FINAL REPORT
STRUCTURE FOUNDATION EXPLORATION
ROS-138-17.28
ROSS COUNTY, OHIO
PID: 115773

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NEAS PROJECT 24-0004

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National Engineering & Architectural Services Inc.

EXECUTIVE SUMMARY

The ODOT District 9 has proposed a bridge replacement project for the existing bridge ROS-138-1728 (SFN: 7104146) carrying SR-138 in Ross County, Ohio. The existing structure is a three-span continuous reinforced concrete slab bridge with capped pile abutments and reinforced concrete piers. The proposed structure is a single-span 3-sided buried concrete arch structure with a span of 60' and a rise of 13'-3". The proposed structure will be supported on concrete footings on a deep foundation system consisting of driven CIP reinforced concrete pipe piles.

National Engineering and Architectural Services Inc. (NEAS) has been contracted to perform geotechnical engineering services for the project. The purpose of the geotechnical engineering services is to perform geotechnical explorations within the project limits to obtain information concerning the subsurface soil and groundwater conditions relevant to the design and construction of the project. NEAS performed the site reconnaissance and field exploration for the project between January 31, 2024, and February 16, 2024. The subsequent document presents the results of the structure foundation exploration with respect to the planned replacement of the existing ROS-138-1728 bridge. As part of the referenced explorations, NEAS advanced 2 project borings and conducted laboratory testing to characterize the soils and/or rock for engineering purposes.

The subsurface profile at the proposed bridge site generally consists of embankment fills over natural glacial till soils. The embankment fills can be described as medium stiff to hard cohesive materials and medium dense to dense granular materials. Natural glacial soils can be described as very stiff to hard cohesive materials and dense to very dense granular materials. Bedrock was not encountered within depths of the two project borings performed at the bridge site.

A deep foundation system analysis was performed for the referenced bridge replacement site based on soil profiles developed from boring locations. For the analysis, 14-inch closed-ended cast-in-place (CIP) friction pipe piles were evaluated for each substructure. The estimated pile lengths for the proposed structure are approximately 35 ft, with pile tip elevations ranging from 688.2 ft and 691.5 ft amsl, depending on the location. Pile drivability results indicate that 14-inch CIP piles with a wall thickness of 0.312 inches at the abutments would not be overstressed during installation for ASTM A 252 Grade 3 steel.

Based on our slope stability analyses for the wingwalls, the minimum slope stability safety factors for short-term (Total Stress) and long-term (Effective Stress) conditions exceeded the desired value of 1.54. It is our opinion that the subsurface conditions encountered at the project site are generally satisfactory and the site can be stable in short-term and long-term conditions.

A seismic site class was also determined at the overall bridge site, in which a Seismic Site Class D is recommended.

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1. INTRODUCTION

1.1. General

National Engineering and Architectural Services Inc. (NEAS) presents our Structure Foundation Exploration Report for the planned replacement of the existing bridge ROS-138-1728 carrying SR-138 over Hay Run in Deerfield Township, adjacent to village of Clarksburg in Ross County, Ohio. The report presents a summary of the encountered surficial and subsurface conditions and our recommendations for bridge foundation design and construction in accordance with Load and Resistance Factor Design (LRFD) method as set forth in AASHTO's Publication LRFD Bridge Design Specifications, 9th Edition (BDS) (AASHTO, 2020), ODOT's 2024 Bridge Design Manual (BDM) (ODOT, 2024) and ODOT's 2024 Geotechnical Design Manual (GDM) (ODOT, 2024).

The exploration was conducted in general accordance with NEAS, Inc.'s proposal to Woolpert dated November 17, 2023, and with the provisions of ODOT's *Specifications for Geotechnical Explorations* (SGE) (ODOT[2], 2024).

The scope of work performed included: 1) a review of published geotechnical information; 2) performing 2 test borings as part of the referenced structure foundation exploration; 3) laboratory testing of soil samples in accordance with the SGE; 4) performing geotechnical engineering analysis to assess foundation design and construction considerations; and 5) development of this summary report.

1.2. Proposed Construction

It is our understanding that ODOT District 9 plans to replace the existing the existing bridge ROS-138-1728 carrying SR-138 over Hay Run. The existing structure is a three-span continuous reinforced concrete slab bridge with capped pile abutments and reinforced concrete piers.

According to the site plan prepared by Woolpert, the proposed structure is a single-span 3-sided buried concrete arch structure with a span of 60' and a rise of 13'-3". The proposed structure will be supported on concrete footings on a deep foundation system consisting of driven CIP reinforced concrete pipe piles.

2. GEOLOGY AND OBSERVATIONS OF THE PROJECT

2.1. Geology and Physiography

The project site is located within the Columbus Lowland Till Plains, a subdivision of the Southern Ohio Loamy Till Plain. This is a moderately low relief (25 ft) lowland surrounded in all directions by relative uplands, having a broad regional slope toward the Scioto Valley, containing many larger streams. Elevations of the region range from 600 to 850 ft above mean sea level (amsl) (950 ft amsl near Powell Moraine). The geology within this region is described as Wisconsinan-age till that is high lime in the west to medium-lime in the east. The geology is also described as containing extensive outwash in Scioto Valley overlying deep Devonian- to Mississippian-age carbonate rocks, shales and siltstones (ODGS, 1998).

Based on the Bedrock Geologic Units Map of Ohio (USGS & ODGS, 2006), bedrock within the project area consists of Dolomite of Salina Group. The Dolomite in this formation is described as gray, yellow gray to olive gray, laminated to thin bedded, occasionally thin bed and laminae of dark gray shale and anhydrite and/or gypsum. The bedrock appears to follow the natural topography of the site which slopes gently downwards from northwest to southeast. (ODGS, 2003). Based on the ODNR bedrock topography map of Ohio, bedrock elevations at the project site can be expected to be from 600 ft to 650 ft amsl.

The soils at the project site near the bridge carrying SR-138 over Hay Run have been mapped (Web Soil Survey) by the Natural Resources Conservation Service (USDA, 2015) as occasionally flooded Gessie silt loam (Ge). According to AASHTO method of soil classification, the soils at the project site are classified as A-1, A-4 and A-6 type soils.

2.2. Hydrology/Hydrogeology

Groundwater at the project site can be expected at an elevation consistent with that of the Hay Run as it is the most dominant hydraulic influence in the vicinity of the project's boundaries. The water level of Hay Run may be generally representative of the local groundwater table.

The project site is located within a regulatory flood hazard area based on available mapping by the Federal Emergency Management Agency's (FEMA) National Flood Hazard mapping program (FEMA, 2019).

2.3. Mining and Oil/Gas Production

No mines were noted on ODNR's Abandoned Underground Mine Locator in the vicinity of the project site. (ODNR [1], 2020).

No oil or gas wells were noted on ODNR's Oil and Gas Well Locator in the vicinity of the project site (ODNR [1], 2020).

2.4. Historical Records and Previous Phases of Project Exploration

A historic record search was performed through ODOT's Transportation Information Management System (TIMS). The following report/plans were available for review and evaluation for this report:

- ROS-138-1750 Bridge Site Plans, Job No. 19573 (007654), 1967.
- ROS-138-(16.54) (17.44), Soil Profile Sheet, Job No. 09573 (014662), 1967.

Two historical soil borings (B-001-0-67 and B-008-0-67) that were drilled as part of the 1967 Structure Exploration for ODOT project ROS-138-1750 were reviewed. A summary of the historic borings (location, elevation, etc.) is provided in Table 1, and their locations are depicted on the historical boring plan provided in Appendix A. The historic borings are provided in Appendix A. It should be noted that the elevations in NAVD 88 are typically lower than they are in NGVD 29; herein the elevations in NAVD 88 are about 0.6 feet lower than they are in NGVD 29.

Table 1: Historical Borings Summary

Boring Number	Alignment	Historical Location (Sta/offset)	Latitude	Longitude	Elevation (NGVD 29) (ft)	Elevation (NAVD 88) (ft)	Existing Substructure	Depth (ft)
B-001-0-67	SR-138	924+12, 3' RT.	39.506161	-83.151154	733.3	732.7	Rear Abutment	41.0
B-008-0-67	SR-138	925+47,21' LT.	39.506416	-83.150798	739.7	739.1	Forward Abutment	50.5

2.5. Field Reconnaissance

A field reconnaissance visit for the overall project area was conducted on January 31, 2024. Site conditions, including the existing land conditions and pavement conditions, were noted and photographed during the visit. Photographs of notable features and a summary of our observations are provided below.

The land use of most of the project area consists of ODOT ROW (Right of Way), single family homes, and woodland.

2.5.1. Bridge Carrying SR-138 over Hay Run (SFN: 7104146)

The existing bridge carrying OH-138 over Hay Run is a 3-span bridge with 2 lanes of traffic on a concrete cast-in-place deck with an asphalt wearing course. The bridge sits atop concrete stub type abutments and concrete solid wall piers on steel H piles.

The roadway embankment slopes at the site generally appeared to be stable with no signs of instability observed during our site visit. The existing roadway embankments appeared to be at about a 2 Horizontal to 1 Vertical (2H:1V) slope and were vegetated with grass and small shrubs. Overall, the bridge appeared to be in fair condition with wear and degradation observed on the bridge superstructure and substructure. The underside of the bridge deck was observed to be in fair condition with evidence of spalling, exposed reinforcing steel, and efflorescence (Photograph 1 & 2). Both abutments were observed to have spalling, cracking, and heavy efflorescence (Photographs 3 & 4). The piers were observed to be in fair condition with minimal pitting erosion. At the time of the visit, there was evidence of scouring at the base of the Eastern pier (Photograph 5). The existing pavement condition was observed to be in good condition with no signs of surface wear (Photograph 6). No apparent signs of structural distress of the bridge due to geotechnical concerns were observed during our field reconnaissance visit.

Photograph 1: Underside of bridge

Photograph 2: Underside of bridge

Photograph 3: Rear Abutment

Photograph 4: Forward Abutment

Photograph 5: Center Pier

Photograph 6: Pavement Conditions

3. GEOTECHNICAL EXPLORATION

3.1. Field Exploration Program

The project subsurface exploration was conducted by NEAS between February 15, 2024, and February 16, 2024, and included 2 borings B-001-0-23 and B-002-0-23 drilled to depth 65 ft below ground surface. The boring locations were selected by NEAS in general accordance with the guidelines contained in the SGE with the intent to evaluate subsurface soil and groundwater conditions. Borings were typically located within the planned project construction areas that were not restricted by underground utilities or dictated by terrain (e.g. steep embankment slopes). Project boring locations were located in the field after drilling by NEAS personnel. Each individual project boring log (included within Appendix B) includes the recorded boring latitude and longitude location (based on the surveyed Ohio State Plane South, NAD83, location) and the corresponding ground surface elevation. The boring locations are depicted on the Site Plan provided in Appendix A. Latitude/Longitude, elevations and stationing and offsets of the borings are shown on Table 2 below.

Table 2: Project Boring Summary

Boring Number	Location (Sta/offset)	Latitude	Longitude	Elevation (NAVD 88) (ft)	Depth (ft)	Structure
B-001-0-23	923+85, 12' LT.	39.506156	-83.151265	746.0	65.0	Rear Abutment
B-002-0-23	925+62, 12' RT.	39.506361	-83.150691	741.1	65.0	Forward Abutment
Notes: 1. *Stationing and Offset are in reference to centerline of Proposed SR-138.*						

Project borings were drilled using a D50 SN481 truck-mounted drilling rig utilizing 3.25-inch (inner diameter) hollow stem auger. In general, soil samples were recovered continuously to a depth of 13.0 ft bgs, then at 2.5-ft interval to a depth of 35.0 ft bgs, and at 5.0-ft intervals thereafter using an 18-inch split spoon sampler (AASHTO T-206 "Standard Method for Penetration Test and Split Barrel Sampling of

Soils."). The soil samples obtained from the exploration program were visually observed in the field by the NEAS field representative and preserved for review by a Geologist for possible laboratory testing. Standard penetration tests (SPT) were conducted using a CME auto hammer calibrated to be 86.8% efficient on March 14, 2022, as indicated on the boring logs.

Field /boring logs were prepared by drilling personnel, and included lithological description, SPT results recorded as blows per 6-inch increment of penetration and estimated unconfined shear strength values on specimens exhibiting cohesion (using a hand-penetrometer). Groundwater level observations were recorded both during and after the completion of drilling. These groundwater level observations are included on the individual boring logs. After completing the borings, the boreholes were backfilled with either auger cuttings, bentonite chips, or a combination of these materials, and patched with cold patch asphalt and/or quickset concrete where necessary and appropriate.

3.2. Laboratory Testing Program

The laboratory testing program consisted of classification testing and moisture content determinations. Data from the laboratory testing program was incorporated onto the boring logs (Appendix B). Soil samples are retained at the laboratory through completion and ODOT approval of Stage 2 plans, after which time they will be discarded.

3.2.1. Classification Testing

Representative soil samples were selected for index properties (Atterberg Limits) and gradation testing for classification purposes on approximately 33% of the samples. At each boring location, samples were selected for testing with the intent of identification and classification of all significant soil units. Soils not selected for testing were compared to laboratory tested samples/strata and classified visually. Moisture content testing was conducted on all samples. The laboratory testing was performed in general accordance with applicable AASHTO specifications.

A final classification of the soil strata was made in accordance with AASHTO M-145 "Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes," as modified by ODOT "Classification of Soils" once laboratory test results became available. The results of the soil classification are presented on the boring logs provided in Appendix B.

3.2.2. Standard Penetration Test Results

Standard Penetration Tests (SPT) and split-barrel (commonly known as split-spoon) sampling of soils were performed at varying intervals (i.e., continuous, 2.5-ft, or 5.0-ft intervals) in the project borings performed. To account for the high efficiency (automatic) hammers used during SPT sampling, field SPT N-values were converted based on the calibrated efficiency (energy ratio) of the specific drill rig's hammer. Field N-values were converted to an equivalent rod energy of 60% (N_{60}) for use in analysis or for correlation purposes. The resulting N_{60} values are shown on the boring logs provided in Appendix B.

3.2.3. D_{50} Values for Scour Evaluation

Grain size distribution testing was performed on the obtained streambed samples to develop D_{50} values (i.e., the diameter in the particle-size distribution curve corresponding to 50% finer). The calculated D_{50} values are shown in Table 3 below and the developed particle-size distribution curve are included with the associated boring log within Appendix B.

Table 3: D_{50} Values for Scour Evaluation

Boring Number	Specimen ID	Specimen Elevation (ft)	ODOT (Modified AASHTO) ~ USCS Classification	D_{50} (mm)	Scour Critical Shear Stress, τ_c (psf)	$D_{50, equiv}$ (mm)	Erosion Category (EC)
B-001-0-23	SS-1	740.1' - 743.5'	A-6a ~ CLAYEY SAND with GRAVEL(SC)	0.156	0.260	12.441	3.255
	SS-3	742.0' - 740.5'	A-4a ~ SANDY LEAN CLAY(CL)	0.042	0.295	14.109	2.754
	SS-4	740.5' - 739.0'	A-4a ~ SANDY LEAN CLAY(CL)	0.044	0.165	7.899	2.868
	SS-5	739.0' - 737.5'	A-6a ~ SANDY LEAN CLAY(CL)	0.049	0.300	14.342	3.337
	SS-6	737.5' - 736.0'	A-6a ~ SANDY LEAN CLAY(CL)	0.022	0.350	16.778	3.337
	SS-9	732.5' - 731.0'	A-1-b ~ SILTY SAND with GRAVEL(SM)	0.964	0.020	0.964	2.181
	SS-10	730.0' - 728.5'	A-1-b ~ SILTY SAND with GRAVEL(SM)	1.883	0.039	1.883	2.530
	SS-11	727.5' - 726.0'	A-4a ~ SANDY LEAN CLAY(CL)	0.025	0.594	28.419	2.754
B-002-0-23	SS-1	740.1' - 738.6'	A-2-4 ~ SILTY SAND with GRAVEL(SM)	1.102	0.023	1.102	2.251
	SS-3	737.1' - 735.6'	A-4a ~ CLAYEY SAND with GRAVEL(SC)	0.120	0.096	4.582	2.975
	SS-4	735.6' - 734.1'	A-4a ~ CLAYEY SAND with GRAVEL(SC)	0.206	0.004	0.206	1.377
	SS-5	734.1' - 732.6'	A-4a ~ CLAYEY SAND with GRAVEL(SC)	0.077	0.110	5.259	2.975
	SS-6	732.6' - 731.1'	A-4a ~ SANDY LEAN CLAY(CL)	0.044	0.273	13.086	2.754
	SS-8	730.1' - 728.6'	A-6a ~ LEAN CLAY with SAND(CL)	0.014	0.810	38.773	3.168
	SS-9	727.6' - 726.1'	A-4a ~ SANDY LEAN CLAY(CL)	0.031	0.650	31.114	2.868

4. GEOTECHNICAL FINDINGS

The subsurface conditions encountered during NEAS's explorations are described in the following subsections and/or on each boring log presented in Appendix B. The boring logs represent NEAS's interpretation of the subsurface conditions encountered at each boring location based on our site observations, field logs, visual review of the soil samples by NEAS's geologist, and laboratory test results. The lines designating the interfaces between various soil strata on the boring logs represent the approximate interface location; the actual transition between strata may be gradual and indistinct. The subsurface soil and groundwater characterizations included herein, including summary test data, are based on the subsurface findings from the geotechnical explorations performed by NEAS as part of the referenced project, and consideration of the geological history of the site.

4.1. Subsurface Conditions

The subsurface profile at the proposed bridge site generally consists of embankment fills over natural glacial till soils. The embankment fills can be described as medium stiff to hard cohesive materials and medium dense to dense granular materials. Natural glacial soils can be described as very stiff to hard cohesive materials and dense to very dense granular materials. Bedrock was not encountered within depths of the two project borings performed at the bridge site.

4.1.1. Overburden Soil

At the proposed bridge site, the fill soils were encountered in both borings B-001-0-23 and B-002-0-23 immediately beneath the pavement section and extended 9.5 ft to 18.0 ft below ground surface (bgs). At the rear abutment, the fills were encountered between the elevation 745.0 ft and 728.0 ft; at the forward abutment, the fills were encountered between the elevation 740.3 ft and 731.6 ft. The fills consisted of Gravel with Sand (A-1-b), Gravel with Sand and Silt (A-2-4), Sandy Silt (A-4a), and Silt and Clay (A-6a). The cohesive fills can be described as having a medium stiff to hard consistency based on N_{60} values between 7 and 22 bpf and unconfined compressive strengths (estimated by means of hand penetrometer) between approximately 1.00 and 4.50 tons per square foot (tsf). Natural moisture contents of the cohesive fills ranged from 10 to 23 percent. Based on Atterberg Limit tests performed on representative samples of the cohesive fills, the liquid and plastic limits ranged from 22 to 30 percent and 14 to 16 percent, respectively. These non-cohesive fills are described as having a relative compactness of medium dense to dense correlating to N_{60} values between 26 and 45. The natural moisture content of the non-cohesive soils ranged from 7 to 11 percent.

Below the fills, the subsurface soils encountered consisted of both cohesive fine-grained soils and non-cohesive coarse- and fine-grained soils. At the rear abutment, the cohesive soils extended to the elevation 704.2 ft, followed by granular materials to the end of boring B-001-0-23. At the forward abutment, the cohesive soils extended to the elevation 696.1 ft, followed by granular materials to the end of boring B-002-0-23. The cohesive glacial till soils are classified on the boring logs as Sandy Silt (A-4a), and Silt and Clay (A-6a). The cohesive soils can be described as having a very stiff to hard consistency based on N_{60} values between 38 and 69 bpf and unconfined compressive strengths (estimated by means of hand penetrometer) between approximately 3.25 and 4.50 tons per square foot (tsf). Natural moisture contents of the cohesive soils ranged from 10 to 15 percent. Based on Atterberg Limit tests performed on representative samples of the cohesive soils, the liquid and plastic limits ranged from 23 to 27 percent and 14 to 15 percent, respectively. The non-cohesive glacial till soils encountered are classified on the boring logs as Gravel with Sand (A-1-b), Gravel with Sand and Silt (A-2-4), Sandy Silt (A-4a) and Silt (A-4b). These non-cohesive soils are described as having a relative compactness of dense to very dense correlating to N_{60} values between 69 bpf and refusal. The natural moisture content of the non-cohesive soils ranged from 7 to 14 percent.

4.1.2. Groundwater

Groundwater measurements were taken during the drilling procedures and/or immediately following the completion of each borehole. Groundwater was encountered in both of the project borings during drilling. Based on these borings, groundwater was encountered at the depth between 45.0 ft and 48.5 ft bgs (at the elevation between 696.1 ft and 697.5 ft amsl).

It should be noted that groundwater is affected by many hydrologic characteristics in the area and may vary from those measured at the time of the exploration.

4.1.3. Bedrock

Bedrock was not encountered within depths of the two project borings performed at the bridge site.

5. ANALYSES AND RECOMMENDATIONS

We understand that the existing SR-138 Bridge over Hay Run in Ross County, Ohio is proposed to be replaced. According to the site plan prepared by Woolpert, the proposed structure is a single-span bridge with composite deck on prestressed concrete box beam superstructure, supported on integral abutments. The proposed single-span bridge will be about 99’-3” in length (from bearing to bearing). The proposed structure will be supported by a deep foundation system consisting of driven CIP reinforced concrete pipe piles.

It is anticipated that each of the proposed substructures will be supported by the natural subsurface material through the use of a deep foundation system. Therefore, a deep pile foundation system consisting of CIP piles was evaluated for the support of the proposed structures. The summary and results of our evaluation as well as recommended "estimated" and "order" pile lengths are presented in subsequent sections.

5.1. Soil Profile for Analysis

For analysis purposes, each boring log was reviewed, and a generalized material profile was developed for analysis. Utilizing the generalized soil profile, engineering properties for each soil strata were estimated based on their field (i.e., SPT N_{60} Values, hand penetrometer values, etc.) and laboratory (i.e., Atterberg Limits, grain size, etc.) test results using correlations provided in published engineering manuals, research reports and guidance documents. The developed soil profile and estimated engineering soil and rock properties (with cited correlation/reference material) used in our evaluation is summarized per boring within Tables 4 and 5 below.

