Average	N/A	N/A	N/A		102		122		Φ = 25 deg	Average	5	N/A	25	Φ' = 25 deg
	Std Dev	N/A	N/A	N/A		3		3			Std Dev	2	N/A	3	
LOOSE GRANULAR										γ_{dry} = 100 pcf					γ_{dry} = 100 pcf
	Avg + Std	N/A	N/A	N/A		105		125		γ_{moist} = 120 pcf	Avg + Std	7	N/A	28	γ_{moist} = 120 pcf
	Avg - Std	N/A	N/A	N/A		99		119			Avg - Std	3	N/A	22	
	Max	N/A	N/A	N/A		125		140			Max	51	N/A	38	
	Min	N/A	N/A	N/A		110		130		S_u = 0 psf	Min	20	N/A	32	c' = 0 psf
Layer 5	Average	N/A	N/A	N/A		117		135		Φ = 34 deg	Average	32	N/A	34	Φ' = 34 deg
	Std Dev	N/A	N/A	N/A		8		5			Std Dev	16	N/A	3	
MEDIUM DENSE TO DENSE GRANULAR										γ_{dry} = 115 pcf					γ_{dry} = 115 pcf
	Avg + Std	N/A	N/A	N/A		124		140		γ_{moist} = 135 pcf	Avg + Std	49	N/A	38	γ_{moist} = 135 pcf
	Avg - Std	N/A	N/A	N/A		109		130			Avg - Std	16	N/A	31	
	Max	4000	4000	4000		130		140			Max	33	200	27	
	Min	4000	4000	4000		130		140		S_u = 4000 psf	Min	33	200	27	c' = 200 psf
Layer 6	Average	4000	4000	4000		130		140		Φ = 0 deg	Average	33	200	27	Φ' = 27 deg
	Std Dev	N/A	N/A	N/A		N/A		N/A			Std Dev	N/A	N/A	N/A	
HARD COHESIVE										γ_{dry} = 130 pcf					γ_{dry} = 130 pcf
	Avg + Std	N/A	N/A	N/A		N/A		N/A		γ_{moist} = 140 pcf	Avg + Std	N/A	N/A	N/A	γ_{moist} = 140 pcf
	Avg - Std	N/A	N/A	N/A		N/A		N/A			Avg - Std	N/A	N/A	N/A	

Soil Strength Parameter Determination

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
Max	33	78	N/A	56	10	7	22	5	25	18	7	17
Min	9	33	N/A	56	10	7	22	5	25	18	7	8
Average	20	59	N/A	56	10	7	22	5	25	18	7	11
Std Dev	12	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5
Avg + Std	32	83	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	16
Avg - Std	7	36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6

	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	N/A	N/A	N/A	N/A	34	4.0	829.3	110	125	0.135	2.71	0.780
Min	N/A	N/A	N/A	N/A	30	2.0	826.8	95	115	0.135	2.71	0.537
Average	N/A	N/A	N/A	N/A	32	2.7	828.3	102	120	0.135	2.71	0.669
Std Dev	N/A	N/A	N/A	N/A	2	1.2	1.3	8	5	N/A	0.00	0.123
Avg + Std	N/A	N/A	N/A	N/A	34	3.8	829.6	109	125	N/A	2.71	0.792
Avg - Std	N/A	N/A	N/A	N/A	29	1.5	827.0	94	115	N/A	2.71	0.547

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)
CR 25	830.8	B-001-0-22	1	-	2.5	SS-1	33	67	-	-	-	-	-	-	-	-	-	8	A-2-4	Granular	1	N/A				34	2.0	828.8	110	125		2.71	0.537
CR 25	830.8	B-001-0-22	3.5	-	4	SS-2A	17	78	-	56	10	7	22	5	25	18	7	17	A-2-4	Granular	1	N/A				31	4.0	826.8	100	120	0.135	2.71	0.691
CR 25	831.3	B-002-0-22	1	-	2.5	SS-1	9	33	-	-	-	-	-	-	-	-	-	9	A-1-b	Granular	1	N/A				30	2.0	829.3	95	115		2.71	0.780

