FRA-33-8.75 STRUCTURE REPLACEMENT
PID NO. 108081
FRANKLIN COUNTY, OHIO

STRUCTURE FOUNDATION EXPLORATION REPORT

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Rii Project No. W-22-156

July 8, 2025

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July 8, 2025

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Re: Structure Foundation Exploration Report
FRA-33-8.75 Culvert Replacement
ODOT District 6
Franklin County, Ohio
PID No. 108081
Rii Project No. W-22-156

Mr. Sopko:

Resource International, Inc. (Rii) is pleased to submit this structure foundation exploration report for the above-referenced project. Engineering logs have been prepared and are attached to this report along with results of laboratory testing. This report includes geotechnical recommendations for proposed FRA-33-8.75 culvert replacement in Columbus, Franklin County, Ohio.

We sincerely appreciate the opportunity to be of service to you on this project. If you have any questions regarding the structure foundation exploration or this report, please contact us.

Sincerely,

RESOURCE INTERNATIONAL, INC.

Ashok Gaire, P.E.
Project Manager

Daniel E. Karch, P.E.
Director – Geotechnical Services

Enclosure: Structure Foundation Exploration Report

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EXECUTIVE SUMMARY

Resource International, Inc. (Rii) has completed the structure foundation exploration performed for the proposed FRA-33-8.75 culvert replacement for ODOT District 6 in Columbus, Franklin County, Ohio. Based on information provided, the existing 8-foot by 8-foot concrete arch culvert with an 84-inch corrugated metal pipe (CMP) extension is planned to be replaced by a reinforced concrete box (RCB) culvert.

The exploration was performed within general accordance of the Ohio Department of Transportation's (ODOT) Specifications for Geotechnical Explorations (SGE), dated July 2022.

Exploration and Findings

On November 12, 2022, two (2) structure borings, designated as B-001-0-22 and B-002-0-22, were drilled along the alignment of proposed culvert replacement. Borings B-001-0-22 and B-002-0-22 were advanced to depths 29.3 and 36.1 feet below the existing ground surface, respectively.

Both borings were performed through the existing US 33 pavement and encountered 18.0 inches of asphalt overlying 4.0 to 5.0 inches of aggregate base. Beneath the surficial materials, the borings encountered previously placed fill soil materials extending to depths ranging from 16 to 18 feet below the existing grade underlain by layers of natural cohesive and granular soils to boring termination depth or top of bedrock.

The existing fill soils consisted of cohesive and granular soils. The cohesive fill soils were described as silt and clay as well as silty clay (ODOT A-6a, A-6b) with varying amounts of sand and gravel. The granular fill soils were described as gravel, gravel with sand, and gravel with sand, silt, and clay (ODOT A-1-a, A-1-b, A-2-6).

The natural cohesive soils encountered were described as sandy silt, silt and clay, silty clay, and clay (ODOT A-4a, A-6a, A-6b and A-7-6) with varying amounts of sand and gravel. The natural granular soils were described as gravel with sand, coarse and fine sand, and gravel with sand and silt (ODOT A-1-b, A-3a, A-2-4).

Bedrock was encountered in boring B-001-0-22 at a depth of 24.0 feet below existing grade, corresponding to elevation 767.8 feet msl. In boring B-002-0-22, auger refusal was encountered at a depth of 36.1 feet below existing grade, corresponding to elevation 755.2 feet msl, potentially indicating the bedrock surface.

Groundwater was not encountered at any time during the drilling operations.

Conclusions and Recommendations

It is understood that the invert elevations of the proposed RCB culvert at inlet and outlet are 765.80 and 764.70 feet above mean sea level (msl), respectively. Very dense granular soils (at inlet) and limestone bedrock (at outlet) were encountered at the culvert invert elevations. Rii understands that the proposed roadway grade will approximately match the existing roadway grade after construction of the proposed culvert structure. Therefore, the construction of the proposed culvert replacement will result in little to negligible net loading on the bearing soils.

Foundation Recommendation

It is understood that the replacement of the existing structure will include new headwalls and wingwalls with bearing elevations at or below the proposed culvert invert elevations.

The bearing elevation of the inlet headwall and wingwalls is anticipated at or below the elevation of 765.80 feet msl. Boring B-002-0-22 drilled in the vicinity of culvert inlet encountered medium dense to very dense granular soils at the anticipated bearing elevation. These soils, in their native conditions, are suitable to support the proposed structure foundation. A foundation bearing at or below the 765.8 feet msl may be proportioned for the bearing resistance values not exceeding those provided below:

- Nominal bearing resistance of q_n = 6.6 ksf at the service limit state.
- Nominal bearing resistance of q_n = 12.0 ksf at the strength limit state.
- LRFD Bearing Resistance Factor of φ = 1.0 at the service limit state.
- LRFD Bearing Resistance Factor of φ = 0.55 at the strength limit state.

The bearing resistance at service limit state is the bearing pressure that results in an estimated maximum total settlement of 1.0 inch.

The bearing elevation of outlet headwall and wingwalls is anticipated at or below the elevation of 764.70 feet msl. Boring B-001-0-22 drilled in the vicinity of culvert outlet encountered limestone bedrock at the anticipated bearing elevation. A foundation bearing on bedrock, at or below the 764.0 feet msl, may be proportioned for the bearing resistance values not exceeding those provided below:

- Nominal bearing resistance of q_n = 55.1 ksf at the strength limit state.

- LRFD Bearing Resistance Factor of φ = 0.55 at the strength limit state.

Settlement of footings bearing on bedrock is negligible, in accordance with the Ohio Department of Transportation (ODOT) Bridge Design Manual (BDM) 2020 Section 305.

Please note that this executive summary does not contain all the information presented in the report. The unabridged subsurface exploration report should be read in its entirety to obtain a more complete understanding of the information presented.

1.0 INTRODUCTION

This report is a presentation of the structure foundation exploration performed for the proposed FRA-33-8.75 culvert replacement for ODOT District 6 in Columbus, Franklin County, Ohio.

