OHIO DEPARTMENT OF TRANSPORTATION
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October 19, 2018 (Revised November 6, 2018)

Mr. Matthew Rotar, E.I.
Ohio Department of Transportation District 6
400 E. William Street
Delaware, Ohio 43015

Re: Office of Geotechnical Engineering Geotechnical Report
Project DEL-315-5.0/6.35/8.10
PID 102124

Dear Mr. Rotar,

The Office of Geotechnical Engineering (OGE) has completed the geohazard exploration for the subject project. The following report discusses the geologic setting for the project, the exploration process and findings, and remediation recommendations. It also identifies a few items that may require further plan detail development and discussion with the District and ODNR.

If you have any questions regarding the contents of this report, please contact me at (614)-466-8341 or Stephen Taliaferro at (614)-351-2873.

Sincerely,

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100 Introduction

Ohio route 315 is located along the western edge of the Olentangy River within Delaware and Franklin Counties. The upper portion of roadway is a two-lane road which has been designated as the "Scenic Olentangy Heritage Corridor" (SOC) which begins at I-270 in Franklin County and extends 10.5 miles to the roadway terminus with US-23 just south of the City of Delaware. The roadway was first commissioned in 1808 and has gone through several upgrades since. Today heavy car traffic utilizes the roadway with over 25,000 cars/day between IR 270 and SR 750 and between 8,787 to over 15,000 cars/day from SR 750 to US 23.

Due to the roadway's proximity to the river, several areas of concern have been identified by ODOT District 6 due to the potential for the waterway to migrate into the river bank resulting in loss of material. If significant loss of material occurs along the toe of the bank, instability may occur along the slope between the river and the roadway. If slope instability occurs, and then continues to progress, the roadway may be adversely impacted.

Three locations were identified where possible corrective actions may be needed to address slope instability due to toe erosion. These locations were identified as DEL-315-5.00 (SLM 5.00), DEL-315-6.35 (SLM 6.35) and DEL-315-8.14 (SLM 8.14). The SLM 5.00 study area extends from Station (Sta.) 1264+25 to 1279+25 for 1,500 linear feet, the SLM 6.35 study area extends from Sta. 1336+50 to 1359+00 for 2,250 linear feet and the SLM 8.10 study area extends from Sta. 1429+00 to 1449+75 for 2,075 linear feet.

The ODOT Geohazard Management System (GHMS) includes the ODOT landslide inventory. Within the SLM 5.00 site, 2 separate landslides were first identified in 2012 and then re-inspected in 2017. From a preliminary rating standpoint both sites are considered Tier 1 (Tiers 1 to 4 with 4 being the highest risk) landslides with the probability of further landslide occurrence judged as moderate (possible values are low, moderate, high, very high). The large traffic volumes on DEL-315 do not factor into the preliminary landslide rating in the GHMS but were considered when this project was selected for ODOT Geologic Site Management Program (GSMP) funding. The SLM 6.35 and 8.10 sites are scheduled for initial inspection and rating by ODOT's Statewide Geohazard Inspection Consultant in late 2018.

200 Geology and Observation

200.1 Geological Information

The study areas are within Delaware County with SLM 5.00 and SLM 6.35 presently located on the Powell USGS Quad sheets while SLM 8.14 is located on the boundary between the Delaware and Powell USGS Quad Sheets. All three study areas are located within the Central Ohio Loamy Till Plain Physiographic Region[1] which is characterized by glacially deposited flat-lying ground moraine with well-defined recessional moraines. Along the larger streams in the area moderate topographic relief is present with limited sand and gravel outwash.

The USDA Web Soil Survey[2] was consulted to evaluate the soils present within the study areas. SLM 5.00 was predominately comprised of Lybrand silt loam (LyE2) 18 to 25% eroded beneath the roadway and between the roadway and the river. This soil type is classified as being well drained with a high calcium carbonate content

[1] Brockman, Scott 1998, Physiographic Regions of Ohio, Ohio Department of Natural Resources.
[2] https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

which has a very high run off potential. The material is typically derived from tills from glacially deposited moraines which are generally silty clay. Figure 200.1 presents the soils map for the SLM 5.00 study area.

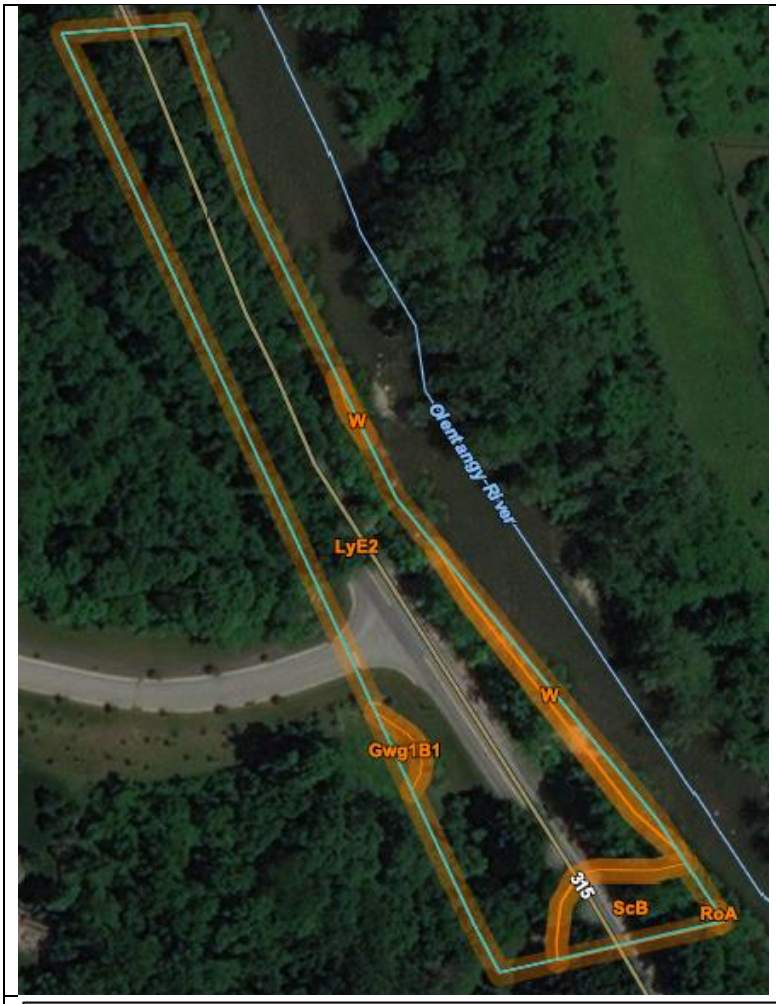


Figure 200.1 Soil Report SLM 5.00
From USDA Web Soil Survey

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Gwg1B1	Glynwood silt loam, ground moraine, 2 to 6 percent slopes	0.0	0.9%
LyE2	Lybrand silt loam, 18 to 25 percent slopes, eroded	2.4	89.3%
RoA	Rossburg silt loam, 0 to 2 percent slopes, occasionally flooded	0.0	0.0%
ScB	Scioto silt loam, 2 to 6 percent slopes	0.2	7.4%
W	Water	0.1	2.4%
Totals for Area of Interest		**2.7**	**100.0%**

The SLM 6.35 study area was predominately comprised of Sloan silt loam (SkA) 0 to 2% slopes, occasionally flooded beneath the roadway and between the roadway and the river. This soil type is classified as being very poorly drained with low runoff potential which are occasionally flooded. The material is typically derived from loamy alluvium. Figure 200.2 presents the soils map for the SLM 6.35 study area.

Figure 200.2 Soil Report SLM 6.35
From USDA Web Soil Survey

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
SkA	Sloan silt loam, 0 to 2 percent slopes, occasionally flooded	2.6	66.6%
W	Water	1.3	33.4%
Totals for Area of Interest		**3.9**	**100.0%**

The SLM 8.14 study area was predominately comprised of Scioto silt loam (ScB) 2 to 6% slopes, Lybrand silt loam (LyE2) 18 to 25% eroded, and Lobdell silt loam (LoA) 0 to 2% slopes, occasionally flooded. Beneath the roadway are typically LyE2 and ScB soils with LoA between the roadway and the river. LyE2 are classified as being well drained with a high calcium carbonate content which has a very high runoff potential. ScB are classified as being well drained with a low runoff potential which are silty and granular. LoA are typically floodplain soils which are silty or clayey and are classified as being moderately well drained with a low runoff potential which can occasionally be flooded. Figure 200.3 presents the soils map for the SLM 8.14 study area.

Figure 200.3 Soil Report SLM 8.14
From USDA Web Soil Survey

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
LoA	Lobdell silt loam, channery substratum, 0 to 2 percent slopes, occasionally flooded	0.6	18.5%
LyE2	Lybrand silt loam, 18 to 25 percent slopes, eroded	1.1	33.0%
ScA	Scioto silt loam, 0 to 2 percent slopes	0.1	3.8%
ScB	Scioto silt loam, 2 to 6 percent slopes	1.5	44.6%
W	Water	0.0	0.1%
Totals for Area of Interest		**3.5**	**100.0%**

Westgate[3] reports that the Olentangy River, south of the City of Delaware, flows within a pre-glacial valley with an average drop of 8 feet per mile to Franklin County Line. The river bed is flowing on bedrock comprised of the Delaware and Columbus Limestones and that steep bedrock banks can be present, especially along the east side of the river. Jointing within the bedrock is very prevalent and can be easily seen within the river valley. Three predominate intersecting joint sets are evident within the river bed. These sets are running approximately N40ºE, N12ºE, and N90ºE. Outside of the immediate river bed glacially deposited soils are present. Rock terraces are present along the river which have thin veneers of alluvium as well as isolated areas within the river bed. Adjacent to the river bed glacially deposited soils comprised predominately of clayey ground moraine tills which can be calcareous and contain boulders are present.

Bedrock geology of the Powell and Delaware USGS Quadrangles indicates that the Olentangy River is flowing on Devonian aged limestone bedrock at each of the three study areas. At SLM 5.00 mapping indicates that the river bed is comprised of Columbus Limestone with Delaware Limestone found within the stream banks and beneath the roadway. Immediately downstream of the project the river bed is flowing on Delaware Limestone. Figure 200.4 present the bedrock mapping for SLM 5.00.

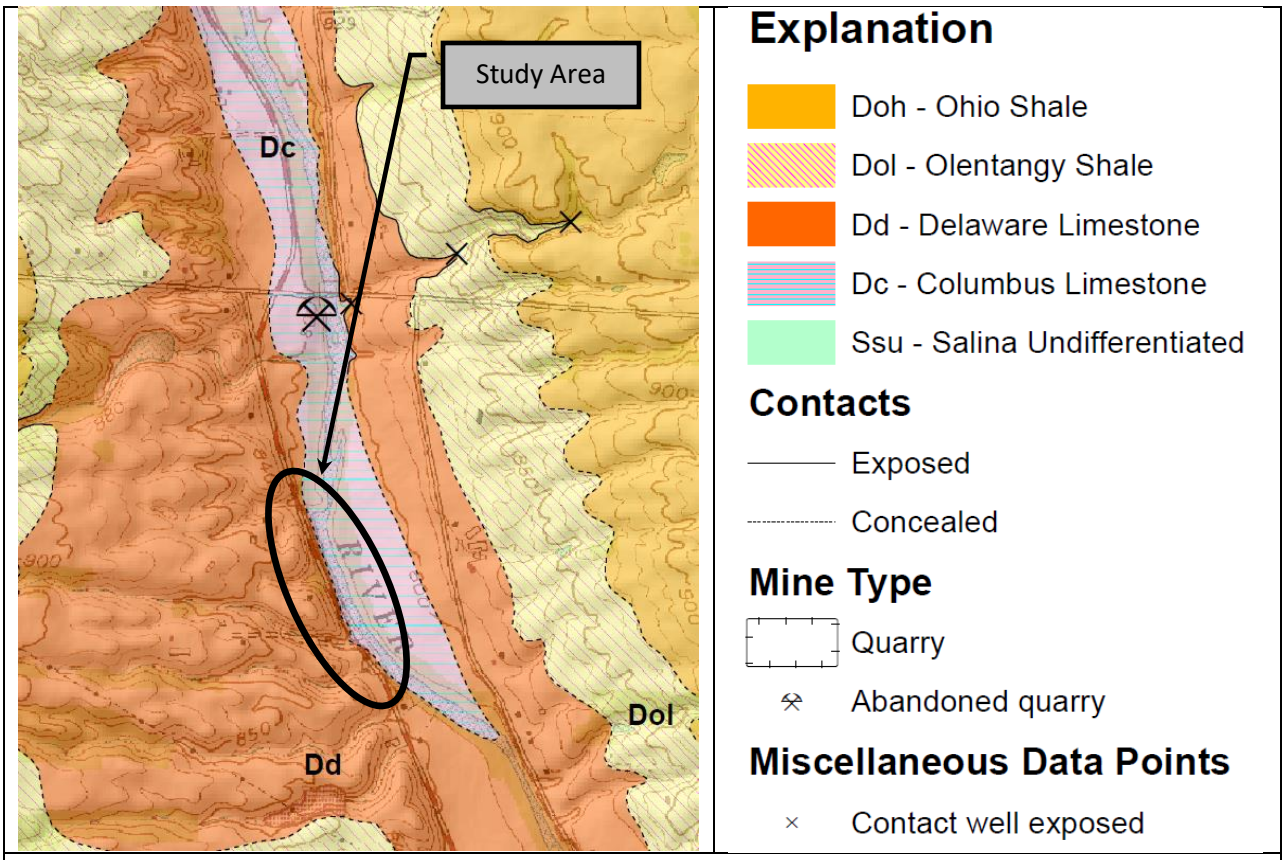


Figure 200.4: Bedrock Geology for Study Area SLM 5.00
From Bedrock geology of the Powell, Ohio, quadrangle;
Slucher, E.R.; Caudill, M.R.; Swinford, E.M.; Brockman, C.S.
Ohio Division of Geological Survey, 2001

[3] Westgate, Lewis G., 1962, Geology of Delaware County, Bulletin 30, Ohio Geological Survey

At SLM 6.35 the Olentangy River is flowing on Columbus Limestone which is also present beneath the roadway. The lower hillsides are comprised of Delaware Limestone and upper hillsides is comprised of Ohio Shale. Figure 200.5 present the bedrock mapping for SLM 6.35.

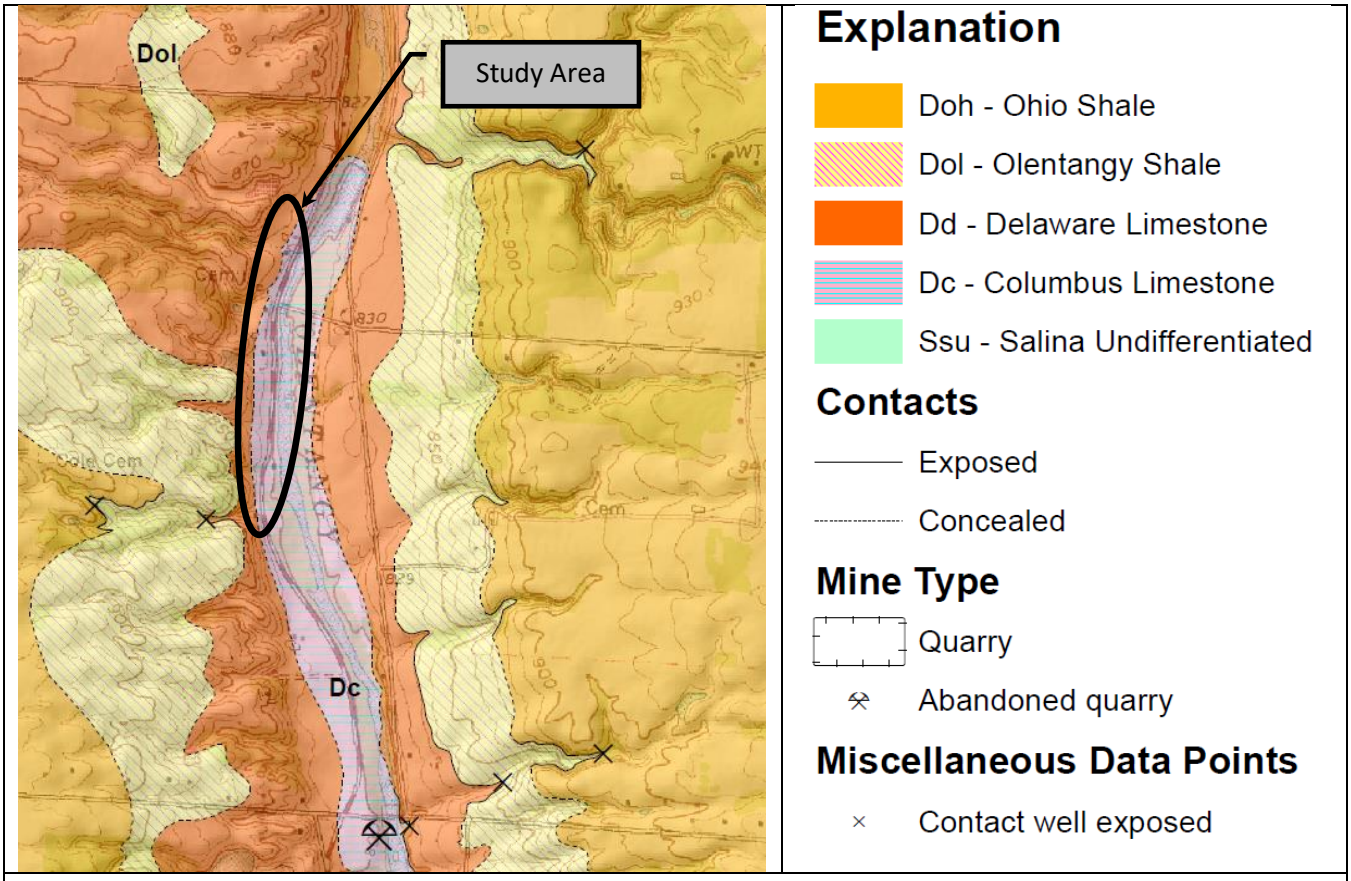


Figure 200.5: Bedrock Geology for Study Area SLM 6.35
From Bedrock geology of the Powell, Ohio, quadrangle;
Slucher, E.R.; Caudill, M.R.; Swinford, E.M.; Brockman, C.S.
Ohio Division of Geological Survey, 2001

At SLM 8.14 the Olentangy River is flowing on Delaware Limestone which is also present beneath the roadway. The hillsides to the west is comprised of Delaware Limestone which is covered with glacial till. East of the river the hillside is comprised of Ohio Shale. Figure 200.6 present the bedrock mapping for SLM 8.14.

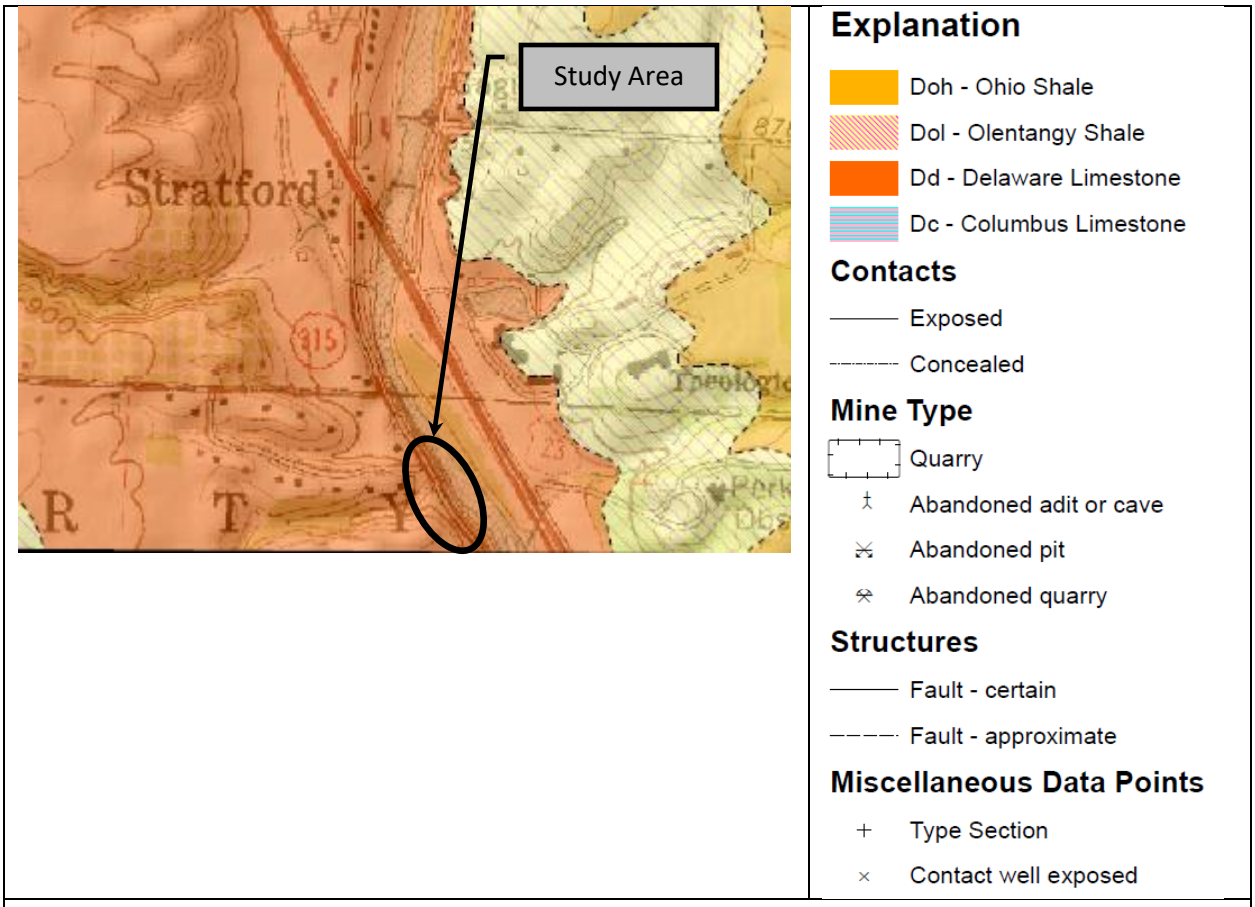


Figure 200.6: Bedrock Geology for Study Area SLM 8.14
From Bedrock geology of the Delaware, Ohio, quadrangle;
Slucher, E.R.; Swinford, E.M.
Ohio Division of Geological Survey, 1992

A water well log search was completed through utilization of ODNR water well viewer. Three water wells were located within proximity to SLM 5.00 study area. All three were present above the roadway and encountered thin overburden soils, 23 to 32 feet thick, underlain by limestone. All three wells were completed within limestone with static water elevations reported between 24 and 74 feet below ground surface, approximately between elevation 812 and 789 feet. At SLM 6.35 no water wells were reported to the roadway study area. At SLM 8.14 one well report was found in proximity to the roadway study area, located to the south, which encountered 18 feet of overburden soils, approximately elevation 832 feet, underlain by limestone with water encountered at approximately elevation 795 feet with static water reported at approximate elevation 840 feet.

200.2 Historical Boring Information

Historical boring information was obtained from the ODOT Transportation Information Mapping System (TIMS).

At SLM 5.00 four (4) historical borings were located for a proposed water and sewer line being installed under SR 315 for the proposed Nelson Farm subdivision. Two (2) borings B-1 and B-2 were completed for the water line on either side of SR 315. B-1 was along the west side of SR 315 and encountered 0.7 feet of topsoil underlain by lean clay with sand to a depth of 8.0 feet when weathered limestone was encountered. The limestone was sampled through coring to a depth of 30 feet. B-2 was completed in the northbound lane of SR 315 and encountered 13 inches of asphalt underlain by 5 inches of aggregate base. Beneath the pavement lean clay with sand was encountered to a depth of 5 feet where weathered limestone was encountered. Limestone was sampled through coring to a depth of 30 feet where the boring was terminated. Two (2) borings, B-3 and B-4, were completed for the proposed sewer line on either side of SR 315. B-3 was completed on the west side of SR 315 and encountered fill to a depth of 2.5 feet underlain by lean clay with sand to a depth of 7.0 feet. At 7.0 feet the boring encountered weathered limestone which was sampled thought coring to a depth of 15 feet. B-4 was completed in the northbound lane of SR 315 and encountered 12 inches of asphalt underlain by 6 inches of aggregate base. Beneath the pavement fill was encountered to a depth of 3.0 feet underlain by lean clay with sand to top of bedrock at a depth of 6.0 feet. Weathered bedrock was sampled to a depth of 14 feet where the boring was terminated.

At the SLM 6.35 study area one (1) historical boring was located for a culvert replacement project (DEL-315-6.69) completed in 2009. This boring was completed in the northbound lane and encountered 5 inches of asphalt underlain by very stiff to hard Silt and Clay (A-6a) soils to elevation 804.4 feet. Beneath the A-6a soils medium dense Stone Fragments with Sand and Silt (A-2-4) was encountered extending to top of bedrock at elevation 802.3 feet. Limestone bedrock was samples through coring methods to elevation 792.3 when the boring was terminated. One compressive strength test of the bedrock was completed at a depth of 11.7 feet (elevation 797.7 feet) with a result of 13,410 psi.

No historical records were located within the SLM 8.14 study area.

200.3 Field Observations

A site visit was completed by ODOT personnel from the Office of Geotechnical Engineering and District 6 on April 3, 2017 to evaluate site conditions and lay out boring locations. Study areas SLM 5.00 and 6.35 were visited during this site visit.

At SLM 5.00 study area, the area was noted as being predominately wooded and rural residential. The pavement along SR 315 was noted as having been repaired in several locations within both the northbound and southbound lanes. Within areas which had not been repaired, several areas of pavement distress were noted with cracking and slight dropping of the pavement within the outside 3 to 4 feet of the northbound lane. West of SR 315 was noted as being wooded hillside with intermediate rural residential lots. The entrance to the Nelson Farms subdivision is well maintained with exposed bedrock noted within the drainage area running parallel to Shale Run Drive. The bedrock was noted as being thin bedded limestone which was moderately weathered and highly jointed. The drainage is carried under SR 315 through DEL-315-5.07 which is box culvert. The outlet to this culvert was noted as having sediment build up with limestone blocks. To the east of SR 315 is the wooded riparian zone between the roadway and the river. The slope was noted as being wooded with isolated areas of erosion and

evidence of slope creep. One area of seepage was noted within the slope which was south of Shale Run Dr. and appears to be water discharging from a joint set within the bedrock. Free blocks of limestone and glacial cobbles and boulders were noted along the edge of water. Grayish brown limestone which appeared to be moderately weathered and highly jointed was noted within the river and above the normal water elevation of the Olentangy River. Isolated areas of minor bedrock plucking was noted along the and within the river bed.

At SLM 6.35 study area, the area was noted as being rural residential. The pavement was noted as being in fair condition with areas of crack sealing and patching noted. To the west of SR 315 are rural residential lots. Between SR 315 and the river the wooded riparian zone is very steep and is exhibiting signs of long term creep instability. No signs of seepage were noted within the slope. The river appears to be flowing on bedrock with minor outcropping above the normal flow elevation. Limestone blocks as well as glacial cobbles and boulders were noted along the edge of the river. The study area ends at the north with the abandoned Winter Road bridge abutment. Most of the drainage ways crossing under the roadway appear to have bedrock exposed, or large limestone slabs with the channels. The larger drainage structures are constructed of limestone blocks which have been extended with cast in place concrete.

The SLM 8.14 study area was noted as having the roadway being much higher than the river relative to the other two study areas. The pavement was noted as being in good condition with areas of crack sealing. To the west of SR 315 the area was noted as being mixed wooded and rural residential. East of SR 315 is a steep hillside which is wooded. Signs of long term creep instability were noted throughout most of the hillside. No signs of seepage were noted within the slope. The river bed is flowing on limestone bedrock with exposures present above the normal water elevation. The primary drainage structure within the study area is a 3-sided slab deck which has a large fall from the outlet to the river bed. Bedrock is exposed below most of the outfall.

300 Exploration

A multifaceted exploration approach was completed within each study area. A combination of borings, dynamic cone penetration (DCP) soundings, and electric resistivity (ER) was completed within each area for better determine the subsurface conditions. All borings were completed with either a truck mounted or track mounted rotary drill unit completed using 3 ¼-inch I.D. hollow stem augers to advance the borings through the soil. Disturbed samples were collected in accordance with the Standard Penetration Test (AASHTO T206) at 2.5-foot intervals within the overburden soils. The borings were advanced into bedrock and sampled (AASHTO T225) using an N series wireline core barrel, water method. Electrical resistivity testing was performed utilizing multi-electrode ER lines. An Advanced Geosciences Inc. (AGI) Supersting R8 control unit was utilized to measure the potential field with dipole-dipole and strong gradient arrays. The collected resistivity data was processed with EarthImager 2D (developed by AGI), an inversion and modeling software package.

At SLM 5.00, four (4) borings, B-001-0-18 through B-004-0-18, were completed as part of the subsurface exploration between July 11 and 12, 2017. The borings were drilled with a truck mounted drill except for B-001 which was completed with a track mounted drill. Two (2) wildcat DCP soundings were completed in conjunction with the borings. D-001-1-17 was completed at the anticipated southern end of instability and D-002-1-17 was completed at the outlet of DEL-315-5.07. Three (3) ER lines were completed behind the guardrail running

parallel to the roadway. The first line was completed July 12, 2017 and the second and third lines were completed on August 9, 2017.

At SLM 6.35, eight (8) borings, B-001-0-17 thought B-006-0-17, B-006-1-17, and B-007-0-17 were completed between July 10 and 15, 2017. The borings were drilled with a truck mounted drill except for B-004 which was completed with a track mounted drill. B-006-1 was initially started with a hand auger, but encountered top of rock immediately and was confirmed utilizing hand coring equipment. One (1) wildcat DCP sounding, D-007-1-17, was completed in the upslope ditch line along with hand coring of boulders. One (1) ER line was completed on August 11, 2018.

At SLM 8.14 two (2) borings, B-001-0-17 and B-002-1-17, were completed as part of the subsurface exploration between July 19 and 20, 2017. The borings were drilled with a truck mounted drill. One (1) wildcat DCP soundings, D-001-1-17, was completed in conjunction with the borings at the inlet for DEL-315-8.17 culvert. One (1) ER line was completed behind the guardrail running parallel to the roadway on August 17, 2018.

400 Findings

400.1 SLM 5.00

Subsurface conditions revealed 12 to 14 inches of asphalt within the roadway and 4 inches topsoil behind the guardrail. Beneath the pavement the borings encountered predominately cohesive soils consisting of Sandy Silt (A-4a) and Silty Clay (A-6b) which ranged from stiff to very stiff in consistency and damp to moist in condition. These materials were encountered to top of rock except in B-003 where a dense Sandy Silt (A-4a) was encountered at elevation 793.3 feet to top of rock. B-001 encountered dense to very dense Stone fragments with sand and silt (A-2-4) which contained boulders and cobbles from beneath the topsoil to top of rock. Limestone bedrock was encountered between elevation 786.8 and 792.5 feet. The bedrock was reported as moderately to slightly weathered, ranging from moderately to very strong and thin bedded. Unit recovery values ranged from 98% to 100% and Unit RQD values ranged from 0% to 91%. Compressive strength testing results ranged from 6,365 to 23,148 psi and is summarized in Table 400.1.

Table 400.1 SLM 5.00 Summary of Unconfined Compressive Strength Testing

Boring	Top of Bedrock Elevation (Feet)	Sample Depth (feet)	Sample Elevation (feet)	Unconfined Compressive Strength (psi)
B-001-0-17	786.8	10.1	785.9	11,424
B-001-0-17	786.8	15.8	780.2	20,033
B-002-0-17	792.5	11.7	787.0	18,630
B-002-0-17	792.5	14.7	784.0	23,148
B-003-0-17	791.3	10.5	788.8	12,062
B-003-0-17	791.3	13.4	785.9	6,365
B-004-0-17	790.4	10.5	790.1	16,772
B-004-0-17	790.4	16.3	784.3	19,032

All the borings were dry prior to introduction of core water. Water levels were not recorded at the completion of the drilling due to the artificial influence of the coring operations. During the field reconnaissance only one point of seepage was noted within the slope between the roadway and the river. However, groundwater will fluctuate seasonally.