Table 4: B-001-0-23 soil profile for analysis

ROS-138-1728 Bridge over SR-138: Soil Profile B-001-0-23								
Soil Description	Unit Weight(1) (pcf)	Moist Unit Weight(1) (pcf)	Saturated Unit Weight(1) (pcf)	Undrained Shear Strength(2) (psf)	Effective Cohesion(3) (psf)	Effective Friction Angle(3) (degrees)	Setup Factor (f_{su})	Depth below Bottom of Footing (ft)
Silt and Clay Depth (746 ft - 742 ft)	110	110	120	1400	150	23	1.50	N/A
Sandy Silt Depth (742 ft - 739 ft)	108	108	118	1150	100	23	1.50	N/A
Silt and Clay Depth (739 ft - 732 ft)	110	110	120	1600	150	23	1.50	N/A
Gravel with Sand Depth (732 ft - 728 ft)	120	120	130	-	-	40	1.00	N/A
Sandy Silt Depth (728 ft - 704.2 ft)	135	125	135	6150	400	29	1.50	0 - 15.2
Silt Depth (704.2 ft - 701.5 ft)	132	122	132	-	-	36	1.50	15.2 - 17.9
Gravel with Sand Depth (701.5 ft - 686.5 ft)	140	130	140	-	-	40	1.00	17.9 - 32.9
Sandy Silt Depth (686.5 ft - 681 ft)	140	130	140	-	-	37	1.20	32.9 - 38.4
Notes: *1. Values interpreted from ODOT Geotechnical Design Manual (GDM) Section 405.* *2. Values calculated from Terzaghi and Peck (1967) if N160<52, else Stroud and Butler (1975) was used.* *3. Values interpreted from LRFD BDS Table 10.4.6.2.4-1 and ODOT GDM Table 400-3.*								

Table 5: B-002-0-23 soil profile for analysis

ROS-138-1728 Bridge over SR-138: Soil Profile B-002-0-23								
Soil Description	Unit Weight(1) (pcf)	Moist Unit Weight(1) (pcf)	Saturated Unit Weight(1) (pcf)	Undrained Shear Strength(2) (psf)	Effective Cohesion(3) (psf)	Effective Friction Angle(3) (degrees)	Setup Factor (f_{su})	Depth below Bottom of Footing (ft)
Gravel with Sand and Silt Depth (741.1 ft - 738.6 ft)	118	118	128	-	-	40	1.20	N/A
Sandy Silt Depth (738.6 ft - 737.1 ft)	115	115	125	2750	250	26	1.50	N/A
Sandy Silt Depth (737.1 ft - 731.6 ft)	108	108	118	1000	100	23	1.50	N/A
Silt and Clay Depth (731.6 ft - 728.1 ft)	130	130	140	6500	450	28	1.50	N/A
Sandy Silt Depth (728.1 ft - 697.6 ft)	122	122	132	5400	375	28	1.50	0 - 21.8
Silt Depth (697.6 ft - 696.1 ft)	130	130	140	6500	450	29	1.50	21.8 - 23.3
Gravel with Sand Depth (696.1 ft - 684.3 ft)	140	130	140	-	-	40	1.00	23.3 - 35.1
Gravel with Sand and Silt Depth (684.3 ft - 679.3 ft)	140	130	140	-	-	40	1.20	35.1 - 40.1
Gravel with Sand Elevation (679.3 ft - 676.1 ft)	140	130	140	-	-	40	1.00	40.1 - 43.3
Notes: *1. Values interpreted from ODOT Geotechnical Design Manual (GDM) Section 405.* *2. Values calculated from Terzaghi and Peck (1967) if N160<52, else Stroud and Butler (1975) was used.* *3. Values interpreted from LRFD BDS Table 10.4.6.2.4-1 and ODOT GDM Table 400-3.*								

5.2. Pavement Design and Recommendations

The subgrade analysis was performed in accordance with ODOT's GDM criteria utilizing the ODOT provided*: Subgrade Analysis Spreadsheet* (SubgradeAnalysis.xls, Version 14.7 dated April 4, 2024). Input information for the spreadsheet was based on the soil characteristics gathered during NEAS's subgrade exploration (i.e., SPT results, laboratory test results, etc.), and our geotechnical experience. For analysis purposes, the proposed roadway elevations were assumed to be the same as the existing roadway elevations.

A subgrade analysis was performed to identify the method, location, and dimensions (including depth) of recommended subgrade stabilization in the referenced project plan. Appropriate stabilization of the subgrade will ensure a constructible pavement buildup, enhance pavement performance over its life, and help reduce costly extra work change orders (ODOT SGE, 2024). In addition to identifying stabilization recommendations, pavement design parameters are also determined to aid in pavement section design. The subsections below present the results of our subgrade analysis including pavement design parameters and unsuitable subgrade conditions if any identified within the project limits. Subgrade analysis spreadsheet for the referenced roadway segment is provided in Appendix C.

5.2.1. Pavement Design Recommendations

It is our understanding that pavement analysis and design is to be performed to determine the proposed pavement sections for the segments within the project limits to undergo full depth replacement. A subgrade analysis was performed using the subgrade soil data obtained during our field exploration program to evaluate the soil characteristics and develop pavement parameters for use in pavement design. The subgrade analysis parameters recommended for use in pavement design are presented in Table 6 below. Provided in the table are ranges of maximum, minimum and average N_{60L} values for the indicated segments as well as the design CBR value recommended for use in pavement design.

Table 6: Pavement Design Values

Segment	Maximum N_{60L}	Minimum N_{60L}	Average N_{60L}	Average PI Value	Design CBR
SR-138	7	6	7	10	8

5.2.2. Unsuitable/Unstable Subgrade

Per ODOT's GB1, the presence of select subgrade conditions may require some form of subgrade stabilization within the subgrade zone for new pavement construction. These unsuitable and unstable subgrade conditions generally include the presence of rock, specific soil types, weak soil conditions, and overly moist soil conditions. With respect to the planned roadways, these subgrade conditions are further discussed in the following subsections.

5.2.2.1. Rock

Rock was not encountered within top 2 ft of the proposed grade in both borings performed; therefore, no specialized remediation efforts are required.

5.2.2.2. Prohibited Soils

Prohibited soil types, per the GB1, include A-4b, A-2-5, A-5, A-7-5, A-8a, A-8b, and soils with liquid limits greater than 65. No prohibited soils were encountered within the subgrade of the referenced project roadway.

5.2.2.3. Weak Soils

The GDM recommends subgrade stabilization for soils considered unstable in which the N_{60} value of a particular soil sample (SS) at a referenced boring location is less than 12 bpf and in some cases less than 15 bpf (i.e., where moisture content is greater than optimum plus 3 percent). Based on the specific N_{60} value at the subject boring, *Figure B - Subgrade Stabilization* within the GB1 recommends a depth of subgrade stabilization for ODOT standard stabilization methods. It should be noted that although a soil sample's N_{60} value may meet the criteria to be considered an unstable soil, the depth in which the unstable soil is encountered in relation to the proposed subgrade is considered when each individual subgrade boring is analyzed. For example, if the GDM recommends an excavate and replace of 12 inches within a weak soil underlying 18 inches of stable material, it would be unreasonable to recommend the removal of both the stable and unstable material for a total of 30 inches of excavate and replace.

Based on N_{60} values encountered within the project borings, our subgrade analysis suggests no need for global subgrade stabilization, but due to small areas of unstable soils, some quantities of item 204 excavate and replace should be considered. A summary of the boring locations where unstable soils were encountered and determined to have a potential impact on subgrade performance are shown in Table 7 below, per the roadway segment for which they were encountered.

Table 7: Unstable Soil Locations Summary

Boring ID	N_{60L}	Subgrade Depth (ft)
B-001-0-23	7	2.5 - 4.0

It should be noted that *Figure B - Subgrade Stabilization* does not apply to soil types A-1-a, A-1-b, A-3, or A-3a, nor to soils with N_{60L} values of 15 or more. Per GB1 guidance, *these soils should be reworked to stabilize the subgrade.*

5.2.2.4. High Moisture Content Soils

High moisture content soils are defined by the GDM as soils that exceed the estimated optimum moisture content (per Figure A - Optimum Moisture Content within the GB1) for a given classification by 3 percent or more. Per the GDM, soils determined to be above the identified moisture content levels are a likely indication of the presence of an unstable subgrade and may require some form of subgrade stabilization. Similar to our analysis of unstable soils, although a soil sample's moisture content may meet the criteria to be considered high, the depth in which the high moisture soil is encountered in relation to the proposed subgrade is considered when each individual subgrade boring is analyzed for stabilization recommendations. Summaries of the boring locations where high moisture content conditions were encountered within the limits of each proposed alignment are shown in Table 8 below.

Table 8: High Moisture Content Soils Summary

Boring ID	Soil Type	Moisture Content (%)	Optimum Moisture Content (%)	Depth Below Subgrade (ft)
B-001-0-23	A-6a	23	14	2.5 - 4.0

5.2.3. Stabilization Recommendations

5.2.3.1. Summary of Stabilization

Unstable subgrade conditions, including areas of weak soils and high moisture content soils, were encountered in the project area as previously indicated in Section 5.2.2 of this report. NEAS recommends spot stabilization in the form of 12 inches of Excavate and Replace for areas where proof rolling shows signs of weak soil with special attention given to the rear abutment location. The excavated material should be replaced with material in accordance with Section 608 "Excavate and Replace (Item 204)" of the ODOT GDM. Stabilization limits should extend 18-inches beyond the edge of the proposed paved roadway, shoulder or median and it is recommended removing any topsoil, existing pavement materials or abandoned structure foundation materials.

The subgrade conditions encountered along the proposed roadway segment include areas of identified unstable soils. It is NEAS's opinion based on: 1) samples obtained from borings performed; 2) the depth and composition of the unstable soils encountered; and 3) the relative density (compactness) of overlying soils, that the recommended 12 inches of spot stabilization where proof rolling shows signs of weak soil would be sufficient in stabilizing the subgrade at all locations within the proposed subgrade. The subgrade analysis is presented in Appendix C.

5.3. Bridge Foundation Analysis and Recommendations

A foundation review was completed for a deep foundation system for the referenced bridge replacement based on the following design information: 1) the site plan conducted by Woolpert; and 2) subsequent conversations with Woolpert. A deep pile foundation will be designed according to LRFD and ODOT BDM criteria. Utilizing the *GRLWeap* computer program with the FHWA static analysis method, a static pile analysis was performed to estimate required driven pile lengths needed to achieve the Ultimate Bearing Value (UBV) for a single pile. Input information for the *GRLWeap* program was based on the soil characteristics gathered during the geotechnical exploration (i.e., SPT results, laboratory test results, etc.) and our geotechnical experience. Tables 3 and 4 in Section 5.1. of this report present each soil strata and their engineering properties that were used in the analysis. The summary and results of our deep foundation evaluation are presented in subsequent sections.

5.3.1. Pile Foundation Vertical Load Analysis

Based on the site plan prepared by Woolpert, 14-in Cast-in-place (CIP) piles were proposed to support the concrete footing of SR-138 over Hay Run (SFN: 7104146). The bottom of footing is approximately at the elevation of 719.42 ft at both rear and forward abutment location. The scour design elevation for 50-year scour is at the elevation of 720.91 ft at both rear and forward abutment locations. The vertical loads were provided by Woolpert through emails on December 30, 2024. The factored design loading varies by manufacturer but has been estimated between 53 kip/linear foot and 76 kip/linear foot. The max Ultimate Bearing Value (UBV) of 14-in CIP piles were used in our foundation design.

According to Section 1304.1.1 of ODOT GDM, to estimate pile lengths under scour condition, the static pile analysis should start from the predicted channel scour elevation. However, the drivability analyses should be performed in the existing, pre-scour condition, with consideration of the additional driving resistance to be overcome through soils in the scour zone at the time of installation. At the proposed structure site, the bottom of scour is above the bottom of the footing. Therefore, scour will not influence the design of deep foundation.

For the purposes of this report and our analysis, the term 'geotechnical pile length' has been assumed to represent the length of pile from bottom of footing at each abutment location to the depth at which the max Ultimate Bearing Value (UBV) is obtained. The max factored pile load equals to the max UBV multiplied by the resistance factor. It is recommended that the piles for the referenced project be installed according to ODOT's Construction and Material Specifications (CMS) 507 and CMS 523, and therefore, a driven pile resistance factor of 0.7 should be used.

The End of Initial Driving (EOID) value is determined due to the potential for soil disturbance caused during pile driving (development of high pore water pressure) near the pile perimeter. This disturbance could cause piles to potentially drive easily or "run" for extended depths and initial driving may not reach the indicated target UBV utilizing the estimated pile lengths. Therefore, it may be necessary to drive the CIP piles to the EOID and then let the piles "set-up" (reduction of pore water pressure in the soils adjacent to the pile) for an established time period based on the material at the substructure and the specific pile size. The EOID values are determined in accordance with Section 305.3.2.4 of the ODOT BDM. Specifically, the EOID is determined by subtracting the amount of side resistance expected to gain from soil setup from the UBV value. The amount of side resistance expected to gain from soil setup is taken as the difference between the side resistance obtained in ultimate (after setup) conditions and the side resistance obtained during driving (dynamic) conditions at the determined geotechnical pile length.

The geotechnical pile lengths, EOID values and wait time for setup are summarized in Table 9 below (*GRLWeap* results included within Appendix D).

Table 9: Deep Foundation Analysis Summary

Substructure	Pile Type	Max Pile Reaction - Strength I (1) (kips)	Max Ultimate Bearing Value(2) (kips)	Geotechnical Pile Length(3) - Ultimate Condition (After Setup)	End of Initial Driving Value (4) - Driving Condition (Before Setup) (kips)	Predicted Pile Length Accounting for Driving Losses (Before Setup) (ft)	Pile Length Difference Ultimate vs. Driving Conditions (ft)	Setup Factor for Waiting Time	Wait Time (days)
ROS-138-17.28									
Rear Abutment	14-inch CIP	273	390.0	26.1	359.2	27.9	1.8	1.09	1
Forward Abutment	14-inch CIP	273	390.0	28.9	350.1	31.2	2.3	1.11	3

Notes:
1. *The referenced resistance factor of 0.7 has been applied to Max UBV to get Max Pile Reaction (2024 ODOT BDM C305.3.2-4)*
2. *Max UBV obtained from 2024 ODOT BDM 305.3.4*
3. *The estimated length of pile from bottom of scour zone to the depth which the Max UBV is obtained under scour condition (2024 ODOT GDM 1304.1.1).*
4. *End of Initial Driving Value (EOID) per 2024 ODOT BDM 305.3.2.4*

The estimated driving resistances at both the rear abutment and forward abutments indicate driving losses that would increase the pile length during driving by less than 10-ft at EOID compared to the maximum UBV. Therefore, NEAS recommends that pile setup does not to be considered in the design of either substructure.

5.3.2. Pile Foundation Recommendations

Based on our evaluation of the subsurface conditions and our geotechnical engineering analysis for the proposed bridge, it is our opinion that the bridge foundations can be supported on driven friction CIP piles seated within very dense natural glacial till material encountered at the site. Since the CIP piles will be seating within very dense soils, and the majority of bearing resistances will come from granular materials, plus the pile cap is proposed to be in firm contact with the ground, the group effect should not be a concern. The recommended pile lengths are listed in Table 9 below.

We recommend that a driven pile foundation be used for support for the referenced substructure foundations. New CIP piles are recommended to be installed in accordance with Sections 507 and 523 of ODOT's CMS. It is recommended that the proposed piles at both substructures be driven to the max UBV listed in Table 9 above.

Pile lengths based on: 1) our Deep Foundation Analysis (presented in Section 5.3.1); and, 2) the "Estimated Length" and "Order Length" definitions and formulas presented in Section 305.3.5.2 of the ODOT BDM, are presented in Table 10 below.

Table 10: Estimated Pile Lengths

Substructure	Bottom of Pile Cap Elevation (ft amsl)	Assumed Pile Cutoff Elevation (ft)	Bottom of Scour Elevation - 50-Year Scour (ft)	Pile Type	MAX Pile Reaction (kips)	Rn- Nominal Pile Bearing Resistance (kips)	Geotechnical Pile Length - 50-Year Scour Condition (ft)	Geotechnical Pile Tip Elevation (ft)	Estimated Pile Length (ft)	Order Length (ft)
ROS-138-17.28										
Rear Abutment	719.4	721.4	720.9	14-inch CIP	273	390	27.9	691.5	35	40
Forward Abutment	719.4	721.4	720.9	14-inch CIP	273	390	31.2	688.2	35	40

5.3.3. Pile Drivability

NEAS's drivability evaluation estimated a Delmag D 19-42 diesel hammer to determine if the 14-inch CIP piles with the wall thickness of 0.312 inches for ASTM A 252 steel, would be overstressed at any time during pile installation. Based on the pile drivability results, 14-inch CIP piles with a wall thickness of 0.312 inches at the abutments would not be overstressed for ASTM A 252 Grade 3 steel during the pile installation process. GRLWEAP Results can be found in Appendix D.

It should be noted that the driving resistance of CIP piles through soils encountered at the bridge site is expected to be high. Driveability is difficult to assess quantitatively as the field test results (i.e., SPT N_{60} values, pocket penetrometer values, etc.) tend to be very high. Furthermore, pile driveability is highly reliant upon the specific equipment used in construction; therefore, it is recommended that the contractor provide an analysis to demonstrate that the equipment and pile combination planned for use is capable of obtaining the UBV without over-stressing the piles.

Per the plan notes 606.7-1 of ODOT's 2024 BDM (ODOT, 2024), the minimum rated energy of the hammer used to install the piles shall be (42,000) foot-pounds. Ensure that stresses in the piles during driving do not exceed (40,500) pounds per square inch.

5.3.4. Global Stability

For purposes of evaluating the stability of the wingwalls, NEAS reviewed the cross-sections and project boring logs to determine the subsurface soil conditions that posed the greatest potential for slope instability. Based on our review, NEAS developed a representative cross-sectional model at wingwalls to use as the basis for global stability analyses. The models were developed from NEAS's interpretation of the available information which included: 1) the Bridge Site Plans prepared by Woolpert; and 2) test borings and laboratory data developed as part of this report. With respect to the soil's engineering properties, the provided Soil Profile Estimated Engineering Properties presented in Section 5.1 of this report were used in our analyses.

The above referenced slope stability models were analyzed for long-term (Effective Stress) and short-term (Total Stress) slope stability utilizing the software entitled Slide 7.0 by Rocscience, Inc. Specifically, the Bishop, Spencer and GLE analysis methods were used to calculate a factor of safety (FOS) for circular type slope failures. The FOS is the ratio of the resisting forces and the driving forces, with the desired safety factor being more than about 1.54 which equates to an AASHTO resistance factor less than 0.65 (per AASHTO, 2020 - the specified resistance factors are essentially the inverse of the FOS that should be targeted in slope stability programs). For this analysis, a resistance factor of 0.65 or lower is targeted as the slope contains or supports a structural element. Scour was not considered in the global stability analysis.

Based on our slope stability analyses for the referenced wingwall locations, the minimum slope stability safety factors for short-term (Total Stress) and long-term (Effective Stress) conditions exceeded the desired value of 1.54. It is our opinion that the subsurface conditions encountered at the project site are generally satisfactory and the site can be considered to be stable at short-term and long-term conditions. The results of the analyses are summarized in Table 11. The graphical output of the slope stability program (cross-sectional model, calculated safety factor, and critical failure plane) is presented in Appendix E.

Table 11: Global Stability Analysis Summary

Global Stability Analsysis at ROS-138 Bridge						
Location	**Boring No.**	**Water Condition**	**Description**	**Minimum Factor of Safety**	**Equivalent Resistance Factor**	**Status (OK/NG)**
Inlet Wingwall	B-001-0-23	Normal Water	Short Term	7.09	0.14	OK
			Long Term	1.64	0.61	OK
		HW100	Short Term	8.23	0.12	OK
			Long Term	1.74	0.58	OK
Outlet Wingwall	B-002-0-23	Normal Water	Short Term	9.42	0.11	OK
			Long Term	1.71	0.59	OK
		HW100	Short Term	11.23	0.09	OK
			Long Term	1.86	0.54	OK

5.4. Seismic Site Class

Based on the results of the subsurface exploration, laboratory test data, and the AASHTO Site Class Definitions indicated in Table 3.10.3.1-1 of the *LRFD Bridge Design Specifications, 9th Edition* (AASHTO LRFD, 2020), the average Standard Penetration Test blow count $\overline{N}$ for B-001-0-23 and B-002-0-23 is 31 blows/ft and 35 blows/ft, respectively. A Seismic Site Class D is recommended for the overall bridge site.

6. QUALIFICATIONS

This investigation was performed in accordance with accepted geotechnical engineering practice for the purpose of characterizing the subsurface conditions at the site of the proposed replacement of SR-138 over Hay Run in Ross County, Ohio. This report has been prepared for Woolpert, ODOT and their design consultants to be used solely in evaluating the soils underlying the indicated structures and presenting geotechnical engineering recommendations specific to this project. The assessment of general site environmental conditions or the presence of pollutants in the soil, rock and groundwater of the site was beyond the scope of this geotechnical exploration. Our recommendations are based on the results of our field explorations, laboratory test results from representative soil samples, and geotechnical engineering analyses. The results of the field explorations and laboratory tests, which form the basis of our recommendations, are presented in the appendices as noted. This report does not reflect any variations that may occur between the borings or elsewhere on the site, or variations whose nature and extent may not become evident until a later stage of construction. In the event that any changes occur in the nature, design or location of the proposed structural work, the conclusions and recommendations contained in this report should not be considered valid until they are reviewed and have been modified or verified in writing by a geotechnical engineer.

It has been a pleasure to be of service to Woolpert in performing this geotechnical exploration for the ROS-138-17.28 project. Please call if there are any questions, or if we can be of further service.