Based on information provided, the existing 8-foot by 8-foot concrete arch culvert with an 84-inch corrugated metal pipe (CMP) extension is planned to be replaced by a reinforced concrete box (RCB) culvert. In addition to the culvert replacement, the project includes regrading of eastern slope above the culvert. According to information provided by Euthenics, the invert elevations of the proposed culvert inlet and outlet are 765.80 and 764.70 feet msl, respectively. Additional detailed information of the proposed culvert including span, height and length were not available at the time of this report. For the proposes of this report, Rii considers that the span of the proposed culvert will be 10 feet or less. Rii understands that headwalls and/or wingwalls will be constructed at inlet and outlet of proposed conduit.

The exploration was performed within general accordance of the Ohio Department of Transportation's (ODOT) Specifications for Geotechnical Explorations (SGE), dated July 2022. The project site and general location of the proposed culvert are as shown on the vicinity map and boring plan presented in Appendix I.

2.0 GEOLOGY AND OBESERVATIONS OF THE PROJECT

2.1 Site Geology

Physiographically, the site lies within the Columbus Lowland District of the Southern Ohio Loamy Till Plain Region. This region is characterized by relatively flat-lying silty loam till ground moraine, interspersed with end and recessional moraines, outwash and alluvial deposits. Ground moraines are deposited during the retreat of a glacier, resulting in an undifferentiated mixture of clay, silt, sand and gravel. End moraines are normally associated with ice melting that is neither advancing nor retreating for a period of time. Recessional moraines are deposited when the ice sheet is retreating. Both end and recessional moraines are commonly associated with boulder belts. Outwash deposits consist of undifferentiated sand and gravel deposited by meltwater in front of glacial ice, and often occurs as valley terraces or low plains. Alluvium and alluvial terrace deposits range from silty clay to cobble sized deposits, usually deposited in present and former floodplain areas, such as the Scioto River and its tributaries.

Based on the Ohio Department of Natural Resources (ODNR), the overburden soils are underlain by Devonian age, Columbus limestone and Delaware limestone formations. Columbus limestone formation is comprised of fossiliferous limestone overlaying brown dolomite, gray to brown in color and weathers brown. The formation ranges from 0 to 105 in thickness. The Delaware limestone formation is argillaceous, cherty, carbonaceous limestone, and gray to brown in color. Delaware limestone ranges from 0 to 45 feet in thickness.

According to the ODNR bedrock topography map, the bedrock surface elevation in the vicinity of project area is 750 feet msl. Based on bedrock surface elevation mapping and existing roadway pavement elevation within the project site being approximately from 790 feet msl, the depth to the bedrock surface within the project site below the existing pavement is estimated to be approximately 40 feet below the existing grade.

According to the mapping of karst features (Known and Probable Karst in Ohio, ODNR Geological Survey Map EG-1, 1999; Revised 2002, 2006), there are no mapped karst features in the general vicinity of the study area.

2.2 Existing Site Conditions

The existing culvert is located under US 33, approximately 0.17 miles north of the intersection of US 33 and Fishinger Road in Franklin County, Ohio. Based on available information, the existing structure is 8-foot by 8-foot concrete arch culvert with an 84-inch corrugated metal pipe (CMP) extension.

During Rii's site reconnaissance, cracks were observed on the headwall and on the concrete arch. Additionally, erosion was observed immediately below the existing guardrail at the eastern slope. Land use immediately surrounding the project area consists predominantly wooded and brush areas along with commercial properties. Surface drainage from the existing roadway embankment appears to be carried along adjacent embankment berms which slope downward in elevation to the creek located below the roadway.

3.0 EXPLORATION

On November 12, 2022, two (2) structure borings, designated as B-001-0-22 and B-002-0-22, were drilled along the alignment of proposed culvert replacement. Borings B-001-0-22 and B-002-0-22 were advanced to depths 29.3 and 36.1 feet below the existing ground surface, respectively. The borings were drilled at locations illustrated on the boring plan presented in Appendix I of this report and a summary of boring information is provided in Table 1.

Additionally, one (1) pavement core, designated as X-001-0-22, was obtained from driving lane of US 33 adjacent to B-001-0-22 to determine the existing pavement composition and condition. The core was obtained with a 4.0-inch diameter thin-walled pavement core bit. Data sheet, including photograph of the retained pavement core, are presented in Appendix IV.

Table 1. Test Boring and Pavement Core Summary

Boring / Core Number	Station [1]	Offset [1]	Latitude	Longitude	Ground Elevation [1] (feet msl)	Boring Depth (feet)
B-001-0-22	12+31	12' Lt	40.032454	-83.092505	791.8	29.3
B-002-0-22	13+48	12' Rt	40.032777	-83.092477	791.3	36.1
X-001-0-22	12+34	12' Lt	40.032458	-83.092503	791.8	---

1. *Station, offset and ground surface elevations were interpolated from basemapping provided by Euthenics.*

The boring locations were determined in the field by Rii personnel. Rii personnel utilized a GPS unit to obtain northing and easting coordinates of the boring location. Ground surface elevations at boring locations were determined from basemaps provided by Euthenics.

The borings were drilled and sampled with CME 55 truck mounted drill rig utilizing 3.25-inch inside diameter hollow stem augers. Standard penetration test (SPT) and split spoon sampling were performed continuously to a depth of 30 feet and at 2.5-foot intervals thereafter. The SPT, per the American Society for Testing and Materials (ASTM) designation D1586, is conducted using a 140-pound hammer free falling 30.0 inches to drive a 2.0-inch outside diameter split spoon sampler 18.0 inches. Rii utilized a calibrated automatic drop hammer to generate consistent energy transfer to the sampler. Driving resistance is recorded on the boring logs in terms of blows per 6.0-inch interval of the driving distance. The second and third intervals are added to obtain the number of blows per foot (N). SPT blow counts aid in determining soil properties applicable in foundation system design and settlement calculation of foundation soil. Measured blow count (N_m) values are corrected to an equivalent (60 percent) energy ratio, N_{60}, by the following equation. Both values are represented on boring logs in Appendix III.

$$N_{60} = N_m*(ER/60)$$

Where:
N_m = measured N value
ER = drill rod energy ratio, expressed as a percent, for the system used

The hammer utilized in CME 55 rig used for this project was calibrated on March 21, 2022 and had a drill rod energy ratio of 87.0 percent.