400.2 SLM 6.35

Borings completed within the roadway encountered 11 to 18 inches of asphalt with typically 12 inches encountered. Beneath the pavement the borings typically encountered cohesive soils consisting of Sandy Silt (A-4a), Silt and Clay (A-6a), and Silty Clay (A-6b). These soils ranged from stiff to very stiff in consistency and damp to moist in condition. The Silty Clay (A-6b) material encountered near the surface in B-004 was moderately organic. B-001 encountered cobbles or a boulder between 8.5 and 10 feet. Beneath the pavement in B-006 the boring encountered medium dense Stone fragment with sand and silt (A-2-4) that was damp in condition extending to top or bedrock. Non-cohesive soils were encountered with depth in B-001 through B-005. These soils consisted of Gravel and Stone Fragments with Sand (A-1-b), Gravel and Stone Fragments with sand and silt (A-2-4), Stone Fragments with sand, silt and clay (A-2-6), Sandy Silt (A-4a) which ranged from medium dense to very dense in compactness and damp to wet in condition. These non-cohesive soils extended to top of bedrock. Limestone bedrock was encountered between elevation 790.7 and 803.4 feet, generally rising in elevation to the north. The bedrock was described as moderately to slightly weathered, ranging from strong to very strong and thin bedded. Unit recovery values ranged from 83% to 100% and Unit RQD values ranged from 8% to 72%. Compressive strength testing results ranged from 10,563 to 21,096 psi and is summarized in Table 400.2.

Table 400.2 SLM 6.35 Summary of Unconfined Compressive Strength Testing

Boring	Top of Bedrock Elevation (Feet)	Sample Depth (feet)	Sample Elevation (feet)	Unconfined Compressive Strength (psi)
B-001-0-17	790.7	18.7	788.1	13,563
B-001-0-17	790.7	23.2	783.6	14,189
B-002-0-17	798.9	13.3	794.6	14,672
B-002-0-17	798.9	16.4	791.5	10,563
B-003-0-17	798.1	14.6	794.0	16,880
B-003-0-17	798.1	18.1	790.5	15,331
B-004-0-17	795.2	14.4	792.8	11,969
B-004-0-17	795.2	20.4	786.8	14,374
B-005-0-17	802.7	16.8	793.4	15,896
B-006-0-17	803.9	8.5	801.5	17,676
B-007-0-17	803.4	8.7	802.5	21,096

All the borings were dry prior to introduction of core water except B-001. Water levels were not recorded at the completion of the drilling due to the artificial influence of the coring operations. B-001 encountered free water during drilling at elevation 796.8 feet and static water prior to coring at elevation 794.8 feet. During the field reconnaissance, no points of seepage were noted within the slope between the roadway and the river. However, groundwater will fluctuate seasonally.

400.3 SLM 8.14

B-001 was completed within the roadway and encountered 23 inches of asphalt. B-002 was completed near the DEL-315-8.30 culvert inlet and encountered 4 inches of topsoil. Beneath the surface material both borings encountered Sandy Silt (A-4a) which was stiff to very stiff in consistency and damp in condition. In B-002, this layer was noted as being moderately organic. At approximately elevation 833, the borings encountered Silt and Clay (A-6a) which was hard and damp in B-001 and stiff and moist in B-002. The soils were also slightly organic in B-002. Top of limestone bedrock was encountered at elevation 827.7 and 829.6 feet, respectively. The bedrock was described as slightly or moderately weathered, very strong, and thin bedded. The Unit recovery was 88% and 90% and the Unit RQD value was 70% and 7%. One unconfined compressive strength test was completed from B-001 at a depth of 16.1 feet, elevation 825.6 feet, with a result of 20,451 psi.

Both borings were dry prior to introduction of core water. Water levels were not recorded at the completion of the drilling due to the artificial influence of the coring operations. During the field reconnaissance no points of seepage were noted within the slope between the roadway and the river. However, groundwater will fluctuate seasonally.

500 Analyses and Recommendations

500.1 Slope Stability

Cross sections for each site were created from the survey data provided by the District 6 survey crew. The cross sections were reviewed in conjunction with the boring logs and a critical section was chosen for each site. The critical section for SLM 5.00 was determined to be at Sta. 1272+67, the critical section for SLM 6.35 was determined to be Sta. 1351+00, and the critical section for SLM 8.14 was determined to be Sta. 1436+50.

After the critical sections were determined for each site, OGE created soil and bedrock profiles for each site using the boring log information closest to each critical section as outlined in Geotechnical Bulletin 7 (GB7). The soil and bedrock profiles were modelled in MicroStation and used to create a slope stability model. OGE used GSTABL7 with STEDwin version 2.005.2 (GSTABL) for the slope stability analysis of the models created in MicroStation. GSTABL is a 2D Limit Equilibrium slope stability program developed by Gregory Geotechnical Software. GSTABL can analyze slope stability using a variety of different methods; OGE used the Modified Bishop Method for its analysis.

In order to analyze a “worst-case” scenario with regards to seasonal variances, the analyses included a much higher groundwater elevation than what was encountered in the borings. All 3 slopes were found to be marginally stable (Factors of Safety greater than 1.0 but less than 1.3) consistent with the slow moving or “creeping” instability condition that has been observed in the past several years. The slope stability analyses results are summarized in Table 500.1.

Table 500.1: Slope Stability Analyses Results – Factor of Safety (for Elevated Groundwater Scenario)	
Location	**Factor of Safety**
DEL-315-5.00	1.15
DEL-315-6.35	1.20
DEL-315-8.10	1.06

500.2 Remediation Options

After the slope stability analyses was completed in GSTABL, OGE proposed four (4) options for remediation. These options were: installation of a plug pile wall, installation of a drilled shaft wall with lagging, construction of a reinforced soil slope, and installation of a GeoWeb wall. OGE analyzed the four options for the critical section at each site. The results are presented in the following sections.

500.2.1 Options 1 & 2 - *Plug Pile Wall and Drilled Shaft Wall with Lagging*

To analyze the effectiveness of the plug pile and drilled shaft wall designs, the force imposed on each plug pile or drilled shaft within each of the wall systems needed to be determined. ODOT GB7 recommends the use of a software program called UA Slope for the analysis of the force applied to a shaft within a reinforcing wall system. UA Slope was developed through a research study conducted by Dr. Robert Liang of the University of Akron in conjunction with ODOT to determine the force imposed on one shaft in a single row of equally spaced drilled shafts by a moving soil mass. UA Slope version 2.3 was utilized by OGE. The location of the drilled shafts was based on the minimum allowed guardrail offset specified by District 6 for all three (3) sites.

The UA slope results are presented in Appendix C and were used to conduct an LPILE analysis on each shaft type to determine the size of shaft needed to resist the calculated force. LPILE is a program developed by Ensoft Inc. for the analysis of a pile under lateral loading using the p-y method. Different shaft and reinforcement sizes were evaluated in LPILE.

The results of the LPILE analysis showed that 24” shafts with minimum HP12x53 steel reinforcement and a 6’ rock socket would be required for the plug pile wall while the drilled shaft wall with lagging would require 36” shafts with minimum HP12x53 steel reinforcement and a 6’ rock socket. There would be limited slope disturbance beyond the plug pile wall while it is being installed whereas the drilled shaft with lagging would require significant excavation beyond the wall to install the lagging and would vary in depth from site to site. The LPILE results are presented in Appendix D.

500.2.2 Option 3 - *Reinforced Soil Slope*

For the analyses of the reinforced soil slope design, OGE used a program called ReSSA. The program developed by Adama Engineering, assesses the rotational and translational stability of slopes with geosynthetic reinforcement. The designer note that accompanies ODOT Supplemental Specification 863 *Reinforced Soil Slopes* (SS 863) was utilized to determine the proper parameters for inclusion in the analyses of the reinforced soil slope.

The inputs previously used for the GSTABL analysis were modified for use with ReSSA and the analyses of the reinforced soil slope option was completed. The ReSSA analysis showed that, to construct the reinforced slope, the excavation limits could extend across the northbound lane of DEL-315 and into the southbound lane. The design would also require erosion protection which could include wrapping of the slope face. The ReSSA results are presented in Appendix E.

500.2.3 Option 4 - *GeoWeb Wall*

Due to the height of the current soil embankment along the DEL-315, a gravity wall was determined to not be feasible. A MSE Wall made from GeoWeb cells was proposed and would require P2 geogrid as outlined in SS 863. An analysis was conducted using a proprietary program provided by the GeoWeb vendor which showed the excavation limits for the GeoWeb wall to include the entire northbound lane of DEL-315. However, OGE has questions over how the GeoWeb software handles existing marginally stable slopes and recommends that if the GeoWeb design is to be pursued, the vendor should provide the detailed design. Due to the expiration of our temporary license for the proprietary software, only the GeoWeb conceptual details are presented in Appendix F.

500.3 Recommendations

OGE visited DEL-315-0.86 (south of DEL-315 intersection with Powell Rd/DEL-750) on November 2, 2018 with District 6 personnel to observe localized areas where the soil mass downhill from the existing plug pile wall had moved. The localized movement occurred to a depth that OGE recommended the District review the consultant's report to determine what the design assumed for a cantilever condition.

After evaluating the four design options, OGE continues to recommend that the District pursue the plug pile wall option. We believe that it provides the least invasive construction of the options along the DEL-315 corridor. We believe that a planting plan or other bio-engineering solutions to provide support to the vegetation of the soil mass downhill from the wall should also be pursued. Those solutions are beyond the expertise of OGE.

Based on discussions with the State Construction Geotechnical Engineer, we believe that a plan note could be added indicating that grading shall not extend beyond the construction limits shown on the plans. This note, while redundant to the ODOT CMS definition of *Construction Limits*, would draw further attention from the contractor during bid development that there needs to be limited disturbance below the wall during construction including for items such as formwork.

As stated previously, OGE recognizes the seasonal variances in groundwater. It is our opinion that for much of the year, the slopes at the three sites are stable. The slow or "creeping" movement that has been observed over several years is occurring during periods of elevated groundwater. We agree with the District that a measure such as placing #57's would be possible beneath the "plug" or unreinforced shafts. It would require details and possibly consultation with a drilled shaft contractor as to how best present in the plans. Based on what has been observed following the construction at DEL-315-0.86, it is possible that the soil mass downhill from the wall will experience instability that could expose the #57's in localized areas.

While it is the opinion of OGE that the existing slope geometry at DEL-315-5.00/6.40/8.10 will be less susceptible to the localized downhill slope movement observed at the DEL-315-0.86 wall, this could still occur. We recommend the District engage ODNR and other riparian experts as to how best address these localized failures.

If you have any questions, please contact our office.

pc: Reading File

Enclosures: Appendices

APPENDIX A
ODOT BORING LOGS, DCP RESULTS, CORE PHOTOS

APPENDIX A.1
DEL-315-5.0

PROJECT: DEL-315-05.00	DRILLING FIRM / OPERATOR: ODOT / BINKLEY	DRILL RIG: ACKER XLS TRACK	STATION / OFFSET: 1265+09, 21' RT.	EXPLORATION ID B-001-0-17
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / AJ	HAMMER: AUTO	ALIGNMENT: CENTERLINE OF SR 315	
PID: 102124 SFN: N/A	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 6/1/17	ELEVATION: 796.0 (MSL) EOB: 19.0 ft.	PAGE 1 OF 1
START: 7/11/17 END: 7/11/17	SAMPLING METHOD: SPT	ENERGY RATIO (%): 89	LAT / LONG: 40.206485, -83.059277	

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
TOPSOIL (4")	796.0																		
	795.2																		
DENSE TO VERY DENSE, BROWN AND GRAY, **STONE FRAGMENTS WITH SAND AND SILT**, TRACE CLAY, DAMP		1																	
		2	10 25 32	85	78	SS-1A	-	55	12	7	18	8	19	17	2	3	A-2-4 (0)	-	
		3																	
		4	28 11 10	31	72	SS-2A	-	-	-	-	-	-	-	-	-	4	A-2-4 (V)	-	
@5.0' - 9.2'; ENCOUNTERED BOULDERS/COBBLES		5																	
		6																	
		7	0		33	NQ2-1											CORE		
		8																	
	786.8	9																	
LIMESTONE, GRAY, SLIGHTLY WEATHERED, STRONG TO VERY STRONG, THIN BEDDED, CRYSTALLINE, FOSSILIFEROUS, SLIGHTLY STYOLITIC, JOINT, MODERATELY FRACTURED, NARROW, VERY ROUGH; BLOCKY, GOOD; RQD 76%, REC 98%.	TR	10																	
@ 10.1' - 10.4'; γ = 169 pcf; Qu = 11,424 psi		11	80		98	NQ2-2											CORE		
		12																	
		13																	
		14																	
@ 15.8' - 16.2'; γ = 168 pcf; Qu = 20,033 psi		15																	
@16.6' - 17.9'; HIGH ANGLE PARTIALLY HEALED FRACTURE		16	70		97	NQ3-3											CORE		
		17																	
		18																	
@18.2' - 18.5'; HIGH ANGLE MODERATELY WEATHERED FRACTURE	777.0	EOB 19																	

NOTES: LAT/LONG/ELEV FROM OGE HANDHELD GPS UNIT. HOLE DRY BEFORE CORING.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 50 LB. BENTONITE CHIPS

PROJECT: DEL-315-05.00	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 1268+15, 8' RT.	EXPLORATION ID B-002-0-17
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / MCLEISH	HAMMER: CME AUTOMATIC	ALIGNMENT: CENTERLINE OF SR 315	
PID: 102124 SFN: N/A	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 6/1/17	ELEVATION: 798.7 (MSL) EOB: 16.3 ft.	PAGE 1 OF 1
START: 7/11/17 END: 7/11/17	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77	LAT / LONG: 40.207172, -83.059899	

MATERIAL DESCRIPTION AND NOTES	ELEV. 798.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
ASPHALT (12")	797.7																		
STIFF, REDDISH BROWN WITH BLACK, **SILTY CLAY**, SOME SAND, TRACE GRAVEL, MOIST		1	3 3 6	12	39	SS-1A	2.00	6	8	14	37	35	38	16	22	20	A-6b (12)	-	
@3.5'; SOME GRAVEL AND STONE FRAGMENTS		2 3 4 5	2 15 60	96	83	SS-2A	1.00	-	-	-	-	-	-	-	-	22	A-6b (V)	-	
	792.5	TR 6	50/2"	-	83	SS-3A	-	-	-	-	-	-	-	-	-	12	A-6b (V)	-	
LIMESTONE, BROWNISH GRAY, MODERATELY WEATHERED, VERY STRONG, THIN BEDDED, CRYSTALLINE, FOSSILIFEROUS, JOINT, FRACTURED, OPEN, VERY ROUGH; BLOCKY, FAIR; RQD 0%, REC 100%. @8.8' - 10.6'; HIGH ANGLE RUST STAINED FRACTURE		7 8 9 10																	
@10.6'; THIN CLAY SEAM	787.9	11	49		100	NQ2-1											CORE		
LIMESTONE, GRAY, SLIGHTLY WEATHERED, VERY STRONG, THIN BEDDED, CRYSTALLINE, FOSSILIFEROUS, SLIGHTLY STYOLITIC, JOINT, MODERATELY FRACTURED, NARROW, VERY ROUGH; BLOCKY, GOOD; RQD 91%, REC 100%. @ 11.7' - 12.0'; γ = 170 pcf; Qu = 18,630 psi @14.4' - 15.2'; PYRITIC @ 14.7' - 15.1'; γ = 169 pcf; Qu = 23,148 psi	782.5	12 13 14 15 EOB 16																	

NOTES: LAT/LONG/ELEV FROM OGE HANDHELD GPS UNIT. HOLE DRY BEFORE CORING.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 75 LB. BENTONITE CHIPS

PROJECT: DEL-315-05.00	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 1271+12, 10' RT.	EXPLORATION ID B-003-0-17
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / CHUDZIK	HAMMER: CME AUTOMATIC	ALIGNMENT: CENTERLINE OF SR 315	
PID: 102124 SFN: N/A	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 6/1/17	ELEVATION: 799.3 (MSL) EOB: 18.0 ft.	PAGE 1 OF 1
START: 7/11/17 END: 7/11/17	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77	LAT / LONG: 40.207922, -83.060309	

MATERIAL DESCRIPTION AND NOTES	ELEV. 799.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
ASPHALT (14") & BASE (2")	798.0																		
STIFF, REDDISH BROWN WITH BLACK, **SILTY CLAY**, SOME SAND, LITTLE GRAVEL, DAMP			2 2 3	6	50	SS-1A	1.50	18	11	13	27	31	33	17	16	22	A-6b (7)	-	
@3.5'; REDDISH BROWN TO DARK BROWN	793.3		2 3 7	13	61	SS-2A	2.00	-	-	-	-	-	-	-	-	19	A-6b (V)	-	
DENSE, BROWN, **SANDY SILT**, LITTLE STONE FRAGMENTS, LITTLE CLAY, DAMP	791.3	TR	15 16 10	33	78	SS-3A	1.50	19	13	14	40	14	NP	NP	NP	16	A-4a (4)	-	
LIMESTONE, BROWNISH GRAY, MODERATELY WEATHERED, STRONG TO VERY STRONG, THIN BEDDED, FOSSILIFEROUS, JOINT, MODERATELY FRACTURED, OPEN, VERY ROUGH; BLOCKY, GOOD; RQD 0%, REC 100%.	789.1																		
LIMESTONE, GRAY, SLIGHTLY WEATHERED, MODERATELY STRONG TO STRONG, THIN BEDDED, CRYSTALLINE, FOSSILIFEROUS, JOINT, MODERATELY FRACTURED, OPEN, VERY ROUGH; BLOCKY, VERY GOOD; RQD 64%, REC 100%. @ 10.5' - 10.8'; γ = 169 pcf; Qu = 12,062 psi @ 13.4' - 13.7'; γ = 171 pcf; Qu = 6,365 psi @15.3' - 18.0'; HIGH ANGLE FRACTURE	781.3	EOB	50		100	NQ2-1										CORE		

NOTES: LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM OSIP DEM. HOLE DRY BEFORE CORING.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 50 LB. BENTONITE CHIPS

PROJECT: DEL-315-05.00	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 1272+67, 8' RT.	EXPLORATION ID B-004-0-17
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / MCLEISH	HAMMER: CME AUTOMATIC	ALIGNMENT: CENTERLINE OF SR 315	
PID: 102124 SFN: N/A	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 6/1/17	ELEVATION: 800.6 (MSL) EOB: 20.3 ft.	PAGE 1 OF 1
START: 7/12/17 END: 7/12/17	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77	LAT / LONG: 40.208312, -83.060530	

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
ASPHALT (12")	800.6																		
	799.6																		
VERY STIFF, BROWN, **SANDY SILT**, SOME CLAY, SOME STONE FRAGMENTS, DAMP		1	4 6 4	13	67	SS-1A	2.50	21	13	17	28	21	23	15	8	14	A-4a (3)	-	
@3.5'; REDDISH BROWN		2 3 4 5	2 4 5	12	67	SS-2A	2.50	-	-	-	-	-	-	-	-	16	A-4a (V)	-	
		6 7 8	6 8 8	21	89	SS-3A	4.00	-	-	-	-	-	-	-	-	15	A-4a (V)	-	
@8.5'; HARD, REDDISH BROWN AND BROWN		9 10	6 8 7	19	89	SS-4A	4.50	21	8	14	32	25	27	17	10	11	A-4a (4)	-	
	790.4	TR																	
LIMESTONE, LIGHT GRAY, MODERATELY WEATHERED, VERY STRONG, THIN BEDDED, CRYSTALLINE, FOSSILIFEROUS, BEDDING, MODERATELY FRACTURED, OPEN, VERY ROUGH; BLOCKY, GOOD; RQD 79%, REC 100%. @ 10.5' - 10.8'; γ = 168 pcf; Qu = 16,772 psi @13.9'; VERY THIN CLAY SEAM		11 12 13 14 15	65		100	NQ2-1											CORE		
@16.0'; 1.0" CLAY SEAM @ 16.3' - 16.6'; γ = 170 pcf; Qu = 19,032 psi @17.0'; 45° FRACTURE @17.2'; 45° FRACTURE @19.5' - 19.9'; HIGH ANGLE HEALED FRACTURE		16 17 18 19 20	93		100	NQ2-2											CORE		
	780.3	EOB																	

NOTES: LAT/LONG/ELEV FROM OGE HANDHELD GPS UNIT. HOLE DRY BEFORE CORING.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 75 LB. BENTONITE CHIPS

WILDCAT DYNAMIC CONE LOG

The Ohio Department of Transportation
Office of Geotechnical Engineering
1600 West Broad Street, Columbus, Ohio 43223

PROJECT NUMBER: 102124
DATE STARTED: 07-10-2017
DATE COMPLETED: 07-10-2017

HOLE #: D-001-1-17
CREW: K. Mcleish, J. Binkley, & A. Jalbrzikowski
PROJECT: DEL-315-5.00
LAT/LONG: 40.206251176,-83.059052512
LOCATION: Delaware County, Ohio

SURFACE ELEVATION: 793.0
WATER ON COMPLETION: none observed
HAMMER WEIGHT: 35 lbs.
CONE AREA: 10 sq. cm

DEPTH	BLOWS PER 10 cm	RESISTANCE Kg/cm²	GRAPH OF CONE RESISTANCE 0 50 100 150	N'	TESTED CONSISTENCY NON-COHESIVE	TESTED CONSISTENCY COHESIVE
-	1	4.4	•	1	VERY LOOSE	VERY SOFT
-	2	8.9	••	2	VERY LOOSE	SOFT
- 1 ft	3	13.3	•••	3	VERY LOOSE	SOFT
-	5	22.2	••••••	6	LOOSE	MEDIUM STIFF
-	7	31.1	•••••••••	8	LOOSE	MEDIUM STIFF
- 2 ft	25	111.0	••••••••••••••••••••••••••••••	25+	DENSE	HARD
-						
-						
- 3 ft						
- 1 m						
-						
- 4 ft						
-						
-						
- 5 ft						
-						
-						
- 6 ft						
-						
- 2 m						
- 7 ft						
-						
-						
- 8 ft						
-						
-						
- 9 ft						
-						
-						
- 3 m 10 ft						
-						
-						
-						
- 11 ft						
-						
-						
- 12 ft						
-						
-						
- 4 m 13 ft						

LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM OSIP DEM.

WILDCAT DYNAMIC CONE LOG

The Ohio Department of Transportation
Office of Geotechnical Engineering
1600 West Broad Street, Columbus, Ohio 43223

PROJECT NUMBER: 102124
DATE STARTED: 07-10-2017
DATE COMPLETED: 07-10-2017

HOLE #: D-002-1-17
CREW: K. Mcleish, J. Binkley, & A. Jalbrzikowski
PROJECT: DEL-315-5.00
LAT/LONG: 40.206890065,-83.059606556
LOCATION: Delaware County, Ohio

SURFACE ELEVATION: 791.7
WATER ON COMPLETION: none observed
HAMMER WEIGHT: 35 lbs.
CONE AREA: 10 sq. cm

DEPTH	BLOWS PER 10 cm	RESISTANCE Kg/cm²	GRAPH OF CONE RESISTANCE 0 50 100 150	N'	TESTED CONSISTENCY NON-COHESIVE	TESTED CONSISTENCY COHESIVE
-	3	13.3	•••	3	VERY LOOSE	SOFT
-	10	44.4	••••••••••••	12	MEDIUM DENSE	STIFF
- 1 ft	5	22.2	••••••	6	LOOSE	MEDIUM STIFF
-	4	17.8	•••••	5	LOOSE	MEDIUM STIFF
-	6	26.6	•••••••	7	LOOSE	MEDIUM STIFF
- 2 ft	6	26.6	•••••••	7	LOOSE	MEDIUM STIFF
-	14	62.2	••••••••••••••••••	17	MEDIUM DENSE	VERY STIFF
-	12	53.3	••••••••••••••	15	MEDIUM DENSE	STIFF
- 3 ft	25	111.0	••••••••••••••••••••••••••••••	25+	DENSE	HARD
- 1 m						
-						
- 4 ft						
-						
-						
- 5 ft						
-						
-						
- 6 ft						
-						
- 2 m						
- 7 ft						
-						
-						
- 8 ft						
-						
-						
- 9 ft						
-						
-						
- 3 m 10 ft						
-						
-						
-						
- 11 ft						
-						
-						
- 12 ft						
-						
-						
- 4 m 13 ft						

LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM OSIP DEM.


DEL-315-5.0
B-001-0-17
END
RUN #1 @ 9.0'
N DIV.
07/14/2017


DEL-315-5.0
B-001-0-17
R2 14'-19'
07/14/2017


DEL-315-5.0
B-002-0-17
07/14/2017


DEL 315-5.0
B003-0-17
07/14/2017


DEL-315-5.0
B-004-0-17
Top
07/14/2017

APPENDIX A.2
DEL-315-6.40

PROJECT: DEL-315-06.40	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 1337+49, 8' RT.	EXPLORATION ID B-001-0-17
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / MCLEISH	HAMMER: CME AUTOMATIC	ALIGNMENT: CENTERLINE OF SR 315	
PID: 102124 SFN: N/A	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 6/1/17	ELEVATION: 806.8 (MSL) EOB: 25.5 ft.	PAGE 1 OF 1
START: 7/12/17 END: 7/12/17	SAMPLING METHOD: SPT / NQ2	ENERGY RATIO (%): 77	LAT / LONG: 40.225064, -83.064749	

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
ASPHALT (12")	806.8																	
	805.8																	
STIFF, BROWN AND REDDISH BROWN MOTTLED, **SILT AND CLAY**, SOME STONE FRAGMENTS, LITTLE SAND, (NOT ENOUGH MATERIAL TO TEST), DAMP TO MOIST			3 3 4	9	11	SS-1A	2.00	-	-	-	-	-	-	-	-	16	A-6a (V)	
@3.5'; NO RECOVERY, AUGER SAMPLE TAKEN			3 4 5	12	0	SS-2A	-	-	-	-	-	-	-	-	-	17	A-6a (V)	
			9 7 7	18	44	SS-3A	1.50	21	7	13	32	27	28	17	11	18	A-6a (5)	
@8.5' - 10.0'; ENCOUNTERED BOULDERS/COBBLES		W 796.8	4 7 5	15	28	SS-4A	1.50	-	-	-	-	-	-	-	-	18	A-6a (V)	
	795.8																	
MEDIUM DENSE, BROWN AND REDDISH BROWN MOTTLED, **STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, MOIST TO WET		▼ 794.8	3 8 4	15	78	SS-5A	-	46	13	10	17	14	34	20	14	23	A-2-6 (1)	
			3 2 14	21	22	SS-6A	-	-	-	-	-	-	-	-	-	17	A-2-6 (V)	
	790.7	TR																
LIMESTONE, LIGHT GRAY, MODERATELY WEATHERED, STRONG, THIN BEDDED, CRYSTALLINE, FOSSILIFEROUS, BEDDING, MODERATELY FRACTURED, OPEN, VERY ROUGH; BLOCKY, GOOD; RQD 63%, REC 96%.			37		95	NQ2-1											CORE	
@ 18.7' - 19.0'; γ = 164 pcf; Qu = 13,563 psi																		
@ 23.2' - 23.5'; γ = 163 pcf; Qu = 14,189 psi			88		97	NQ2-2											CORE	
	781.3	EOB																

NOTES: LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM OSIP DEM.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 100 LB. BENTONITE CHIPS

PROJECT: DEL-315-06.40	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 1343+91, 6' RT.	EXPLORATION ID B-002-0-17
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / MCLEISH	HAMMER: CME AUTOMATIC	ALIGNMENT: CENTERLINE OF SR 315	
PID: 102124 SFN: N/A	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 6/1/17	ELEVATION: 807.9 (MSL) EOB: 19.0 ft.	PAGE 1 OF 1
START: 7/15/17 END: 7/15/17	SAMPLING METHOD: SPT / NQ2	ENERGY RATIO (%): 77	LAT / LONG: 40.226824, -83.064635	

MATERIAL DESCRIPTION AND NOTES	ELEV. 807.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
ASPHALT (12")	806.9																	
VERY STIFF, BROWN, **SILTY CLAY**, SOME SAND, LITTLE STONE FRAGMENTS, DAMP	804.4	1	5 14 9	30	56	SS-1A	3.50	17	13	16	24	30	37	17	20	15	A-6b (8)	
VERY DENSE, GRAY, **GRAVEL AND STONE FRAGMENTS WITH SAND AND SILT**, TRACE CLAY, DAMP		2	8 25 27	67	56	SS-2A	-	51	11	12	20	6	NP	NP	NP	6	A-2-4 (0)	
@6.0'; DENSE, BROWN	798.9	3 4 5 6 7 8	11 12 24	46	89	SS-3A	-	41	13	13	25	8	NP	NP	NP	7	A-2-4 (0)	
		TR 9	35	-	100	SS-4A	-	-	-	-	-	-	-	-	-	8	A-2-4 (V)	
LIMESTONE, LIGHT GRAY, MODERATELY WEATHERED, STRONG, THIN BEDDED, CRYSTALLINE, SLIGHTLY STYLOLITIC, BEDDING, MODERATELY FRACTURED, OPEN, VERY ROUGH; BLOCKY, GOOD; RQD 25%, REC 83%.		W 795.9 10 11 12	8		93	NQ2-1											CORE	
@ 13.3' - 13.6'; γ = 165 pcf; Qu = 14,672 psi		13 14 15 16	54		92	NQ2-2											CORE	
@ 16.4' - 16.8'; γ = 163 pcf; Qu = 10,563 psi	788.9	EOB 17 18 19																

NOTES: LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM OSIP DEM. HOLE DRY BEFORE CORING.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 70 LB. BENTONITE CHIPS

PROJECT: DEL-315-06.40	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 1345+40, 4' RT.	EXPLORATION ID B-003-0-17
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / MCLEISH	HAMMER: CME AUTOMATIC	ALIGNMENT: CENTERLINE OF SR 315	
PID: 102124 SFN: N/A	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 6/1/17	ELEVATION: 808.6 (MSL) EOB: 20.5 ft.	PAGE 1 OF 1
START: 7/15/17 END: 7/15/17	SAMPLING METHOD: SPT / NQ2	ENERGY RATIO (%): 77	LAT / LONG: 40.227234, -83.064613	

MATERIAL DESCRIPTION AND NOTES	ELEV. 808.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
ASPHALT (12")	807.6																	
VERY STIFF, DARK BROWN, **SILTY CLAY**, "AND" STONE FRAGMENTS, LITTLE SAND, DAMP	805.1		7 4 7	14	67	SS-1A	4.00	38	9	10	20	23	39	17	22	17	A-6b (5)	
VERY DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND AND SILT**, TRACE CLAY, DAMP @6.0'; MEDIUM DENSE	800.1		8 55	-	83	SS-2A	-	-	-	-	-	-	-	-	-	7	A-2-4 (V)	
			14 11 6	22	100	SS-3A	-	44	14	12	22	8	NP	NP	NP	8	A-2-4 (0)	
VERY DENSE, GRAY, **GRAVEL AND STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP	798.1		27 31 42	94	17	SS-4A	-	54	14	9	17	6	NP	NP	NP	3	A-1-b (0)	
LIMESTONE, LIGHT GRAY, MODERATELY WEATHERED, VERY STRONG, THIN BEDDED, CRYSTALLINE, FOSSILIFEROUS, SLIGHTLY STYLOLITIC, BEDDING, HIGHLY FRACTURED, OPEN, VERY ROUGH; VERY BLOCKY, FAIR; RQD 45%, REC 100%. @12.5'; SLIGHTLY WEATHERED, FRACTURED TO MODERATELY FRACTURED, BLOCKY, GOOD. @ 14.6' - 14.9'; γ = 164 pcf; Qu = 16,880 psi		TR	18		100	NQ2-1											CORE	
@ 18.1' - 18.5'; γ = 164 pcf; Qu = 15,331 psi @18.7'; CLAY INFILLING @19.2' - 19.3'; CLAY INFILLING	788.1	EOB	72		100	NQ2-2											CORE	

NOTES: LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM OSIP DEM. HOLE DRY BEFORE CORING.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 50 LB. BENTONITE CHIPS

PROJECT: DEL-315-06.40
TYPE: LANDSLIDE
PID: 102124 SFN: N/A
START: 7/15/17 END: 7/15/17

DRILLING FIRM / OPERATOR: ODOT / BINKLEY
SAMPLING FIRM / LOGGER: ODOT / AJ
DRILLING METHOD: 3.25" HSA / NQ2
SAMPLING METHOD: SPT / NQ2