Respectfully Submitted,

Chunmei (Melinda) He, Ph.D., P.E.
Project Manager

Zhao Mankoci, Ph.D., P.E.
Geotechnical Engineer

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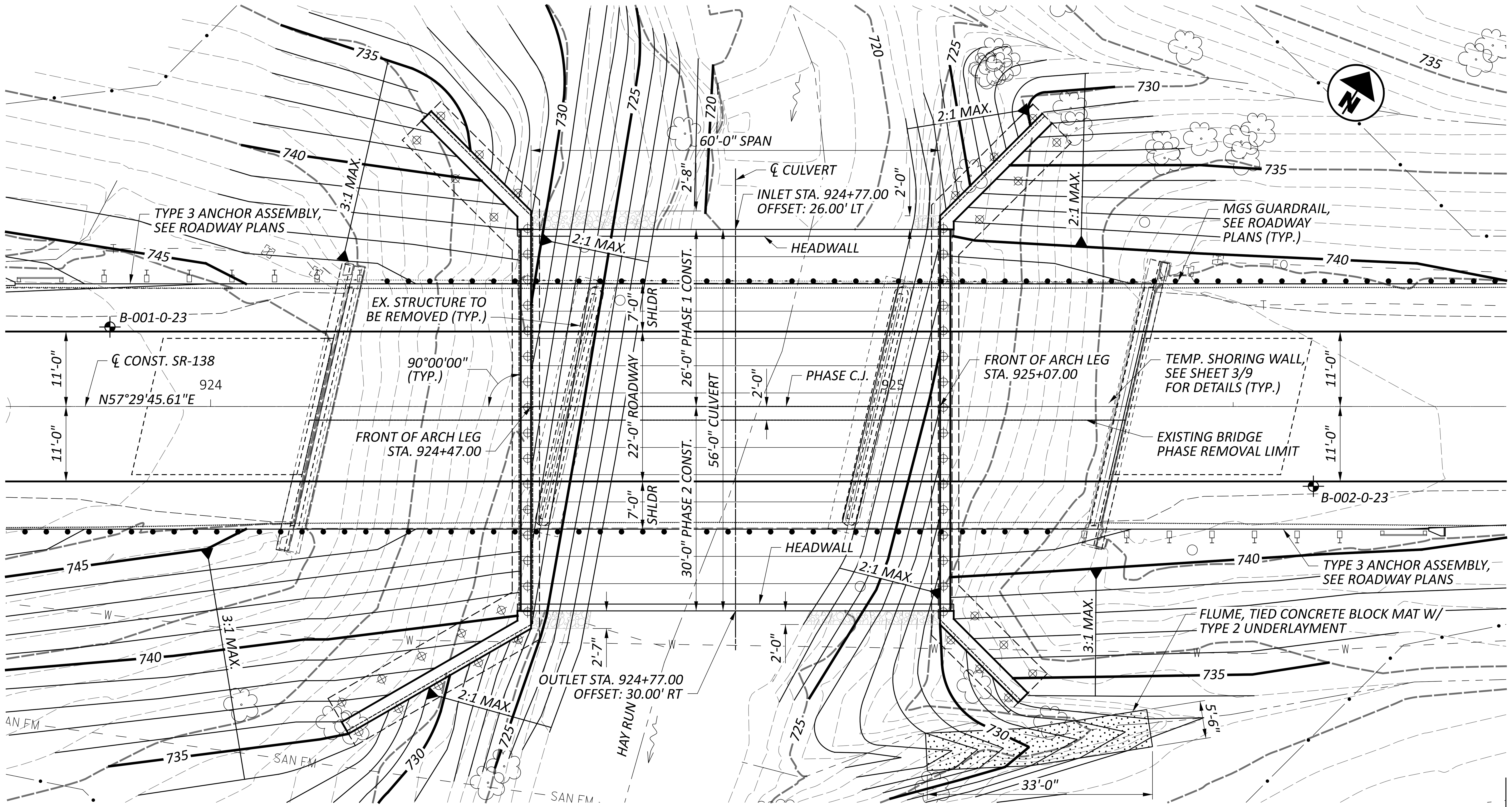
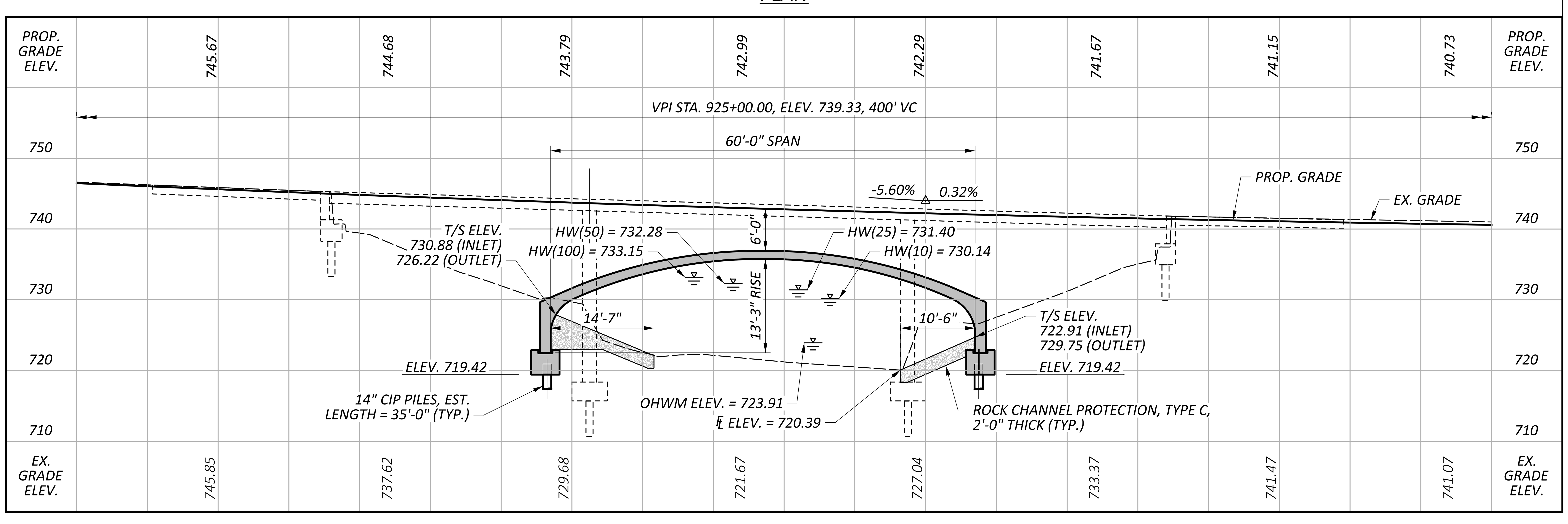
APPENDIX A

SITE PLAN



PLAN



PROFILE

(ALONG ℄ CONST. SR-138)

BENCHMARK DATA

CNPT #1 STA.	922+38.97,	ELEV.	752.61,	OFFSET	20.55',	LT
CNPT #2 STA.	925+43.99,	ELEV.	740.77,	OFFSET	21.06',	RT
CNPT #3 STA.	928+22.44,	ELEV.	741.26,	OFFSET	16.44',	RT

FOR ADDITIONAL BENCHMARK INFORMATION, SEE ROADWAY PLAN P.02.

NOTES

EARTHWORK LIMITS SHOWN ARE APPROXIMATE. ACTUAL SLOPES SHALL CONFORM TO PLAN CROSS SECTIONS.

DESIGN TRAFFIC:
2024 ADT = 1,000 2024 ADTT = 100
2044 ADT = N/A 2044 ADTT = N/A
DIRECTIONAL DISTRIBUTION = N/A

LEGEND

- BORING LOCATION
- * - PHASE 1 CONSTRUCTION
- ** - PHASE 2 CONSTRUCTION
- TYPE C RCP, 2'-0' THICK
- 730 EXISTING CONTOURS
- 730 PROPOSED CONTOURS

HYDRAULIC DATA

DRAINAGE AREA = 22.0 SQ. MILES

Q (10) =	2420 CFS	V (10) =	6.47 FT/S
Q (25) =	3250 CFS	V (25) =	7.55 FT/S
Q (50) =	3940 CFS	V (50) =	8.47 FT/S
Q (100) =	4670 CFS	V (100) =	9.44 FT/S

STRUCTURE CLEARS THE 100 YEAR HW BY 2.90 FEET.
SCOUR DESIGN ELEVATION = 724.80 (25 YEAR), 720.91 (50 YEAR).

EXISTING STRUCTURE

TYPE: CONTINUOUS REINFORCED CONCRETE SLAB WITH CAPPED PILE ABUTMENTS AND REINFORCED CONCRETE PIERS.

SPANS: 36'-0"±, 45'-0"±, 36'-0"± C/C BEARINGS
ROADWAY: 36'-0"± F/F GUARDRAIL
LOADING: HS20-44
SKEW: 13° 0' 0"± LEFT FORWARD
WEARING SURFACE: 1"± MONLITHIC CONCRETE
APPROACH SLABS: AS-1-67 (25'-0"± LONG)
ALIGNMENT: TANGENT
CROWN: 3/16± IN/FT
STRUCTURE FILE NUMBER: 7104146
DATE BUILT: 7/1/1969
DISPOSITION: TO BE REPLACED

PROPOSED STRUCTURE

TYPE: SINGLE SPAN 3-SIDED BURIED CONCRETE ARCH STRUCTURE SUPPORTED ON CONCRETE FOOTINGS ON PILING.

SPAN: 60'-0"
RISE: 13'-3"
ROADWAY: 36'-0" F/F GUARDRAIL
LOADING: HL93 AND 0.060 KSF FUTURE WEARING SURFACE
6'-0" MAX. FILL
3'-0" MIN. FILL
SKEW: NONE
APPROACH SLABS: NONE
ALIGNMENT: TANGENT
COORDINATES: LATITUDE 39° 30' 22.38" N
LONGITUDE 83° 09' 3.87" W

HORIZONTAL SCALE IN FEET 0 5 10 20

ALTERNATIVE 4 SITE PLAN
BRIDGE NO. ROS-138-1728
SR-138 OVER HAY RUN

SFN 7104147

DESIGN AGENCY: WOOLPERT

DESIGNER	CHECKER
BTR	MJZ
REVIEWER	
TML 01/03/25	
PROJECT ID	
115773	
SUBSET	TOTAL
1	9
SHEET	TOTAL
P.05	13

ROS-138-17.28

MODEL: Sheet_SurvFt PAPERSIZE: 34x22 (in.) DATE: 1/2/2025 TIME: 9:17:13 AM USER: Rivera
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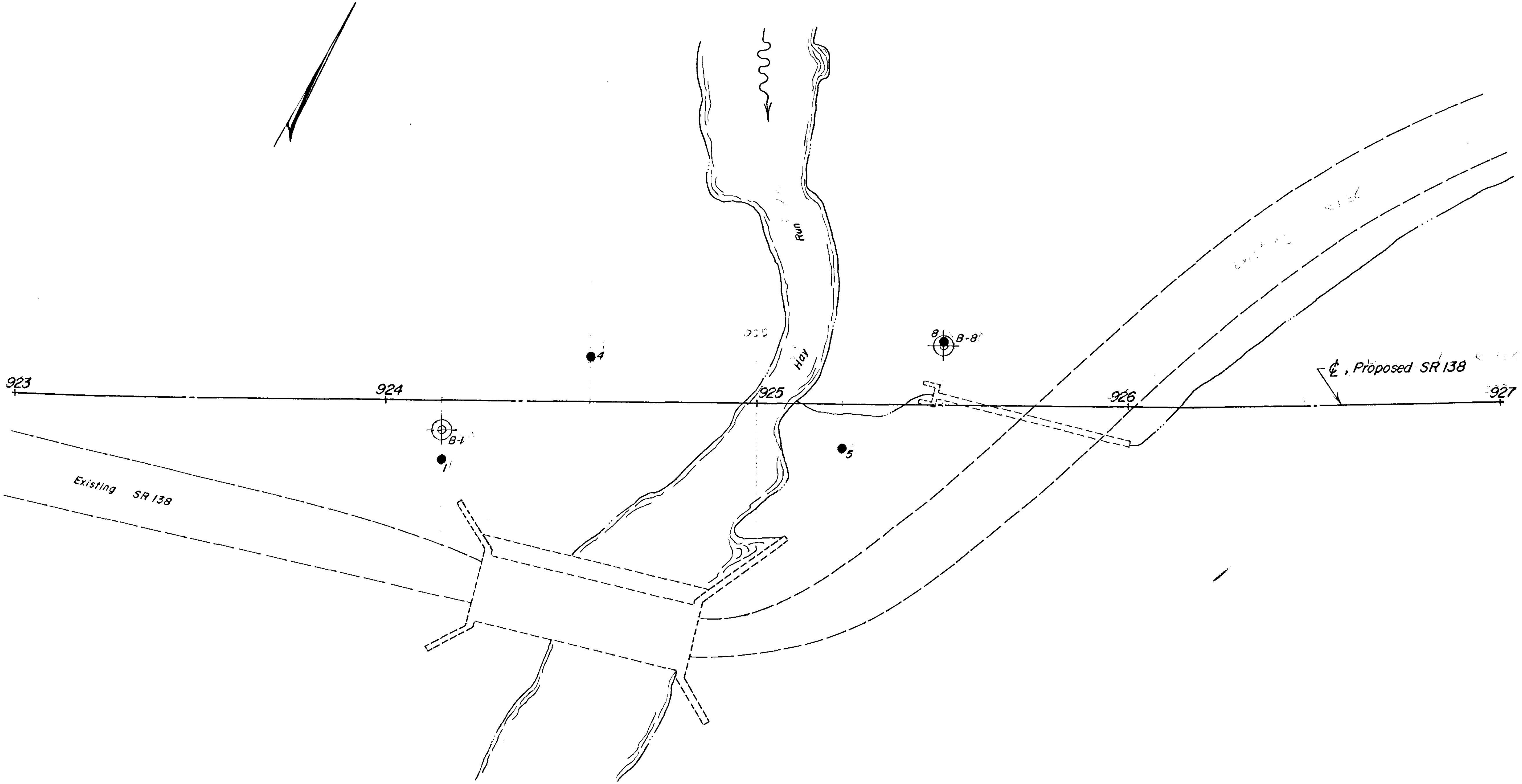


Run
Hay
B-8
B-1
4
1
5
8
923
924
925
926
927
Existing SR 138
℄, Proposed SR 138

APPENDIX B

SOIL BORING LOGS

PROJECT: ROS-138-17.28	DRILLING FIRM / OPERATOR: CS / TS	DRILL RIG: D50 SN481	STATION / OFFSET: 923+85, 12' LT.	EXPLORATION ID B-001-0-23
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: NEAS / LR	HAMMER: CME AUTOMATIC	ALIGNMENT: SR-138	
PID: SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 3/14/22	ELEVATION: 746.0 (MSL) EOB: 65.0 ft.	PAGE 1 OF 3
START: 2/15/24 END: 2/15/24	SAMPLING METHOD: SPT	ENERGY RATIO (%): 86.8	LAT / LONG: 39.506156, -83.151265	

MATERIAL DESCRIPTION AND NOTES	ELEV. 746.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
9.0" ASPHALT AND 3.0" BASE	745.0																	
STIFF TO VERY STIFF, BROWN, **SILT AND CLAY**, SOME GRAVEL, SOME SAND, DAMP TO MOIST **(FILL)**		1 – 2	5 / 5 / 4	13	56	SS-1	2.75	31	12	12	27	18	29	16	13	13	A-6a (3)	
	742.0	3 – 4	2 / 3 / 4	10	78	SS-2	2.00	-	-	-	-	-	-	-	-	23	A-6a (V)	
STIFF TO VERY STIFF, BROWN, **SANDY SILT**, SOME CLAY, TRACE TO LITTLE GRAVEL, DAMP **(FILL)**		5	3 / 5 / 3	12	50	SS-3	3.75	11	13	19	36	21	22	14	8	12	A-4a (4)	
	739.0	6 – 7	4 / 2 / 3	7	94	SS-4	2.00	8	16	20	34	22	24	15	9	15	A-4a (4)	
MEDIUM STIFF TO VERY STIFF, BROWN, **SILT AND CLAY**, SOME TO "AND" SAND, TRACE GRAVEL, DAMP TO MOIST **(FILL)**		8	3 / 5 / 7	17	94	SS-5	3.50	10	13	23	28	26	30	16	14	16	A-6a (5)	
		9 – 10	4 / 4 / 4	12	100	SS-6	3.00	8	11	17	35	29	30	16	14	17	A-6a (7)	
		11	4 / 3 / 2	7	100	SS-7	1.00	-	-	-	-	-	-	-	-	19	A-6a (V)	
	732.0	12 – 13	3 / 5 / 6	16	100	SS-8	3.75	-	-	-	-	-	-	-	-	19	A-6a (V)	
MEDIUM DENSE TO DENSE, BROWN, **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST TO DAMP **(FILL)**		14 – 15	7 / 13 / 18	45	83	SS-9	-	40	21	14	18	7	NP	NP	NP	11	A-1-b (0)	
	728.0	16 – 17	9 / 10 / 10	29	44	SS-10	-	49	21	11	14	5	NP	NP	NP	7	A-1-b (0)	
HARD, GRAY, **SANDY SILT**, SOME CLAY, TRACE TO LITTLE GRAVEL AND STONE FRAGMENTS, GLACIAL TILL, DAMP		18 – 20	6 / 13 / 17	43	89	SS-11	4.50	9	10	16	38	27	23	15	8	10	A-4a (6)	
SS-12 CONTAINS NO RECOVERY, POUNDED ON COBBLE		21 – 22	14 / 22 / 26	69	0	SS-12	-	-	-	-	-	-	-	-	-	-	A-4a (V)	
		23 – 24	13 / 16 / 21	54	100	SS-13	4.50	-	-	-	-	-	-	-	-	10	A-4a (V)	
@25.0' ADDED WATER AS CIRCULATING FLUID		25 – 27	10 / 13 / 18	45	100	SS-14	4.50	-	-	-	-	-	-	-	-	12	A-4a (V)	
		28 – 29	19 / 20 / 25	65	61	SS-15	4.50	-	-	-	-	-	-	-	-	11	A-4a (V)	

PID:	SFN:	PROJECT: ROS-138-17.28	STATION / OFFSET: 923+85, 12' LT.	START: 2/15/24	END: 2/15/24	PG 2 OF 3	B-001-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV. 716.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
HARD, GRAY, **SANDY SILT**, SOME CLAY, TRACE TO LITTLE GRAVEL AND STONE FRAGMENTS, GLACIAL TILL, DAMP *(continued)*			9 11 15	38	100	SS-16	4.50	-	-	-	-	-	-	-	-	11	A-4a (V)	
			8 12 17	42	100	SS-17	4.50	-	-	-	-	-	-	-	-	12	A-4a (V)	
			8 11 15	38	100	SS-18	4.50	-	-	-	-	-	-	-	-	11	A-4a (V)	
	704.2																	
VERY DENSE, GRAY, **SILT**, LITTLE CLAY, LITTLE SAND, TRACE GRAVEL, GLACIAL TILL, MOIST			25 32 50/5"	-	100	SS-19	-	-	-	-	-	-	-	-	-	14	A-4b (V)	
	701.5																	
VERY DENSE, GRAY, **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, GLACIAL TILL, WET		W 697.5																
			19 33 40	106	100	SS-20	-	44	25	19	9	3	NP	NP	NP	12	A-1-b (0)	
@50.0'; ADDED SUPER GEL X AS CIRCULATING FLUID @50.0' TO 59.5'; RIG CHATTER																		
			19 36 36	104	100	SS-21	-	-	-	-	-	-	-	-	-	7	A-1-b (V)	
			21 24 24	69	100	SS-22	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
	686.5																	
VERY DENSE, GRAY, **SANDY SILT**, LITTLE GRAVEL, TRACE CLAY, GLACIAL TILL, MOIST																		

Depths: 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61

PID: ________	SFN: ______________	PROJECT: ROS-138-17.28	STATION / OFFSET: 923+85, 12' LT.	START: 2/15/24	END: 2/15/24	PG 3 OF 3	B-001-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV. 683.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
VERY DENSE, GRAY, **SANDY SILT**, LITTLE GRAVEL, TRACE CLAY, GLACIAL TILL, MOIST *(continued)*		63																
	681.0	64 – EOB – 65	26 36 21	82	100	SS-23	-	19	18	20	35	8	NP	NP	NP	12	A-4a (2)	

NOTES: GROUNDWATER ENCOUNTERED AT 48.5' DURING DRILLING. HOLE DID NOT CAVE. DRILLED AS STAKED.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; PUMPED 50 GAL. BENTONITE GROUT; POURED 1 BAG HOLE PLUG

PROJECT: ROS-138-17.28	DRILLING FIRM / OPERATOR: CS / TS	DRILL RIG: D50 SN481	STATION / OFFSET: 925+62, 12' RT.
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: NEAS / LR	HAMMER: CME AUTOMATIC	ALIGNMENT: SR-138
PID: SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 3/14/22	ELEVATION: 741.1 (MSL) EOB: 65.0 ft.
START: 2/16/24 END: 2/16/24	SAMPLING METHOD: SPT	ENERGY RATIO (%): 86.8	LAT / LONG: 39.506361, -83.150691

EXPLORATION ID B-002-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV. 741.1
9.5" ASPHALT	740.3
MEDIUM DENSE, BROWN, **GRAVEL WITH SAND AND SILT**, TRACE CLAY, DAMP **(FILL)**	738.6
STIFF TO HARD, BROWN, **SANDY SILT**, TRACE TO SOME GRAVEL, LITTLE TO SOME CLAY, DAMP TO MOIST **(FILL)** SS-6 IS A 1.0' SAMPLE	731.6
HARD, BROWN, **SILT AND CLAY**, SOME SAND, TRACE GRAVEL, DAMP	728.1
VERY STIFF TO HARD, GRAY, **SANDY SILT**, SOME CLAY, TRACE TO LITTLE GRAVEL, DAMP @16.0' ADDED WATER AS CIRCULATING FLUID	

SPT/RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
11-9-9	26	50	SS-1	-	43	19	11	21	6	NP	NP	NP	7	A-2-4 (0)
7-9-6	22	94	SS-2	4.50	-	-	-	-	-	-	-	-	10	A-4a (V)
4-2-2	6	44	SS-3	1.50	22	15	18	30	15	25	15	10	16	A-4a (2)
2-3-4	10	22	SS-4	1.25	26	17	18	28	11	25	16	9	17	A-4a (1)
4-3-3	9	50	SS-5	1.25	21	11	18	32	18	26	16	10	16	A-4a (3)
5-13	-	100	SS-6	4.25	9	14	19	36	22	22	14	8	13	A-4a (5)
12-15-24	56	11	SS-7	4.25	-	-	-	-	-	-	-	-	14	A-6a (V)
9-13-20	48	100	SS-8	4.50	6	9	15	36	34	27	15	12	12	A-6a (8)
11-15-20	51	100	SS-9	4.50	12	10	15	37	26	23	14	9	10	A-4a (6)
11-13-19	46	100	SS-10	4.50	-	-	-	-	-	-	-	-	12	A-4a (V)
12-17-20	54	100	SS-11	4.50	-	-	-	-	-	-	-	-	11	A-4a (V)
9-12-16	41	100	SS-12	4.50	-	-	-	-	-	-	-	-	11	A-4a (V)
9-13-17	43	100	SS-13	4.50	-	-	-	-	-	-	-	-	11	A-4a (V)
8-11-18	42	100	SS-14	4.50	-	-	-	-	-	-	-	-	11	A-4a (V)
10-13-17	43	100	SS-15	4.50	-	-	-	-	-	-	-	-	12	A-4a (V)

DEPTHS: 1 – 29 ft. HOLE SEALED.