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
Max	7	89	1.0	12	6	16	45	21	24	19	5	14
Min	7	89	0.5	12	6	16	45	21	24	19	5	14
Average	7	89	0.8	12	6	16	45	21	24	19	5	14
Std Dev	N/A	N/A	0.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Avg + Std	N/A	N/A	1.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Avg - Std	N/A	N/A	0.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	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	1000	525	931	88	22	5.0	827.3	115	110	0.126	2.72	0.787
Min	500	525	931	88	22	4.0	825.8	95	110	0.126	2.72	0.476
Average	750	525	931	88	22	4.5	826.6	105	110	0.126	2.72	0.631
Std Dev	354	N/A	N/A	N/A	N/A	0.7	1.1	14	N/A	N/A	0.00	0.220
Avg + Std	1104	N/A	N/A	N/A	N/A	5.2	827.6	119	N/A	N/A	2.72	0.851
Avg - Std	396	N/A	N/A	N/A	N/A	3.8	825.5	91	N/A	N/A	2.72	0.412

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
CR 25	830.8	B-001-0-22	4	-	5	SS-2B	-	-	0.5	-	-	-	-	-	-	-	-	-	A-6a	Cohesive	2
CR 25	831.3	B-002-0-22	3.5	-	5	SS-2	7	89	1	12	6	16	45	21	24	19	5	14	A-4a	Cohesive	2

Exploration ID	Sample ID	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)
B-001-0-22	SS-2B	500	N/A	N/A			5.0	825.8	115			2.72	0.476
B-002-0-22	SS-2	1000	525	931	88	22	4.0	827.3	95	110	0.126	2.72	0.787

Soil Strength Parameter Determination

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
Max	7	100	2.0	8	10	29	57	36	29	19	10	33
Min	1	4	0.3	0	1	9	42	13	20	17	1	22
Average	4	69	0.9	1	4	21	50	24	25	18	6	26
Std Dev	2	39	0.6	3	4	7	5	8	3	1	3	4
Avg + Std	6	108	1.5	4	8	27	56	31	27	19	9	30
Avg - Std	2	30	0.2	-2	1	14	45	16	22	18	3	22

	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	2000	525	931	88	22	15.0	824.3	95	120	0.171	2.72	0.886
Min	250	75	133	15	15	7.0	816.3	90	110	0.090	2.72	0.787
Average	861	281	499	48	19	10.6	820.5	92	113	0.131	2.72	0.849
Std Dev	614	159	282	26	3	2.7	2.6	3	5	0.025	0.00	0.051
Avg + Std	1475	440	781	73	21	13.3	823.1	94	118	0.156	2.72	0.900
Avg - Std	247	122	217	22	16	7.9	817.9	89	109	0.106	2.72	0.797

	Strength Testing: Dry Unit Wt (pcf)	Moist Unit Wt (pcf)	Qu/UU Su (psf)	CU Eff. c (psf)	CU Eff. phi (deg)	CU Total c (psf)	CU Total phi (deg)	Consolidation Testing: Dry Unit Wt (pcf)	Moist Unit Wt (pcf)	Laboratory Tested Values eo	Cc	Cr	Pc	σ_o
Max	97	125	500	N/A	N/A	N/A	N/A	101	115	1	0	0	2	N/A
Min	97	125	500	N/A	N/A	N/A	N/A	101	115	1	0	0	2	N/A
Average	97	125	500	N/A	N/A	N/A	N/A	101	115	1	0	0	2	N/A
Std Dev	N/A	N/A	N/A	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	N/A	N/A	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	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	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
CR 25	830.8	B-001-0-22	6	-	7.5	SS-3	4	67	0.25	-	-	-	-	-	-	-	-	22	A-4b	Cohesive	3
CR 25	830.8	B-001-0-22	8	-	10	ST-4	ST	4	-	-	-	-	-	-	-	-	-	24	A-4b	Cohesive	3
CR 25	830.8	B-001-0-22	10	-	11.5	SS-5	1	100	0.25	0	1	26	54	19	24	17	7	29	A-4b	Cohesive	3
CR 25	830.8	B-001-0-22	12	-	13.5	SS-6	7	11	0.25	8	2	20	57	13	23	18	5	25	A-4b	Cohesive	3
CR 25	831.3	B-002-0-22	6	-	7.5	SS-3	4	100	0.5	-	-	-	-	-	-	-	-	31	A-4b	Cohesive	3
CR 25	831.3	B-002-0-22	7.5	-	9.5	ST-4	ST	75	1	0	1	9	54	36	29	19	10	29	A-4b	Cohesive	3
CR 25	831.3	B-002-0-22	9.5	-	11	SS-5	3	100	1	1	2	16	50	31	26	19	7	33	A-4b	Cohesive	3
CR 25	831.3	B-002-0-22	11	-	12.5	SS-6	1	33	1	0	8	21	51	20	20	19	1	24	A-4b	Cohesive	3
CR 25	831.3	B-002-0-22	12.5	-	14	SS-7	6	100	2	0	10	23	44	23	25	19	6	22	A-4a	Cohesive	3
CR 25	831.3	B-002-0-22	14	-	15.5	SS-8	4	100	1.5	0	5	29	42	24	25	18	7	22	A-4a	Cohesive	3