The depth to bedrock was determined by split spoon sampler refusal and/or auger refusal on bedrock. Boring B-001-0-22 was extended into the bedrock using an NQ-2 double-tube diamond bit core barrel (utilizing wire line equipment) was used to core the bedrock. The rock cores obtained from the boring were logged in the field and visually classified in the laboratory. The retrieved core was analyzed to identify the type of rock, color, mineral content, bedding planes and other geological and mechanical features of interest in this project. The Rock Quality Designation (RQD) for each rock core run was calculated according to the following equation:

$$RQD = \frac{\sum \text{segments equal to or longer than 4.0 inches}}{\text{core run length}} \times 100$$

The RQD value aids in estimating the general quality of the rock and is used in conjunction with other parameters to designate the quality of the rock mass.

Upon completion of drilling, the borings were sealed with a cement-bentonite grout or bentonite pellets, in accordance with ODOT standards. Pavement was patched with equivalent thickness of cold patch asphalt.

In general, for instances of no recovery from standard split spoon sampling, a 2.5-inch outside diameter split spoon sampler was driven the full length of the standard split spoon interval plus an additional 6.0 inches to obtain a representative sample. These samples are designated with a "2S" preceding the sample number on the boring logs. Only the final 6.0 inches of sample were retained for classification. Blow counts from the 2S sampling are not correlated with N_{60} values.

Hand penetrometer readings, which provide a rough estimate of the unconfined compression strength (UCS) of the soil, were reported on the boring logs in units of tons per square foot (tsf) and were utilized to classify the consistency of the cohesive soil in each layer. An indirect estimate of the unconfined compressive strength of the cohesive split spoon samples can also be made from a correlation with the blow counts (N_{60}). Please note that split spoon samples are considered to be disturbed and the laboratory determination of their shear strengths may vary from undisturbed conditions.

During drilling, field personnel prepared field logs showing the encountered subsurface conditions. Soil samples obtained from the drilling operation were preserved in sealed glass jars and delivered to the soil laboratory. In the laboratory, the soil samples were visually classified and select samples were tested, as noted in Table 2.

Table 2. Laboratory Test Schedule

Laboratory Test	Test Designation	Number of Tests Performed
Natural Moisture Content	AASHTO T265	35
Plastic and Liquid Limits	AASHTO T89, T90	10
Sieve/Hydrometers	AASHTO T88	17
Point Load Strength Test	D ASTM 5731	1

The tests performed are necessary to classify existing soil according to the Ohio Department of Transportation (ODOT) classification system and to estimate engineering properties of importance in determining foundation design and construction recommendations. A description of the soil terms used throughout this report is presented in Appendix II. Results of the laboratory testing are presented on the boring logs in Appendix III.

Due to slope stability concerns, and to supplement the boring program in areas inaccessible to a drill rig, Rii performed three (3) Wildcat Dynamic Cone Penetrometer (DCP) tests at locations on the eastern slope of the site. The DCP test locations are presented in Appendix I, and the DCP test logs are presented in Appendix V.

4.0 FINDINGS

Interpreted engineering logs have been prepared from field logs, visual examination of samples and laboratory testing. Classification follows the current version of the ODOT Specifications of Geotechnical Exploration (SGE). The following is a generalization of what was found in the test borings and what is represented on the boring logs.

4.1 Surface Materials

Both borings were performed through the existing US 33 pavement and encountered 18.0 inches of asphalt overlying 4.0 to 5.0 inches of aggregate base. Pavement core X-001-0-22 encountered 20.0 inches of asphalt overlaying 4.0 inches of aggregate base materials.

4.2 Subsurface Soils

Beneath the surficial materials, the borings encountered previously placed fill soil materials extending to depths ranging from 16 to 18 feet below the existing grade underlain by layers of natural cohesive and granular soils to boring termination depth or top of bedrock.

The existing fill soils consisted of cohesive and granular soils. The cohesive fill soils were described as silt and clay as well as silty clay (ODOT A-6a, A-6b) with varying amounts of sand and gravel. The SPT N_{60} values determined within these cohesive fill soils ranged from 9 to 25 blows per foot (bpf), and the hand penetrometer values (HP) determined within these cohesive fill soils ranged from 1.5 to 3.0 tsf. The granular fill soils were described as gravel, gravel with sand, and gravel with sand, silt, and clay (ODOT A-1-a, A-1-b, A-2-6). SPT N_{60} values determined within these granular fill soils ranged from 9 to 73 bpf.

The natural cohesive soils encountered were described as sandy silt, silt and clay, silty clay, and clay (ODOT A-4a, A-6a, A-6b and A-7-6) with varying amounts of sand and gravel. The shear strength and consistency of the cohesive soils are primarily derived from the hand penetrometer values (HP). The consistency of cohesive soils encountered ranged from stiff (1.0 tsf $\leq$ HP $\leq$ 2.0 tsf) to hard (HP $>$ 4.0 tsf). The unconfined compressive strength of the cohesive soil samples tested, obtained from the hand penetrometer, ranged from 2.0 to 4.25 tsf.

The natural granular soils were described as gravel with sand, coarse and fine sand, and gravel with sand and silt (ODOT A-1-b, A-3a, A-2-4). SPT N_{60} values determined within the natural granular soils ranged from 22 to split spoon refusal (less than 6 inches of penetration for 50 blows). Floating cobbles and/or boulders were encountered within the granular soils below a depth of 31 feet in boring B-002-0-22.

Moisture contents of the cohesive soil samples tested ranged from 11 to 22 percent and moisture content of the granular soil samples tested ranged from 2 to 17 percent. The moisture contents of the cohesive soil samples tested for plasticity ranged from 6 percent to 2 percent above below their corresponding plastic limits. In general, the cohesive soil exhibited natural moisture contents ranging from slightly below to moderately above their estimated optimum moisture levels.

4.3 Bedrock

Bedrock was encountered in boring B-001-0-22 at a depth of 24.0 feet below existing grade, corresponding to elevation 767.8 feet msl. In boring B-002-0-22, auger refusal was encountered at a depth of 36.1 feet below existing grade, corresponding to elevation 755.2 feet msl, potentially indicating the bedrock surface.

Rock coring was performed in boring B-001-0-22 upon encountering auger refusal on bedrock. The recovered cored rock samples were described as brownish gray, moderately weathered, weak limestone bedrock.