DRILL RIG: ACKER XLS TRACK
HAMMER: ACKER AUTOMATIC
CALIBRATION DATE: 6/1/17
ENERGY RATIO (%): 81

STATION / OFFSET: 1346+80, 20' RT.
ALIGNMENT: CENTERLINE OF SR 315
ELEVATION: 807.2 (MSL) EOB: 22.0 ft.
LAT / LONG: 40.227619, -83.064549

EXPLORATION ID B-004-0-17

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
TOPSOIL (6")	807.2																	
VERY STIFF, DARK BROWN, **SILTY CLAY**, MODERATELY ORGANIC (LOI = 4.9%), DAMP	806.7		2 3 4	9	44	SS-1A	3.50	19	26	18	27	10	40	19	21	18	A-6b (3)	
			2 6 20	35	28	SS-2A	2.00	-	-	-	-	-	-	-	-	18	A-6b (V)	
DENSE TO VERY DENSE, BROWN AND REDDISH BROWN, **SANDY SILT**, SOME STONE FRAGMENTS, SOME CLAY, DAMP TO MOIST	801.2		9 17 19	49	56	SS-3A	1.50	35	6	10	23	26	NP	NP	NP	13	A-4a (3)	
			1 6 50/4"	-	45	SS-4A	1.00	-	-	-	-	-	-	-	-	21	A-4a (V)	
	795.2	TR	1 50/1"	-	14	SS-5A	-	-	-	-	-	-	-	-	-	9	A-4a (V)	
LIMESTONE, LIGHT GRAY, MODERATELY WEATHERED, STRONG, THIN BEDDED, FOSSILIFEROUS, STYLOLITIC, PETROLIFEROUS, BEDDING, MODERATELY FRACTURED, OPEN, VERY ROUGH; BLOCKY, GOOD; RQD 45%, REC 96%. @ 14.4' - 14.8'; γ = 162 pcf; Qu = 11,969 psi			0		100	NQ2-1											CORE	
@17.8' - 18.0'; HIGH ANGLE FRACTURE			63		94	NQ2-2											CORE	
@ 20.4' - 20.8'; γ = 163 pcf; Qu = 14,374 psi	785.2	EOB	80		93	NQ2-3											CORE	

NOTES: LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM OSIP DEM. HOLE DRY BEFORE CORING.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 75 LB. BENTONITE CHIPS

PROJECT: DEL-315-06.40	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 1351+01, 5' RT.	EXPLORATION ID B-005-0-17
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / MCLEISH	HAMMER: CME AUTOMATIC	ALIGNMENT: CENTERLINE OF SR 315	
PID: 102124 SFN: N/A	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 6/1/17	ELEVATION: 810.2 (MSL) EOB: 17.5 ft.	PAGE 1 OF 1
START: 7/15/17 END: 7/15/17	SAMPLING METHOD: SPT / NQ2	ENERGY RATIO (%): 77	LAT / LONG: 40.228764, -83.064566	

MATERIAL DESCRIPTION AND NOTES	ELEV. 810.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
ASPHALT (14")	809.0	1																
VERY STIFF, BROWN, **SANDY SILT**, SOME CLAY, LITTLE STONE FRAGMENTS, DAMP		2	3 4 6	13	56	SS-1A	3.00	16	16	16	25	27	34	28	6	15	A-4a (3)	
@3.5'; SOME STONE FRAGMENTS		3 4 5	3 6 12	23	44	SS-2A	-	-	-	-	-	-	-	-	-	14	A-4a (V)	
	804.2	6																
VERY DENSE, BROWN AND GRAY, **GRAVEL AND STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP	802.7	7 TR	37 18 31	63	33	SS-3A	-	66	10	7	13	4	NP	NP	NP	6	A-1-b (0)	
LIMESTONE, BROWNISH GRAY, MODERATELY WEATHERED, VERY STRONG, THIN BEDDED, CRYSTALLINE, CONTAINS CLAY INFILLING, JOINTED, FRACTURED, OPEN, VERY ROUGH; VERY BLOCKY, POOR; RQD 8%, REC 100%. @8.1' - 16.8'; HIGH ANGLE FRACTURE WITH CLAY INFILLING AND RUST STAINING		8 9 10 11 12	0		100	NQ2-1											CORE	
@16.8'; MODERATELY FRACTURED @ 16.8' - 17.1'; γ = 167 pcf; Qu = 15,896 psi	792.7	13 14 15 16 17 EOB	15		100	NQ2-2											CORE	

NOTES: LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM OSIP DEM. HOLE DRY BEFORE CORING.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 50 LB. BENTONITE CHIPS

PROJECT: DEL-315-06.40	DRILLING FIRM / OPERATOR: ODOT / MCLEISH	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 1356+38, 5' LT.	EXPLORATION ID B-006-0-17
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / AJ	HAMMER: CME AUTOMATIC	ALIGNMENT: CENTERLINE OF SR 315	
PID: 102124 SFN: N/A	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 6/1/17	ELEVATION: 810.0 (MSL) EOB: 11.3 ft.	PAGE 1 OF 1
START: 7/15/17 END: 7/15/17	SAMPLING METHOD: SPT / NQ2	ENERGY RATIO (%): 77	LAT / LONG: 40.230148, -83.063919	

MATERIAL DESCRIPTION AND NOTES	ELEV. 810.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
ASPHALT (11") & BASE (2")	808.9																	
MEDIUM DENSE, BROWN, **STONE FRAGMENTS WITH SAND AND SILT**, LITTLE CLAY, DAMP		1																
		2	17 7 4	14	44	SS-1A	1.50	-	-	-	-	-	-	-	-	11	A-2-4 (V)	
		3																
		4	17 21 50	91	89	SS-2A	3.50	44	13	15	17	11	22	17	5	13	A-2-4 (0)	
	803.9	5																
LIMESTONE, LIGHT GRAY, SLIGHTLY WEATHERED, VERY STRONG, THIN BEDDED, CRYSTALLINE, BEDDING, MODERATELY FRACTURED, OPEN, VERY ROUGH; BLOCKY, GOOD; RQD 40%, REC 100%. @ 7.9' - 8.0'; CLAY SEAM @ 8.5' - 8.9'; γ = 167 pcf; Qu = 17,676 psi		TR 6	50/1"	-	83	SS-3A	-	-	-	-	-	-	-	-	-	8	A-2-4 (V)	
		7																
		8																
		9	40		100	NQ2-1											CORE	
		10																
	798.7	EOB 11																

NOTES: LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM OSIP DEM. HOLE DRY BEFORE CORING.

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

PROJECT: DEL-315-06.40	DRILLING FIRM / OPERATOR: ODOT / BINKLEY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 1356+51, 26' RT.	EXPLORATION ID B-006-1-17
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / AJ	HAMMER: CME AUTOMATIC	ALIGNMENT: CENTERLINE OF SR 315	
PID: 102124 SFN: N/A	DRILLING METHOD: HAND AUGER / NX	CALIBRATION DATE: 6/1/17	ELEVATION: 802.1 (MSL) EOB: 2.0 ft.	PAGE 1 OF 1
START: 7/10/17 END: 7/10/17	SAMPLING METHOD: HAND AUGER	ENERGY RATIO (%): 77	LAT / LONG: 40.230151, -83.063798	

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	ABAN-DONED
LIMESTONE, LIGHT GRAY, SLIGHTLY WEATHERED, VERY STRONG, THIN BEDDED, CRYSTALLINE, BEDDING, MODERATELY FRACTURED, OPEN, VERY ROUGH; BLOCKY, GOOD; RQD 20%, REC 100%. @ 1.4' - 1.8'; γ = 166 pcf; Qu = 17,037 psi	802.1	TR 1	21		100												CORE	
	800.1	EOB 2																

NOTES: LAT/LONG/ELEV FROM OGE HANDHELD GPS UNIT. HOLE DRY BEFORE CORING.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: NOT RECORDED

PROJECT: DEL-315-06.40	DRILLING FIRM / OPERATOR: ODOT / MCLEISH	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 1358+39, 1' RT.	EXPLORATION ID B-007-0-17
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / AJ	HAMMER: CME AUTOMATIC	ALIGNMENT: CENTERLINE OF SR 315	
PID: 102124 SFN: N/A	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 6/1/17	ELEVATION: 811.2 (MSL) EOB: 12.7 ft.	PAGE 1 OF 1
START: 7/15/17 END: 7/15/17	SAMPLING METHOD: SPT / NQ2	ENERGY RATIO (%): 77	LAT / LONG: 40.230656, -83.063635	

MATERIAL DESCRIPTION AND NOTES	ELEV. 811.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
ASPHALT (18")	809.7	1																
STIFF TO VERY STIFF, REDDISH BROWN, **SILT AND CLAY**, "AND" STONE FRAGMENTS, SOME SAND, DAMP		2	8 16 10	33	28	SS-1A	2.00	41	12	11	19	17	27	16	11	10	A-6a (0)	
		3																
		4	4 4 5	12	44	SS-2A	1.50	-	-	-	-	-	-	-	-	13	A-6a (V)	
		5																
@6.0'; WITH WOOD FRAGMENTS, MOIST	803.4	6	10 6 50/4"	-	58	SS-3A	1.00	-	-	-	-	-	-	-	-	18	A-6a (V)	
	TR	7																
LIMESTONE, GRAY, SLIGHTLY WEATHERED, VERY STRONG, THIN BEDDED, CRYSTALLINE, SLIGHTLY STYOLITIC, BEDDING AND JOINTED, MODERATELY FRACTURED, OPEN, VERY ROUGH; BLOCKY, GOOD; RQD 72%, REC 88%. @ 8.7' - 9.0'; γ = 168 pcf; Qu = 21,096 psi @9.4' - 10.1'; CLAY SEAM @11.3' - 11.7'; HIGH ANGLE PARTIALLY HEALED FRACTURE	798.5	8 9 10 11 12	72		88	NQ2-1											CORE	
	EOB																	

NOTES: LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM OSIP DEM. HOLE DRY BEFORE CORING.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 75 LB. BENTONITE CHIPS

WILDCAT DYNAMIC CONE LOG

The Ohio Department of Transportation
Office of Geotechnical Engineering
1600 West Broad Street, Columbus, Ohio 43223

PROJECT NUMBER: 102124
DATE STARTED: 07-10-2017
DATE COMPLETED: 07-10-2017

HOLE #: D-007-1-17
CREW: K. Mcleish, J. Binkley, & A. Jalbrzikowski
PROJECT: DEL-315-6.4
LAT/LONG: 40.230701398,-83.063684003
LOCATION: Delaware County, Ohio

SURFACE ELEVATION: 808.6
WATER ON COMPLETION: none observed
HAMMER WEIGHT: 35 lbs.
CONE AREA: 10 sq. cm

DEPTH	BLOWS PER 10 cm	RESISTANCE Kg/cm²	GRAPH OF CONE RESISTANCE 0 50 100 150	N'	TESTED CONSISTENCY NON-COHESIVE	TESTED CONSISTENCY COHESIVE
-	0	0.0	0'-0.7'; LIMESTONE FRAGMENTS	0	VERY LOOSE	VERY SOFT
-	0	0.0		0	VERY LOOSE	VERY SOFT
- 1 ft	0	0.0	0.7'-1.8'; LIMESTONE BOULDERS	0	VERY LOOSE	VERY SOFT
-	0	0.0		0	VERY LOOSE	VERY SOFT
-	0	0.0		0	VERY LOOSE	VERY SOFT
- 2 ft	0	0.0	1.8'-3.5'; BROWN STONE FRAGMENTS WITH SAND, SILT, AND CLAY, DAMP	0	VERY LOOSE	VERY SOFT
-	0	0.0		0	VERY LOOSE	VERY SOFT
-	0	0.0		0	VERY LOOSE	VERY SOFT
- 3 ft	0	0.0		0	VERY LOOSE	VERY SOFT
- 1 m	0	0.0	WILDCAT DCP STARTED @3.5'	0	VERY LOOSE	VERY SOFT
-	12	46.3	••••••••••••	13	MEDIUM DENSE	STIFF
- 4 ft	24	92.6	••••••••••••••••••••••••••	25+	MEDIUM DENSE	VERY STIFF
-	15	57.9	••••••••••••••••	16	MEDIUM DENSE	VERY STIFF
-	25	96.5	••••••••••••••••••••••••••	25+	MEDIUM DENSE	VERY STIFF
- 5 ft						
-						
-						
- 6 ft						
-						
- 2 m						
- 7 ft						
-						
-						
- 8 ft						
-						
-						
- 9 ft						
-						
-						
- 3 m 10 ft						
-						
-						
-						
- 11 ft						
-						
-						
- 12 ft						
-						
-						
- 4 m 13 ft						

LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM OSIP DEM. HOLE DRY BEFORE CORING. HOLE ADVANCED WITH HANDHELD NX CORE DRILL.


DEL-315-6.40
B001-0-17
15.5'-20.5'
20.5'-25.5'
07/24/2017


DEL-315-6.40
B002-0-17
9.0' - 19.0'
07/24/2017


DEL-315-6.40
B-003-0-17
10.5 to 20.5'
HELIX


DEL-315-6.40
B004-0-17
R-1 12.0' to 22.0'
STAINLESS STEEL RULER
FLEXIBLE
HELIX
NON-SKID


DEL-315-6.40
B005-0-17
R-1 7.5' to 17.5'


DEL-315-6.40
B006-0-17
6.1' - 11.3'
N DIV.
07/24/2017


DEL-315-6.40
B007-0-17
7.7'- 12.7'
07/24/2017

APPENDIX A.3
DEL-315-8.10

PROJECT: DEL-315-08.10	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 1436+45, 8' RT.	EXPLORATION ID B-001-0-17
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / CHUDZIK	HAMMER: CME AUTOMATIC	ALIGNMENT: CENTERLINE OF SR 315	
PID: 102124 SFN: N/A	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 6/1/17	ELEVATION: 841.7 (MSL) EOB: 19.0 ft.	PAGE 1 OF 1
START: 7/19/17 END: 7/19/17	SAMPLING METHOD: SPT / NQ2	ENERGY RATIO (%): 77	LAT / LONG: 40.251238, -83.061525	

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
ASPHALT (23")	841.7																		
	839.8																		
STIFF, DARK BROWN, **SANDY SILT**, SOME CLAY, LITTLE GRAVEL, DAMP			9 5 4	12	50	SS-1A	2.00	-	-	-	-	-	-	-	-	15	A-4a (V)	-	
			2 2 2	5	56	SS-2A	1.50	10	8	13	40	29	27	18	9	13	A-4a (7)	-	
@6.0'; VERY STIFF			2 5 6	14	67	SS-3A	2.50	-	-	-	-	-	-	-	-	15	A-4a (V)	-	
	833.2																		
HARD, DARK BROWN, **SILT AND CLAY**, LITTLE SAND, LITTLE GRAVEL, DAMP			4 7 10	22	94	SS-4A	4.50	-	-	-	-	-	-	-	-	15	A-6a (V)	-	
			5 6 8	18	83	SS-5A	4.00	11	6	12	33	38	31	17	14	14	A-6a (9)	-	
	827.7	TR	50/4"	-	83	SS-6A	4.50	-	-	-	-	-	-	-	-	15	A-6a (V)	-	
LIMESTONE, LIGHT GRAY, SLIGHTLY WEATHERED, VERY STRONG, THIN BEDDED, PYRITIC, CRYSTALLINE, JOINT, MODERATELY FRACTURED, OPEN, VERY ROUGH; BLOCKY, GOOD; RQD 70%, REC 88%. @ 16.1' - 16.5'; γ = 166 pcf; Qu = 20,451 psi	822.7	EOB																	

NOTES: HOLE DRY BEFORE CORING. LAT/LONG/ELEV FROM OGE HANDHELD GPS UNIT.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 75 LB. BENTONITE CHIPS

PROJECT: DEL-315-08.10	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 1436+62, 16' LT.	EXPLORATION ID B-002-0-17
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / CHUDZIK	HAMMER: CME AUTOMATIC	ALIGNMENT: CENTERLINE OF SR 315	
PID: 102124 SFN: N/A	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 6/1/17	ELEVATION: 841.6 (MSL) EOB: 17.5 ft.	PAGE 1 OF 1
START: 7/19/17 END: 7/20/17	SAMPLING METHOD: SPT / NQ2	ENERGY RATIO (%): 77	LAT / LONG: 40.251249, -83.061628	

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
TOPSOIL (4")	841.6																		
	840.1	1																	
STIFF TO VERY STIFF, DARK BROWN, **SANDY SILT**, SOME CLAY, LITTLE GRAVEL, MODERATELY ORGANIC (LOI = 4.2%), DAMP		2	0 2 3	6	78	SS-1A	2.00	17	10	15	31	27	26	17	9	13	A-4a (5)	-	
		3																	
		4	2 2 4	8	78	SS-2A	2.50	-	-	-	-	-	-	-	-	17	A-4a (V)	-	
		5																	
@6.0'; BROWN, TRACE GRAVEL AND STONE FRAGMENTS, MOIST		6	2 4 5	12	61	SS-3A	1.50	8	10	20	36	26	26	17	9	19	A-4a (5)	-	
	833.1	7																	
		8																	
STIFF, BROWN, **SILT AND CLAY**, SOME SAND, TRACE GRAVEL AND STONE FRAGMENTS, SLIGHTLY ORGANIC (LOI = 3.8%), MOIST		9	1 1 6	9	67	SS-4A	1.00	5	8	15	40	32	33	20	13	24	A-6a (9)	-	
		10																	
@11.0'; VERY STIFF, DARK BROWN AND REDDISH BROWN	829.6	11																	
	TR	12	4 11 11	28	78	SS-5A	2.00	-	-	-	-	-	-	-	-	28	A-6a (V)	-	
LIMESTONE, LIGHT GRAY, MODERATELY WEATHERED, VERY STRONG, THIN BEDDED, PYRITIC, CRYSTALLINE, JOINT, FRACTURED, OPEN, VERY ROUGH; BLOCKY, FAIR; RQD 7%, REC 90%. @12.8' - 13.1'; CLAY SEAM @13.2' - 16.0'; HIGH ANGLE FRACTURE		13																	
		14																	
		15																	
		16																	
	824.1	17																	
	EOB																		

NOTES: HOLE DRY BEFORE CORING. LAT/LONG/ELEV FROM OGE HANDHELD GPS UNIT.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 75 LB. BENTONITE CHIPS

WILDCAT DYNAMIC CONE LOG

The Ohio Department of Transportation
Office of Geotechnical Engineering
1600 West Broad Street, Columbus, Ohio 43223

PROJECT NUMBER: 102124
DATE STARTED: 08-22-2017
DATE COMPLETED: 08-22-2017

HOLE #: D-001-1-17
CREW: J. Lautanen & A. Jalbrzikowski
PROJECT: DEL-315-8.10
LAT/LONG: 40.249985635,-83.060284535
LOCATION: Delaware County, Ohio

SURFACE ELEVATION: 831.7
WATER ON COMPLETION: none observed
HAMMER WEIGHT: 35 lbs.
CONE AREA: 10 sq. cm

DEPTH	BLOWS PER 10 cm	RESISTANCE Kg/cm²	GRAPH OF CONE RESISTANCE 0 50 100 150	N'	TESTED CONSISTENCY NON-COHESIVE	TESTED CONSISTENCY COHESIVE
-	6	26.6	•••••••	7	LOOSE	MEDIUM STIFF
-	44	195.4	••	25+	VERY DENSE	HARD
- 1 ft	29	128.8	••••••••••••••••••••••••••••••••••	25+	DENSE	HARD
-	22	97.7	••••••••••••••••••••••••••	25+	MEDIUM DENSE	VERY STIFF
-	25	111.0	••••••••••••••••••••••••••••••	25+	DENSE	HARD
- 2 ft						
-						
-						
- 3 ft						
- 1 m						
-						
- 4 ft						
-						
-						
- 5 ft						
-						
-						
- 6 ft						
-						
- 2 m						
- 7 ft						
-						
-						
- 8 ft						
-						
-						
- 9 ft						
-						
-						
- 3 m 10 ft						
-						
-						
-						
- 11 ft						
-						
-						
- 12 ft						
-						
-						
- 4 m 13 ft						

LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM OSIP DEM.

DEL-315-8.17
B00.1-0-17
14'-19'

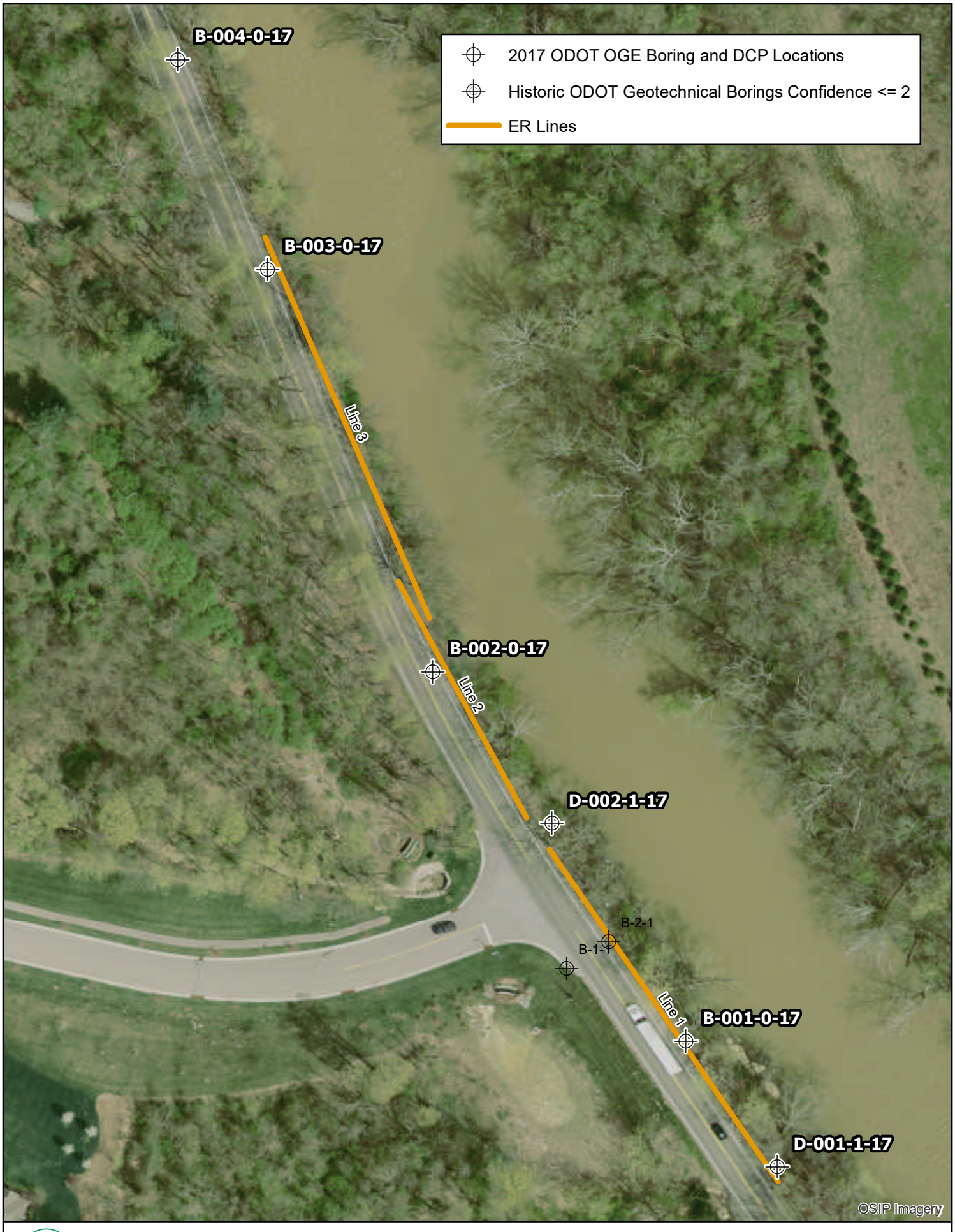
07/25/2017

DEL-315-8.17
B002-0-17
12'-17'

07/25/2017

APPENDIX B
ODOT RESISTIVITY RESULTS

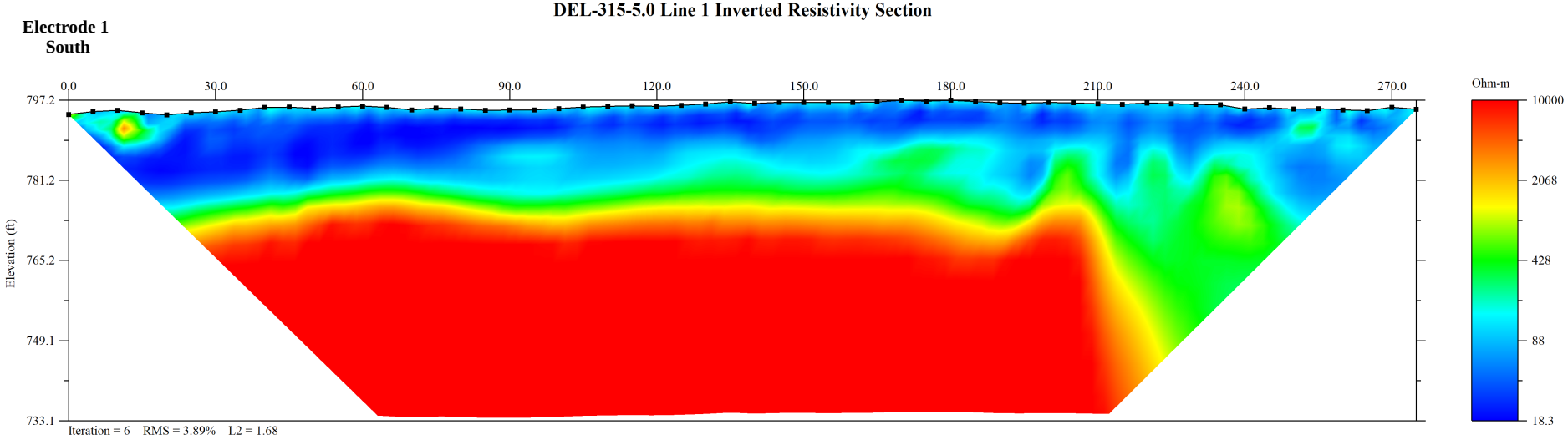
APPENDIX B.1
DEL-315-5.0



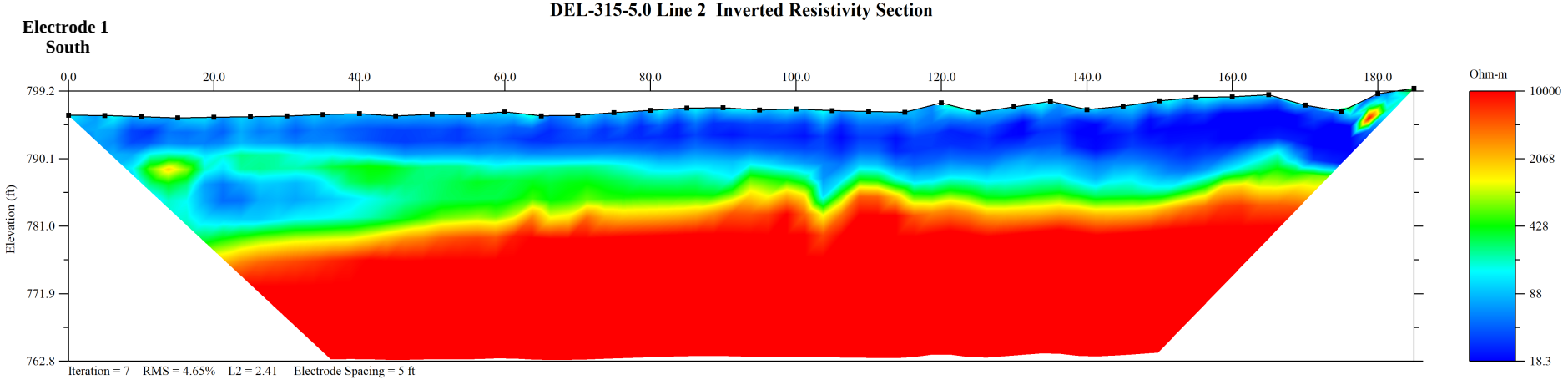
DEL-315-5.0
Exploration Plan

0 25 50 100
Feet

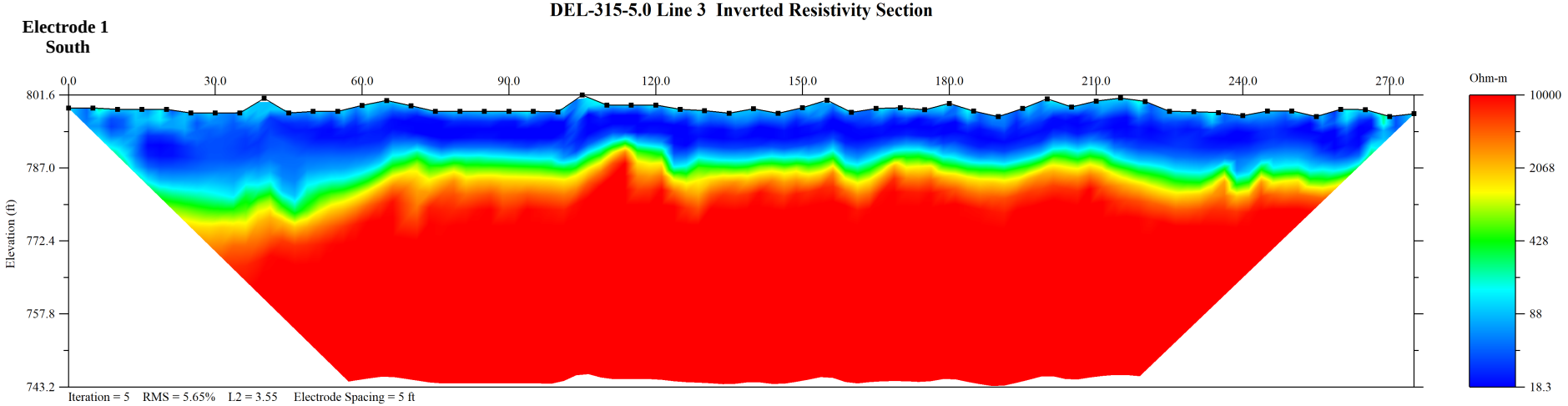
DEL-315-5.0 Line 1 Inverted Resistivity Section