Exploration ID	Sample ID	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)
B-001-0-22	SS-3	250	300	532	50	20	7.0	823.8	90	110		2.72	0.886
B-001-0-22	ST-4	N/A	N/A	N/A			9.0	821.8				2.72	
B-001-0-22	SS-5	250	75	133	15	15	11.0	819.8	90	110	0.126	2.72	0.886
B-001-0-22	SS-6	250	525	931	88	22	13.0	817.8	95	120	0.117	2.72	0.787
B-002-0-22	SS-3	500	300	532	50	20	7.0	824.3	90	110		2.72	0.886
B-002-0-22	ST-4	1000	N/A	N/A			9.0	822.3			0.171	2.72	
B-002-0-22	SS-5	1000	225	399	38	19	10.0	821.3	90	110	0.144	2.72	0.886
B-002-0-22	SS-6	1000	75	133	15	15	12.0	819.3	90	110	0.09	2.72	0.886
B-002-0-22	SS-7	2000	450	798	75	21	13.0	818.3	95	120	0.135	2.72	0.787
B-002-0-22	SS-8	1500	300	532	50	20	15.0	816.3	95	115	0.135	2.72	0.787

Exploration ID	Sample ID	Strength Testing: Dry Unit Wt (pcf)	Moist Unit Wt (pcf)	Qu/UU Su (psf)	CU Eff. c (psf)	CU Eff. phi (deg)	CU Total c (psf)	CU Total phi (deg)	Consolidation Testing: Dry Unit Wt (pcf)	Moist Unit Wt (pcf)	Laboratory Tested Values eo	Cc	Cr	Pc	σ_o
B-001-0-22	SS-3														
B-001-0-22	ST-4														
B-001-0-22	SS-5														
B-001-0-22	SS-6														
B-002-0-22	SS-3														
B-002-0-22	ST-4	97.4	125.4	500					101.4	115.2	0.66	0.12	0.01	2.18	
B-002-0-22	SS-5														
B-002-0-22	SS-6														
B-002-0-22	SS-7														
B-002-0-22	SS-8														

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
Max	7	100	N/A	44	13	48	29	7	31	18	13	29
Min	4	67	N/A	6	10	33	7	3	16	15	13	22
Average	5	85	N/A	25	12	41	18	5	24	17	13	26
Std Dev	2	17	N/A	27	2	11	16	3	11	2	N/A	4
Avg + Std	7	102	N/A	52	14	51	34	8	34	19	N/A	30
Avg - Std	3	69	N/A	-2	9	30	2	2	13	14	N/A	23

	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	N/A	N/A	N/A	N/A	29	18.0	816.8	105	125	0.189	2.72	0.697
Min	N/A	N/A	N/A	N/A	23	14.0	812.8	100	120	0.054	2.71	0.611
Average	N/A	N/A	N/A	N/A	25	16.0	814.8	102	122	0.122	2.72	0.668
Std Dev	N/A	N/A	N/A	N/A	3	2.0	2.0	3	3	0.095	0.01	0.050
Avg + Std	N/A	N/A	N/A	N/A	28	18.0	816.8	105	125	0.217	2.72	0.718
Avg - Std	N/A	N/A	N/A	N/A	22	14.0	812.8	99	119	0.026	2.71	0.618

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)
CR 25	830.8	B-001-0-22	13.5	-	15	SS-7	7	67	-	44	13	33	7	3	31	18	13	22	A-2-6	Granular	4	N/A				29	14.0	816.8	105	125	0.189	2.71	0.611
CR 25	830.8	B-001-0-22	15	-	16.5	SS-8	4	89	-	6	10	48	29	7	16	15	NP	28	A-4a	NP SILT	4	N/A				23	16.0	814.8	100	120	0.054	2.72	0.697
CR 25	830.8	B-001-0-22	17.5	-	19	SS-9	4	100	-	-	-	-	-	-	-	-	NP	29	A-4a	NP SILT	4	N/A				23	18.0	812.8	100	120		2.72	0.697