The recovered rock core samples exhibited core recovery value of 60 percent and rock quality designation (RQD) value of 7 percent. The point load strength testing performed on a selected bedrock core sample exhibited unconfined compressive strength (Qu) value of 1,009 psi.

A detailed description of recovered rock cores is provided on the boring logs in Appendix III. A photographic summary of rock core samples is provided at the end of boring log in Appendix III.

4.4 Groundwater

Groundwater was not encountered at any time during drilling operations. Please note that the ground water level at the completion of rock coring in boring B-001-0-22 was not recorded due to the influence of water added during the coring process.

Please note that short-term water level readings, especially in cohesive materials, are not necessarily an accurate indication of the actual groundwater level. In addition, groundwater levels and the presence of groundwater are considered to be dependent on seasonal fluctuations in precipitation and groundwater levels in nearby bodies of water at the time of the investigation.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Data obtained from the drilling and testing program have been used to determine the foundation support capabilities and the settlement potential for the soil conditions encountered at the site. These parameters have been used to provide guidelines for the design of foundation system for the subject culvert headwall as well as the construction specifications related to the placement of foundation systems and general earthwork recommendations, all of which are discussed in the following paragraphs.

5.1 Foundation Recommendations

5.1.1 4-Sided Precast Reinforced Box Culvert Support

It is understood that the invert elevations of the proposed RCB culvert at inlet and outlet are 765.80 and 764.70 feet msl, respectively. Medium dense granular soils (at inlet) and limestone bedrock (at outlet) were encountered at the culvert invert elevations. These soils and bedrock, in their native conditions, are suitable to support the proposed RCB culvert structure. Based on the invert elevation of proposed culvert and bedrock surface elevation, up to approximately 3.1 feet of rock excavation should be anticipated to achieve culvert invert elevations.

Rii understands that the proposed roadway grade will approximately match the existing roadway grade after construction of the proposed culvert structure. Therefore, the construction of the proposed culvert replacement will result in little to negligible net loading on the bearing soils.

5.1.2 Foundation Support

It is understood that the replacement of the existing structure will include new headwalls and wingwalls with bearing elevations at or below the proposed culvert invert elevations.

The bearing elevation of inlet headwall wingwall is anticipated at or below the elevation of 765.80 feet msl. Boring B-002-0-22 drilled in the vicinity of culvert inlet encountered medium dense to very dense granular soils at the anticipated bearing elevation. These soils, in their native conditions, are suitable to support the proposed structure foundation. A foundation bearing at or below the 765.8 feet msl may be proportioned for the bearing resistance values not exceeding those provided below:

- Nominal bearing resistance of q_n = 6.6 ksf at the service limit state.
- Nominal bearing resistance of q_n = 12.0 ksf at the strength limit state.
- LRFD Bearing Resistance Factor of φ = 1.0 at the service limit state.
- LRFD Bearing Resistance Factor of φ = 0.55 at the strength limit state.

The bearing resistance at service limit state is the bearing pressure that results in an estimated maximum total settlement of 1.0 inch.

The bearing elevation of outlet headwall and wingwall is anticipated at or below the elevation of 764.70 feet msl. Boring B-001-0-22 drilled in the vicinity of culvert outlet encountered limestone bedrock at the anticipated bearing elevation. A foundation bearing on bedrock, at or below the 764.0 feet msl, may be proportioned for the bearing resistance values not exceeding those provided below:

- Nominal bearing resistance of q_n = 55.1 ksf at the strength limit state.
- LRFD Bearing Resistance Factor of φ = 0.55 at the strength limit state.

Settlement of footings bearing on bedrock is negligible, in accordance with the Ohio Department of Transportation (ODOT) Bridge Design Manual (BDM) 2020 Section 305.

5.1.3 General Shallow Foundation Consideration

- If soft, loose, wet and/or highly plastic soils are encountered at the foundation bearing elevations, these soils should be undercut and removed, and replaced with lean concrete up to the foundation bearing elevation. Lean concrete shall have minimum 28-day compressive strength of 500 psi. All bearing surfaces should be observed and approved by a geotechnical engineer or his/or representative.

- In order to protect against frost, footings supported on soil should be placed at a minimum frost depth of 36.0 inches below the adjacent exterior grade. All foundations should be protected against scour.

- Bearing resistance values provided in this report are determined using foundation width of 7.0 feet. If the foundation width is significantly different that what is estimated in this report, Rii should be provided this information for our review and our report revised and/or amended, if necessary.

- Footing concrete should be placed as soon as possible following excavation, preferably the same day.

- Protect foundation support materials exposed in an open excavation from freezing weather, severe drying, and water accumulations.

- Foundation concrete should completely fill the open excavation. Forming the foundations and then backfilling the space behind the forms tends to allow moisture to penetrate and softened bearing materials resulting in poor foundation bearing capacity.

- Bearing rock surface should be free of loose or disturbed materials and should be in a relatively dry condition.

5.2 Soldier Pile Wall Recommendations

Based on the information provided to Rii, it is understood that a soldier pile wall embedded into bedrock may be utilized for the stabilization of the existing slopes located at the inlet of the structure. The proposed wall may be designed utilizing the soil and rock parameters provided in Appendix VIII of this report. It should be noted that the rock parameters were estimated from the results of boring B-001-0-22, whereas the proposed soldier pile wall would be located closer to B-002-0-22. Bedrock was not cored at boring B-002-0-22 during the field exploration.

In order to evaluate the lateral capacity, it is recommended that a derivation of COM624, such as LPILE, be utilized to determine the proper embedment depth and cross section to resists the lateral load for given end condition and deflection. The piles should be analyzed to verify that it has enough lateral and bending resistance against the applied loads. Soil and rock parameters provided in Appendix VIII may be utilized for the design. The following table, Table 3, lists the different soil types internal to the LPILE program. These strata were utilized in Appendix VIII, in evaluating the soil and rock layers.