PID:	SFN:	PROJECT: ROS-138-17.28	STATION / OFFSET: 925+62, 12' RT.	START: 2/16/24	END: 2/16/24	PG 2 OF 3	B-002-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV. 711.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
VERY STIFF TO HARD, GRAY, **SANDY SILT**, SOME CLAY, TRACE TO LITTLE GRAVEL, DAMP *(continued)*		31																
		32	9 13 16	42	100	SS-16	4.50	-	-	-	-	-	-	-	-	11	A-4a (V)	
		34	7 12 15	39	100	SS-17	4.25	-	-	-	-	-	-	-	-	12	A-4a (V)	
		39	11 9 14	33	100	SS-18	3.25	-	-	-	-	-	-	-	-	15	A-4a (V)	
	697.6	43																
HARD, GRAY, **SILT**, LITTLE CLAY, LITTLE SAND, TRACE GRAVEL, DAMP		44	14 16 22	55	100	SS-19	4.50	-	-	-	-	-	-	-	-	11	A-4b (V)	
	696.1	W 696.1																
DENSE, GRAY, **COARSE AND FINE SAND**, TRACE SILT, TRACE CLAY, TRACE GRAVEL, WET		45																
	692.1	48																
@48.5'; 1.5' SAND HEAVE @48.5'; ADDED SUPER GEL X AS CIRCULATING FLUID		49	19 28 31	85	83	SS-20	-	44	29	13	11	3	NP	NP	NP	9	A-1-b (0)	
VERY DENSE, GRAY, **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, WET		50																
		54	26 32 36	98	56	SS-21	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	
@55.0' TO 65.0'; RIG CHATTER		55																
	684.3	57																
VERY DENSE, BROWN AND GRAY, **GRAVEL WITH SAND AND SILT**, TRACE CLAY, WET		59	44 50/4"	-	100	SS-22	-	30	26	11	26	7	NP	NP	NP	11	A-2-4 (0)	
	679.3	61																

PID: ________ | SFN: ________ | PROJECT: ROS-138-17.28 | STATION / OFFSET: 925+62, 12' RT. | START: 2/16/24 | END: 2/16/24 | | B-002-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV. 679.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
VERY DENSE, BROWN AND GRAY, **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, WET *(continued)*		63																
	676.1	64	20 32 33	94	61	SS-23	-	-	-	-	-	-	-	-	-	11	A-1-b (V)	
		EOB 65																

NOTES: GROUNDWATER ENCOUNTERED AT 45.0' DURING DRILLING. HOLE DID NOT CAVE. DRILLED AS STAKED.

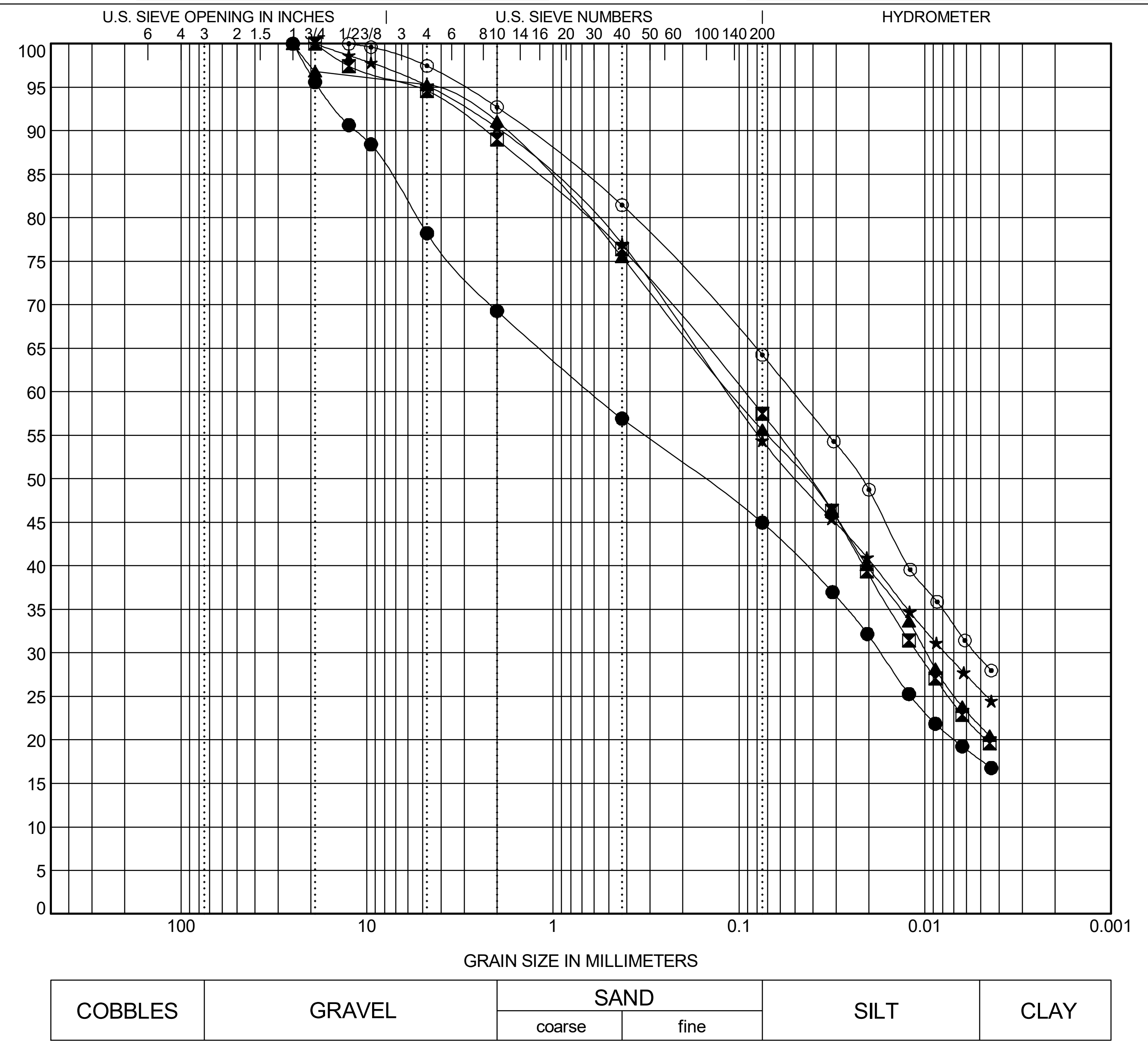
ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; PUMPED 50 GAL. BENTONITE GROUT; POURED 1 BAG HOLE PLUG

GRAIN SIZE DISTRIBUTION

OHIO DEPARTMENT OF TRANSPORTION
OFFICE OF GEOTECHNICAL ENGINEERING

PROJECT ROS-138-17.28 **PID**

OGE NUMBER 0 **PROJECT TYPE**



Specimen Identification		ODOT (Modified AASHTO) ~ USCS Classification	LL	PL	PI
● B-001-0-23	1.0	**A-6a ~ CLAYEY SAND with GRAVEL(SC)**	29	16	13
⧗ B-001-0-23	4.0	**A-4a ~ SANDY LEAN CLAY(CL)**	22	14	8
▲ B-001-0-23	5.5	**A-4a ~ SANDY LEAN CLAY(CL)**	24	15	9
★ B-001-0-23	7.0	**A-6a ~ SANDY LEAN CLAY(CL)**	30	16	14
⊙ B-001-0-23	8.5	**A-6a ~ SANDY LEAN CLAY(CL)**	30	16	14

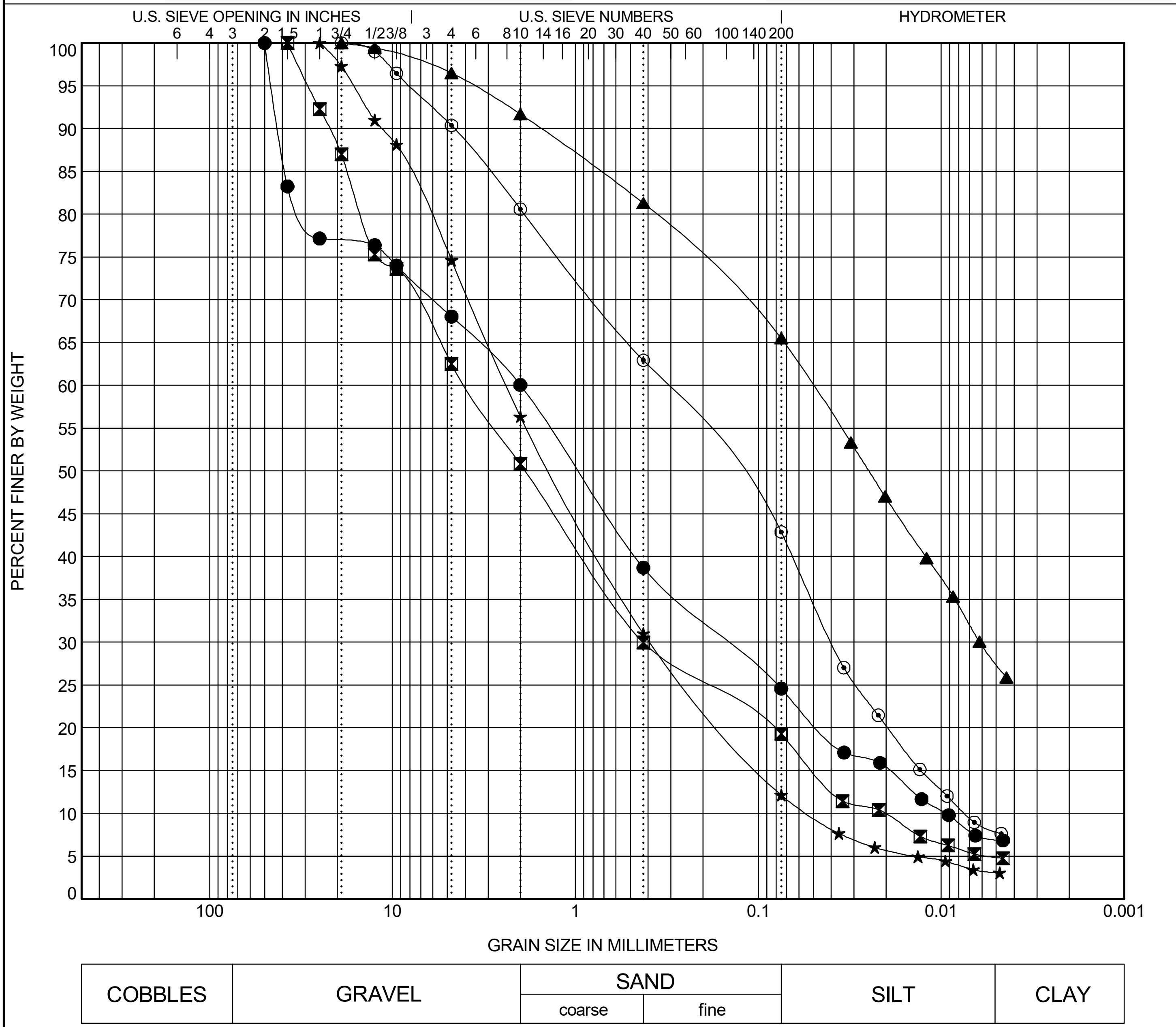
Specimen Identification		D90	D50	D30	D10	%G	%CS	%FS	%M	%C	Cc	Cu
● B-001-0-23	1.0	11.527	0.156	0.017		31	12	12	27	18		
⧗ B-001-0-23	4.0	2.336	0.042	0.011		11	13	19	36	21		
▲ B-001-0-23	5.5	1.793	0.044	0.01		8	16	20	34	22		
★ B-001-0-23	7.0	1.918	0.049	0.008		10	13	23	28	26		
⊙ B-001-0-23	8.5	1.375	0.022	0.005		8	11	17	35	29		

GRAIN SIZE DISTRIBUTION

OHIO DEPARTMENT OF TRANSPORTION
OFFICE OF GEOTECHNICAL ENGINEERING

PROJECT ROS-138-17.28 **PID**

OGE NUMBER 0 **PROJECT TYPE**



Specimen Identification			ODOT (Modified AASHTO) ~ USCS Classification	LL	PL	PI
●	**B-001-0-23**	**13.5**	**A-1-b ~ SILTY SAND with GRAVEL(SM)**	**NP**	**NP**	**NP**
⧗	**B-001-0-23**	**16.0**	**A-1-b ~ SILTY SAND with GRAVEL(SM)**	**NP**	**NP**	**NP**
▲	**B-001-0-23**	**18.5**	**A-4a ~ SANDY LEAN CLAY(CL)**	**23**	**15**	**8**
★	**B-001-0-23**	**48.5**	**A-1-b ~ SILTY SAND with GRAVEL(SM)**	**NP**	**NP**	**NP**
⊙	**B-001-0-23**	**63.5**	**A-4a ~ SILTY SAND(SM)**	**NP**	**NP**	**NP**

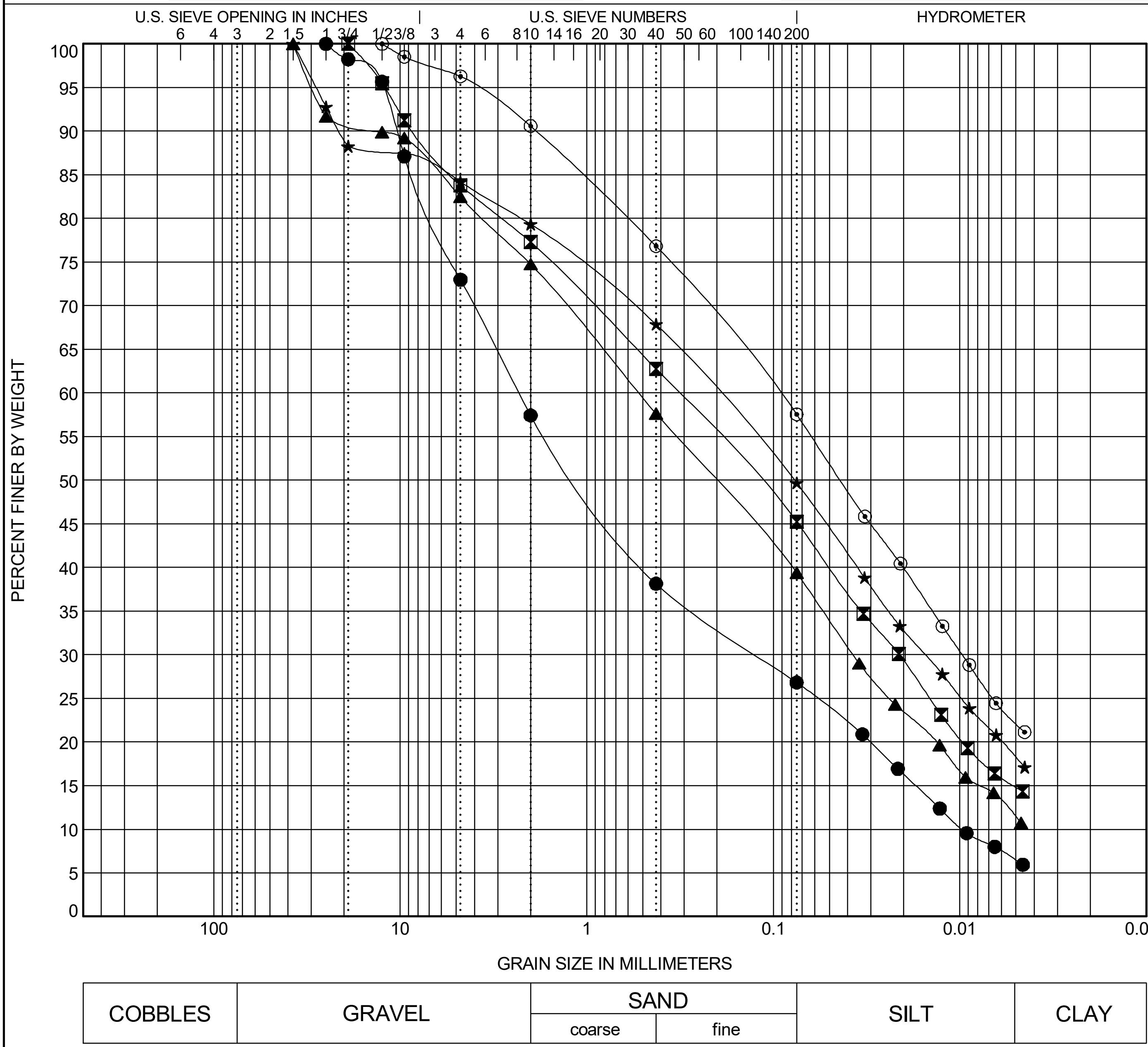
Specimen Identification			D90	D50	D30	D10	%G	%CS	%FS	%M	%C	Cc	Cu
●	**B-001-0-23**	**13.5**	**42.106**	**0.964**	**0.146**	**0.009**	**40**	**21**	**14**	**18**	**7**	**1.13**	**210.88**
⧗	**B-001-0-23**	**16.0**	**22.205**	**1.883**	**0.426**	**0.02**	**49**	**21**	**11**	**14**	**5**	**2.24**	**192.86**
▲	**B-001-0-23**	**18.5**	**1.551**	**0.025**	**0.006**		**9**	**10**	**16**	**38**	**27**		
★	**B-001-0-23**	**48.5**	**11.357**	**1.356**	**0.387**	**0.053**	**44**	**25**	**19**	**9**	**3**	**1.19**	**44.88**
⊙	**B-001-0-23**	**63.5**	**4.592**	**0.139**	**0.04**	**0.007**	**19**	**18**	**20**	**35**	**8**	**0.64**	**44.49**

GRAIN SIZE DISTRIBUTION

OHIO DEPARTMENT OF TRANSPORTION
OFFICE OF GEOTECHNICAL ENGINEERING

PROJECT ROS-138-17.28 **PID**

OGE NUMBER 0 **PROJECT TYPE**



Specimen Identification			ODOT (Modified AASHTO) ~ USCS Classification	LL	PL	PI
●	**B-002-0-23**	**1.0**	**A-2-4 ~ SILTY SAND with GRAVEL(SM)**	**NP**	**NP**	**NP**
⧗	**B-002-0-23**	**4.0**	**A-4a ~ CLAYEY SAND with GRAVEL(SC)**	**25**	**15**	**10**
▲	**B-002-0-23**	**5.5**	**A-4a ~ CLAYEY SAND with GRAVEL(SC)**	**25**	**16**	**9**
★	**B-002-0-23**	**7.0**	**A-4a ~ CLAYEY SAND with GRAVEL(SC)**	**26**	**16**	**10**
⊙	**B-002-0-23**	**8.5**	**A-4a ~ SANDY LEAN CLAY(CL)**	**22**	**14**	**8**

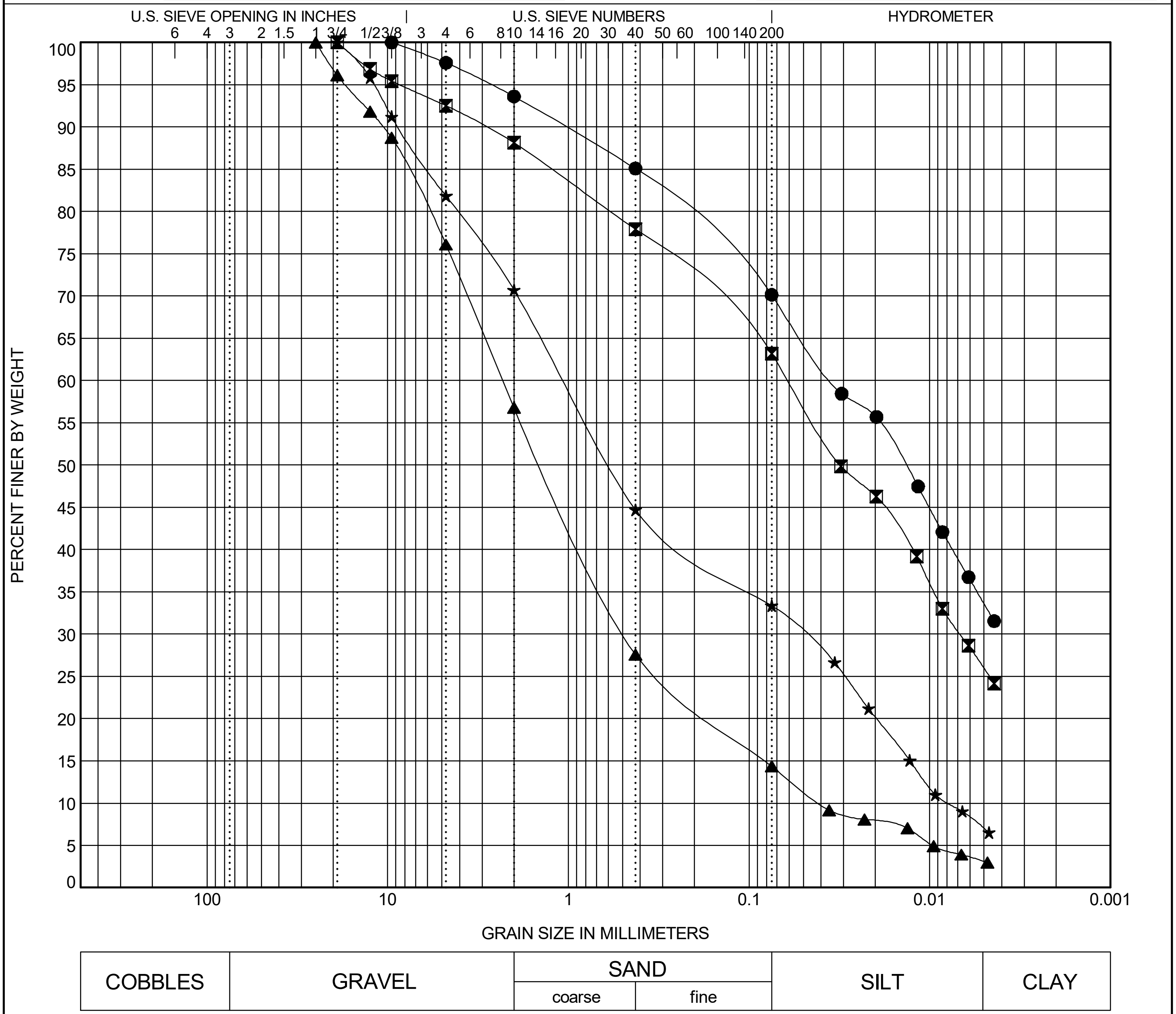
Specimen Identification			D90	D50	D30	D10	%G	%CS	%FS	%M	%C	Cc	Cu
●	**B-002-0-23**	**1.0**	**10.423**	**1.102**	**0.122**	**0.01**	**43**	**19**	**11**	**21**	**6**	**0.67**	**238.16**
⧗	**B-002-0-23**	**4.0**	**8.458**	**0.12**	**0.021**		**22**	**15**	**18**	**30**	**15**		
▲	**B-002-0-23**	**5.5**	**13.138**	**0.206**	**0.037**		**26**	**17**	**18**	**28**	**11**		
★	**B-002-0-23**	**7.0**	**21.116**	**0.077**	**0.015**		**21**	**11**	**18**	**32**	**18**		
⊙	**B-002-0-23**	**8.5**	**1.871**	**0.044**	**0.01**		**9**	**14**	**19**	**36**	**22**		