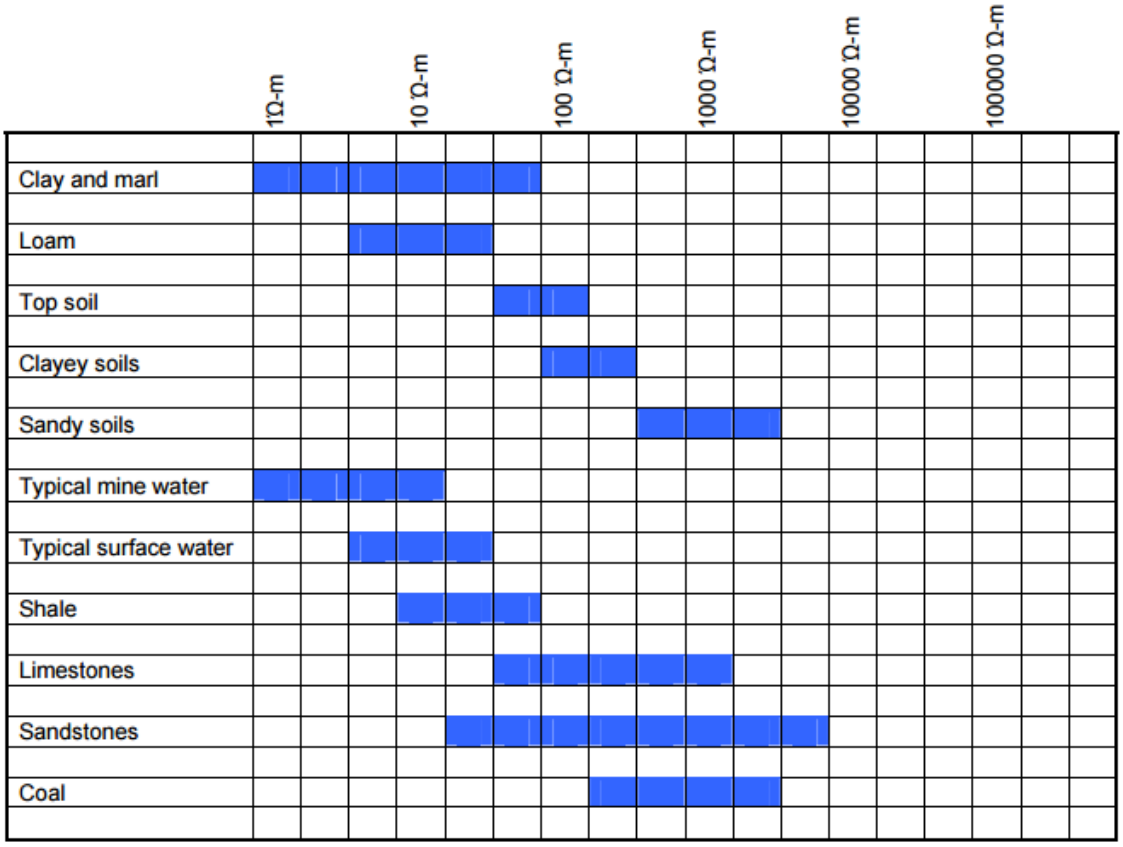


DEL-315-5.0 Line 2 Inverted Resistivity Section



DEL-315-5.0 Line 3 Inverted Resistivity Section

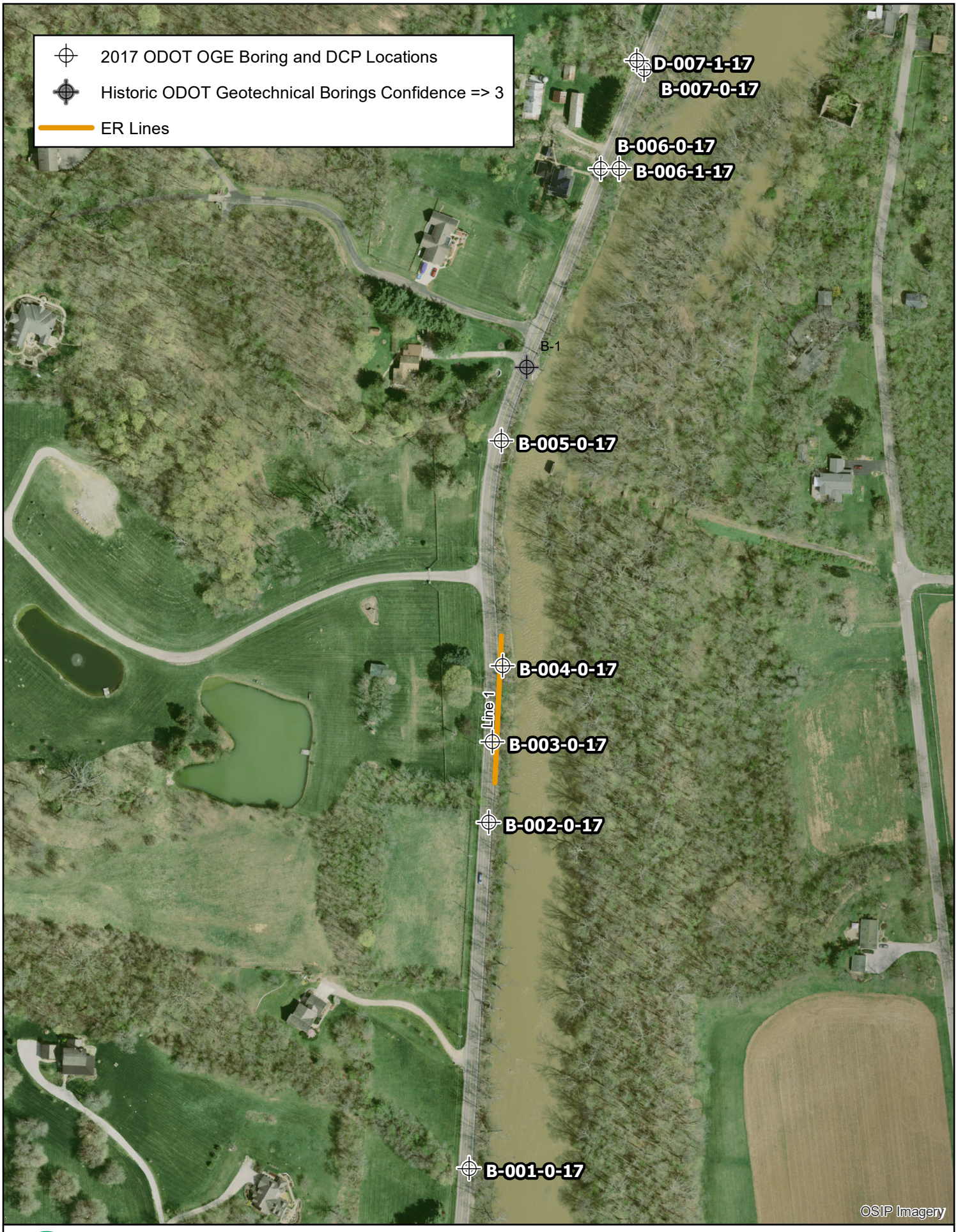




Typical resistivity range of earth materials in ohm-meters

Johnson, J. (2003) Application of the Electrical Resistivity Method for Detection of Underground Mine Workings. Monroeville, PA. Retrieved December 17, 2015 from: https://www.fhwa.dot.gov/engineering/geotech/hazards/mine/workshops/ktwkshp/ky0311.pdf

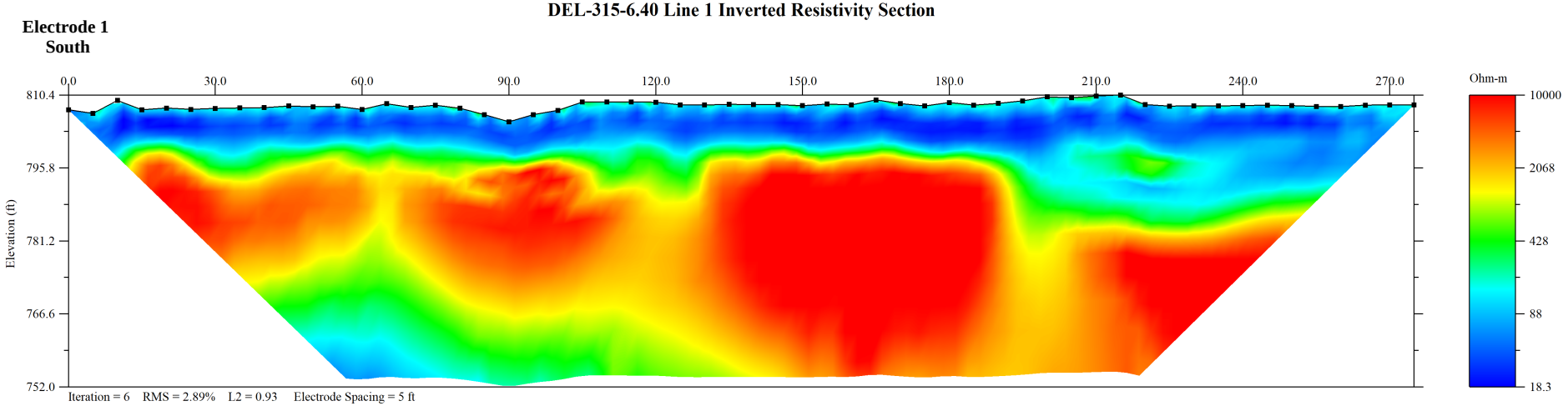
APPENDIX B.2
DEL-315-6.40

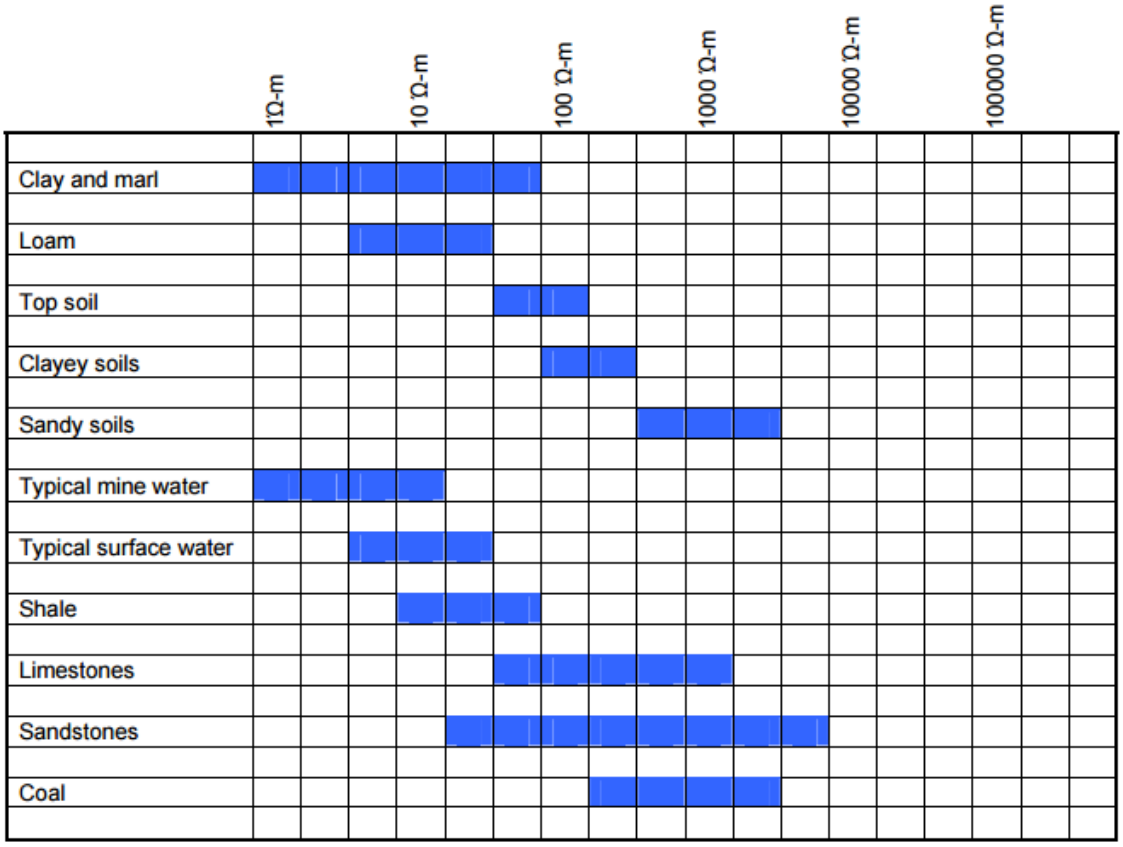


DEL-315-6.40
Exploration Plan

0 75 150 300
Feet

DEL-315-6.40 Line 1 Inverted Resistivity Section

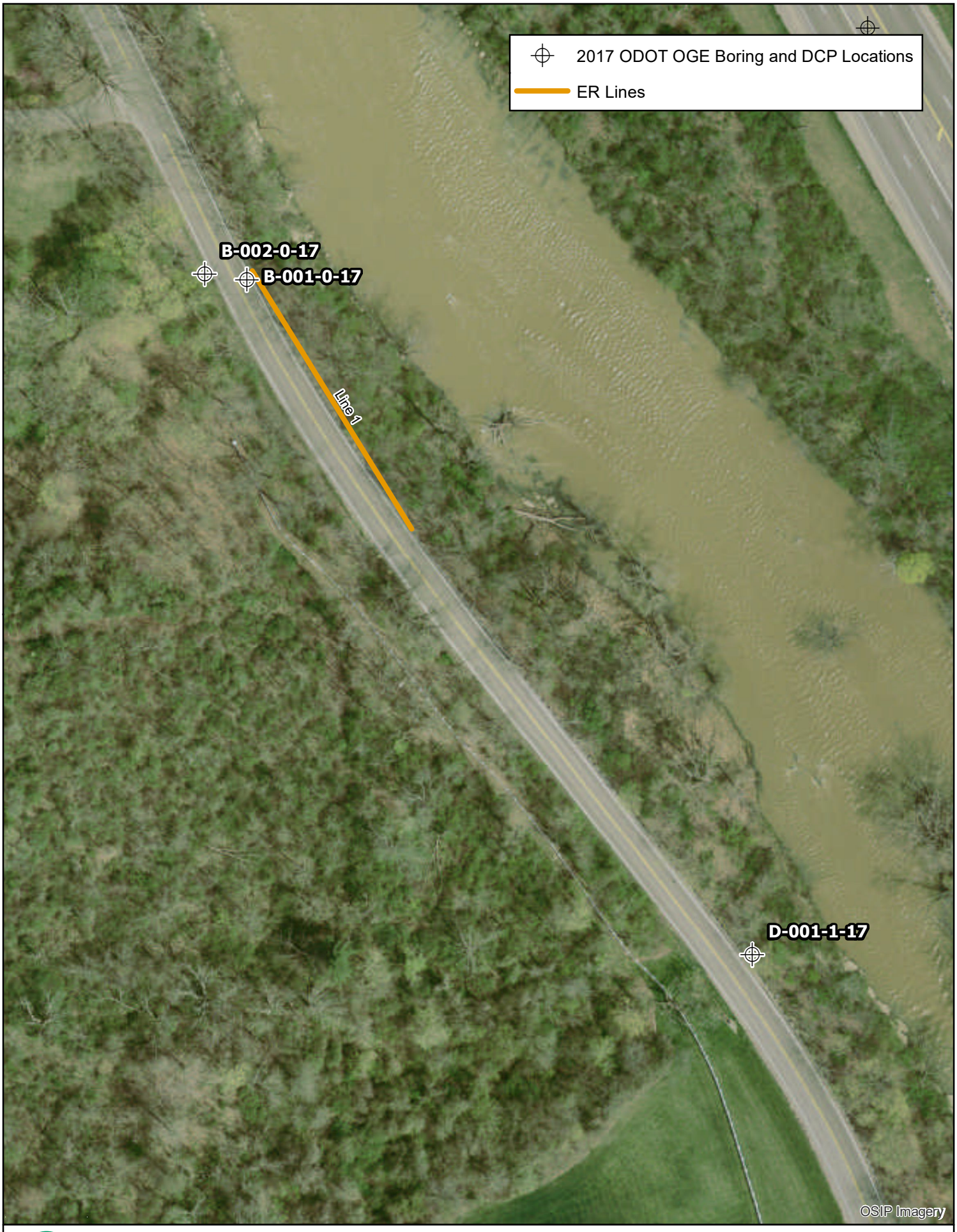




Typical resistivity range of earth materials in ohm-meters

Johnson, J. (2003) Application of the Electrical Resistivity Method for Detection of Underground Mine Workings. Monroeville, PA. Retrieved December 17, 2015 from: https://www.fhwa.dot.gov/engineering/geotech/hazards/mine/workshops/ktwkshp/ky0311.pdf

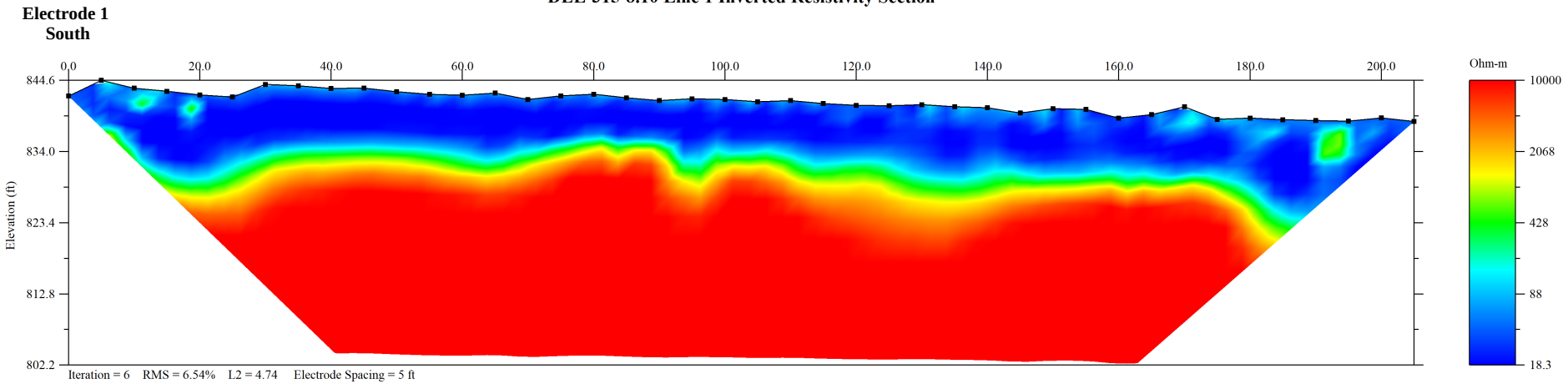
APPENDIX B.3
DEL-315-8.10

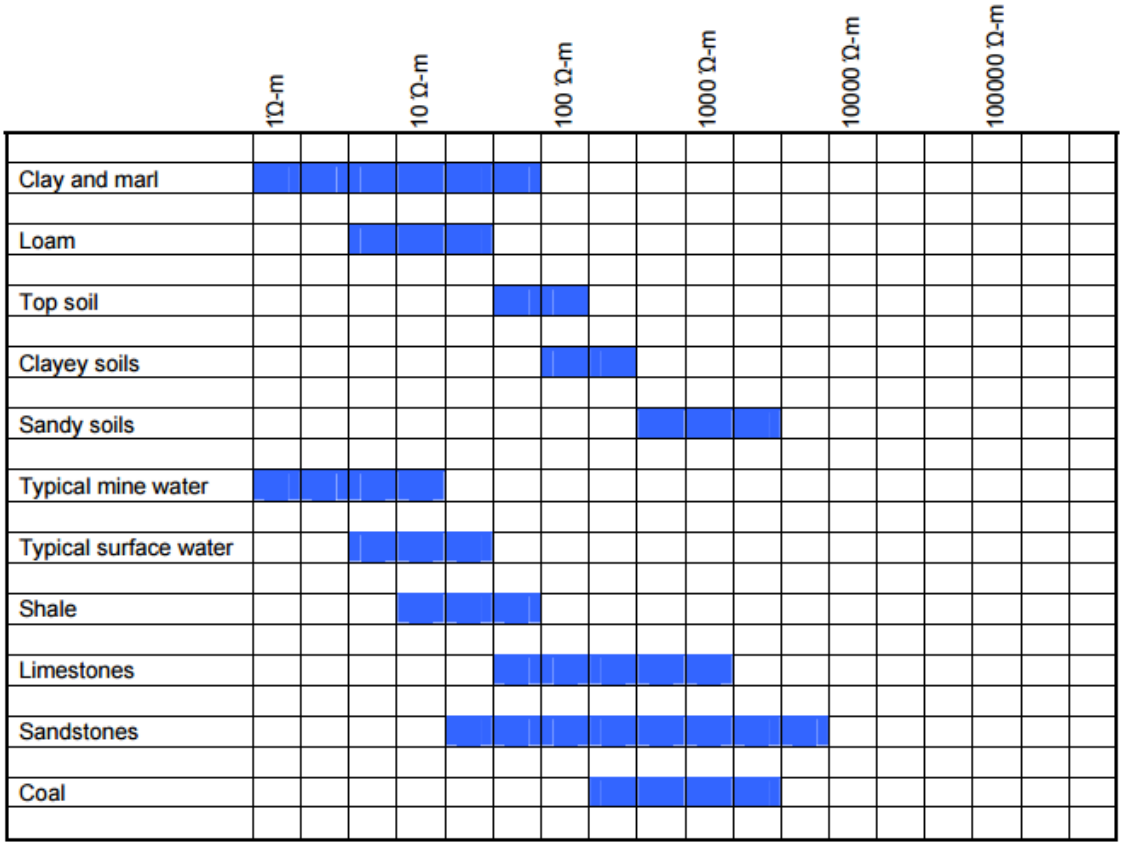


DEL-315-8.10
Exploration Plan

0 25 50 100
Feet

DEL-315-8.10 Line 1 Inverted Resistivity Section





Typical resistivity range of earth materials in ohm-meters

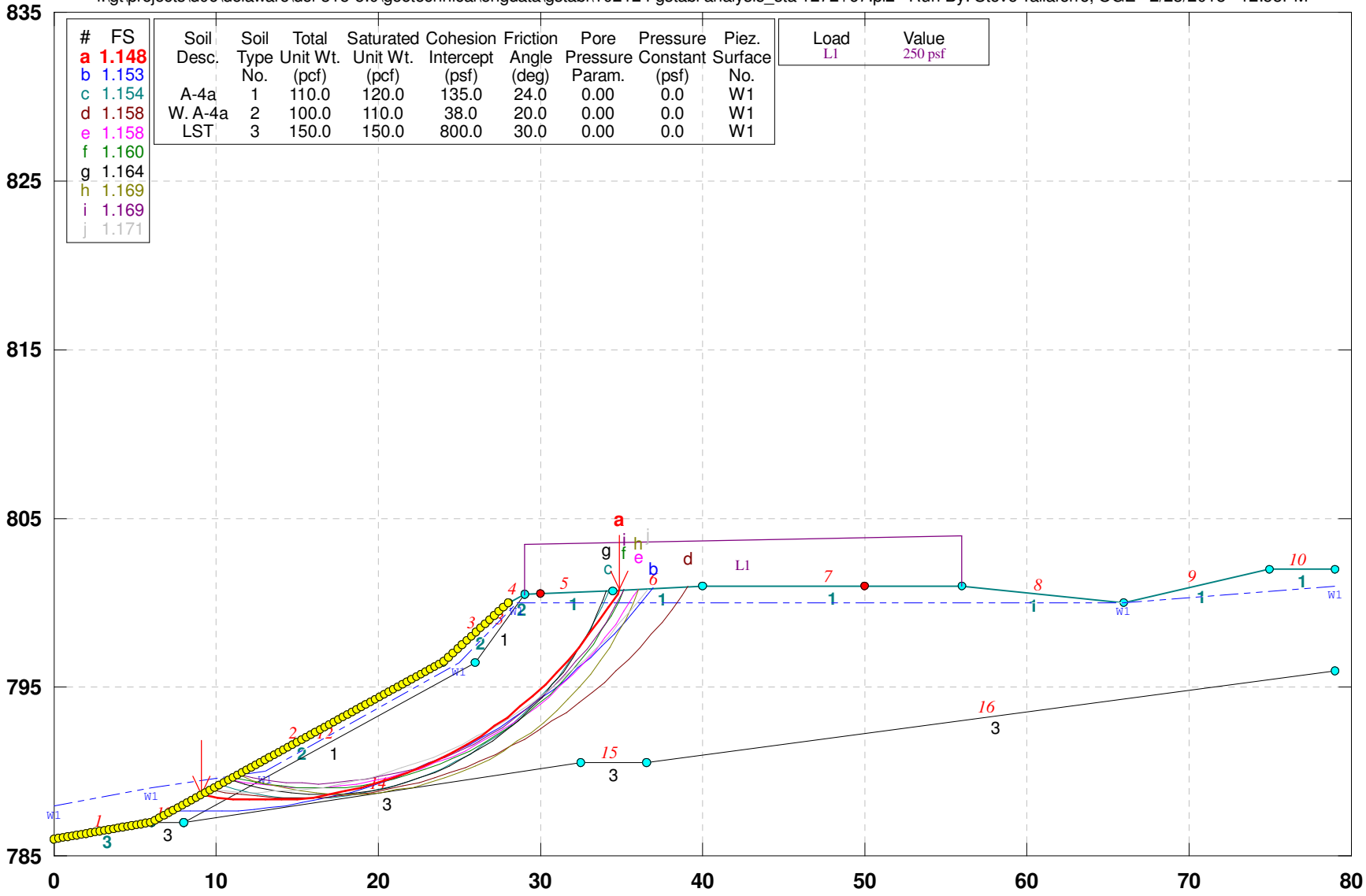
Johnson, J. (2003) Application of the Electrical Resistivity Method for Detection of Underground Mine Workings. Monroeville, PA. Retrieved December 17, 2015 from: https://www.fhwa.dot.gov/engineering/geotech/hazards/mine/workshops/ktwkshp/ky0311.pdf

APPENDIX C
SLOPE STABILITY ANALYSES
GSTABL AND UA SLOPE

APPENDIX C.1
DEL-315-5.0

102124 DEL-315-5.0, Sta. 1272+67, B-004-0-17

i:\gt\projects\d06\delaware\del-315-5.0\geotechnical\engdata\gstabl\102124 gstabl analysis_sta 1272+67.pl2 Run By: Steve Taliaferro, OGE 2/23/2018 12:58PM



#	FS
a	1.148
b	1.153
c	1.154
d	1.158
e	1.158
f	1.160
g	1.164
h	1.169
i	1.169
j	1.171

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
A-4a	1	110.0	120.0	135.0	24.0	0.00	0.0	W1
W. A-4a	2	100.0	110.0	38.0	20.0	0.00	0.0	W1
LST	3	150.0	150.0	800.0	30.0	0.00	0.0	W1

Load	Value
L1	250 psf

GSTABL7 v.2 FSmin=1.148

Safety Factors Are Calculated By The Modified Bishop Method

GSTABL7

UA Slope Program Version 2.3 - I:\gt\Projects\D06\Delaware\DEL-315-5.0\Geotechnical\EngData\UA Slope\1272_67.ua3*

File Run Options Help

Calculated Results

Factor of Safety: 1.93

Force per Shaft: 7523.807 lb

Acting Point X: 52.500 ft Y: 7.640 ft

Analysis Unit System

(•) English ( ) Metric

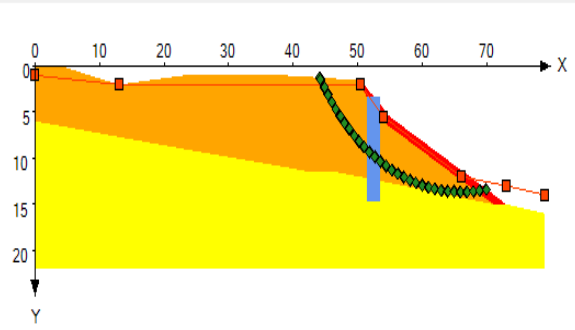
Number of Vertical Sections and Soil Layers

Vertical Section Num: 15 Soil Layer Num: 3

Analysis Method

( ) Total Stress (•) Effective Stress

Chart (Double-Click for More Options)



Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
Layer1	38.0	20.0	100.0
Layer2	135.0	24.0	110.0
Layer3	800.0	30.0	150.0

Slope Profile Vertical Sections

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Section 10	Section 11	Section 12	Section 13	Section 14
X (ft)	0.00	4.00	13.00	23.00	39.00	42.50	44.50	46.50	50.00	51.00	53.00	55.00	71.00	73.00
Y1 (ft)	0.00	0.00	2.00	1.00	1.00	1.15	1.25	1.35	1.50	2.00	3.75	5.50	13.90	15.00
Y2 (ft)	0.00	0.00	2.00	1.00	1.00	1.15	1.25	1.35	1.50	2.80	5.50	6.60	15.00	15.00
Y3 (ft)	6.00	6.50	7.70	9.00	11.00	11.50	11.50	11.50	12.00	12.10	12.40	12.70	15.00	15.00
Y4 (ft)	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00

Coordinates of Crest X: 50.00 ft Y: 1.50 ft Coordinates of Toe X: 79.00 ft Y: 16.00 ft

Drilled Shaft Information

( ) Calculate without Drilled Shaft

( ) Automatic Load Transfer Factor

(•) Manually Defined Load Transfer Factor

[ ] Anchor (On/Off)

Anchor force: 0.00 lb

Anchor angle: 0.00

Anchor spacing: 0.00 ft

Auto ( ) On (•) Off 0.000 (η)

Xmin 0.00 Diameter: 2.00 ft

Xmax 0.00 CTC Spacing: 4.00 ft

XDelta 0.00 X Coordinate: 52.50 ft

[ ] Auto Save Data

Run

Pore Water Pressure

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

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
X (ft)	0.00	13.00	50.50	54.00	66.00	73.00	79.00
Y (ft)	1.00	2.00	2.00	5.50	12.00	13.00	14.00

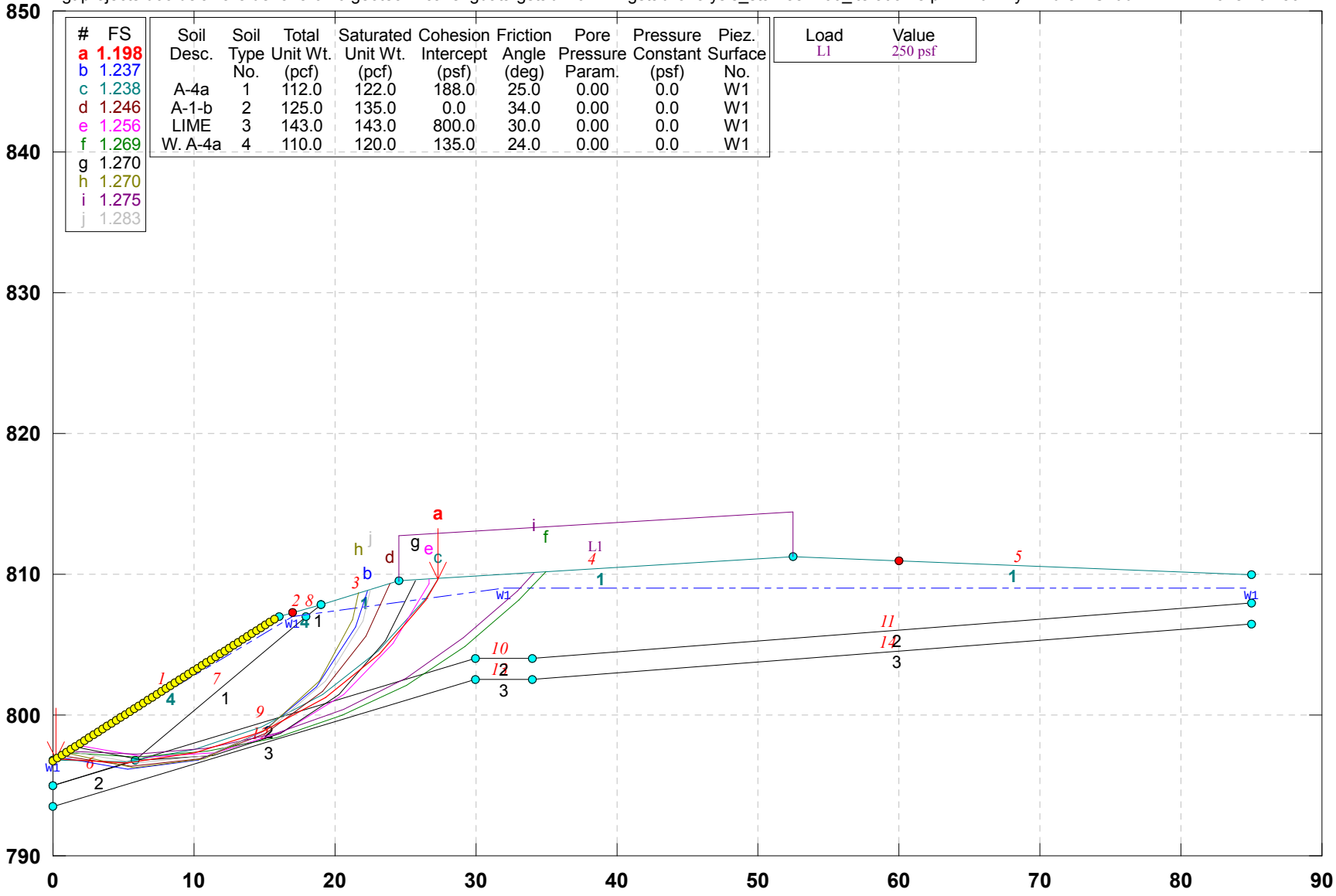
Slip Surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7	Point 8	Point 9	Point 10	Point 11	Point 12	Point 13	Point 14	Point 15	Point 16	Point 17	Po
X (ft)	44.16	44.29	44.83	45.40	46.00	46.63	47.29	47.98	48.70	49.45	50.22	51.01	51.83	52.67	53.53	54.41	55.31	56.2
Y (ft)	1.24	1.45	2.29	3.11	3.91	4.69	5.44	6.16	6.85	7.52	8.16	8.76	9.34	9.88	10.39	10.86	11.30	11.7

APPENDIX C.2
DEL-315-6.40

102124 DEL-315-6.40, Sta. 1351+00, B-005-0-17, Water in Soil, Weakened Soil

i:\gt\projects\d06\delaware\del-315-6.40\geotechnical\engdata\gstabl\102124 gstabl analysis_sta 1351+00_iteration 8.pl2 Run By: Andrew Chudzik 2/27/2018 07:50AM



GSTABL7 v.2 FSmin=1.198

Safety Factors Are Calculated By The Modified Bishop Method

UA Slope Program Version 2.3 - I:\gt\Projects\D06\Delaware\DEL-315-6.40\Geotechnical\EngData\UA Slope\102124_Slope Analysis (6.40).ua3*