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 5

	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC
Max	51	100	N/A	49	21	19	18	6	20	20	N/A	21
Min	20	0	N/A	36	14	14	17	6	18	20	N/A	14
Average	32	56	N/A	43	18	17	18	6	19	20	N/A	17
Std Dev	16	42	N/A	9	5	4	1	0	1	N/A	N/A	3
Avg + Std	49	97	N/A	52	22	20	18	6	20	N/A	N/A	20
Avg - Std	16	14	N/A	33	13	13	17	6	18	N/A	N/A	13

	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	N/A	N/A	N/A	N/A	38	26.0	812.3	125	140	0.090	2.71	0.537
Min	N/A	N/A	N/A	N/A	32	19.0	805.3	110	130	0.072	2.71	0.353
Average	N/A	N/A	N/A	N/A	34	21.5	809.7	117	135	0.081	2.71	0.454
Std Dev	N/A	N/A	N/A	N/A	3	3.1	3.1	8	5	0.013	0.00	0.093
Avg + Std	N/A	N/A	N/A	N/A	38	24.6	812.8	124	140	0.094	2.71	0.547
Avg - Std	N/A	N/A	N/A	N/A	31	18.4	806.6	109	130	0.068	2.71	0.360

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
CR 25	830.8	B-001-0-22	20	-	21.5	SS-10	51	67	-	49	14	14	17	6	18	NP	NP	15	A-1-b	Granular	5
CR 25	831.3	B-002-0-22	17.5	-	19.5	ST-9	ST	0	-	-	-	-	-	-	-	-	-	21	A-1-b	Granular	5
CR 25	831.3	B-002-0-22	19.5	-	21	SS-10	20	100	-	36	21	19	18	6	20	20	NP	16	A-1-b	Granular	5
CR 25	831.3	B-002-0-22	25	-	26.5	SS-11	26	56	-	-	-	-	-	-	-	-	-	14	A-1-b	Granular	5

Exploration ID	Sample ID	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)
B-001-0-22	SS-10	N/A				38	21.0	809.8	125	140	0.072	2.71	0.353
B-002-0-22	ST-9	N/A					19.0	812.3				2.71	
B-002-0-22	SS-10	N/A				32	20.0	811.3	110	130	0.09	2.71	0.537
B-002-0-22	SS-11	N/A				33	26.0	805.3	115	135		2.71	0.470

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 6

	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	33	100	4.0	0	3	2	60	35	30	19	11	17	Max	4000	4000	4000	200	27	26.0	804.8	130	140	0.180	2.72	0.306
Min	33	100	4.0	0	3	2	60	35	30	19	11	17	Min	4000	4000	4000	200	27	26.0	804.8	130	140	0.180	2.72	0.306
Average	33	100	4.0	0	3	2	60	35	30	19	11	17	Average	4000	4000	4000	200	27	26.0	804.8	130	140	0.180	2.72	0.306
Std Dev	N/A	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	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	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	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	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	N/A	N/A	N/A	N/A	N/A	N/A	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)
CR 25	830.8	B-001-0-22	25	-	26.5	SS-11	33	100	4	0	3	2	60	35	30	19	11	17	A-6a	Cohesive	6	4000	4000	4000	200	27	26.0	804.8	130	140	0.18	2.72	0.306

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)
PER-CR25-2.00	B-001-0-20	35	NQ2-2	Sandstone	Gray	160.5	15,571	107.4	NA	-	45-55	50	10.0	1450377	1450377
PER-CR25-2.00	B-002-0-20	40.2	NQ2-2	Sandstone	Gray	158.0	14,247	98.2	NA	-	50-60	55	13.2	1916912	1916912
				Sandstone	Maximum	160.5	15571		NA = Not Available				Sandstone	Maximum	1916912
					Minimum	158.0	14247							Minimum	1450377
					Average	159	14909							Average	1683645
					Std Dev	2	936							Std Dev	329890
					Recommended Value	160	14200							Recommended Value	1650000

BEDROCK QUALITY

Project	Exploration ID	Rock Type	Depth Range (ft.) From	Depth Range (ft.) To	Thickness (ft)	Layer RQD (%)	Weighted RQD*(Length / Total Length)
PER-CR25-2.00	B-001-0-22	Sandstone	30.5	35	4.5	22	3.4
PER-CR25-2.00	B-001-0-22	Sandstone	35	40	5	65	11.2
PER-CR25-2.00	B-001-0-22	Sandstone	40	45	5	73	12.6
PER-CR25-2.00	B-002-0-22	Sandstone	30.5	35	4.5	22	3.4
PER-CR25-2.00	B-002-0-22	Sandstone	35	45	10	85	29.3
				Sandstone	29	RQD SUM	60
				Maximum	10	85	
				Minimum	4.5	22	
				Average	5.8	53.4	
						Recommended Value	50