Table 3. Strata Description

Strata	Description
1	Soft Clay
2	Stiff Clay with Water
3	Stiff Clay without Free Water
4	Sand (Reese)
5	User Defined
6	Vuggy Limestone (Strong Rock)
7	Silt (with cohesion and internal friction angle)
8	API Sand
9	Weak Rock
10	Liquefiable Sand (Rollins)
11	Stiff Clay without free water with a specified initial K (Brown)

5.3 Global Stability Analysis

Global stability analyses were performed to check the stability of the existing and proposed regraded slopes, proposed retaining walls (CIP and Shoulder Pile and Lagging) using Bishop Simplified method and the SLIDE computer software program (Version 9.009). The cross-sections utilized in stability analyses were determined from available basemaps and are shown in Appendix I. The soil parameters used in the stability analysis of the slope profile were estimated based on the subsurface conditions encountered in the soil borings, the results of the field and laboratory testing, and Rii's experience with similar project and site conditions. A summary of soil strength parameters utilized in stability analysis are shown in Appendix VII.

Per Section 11.6.2.3 of the 2020 AASHTO LRFD BDS, overall (global) stability for walls that are not supporting structural foundations or elements is satisfied if the product of the factor of safety from the slope stability output multiplied by the resistance factor φ=0.75 is greater than 1.0. Therefore, global stability is satisfied when a minimum factor of safety of 1.3 is obtained.

Global Stability Analysis at Proposed Retaining Wall Footprint (Headwall)

Rii performed global stability analysis at the inlet of the proposed structure utilizing side slope of 2H:1V (horizontal: vertical) above headwall and considering top of headwall elevation of 780 feet msl and bottom of footing elevation of 763.8 feet msl. The resulting factor of safety (FOS) under drained (long-term stability) and undrained conditions (short-term stability) using the Bishop's analysis method were 1.26 and 2.52, respectively. The results global stability analysis exhibited FOS less than required minimum FOS for long-term stability of wall.

Rii performed a subsequent set of global stability analysis utilizing bottom of footing elevation of 761.0 feet msl at the inlet of the proposed structure. The resulting factor of safety (FOS) under drained conditions (long-term) and undrained (short-term) using Bishop's Simplified analysis method were 1.66 and 2.64 which is higher than required minimum FOS.

Additionally, a set of global stability analysis was performed at the inlet of the proposed structure utilizing bottom of footing elevation of 763.8 feet msl and foundation improvement by over-excavation of foundation soil and replacement with Item 613 Low strength mortar. The over-excavation and replacement was extended to an elevation of 761.0 feet msl. The resulting factor of safety (FOS) under drained conditions (long-term) and undrained (short-term) using Bishop's analysis method were 1.31 and 2.55 which is higher than required minimum FOS.

Based on the results of global stability analysis, Rii recommends that the foundation of the wall at the inlet of the proposed structure be founded at or below the elevation of 761.0 feet msl. As an alternative, the foundation improvement be performed up to elevation 761.0 feet msl as described above and footing be founded at 763.8 feet msl.

Global Stability Analysis at the Existing and Proposed Regraded Slope

Immediately north and south of the existing inlet headwall, the existing slope slopes down at rate 1.6H: 1V to 1.8H: 1V. Rii understands that the existing slope at immediately north of the existing inlet headwall has exhibited erosion and require stabilization. Rii performed global stability analysis utilizing the cross section of the existing slope at north. The resulting factor of safety (FOS) under drained (long-term stability) and undrained conditions (short-term stability) using the Bishop's simplified analysis method were 1.0 and 2.71, respectively. The results global stability analysis exhibited FOS less than required minimum FOS for long-term stability of slope.

Rii performed a subsequent set of global stability analysis utilizing the 2H:1V regraded slope. This alternative considers that the existing slope be regraded at 2H:1V and a portion of native soils at the toe of the proposed slope be replaced with Item 203 Embankment material as described in Appendix VII (***SECTION - "YY" – New Regraded Slope***). This alternative considers that the engineered fill (ODOT CMS Item 203 Embankment) utilized will have shear strength properties equal to greater than what is utilized in global stability analysis. The resulting factor of safety (FOS) under drained (long-term) and undrained (short-term) conditions using the Bishop's Simplified analysis method were 1.32 and 2.90, respectively. The results of global stability analysis exhibited FOS more than required minimum FOS for long-term & short-term stability of the slope. Therefore, the existing slope may be stabilized as shown/described in Appendix VII (***SECTION - "YY" – New Regraded Slope***).

As an alternative, the existing slopes may be stabilized by construction of retaining wall as described in this report.

Global Stability Analysis at Proposed Retaining Wall Footprint (Soldier Pile Wall)

Rii performed global stability analysis at the inlet of the proposed structure utilizing a side slope of 2H:1V above the top of the retaining wall and considering top of retaining wall elevation of 780 feet msl with the retaining wall embedded into the existing bedrock. The resulting factor of safety (FOS) under drained (long-term) and undrained (short-term) conditions using the Bishop's analysis method were 3.24 and 3.83, respectively. The results global stability analysis exhibited FOS more than required minimum FOS for both short term and long-term stability of wall. Please note that the design of retaining wall is beyond the scope of this project.

5.4 Lateral Earth Pressure Parameters

For the soil types encountered in the borings, the "in-situ" unit weight (γ), cohesion (c), effective angle of friction (φ'), and lateral earth pressure coefficients for at-rest conditions (k_o), active conditions (k_a), and passive conditions (k_p) have been estimated and are provided in Table 4 and Table 5.

Table 4. Estimated Undrained Soil Parameters for Design

Soil Type	γ (pcf) [1]	*c* (psf)	*φ*	k_a	k_o	k_p
Existing Cohesive Fill Soils	125	1,000	0°	N/A	N/A	N/A
Existing Granular Fill Soils	125	0	30°	0.33	0.5	3.03
Very Stiff to Hard Cohesive soils	125	2,500	0°	N/A	N/A	N/A
Medium Dense to Dense Granular Soil	130	0	32°	0.31	0.47	3.25
Very Dense Granular Soil	135	0	34°	0.28	0.44	3.53
Compacted Cohesive Engineered Fill	125	2,000	0°	N/A	N/A	N/A
Compacted Granular Engineered Fill	130	0	33°	0.30	0.46	3.39

1. *When below groundwater table, use effective unit weight, γ' = γ - 62.4 pcf and add hydrostatic water pressure.*