File Run Options Help

Calculated Results

Factor of Safety: 1.31

Force per Shaft: 2264.379 lb

Acting Point X: 63.440 ft Y: 8.520 ft

Analysis Unit System

(•) English ( ) Metric

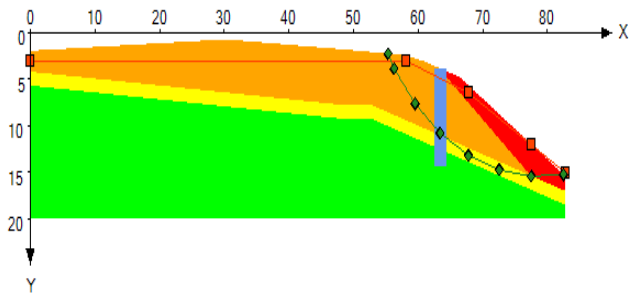
Number of Vertical Sections and Soil Layers

Vertical Section Num: 10 Soil Layer Num: 4

Analysis Method

( ) Total Stress (•) Effective Stress

Chart (Double-Click for More Options)



Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
Layer1	135.0	24.0	120.0
Layer2	188.0	25.0	122.0
Layer3	0.0	34.0	135.0
Layer4	800.0	30.0	143.0

Slope Profile Vertical Sections

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Section 10
X (ft)	0.00	30.25	48.91	52.91	58.06	61.12	63.16	66.43	77.39	82.67
Y1 (ft)	1.92	0.69	1.80	2.07	2.39	3.11	3.76	4.76	11.92	15.37
Y2 (ft)	1.92	0.69	1.80	2.07	2.39	3.11	3.76	6.43	15.37	17.00
Y3 (ft)	4.17	6.42	7.80	7.80	9.39	10.34	10.97	11.98	15.37	17.00
Y4 (ft)	5.67	7.92	9.30	9.30	10.89	11.84	12.47	13.48	16.87	18.50
Y5 (ft)	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00

Coordinates of Crest X: 0.00 ft Y: 1.00 ft Coordinates of Toe X: 0.00 ft Y: 23.25 ft

Drilled Shaft Information

( ) Calculate without Drilled Shaft

( ) Automatic Load Transfer Factor

(•) Manually Defined Load Transfer Factor

[ ] Anchor (On/Off)

Anchor force: 0.00 lb

Anchor angle: 0.00

Anchor spacing: 0.00 ft

Auto ( ) On (•) Off 0.000 (η)

Xmin 0.00 Diameter: 2.00 ft

Xmax 0.00 CTC Spacing: 2.00 ft

XDelta 0.00 X Coordinate: 63.44 ft

[ ] Auto Save Data

Run

Pore Water Pressure

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

	Point 1	Point 2	Point 3	Point 4	Point 5
X (ft)	0.00	58.06	67.71	77.39	82.67
Y (ft)	3.00	3.00	6.43	11.98	15.00

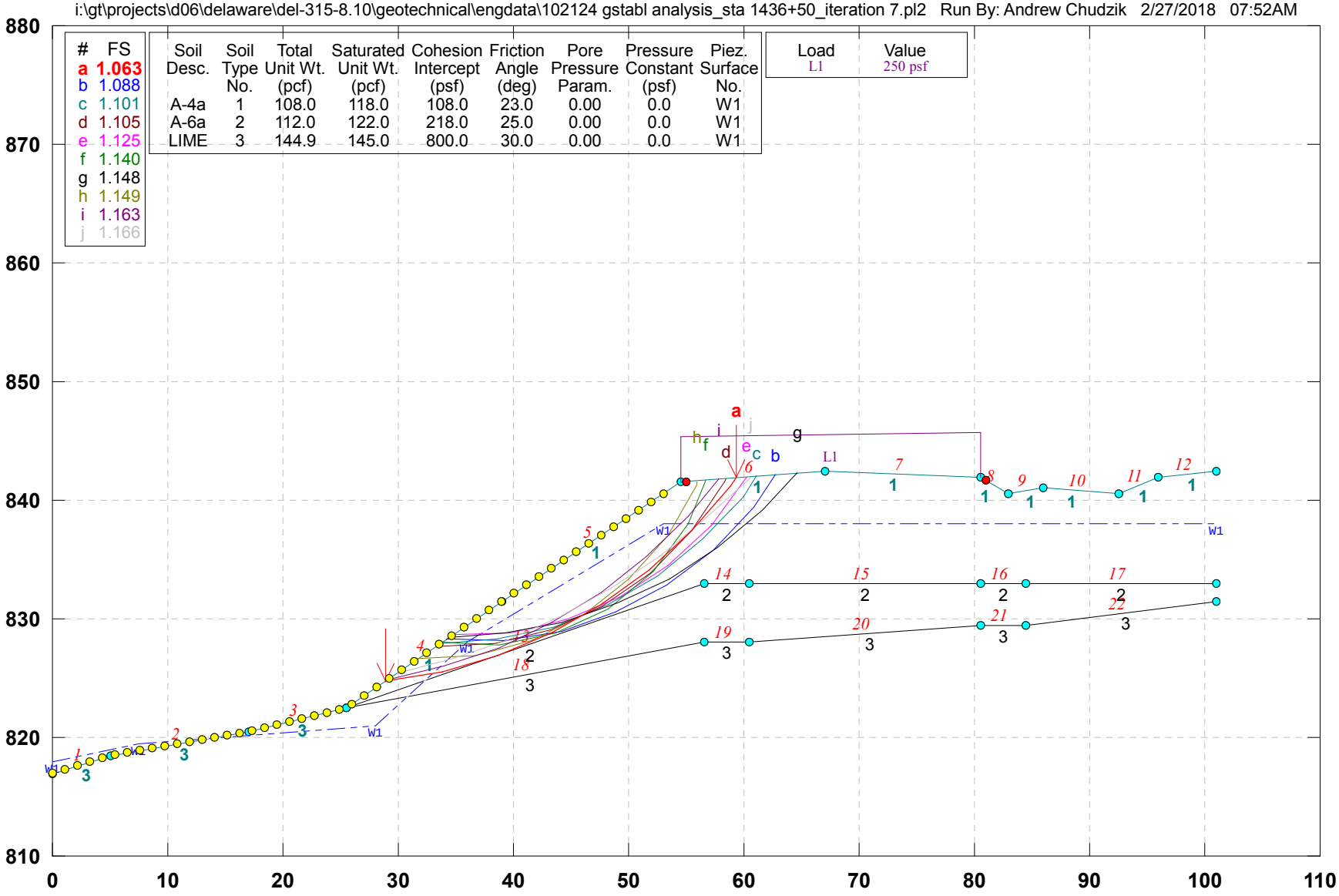
Slip Surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7	Point 8
X (ft)	55.35	56.28	59.52	63.40	67.79	72.53	77.48	82.48
Y (ft)	2.22	3.84	7.64	10.80	13.20	14.77	15.46	15.24

APPENDIX C.3
DEL-315-8.10

102124 DEL-315-8.10, Sta. 1436+25, B-002-0-17

i:\gt\projects\d06\delaware\del-315-8.10\geotechnical\engdata\102124 gstabl analysis_sta 1436+50_iteration 7.pl2 Run By: Andrew Chudzik 2/27/2018 07:52AM



GSTABL7 v.2 FSmin=1.063

Safety Factors Are Calculated By The Modified Bishop Method

UA Slope Program Version 2.3 - I:\gt\Projects\D06\Delaware\DEL-315-8.10\Geotechnical\EngData\UA Slope\102124_Slope Analysis (8.10).ua3*

File Run Options Help

Calculated Results

Factor of Safety: 1.31

Force per Shaft: 5569.685 lb

Acting Point X: 50.680 ft Y: 25.239 ft

Analysis Unit System

(•) English ( ) Metric

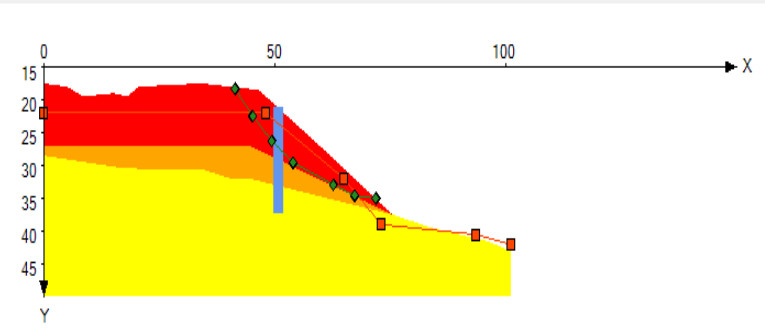
Number of Vertical Sections and Soil Layers

Vertical Section Num: 16 Soil Layer Num: 3

Analysis Method

( ) Total Stress (•) Effective Stress

Chart (Double-Click for More Options)



Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
Layer1	108.0	23.0	118.0
Layer2	218.0	25.0	122.0
Layer3	800.0	30.0	145.0

Slope Profile Vertical Sections

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Section 10	Section 11	Section 12	Section 13	Section 14
X (ft)	0.00	5.00	8.50	15.00	16.50	18.00	20.50	34.00	40.50	44.50	46.50	62.00	75.50	84.00
Y1 (ft)	17.50	18.00	19.50	19.00	19.25	19.50	18.00	17.50	18.02	18.34	18.50	28.50	37.50	39.50
Y2 (ft)	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.68	32.93	37.50	39.50
Y3 (ft)	28.50	29.06	29.44	30.17	30.33	30.33	30.50	30.50	32.00	32.00	32.35	35.10	37.50	39.50
Y4 (ft)	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00

Coordinates of Crest X: 46.50 ft Y: 18.50 ft Coordinates of Toe X: 75.50 ft Y: 37.50 ft

Drilled Shaft Information

( ) Calculate without Drilled Shaft

( ) Automatic Load Transfer Factor

(•) Manually Defined Load Transfer Factor

[ ] Anchor (On/Off)

Anchor force: 0.00 lb

Anchor angle: 0.00

Anchor spacing: 0.00 ft

Auto ( ) On (•) Off 0.000 (n)

Xmin 0.00 Diameter: 2.00 ft

Xmax 0.00 CTC Spacing: 4.00 ft

XDelta 0.00 X Coordinate: 50.68 ft

[ ] Auto Save Data

Run

Pore Water Pressure

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

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6
X (ft)	0.00	48.00	65.00	73.00	93.50	101.00
Y (ft)	22.00	22.00	32.00	39.00	40.50	42.00

Slip Surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
X (ft)	41.42	45.17	49.33	53.92	62.67	67.25	71.83
Y (ft)	18.33	22.50	26.25	29.58	32.92	34.58	35.00

APPENDIX D
LPILE ANALYSIS

APPENDIX D.1
DEL-315-5.0

==
LPile for Windows, Version 2016-09.010
Analysis of Individual Piles and Drilled Shafts
Subjected to Lateral Loading Using the p-y Method

==
This copy of LPile is being used by:

odot
1980 west broad st, columbus,oh

Serial Number of Security Device: 228746756

This copy of LPile is licensed for exclusive use by:

Ohio Dept. of Transportation, Co

Use of this program by any entity other than Ohio Dept. of Transportation, Co
is a violation of the software license agreement.

Files Used for Analysis

Path to file locations:
\gt\Projects\D06\Delaware\DEL-315-5.0\Geotechnical\EngData\LPILE\

Name of input data file:
24in_HP12_53_6ftsocket_factored.lp9d

Name of output report file:
24in_HP12_53_6ftsocket_factored.lp9o

Name of plot output file:
24in_HP12_53_6ftsocket_factored.lp9p

Name of runtime message file:
24in_HP12_53_6ftsocket_factored.lp9r

Date and Time of Analysis

Date: March 1, 2018 Time: 8:56:07

Problem Title

Project Name: DEL-315-5.00
Job Number: 102124
Client:

Engineer: Taliaferro
Description: Plug Pile Wall

Program Options and Settings

Computational Options:
- Use unfactored loads in computations (conventional analysis)

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

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

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

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

Output Options:
- Output files use decimal points to denote decimal symbols.
- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (nodal spacing of output points) = 1
- No p-y curves to be computed and reported for user-specified depths
- Print using wide report formats

Pile Structural Properties and Geometry

Number of pile sections defined = 1
Total length of pile = 16.000 ft
Depth of ground surface below top of pile = 3.4000 ft

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

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

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0	24
2	16	24

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is an elastic pile
Cross-sectional Shape = Circular Pile
Length of section = 16.000000 ft
Width of top of section = 24.000000 in
Width of bottom of section = 24.000000 in
Top Area = 15.500000 sq. in
Bottom Area = 15.500000 sq. in
Moment of Inertia at Top = 393.000000 in^4
Moment of Inertia at Bottom = 393.000000 in^4
Elastic Modulus = 29000000. psi

Ground Slope and Pile Batter Angles

Ground Slope Angle = 0.000 degrees
= 0.000 radians

Pile Batter Angle = 0.000 degrees
= 0.000 radians

Soil and Rock Layering Information

The soil profile is modelled using 3 layers

Layer 1 is soft clay, p-y criteria by Matlock, 1970

Distance from top of pile to top of layer = 3.400000 ft
Distance from top of pile to bottom of layer = 5.400000 ft
Effective unit weight at top of layer = 37.600000 pcf
Effective unit weight at bottom of layer = 37.600000 pcf
Undrained cohesion at top of layer = 375.000000 psf
Undrained cohesion at bottom of layer = 375.000000 psf
Epsilon-50 at top of layer = 0.019400
Epsilon-50 at bottom of layer = 0.019400

Layer 2 is stiff clay with water-induced erosion

Distance from top of pile to top of layer = 5.400000 ft
Distance from top of pile to bottom of layer = 10.000000 ft
Effective unit weight at top of layer = 57.600000 pcf
Effective unit weight at bottom of layer = 57.600000 pcf
Undrained cohesion at top of layer = 1250. psf
Undrained cohesion at bottom of layer = 1250. psf
Epsilon-50 at top of layer = 0.008200
Epsilon-50 at bottom of layer = 0.008200
Subgrade k at top of layer = 0.0000 pci
Subgrade k at bottom of layer = 0.0000 pci

NOTE: Default values for subgrade k will be computed for this layer.

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

Distance from top of pile to top of layer = 10.000000 ft
Distance from top of pile to bottom of layer = 20.000000 ft
Effective unit weight at top of layer = 79.800000 pcf
Effective unit weight at bottom of layer = 79.800000 pcf
Uniaxial compressive strength at top of layer = 2000. psi
Uniaxial compressive strength at bottom of layer = 2000. psi
Initial modulus of rock at top of layer = 540000. psi
Initial modulus of rock at bottom of layer = 540000. psi
RQD of rock at top of layer = 30.000000 %
RQD of rock at bottom of layer = 30.000000 %
k rm of rock at top of layer = 0.0000500
k rm of rock at bottom of layer = 0.0000500

(Depth of the lowest soil layer extends 4.000 ft below the pile tip)

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Undrained Cohesion psf	Uniaxial qu psi	RQD %	E50 or krm	kpy pci	Rock Mass Modulus psi
1	Soft	3.4	37.6	375	--	--	0.0194	--	--
	Clay	5.4	37.6	375	--	--	0.0194	--	--
2	Stiff Clay	5.4	57.6	1250	--	--	0.0082	default	--
	with Free Wat	10	57.6	1250	--	--	0.0082	default	--
3	Weak	10	79.8	--	2000	30	5.00E-05	--	540000
	Rock	20	79.8	--	2000	30	5.00E-05	--	540000

p-y Modification Factors for Group Action

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

Point No.	Depth X ft	p-mult	y-mult
1	3.4	0.81	1
2	10	0.81	1

Static Loading Type

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

Distributed Lateral Loading for Individual Load Cases

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

---

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load No.	Load Type	Condition 1		Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length
1	1	V = 0.0000 lbs	M =	0.0000 in-lbs	0.00	Yes

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

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

---

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

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Moment-curvature properties were derived from elastic section properties

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Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	3.4	0	N.A.	No	0	5046
2	5.4	9.0583	No	No	5046	15338
3	10	6.6	No	Yes	N.A.	N.A.

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

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

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

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

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness in-lb^2	Soil Res. p lb/inch	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0	0.4519	6.52E-06	4.47E-08	-0.00501	1.99E-07	1.14E+10	0	0	134.566
0.16	0.4423	248.0321	264.7777	-0.00501	7.5735	1.14E+10	0	0	141.2441
0.32	0.4327	1017	544.5144	-0.00501	31.0457	1.14E+10	0	0	150.1482
0.48	0.4231	2339	841.347	-0.00501	71.4189	1.14E+10	0	0	159.0524
0.64	0.4135	4248	1155	-0.00501	129.6952	1.14E+10	0	0	167.9565
0.8	0.4039	6775	1486	-0.00501	206.8771	1.14E+10	0	0	176.8606
0.96	0.3942	9955	1834	-0.00501	303.9667	1.14E+10	0	0	185.7647
1.12	0.3846	13819	2200	-0.005	421.9664	1.14E+10	0	0	194.6689
1.28	0.375	18402	2582	-0.005	561.8783	1.14E+10	0	0	203.573
1.44	0.3654	23734	2981	-0.005	724.7048	1.14E+10	0	0	212.4771
1.6	0.3558	29850	3398	-0.00499	911.4481	1.14E+10	0	0	221.3812
1.76	0.3462	36782	3831	-0.00499	1123	1.14E+10	0	0	230.2854
1.92	0.3367	44563	4282	-0.00498	1361	1.14E+10	0	0	239.1895
2.08	0.3271	53225	4750	-0.00497	1625	1.14E+10	0	0	248.0936
2.24	0.3176	62803	5235	-0.00496	1918	1.14E+10	0	0	256.9977
2.4	0.3081	73327	5737	-0.00495	2239	1.14E+10	0	0	265.9018
2.56	0.2986	84832	6256	-0.00494	2590	1.14E+10	0	0	274.806

2.72	0.2891	97350	6792	-0.00492	2973	1.14E+10	0	0	283.7101
2.88	0.2797	110913	7345	-0.00491	3387	1.14E+10	0	0	292.6142
3.04	0.2703	125556	7916	-0.00489	3834	1.14E+10	0	0	301.5183
3.2	0.2609	141310	8503	-0.00486	4315	1.14E+10	0	0	310.4225
3.36	0.2516	158208	9108	-0.00484	4831	1.14E+10	0	0	319.3266
3.52	0.2423	176284	9686	-0.00481	5383	1.14E+10	-45.6374	361.5873	328.2307
3.68	0.2331	195401	10236	-0.00478	5966	1.14E+10	-45.882	377.8802	337.1348
3.84	0.224	215592	10804	-0.00474	6583	1.14E+10	-46.0932	395.1145	346.039
4	0.2149	236888	11388	-0.00471	7233	1.14E+10	-46.2701	413.3744	354.9431
4.16	0.2059	259323	11989	-0.00466	7918	1.14E+10	-46.4116	432.7534	363.8472
4.32	0.197	282927	12607	-0.00462	8639	1.14E+10	-46.5168	453.356	372.7513
4.48	0.1882	307735	13242	-0.00457	9396	1.14E+10	-46.5848	475.299	381.6554
4.64	0.1795	333777	13894	-0.00451	10192	1.14E+10	-46.6144	498.7135	390.5596
4.8	0.1708	361088	14563	-0.00446	11026	1.14E+10	-46.6047	523.7465	399.4637
4.96	0.1624	389699	15249	-0.00439	11899	1.14E+10	-46.5547	550.5638	408.3678
5.12	0.154	419644	15952	-0.00432	12814	1.14E+10	-46.4633	579.3521	417.2719
5.28	0.1457	450956	16673	-0.00425	13770	1.14E+10	-46.3295	610.3227	426.1761
5.44	0.1377	483668	16720	-0.00417	14768	1.14E+10	-765.444	10676	435.0802
5.6	0.1297	515162	16112	-0.00409	15730	1.14E+10	-747.906	11069	443.9843
5.76	0.122	545536	15555	-0.004	16658	1.14E+10	-729.219	11480	452.8884
5.92	0.1144	574891	15053	-0.0039	17554	1.14E+10	-707.549	11878	461.7926
6.08	0.107	603341	14612	-0.0038	18423	1.14E+10	-684.267	12282	470.6967
6.24	0.09976	631003	14233	-0.0037	19267	1.14E+10	-660.81	12718	479.6008
6.4	0.09276	657997	13917	-0.00359	20092	1.14E+10	-637.192	13189	488.5049
6.56	0.08597	684443	13244	-0.00348	20899	1.14E+10	-613.423	13701	61.6892
6.72	0.0794	708855	12149	-0.00336	21644	1.14E+10	-589.518	14256	0
6.88	0.07306	731094	11040	-0.00324	22323	1.14E+10	-565.49	14862	0
7.04	0.06695	751248	9977	-0.00312	22939	1.14E+10	-541.351	15525	0
7.2	0.06109	769406	8961	-0.00299	23493	1.14E+10	-517.114	16252	0
7.36	0.05548	785659	7992	-0.00286	23990	1.14E+10	-492.79	17054	0
7.52	0.05012	800094	7069	-0.00272	24430	1.14E+10	-468.39	17943	0
7.68	0.04502	812803	6193	-0.00259	24818	1.14E+10	-443.925	18932	0
7.84	0.04019	823876	5364	-0.00245	25157	1.14E+10	-419.405	20039	0
8	0.03562	833402	4583	-0.00231	25447	1.14E+10	-394.839	21285	0
8.16	0.03132	841473	3848	-0.00217	25694	1.14E+10	-370.237	22700	0
8.32	0.02729	848179	3161	-0.00203	25899	1.14E+10	-345.607	24318	0
8.48	0.02353	853611	2521	-0.00188	26064	1.14E+10	-320.957	26185	0
8.64	0.02006	857860	1928	-0.00174	26194	1.14E+10	-296.297	28365	0
8.8	0.01686	861016	1383	-0.00159	26291	1.14E+10	-271.633	30940	0
8.96	0.01393	863172	885.3943	-0.00145	26356	1.14E+10	-246.974	34029	0
9.12	0.01129	864416	434.8641	-0.0013	26394	1.14E+10	-222.328	37802	0
9.28	0.00893	864841	31.6314	-0.00116	26407	1.14E+10	-197.706	42510	0
9.44	0.00685	864538	-324.359	-0.00101	26398	1.14E+10	-173.117	48548	0
9.6	0.00504	863596	-633.187	-8.67E-04	26369	1.14E+10	-148.579	56566	0
9.76	0.00352	862106	-880.244	-7.21E-04	26324	1.14E+10	-108.773	59346	0
9.92	0.00227	860216	-1054	-5.76E-04	26266	1.14E+10	-72.0517	60839	0
10.08	0.00131	858060	-21009	-4.31E-04	26200	1.14E+10	-20714	3.04E+07	0

10.24	6.17E-04	779543	-59130	-2.93E-04	23803	1.14E+10	-18996	5.91E+07	0
10.4	1.80E-04	631000	-89195	-1.75E-04	19267	1.14E+10	-12322	1.31E+08	0
10.56	-5.30E-05	437033	-97249	-8.46E-05	13345	1.14E+10	3933	1.42E+08	0
10.72	-1.45E-04	257564	-82359	-2.61E-05	7865	1.14E+10	11577	1.53E+08	0
10.88	-1.53E-04	120773	-58630	5.74E-06	3688	1.14E+10	13141	1.65E+08	0
11.04	-1.23E-04	32426	-35232	1.86E-05	990.1054	1.14E+10	11231	1.76E+08	0
11.2	-8.18E-05	-14517	-16817	2.02E-05	443.2717	1.14E+10	7950	1.87E+08	0
11.36	-4.55E-05	-32152	-4692	1.62E-05	981.7546	1.14E+10	4680	1.98E+08	0
11.52	-1.95E-05	-32536	1837	1.08E-05	993.4759	1.14E+10	2121	2.09E+08	0
11.68	-4.09E-06	-25100	4323	5.92E-06	766.4214	1.14E+10	468.7694	2.20E+08	0
11.84	3.20E-06	-15936	4403	2.46E-06	486.6013	1.14E+10	-385.145	2.31E+08	0
12	5.35E-06	-8192	3387	4.26E-07	250.1339	1.14E+10	-673.65	2.42E+08	0
12.16	4.84E-06	-2931	2128	-5.11E-07	89.4938	1.14E+10	-637.722	2.53E+08	0
12.32	3.39E-06	-20.854	1069	-7.59E-07	0.6368	1.14E+10	-465.588	2.64E+08	0
12.48	1.92E-06	1173	357.0259	-6.62E-07	35.8128	1.14E+10	-275.734	2.75E+08	0
12.64	8.43E-07	1350	-28.2423	-4.50E-07	41.2252	1.14E+10	-125.587	2.86E+08	0
12.8	1.98E-07	1064	-178.163	-2.46E-07	32.5013	1.14E+10	-30.5804	2.97E+08	0
12.96	-1.03E-07	665.9783	-191.605	-1.01E-07	20.3352	1.14E+10	16.5789	3.08E+08	0
13.12	-1.89E-07	328.6555	-145.568	-1.68E-08	10.0353	1.14E+10	31.376	3.19E+08	0
13.28	-1.68E-07	106.9971	-87.7377	1.99E-08	3.2671	1.14E+10	28.8639	3.30E+08	0
13.44	-1.12E-07	-8.2574	-40.8706	2.82E-08	0.2521	1.14E+10	19.9561	3.41E+08	0
13.6	-5.94E-08	-49.9459	-11.2497	2.33E-08	1.5251	1.14E+10	10.899	3.53E+08	0
13.76	-2.27E-08	-51.4564	3.3338	1.48E-08	1.5712	1.14E+10	4.2922	3.64E+08	0
13.92	-2.61E-09	-37.1442	7.9441	7.31E-09	1.1342	1.14E+10	0.5102	3.75E+08	0
14.08	5.42E-09	-20.9511	7.3881	2.42E-09	0.6397	1.14E+10	-1.0893	3.86E+08	0
14.24	6.68E-09	-8.7737	5.0165	-8.23E-11	0.2679	1.14E+10	-1.3811	3.97E+08	0
14.4	5.11E-09	-1.6876	2.6494	-9.64E-10	0.05153	1.14E+10	-1.0846	4.08E+08	0
14.56	2.98E-09	1.4001	0.9833	-9.88E-10	0.04275	1.14E+10	-0.6509	4.19E+08	0
14.72	1.31E-09	2.0882	0.07597	-6.94E-10	0.06376	1.14E+10	-0.2942	4.30E+08	0
14.88	3.19E-10	1.6918	-0.2768	-3.75E-10	0.05166	1.14E+10	-0.07332	4.41E+08	0
15.04	-1.28E-10	1.0252	-0.3183	-1.47E-10	0.0313	1.14E+10	0.03015	4.52E+08	0
15.2	-2.44E-10	0.4696	-0.2329	-2.07E-11	0.01434	1.14E+10	0.05879	4.63E+08	0
15.36	-2.08E-10	0.1309	-0.1272	2.99E-11	0.004	1.14E+10	0.05126	4.74E+08	0
15.52	-1.29E-10	-0.01899	-0.04674	3.93E-11	5.80E-04	1.14E+10	0.03261	4.85E+08	0
15.68	-5.66E-11	-0.04863	-0.00138	3.36E-11	0.00148	1.14E+10	0.01464	4.96E+08	0
15.84	0	-0.0243	0.01266	2.75E-11	7.42E-04	1.14E+10	-7.10E-06	5.07E+08	0
16	4.88E-11	0	0	2.54E-11	0	1.14E+10	-0.01318	2.59E+08	0

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

Output Summary for Load Case No. 1:

Pile-head deflection = 0.45193820 inches
Computed slope at pile head = -0.00500942 radians
Maximum bending moment = 864841. inch-lbs
Maximum shear force = -97249. lbs
Depth of maximum bending moment = 9.28000000 feet below pile head

Depth of maximum shear force = 10.56000000 feet below pile head
Number of iterations = 13
Number of zero deflection points = 6

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

Boundary Condition Type 1, Shear and Moment

Shear = 0.0 lbs
Moment = 0.0 in-lbs
Axial Load = 0.0 lbs

Pile Length feet	Pile Head Deflection inches	Maximum Moment ln-lbs	Maximum Shear lbs
16	0.451938	864841	-97249
15.2	0.453096	879949	-100338
14.4	0.456223	874425	-99980
13.6	0.451424	865895	-97499
12.8	0.463669	882084	-99109
12	0.463675	889171	-101618
11.2	0.461901	882212	-104366
10.4	1.113438	672992	-70632

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

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

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	0	M, in-lb	0	0	0.4519	-0.00501	-97249	864841

Maximum pile-head deflection = 0.4519381961 inches
Maximum pile-head rotation = -0.0050094190 radians = -0.287019 deg.

Summary of Warning Messages

The following warning was reported 3042 times

**** Warning ****

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

The analysis ended normally.

==
LPile for Windows, Version 2016-09.010

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

==
This copy of LPile is being used by:

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Files Used for Analysis

Path to file locations:
\gt\Projects\D06\Delaware\DEL-315-5.0\Geotechnical\EngData\LPILE\

Name of input data file:
24in_HP12_53_6ftsocket_unfactored.lp9d

Name of output report file:
24in_HP12_53_6ftsocket_unfactored.lp9o

Name of plot output file:
24in_HP12_53_6ftsocket_unfactored.lp9p

Name of runtime message file:
24in_HP12_53_6ftsocket_unfactored.lp9r

Date and Time of Analysis

Date: February 26, 2018 Time: 9:56:19

Problem Title

Project Name: DEL-315-5.00
Job Number: 102124

Client:
Engineer: Taliaferro
Description: Plug Pile Wall

Program Options and Settings

Computational Options:
- Use unfactored loads in computations (conventional analysis)

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

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

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

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

Output Options:
- Output files use decimal points to denote decimal symbols.
- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (nodal spacing of output points) = 1
- No p-y curves to be computed and reported for user-specified depths
- Print using wide report formats

Pile Structural Properties and Geometry

Number of pile sections defined = 1
Total length of pile = 16.000 ft
Depth of ground surface below top of pile = 3.4000 ft

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

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

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0	24
2	16	24

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is an elastic pile
Cross-sectional Shape = Circular Pile
Length of section = 16.000000 ft
Width of top of section = 24.000000 in
Width of bottom of section = 24.000000 in
Top Area = 15.500000 sq. in
Bottom Area = 15.500000 sq. in
Moment of Inertia at Top = 393.000000 in^4
Moment of Inertia at Bottom = 393.000000 in^4
Elastic Modulus = 29000000. psi

Ground Slope and Pile Batter Angles

Ground Slope Angle = 0.000 degrees
= 0.000 radians

Pile Batter Angle = 0.000 degrees
= 0.000 radians

Soil and Rock Layering Information

The soil profile is modelled using 3 layers

Layer 1 is soft clay, p-y criteria by Matlock, 1970

Distance from top of pile to top of layer = 3.400000 ft
Distance from top of pile to bottom of layer = 5.400000 ft
Effective unit weight at top of layer = 37.600000 pcf
Effective unit weight at bottom of layer = 37.600000 pcf
Undrained cohesion at top of layer = 375.000000 psf
Undrained cohesion at bottom of layer = 375.000000 psf
Epsilon-50 at top of layer = 0.019400
Epsilon-50 at bottom of layer = 0.019400

Layer 2 is stiff clay with water-induced erosion

Distance from top of pile to top of layer = 5.400000 ft
Distance from top of pile to bottom of layer = 10.000000 ft
Effective unit weight at top of layer = 57.600000 pcf
Effective unit weight at bottom of layer = 57.600000 pcf
Undrained cohesion at top of layer = 1250. psf
Undrained cohesion at bottom of layer = 1250. psf
Epsilon-50 at top of layer = 0.008200
Epsilon-50 at bottom of layer = 0.008200
Subgrade k at top of layer = 0.0000 pci
Subgrade k at bottom of layer = 0.0000 pci

NOTE: Default values for subgrade k will be computed for this layer.