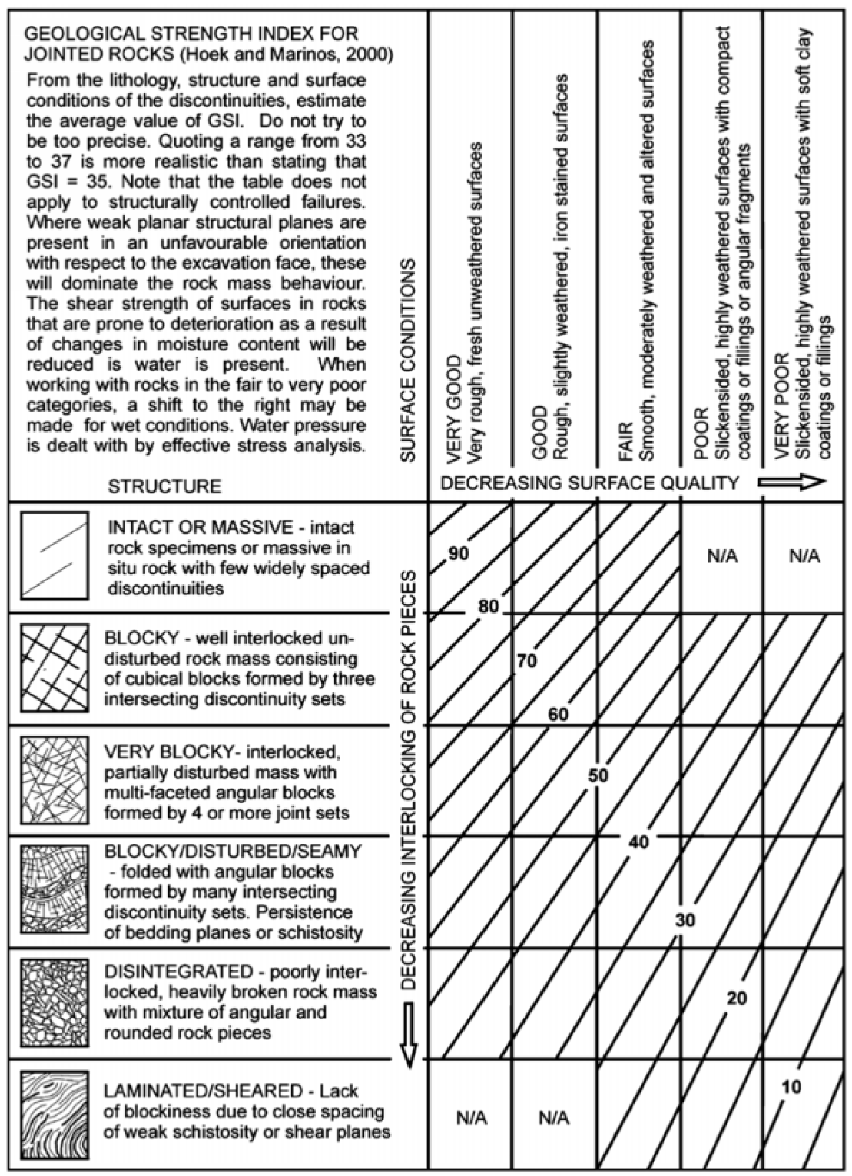


Figure 10.4.6.4-1—Determination of *GSI* for Jointed Rock Mass (Hoek and Marinos, 2000)