GRAIN SIZE DISTRIBUTION

OHIO DEPARTMENT OF TRANSPORTION
OFFICE OF GEOTECHNICAL ENGINEERING

PROJECT ROS-138-17.28 **PID**

OGE NUMBER 0 **PROJECT TYPE**



	Specimen Identification		ODOT (Modified AASHTO) ~ USCS Classification	LL	PL	PI
●	**B-002-0-23**	**11.0**	**A-6a ~ LEAN CLAY with SAND(CL)**	**27**	**15**	**12**
⧗	**B-002-0-23**	**13.5**	**A-4a ~ SANDY LEAN CLAY(CL)**	**23**	**14**	**9**
▲	**B-002-0-23**	**48.5**	**A-1-b ~ SILTY SAND with GRAVEL(SM)**	**NP**	**NP**	**NP**
★	**B-002-0-23**	**58.5**	**A-2-4 ~ SILTY SAND with GRAVEL(SM)**	**NP**	**NP**	**NP**

	Specimen Identification		D90	D50	D30	D10	%G	%CS	%FS	%M	%C	Cc	Cu
●	**B-002-0-23**	**11.0**	**1.036**	**0.014**			**6**	**9**	**15**	**36**	**34**		
⧗	**B-002-0-23**	**13.5**	**2.882**	**0.031**	**0.007**		**12**	**10**	**15**	**37**	**26**		
▲	**B-002-0-23**	**48.5**	**10.634**	**1.396**	**0.483**	**0.041**	**44**	**29**	**13**	**11**	**3**	**2.49**	**56.99**
★	**B-002-0-23**	**58.5**	**8.678**	**0.582**	**0.05**	**0.008**	**30**	**26**	**11**	**26**	**7**	**0.30**	**135.12**

LOG OF BORING

Date Started 6-12-67
Date Completed 6-13-67
Boring No. B-1

Sampler Type SS   Dia. 1 3/8"
Casing: Length ______   Dia. ______
Station & Offset 924+15, 8' Rt. (Rear Abutment)

Water Elev. ______
Surface Elev. 733.3'

Elev.	Depth	Std. Pen. (N)	Rec. ft.	Loss ft.	Description	Sample No.	Physical Characteristics								SHTL Class.
							% Agg.	% C.S.	% F.S.	% Silt	% Clay	L.L.	P.I.	W.C.	
733.3	0														
	2														
	4														
728.3															
	6	9/13			Brown Silty Sandy Gravel	1	54	13	12	-21	-	NP	NP	9	A-1-b
725.8	8														
		30/39			Gray Gravelly Sandy Silt	2	16	9	15	30	30	25	10	10	A-4a
723.3	10														
		21/34			Gray Gravelly Sandy Silt	3	16	6	14	34	30	24	7	10	A-4a
	12														
720.8															
	14	19/38			Gray Sandy Gravelly Silt	4	24	7	12	29	28	25	9	10	A-4a
718.3															
	16	23/35			Gray Sandy Silt	5	14	7	14	31	34	24	9	10	A-4a
715.8	18														
		21/36			Gray Sandy Silt	6	14	8	16	29	33	24	8	10	A-4a
713.3	20														
		18/31			Gray Sandy Gravelly Silt	7	22	6	14	29	29	24	8	11	A-4a
	22														
	24														
708.3															
	26	21/26			Gray Gravelly Sandy Silt	8	21	8	14	27	30	NP	NP	12	A-4a
	28														
703.3	30														
		27/41			Gray Silt	9	0	1	15	69	15	NP	NP	17	A-4b
	32														
	34														
698.3															
	36	31/27			Brown Sandy Gravel	10	69	16	7	- 8	-	NP	NP	7	A-1-a
	38														
					BOTTOM OF BORING										
693.3	40														
692.3					Gray Sand, Gravel, and Boulders (Wash Sample)	11	0	5	83	-12	-	NP	NP	22	A-3a

Dolomite

Bou

LOG OF BORING

Date Started 6-7-67 Sampler Type SS Dia. 1 3/8" Water Elev. ______

Date Completed 6-7-67 Casing: Length 35' Dia. 3 1/2"

Boring No. B-8 Station & Offset 925+50, 16' Lt.(Forward Abutment) Surface Elev. 739.7'

Elev.	Depth	Std. Pen. (N)	Rec. ft.	Loss ft.	Description	Sample No.	% Agg.	% C.S.	% F.S.	% Silt	% Clay	L.L.	P.I.	W.C.	SHTL Class.
739.7	0														
	2														
	4														
734.7															
	6	20/31			Brown Gravelly Sandy Silt	1	15	10	14	31	30	23	6	11	A-4a
732.2	8														
		20/30			Brown Sandy Gravelly Silt	2	24	9	13	21	24	23	7	10	A-4a
729.7	10														
		20/22			Brown Sandy Silt	3	10	9	15	31	35	24	8	12	A-4a
	12														
727.2															
	14	21/23			Brown Gravelly Sandy Silt	4	16	10	14	30	30	23	6	12	A-4a
724.7															
	16	22/44			Gray Gravelly Sandy Silt	5	19	9	15	28	29	23	8	12	A-4a
722.2	18														
		22/25			No Sample Recovered - Boulders(Driller's Description)		V	I		S		U	A	L	
719.7	20														
		20/27			Gray Sandy Gravelly Silt with Boulders	6	23	9	13	29	26	22	7	11	A-4a
	22														
717.2															
	24	19/28			Gray Sandy Silt with Boulders	7	14	8	14	33	31	21	6	11	A-4a
714.7															
	26	22/33			Gray Sandy Silt with Boulders	8	12	9	14	36	29	21	6	12	A-4a
	28														
709.7	30														
		22/33			Gray Silty Gravelly Sand	9	15	51	15	8	11	16	3	18	A-1-b
	32														
	34														
704.7															
	36	18/22			Gray Gravelly Sandy Silt	10	17	8	15	31	29	23	8	10	A-4a
	38														
699.7	40														
		50/*			Gray Sandy Gravelly Silt with Boulders	11	26	8	13	25	28	19	4	11	A-4a
	42														
	44														
694.7															
	46	50/*			Gray Silty Sandy Gravel	12	50	29	9	12	-	NP	NP	11	A-1-a
	48														
689.7	50				BOTTOM OF BORING										
689.2		50/*			Gray Silty Sandy Gravel	13	48	23	12	17	-	NP	NP	6	A-1-b

*Refusal

APPENDIX C

GEOTECHNICAL BULLETIN 1 (GB1)
SUBGRADE ANALYSIS

OHIO DEPARTMENT OF TRANSPORTATION

OFFICE OF GEOTECHNICAL ENGINEERING

PLAN SUBGRADES
Geotechnical Design Manual Section 600

Instructions: Enter data in the shaded cells only.
(Enter state route number, project description,county, consultant's name, prepared by name, and date prepared. This information will be transferred to all other sheets. The date prepared must be entered in the appropriate cell on this sheet to remove these instructions prior to printing.)

ROS-138-17.28
115773

Replacement of SR-138 Bridge Over Hay Run

NEAS, Inc.

Prepared By: Zhao Mankoci
Date prepared: Wednesday, July 17, 2024

Chunmei (Melinda) He, Ph.D., P.E.
2800 Corporate Exchange Drive
Suite 240
Columbus, OH 43231
614.714.0299 Ext 111
che@neasinc.com

NO. OF BORINGS: 2

#	Boring ID	Alignment	Station	Offset	Dir	Drill Rig	ER	Boring EL.	Proposed Subgrade EL	Cut Fill
1	B-001-0-23	SR-138	923+85	12	LT	D50 SN481	87	746.0	744.5	1.5 C
2	B-002-0-23	SR-138	925+62	12	RT	D50 SN481	87	741.1	739.6	1.5 C

OHIO DEPARTMENT OF TRANSPORTATION

Subgrade Analysis

V. 14.7 4/4/2024

#	Boring	Sample	Sample Depth		Subgrade Depth		Standard Penetration		HP (tsf)	Physical Characteristics						Moisture		Ohio DOT		Sulfate Content (ppm)	Problem		Excavate and Replace (Item 204)		Recommendation (Enter depth in inches)
			From	To	From	To	N_{60}	N_{60L}		LL	PL	PI	% Silt	% Clay	P200	M_C	M_{OPT}	Class	GI		Unsuitable	Unstable	Unsuitable	Unstable	
1	B 001-0 23	SS-1	1.0	2.5	-0.5	1.0	13		2.75	29	16	13	27	18	45	13	14	A-6a	3						
		SS-2	2.5	4.0	1.0	2.5	10		2							23	14	A-6a	10			N_{60} & Mc		**12''**	
		SS-3	4.0	5.5	2.5	4.0	12		3.75	22	14	8	36	21	57	12	10	A-4a	4						
		SS-4	5.5	7.0	4.0	5.5	7	7	2	24	15	9	34	22	56	15	10	A-4a	4						
2	B 002-0 23	SS-1	1.0	2.5	-0.5	1.0	26			NP	NP	NP	21	6	27	7	10	A-2-4	0						
		SS-2	2.5	4.0	1.0	2.5	22		4.5							10	10	A-4a	8						
		SS-3	4.0	5.5	2.5	4.0	6		1.5	25	15	10	30	15	45	16	10	A-4a	2						
		SS-4	5.5	7.0	4.0	5.5	10	6	1.25	25	16	9	28	11	39	17	11	A-4a	1						

PID: 115773

County-Route-Section: ROS-138-17.28

No. of Borings: 2

Geotechnical Consultant: NEAS, Inc.

Prepared By: Zhao Mankoci

Date prepared: 7/17/2024

Chemical Stabilization Options		
320	Rubblize & Roll	No
206	Cement Stabilization	Option
	Lime Stabilization	No
206	Depth	14"

Excavate and Replace Stabilization Options	
Global Geotextile Average(N60L): Average(HP):	 18" 0"
Global Geogrid Average(N60L): Average(HP):	 0" 0"

Design CBR	8

% Samples within 3 feet of subgrade			
$N_{60} \leq 5$	0%	HP ≤ 0.5	0%
$N_{60} < 12$	25%	0.5 < HP ≤ 1	0%
$12 \leq N_{60} < 15$	25%	1 < HP ≤ 2	25%
$N_{60} \geq 20$	25%	HP > 2	38%
M+	13%		
Rock	0%		
Unsuitable Soil	0%		

Excavate and Replace at Surface	
Average	0"
Maximum	0"
Minimum	0"

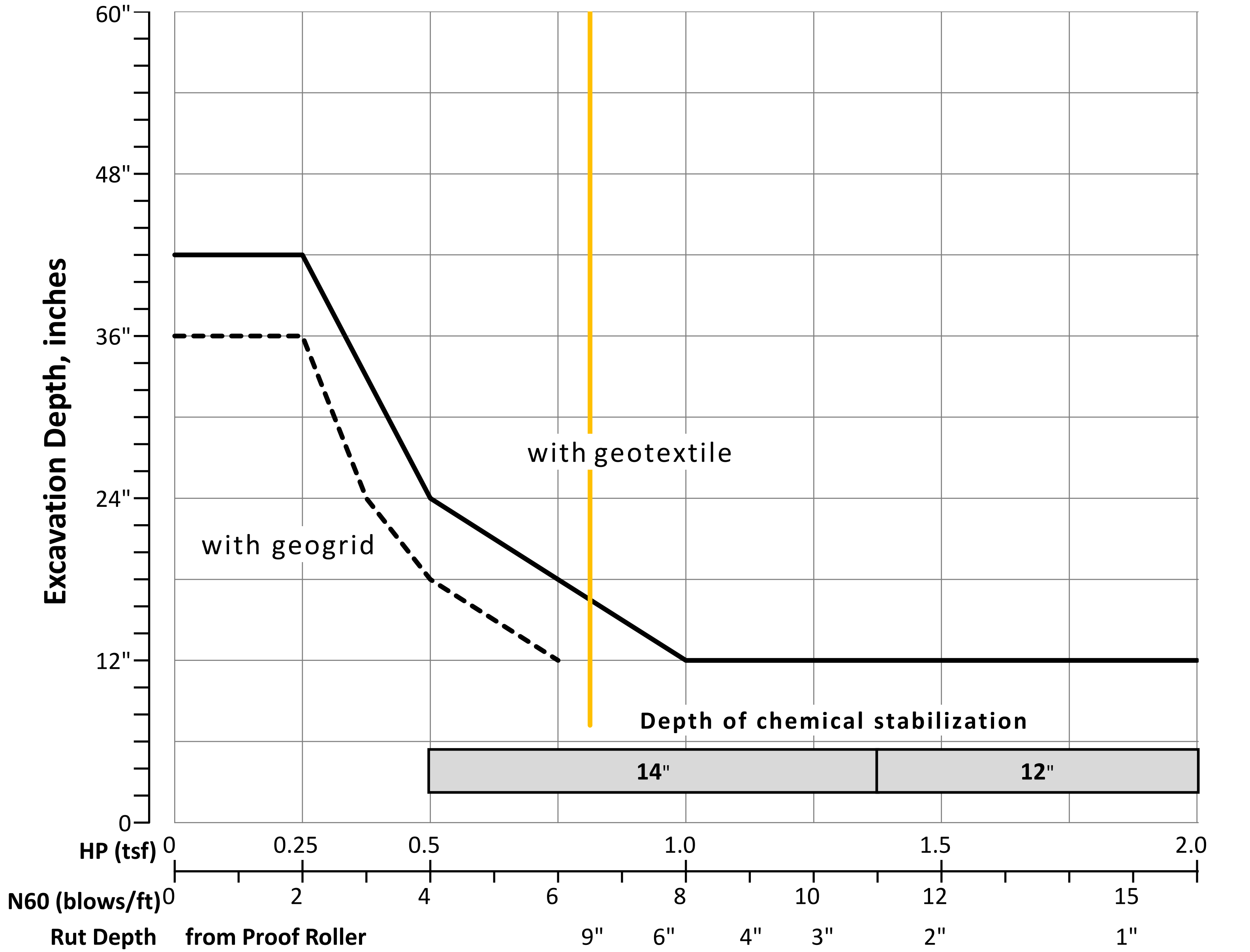
% Proposed Subgrade Surface	
Unstable & Unsuitable	17%
Unstable	17%
Unsuitable (Soil & Rock)	0%

	N_{60}	N_{60L}	HP	LL	PL	PI	Silt	Clay	P 200	M_C	M_{OPT}	GI
Average	13	7	2.54	25	15	10	29	16	45	14	11	4
Maximum	26	7	4.50	29	16	13	36	22	57	23	14	10
Minimum	6	6	1.25	22	14	8	21	6	27	7	10	0

Classification Counts by Sample

ODOT Class	UCF	Rock	A-1-a	A-1-b	A-2-4	A-2-5	A-2-6	A-2-7	A-3	A-3a	A-4a	A-4b	A-5	A-6a	A-6b	A-7-5	A-7-6	A-8a	A-8b	Totals
Count	0	0	0	0	1	0	0	0	0	0	5	0	0	2	0	0	0	0	0	8
Percent	0%	0%	0%	0%	13%	0%	0%	0%	0%	0%	63%	0%	0%	25%	0%	0%	0%	0%	0%	100%
% Rock|Granular|Cohesive	0%	0%	75%									25%								100%
Surface Class Count	0	0	0	0	1	0	0	0	0	0	3	0	0	2	0	0	0	0	0	6
Surface Class Percent	0%	0%	0%	0%	17%	0%	0%	0%	0%	0%	50%	0%	0%	33%	0%	0%	0%	0%	0%	100%

Fig. 600-1 – Subgrade Stabilization

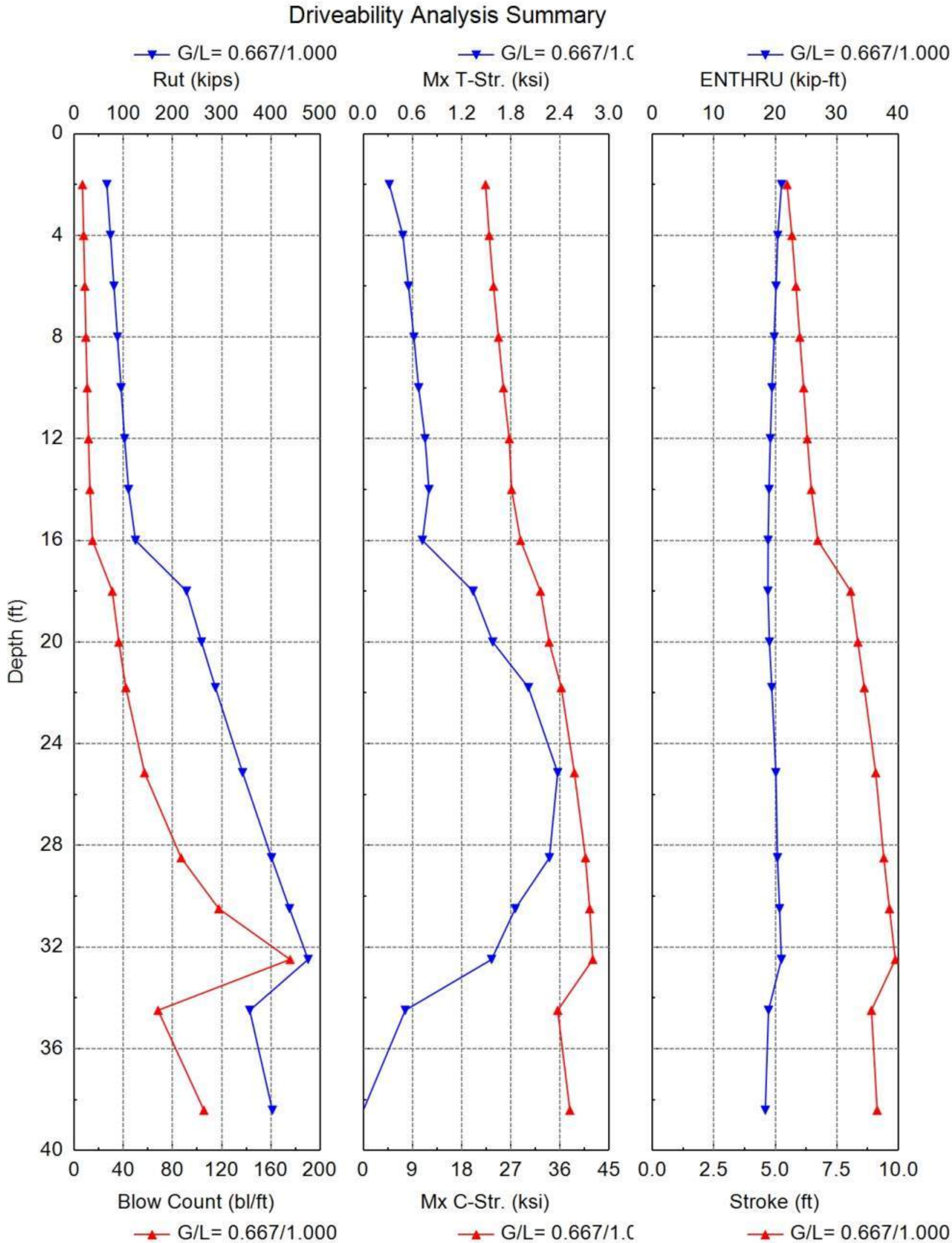


OVERRIDE TABLE

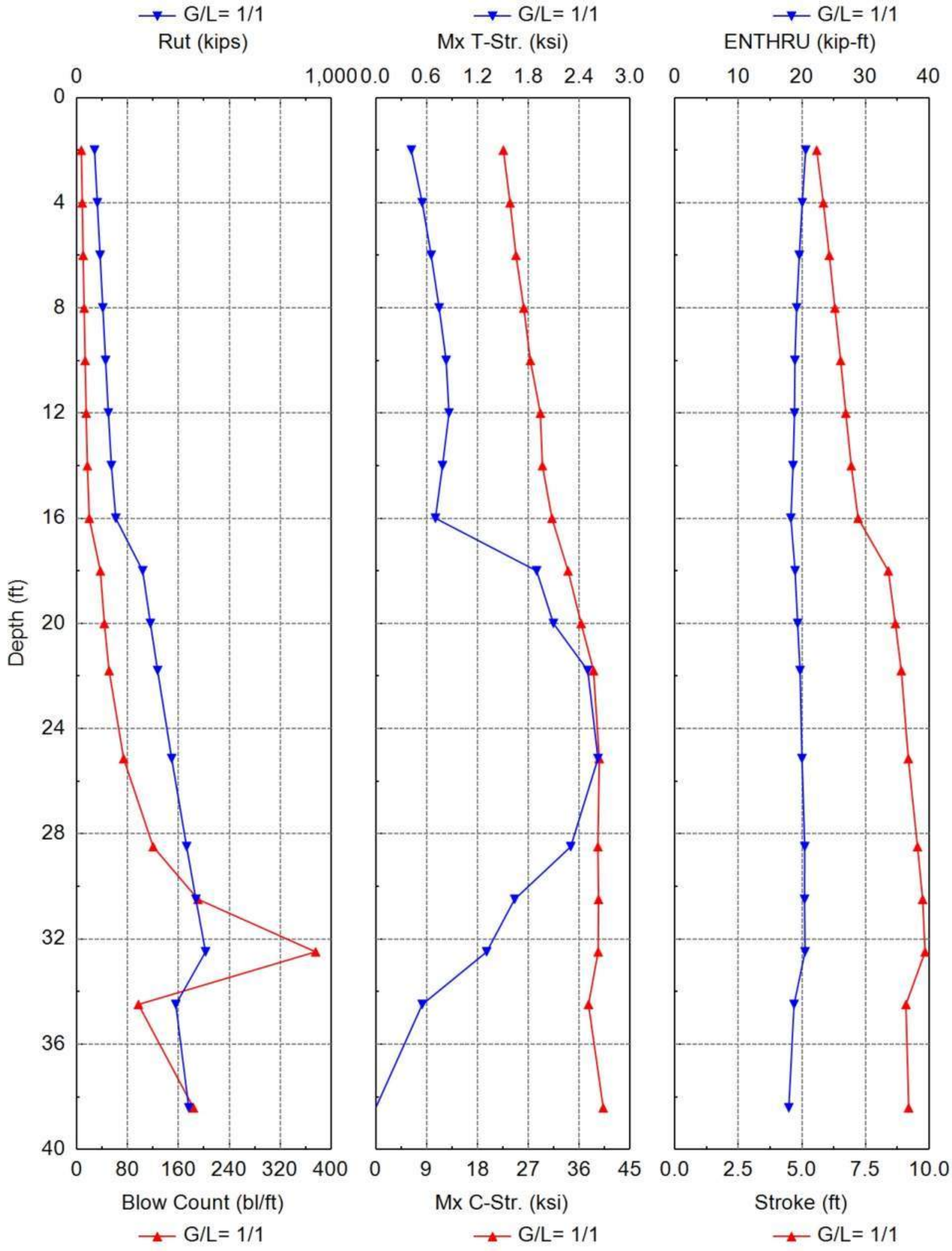
Calculated Average	New Values	Check to Override
2.54	0.50	☐ HP
6.50	6.00	☐ N60L