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

Distance from top of pile to top of layer = 10.000000 ft
Distance from top of pile to bottom of layer = 20.000000 ft
Effective unit weight at top of layer = 79.800000 pcf
Effective unit weight at bottom of layer = 79.800000 pcf
Uniaxial compressive strength at top of layer = 2000. psi
Uniaxial compressive strength at bottom of layer = 2000. psi
Initial modulus of rock at top of layer = 540000. psi
Initial modulus of rock at bottom of layer = 540000. psi
RQD of rock at top of layer = 30.000000 %
RQD of rock at bottom of layer = 30.000000 %
k rm of rock at top of layer = 0.0000500
k rm of rock at bottom of layer = 0.0000500

(Depth of the lowest soil layer extends 4.000 ft below the pile tip)

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Undrained Cohesion psf	Uniaxial qu psi	RQD %	E50 or krm	kpy pci	Rock Mass Modulus psi
1	Soft	3.4	37.6	375	--	--	0.0194	--	--
	Clay	5.4	37.6	375	--	--	0.0194	--	--
2	Stiff Clay	5.4	57.6	1250	--	--	0.0082	default	--
with Free Water		10	57.6	1250	--	--	0.0082	default	--
3	Weak	10	79.8	--	2000	30	5.00E-05	--	540000
	Rock	20	79.8	--	2000	30	5.00E-05	--	540000

p-y Modification Factors for Group Action

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

Point No.	Depth X ft	p-mult	y-mult
1	3.4	0.81	1
2	10	0.81	1

Static Loading Type

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

Distributed Lateral Loading for Individual Load Cases

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

---

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length
1	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0	Yes

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

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

---

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

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Moment-curvature properties were derived from elastic section properties

---

Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	3.4	0	N.A.	No	0	5046
2	5.4	9.0583	No	No	5046	15338
3	10	6.6	No	Yes	N.A.	N.A.

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

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

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

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

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness in-lb^2	Soil Res. p lb/inch	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0	0.248	1.54E-06	0	-0.0028	4.72E-08	1.14E+10	0	0	77.1041
0.16	0.2426	142.1182	152.3139	-0.0028	4.3395	1.14E+10	0	0	81.5562
0.32	0.2372	584.8854	314.6007	-0.0028	17.8591	1.14E+10	0	0	87.4925
0.48	0.2318	1350	488.2851	-0.0028	41.227	1.14E+10	0	0	93.4287
0.64	0.2265	2460	673.367	-0.0028	75.1115	1.14E+10	0	0	99.365
0.8	0.2211	3936	869.8466	-0.0028	120.1806	1.14E+10	0	0	105.3012
0.96	0.2157	5800	1078	-0.0028	177.1026	1.14E+10	0	0	111.2375
1.12	0.2103	8074	1297	-0.0028	246.5458	1.14E+10	0	0	117.1737
1.28	0.2049	10781	1528	-0.0028	329.1782	1.14E+10	0	0	123.11
1.44	0.1996	13941	1770	-0.0028	425.6681	1.14E+10	0	0	129.0462
1.6	0.1942	17576	2023	-0.0028	536.6837	1.14E+10	0	0	134.9825
1.76	0.1888	21710	2288	-0.00279	662.8931	1.14E+10	0	0	140.9187
1.92	0.1835	26363	2564	-0.00279	804.9646	1.14E+10	0	0	146.855
2.08	0.1781	31557	2852	-0.00278	963.5664	1.14E+10	0	0	152.7912
2.24	0.1728	37314	3151	-0.00278	1139	1.14E+10	0	0	158.7274
2.4	0.1674	43657	3462	-0.00277	1333	1.14E+10	0	0	164.6637
2.56	0.1621	50606	3783	-0.00276	1545	1.14E+10	0	0	170.5999

2.72	0.1568	58185	4117	-0.00275	1777	1.14E+10	0	0	176.5362
2.88	0.1516	66414	4461	-0.00274	2028	1.14E+10	0	0	182.4724
3.04	0.1463	75316	4817	-0.00273	2300	1.14E+10	0	0	188.4087
3.2	0.1411	84913	5185	-0.00272	2593	1.14E+10	0	0	194.3449
3.36	0.1359	95226	5564	-0.0027	2908	1.14E+10	0	0	200.2812
3.52	0.1307	106277	5918	-0.00269	3245	1.14E+10	-37.1485	545.7307	206.2174
3.68	0.1256	117951	6248	-0.00267	3602	1.14E+10	-37.3304	570.8484	212.1537
3.84	0.1205	130270	6590	-0.00265	3978	1.14E+10	-37.4839	597.4681	218.0899
4	0.1154	143255	6942	-0.00262	4374	1.14E+10	-37.6082	625.7279	224.0262
4.16	0.1104	156927	7305	-0.0026	4792	1.14E+10	-37.7026	655.7816	229.9624
4.32	0.1054	171308	7680	-0.00257	5231	1.14E+10	-37.7661	687.8017	235.8986
4.48	0.1005	186419	8066	-0.00254	5692	1.14E+10	-37.7979	721.9814	241.8349
4.64	0.09567	202282	8464	-0.00251	6177	1.14E+10	-37.7973	758.5379	247.7711
4.8	0.09089	218920	8873	-0.00247	6685	1.14E+10	-37.7633	797.7158	253.7074
4.96	0.08618	236353	9293	-0.00243	7217	1.14E+10	-37.6951	839.791	259.6436
5.12	0.08155	254605	9725	-0.00239	7774	1.14E+10	-37.592	885.0751	265.5799
5.28	0.077	273697	10168	-0.00235	8357	1.14E+10	-37.453	933.9212	271.5161
5.44	0.07254	293651	10119	-0.0023	8966	1.14E+10	-563.474	14915	277.4524
5.6	0.06817	312552	9592	-0.00225	9544	1.14E+10	-546.247	15385	283.3886
5.76	0.0639	330483	9109	-0.00219	10091	1.14E+10	-528.878	15891	289.3249
5.92	0.05974	347532	8672	-0.00214	10612	1.14E+10	-511.376	16435	295.2611
6.08	0.0557	363784	8280	-0.00208	11108	1.14E+10	-493.752	17021	301.1974
6.24	0.05177	379325	7933	-0.00201	11582	1.14E+10	-476.017	17655	307.1336
6.4	0.04796	394245	7631	-0.00195	12038	1.14E+10	-458.181	18343	313.0698
6.56	0.04428	408629	7107	-0.00188	12477	1.14E+10	-440.257	19090	39.5511
6.72	0.04073	421536	6317	-0.00181	12871	1.14E+10	-422.256	19903	0
6.88	0.03732	432887	5524	-0.00174	13218	1.14E+10	-404.193	20793	0
7.04	0.03405	442747	4765	-0.00167	13519	1.14E+10	-386.078	21768	0
7.2	0.03093	451185	4041	-0.00159	13777	1.14E+10	-367.922	22843	0
7.36	0.02794	458266	3352	-0.00151	13993	1.14E+10	-349.738	24030	0
7.52	0.02511	464058	2698	-0.00144	14170	1.14E+10	-331.535	25350	0
7.68	0.02243	468627	2079	-0.00136	14309	1.14E+10	-313.322	26823	0
7.84	0.0199	472042	1495	-0.00128	14413	1.14E+10	-295.11	28479	0
8	0.01752	474368	945.9767	-0.0012	14485	1.14E+10	-276.907	30351	0
8.16	0.01529	475674	431.7738	-0.00112	14524	1.14E+10	-258.721	32484	0
8.32	0.01322	476026	-47.5359	-0.00104	14535	1.14E+10	-240.56	34937	0
8.48	0.0113	475492	-492.007	-9.59E-04	14519	1.14E+10	-222.431	37784	0
8.64	0.00954	474137	-901.708	-8.79E-04	14477	1.14E+10	-204.341	41130	0
8.8	0.00793	472029	-1277	-7.99E-04	14413	1.14E+10	-186.296	45114	0
8.96	0.00647	469235	-1617	-7.20E-04	14328	1.14E+10	-168.302	49937	0
9.12	0.00516	465819	-1917	-6.41E-04	14223	1.14E+10	-143.583	53374	0
9.28	0.00401	461875	-2164	-5.63E-04	14103	1.14E+10	-114.586	54867	0
9.44	0.003	457508	-2359	-4.85E-04	13970	1.14E+10	-88.1773	56360	0
9.6	0.00215	452816	-2506	-4.09E-04	13826	1.14E+10	-64.6637	57853	0
9.76	0.00143	447886	-2610	-3.33E-04	13676	1.14E+10	-44.3432	59346	0
9.92	8.68E-04	442792	-2679	-2.58E-04	13520	1.14E+10	-27.5068	60839	0
10.08	4.45E-04	437597	-17895	-1.84E-04	13362	1.14E+10	-15822	6.83E+07	0

10.24	1.63E-04	374077	-42885	-1.15E-04	11422	1.14E+10	-10210	1.20E+08	0
10.4	2.21E-06	272920	-52831	-6.07E-05	8333	1.14E+10	-151.344	1.31E+08	0
10.56	-7.03E-05	171205	-47973	-2.33E-05	5228	1.14E+10	5212	1.42E+08	0
10.72	-8.74E-05	88705	-36263	-1.45E-06	2709	1.14E+10	6985	1.53E+08	0
10.88	-7.58E-05	31957	-23319	8.72E-06	975.7711	1.14E+10	6498	1.65E+08	0
11.04	-5.39E-05	-839.583	-12347	1.13E-05	25.6361	1.14E+10	4931	1.76E+08	0
11.2	-3.23E-05	-15458	-4600	9.97E-06	471.9859	1.14E+10	3139	1.87E+08	0
11.36	-1.57E-05	-18505	-39.7287	7.11E-06	565.0333	1.14E+10	1612	1.98E+08	0
11.52	-5.00E-06	-15610	2030	4.23E-06	476.6442	1.14E+10	544.1133	2.09E+08	0
11.68	5.97E-07	-10710	2487	2.02E-06	327.0087	1.14E+10	-68.3259	2.20E+08	0
11.84	2.73E-06	-6061	2106	6.03E-07	185.0642	1.14E+10	-328.779	2.31E+08	0
12	2.91E-06	-2624	1438	-1.29E-07	80.1276	1.14E+10	-366.846	2.42E+08	0
12.16	2.24E-06	-539.847	802.2784	-3.95E-07	16.4839	1.14E+10	-295.115	2.53E+08	0
12.32	1.39E-06	456.5707	334.9992	-4.02E-07	13.9411	1.14E+10	-191.634	2.64E+08	0
12.48	6.95E-07	746.5498	55.4509	-3.01E-07	22.7954	1.14E+10	-99.5624	2.75E+08	0
12.64	2.38E-07	669.5021	-74.1439	-1.82E-07	20.4428	1.14E+10	-35.4322	2.86E+08	0
12.8	-2.86E-09	461.8374	-107.735	-8.64E-08	14.1019	1.14E+10	0.442	2.97E+08	0
12.96	-9.41E-08	255.8018	-92.8115	-2.60E-08	7.8107	1.14E+10	15.1028	3.08E+08	0
13.12	-1.03E-07	105.4411	-61.942	4.47E-09	3.2196	1.14E+10	17.053	3.19E+08	0
13.28	-7.69E-08	17.9444	-32.8686	1.49E-08	0.5479	1.14E+10	13.2319	3.30E+08	0
13.44	-4.55E-08	-20.7743	-12.4061	1.46E-08	0.6343	1.14E+10	8.0832	3.41E+08	0
13.6	-2.07E-08	-29.6951	-0.9924	1.04E-08	0.9067	1.14E+10	3.8061	3.53E+08	0
13.76	-5.61E-09	-24.5852	3.6818	5.80E-09	0.7507	1.14E+10	1.0629	3.64E+08	0
13.92	1.55E-09	-15.5569	4.4116	2.42E-09	0.475	1.14E+10	-0.3027	3.75E+08	0
14.08	3.68E-09	-7.6446	3.4104	4.67E-10	0.2334	1.14E+10	-0.7401	3.86E+08	0
14.24	3.34E-09	-2.4608	2.0364	-3.84E-10	0.07514	1.14E+10	-0.6912	3.97E+08	0
14.4	2.21E-09	0.1751	0.9224	-5.77E-10	0.00535	1.14E+10	-0.4692	4.08E+08	0
14.56	1.13E-09	1.0814	0.2354	-4.71E-10	0.03302	1.14E+10	-0.2465	4.19E+08	0
14.72	4.01E-10	1.0789	-0.08737	-2.89E-10	0.03294	1.14E+10	-0.0897	4.30E+08	0
14.88	2.03E-11	0.7459	-0.1779	-1.35E-10	0.02277	1.14E+10	-0.00465	4.41E+08	0
15.04	-1.19E-10	0.3956	-0.1556	-3.91E-11	0.01208	1.14E+10	0.02798	4.52E+08	0
15.2	-1.30E-10	0.1485	-0.09861	6.72E-12	0.00453	1.14E+10	0.03134	4.63E+08	0
15.36	-9.30E-11	0.01697	-0.04646	2.07E-11	5.18E-04	1.14E+10	0.02298	4.74E+08	0
15.52	-5.06E-11	-0.02988	-0.01212	1.96E-11	9.12E-04	1.14E+10	0.01279	4.85E+08	0
15.68	-1.79E-11	-0.02956	0.0046	1.46E-11	9.03E-04	1.14E+10	0.00462	4.96E+08	0
15.84	5.29E-12	-0.0122	0.0077	1.10E-11	3.73E-04	1.14E+10	-0.0014	5.07E+08	0
16	2.45E-11	0	0	1.00E-11	0	1.14E+10	-0.00662	2.59E+08	0

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

Output Summary for Load Case No. 1:

Pile-head deflection = 0.24799776 inches
Computed slope at pile head = -0.00280497 radians
Maximum bending moment = 476026. inch-lbs
Maximum shear force = -52831. lbs
Depth of maximum bending moment = 8.32000000 feet below pile head

Depth of maximum shear force = 10.40000000 feet below pile head
Number of iterations = 11
Number of zero deflection points = 6

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

Boundary Condition Type 1, Shear and Moment

Shear = 0.0 lbs
Moment = 0.0 in-lbs
Axial Load = 0.0 lbs

Pile Length feet	Pile Head Deflection inches	Maximum Moment ln-lbs	Maximum Shear lbs
16	0.247998	476026	-52831
15.2	0.249319	483208	-53926
14.4	0.250601	481123	-53395
13.6	0.247559	476137	-52355
12.8	0.254729	486262	-54602
12	0.255052	489603	-55696
11.2	0.25377	486234	-55280
10.4	0.35434	400280	-46493

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

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

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	0	M, in-lb	0	0	0.248	-0.0028	-52831	476026

Maximum pile-head deflection = 0.2479977594 inches
Maximum pile-head rotation = -0.0028049671 radians = -0.160713 deg.

Summary of Warning Messages

The following warning was reported 2463 times

**** Warning ****

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

The analysis ended normally.

APPENDIX D.2
DEL-315-6.40

==========

LPile for Windows, Version 2016-09.010

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

==========

This copy of LPile is being used by:

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Files Used for Analysis

Path to file locations:
\gt\Projects\D06\Delaware\DEL-315-6.40\Geotechnical\EngData\LPILE\

Name of input data file:
24in_HP12_53_6ftsocket_factored.lp9d

Name of output report file:
24in_HP12_53_6ftsocket_factored.lp9o

Name of plot output file:
24in_HP12_53_6ftsocket_factored.lp9p

Name of runtime message file:
24in_HP12_53_6ftsocket_factored.lp9r

Date and Time of Analysis

Date: March 5, 2018 Time: 15:34:37

Problem Title

Project Name: DEL-315-6.40
Job Number: 102124

Client:
Engineer: Taliaferro
Description: Plug Pile Wall

Program Options and Settings

Computational Options:
- Use unfactored loads in computations (conventional analysis)

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

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

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

- Analysis uses p-y modification factors for p-y curves
- Analysis includes loading by one distributed lateral load acting on pile
- Loading by lateral soil movements acting on pile not selected
- Input of shear resistance at the pile tip not selected
- Computation of pile-head foundation stiffness matrix not selected
- Push-over analysis of pile not selected
- Buckling analysis of pile not selected

Output Options:
- Output files use decimal points to denote decimal symbols.
- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (nodal spacing of output points) = 1
- No p-y curves to be computed and reported for user-specified depths
- Print using wide report formats

Pile Structural Properties and Geometry

Number of pile sections defined = 1
Total length of pile = 14.400 ft
Depth of ground surface below top of pile = 2.1300 ft

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

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

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0	24
2	14.4	24

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is an elastic pile
Cross-sectional Shape = Circular Pile
Length of section = 14.400000 ft
Width of top of section = 24.000000 in
Width of bottom of section = 24.000000 in
Top Area = 15.500000 sq. in
Bottom Area = 15.500000 sq. in
Moment of Inertia at Top = 393.000000 in^4
Moment of Inertia at Bottom = 393.000000 in^4
Elastic Modulus = 29000000. psi

Ground Slope and Pile Batter Angles

Ground Slope Angle = 0.000 degrees
= 0.000 radians

Pile Batter Angle = 0.000 degrees
= 0.000 radians

Soil and Rock Layering Information

The soil profile is modelled using 4 layers

Layer 1 is stiff clay with water-induced erosion

Distance from top of pile to top of layer = 2.130000 ft
Distance from top of pile to bottom of layer = 3.500000 ft
Effective unit weight at top of layer = 57.600000 pcf
Effective unit weight at bottom of layer = 62.600000 pcf
Undrained cohesion at top of layer = 1625. psf
Undrained cohesion at bottom of layer = 1625. psf
Epsilon-50 at top of layer = 0.007000
Epsilon-50 at bottom of layer = 0.007000
Subgrade k at top of layer = 0.0000 pci
Subgrade k at bottom of layer = 0.0000 pci

NOTE: Default values for subgrade k will be computed for this layer.

Layer 2 is stiff clay with water-induced erosion

Distance from top of pile to top of layer = 3.500000 ft
Distance from top of pile to bottom of layer = 6.000000 ft
Effective unit weight at top of layer = 62.600000 pcf
Effective unit weight at bottom of layer = 62.600000 pcf
Undrained cohesion at top of layer = 2875. psf
Undrained cohesion at bottom of layer = 2875. psf
Epsilon-50 at top of layer = 0.005200
Epsilon-50 at bottom of layer = 0.005200
Subgrade k at top of layer = 0.0000 pci
Subgrade k at bottom of layer = 0.0000 pci

NOTE: Default values for subgrade k will be computed for this layer.

Layer 3 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 6.000000 ft
Distance from top of pile to bottom of layer = 7.500000 ft
Effective unit weight at top of layer = 72.600000 pcf
Effective unit weight at bottom of layer = 72.600000 pcf
Friction angle at top of layer = 34.000000 deg.
Friction angle at bottom of layer = 34.000000 deg.
Subgrade k at top of layer = 0.0000 pci
Subgrade k at bottom of layer = 0.0000 pci

NOTE: Default values for subgrade k will be computed for this layer.

Layer 4 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer = 7.500000 ft
Distance from top of pile to bottom of layer = 17.500000 ft
Effective unit weight at top of layer = 80.700000 pcf
Effective unit weight at bottom of layer = 80.700000 pcf
Uniaxial compressive strength at top of layer = 15896. psi
Uniaxial compressive strength at bottom of layer = 15896. psi
Initial modulus of rock at top of layer = 1400000. psi
Initial modulus of rock at bottom of layer = 1400000. psi
RQD of rock at top of layer = 8.000000 %
RQD of rock at bottom of layer = 8.000000 %
k rm of rock at top of layer = 0.0000500
k rm of rock at bottom of layer = 0.0000500

(Depth of the lowest soil layer extends 3.100 ft below the pile tip)

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Undrained Cohesion psf	Angle of Friction deg.	Uniaxial qu psi	RQD %	E50 or krm	kpy pci	Rock Mass Modulus psi
1	Stiff Clay	2.13	57.6	1625	--	--	--	0.007	default	--
	with Free Water	3.5	62.6	1625	--	--	--	0.007	default	--
2	Stiff Clay	3.5	62.6	2875	--	--	--	0.0052	default	--
	with Free Water	6	62.6	2875	--	--	--	0.0052	default	--
3	Sand	6	72.6	--	34	--	--	--	default	--
	(Reese, et al.)	7.5	72.6	--	34	--	--	--	default	--
4	Weak	7.5	80.7	--	--	15896	8	5.00E-05	--	1400000
	Rock	17.5	80.7	--	--	15896	8	5.00E-05	--	1400000

---

p-y Modification Factors for Group Action

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

Point No.	Depth X ft	p-mult	y-mult
1	2.13	0.81	1
2	7	0.81	1

Static Loading Type

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

Distributed Lateral Loading Used For All Load Cases

Distributed lateral load intensity defined using 2 points

Point No.	Depth X in	Dist. Load lb/in
1	0	77.86
2	84	239.6

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length
1	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0	No

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

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

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

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Moment-curvature properties were derived from elastic section properties

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Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	2.13	0	N.A.	No	0	591.8196
2	3.5	1.37	Yes	No	591.8196	6595
3	6	3.0845	No	No	7187	11172
4	7.5	5.37	No	Yes	N.A.	N.A.

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

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

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

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

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness in-lb^2	Soil Res. p lb/inch	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0	0.05255	-1.32E-07	0	-7.87E-04	4.04E-09	1.14E+10	0	0	78.6918
0.144	0.05119	117.4862	138.1355	-7.87E-04	3.5874	1.14E+10	0	0	81.1872
0.288	0.04983	477.3962	281.3017	-7.87E-04	14.577	1.14E+10	0	0	84.5144
0.432	0.04847	1090	430.2174	-7.87E-04	33.2722	1.14E+10	0	0	87.8417
0.576	0.04711	1964	584.8825	-7.87E-04	59.9764	1.14E+10	0	0	91.1689
0.72	0.04575	3111	745.2971	-7.86E-04	94.9929	1.14E+10	0	0	94.4961
0.864	0.04439	4540	911.4611	-7.86E-04	138.6252	1.14E+10	0	0	97.8233
1.008	0.04304	6261	1083	-7.85E-04	191.1764	1.14E+10	0	0	101.1506
1.152	0.04168	8284	1261	-7.84E-04	252.9501	1.14E+10	0	0	104.4778
1.296	0.04033	10619	1444	-7.82E-04	324.2496	1.14E+10	0	0	107.805
1.44	0.03898	13276	1634	-7.80E-04	405.3782	1.14E+10	0	0	111.1322
1.584	0.03763	16265	1829	-7.78E-04	496.6392	1.14E+10	0	0	114.4595
1.728	0.03629	19596	2029	-7.75E-04	598.3362	1.14E+10	0	0	117.7867
1.872	0.03495	23278	2236	-7.72E-04	710.7723	1.14E+10	0	0	121.1139
2.016	0.03362	27322	2448	-7.68E-04	834.251	1.14E+10	0	0	124.4411
2.16	0.0323	31737	2662	-7.64E-04	969.0757	1.14E+10	-4.709	251.9424	127.7683
2.304	0.03098	36520	2859	-7.59E-04	1115	1.14E+10	-26.1994	1461	131.0956
2.448	0.02968	41616	3026	-7.53E-04	1271	1.14E+10	-45.8628	2671	134.4228
2.592	0.02838	46977	3166	-7.46E-04	1434	1.14E+10	-63.7225	3880	137.75
2.736	0.0271	52559	3283	-7.39E-04	1605	1.14E+10	-79.8053	5089	141.0772
2.88	0.02583	58323	3379	-7.30E-04	1781	1.14E+10	-94.1425	6299	144.4045
3.024	0.02457	64238	3458	-7.21E-04	1961	1.14E+10	-106.77	7508	147.7317
3.168	0.02334	70275	3522	-7.11E-04	2146	1.14E+10	-117.726	8717	151.0589
3.312	0.02212	76412	3575	-6.99E-04	2333	1.14E+10	-127.057	9927	154.3861
3.456	0.02092	82630	3618	-6.87E-04	2523	1.14E+10	-134.811	11136	157.7133
3.6	0.01974	88916	3533	-6.74E-04	2715	1.14E+10	-282.085	24690	161.0406
3.744	0.01859	94841	3319	-6.60E-04	2896	1.14E+10	-291.617	27109	164.3678
3.888	0.01746	100386	3096	-6.46E-04	3065	1.14E+10	-298.344	29528	167.695
4.032	0.01636	105541	2870	-6.30E-04	3223	1.14E+10	-302.398	31946	171.0222
4.176	0.01528	110304	2644	-6.14E-04	3368	1.14E+10	-303.914	34365	174.3495
4.32	0.01424	114680	2424	-5.97E-04	3502	1.14E+10	-303.037	36784	177.6767
4.464	0.01322	118682	2213	-5.79E-04	3624	1.14E+10	-299.912	39202	181.0039
4.608	0.01223	122328	2015	-5.61E-04	3735	1.14E+10	-294.693	41621	184.3311
4.752	0.01128	125645	1833	-5.42E-04	3836	1.14E+10	-287.533	44040	187.6584
4.896	0.01036	128664	1671	-5.23E-04	3929	1.14E+10	-278.591	46458	190.9856
5.04	0.00948	131421	1532	-5.03E-04	4013	1.14E+10	-268.027	48877	194.3128
5.184	0.00862	133958	1418	-4.83E-04	4090	1.14E+10	-256.004	51295	197.64

5.328	0.00781	136321	1331	-4.62E-04	4162	1.14E+10	-242.687	53714	200.9672
5.472	0.00703	138559	1275	-4.41E-04	4231	1.14E+10	-228.245	56133	204.2945
5.616	0.00628	140725	1249	-4.20E-04	4297	1.14E+10	-212.846	58551	207.6217
5.76	0.00557	142876	1257	-3.99E-04	4363	1.14E+10	-196.663	60970	210.9489
5.904	0.0049	145070	1299	-3.77E-04	4430	1.14E+10	-179.872	63389	214.2761
6.048	0.00427	147367	1506	-3.55E-04	4500	1.14E+10	-12.2052	4938	217.6034
6.192	0.00368	150276	1865	-3.32E-04	4589	1.14E+10	-10.8946	5120	220.9306
6.336	0.00312	153813	2232	-3.09E-04	4697	1.14E+10	-9.58	5301	224.2578
6.48	0.00261	157991	2607	-2.86E-04	4824	1.14E+10	-8.2768	5483	227.585
6.624	0.00214	162824	2990	-2.61E-04	4972	1.14E+10	-7.0013	5664	230.9123
6.768	0.00171	168325	3381	-2.36E-04	5140	1.14E+10	-5.7709	5846	234.2395
6.912	0.00132	174509	3780	-2.10E-04	5329	1.14E+10	-4.6039	6027	237.5667
7.056	9.80E-04	181388	4000	-1.83E-04	5539	1.14E+10	-4.3457	7665	26.6017
7.2	6.87E-04	188334	4017	-1.55E-04	5751	1.14E+10	-3.1364	7889	0
7.344	4.44E-04	195270	4012	-1.26E-04	5962	1.14E+10	-2.0829	8113	0
7.488	2.51E-04	202200	4009	-9.59E-05	6174	1.14E+10	-1.2131	8337	0
7.632	1.12E-04	209127	-10757	-6.47E-05	6386	1.14E+10	-17089	2.63E+08	0
7.776	2.77E-05	165025	-29496	-3.64E-05	5039	1.14E+10	-4600	2.86E+08	0
7.92	-1.35E-05	107189	-31386	-1.57E-05	3273	1.14E+10	2412	3.10E+08	0
8.064	-2.66E-05	56555	-24878	-3.31E-06	1727	1.14E+10	5121	3.33E+08	0
8.208	-2.49E-05	21212	-16021	2.59E-06	647.6817	1.14E+10	5129	3.56E+08	0
8.352	-1.76E-05	1185	-8244	4.29E-06	36.1816	1.14E+10	3872	3.79E+08	0
8.496	-1.01E-05	-7279	-2869	3.82E-06	222.2486	1.14E+10	2348	4.03E+08	0
8.64	-4.43E-06	-8730	102.1425	2.61E-06	266.5795	1.14E+10	1091	4.26E+08	0
8.784	-1.06E-06	-6926	1282	1.42E-06	211.4698	1.14E+10	275.4697	4.49E+08	0
8.928	4.92E-07	-4298	1404	5.72E-07	131.2442	1.14E+10	-134.333	4.72E+08	0
9.072	9.17E-07	-2072	1061	8.92E-08	63.2664	1.14E+10	-262.962	4.95E+08	0
9.216	8.00E-07	-630.903	626.5165	-1.16E-07	19.2642	1.14E+10	-240.089	5.19E+08	0
9.36	5.17E-07	93.267	278.9159	-1.56E-07	2.8478	1.14E+10	-162.227	5.42E+08	0
9.504	2.59E-07	333.0308	65.5192	-1.24E-07	10.1689	1.14E+10	-84.7604	5.65E+08	0
9.648	8.83E-08	319.7013	-33.6888	-7.47E-08	9.7619	1.14E+10	-30.0636	5.88E+08	0
9.792	1.18E-09	216.6024	-60.0253	-3.40E-08	6.6138	1.14E+10	-0.4184	6.12E+08	0
9.936	-2.92E-08	112.254	-51.1237	-9.06E-09	3.4276	1.14E+10	10.7211	6.35E+08	0
10.08	-3.01E-08	39.9187	-31.9442	2.47E-09	1.2189	1.14E+10	11.4774	6.58E+08	0
10.224	-2.06E-08	1.8549	-14.9979	5.64E-09	0.05664	1.14E+10	8.1363	6.81E+08	0
10.368	-1.06E-08	-11.9141	-4.2171	4.88E-09	0.3638	1.14E+10	4.3416	7.04E+08	0
10.512	-3.78E-09	-12.7193	0.9102	3.01E-09	0.3884	1.14E+10	1.5929	7.28E+08	0
10.656	-2.48E-10	-8.7683	2.3795	1.38E-09	0.2677	1.14E+10	0.1077	7.51E+08	0
10.8	9.89E-10	-4.4956	2.0896	3.75E-10	0.1373	1.14E+10	-0.4433	7.74E+08	0
10.944	1.05E-09	-1.5466	1.2884	-8.28E-11	0.04722	1.14E+10	-0.484	7.97E+08	0
11.088	7.03E-10	-0.04282	0.5817	-2.03E-10	0.00131	1.14E+10	-0.3339	8.21E+08	0
11.232	3.46E-10	0.4639	0.1472	-1.71E-10	0.01416	1.14E+10	-0.1691	8.44E+08	0
11.376	1.11E-10	0.4658	-0.0469	-1.01E-10	0.01422	1.14E+10	-0.05557	8.67E+08	0
11.52	-2.63E-12	0.3018	-0.09374	-4.27E-11	0.00922	1.14E+10	0.00135	8.90E+08	0
11.664	-3.69E-11	0.1419	-0.0757	-9.10E-12	0.00433	1.14E+10	0.01953	9.13E+08	0
11.808	-3.41E-11	0.04019	-0.04287	4.70E-12	0.00123	1.14E+10	0.01847	9.37E+08	0
11.952	-2.07E-11	-0.00631	-0.01698	7.27E-12	1.93E-04	1.14E+10	0.0115	9.60E+08	0

12.096	-8.97E-12	-0.01848	-0.00263	5.39E-12	5.64E-04	1.14E+10	0.0051	9.83E+08	0
12.24	-2.08E-12	-0.01542	0.00282	2.82E-12	4.71E-04	1.14E+10	0.00121	1.01E+09	0
12.384	0	-0.00874	0.00347	0	2.67E-04	1.14E+10	-4.58E-04	1.03E+09	0
12.528	1.33E-12	-0.00343	0.00238	0	1.05E-04	1.14E+10	-8.07E-04	1.05E+09	0
12.672	0	-5.26E-04	0.00115	0	1.61E-05	1.14E+10	-6.13E-04	1.08E+09	0
12.816	0	5.46E-04	3.42E-04	0	1.67E-05	1.14E+10	-3.22E-04	1.10E+09	0
12.96	0	6.56E-04	-3.21E-05	0	2.00E-05	1.14E+10	-1.11E-04	1.12E+09	0
13.104	0	4.35E-04	-1.32E-04	0	1.33E-05	1.14E+10	-4.46E-06	1.15E+09	0
13.248	0	2.01E-04	-1.10E-04	0	6.13E-06	1.14E+10	2.92E-05	1.17E+09	0
13.392	0	5.37E-05	-6.10E-05	0	1.64E-06	1.14E+10	2.79E-05	1.19E+09	0
13.536	0	-9.97E-06	-2.26E-05	0	3.04E-07	1.14E+10	1.66E-05	1.21E+09	0
13.68	0	-2.42E-05	-2.53E-06	0	7.40E-07	1.14E+10	6.63E-06	1.21E+09	0
13.824	0	-1.87E-05	4.20E-06	0	5.71E-07	1.14E+10	1.16E-06	1.21E+09	0
13.968	0	-9.72E-06	4.43E-06	0	2.97E-07	1.14E+10	-8.90E-07	1.21E+09	0
14.112	0	-3.39E-06	2.66E-06	0	1.04E-07	1.14E+10	-1.15E-06	1.21E+09	0
14.256	0	-5.10E-07	9.82E-07	0	1.56E-08	1.14E+10	-7.94E-07	1.21E+09	0
14.4	0	0	0	0	0	1.14E+10	-3.42E-07	6.05E+08	0

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

Output Summary for Load Case No. 1:

Pile-head deflection = 0.05255032 inches
Computed slope at pile head = -0.00078692 radians
Maximum bending moment = 209127. inch-lbs
Maximum shear force = -31386. lbs
Depth of maximum bending moment = 7.63200000 feet below pile head
Depth of maximum shear force = 7.92000000 feet below pile head
Number of iterations = 6
Number of zero deflection points = 9

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

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

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	0	M, in-lb	0	0	0.05255	-7.87E-04	-31386	209127

Maximum pile-head deflection = 0.0525503174 inches
Maximum pile-head rotation = -0.0007869225 radians = -0.045087 deg.