Table 5. Estimated Drained Soil Parameters for Design

Soil Type	γ (pcf) [1]	*c* (psf)	*φ'*	k_a	k_o	k_p
Existing Cohesive Fill Soils	125	0	24°	0.42	0.59	2.37
Existing Granular Fill Soils	125	0	30°	0.33	0.5	3.03
Very Stiff to Hard Cohesive Soil	130	0	26°	0.39	0.56	2.56
Medium Dense to Dense Granular Soil	130	0	32°	0.31	0.47	3.25
Very Dense Granular Soil	130	0	34°	0.28	0.44	3.53
Compacted Cohesive Engineered Fill	125	0	28°	0.36	0.53	2.77
Compacted Granular Engineered Fill	130	0	33°	0.29	0.46	3.39

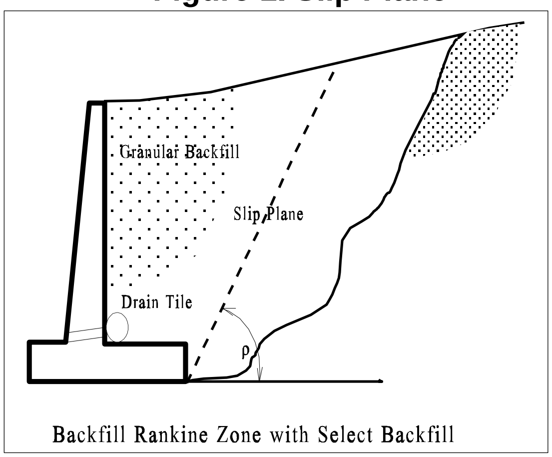
1. *When below groundwater table, use effective unit weight, γ' = γ - 62.4 pcf and add hydrostatic water pressure.*

These parameters are considered appropriate for the design of subsurface walls, wing walls, headwalls and excavation support systems. Subsurface structures (where the top of the structure is restrained from movement) should be designed based on at-rest conditions. For proposed wing walls or temporary retaining structures (where the top of the structure is allowed to move), earth pressure distributions should be based on active conditions (k_a) and passive pressure (k_p). The values in this table have been estimated from correlation charts based on minimum standards specified for compacted engineered fill materials. These recommendations do not take into consideration the effect of any surcharge loading or a sloped ground surface (a flat surface is assumed). Earth pressures on excavation support systems will be dependent on the type of sheeting and method of bracing or anchorage.

In order to alleviate the build-up of hydrostatic pressure above the flow line of the stream behind the walls a minimum of 2.0 feet of clean free-draining granular fill (i.e., No. 57 gravel) should be placed full depth behind the walls. If granular fill other than No. 57 gravel is used, it should not have more than 8 percent (by weight) passing the No. 200 screen, and should be compacted to 95 percent of the maximum dry density as determined by the Standard Proctor Test (ASTM D698). A perforated, corrugated drain tile, wrapped with filter fabric, should be placed along the perimeter at the base of the walls or at the design flow line/flood line for drainage purposes. A clay cap (minimum 1.0-foot thick) should be placed overtop the granular backfill to deter inflow of the surface water. The drainage system should properly outlet to a sewer or to a properly sized sump pump system.

The 2.0 feet of free draining material placed behind the wall prevents the formation of hydrostatic pressures as noted above. However, unless the free draining granular backfill is placed beyond the slip plane, it has no influence on the equivalent fluid weight of the soil. If free draining granular fill (meeting the requirements listed above) is to be placed beyond the slip plane (ρ=45° for at-rest conditions; ρ=45°+φ/2 for active conditions), the values presented for the compacted granular engineered fill can be employed, consequently lowering the pressures on the wall.

Figure 1. Slip Plane



5.5 Groundwater Considerations

Groundwater was not encountered during field exploration. Additionally, based on our experience with the geology at this site, groundwater conditions affecting construction may be encountered within the trapped/perched zones. These trapped/perched zones are generally the layer(s) of granular soils that are isolated within the fine-grained soil layers and may not be identified in boring logs. If excavation encounter such layers, temporary dewatering may be accomplished by placing localized sumps and pumps within and beyond the excavation. Seepage rates from these layers are difficult to predict and flow rate could be significant. Additionally, seepage should be anticipated at the interface of overburden soil and bedrock surface.

Groundwater, wherever encountered, proper groundwater control measures should be implemented to prevent disturbance to excavation bottoms consisting of cohesive soil, and to prevent the possible development of a quick or “boiling” condition if soft/loose silts and/or fine sands are encountered. It is preferable that the groundwater level, if encountered, be maintained at least 36.0 inches below the deepest excavation. Note that determining and maintaining actual groundwater levels during construction is the responsibility of the contractor.

5.6 Construction Considerations

All site work shall conform to local codes and to the latest ODOT Construction and Material Specifications (CMS).

5.7 Excavation Considerations

All excavations should be shored / braced or laid back at a safe angle in accordance to Occupational Safety and Health Administration (OSHA) guidelines. During excavation, if slopes cannot be laid back to OSHA Standards due to adjacent structures or other obstructions, temporary shoring may be required. The following table should be utilized as a general guide for implementing OSHA guidelines when estimating excavation back slopes at the various boring locations. Actual excavation back slopes must be field verified by qualified personnel at the time of excavation in strict accordance with OSHA guidelines.

Table 6. Excavation Back Slopes

Soil	Maximum Back Slope (H:V)	Notes
Soft to Medium Stiff Cohesive	1.5 : 1.0	Above Ground Water Table and No Seepage
Stiff Cohesive	1.0 : 1.0	Above Ground Water Table and No Seepage
Very Stiff to Hard Cohesive	0.75 : 1.0	Above Ground Water Table and No Seepage
All Granular & Cohesive Soil Below Ground Water Table or with Seepage	1.5 : 1.0	None
Bedrock	0.75 : 1.0	Above Ground Water Table and No Seepage
Stable Bedrock	Vertical	Above Ground Water Table and No Seepage

6.0 LIMITATIONS OF STUDY

The recommendations presented in this report are predicated upon construction inspection by a qualified soil technician under the direct supervision of a professional geotechnical engineer. Adequate testing and inspection during construction are considered necessary to assure an adequate foundation system and are part of our recommendations.

The recommendations for this project were developed utilizing soil and bedrock information obtained from the test borings that were made at the proposed site. At this time we would like to point out that soil borings only depict the soil and bedrock conditions at the specific locations and time at which they were made. The conditions at other locations on the site may differ from those occurring at the boring locations.