APPENDIX D

DEEP FOUNDATION ANALYSIS


Driveability Analysis Summary
G/L= 0.667/1.000
Rut (kips)
0 100 200 300 400 500
G/L= 0.667/1.(
Mx T-Str. (ksi)
0.0 0.6 1.2 1.8 2.4 3.0
G/L= 0.667/1.000
ENTHRU (kip-ft)
0 10 20 30 40
Depth (ft)
0 4 8 12 16 20 24 28 32 36 40
0 40 80 120 160 200
Blow Count (bl/ft)
G/L= 0.667/1.000
0 9 18 27 36 45
Mx C-Str. (ksi)
G/L= 0.667/1.(
0.0 2.5 5.0 7.5 10.0
Stroke (ft)
G/L= 0.667/1.000

Driveability Analysis Summary



Gain/Loss Factor at Shaft/Toe = 0.667/1.000

Depth	Rut	Rshaft	Rtoe	Blow Ct	Mx C-Str	Mx T-Str.	Stroke	ENTHRU	Hammer
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft	-
2.0	66.4	7.2	59.2	6.7	22.371	0.318	5.48	21.0	D 19-42
4.0	73.6	14.4	59.2	7.7	23.038	0.482	5.67	20.4	D 19-42
6.0	80.8	21.6	59.2	8.6	23.831	0.552	5.84	20.1	D 19-42
8.0	88.0	28.9	59.2	9.5	24.737	0.617	6.00	19.8	D 19-42
10.0	95.2	36.1	59.2	10.6	25.647	0.676	6.15	19.5	D 19-42
12.0	102.6	43.4	59.2	11.6	26.715	0.754	6.30	19.2	D 19-42
14.0	110.5	51.3	59.2	12.8	27.146	0.801	6.47	19.0	D 19-42
16.0	124.6	57.7	66.9	14.9	28.781	0.721	6.73	18.8	D 19-42
18.0	228.5	61.9	166.5	31.0	32.429	1.340	8.07	18.8	D 19-42
20.0	258.9	72.5	186.4	36.3	34.013	1.580	8.36	19.0	D 19-42
21.8	287.1	82.9	204.2	42.0	36.238	2.015	8.62	19.4	D 19-42
25.1	342.5	105.0	237.6	57.2	38.629	2.372	9.08	20.1	D 19-42
28.5	401.2	130.3	270.9	87.0	40.661	2.271	9.41	20.3	D 19-42
30.5	437.9	147.1	290.8	117.6	41.437	1.854	9.64	20.7	D 19-42
32.5	475.7	165.0	310.7	175.6	41.998	1.565	9.88	21.0	D 19-42
34.5	356.9	178.2	178.7	68.2	35.582	0.512	8.91	18.9	D 19-42
38.4	403.0	203.1	199.9	105.5	37.806	0.000	9.14	18.4	D 19-42

390 kips @ 27.9 ft

Total driving time: 46 minutes; Total Number of Blows: 1817 (starting at penetration 2.0 ft)

Gain/Loss Factor at Shaft/Toe = 1.000/1.000

Depth	Rut	Rshaft	Rtoe	Blow Ct	Mx C-Str	Mx T-Str.	Stroke	ENTHRU	Hammer
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft	-
2.0	70.0	10.8	59.2	7.2	22.579	0.420	5.58	20.6	D 19-42
4.0	80.8	21.6	59.2	8.6	23.768	0.548	5.84	20.1	D 19-42
6.0	91.6	32.5	59.2	10.0	24.818	0.654	6.08	19.6	D 19-42
8.0	102.4	43.3	59.2	11.6	26.197	0.748	6.30	19.2	D 19-42
10.0	113.3	54.1	59.2	13.2	27.360	0.831	6.52	18.9	D 19-42
12.0	124.2	65.1	59.2	14.8	29.129	0.864	6.73	18.8	D 19-42
14.0	136.2	77.0	59.2	16.7	29.499	0.787	6.94	18.6	D 19-42
16.0	153.5	86.6	66.9	19.7	31.184	0.704	7.21	18.3	D 19-42
18.0	259.3	92.7	166.5	37.1	34.032	1.898	8.40	18.9	D 19-42
20.0	289.7	103.2	186.4	43.4	36.348	2.096	8.68	19.3	D 19-42
21.8	317.9	113.7	204.2	50.8	38.539	2.501	8.91	19.7	D 19-42
25.1	373.3	135.7	237.6	73.8	39.554	2.622	9.19	20.0	D 19-42
28.5	432.0	161.1	270.9	120.2	39.318	2.300	9.55	20.5	D 19-42
30.5	468.7	177.9	290.8	190.7	39.424	1.639	9.75	20.4	D 19-42

390 kips @ 26.1 ft

32.5	506.5	195.8	310.7	375.8	39.357	1.308	9.84	20.5	D 19-42
34.5	389.6	210.8	178.7	97.0	37.651	0.549	9.09	18.8	D 19-42
38.4	440.6	240.7	199.9	183.6	40.259	0.000	9.20	17.9	D 19-42

Total driving time: 73 minutes; Total Number of Blows: 2833 (starting at penetration 2.0 ft)

Alt 4 RB + CIP14 B1 12/31/2024
NATIONAL ENGINEERING AND ARCHITECTURAL GRLWEAP 14.1.20.1

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

The GRLWEAP program simulates the behavior of a preformed pile driven by either an impact hammer or a vibratory hammer. The program is based on mathematical models, which describe motion and forces of hammer, driving system, pile and soil under the hammer action. Under certain conditions, the models only crudely approximate, often complex, dynamic situations.

A wave equation analysis generally relies on input data, which represents normal situations. In particular, the hammer data file supplied with the program assumes that the hammer is in good working order. All of the input data selected by the user may be the best available information at the time when the analysis is performed. However, input data and therefore results may significantly differ from actual field conditions.

Therefore, the program authors recommend prudent use of the GRLWEAP results. Soil response and hammer performance should be verified by static and/or dynamic testing and measurements. Estimates of bending or other local stresses (e.g., helmet or clamp contact, uneven rock surfaces etc.), prestress effects and others must also be accounted for by the user.

The calculated capacity-blow count relationship, i.e. the bearing graph, should be used in conjunction with observed blow counts for the capacity assessment of a driven pile. Soil setup occurring after pile installation may produce bearing capacity values that differ substantially from those expected from a wave equation analysis due to soil setup or relaxation. This is particularly true for pile driven with vibratory hammers. The GRLWEAP user must estimate such effects and should also use proper care when applying blow counts from restrike because of the variability of hammer energy, soil resistance and blow count during early restriking.

Finally, the GRLWEAP capacities are ultimate values. They MUST be reduced by means of an appropriate factor of safety to yield a design or working load. The selection of a factor of safety should consider the quality of the construction control, the variability of the site conditions, uncertainties in the loads, the importance of structure and other factors.

SOIL PROFILE

Depth	Soil Type	Spec. Wt	Su	Phi	Unit Rs	Unit Rt
ft	-	lb/ft³	ksf	°	ksf	ksf
0.0	Clay	135.0	6.1	0.0	1.51	55.35
15.2	Clay	135.0	6.1	0.0	1.51	55.35
15.2	Sand	132.0	0.0	36.0	0.74	59.63
17.9	Sand	132.0	0.0	36.0	0.86	69.77
17.9	Sand	140.0	0.0	40.0	1.35	155.04
32.9	Sand	140.0	0.0	40.0	2.56	294.63
32.9	Sand	140.0	0.0	37.0	1.87	159.31
38.4	Sand	140.0	0.0	37.0	2.19	186.98

PILE INPUT

Uniform Pile		Pile Type:	Closed-End Pipe
Pile Length: (ft)	38.420	Pile Penetration: (ft)	38.420
Pile Size: (ft)	1.17	Toe Area: (in²)	153.94

Pile Profile

Lb Top	X-Area	E-Modulus	Spec. Wt	Perim.	Crit. Index
ft	in²	ksi	lb/ft³	ft	-
0.0	13.4	30,000.0	492.0	3.7	0
38.4	13.4	30,000.0	492.0	3.7	0

HAMMER INPUT

ID	41	Made By:	DELMAG
Model	D 19-42	Type:	OED

Hammer Data

ID	Ram Wt	Ram L.	Ram Ar.	Rtd. Stk	Effic.	Rtd. Energy
-	kips	in	in²	ft	-	kip-ft
41	4.000	129.1	124.7	10.8	0.80	43.2

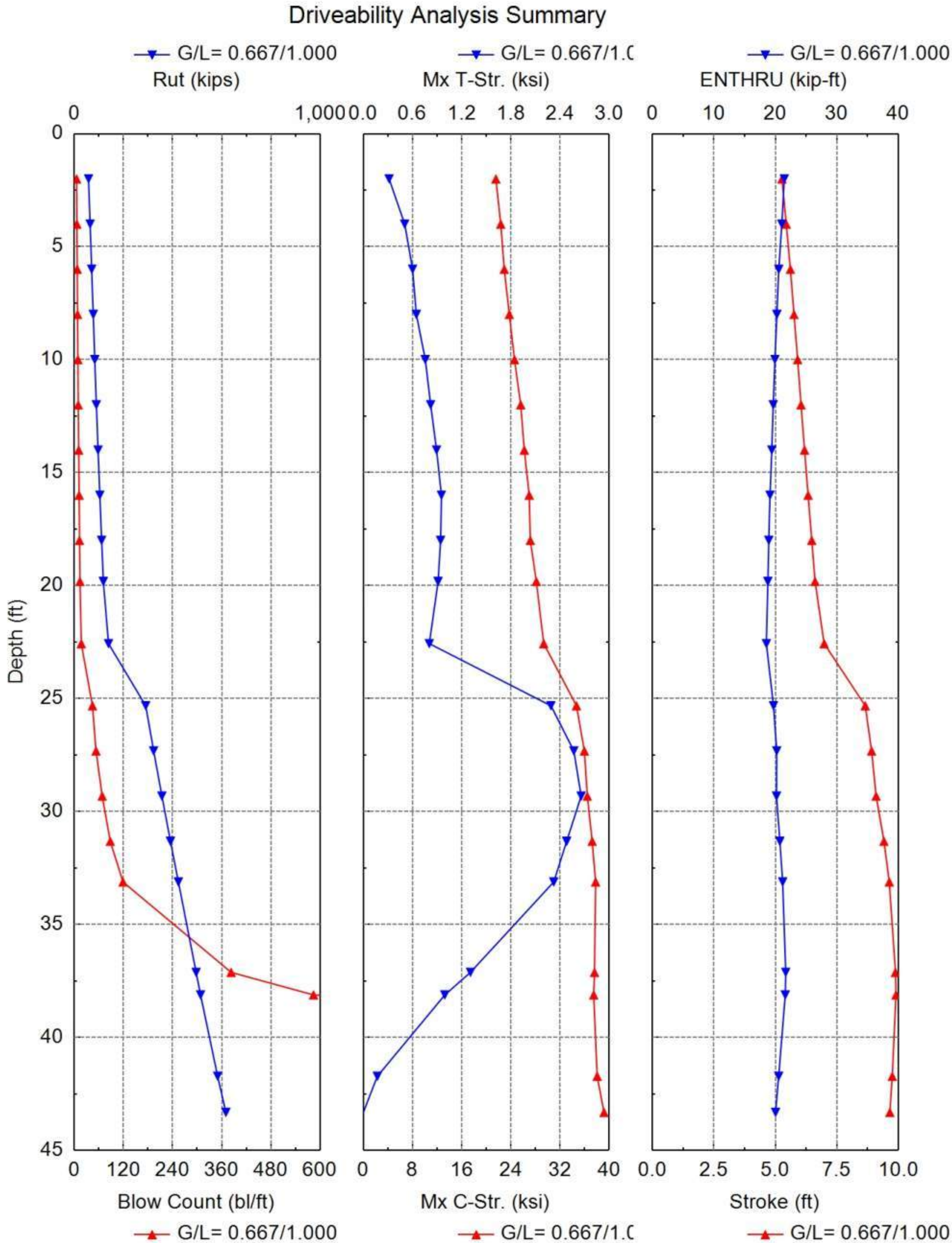
DRIVE SYSTEM FOR DELMAG D 19-42-OED

Type	X-Area	E-Modulus	Thickness	COR	Round-out	Stiffness
-	in²	ksi	in	-	in	kips/in
Hammer C.	227.000	530.000	2.000	0.800	0.120	60155.555
Helmet Wt.	1.900	kips				

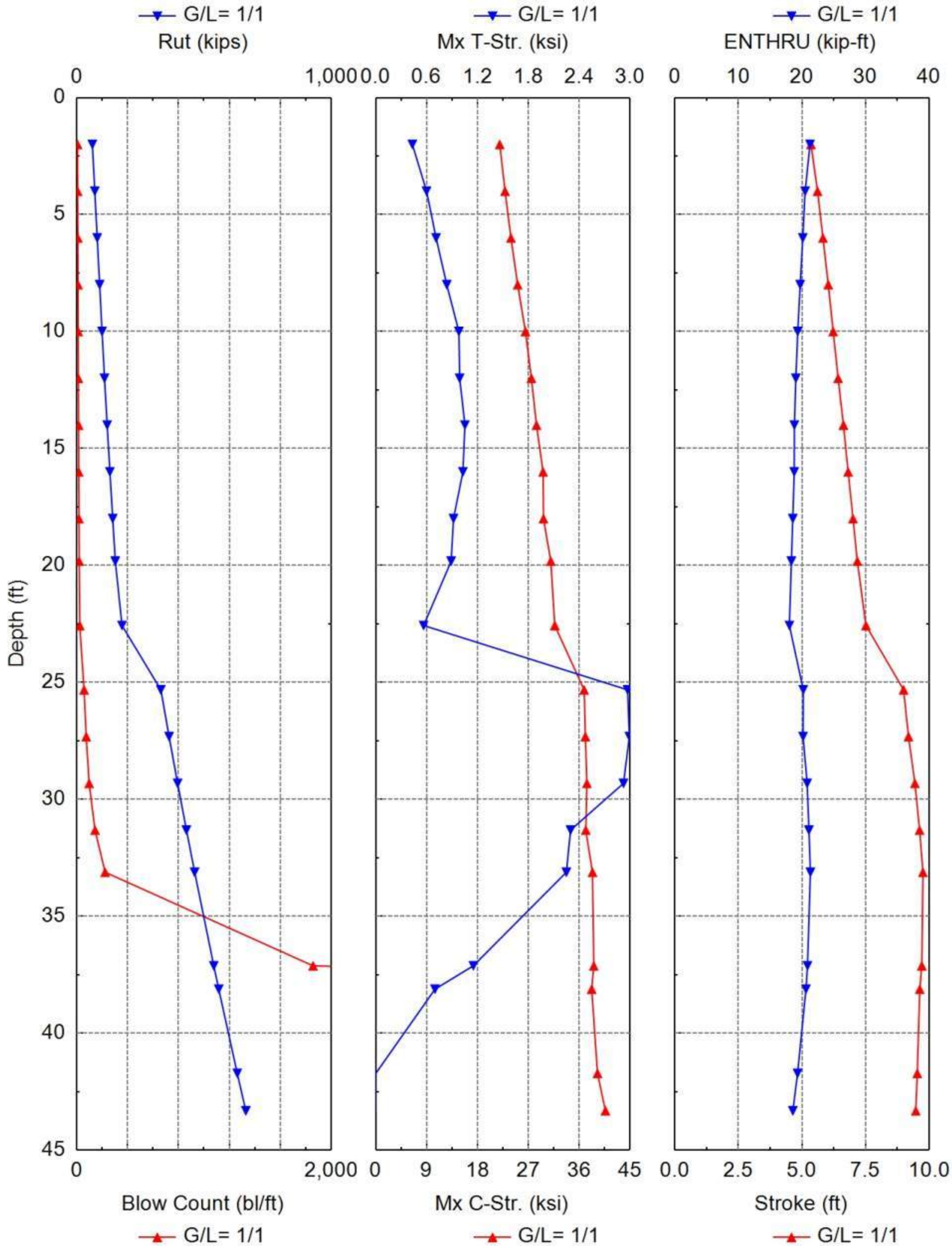
SOIL RESISTANCE DISTRIBUTION

Depth	Unit Rs	Unit Rt	Qs	Qt	Js	Jt	Set. F.	Limit D.	Set. T.	EB Area

ft	ksf	ksf	in	in	s/ft	s/ft	-	ft	Hours	in²
0.0	1.5	55.3	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
1.7	1.5	55.3	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
3.4	1.5	55.3	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
5.1	1.5	55.3	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
6.8	1.5	55.3	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
8.5	1.5	55.3	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
10.1	1.5	55.3	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
11.8	1.5	55.3	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
13.5	1.5	55.3	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
15.2	1.5	55.3	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
15.2	0.7	59.6	0.10	0.13	0.10	0.15	1.5	6.0	24.0	153.9
16.6	0.8	64.7	0.10	0.13	0.10	0.15	1.5	6.0	24.0	153.9
17.9	0.9	69.8	0.10	0.13	0.10	0.15	1.5	6.0	24.0	153.9
17.9	1.3	155.0	0.10	0.11	0.05	0.15	1.0	6.0	1.0	153.9
19.6	1.5	170.6	0.10	0.11	0.05	0.15	1.0	6.0	1.0	153.9
21.3	1.6	186.1	0.10	0.11	0.05	0.15	1.0	6.0	1.0	153.9
22.9	1.8	201.6	0.10	0.11	0.05	0.15	1.0	6.0	1.0	153.9
24.6	1.9	217.1	0.10	0.11	0.05	0.15	1.0	6.0	1.0	153.9
26.3	2.0	232.6	0.10	0.11	0.05	0.15	1.0	6.0	1.0	153.9
27.9	2.2	248.1	0.10	0.11	0.05	0.15	1.0	6.0	1.0	153.9
29.6	2.3	263.6	0.10	0.11	0.05	0.15	1.0	6.0	1.0	153.9
31.3	2.4	279.1	0.10	0.11	0.05	0.15	1.0	6.0	1.0	153.9
32.9	2.6	294.6	0.10	0.11	0.05	0.15	1.0	6.0	1.0	153.9
32.9	1.9	159.3	0.10	0.12	0.10	0.15	1.2	6.0	24.0	153.9
34.8	2.0	168.5	0.10	0.12	0.10	0.15	1.2	6.0	24.0	153.9
36.6	2.1	177.8	0.10	0.12	0.10	0.15	1.2	6.0	24.0	153.9
38.4	2.2	187.0	0.10	0.12	0.10	0.15	1.2	6.0	24.0	153.9


Driveability Analysis Summary
G/L= 0.667/1.000
Rut (kips)
0
1,000
G/L= 0.667/1.0
Mx T-Str. (ksi)
0.0 0.6 1.2 1.8 2.4 3.0
G/L= 0.667/1.000
ENTHRU (kip-ft)
0 10 20 30 40
Depth (ft)
0 5 10 15 20 25 30 35 40 45
0 120 240 360 480 600
Blow Count (bl/ft)
G/L= 0.667/1.000
0 8 16 24 32 40
Mx C-Str. (ksi)
G/L= 0.667/1.0
0.0 2.5 5.0 7.5 10.0
Stroke (ft)
G/L= 0.667/1.000

Driveability Analysis Summary



Gain/Loss Factor at Shaft/Toe = 0.667/1.000

Depth	Rut	Rshaft	Rtoe	Blow Ct	Mx C-Str	Mx T-Str.	Stroke	ENTHRU	Hammer
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft	-
2.0	58.3	6.3	52.0	5.8	21.565	0.315	5.27	21.5	D 19-42
4.0	64.6	12.7	52.0	6.5	22.362	0.505	5.45	21.1	D 19-42
6.0	71.0	19.0	52.0	7.3	22.931	0.601	5.61	20.6	D 19-42
8.0	77.3	25.3	52.0	8.1	23.752	0.647	5.76	20.2	D 19-42
10.0	83.6	31.7	52.0	9.0	24.602	0.757	5.91	19.9	D 19-42
12.0	90.0	38.1	52.0	9.8	25.608	0.822	6.05	19.7	D 19-42
14.0	97.0	45.1	52.0	10.8	26.188	0.894	6.19	19.4	D 19-42
16.0	104.2	52.2	52.0	11.9	26.990	0.953	6.33	19.1	D 19-42
18.0	111.5	59.6	52.0	12.9	27.172	0.943	6.48	18.9	D 19-42
19.8	118.4	66.4	52.0	14.0	28.155	0.913	6.62	18.8	D 19-42
22.6	139.5	77.0	62.5	17.3	29.352	0.805	6.99	18.5	D 19-42
25.3	290.7	91.1	199.6	44.5	34.683	2.290	8.66	19.7	D 19-42
27.3	323.1	103.6	219.5	53.2	35.963	2.569	8.92	20.2	D 19-42
29.3	356.7	117.3	239.4	68.3	36.449	2.658	9.10	20.2	D 19-42
31.3	391.4	132.2	259.3	88.0	37.240	2.481	9.42	20.7	D 19-42
33.1	423.7	146.6	277.2	119.1	37.794	2.324	9.64	21.2	D 19-42
37.1	495.9	178.9	317.0	383.0	37.610	1.308	9.89	21.7	D 19-42
38.1	513.9	186.9	326.9	584.0	37.483	0.995	9.91	21.6	D 19-42
41.7	583.3	220.6	362.7	9999.0	38.053	0.171	9.76	20.5	D 19-42
43.3	616.9	238.3	378.7	9999.0	39.165	0.000	9.66	20.0	D 19-42

390 kips @ 31.2 ft

Refusal occurred; no driving time output possible.