Summary of Warning Messages

The following warning was reported 288 times

**** Warning ****

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

The analysis ended normally.

==========

LPile for Windows, Version 2016-09.010

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

==========

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Files Used for Analysis

Path to file locations:
\gt\Projects\D06\Delaware\DEL-315-6.40\Geotechnical\EngData\LPILE\

Name of input data file:
24in_HP12_53_6ftsocket_unfactored.lp9d

Name of output report file:
24in_HP12_53_6ftsocket_unfactored.lp9o

Name of plot output file:
24in_HP12_53_6ftsocket_unfactored.lp9p

Name of runtime message file:
24in_HP12_53_6ftsocket_unfactored.lp9r

Date and Time of Analysis

Date: March 5, 2018 Time: 10:49:37

Problem Title

Project Name: DEL-315-6.40
Job Number: 102124

Client:
Engineer: Taliaferro
Description: Plug Pile Wall

Program Options and Settings

Computational Options:
- Use unfactored loads in computations (conventional analysis)

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

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

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

- Analysis uses p-y modification factors for p-y curves
- Analysis includes loading by one distributed lateral load acting on pile
- Loading by lateral soil movements acting on pile not selected
- Input of shear resistance at the pile tip not selected
- Computation of pile-head foundation stiffness matrix not selected
- Push-over analysis of pile not selected
- Buckling analysis of pile not selected

Output Options:
- Output files use decimal points to denote decimal symbols.
- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (nodal spacing of output points) = 1
- No p-y curves to be computed and reported for user-specified depths
- Print using wide report formats

Pile Structural Properties and Geometry

Number of pile sections defined = 1
Total length of pile = 14.000 ft
Depth of ground surface below top of pile = 2.1200 ft

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

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

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0	24
2	14	24

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is an elastic pile
Cross-sectional Shape = Circular Pile
Length of section = 14.000000 ft
Width of top of section = 24.000000 in
Width of bottom of section = 24.000000 in
Top Area = 15.500000 sq. in
Bottom Area = 15.500000 sq. in
Moment of Inertia at Top = 393.000000 in^4
Moment of Inertia at Bottom = 393.000000 in^4
Elastic Modulus = 29000000. psi

Ground Slope and Pile Batter Angles

Ground Slope Angle = 0.000 degrees
= 0.000 radians

Pile Batter Angle = 0.000 degrees
= 0.000 radians

Soil and Rock Layering Information

The soil profile is modelled using 4 layers

Layer 1 is stiff clay with water-induced erosion

Distance from top of pile to top of layer = 2.120000 ft
Distance from top of pile to bottom of layer = 3.500000 ft
Effective unit weight at top of layer = 57.600000 pcf
Effective unit weight at bottom of layer = 62.600000 pcf
Undrained cohesion at top of layer = 1625. psf
Undrained cohesion at bottom of layer = 1625. psf
Epsilon-50 at top of layer = 0.007000
Epsilon-50 at bottom of layer = 0.007000
Subgrade k at top of layer = 0.0000 pci
Subgrade k at bottom of layer = 0.0000 pci

NOTE: Default values for subgrade k will be computed for this layer.

Layer 2 is stiff clay with water-induced erosion

Distance from top of pile to top of layer = 3.500000 ft
Distance from top of pile to bottom of layer = 6.000000 ft
Effective unit weight at top of layer = 62.600000 pcf
Effective unit weight at bottom of layer = 62.600000 pcf
Undrained cohesion at top of layer = 2875. psf
Undrained cohesion at bottom of layer = 2875. psf
Epsilon-50 at top of layer = 0.005200
Epsilon-50 at bottom of layer = 0.005200
Subgrade k at top of layer = 0.0000 pci
Subgrade k at bottom of layer = 0.0000 pci

NOTE: Default values for subgrade k will be computed for this layer.

Layer 3 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 6.000000 ft
Distance from top of pile to bottom of layer = 7.500000 ft
Effective unit weight at top of layer = 72.600000 pcf
Effective unit weight at bottom of layer = 72.600000 pcf
Friction angle at top of layer = 34.000000 deg.
Friction angle at bottom of layer = 34.000000 deg.
Subgrade k at top of layer = 0.0000 pci
Subgrade k at bottom of layer = 0.0000 pci

NOTE: Default values for subgrade k will be computed for this layer.

Layer 4 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer = 7.500000 ft
Distance from top of pile to bottom of layer = 17.500000 ft
Effective unit weight at top of layer = 80.700000 pcf
Effective unit weight at bottom of layer = 80.700000 pcf
Uniaxial compressive strength at top of layer = 15896. psi
Uniaxial compressive strength at bottom of layer = 15896. psi
Initial modulus of rock at top of layer = 1400000. psi
Initial modulus of rock at bottom of layer = 1400000. psi
RQD of rock at top of layer = 8.000000 %
RQD of rock at bottom of layer = 8.000000 %
k rm of rock at top of layer = 0.0000500
k rm of rock at bottom of layer = 0.0000500

(Depth of the lowest soil layer extends 3.500 ft below the pile tip)

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Undrained Cohesion psf	Angle of Friction deg.	Uniaxial qu psi	RQD %	E50 or krm	kpy pci	Rock Mass Modulus psi
1	Stiff Clay	2.12	57.6	1625	--	--	--	0.007	default	--
	with Free Water	3.5	62.6	1625	--	--	--	0.007	default	--
2	Stiff Clay	3.5	62.6	2875	--	--	--	0.0052	default	--
	with Free Water	6	62.6	2875	--	--	--	0.0052	default	--
3	Sand	6	72.6	--	34	--	--	--	default	--
	(Reese, et al.)	7.5	72.6	--	34	--	--	--	default	--
4	Weak	7.5	80.7	--	--	15896	8	5.00E-05	--	1400000
	Rock	17.5	80.7	--	--	15896	8	5.00E-05	--	1400000

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p-y Modification Factors for Group Action

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

Point No.	Depth X ft	p-mult	y-mult
1	2.124	0.81	1
2	6.969	0.81	1

Static Loading Type

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

Distributed Lateral Loading Used For All Load Cases

Distributed lateral load intensity defined using 2 points

Point No.	Depth X in	Dist. Load lb/in
1	0	0
2	83.628	108.307

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length
1	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0	No

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

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

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

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Moment-curvature properties were derived from elastic section properties

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Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	2.12	0	N.A.	No	0	600.1836
2	3.5	1.38	Yes	No	600.1836	6618
3	6	3.0909	No	No	7218	11194
4	7.5	5.38	No	Yes	N.A.	N.A.

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

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

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

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

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness in-lb^2	Soil Res. p lb/inch	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0	0.01247	4.20E-08	2.08E-09	-1.75E-04	1.28E-09	1.14E+10	0	0	0.5439
0.14	0.01217	0.7676	2.2846	-1.75E-04	0.02344	1.14E+10	0	0	2.1758
0.28	0.01188	7.6761	7.7675	-1.75E-04	0.2344	1.14E+10	0	0	4.3516
0.42	0.01159	26.8665	16.9058	-1.75E-04	0.8204	1.14E+10	0	0	6.5273
0.56	0.01129	64.4795	29.6993	-1.75E-04	1.9688	1.14E+10	0	0	8.7031
0.7	0.011	126.6562	46.1482	-1.75E-04	3.8674	1.14E+10	0	0	10.8789
0.84	0.01071	219.5375	66.2524	-1.75E-04	6.7034	1.14E+10	0	0	13.0547
0.98	0.01041	349.2642	90.0118	-1.75E-04	10.6646	1.14E+10	0	0	15.2304
1.12	0.01012	521.9773	117.4266	-1.75E-04	15.9382	1.14E+10	0	0	17.4062
1.26	0.00983	743.8176	148.4967	-1.75E-04	22.712	1.14E+10	0	0	19.582
1.4	0.00953	1021	183.2221	-1.74E-04	31.1733	1.14E+10	0	0	21.7578
1.54	0.00924	1359	221.6027	-1.74E-04	41.5097	1.14E+10	0	0	23.9335
1.68	0.00895	1766	263.6387	-1.74E-04	53.9087	1.14E+10	0	0	26.1093
1.82	0.00866	2245	309.33	-1.74E-04	68.5579	1.14E+10	0	0	28.2851
1.96	0.00836	2805	358.6766	-1.73E-04	85.6446	1.14E+10	0	0	30.4609
2.1	0.00807	3450	411.6785	-1.73E-04	105.3564	1.14E+10	0	0	32.6366
2.24	0.00778	4188	464.5229	-1.72E-04	127.8809	1.14E+10	-4.539	979.776	34.8124
2.38	0.00749	5011	513.0684	-1.72E-04	153.0144	1.14E+10	-9.4694	2123	36.9882
2.52	0.00721	5912	557.3145	-1.71E-04	180.5194	1.14E+10	-14.0089	3266	39.164
2.66	0.00692	6884	597.9151	-1.70E-04	210.1923	1.14E+10	-18.1607	4409	41.3397
2.8	0.00664	7921	635.5185	-1.69E-04	241.8627	1.14E+10	-21.9286	5552	43.5155
2.94	0.00635	9019	670.7658	-1.68E-04	275.3936	1.14E+10	-25.3171	6695	45.6913
3.08	0.00607	10175	704.29	-1.66E-04	310.6802	1.14E+10	-28.3315	7838	47.8671
3.22	0.00579	11386	736.7146	-1.65E-04	347.6505	1.14E+10	-30.9777	8981	50.0428
3.36	0.00552	12650	768.6521	-1.63E-04	386.2638	1.14E+10	-33.2629	10124	52.2186
3.5	0.00525	13968	771.1388	-1.61E-04	426.5107	1.14E+10	-70.3897	22535	54.3944
3.64	0.00498	15241	743.4273	-1.59E-04	465.3791	1.14E+10	-73.5647	24821	56.5702
3.78	0.00471	16466	714.5997	-1.56E-04	502.7829	1.14E+10	-76.07	27107	58.7459
3.92	0.00445	17642	685.7636	-1.54E-04	538.6937	1.14E+10	-77.9263	29393	60.9217
4.06	0.0042	18770	657.9907	-1.51E-04	573.1391	1.14E+10	-79.1559	31679	63.0975
4.2	0.00395	19853	632.3143	-1.48E-04	606.2006	1.14E+10	-79.782	33966	65.2733
4.34	0.0037	20895	609.7272	-1.45E-04	638.0117	1.14E+10	-79.8296	36252	67.449
4.48	0.00346	21902	591.1797	-1.42E-04	668.7558	1.14E+10	-79.3246	38538	69.6248
4.62	0.00322	22881	577.5772	-1.39E-04	698.664	1.14E+10	-78.2942	40824	71.8006
4.76	0.00299	23842	569.7785	-1.35E-04	728.0126	1.14E+10	-76.7668	43110	73.9764
4.9	0.00277	24796	568.594	-1.32E-04	757.1207	1.14E+10	-74.7719	45396	76.1521
5.04	0.00255	25753	574.7829	-1.28E-04	786.3477	1.14E+10	-72.3403	47682	78.3279

5.18	0.00234	26727	589.0521	-1.24E-04	816.0908	1.14E+10	-69.5042	49969	80.5037
5.32	0.00213	27732	612.0529	-1.20E-04	846.7818	1.14E+10	-66.2971	52255	82.6795
5.46	0.00193	28783	644.3792	-1.16E-04	878.8846	1.14E+10	-62.754	54541	84.8552
5.6	0.00174	29897	686.5643	-1.12E-04	912.8921	1.14E+10	-58.9119	56827	87.031
5.74	0.00156	31090	739.0781	-1.07E-04	949.3229	1.14E+10	-54.8095	59113	89.2068
5.88	0.00138	32381	802.3233	-1.03E-04	988.7181	1.14E+10	-50.4879	61399	91.3826
6.02	0.00121	33786	912.3649	-9.76E-05	1032	1.14E+10	-3.4511	4779	93.5583
6.16	0.00105	35446	1066	-9.25E-05	1082	1.14E+10	-3.1039	4950	95.7341
6.3	9.02E-04	37367	1224	-8.72E-05	1141	1.14E+10	-2.7508	5122	97.9099
6.44	7.60E-04	39557	1386	-8.15E-05	1208	1.14E+10	-2.3961	5294	100.0857
6.58	6.28E-04	42023	1552	-7.55E-05	1283	1.14E+10	-2.0442	5465	102.2615
6.72	5.07E-04	44772	1722	-6.91E-05	1367	1.14E+10	-1.7003	5637	104.4372
6.86	3.96E-04	47810	1897	-6.23E-05	1460	1.14E+10	-1.3699	5808	106.613
7	2.98E-04	51146	2010	-5.50E-05	1562	1.14E+10	-1.3075	7382	30.0868
7.14	2.12E-04	54562	2033	-4.72E-05	1666	1.14E+10	-0.9561	7594	0
7.28	1.39E-04	57976	2032	-3.89E-05	1770	1.14E+10	-0.6458	7806	0
7.42	8.08E-05	61389	2031	-3.01E-05	1874	1.14E+10	-0.3858	8018	0
7.56	3.79E-05	64800	-2601	-2.08E-05	1979	1.14E+10	-5514	2.45E+08	0
7.7	1.10E-05	52649	-8693	-1.21E-05	1608	1.14E+10	-1738	2.67E+08	0
7.84	-2.92E-06	35592	-9732	-5.64E-06	1087	1.14E+10	501.474	2.89E+08	0
7.98	-7.98E-06	19951	-8071	-1.54E-06	609.1905	1.14E+10	1475	3.10E+08	0
8.12	-8.10E-06	8472	-5486	5.53E-07	258.7009	1.14E+10	1603	3.32E+08	0
8.26	-6.12E-06	1518	-3054	1.29E-06	46.3598	1.14E+10	1292	3.54E+08	0
8.4	-3.77E-06	-1790	-1260	1.27E-06	54.6631	1.14E+10	844.4575	3.76E+08	0
8.54	-1.86E-06	-2715	-180.376	9.37E-07	82.9105	1.14E+10	440.8098	3.98E+08	0
8.68	-6.21E-07	-2396	320.4681	5.60E-07	73.1689	1.14E+10	155.4333	4.20E+08	0
8.82	2.32E-08	-1639	445.9015	2.63E-07	50.032	1.14E+10	-6.1078	4.42E+08	0
8.96	2.62E-07	-898.052	379.9616	7.60E-08	27.4214	1.14E+10	-72.3921	4.64E+08	0
9.1	2.78E-07	-361.876	251.4727	-1.69E-08	11.0496	1.14E+10	-80.5709	4.86E+08	0
9.24	2.05E-07	-53.1035	131.6467	-4.75E-08	1.6215	1.14E+10	-62.0791	5.08E+08	0
9.38	1.19E-07	80.4569	47.9782	-4.55E-08	2.4567	1.14E+10	-37.5262	5.30E+08	0
9.52	5.25E-08	108.1033	1.9552	-3.16E-08	3.3009	1.14E+10	-17.2631	5.52E+08	0
9.66	1.29E-08	87.0264	-16.2498	-1.72E-08	2.6573	1.14E+10	-4.4095	5.74E+08	0
9.8	-5.18E-09	53.5041	-18.4112	-6.82E-09	1.6337	1.14E+10	1.8364	5.96E+08	0
9.94	-1.00E-08	25.1648	-13.7754	-1.02E-09	0.7684	1.14E+10	3.6824	6.18E+08	0
10.08	-8.62E-09	7.2187	-7.9255	1.36E-09	0.2204	1.14E+10	3.2817	6.40E+08	0
10.22	-5.43E-09	-1.465	-3.3709	1.79E-09	0.04473	1.14E+10	2.1404	6.62E+08	0
10.36	-2.61E-09	-4.1076	-0.6795	1.38E-09	0.1254	1.14E+10	1.0636	6.84E+08	0
10.5	-8.10E-10	-3.7482	0.4998	7.97E-10	0.1144	1.14E+10	0.3403	7.06E+08	0
10.64	6.50E-11	-2.4284	0.762	3.42E-10	0.07415	1.14E+10	-0.02815	7.28E+08	0
10.78	3.39E-10	-1.188	0.6113	7.55E-11	0.03627	1.14E+10	-0.1512	7.50E+08	0
10.92	3.19E-10	-0.3743	0.3615	-3.97E-11	0.01143	1.14E+10	-0.1463	7.71E+08	0
11.06	2.06E-10	0.02648	0.157	-6.53E-11	8.09E-04	1.14E+10	-0.09707	7.93E+08	0
11.2	9.91E-11	0.1533	0.03511	-5.21E-11	0.00468	1.14E+10	-0.04808	8.15E+08	0
11.34	3.06E-11	0.1444	-0.01808	-3.01E-11	0.00441	1.14E+10	-0.01524	8.37E+08	0
11.48	-2.15E-12	0.09255	-0.02996	-1.27E-11	0.00283	1.14E+10	0.0011	8.59E+08	0
11.62	-1.20E-11	0.04376	-0.02378	-2.61E-12	0.00134	1.14E+10	0.00627	8.81E+08	0

11.76	-1.09E-11	0.01267	-0.01358	1.55E-12	3.87E-04	1.14E+10	0.00587	9.03E+08	0
11.9	-6.75E-12	-0.00186	-0.00553	2.35E-12	5.68E-05	1.14E+10	0.00372	9.25E+08	0
12.04	-3.04E-12	-0.0059	-9.67E-04	1.77E-12	1.80E-04	1.14E+10	0.00171	9.47E+08	0
12.18	0	-0.00511	8.53E-04	0	1.56E-04	1.14E+10	4.54E-04	9.69E+08	0
12.32	0	-0.00303	0.00114	0	9.26E-05	1.14E+10	-1.16E-04	9.91E+08	0
12.46	0	-0.00129	8.22E-04	0	3.93E-05	1.14E+10	-2.59E-04	1.01E+09	0
12.6	0	-2.72E-04	4.26E-04	0	8.32E-06	1.14E+10	-2.12E-04	1.03E+09	0
12.74	0	1.44E-04	1.46E-04	0	4.38E-06	1.14E+10	-1.20E-04	1.06E+09	0
12.88	0	2.20E-04	5.40E-06	0	6.71E-06	1.14E+10	-4.75E-05	1.08E+09	0
13.02	0	1.62E-04	-4.05E-05	0	4.94E-06	1.14E+10	-7.12E-06	1.10E+09	0
13.16	0	8.37E-05	-3.96E-05	0	2.55E-06	1.14E+10	8.13E-06	1.12E+09	0
13.3	0	2.86E-05	-2.45E-05	0	8.72E-07	1.14E+10	9.87E-06	1.14E+09	0
13.44	0	1.34E-06	-1.05E-05	0	4.09E-08	1.14E+10	6.76E-06	1.17E+09	0
13.58	0	-6.79E-06	-2.10E-06	0	2.07E-07	1.14E+10	3.26E-06	1.18E+09	0
13.72	0	-5.72E-06	1.38E-06	0	1.75E-07	1.14E+10	8.83E-07	1.18E+09	0
13.86	0	-2.15E-06	1.70E-06	0	6.55E-08	1.14E+10	-5.05E-07	1.18E+09	0
14	0	0	0	0	0	1.14E+10	-1.52E-06	5.88E+08	0

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

Output Summary for Load Case No. 1:

Pile-head deflection = 0.01246821 inches
Computed slope at pile head = -0.00017479 radians
Maximum bending moment = 64800. inch-lbs
Maximum shear force = -9732. lbs
Depth of maximum bending moment = 7.56000000 feet below pile head
Depth of maximum shear force = 7.84000000 feet below pile head
Number of iterations = 6
Number of zero deflection points = 8

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

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

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	0	M, in-lb	0	0	0.01247	-1.75E-04	-9732	64800

Maximum pile-head deflection = 0.0124682131 inches
Maximum pile-head rotation = -0.0001747935 radians = -0.010015 deg.

Summary of Warning Messages

The following warning was reported 282 times

**** Warning ****

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

The analysis ended normally.

APPENDIX D.3
DEL-315-8.10

This copy of LPile is being used by:

odot
1980 west broad st, columbus,oh

Serial Number of Security Device: 228746756

This copy of LPile is licensed for exclusive use by:

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Files Used for Analysis

Path to file locations:
\gt\Projects\D06\Delaware\DEL-315-8.10\Geotechnical\EngData\LPILE\

Name of input data file:
24in_HP12_53_6ftsocket_factored.lp9d

Name of output report file:
24in_HP12_53_6ftsocket_factored.lp9o

Name of plot output file:
24in_HP12_53_6ftsocket_factored.lp9p

Name of runtime message file:
24in_HP12_53_6ftsocket_factored.lp9r

Date and Time of Analysis

Date: March 1, 2018 Time: 14:33:38

Problem Title

Project Name: DEL-315-8.10
Job Number: 102124
Client:

Engineer: Taliaferro
Description: Plug Pile Wall

Program Options and Settings

Computational Options:
- Use unfactored loads in computations (conventional analysis)

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

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

Loading Type and Number of Cycles of Loading:
- Static loading specified
- Analysis uses p-y modification factors for p-y curves
- Analysis includes loading by multiple distributed lateral loads acting on pile
- Loading by lateral soil movements acting on pile not selected
- Input of shear resistance at the pile tip not selected
- Computation of pile-head foundation stiffness matrix not selected
- Push-over analysis of pile not selected
- Buckling analysis of pile not selected

Output Options:
- Output files use decimal points to denote decimal symbols.
- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (nodal spacing of output points) = 1
- No p-y curves to be computed and reported for user-specified depths
- Print using wide report formats

Pile Structural Properties and Geometry

Number of pile sections defined = 1
Total length of pile = 14.000 ft
Depth of ground surface below top of pile = 1.5000 ft

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

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

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0	24
2	14	24

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is an elastic pile
Cross-sectional Shape = Circular Pile
Length of section = 14.000000 ft
Width of top of section = 24.000000 in
Width of bottom of section = 24.000000 in
Top Area = 15.500000 sq. in
Bottom Area = 15.500000 sq. in
Moment of Inertia at Top = 393.000000 in^4
Moment of Inertia at Bottom = 393.000000 in^4
Elastic Modulus = 29000000. psi

Ground Slope and Pile Batter Angles

Ground Slope Angle = 0.000 degrees
= 0.000 radians

Pile Batter Angle = 0.000 degrees
= 0.000 radians

Soil and Rock Layering Information

The soil profile is modelled using 3 layers

Layer 1 is stiff clay with water-induced erosion
Distance from top of pile to top of layer = 1.500000 ft
Distance from top of pile to bottom of layer = 8.500000 ft
Effective unit weight at top of layer = 55.600000 pcf
Effective unit weight at bottom of layer = 55.600000 pcf
Undrained cohesion at top of layer = 1083. psf
Undrained cohesion at bottom of layer = 1083. psf
Epsilon-50 at top of layer = 0.009000
Epsilon-50 at bottom of layer = 0.009000
Subgrade k at top of layer = 0.0000 pci
Subgrade k at bottom of layer = 0.0000 pci

NOTE: Default values for subgrade k will be computed for this layer.

Layer 2 is stiff clay with water-induced erosion
Distance from top of pile to top of layer = 8.500000 ft
Distance from top of pile to bottom of layer = 12.000000 ft
Effective unit weight at top of layer = 59.600000 pcf
Effective unit weight at bottom of layer = 59.600000 pcf
Undrained cohesion at top of layer = 2313. psf
Undrained cohesion at bottom of layer = 2313. psf
Epsilon-50 at top of layer = 0.005800
Epsilon-50 at bottom of layer = 0.005800
Subgrade k at top of layer = 0.0000 pci
Subgrade k at bottom of layer = 0.0000 pci

NOTE: Default values for subgrade k will be computed for this layer.

Layer 3 is weak rock, p-y criteria by Reese, 1997
Distance from top of pile to top of layer = 12.000000 ft
Distance from top of pile to bottom of layer = 17.500000 ft
Effective unit weight at top of layer = 82.500000 pcf
Effective unit weight at bottom of layer = 82.500000 pcf
Uniaxial compressive strength at top of layer = 20451. psi
Uniaxial compressive strength at bottom of layer = 20451. psi
Initial modulus of rock at top of layer = 1800000. psi
Initial modulus of rock at bottom of layer = 1800000. psi
RQD of rock at top of layer = 7.000000 %
RQD of rock at bottom of layer = 7.000000 %
k rm of rock at top of layer = 0.0000500
k rm of rock at bottom of layer = 0.0000500

(Depth of the lowest soil layer extends 3.500 ft below the pile tip)

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Undrained Cohesion psf	Uniaxial qu psi	RQD %	E50 or krm	kpy pci	Rock Mass Modulus psi
1	Stiff Clay	1.5	55.6	1083	--	--	0.009	default	--
	with Free Water	8.5	55.6	1083	--	--	0.009	default	--
2	Stiff Clay	8.5	59.6	2313	--	--	0.0058	default	--
	with Free Water	12	59.6	2313	--	--	0.0058	default	--
3	Weak	12	82.5	--	20451	7	5.00E-05	--	1800000
	Rock	17.5	82.5	--	20451	7	5.00E-05	--	1800000

p-y Modification Factors for Group Action

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

Point No.	Depth X ft	p-mult	y-mult
1	3.4	0.81	1
2	10	0.81	1

Static Loading Type

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

Distributed Lateral Loading for Individual Load Cases

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

---

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length
1	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0	Yes

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

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

---

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

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Moment-curvature properties were derived from elastic section properties

---

Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	1.5	0	N.A.	No	0	8740
2	8.5	7	Yes	No	8740	48741
3	12	10.5	No	Yes	N.A.	N.A.

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

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

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

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

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness in-lb^2	Soil Res. p lb/inch	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0	0.2422	2.80E-06	0	-0.00266	8.56E-08	1.14E+10	0	0	134.2878
0.14	0.2378	189.5069	230.5119	-0.00266	5.7865	1.14E+10	0	0	140.1311
0.28	0.2333	774.5199	472.4767	-0.00266	23.6495	1.14E+10	0	0	147.9222
0.42	0.2288	1777	727.5305	-0.00266	54.2604	1.14E+10	0	0	155.7133
0.56	0.2244	3219	995.6734	-0.00266	98.2908	1.14E+10	0	0	163.5044
0.7	0.2199	5122	1277	-0.00266	156.4119	1.14E+10	0	0	171.2955
0.84	0.2154	7509	1571	-0.00266	229.2954	1.14E+10	0	0	179.0866
0.98	0.2109	10402	1879	-0.00266	317.6126	1.14E+10	0	0	186.8778
1.12	0.2065	13822	2199	-0.00266	422.0349	1.14E+10	0	0	194.6689
1.26	0.202	17791	2533	-0.00265	543.2338	1.14E+10	0	0	202.46
1.4	0.1976	22332	2879	-0.00265	681.8808	1.14E+10	0	0	210.2511
1.54	0.1931	27466	3200	-0.00265	838.6472	1.14E+10	-46.3468	403.2	218.0422
1.68	0.1887	33084	3429	-0.00264	1010	1.14E+10	-125.46	1117	225.8333
1.82	0.1842	38986	3587	-0.00264	1190	1.14E+10	-145.767	1329	233.6244
1.96	0.1798	45136	3725	-0.00263	1378	1.14E+10	-165.298	1544	241.4155
2.1	0.1754	51501	3843	-0.00262	1573	1.14E+10	-184.099	1763	249.2066
2.24	0.171	58050	3944	-0.00262	1773	1.14E+10	-202.202	1987	256.9977
2.38	0.1666	64753	4028	-0.00261	1977	1.14E+10	-219.632	2215	264.7888

2.52	0.1622	71584	4096	-0.0026	2186	1.14E+10	-236.403	2448	272.5799
2.66	0.1579	78516	4150	-0.00259	2397	1.14E+10	-252.528	2687	280.371
2.8	0.1535	85528	4190	-0.00257	2612	1.14E+10	-268.013	2933	288.1622
2.94	0.1492	92596	4218	-0.00256	2827	1.14E+10	-282.861	3185	295.9533
3.08	0.1449	99701	4235	-0.00255	3044	1.14E+10	-297.072	3444	303.7444
3.22	0.1407	106825	4241	-0.00253	3262	1.14E+10	-310.642	3710	311.5355
3.36	0.1364	113952	4238	-0.00252	3479	1.14E+10	-323.564	3985	319.3266
3.5	0.1322	121066	4281	-0.0025	3697	1.14E+10	-272.021	3457	327.1177
3.64	0.128	128336	4372	-0.00248	3919	1.14E+10	-281.408	3693	334.9088
3.78	0.1239	135757	4461	-0.00246	4145	1.14E+10	-290.23	3936	342.6999
3.92	0.1198	143326	4549	-0.00244	4376	1.14E+10	-298.458	4187	350.491
4.06	0.1157	151042	4637	-0.00242	4612	1.14E+10	-306.04	4445	358.2821
4.2	0.1116	158906	4725	-0.0024	4852	1.14E+10	-312.85	4709	366.0732
4.34	0.1076	166920	4817	-0.00237	5097	1.14E+10	-318.089	4966	373.8643
4.48	0.1037	175091	4913	-0.00235	5346	1.14E+10	-322.572	5228	381.6554
4.62	0.09974	183429	5016	-0.00232	5601	1.14E+10	-326.612	5502	389.4466
4.76	0.09586	191944	5125	-0.00229	5861	1.14E+10	-330.202	5787	397.2377
4.9	0.09203	200648	5241	-0.00226	6127	1.14E+10	-333.339	6085	405.0288
5.04	0.08826	209555	5366	-0.00223	6399	1.14E+10	-336.019	6396	412.8199
5.18	0.08453	218678	5500	-0.0022	6677	1.14E+10	-338.239	6722	420.611
5.32	0.08086	228034	5643	-0.00217	6963	1.14E+10	-339.994	7064	428.4021
5.46	0.07724	237640	5797	-0.00213	7256	1.14E+10	-341.281	7423	436.1932
5.6	0.07369	247513	5963	-0.0021	7558	1.14E+10	-342.098	7799	443.9843
5.74	0.07019	257674	6140	-0.00206	7868	1.14E+10	-342.442	8196	451.7754
5.88	0.06676	268144	6330	-0.00202	8188	1.14E+10	-342.311	8614	459.5665
6.02	0.0634	278944	6534	-0.00198	8517	1.14E+10	-341.704	9055	467.3576
6.16	0.0601	290100	6753	-0.00194	8858	1.14E+10	-340.62	9521	475.1487
6.3	0.05688	301634	6987	-0.0019	9210	1.14E+10	-339.06	10015	482.9398
6.44	0.05373	313575	7207	-0.00185	9575	1.14E+10	-337.025	10538	455.4204
6.58	0.05066	325850	7026	-0.0018	9950	1.14E+10	-334.518	11094	0
6.72	0.04767	337181	6466	-0.00176	10296	1.14E+10	-331.543	11685	0
6.86	0.04476	347577	5912	-0.0017	10613	1.14E+10	-328.106	12315	0
7	0.04194	357046	5364	-0.00165	10902	1.14E+10	-324.21	12988	0
7.14	0.03921	365600	4823	-0.0016	11163	1.14E+10	-319.863	13707	0
7.28	0.03656	373251	4290	-0.00155	11397	1.14E+10	-315.071	14477	0
7.42	0.03401	380013	3765	-0.00149	11603	1.14E+10	-309.843	15304	0
7.56	0.03156	385901	3249	-0.00143	11783	1.14E+10	-304.185	16193	0
7.7	0.0292	390930	2745	-0.00138	11937	1.14E+10	-295.654	17011	0
7.84	0.02693	395124	2258	-0.00132	12065	1.14E+10	-283.964	17712	0
7.98	0.02477	398517	1791	-0.00126	12168	1.14E+10	-272.31	18470	0
8.12	0.0227	401142	1343	-0.0012	12249	1.14E+10	-260.703	19292	0
8.26	0.02074	403031	914.9603	-0.00114	12306	1.14E+10	-249.151	20187	0
8.4	0.01887	404216	506.0344	-0.00108	12342	1.14E+10	-237.666	21162	0
8.54	0.0171	404731	-199.246	-0.00102	12358	1.14E+10	-601.954	59139	0
8.68	0.01543	403547	-1185	-9.63E-04	12322	1.14E+10	-571.857	62251	0
8.82	0.01387	400749	-2121	-9.03E-04	12237	1.14E+10	-542.043	65676	0
8.96	0.0124	396420	-3007	-8.45E-04	12104	1.14E+10	-512.546	69455	0