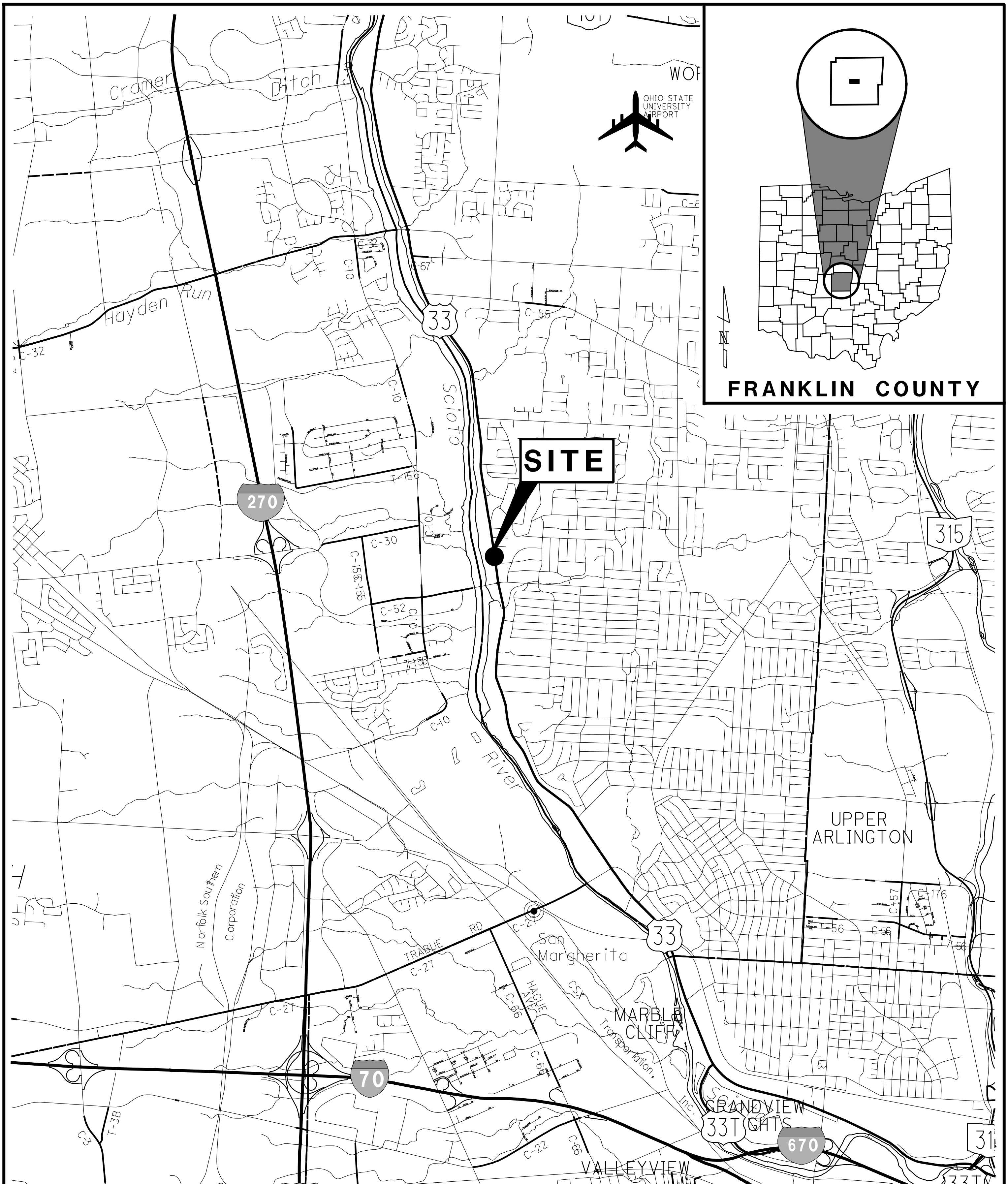
The conclusions and recommendations herein have been based upon the available soil information and the preliminary design details furnished by a representative of the owner of the proposed project. Any revision in the plans for the proposed construction from those anticipated in this report should be brought to the attention of the geotechnical engineer to determine whether any changes in the foundation or earthwork recommendations are necessary. If deviations from the noted subsurface conditions are encountered during construction, they should also be brought to the attention of the geotechnical engineer.

The scope of our services does not include any environmental assessment or investigation for the presence or absence or hazardous or toxic materials in the soil, groundwater or surface water within or beyond the site studied. Any statements in this report or on the test boring logs regarding odors, staining of soils or other unusual conditions observed are strictly for the information of our client.

Our professional services have been performed, our findings obtained, and our recommendations prepared in accordance with generally accepted geotechnical engineering principles and practices. Resource International is not responsible for the conclusions, opinions or recommendations made by others based upon the data included.