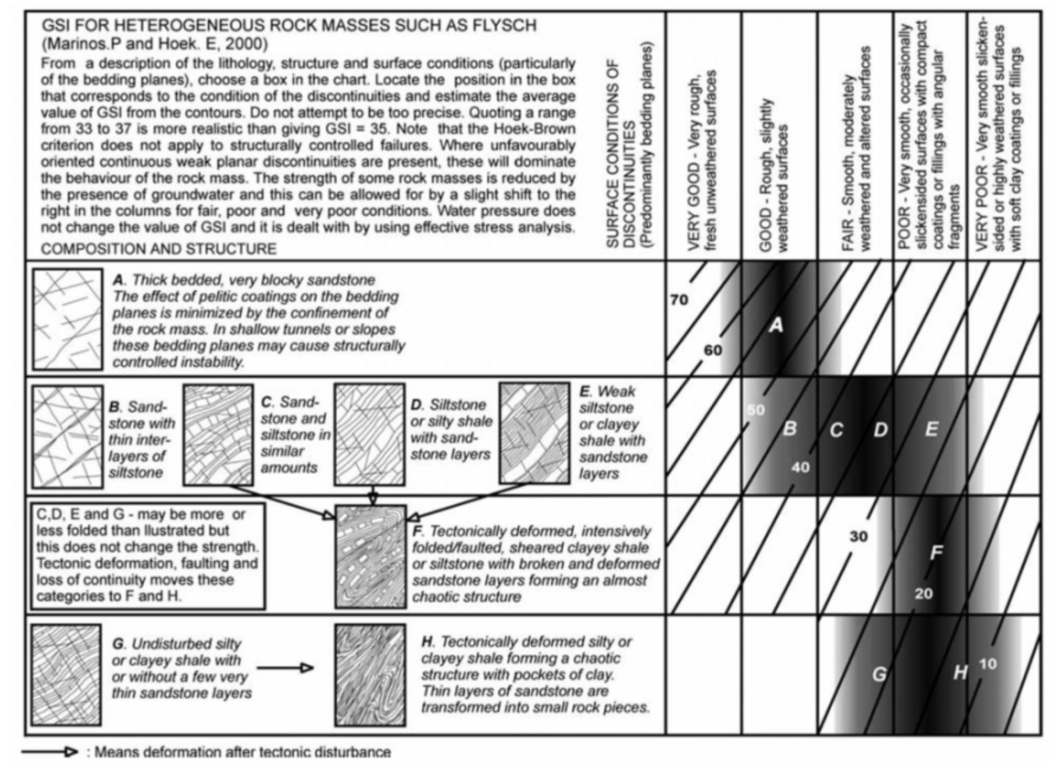


Figure 10.4.6.4-2—Determination of *GSI* for Tectonically Deformed Heterogeneous Rock Masses (Marinos and Hoek 2000)

Table 10.4.6.5-1—Estimation of E_m Based on GSI

Expression	Notes/Remarks	Reference
$E_m(GPa) = \sqrt{\frac{q_u}{100}}\,10^{\frac{GSI-10}{40}}$ for $q_u \le 100$ MPa $E_m(GPa) = 10^{\frac{GSI-10}{40}}$ 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.

LPILE Parameters

Soil Lateral Design Profile

Soil Type	Cohesion (psf)	Phi (deg)	Unit Wt (pcf) Total	Effective[1]	ε50	k
1 - Granular Fill	0	32	120	120	N/A	90
2 - Cohesive Fill	900	0	110	110	0.01	N/A
3 - Very Soft to Soft Cohesive	500	0	120	120	0.02	N/A
4 - Loose Granular	0	25	120	57.6	N/A	20
5 - Medium Dense to Dense Granular	0	33	135	72.6	N/A	60
6 - Hard Cohesive	4000	0	140	77.6	0.005	N/A

1. Effective unit weights to be applied below groundwater table (assumed at El 815 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)

Scour Analysis Parameters

Project:	PER-CR25-2.00	**Calculated By:**	DCM	**Date:** 11/23/2022
Client:	ODOT	**Checked By:**	DMV	**Date:** 11/28/2022
Task:	**Scour Analysis**			

Reference

ODOT Geotechnical Design Manual (GDM)

Critical Shear Stress (Tc)

Cohesive Soils (GDM 1302.1)

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

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	820.79	-	819.39	0.0259	29	73	24	1000	47880.3	0.1	7.382	0.154	3.91
	SS-6	818.7	-	817.29	0.0329	25	70	23	1000	47880.3	0.1	8.642	0.180	3.87
	SS-7	817.29	-	815.79	0.9635	22	10	31	Granular	Granular	0.1	0.964	0.020	2.18
	SS-8	815.79	-	814.29	0.1258	28	36	16	Granular	Granular	0.1	0.126	0.003	1.12
B-002-0-22	SS-5	821.78	-	820.28	0.0133	33	81	19	1000	47880.3	0.1	5.181	0.108	3.67
	SS-6	820.28	-	818.78	0.0253	24	71	19	1000	47880.3	0.1	7.526	0.157	3.67
	SS-7	818.78	-	817.28	0.0282	22	67	19	1000	47880.3	0.1	7.975	0.167	3.67
	SS-8	817.28	-	815.78	0.0266	22	66	18	1000	47880.3	0.1	7.214	0.151	3.61

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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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

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

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

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.