Gain/Loss Factor at Shaft/Toe = 1.000/1.000

Depth	Rut	Rshaft	Rtoe	Blow Ct	Mx C-Str	Mx T-Str.	Stroke	ENTHRU	Hammer
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft	-
2.0	61.5	9.5	52.0	6.1	21.938	0.432	5.36	21.3	D 19-42
4.0	71.0	19.0	52.0	7.3	22.882	0.599	5.62	20.5	D 19-42
6.0	80.5	28.5	52.0	8.5	23.922	0.712	5.83	20.1	D 19-42
8.0	90.0	38.0	52.0	9.8	25.115	0.838	6.04	19.7	D 19-42
10.0	99.5	47.5	52.0	11.1	26.490	0.981	6.23	19.3	D 19-42
12.0	109.1	57.1	52.0	12.5	27.542	0.990	6.43	19.0	D 19-42
14.0	119.6	67.6	52.0	14.1	28.442	1.052	6.63	18.8	D 19-42
16.0	130.3	78.4	52.0	15.7	29.609	1.028	6.82	18.8	D 19-42
18.0	141.3	89.4	52.0	17.5	29.679	0.917	7.01	18.6	D 19-42
19.8	151.6	99.6	52.0	19.4	30.975	0.890	7.18	18.3	D 19-42
22.6	178.0	115.5	62.5	23.8	31.684	0.565	7.52	18.0	D 19-42

25.3	330.6	131.0	199.6	57.4	36.876	2.971	9.00	20.2	D 19-42
27.3	363.0	143.5	219.5	74.3	37.094	2.992	9.19	20.2	D 19-42
29.3	396.6	157.2	239.4	97.5	37.370	2.923	9.45	20.8	D 19-42
31.3	431.4	172.1	259.3	143.7	37.166	2.298	9.63	21.1	D 19-42
33.1	463.7	186.5	277.2	223.2	38.360	2.249	9.76	21.3	D 19-42
37.1	538.9	221.9	317.0	1858.5	38.578	1.151	9.72	20.9	D 19-42
38.1	558.4	231.5	326.9	9999.0	38.216	0.699	9.64	20.6	D 19-42
41.7	631.2	268.5	362.7	9999.0	39.240	0.000	9.54	19.3	D 19-42
43.3	664.8	286.2	378.7	9999.0	40.647	0.000	9.48	18.6	D 19-42

390 kips @ 28.9 ft

Refusal occurred; no driving time output possible.

GRLWEAP: Wave Equation Analysis of Pile Foundations

Alt 4 FB + CIP14 B2 12/31/2024
NATIONAL ENGINEERING AND ARCHITECTURAL GRLWEAP 14.1.20.1

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

The GRLWEAP program simulates the behavior of a preformed pile driven by either an impact hammer or a vibratory hammer. The program is based on mathematical models, which describe motion and forces of hammer, driving system, pile and soil under the hammer action. Under certain conditions, the models only crudely approximate, often complex, dynamic situations.

A wave equation analysis generally relies on input data, which represents normal situations. In particular, the hammer data file supplied with the program assumes that the hammer is in good working order. All of the input data selected by the user may be the best available information at the time when the analysis is performed. However, input data and therefore results may significantly differ from actual field conditions.

Therefore, the program authors recommend prudent use of the GRLWEAP results. Soil response and hammer performance should be verified by static and/or dynamic testing and measurements. Estimates of bending or other local stresses (e.g., helmet or clamp contact, uneven rock surfaces etc.), prestress effects and others must also be accounted for by the user.

The calculated capacity-blow count relationship, i.e. the bearing graph, should be used in conjunction with observed blow counts for the capacity assessment of a driven pile. Soil setup occurring after pile installation may produce bearing capacity values that differ substantially from those expected from a wave equation analysis due to soil setup or relaxation. This is particularly true for pile driven with vibratory hammers. The GRLWEAP user must estimate such effects and should also use proper care when applying blow counts from restrike because of the variability of hammer energy, soil resistance and blow count during early restriking.

Finally, the GRLWEAP capacities are ultimate values. They MUST be reduced by means of an appropriate factor of safety to yield a design or working load. The selection of a factor of safety should consider the quality of the construction control, the variability of the site conditions, uncertainties in the loads, the importance of structure and other factors.

SOIL PROFILE

Depth ft	Soil Type -	Spec. Wt lb/ft³	Su ksf	Phi °	Unit Rs ksf	Unit Rt ksf
0.0	Clay	122.0	5.4	0.0	1.39	48.60
21.8	Clay	122.0	5.4	0.0	1.39	48.60
21.8	Clay	130.0	6.5	0.0	1.56	58.50
23.3	Clay	130.0	6.5	0.0	1.56	58.50
23.3	Sand	140.0	0.0	40.0	1.46	168.09
35.1	Sand	140.0	0.0	40.0	2.42	277.90
35.1	Sand	140.0	0.0	40.0	2.42	277.90
40.1	Sand	140.0	0.0	40.0	2.82	324.43
40.1	Sand	140.0	0.0	40.0	2.82	324.43
43.3	Sand	140.0	0.0	40.0	3.08	354.21

PILE INPUT

Uniform Pile		Pile Type:	Closed-End Pipe
Pile Length: (ft)	43.320	Pile Penetration: (ft)	43.320
Pile Size: (ft)	1.17	Toe Area: (in²)	153.94

Pile Profile

Lb Top ft	X-Area in²	E-Modulus ksi	Spec. Wt lb/ft³	Perim. ft	Crit. Index -
0.0	13.4	30,000.0	492.0	3.7	0
43.3	13.4	30,000.0	492.0	3.7	0

HAMMER INPUT

ID	41	Made By:	DELMAG
Model	D 19-42	Type:	OED

Hammer Data

ID -	Ram Wt kips	Ram L. in	Ram Ar. in²	Rtd. Stk ft	Effic. -	Rtd. Energy kip-ft
41	4.000	129.1	124.7	10.8	0.80	43.2

DRIVE SYSTEM FOR DELMAG D 19-42-OED

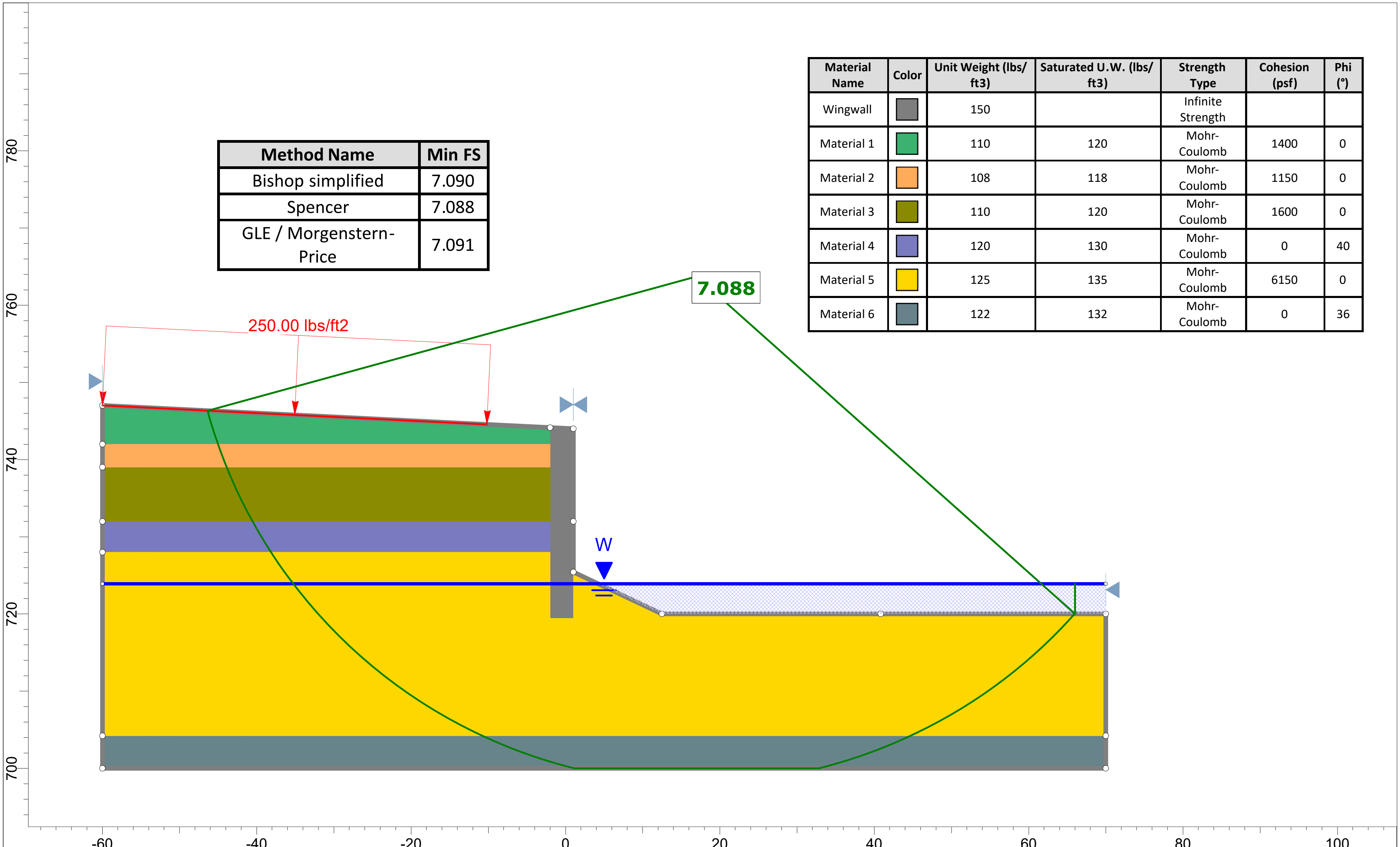
Type -	X-Area in²	E-Modulus ksi	Thickness in	COR -	Round-out in	Stiffness kips/in
Hammer C.	227.000	530.000	2.000	0.800	0.120	60155.555
Helmet Wt.	1.900	kips				

SOIL RESISTANCE DISTRIBUTION

Depth ft	Unit Rs ksf	Unit Rt ksf	Qs in	Qt in	Js s/ft	Jt s/ft	Set. F. -	Limit D. ft	Set. T. Hours	EB Area in²
0.0	1.4	48.6	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
1.7	1.4	48.6	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
3.4	1.4	48.6	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
5.0	1.4	48.6	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
6.7	1.4	48.6	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
8.4	1.4	48.6	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
10.1	1.4	48.6	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
11.7	1.4	48.6	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
13.4	1.4	48.6	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
15.1	1.4	48.6	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
16.8	1.4	48.6	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
18.5	1.4	48.6	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
20.1	1.4	48.6	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
21.8	1.4	48.6	0.10	0.11	0.15	0.15	1.5	6.0	168.0	153.9
21.8	1.6	58.5	0.10	0.11	0.15	0.15	1.5	6.0	24.0	153.9
23.3	1.6	58.5	0.10	0.11	0.15	0.15	1.5	6.0	24.0	153.9
23.3	1.5	168.1	0.10	0.11	0.05	0.15	1.0	6.0	1.0	153.9
25.0	1.6	183.8	0.10	0.11	0.05	0.15	1.0	6.0	1.0	153.9
26.7	1.7	199.5	0.10	0.11	0.05	0.15	1.0	6.0	1.0	153.9
28.4	1.9	215.1	0.10	0.11	0.05	0.15	1.0	6.0	1.0	153.9
30.1	2.0	230.8	0.10	0.11	0.05	0.15	1.0	6.0	1.0	153.9
31.7	2.1	246.5	0.10	0.11	0.05	0.15	1.0	6.0	1.0	153.9
33.4	2.3	262.2	0.10	0.11	0.05	0.15	1.0	6.0	1.0	153.9
35.1	2.4	277.9	0.10	0.11	0.05	0.15	1.0	6.0	1.0	153.9
35.1	2.4	277.9	0.10	0.12	0.10	0.15	1.2	6.0	24.0	153.9
36.8	2.6	293.4	0.10	0.12	0.10	0.15	1.2	6.0	24.0	153.9
38.5	2.7	308.9	0.10	0.12	0.10	0.15	1.2	6.0	24.0	153.9
40.1	2.8	324.4	0.10	0.12	0.10	0.15	1.2	6.0	24.0	153.9
40.1	2.8	324.4	0.10	0.12	0.05	0.15	1.0	6.0	1.0	153.9
41.7	3.0	339.3	0.10	0.12	0.05	0.15	1.0	6.0	1.0	153.9
43.3	3.1	354.2	0.10	0.12	0.05	0.15	1.0	6.0	1.0	153.9

APPENDIX E

GLOBAL STABILITY ANALYSIS



Method Name	Min FS
Bishop simplified	7.090
Spencer	7.088
GLE / Morgenstern-Price	7.091

Material Name	Color	Unit Weight (lbs/ft3)	Saturated U.W. (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (°)
Wingwall		150		Infinite Strength		
Material 1		110	120	Mohr-Coulomb	1400	0
Material 2		108	118	Mohr-Coulomb	1150	0
Material 3		110	120	Mohr-Coulomb	1600	0
Material 4		120	130	Mohr-Coulomb	0	40
Material 5		125	135	Mohr-Coulomb	6150	0
Material 6		122	132	Mohr-Coulomb	0	36

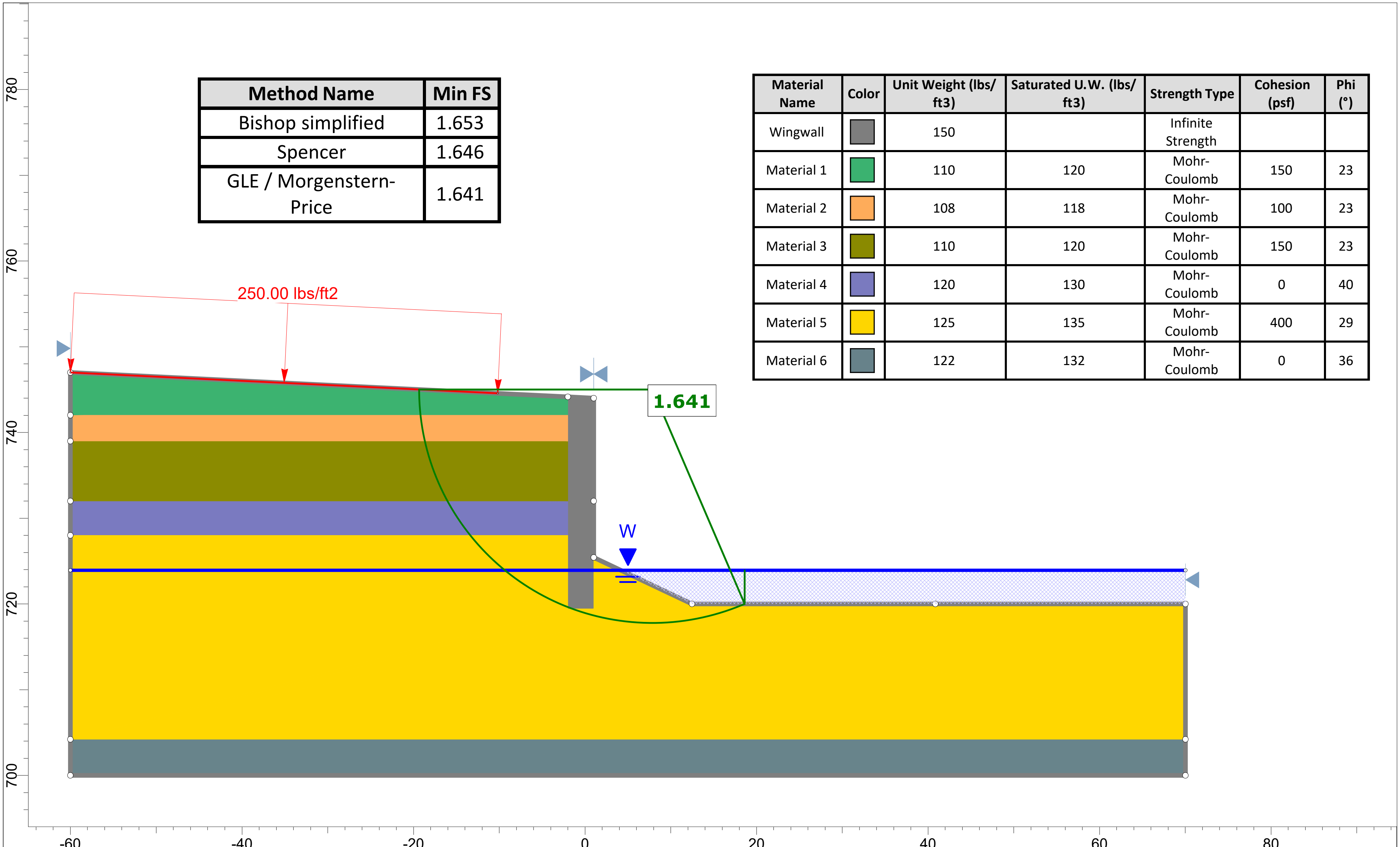
rocscience

SLIDEINTERPRET 9.036

Project	ROS-138-17.28		
Group	Group 1	*Scenario*	Master Scenario
Drawn By	ZM	*Company*	NEAS, Inc.
Date	1/2/2025	*File Name*	ROS-138-17.28_Inlet_Normal Water_Total_B1.slmd

Method Name	Min FS
Bishop simplified	1.653
Spencer	1.646
GLE / Morgenstern-Price	1.641

Material Name	Color	Unit Weight (lbs/ft3)	Saturated U.W. (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (°)
Wingwall		150		Infinite Strength		
Material 1		110	120	Mohr-Coulomb	150	23
Material 2		108	118	Mohr-Coulomb	100	23
Material 3		110	120	Mohr-Coulomb	150	23
Material 4		120	130	Mohr-Coulomb	0	40
Material 5		125	135	Mohr-Coulomb	400	29
Material 6		122	132	Mohr-Coulomb	0	36



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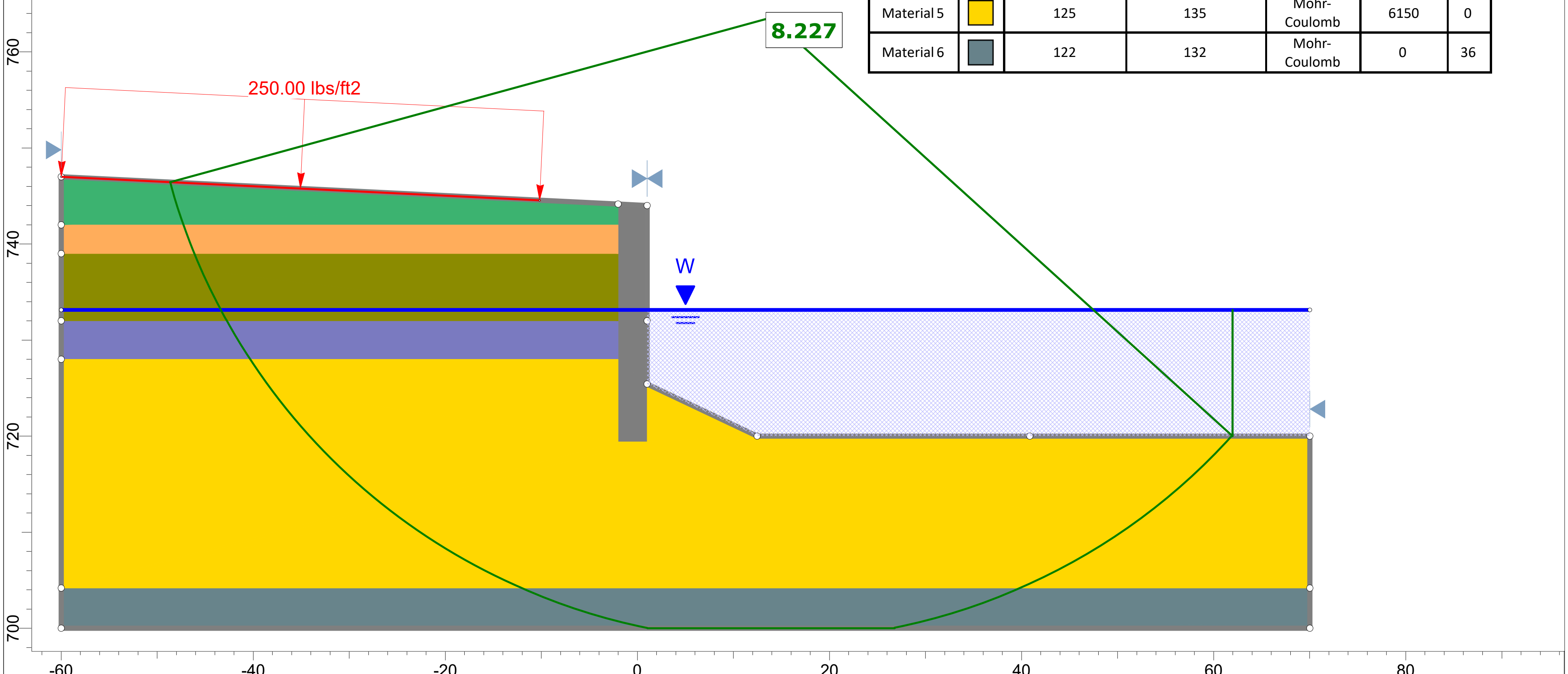
SLIDEINTERPRET 9.036