9.1	0.01103	390646	-3843	-7.87E-04	11928	1.14E+10	-483.401	73643	0
9.24	0.00975	383507	-4631	-7.30E-04	11710	1.14E+10	-454.642	78302	0
9.38	0.00858	375084	-5371	-6.74E-04	11453	1.14E+10	-426.303	83507	0
9.52	0.00749	365459	-6064	-6.19E-04	11159	1.14E+10	-398.419	89352	0
9.66	0.0065	354709	-6710	-5.66E-04	10831	1.14E+10	-371.024	95949	0
9.8	0.00559	342912	-7311	-5.15E-04	10471	1.14E+10	-344.153	103441	0
9.94	0.00477	330144	-7867	-4.65E-04	10081	1.14E+10	-317.841	112005	0
10.08	0.00403	316478	-8437	-4.17E-04	9663	1.14E+10	-360.648	150450	0
10.22	0.00337	301795	-9017	-3.72E-04	9215	1.14E+10	-329.683	164582	0
10.36	0.00278	286181	-9542	-3.28E-04	8738	1.14E+10	-295.374	178618	0
10.5	0.00226	269733	-9995	-2.87E-04	8236	1.14E+10	-244.284	181440	0
10.64	0.00181	252596	-10368	-2.49E-04	7713	1.14E+10	-198.786	184262	0
10.78	0.00143	234898	-10668	-2.13E-04	7172	1.14E+10	-158.744	187085	0
10.92	0.0011	216752	-10905	-1.80E-04	6618	1.14E+10	-123.978	189907	0
11.06	8.22E-04	198256	-11089	-1.49E-04	6054	1.14E+10	-94.2648	192730	0
11.2	5.96E-04	179494	-11226	-1.21E-04	5481	1.14E+10	-69.3424	195552	0
11.34	4.14E-04	160536	-11325	-9.62E-05	4902	1.14E+10	-48.9094	198374	0
11.48	2.72E-04	141440	-11394	-7.40E-05	4319	1.14E+10	-32.6277	201197	0
11.62	1.66E-04	122252	-11438	-5.45E-05	3733	1.14E+10	-20.1234	204019	0
11.76	8.92E-05	103008	-11464	-3.79E-05	3145	1.14E+10	-10.9878	206842	0
11.9	3.83E-05	83732	-11478	-2.42E-05	2557	1.14E+10	-4.7789	209664	0
12.04	8.08E-06	64443	-12735	-1.32E-05	1968	1.14E+10	-1492	3.10E+08	0
12.18	-6.18E-06	40941	-12942	-5.47E-06	1250	1.14E+10	1246	3.39E+08	0
12.32	-1.03E-05	20957	-10006	-9.07E-07	639.8959	1.14E+10	2250	3.67E+08	0
12.46	-9.23E-06	7321	-6293	1.18E-06	223.5523	1.14E+10	2171	3.95E+08	0
12.6	-6.35E-06	-187.301	-3126	1.70E-06	5.7191	1.14E+10	1599	4.23E+08	0
12.74	-3.51E-06	-3183	-991.189	1.45E-06	97.1904	1.14E+10	942.8065	4.52E+08	0
12.88	-1.46E-06	-3518	150.5561	9.61E-07	107.4105	1.14E+10	416.4134	4.80E+08	0
13.02	-2.80E-07	-2677	571.3996	5.04E-07	81.744	1.14E+10	84.5908	5.08E+08	0
13.16	2.36E-07	-1598	579.2864	1.89E-07	48.7875	1.14E+10	-75.2017	5.36E+08	0
13.3	3.55E-07	-730.715	415.855	1.74E-08	22.3119	1.14E+10	-119.36	5.64E+08	0
13.44	2.94E-07	-200.519	228.4887	-5.13E-08	6.1227	1.14E+10	-103.696	5.93E+08	0
13.58	1.83E-07	37.0069	84.5852	-6.33E-08	1.13	1.14E+10	-67.6181	6.21E+08	0
13.72	8.11E-08	83.6874	1.4494	-5.44E-08	2.5553	1.14E+10	-31.3531	6.49E+08	0
13.86	5.84E-11	41.877	-24.907	-4.52E-08	1.2787	1.14E+10	-0.02356	6.77E+08	0
14	-7.07E-08	0	0	-4.21E-08	0	1.14E+10	29.6747	3.53E+08	0

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

Output Summary for Load Case No. 1:

Pile-head deflection = 0.24224816 inches
Computed slope at pile head = -0.00266233 radians
Maximum bending moment = 404731. inch-lbs
Maximum shear force = -12942. lbs
Depth of maximum bending moment = 8.54000000 feet below pile head
Depth of maximum shear force = 12.18000000 feet below pile head

Number of iterations = 16
Number of zero deflection points = 3

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

Boundary Condition Type 1, Shear and Moment

Shear = 0.0 lbs
Moment = 0.0 in-lbs
Axial Load = 0.0 lbs

Pile Length feet	Pile Head Deflection inches	Maximum Moment ln-lbs	Maximum Shear lbs
14	0.242248	404731	-12942
13.3	0.241868	405137	-12066
12.6	0.244308	406072	-13259
11.9	0.289994	330961	-11952
11.2	0.337612	295246	-11921
10.5	0.449654	263617	-11525

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

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

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	0	M, in-lb	0	0	0.2422	-0.00266	-12942	404731

Maximum pile-head deflection = 0.2422481624 inches
Maximum pile-head rotation = -0.0026623256 radians = -0.152540 deg.

Summary of Warning Messages

The following warning was reported 720 times

**** Warning ****

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

The analysis ended normally.

APPENDIX E
RSS ANALYSIS

APPENDIX E.1
DEL-315-5.0

ReSSA Output 5.0

Data for circles, ending point - Lower part on 10/31/18 at 07:45:09 AM

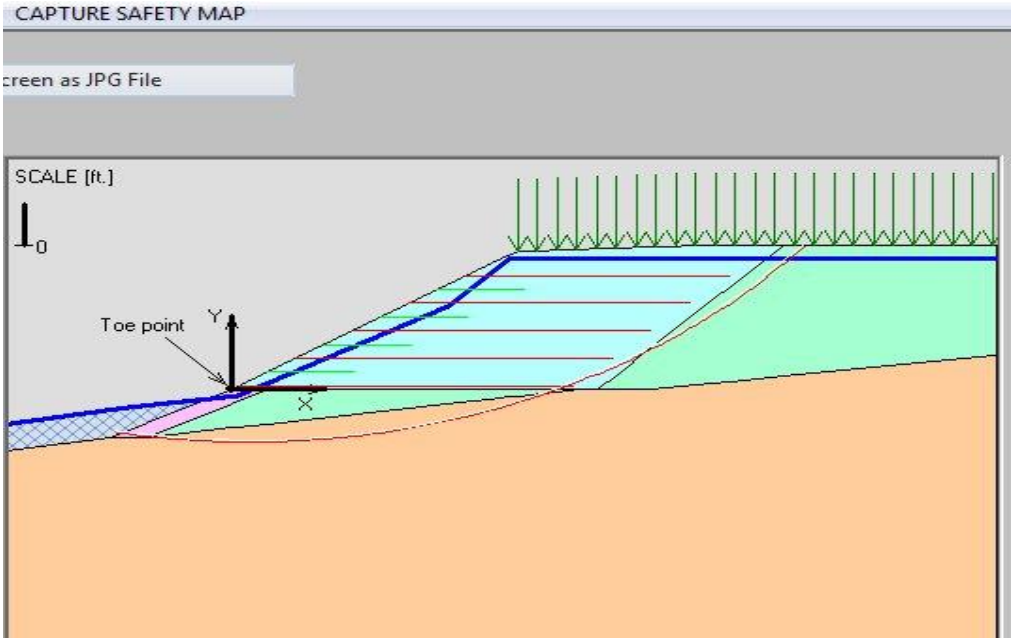
	X center [ft]	Y center [ft]	Radius [ft]	Factor of Safety	X down [ft]	Y down [ft]	X up [ft]	Y up [ft]	Theta [degrees]
1	13.84	828.38	41.71	1.304	6.32	787.36	45.30	801.00	10.0
2	12.56	843.86	55.61	1.335	8.62	788.38	48.00	801.00	4.0
3	17.82	825.76	36.99	1.317	10.39	789.52	45.30	801.00	11.0
4	21.11	814.54	25.40	1.368	12.76	790.55	42.60	801.00	19.0
5	24.80	814.01	24.28	1.484	14.66	791.94	45.30	801.00	24.0
6	26.84	806.67	16.75	1.692	16.78	793.29	42.60	801.00	36.0
7	27.51	816.38	23.52	1.925	18.92	794.49	45.30	801.00	21.0
8	29.65	807.42	14.45	2.297	21.03	795.82	42.60	801.00	36.0
9	30.91	808.83	14.07	2.812	23.13	797.10	42.60	801.00	33.0
10	31.04	808.23	11.44	3.775	25.32	798.33	39.90	801.00	30.0
11	27.53	801.46	1.84	1.579	27.40	799.63	29.10	800.50	4.0

Lower Part Minimum Factor of Safety = 1.304

Data for circles, starting point - Upper part on 10/31/18 at 07:44:56 AM

	X center [ft]	Y center [ft]	Radius [ft]	Factor of Safety	X down [ft]	Y down [ft]	X up [ft]	Y up [ft]	Theta [degrees]
1	27.53	801.46	1.84	1.579	27.40	799.63	29.10	800.50	4.0
2	28.98	802.86	3.60	2.119	27.37	799.64	31.80	800.63	26.0
3	16.47	802.50	18.12	1.857	6.35	787.47	34.50	800.75	33.0
4	15.99	807.44	22.21	1.598	6.60	787.31	37.20	800.87	25.0
5	16.25	811.19	25.76	1.408	6.57	787.32	39.90	801.00	22.0
6	14.38	821.02	34.60	1.312	6.30	787.38	42.60	801.00	13.0
7	13.84	828.38	41.71	1.304	6.32	787.36	45.30	801.00	10.0
8	12.56	843.86	55.61	1.335	8.62	788.38	48.00	801.00	4.0
9	17.84	839.81	50.85	1.377	10.38	789.50	50.70	801.00	8.0
10	17.90	847.58	58.57	1.420	10.38	789.50	53.40	801.00	7.0
11	10.24	877.91	89.54	1.507	8.40	788.38	56.10	801.00	1.0

Upper Part Minimum Factor of Safety = 1.304



APPENDIX E.2
DEL-315-6.40

ReSSA Output 6.40

Data for circles, ending point - Lower part on 10/31/18 at 07:46:49 AM

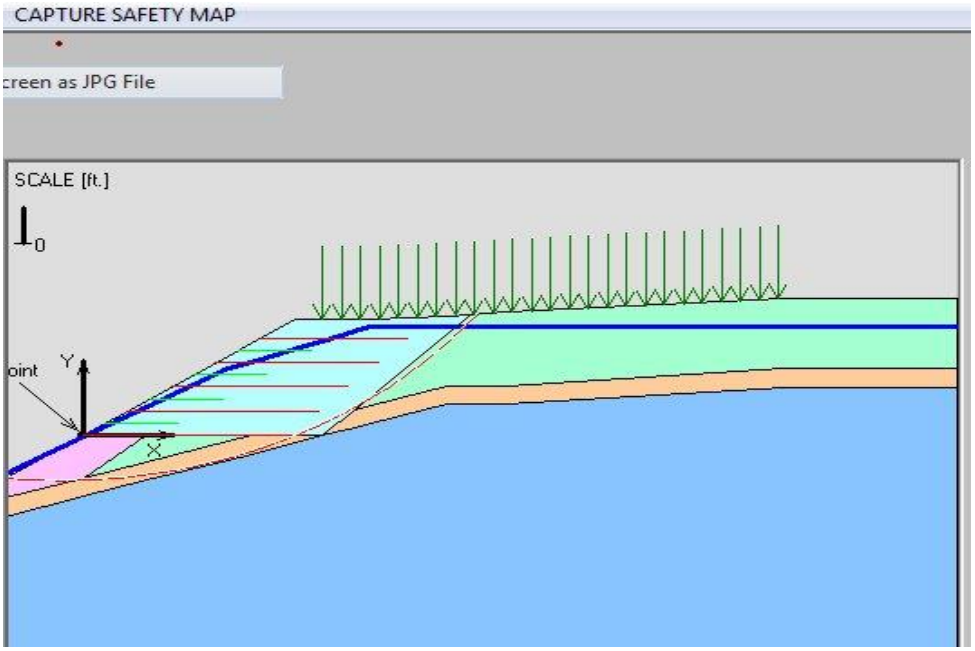
	X center [ft]	Y center [ft]	Radius [ft]	Factor of Safety	X down [ft]	Y down [ft]	X up [ft]	Y up [ft]	Theta [degrees]
1	3.73	832.14	35.71	1.309	-0.07	796.64	31.80	810.06	6.0
2	7.62	826.87	29.44	1.376	1.74	798.02	31.80	810.06	11.0
3	10.80	823.01	24.67	1.501	3.70	799.38	31.80	810.06	16.0
4	13.68	819.63	20.49	1.751	5.85	800.69	31.80	810.06	22.0
5	15.37	819.32	18.86	2.075	8.00	801.96	31.80	810.06	23.0
6	17.42	817.87	16.35	2.377	9.91	803.34	31.80	810.06	27.0
7	19.21	817.13	14.43	2.821	11.98	804.64	31.80	810.06	30.0
8	20.98	816.32	12.49	3.525	13.87	806.05	31.80	810.06	34.0
9	22.65	815.81	10.80	4.767	15.88	807.39	31.80	810.06	38.0
10	20.32	813.85	5.71	6.356	17.96	808.65	24.15	809.61	24.0
11	22.08	811.35	2.71	9.707	19.98	809.63	24.15	809.61	50.0

Lower Part Minimum Factor of Safety = 1.309

Data for circles, starting point - Upper part on 10/31/18 at 07:46:40 AM

	X center [ft]	Y center [ft]	Radius [ft]	Factor of Safety	X down [ft]	Y down [ft]	X up [ft]	Y up [ft]	Theta [degrees]
1	5.01	811.19	15.40	4.419	-0.15	796.68	20.33	809.61	19.0
2	10.74	810.97	13.48	2.201	3.87	799.37	24.15	809.61	30.0
3	4.65	823.02	26.80	1.469	-0.03	796.63	27.98	809.82	10.0
4	3.73	832.14	35.71	1.309	-0.07	796.64	31.80	810.06	6.0
5	1.70	845.40	48.80	1.383	-0.07	796.63	35.62	810.31	2.0
6	0.00	859.50	62.87	1.539	-0.00	796.63	39.44	810.54	0.0
7	3.20	866.96	69.01	1.799	1.84	797.97	43.26	810.77	1.0
8	0.43	887.87	89.92	1.946	1.81	797.96	47.08	811.00	-1.0
9	-4.29	917.92	120.12	2.172	1.92	797.96	50.91	811.23	-3.0
10	-12.80	967.15	169.84	2.532	1.48	797.92	54.73	811.32	-5.0
11	-30.32	1061.19	265.21	2.910	1.54	797.91	58.55	811.32	-7.0

Upper Part Minimum Factor of Safety = 1.309



APPENDIX E.3
DEL-315-8.10

ReSSA Output 8.10

Data for circles, ending point - Lower part on 10/31/18 at 07:47:57 AM

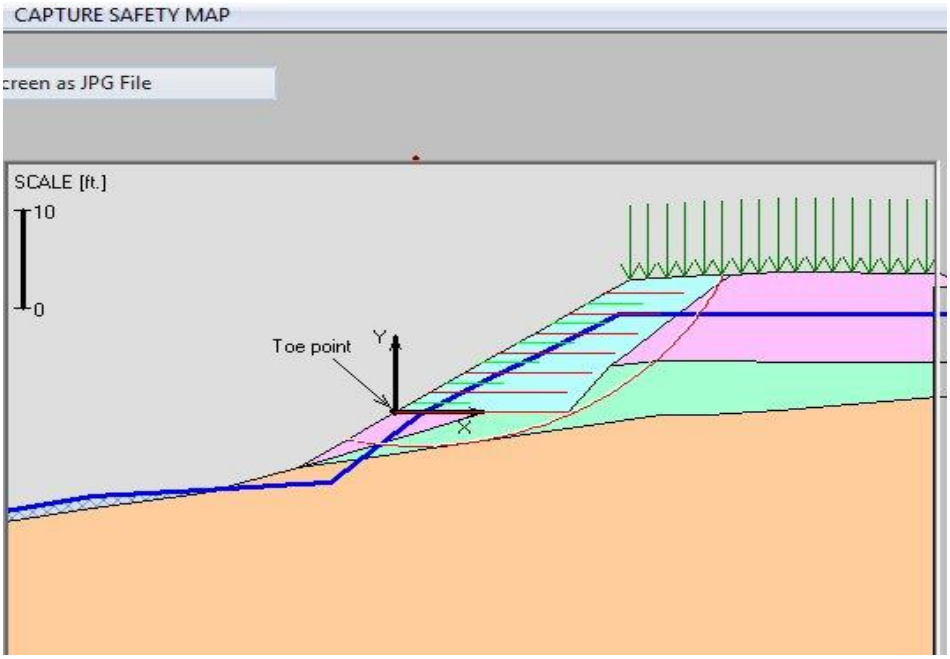
	X center [ft]	Y center [ft]	Radius [ft]	Factor of Safety	X down [ft]	Y down [ft]	X up [ft]	Y up [ft]	Theta [degrees]
1	24.22	870.05	56.65	2.618	2.29	817.81	73.53	842.15	22.0
2	25.74	866.34	51.00	2.569	8.15	818.47	70.67	842.20	20.0
3	24.88	868.17	50.14	2.509	13.12	819.43	67.80	842.25	13.0
4	7.51	928.86	108.98	2.312	18.64	820.45	73.53	842.15	-6.0
5	-2.46	947.55	128.24	1.822	24.14	822.10	70.67	842.20	-12.0
6	35.52	853.59	28.97	1.298	29.34	825.28	62.07	841.96	12.0
7	43.17	850.58	23.35	1.521	34.55	828.88	64.93	842.14	21.0
8	45.86	849.04	17.68	1.775	39.90	832.39	62.07	841.96	19.0
9	50.99	846.37	11.92	2.372	45.35	835.88	62.07	841.96	28.0
10	55.37	845.15	7.42	4.708	50.70	839.39	62.07	841.96	39.0
11	61.11	857.36	16.53	20.499	55.96	841.66	67.80	842.25	18.0

Lower Part Minimum Factor of Safety = 1.298

Data for circles, starting point - Upper part on 10/31/18 at 07:47:44 AM

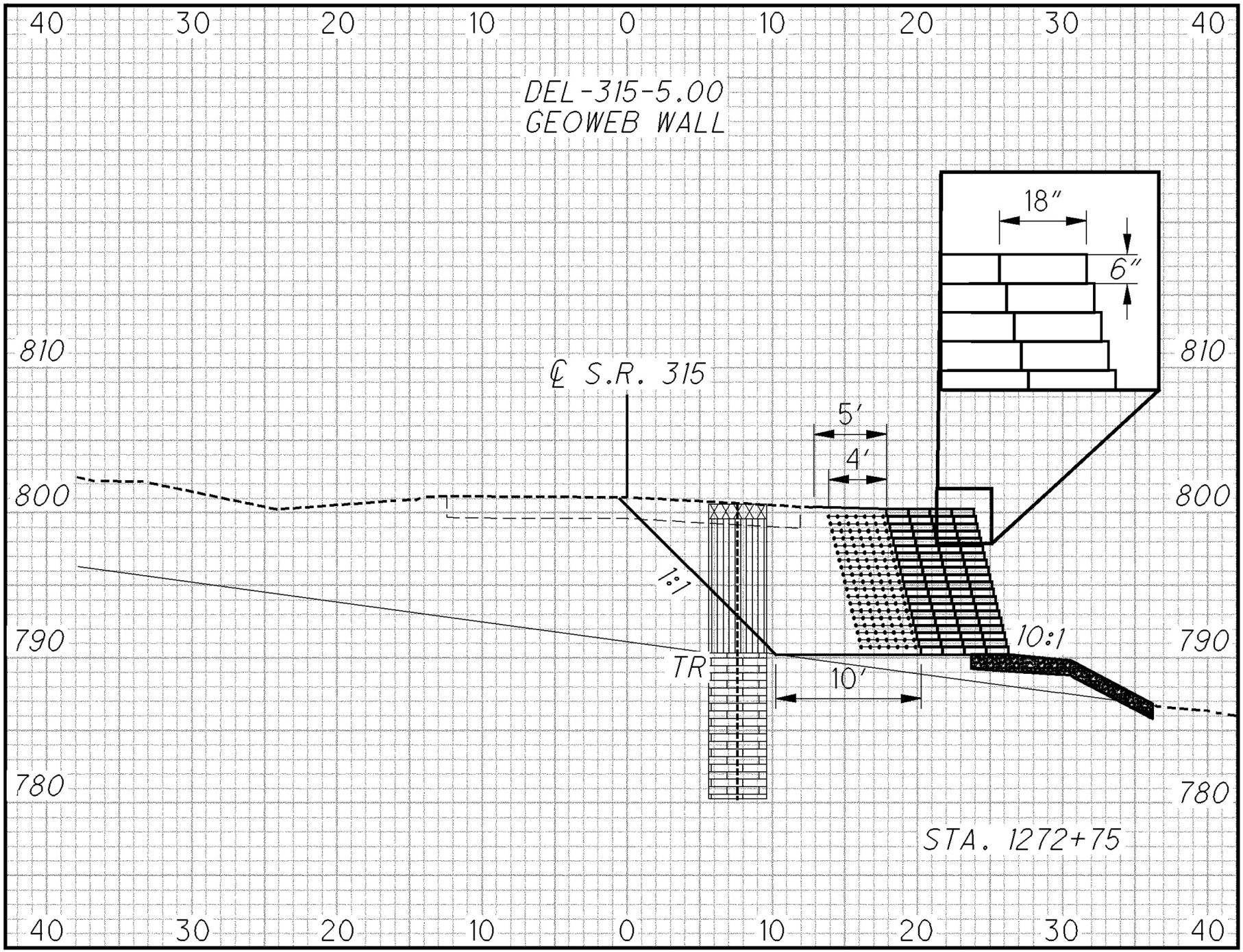
	X center [ft]	Y center [ft]	Radius [ft]	Factor of Safety	X down [ft]	Y down [ft]	X up [ft]	Y up [ft]	Theta [degrees]
1	35.12	846.20	21.70	1.883	29.31	825.30	56.33	841.66	15.0
2	35.20	849.93	25.34	1.451	29.30	825.29	59.20	841.81	13.0
3	35.52	853.59	28.97	1.298	29.34	825.28	62.07	841.96	12.0
4	34.92	859.48	34.66	1.298	29.27	825.28	64.93	842.14	9.0
5	33.89	867.00	41.99	1.327	29.16	825.28	67.80	842.25	6.0
6	35.03	870.28	45.37	1.373	29.32	825.27	70.67	842.20	7.0
7	34.93	876.90	51.94	1.430	29.35	825.26	73.53	842.15	6.0
8	34.68	884.49	59.47	1.495	29.36	825.26	76.40	842.11	5.0
9	34.25	893.23	68.15	1.568	29.37	825.26	79.27	842.06	4.0
10	33.73	905.87	80.73	1.694	29.38	825.25	82.13	841.26	3.0
11	32.84	920.81	95.62	1.847	29.00	825.27	85.00	840.67	2.0

Upper Part Minimum Factor of Safety = 1.298



APPENDIX F
GEOWEB ANALYSES

APPENDIX F.1
DEL-315-5.0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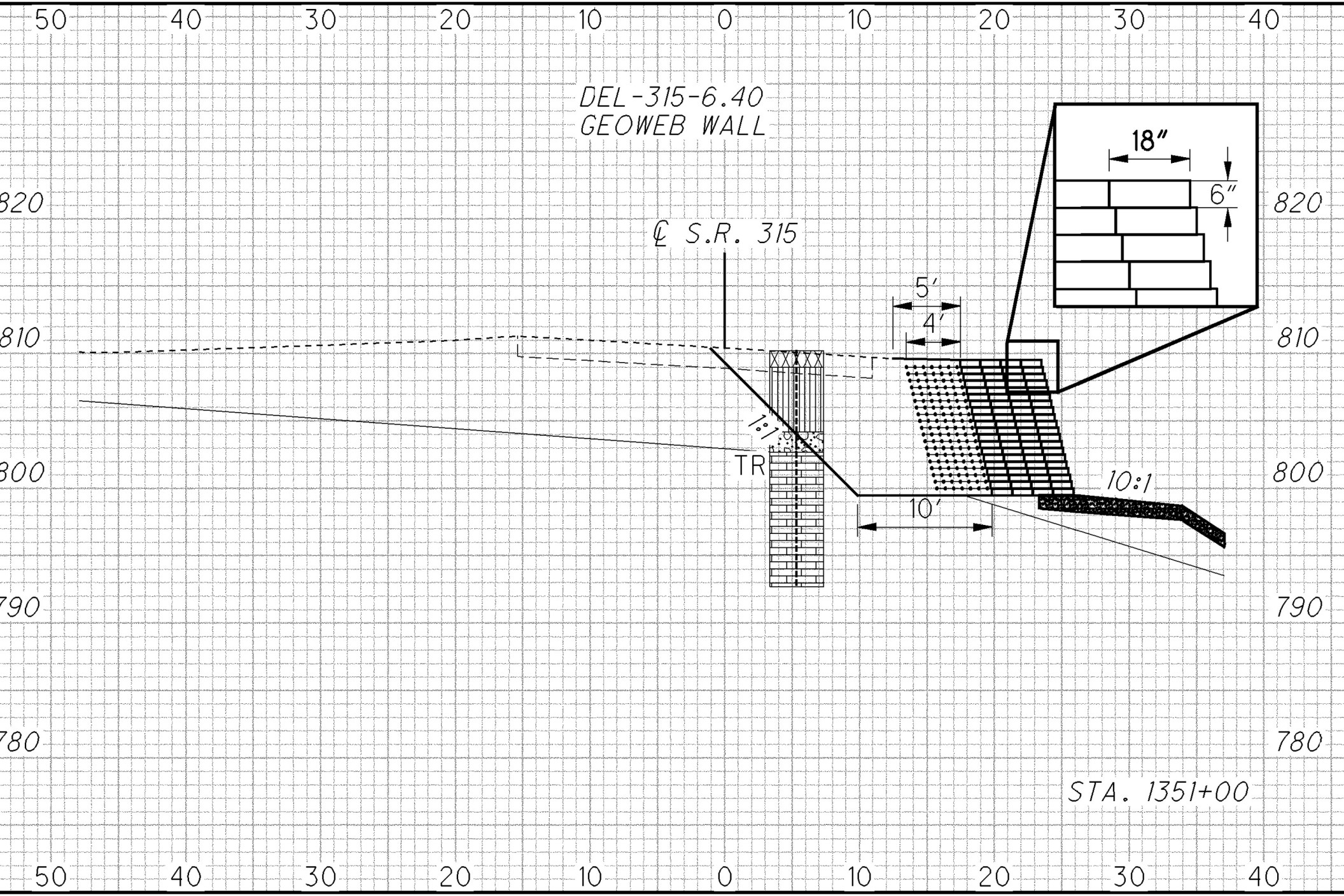
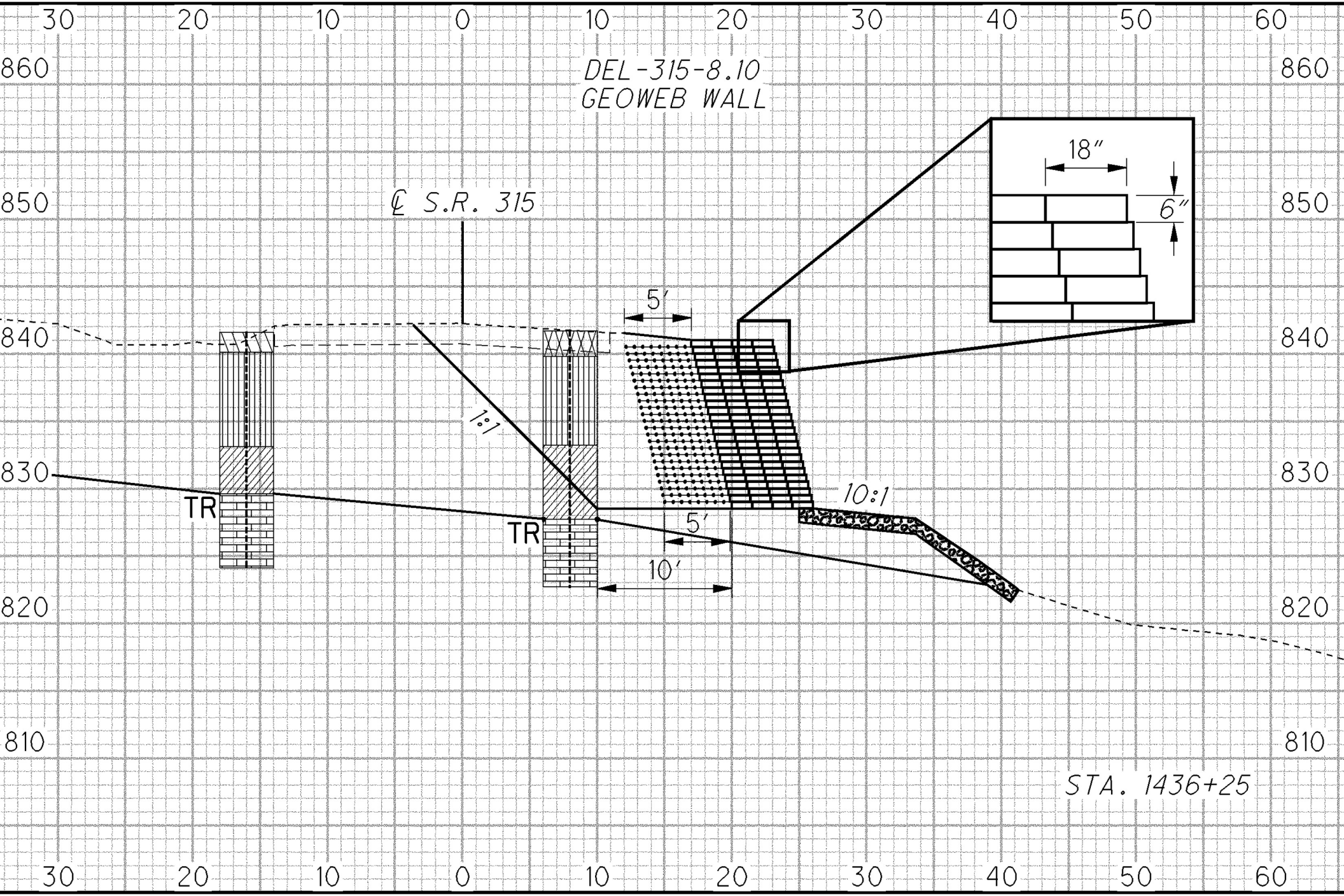
30
20
10
0
10
20
30
40
DEL-315-5.00
GEOWEB WALL
18"
6"
810
℄ S.R. 315
5'
4'
800
1:1
790
TR
10:1
10'
780
STA. 1272+75

APPENDIX F.2
DEL-315-6.40


50
40
30
20
10
0
10
20
30
40
DEL-315-6.40
GEOWEB WALL
820
810
800
790
780
℄ S.R. 315
18"
6"
5'
4'
1:1
TR
10:1
10'
STA. 1351+00

APPENDIX F.3
DEL-315-8.10


30
20
10
0
10
20
30
40
50
60
860
850
840
830
820
810
DEL-315-8.10
GEOWEB WALL
℄ S.R. 315
18″
6″
5′
1:1
10:1
TR
TR
5′
10′
STA. 1436+25