Project	ROS-138-17.28		
Group	Group 1	*Scenario*	Master Scenario
Drawn By	ZM	*Company*	NEAS, Inc.
Date	1/2/2025	*File Name*	ROS-138-17.28_Inlet_Normal Water _Effective_B1.slmd

Method Name	Min FS
Bishop simplified	8.227
Spencer	8.231
GLE / Morgenstern-Price	8.235

Material Name	Color	Unit Weight (lbs/ft3)	Saturated U.W. (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (°)
Wingwall		150		Infinite Strength		
Material 1		110	120	Mohr-Coulomb	1400	0
Material 2		108	118	Mohr-Coulomb	1150	0
Material 3		110	120	Mohr-Coulomb	1600	0
Material 4		120	130	Mohr-Coulomb	0	40
Material 5		125	135	Mohr-Coulomb	6150	0
Material 6		122	132	Mohr-Coulomb	0	36



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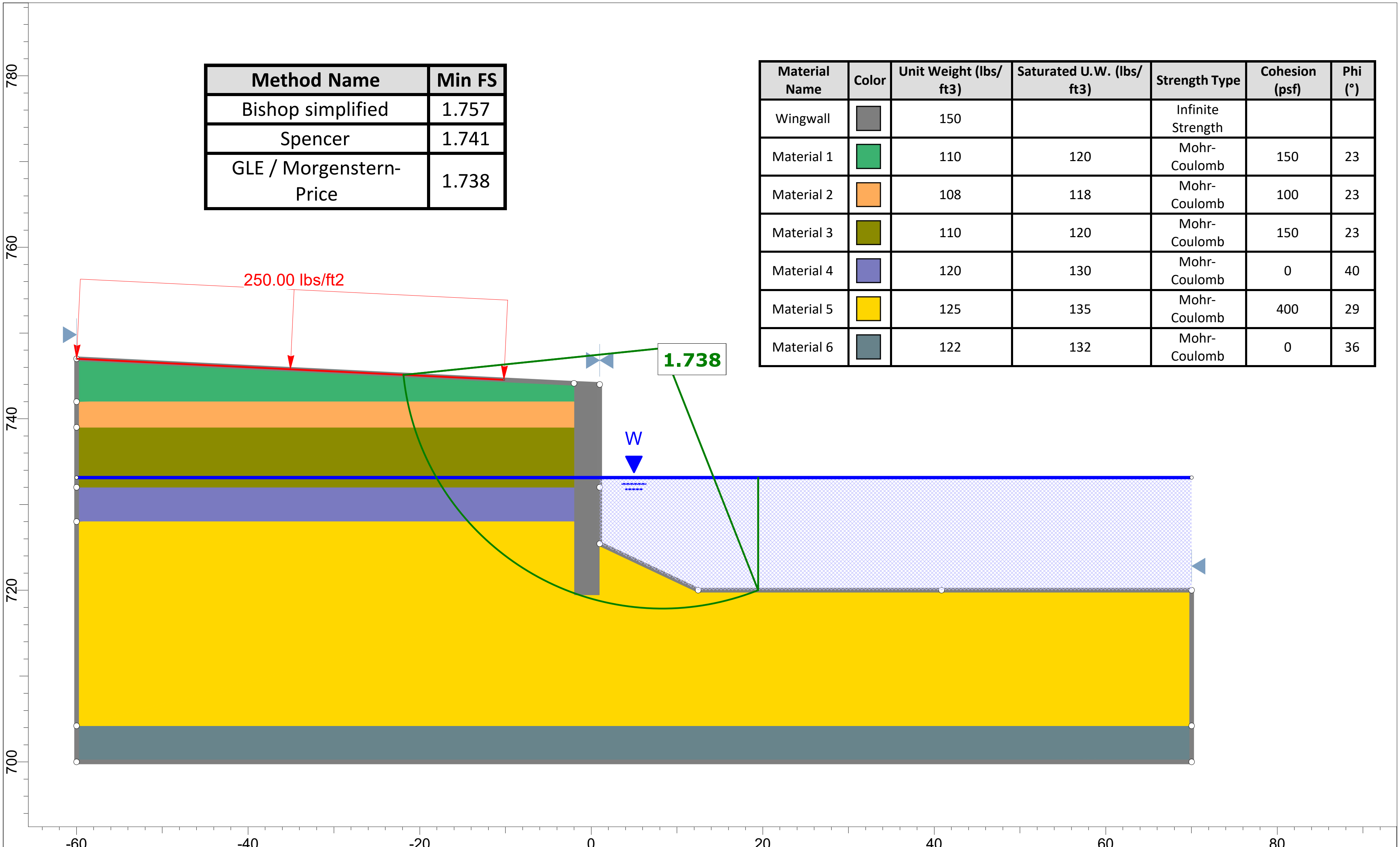
SLIDEINTERPRET 9.036

Project	ROS-138-17.28

Group	Group 1	*Scenario*	Master Scenario
Drawn By	ZM	*Company*	NEAS, Inc.
Date	1/2/2025	*File Name*	ROS-138-17.28_Inlet_HW100_Total_B1.slmd

Method Name	Min FS
Bishop simplified	1.757
Spencer	1.741
GLE / Morgenstern-Price	1.738

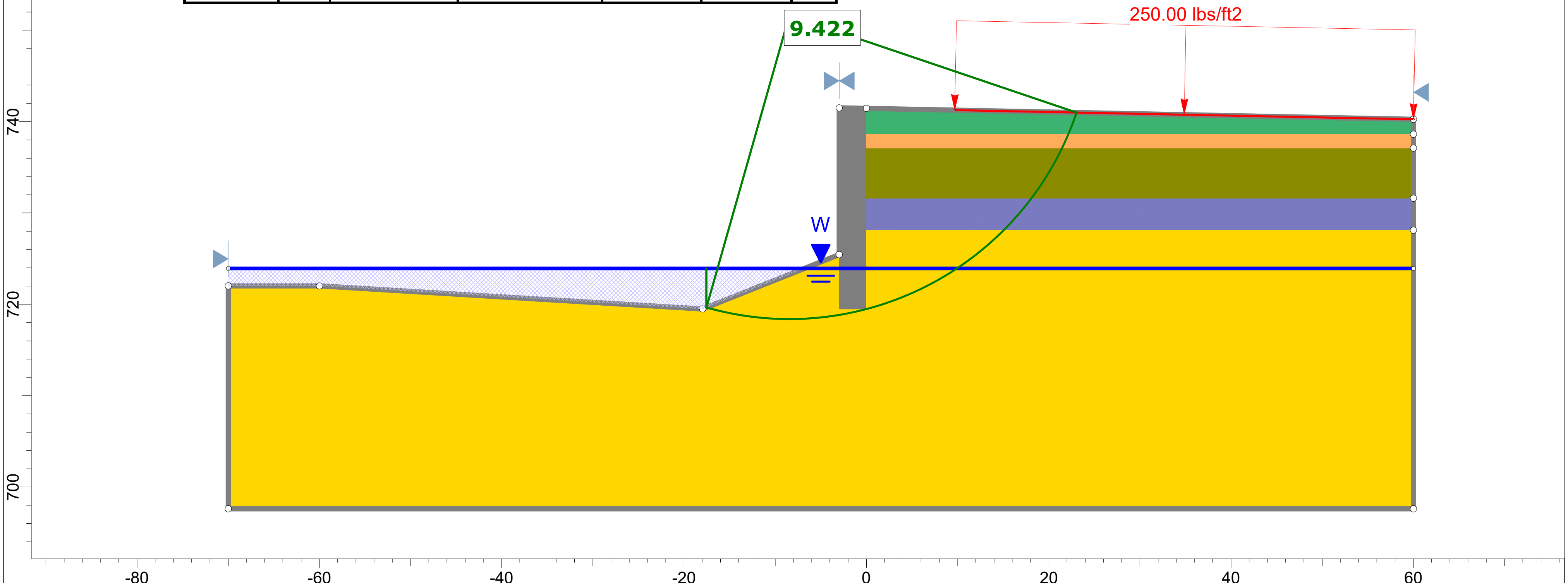
Material Name	Color	Unit Weight (lbs/ft3)	Saturated U.W. (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (°)
Wingwall		150		Infinite Strength		
Material 1		110	120	Mohr-Coulomb	150	23
Material 2		108	118	Mohr-Coulomb	100	23
Material 3		110	120	Mohr-Coulomb	150	23
Material 4		120	130	Mohr-Coulomb	0	40
Material 5		125	135	Mohr-Coulomb	400	29
Material 6		122	132	Mohr-Coulomb	0	36



rocscience	Project	ROS-138-17.28	
	Group: Group 1	Scenario: Master Scenario	
	Drawn By: ZM	Company: NEAS, Inc.	
SLIDEINTERPRET 9.036	Date: 1/2/2025	File Name: ROS-138-17.28_Inlet_HW100 _Effective_B1.slmd	

Material Name	Color	Unit Weight (lbs/ft3)	Saturated U.W. (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (°)
Wingwall		150		Infinite Strength		
Material 1		118	128	Mohr-Coulomb	0	40
Material 2		115	125	Mohr-Coulomb	2750	0
Material 3		108	118	Mohr-Coulomb	1000	0
Material 4		130	140	Mohr-Coulomb	6500	0
Material 5		122	132	Mohr-Coulomb	5400	0

Method Name	Min FS
Bishop simplified	9.433
Spencer	9.422
GLE / Morgenstern-Price	9.432



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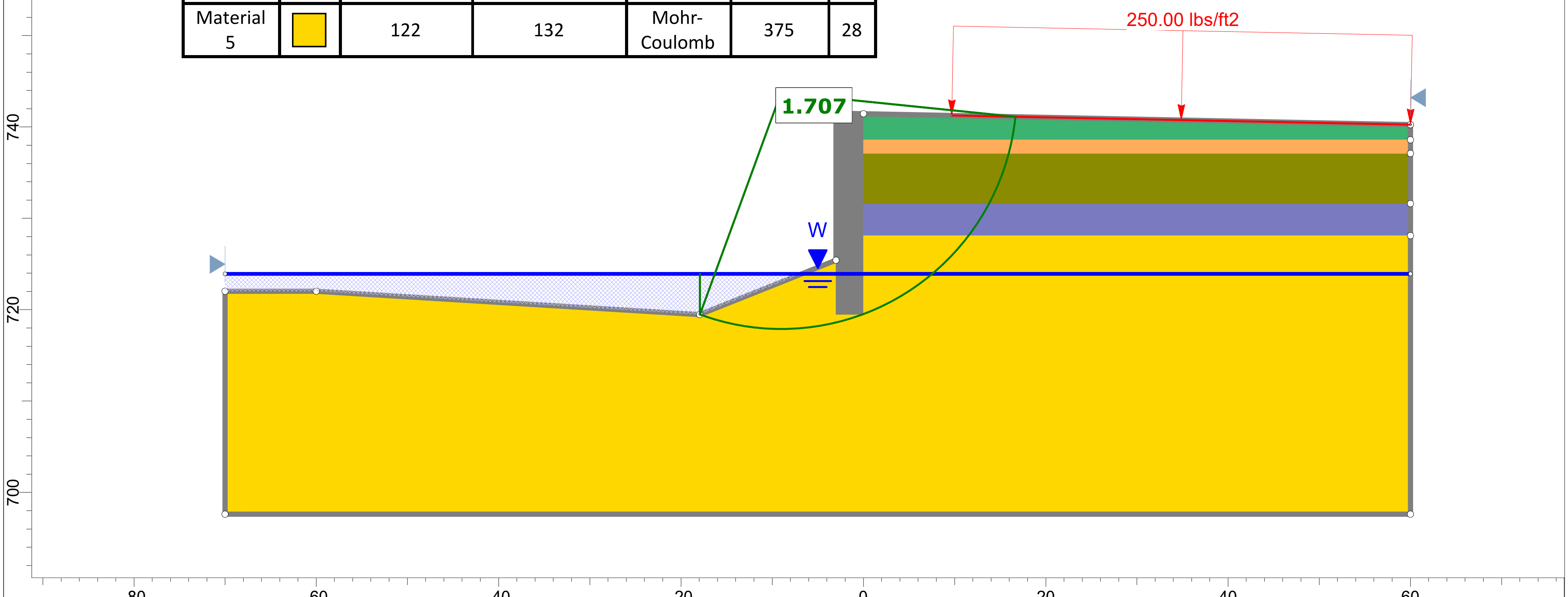
SLIDEINTERPRET 9.036

Project	ROS-138-17.28		
Group	Group 1	*Scenario*	Master Scenario
Drawn By	ZM	*Company*	NEAS, Inc.
Date	1/2/2025	*File Name*	ROS-138-17.28_Outlet_Normal Water_Total_B2.slmd

Material Name	Color	Unit Weight (lbs/ft3)	Saturated U.W. (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (°)
Wingwall		150		Infinite Strength		
Material 1		118	128	Mohr-Coulomb	0	40
Material 2		115	125	Mohr-Coulomb	250	26
Material 3		108	118	Mohr-Coulomb	100	23
Material 4		130	140	Mohr-Coulomb	450	28
Material 5		122	132	Mohr-Coulomb	375	28

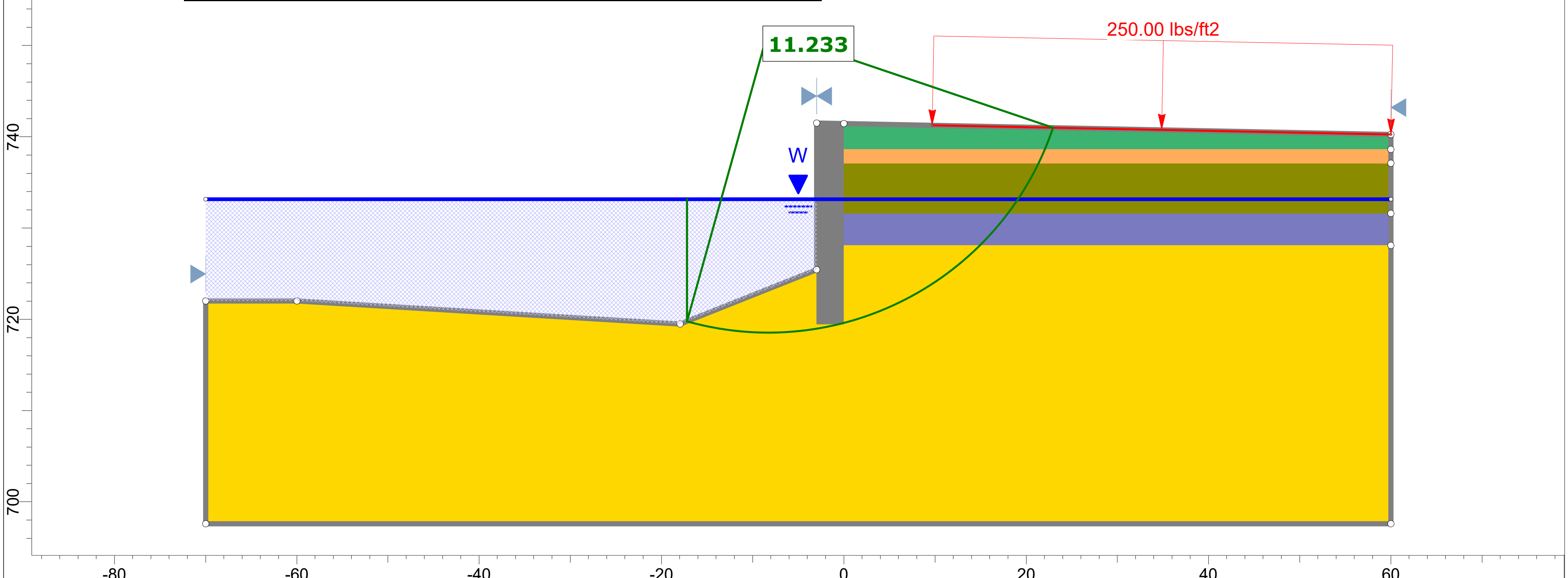
Method Name	Min FS
Bishop simplified	1.716
Spencer	1.707
GLE / Morgenstern-Price	1.707



rocscience	Project	ROS-138-17.28	
	Group: Group 1	Scenario: Master Scenario	
	Drawn By: ZM	Company: NEAS, Inc.	
SLIDEINTERPRET 9.036	Date: 7/1/2024	File Name: ROS-138-17.28_Outlet_Normal Water_Effective_B2.slmd	

Material Name	Color	Unit Weight (lbs/ft3)	Saturated U.W. (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (°)
Wingwall		150		Infinite Strength		
Material 1		118	128	Mohr-Coulomb	0	40
Material 2		115	125	Mohr-Coulomb	2750	0
Material 3		108	118	Mohr-Coulomb	1000	0
Material 4		130	140	Mohr-Coulomb	6500	0
Material 5		122	132	Mohr-Coulomb	5400	0

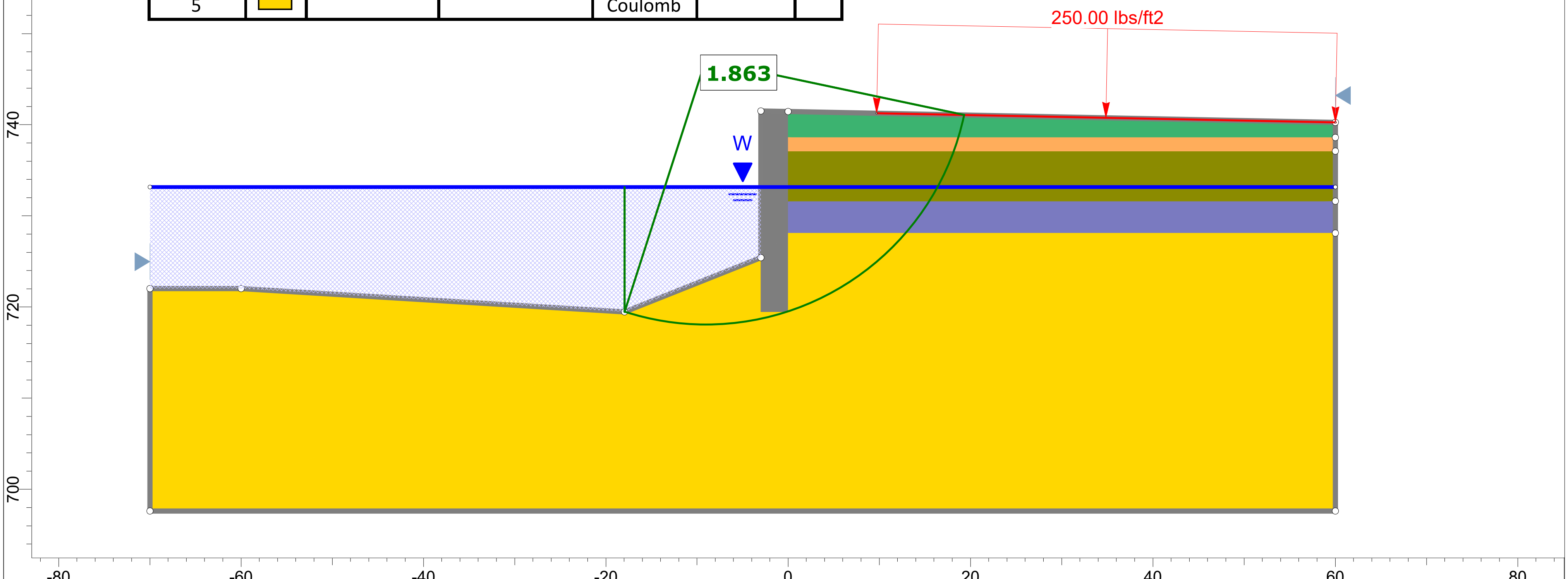
Method Name	Min FS
Bishop simplified	11.246
Spencer	11.233
GLE / Morgenstern-Price	11.247



rocscience	*Project* ROS-138-17.28		
	Group Group 1	*Scenario* Master Scenario	
	Drawn By ZM	*Company* NEAS, Inc.	
SLIDEINTERPRET 9.036	*Date* 1/2/2025	*File Name* ROS-138-17.28_Outlet_HW100_Total_B2.slmd	

Material Name	Color	Unit Weight (lbs/ft3)	Saturated U.W. (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (°)
Wingwall		150		Infinite Strength		
Material 1		118	128	Mohr-Coulomb	0	40
Material 2		115	125	Mohr-Coulomb	250	26
Material 3		108	118	Mohr-Coulomb	100	23
Material 4		130	140	Mohr-Coulomb	450	28
Material 5		122	132	Mohr-Coulomb	375	28

Method Name	Min FS
Bishop simplified	1.873
Spencer	1.866
GLE / Morgenstern-Price	1.863



rocscience	*Project* ROS-138-17.28		
	Group Group 1	*Scenario* Master Scenario	
	Drawn By ZM	*Company* NEAS, Inc.	
SLIDEINTERPRET 9.036	*Date* 1/2/2025	*File Name* ROS-138-17.28_Outlet_HW100_Effective_B2.slmd	