Appendix I

VICINITY MAP AND BORING PLAN



VICINITY MAP

FRA-33-8.75 STRUCTURE REPLACEMENT

COLUMBUS, OHIO

RII PROJECT NO.
W-22-156

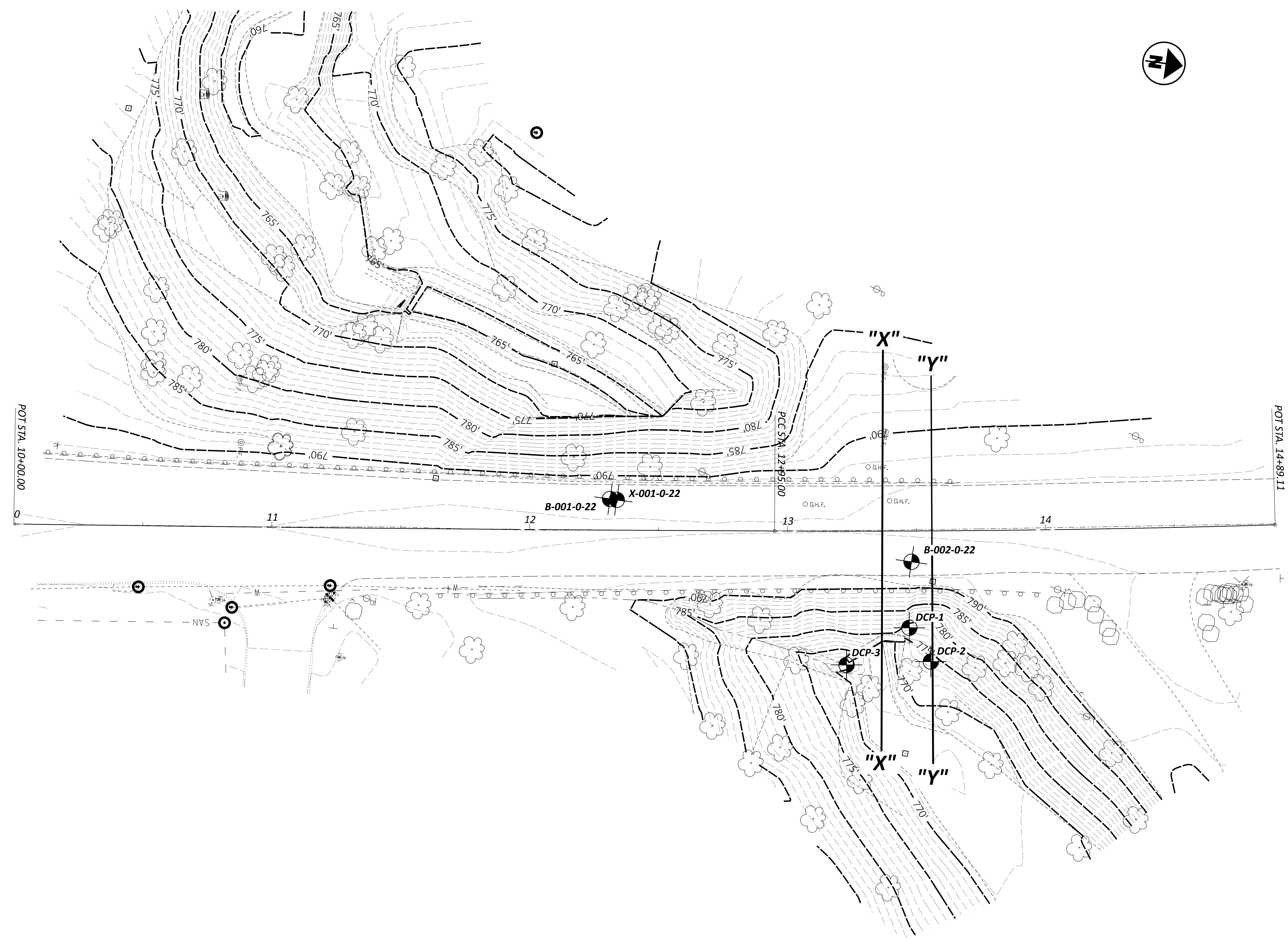
SCALE: 1"=5000'
0 2500 5000

DRAWN
JAS

REVIEWED
DEK

DATE
2/08/2023

RESOURCE INTERNATIONAL



EXPLORATION PLAN
FRA-33-8.75

HORIZONTAL SCALE IN FEET
0 10 20 40

DESIGN AGENCY

RESOURCE INTERNATIONAL

6350 PRESIDENTIAL GATEWAY
COLUMBUS, OHIO 43231
(614) 823-4949

DESIGNER
JAS

REVIEWER
XXX MM-DD-YY

PROJECT ID
108081

SHEET	TOTAL
P.0	0

FRA-33-8.75

MODEL: CLP_U33 - Plan 1 PAPERSIZE: 17x11 (in.) DATE: 2/21/2023 TIME: 4:22:03 PM USER: juans
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Appendix II

DESCRIPTION OF SOIL TERMS

CLASSIFICATION OF SOILS

Ohio Department of Transportation

(The classification of a soil is found by proceeding from top to bottom of the chart. The first classification that the test data fits is the correct classification.)

SYMBOL	DESCRIPTION	Classifcation		LL_O/LL × 100*	% Pass #40	% Pass #200	Liquid Limit (LL)	Plastic Index (PI)	Group Index Max.	REMARKS
		AASHTO	OHIO							
	Gravel and/or Stone Fragments	A-1-a			30 Max.	15 Max.		6 Max.	0	Min. of 50% combined gravel, cobble and boulder sizes
	Gravel and/or Stone Fragments with Sand	A-1-b			50 Max.	25 Max.		6 Max.	0	
F S	Fine Sand	A-3			51 Min.	10 Max.	NON-PLASTIC		0	
	Coarse and Fine Sand	--	A-3a			35 Max.		6 Max.	0	Min. of 50% combined coarse and fine sand sizes
	Gravel and/or Stone Fragments with Sand and Silt	A-2-4				35 Max.	40 Max.	10 Max.	0	
		A-2-5					41 Min.			
	Gravel and/or Stone Fragments with Sand, Silt and Clay	A-2-6				35 Max.	40 Max.	11 Min.	4	
		A-2-7					41 Min.			
	Sandy Silt	A-4	A-4a	76 Min.		36 Min.	40 Max.	10 Max.	8	Less than 50% silt sizes
	Silt	A-4	A-4b	76 Min.		50 Min.	40 Max.	10 Max.	8	50% or more silt sizes
	Elastic Silt and Clay	A-5		76 Min.		36 Min.	41 Min.	10 Max.	12	
	Silt and Clay	A-6	A-6a	76 Min.		36 Min.	40 Max.	11 - 15	10	
	Silty Clay	A-6	A-6b	76 Min.		36 Min.	40 Max.	16 Min.	16	
	Elastic Clay	A-7-5		76 Min.		36 Min.	41 Min.	≦LL-30	20	
	Clay	A-7-6		76 Min.		36 Min.	41 Min.	>LL-30	20	
	Organic Silt	A-8	A-8a	75 Max.		36 Min.				W/o organics would classify as A-4a or A-4b
	Organic Clay	A-8	A-8b	75 Max.		36 Min.				W/o organics would classify as A-5, A-6a, A-6b, A-7-5 or A-7-6

MATERIAL CLASSIFIED BY VISUAL INSPECTION

- Sod and Topsoil
- Pavement or Base
- Uncontrolled Fill (Describe)
- Bouldery Zone
- P Peat

* Only perform the oven-dried liquid limit test and this calculation if organic material is present in the sample.

DESCRIPTION OF SOIL TERMS

The following terminology was used to describe soils throughout this report and is generally adapted from ASTM 2487/2488 and ODOT Specifications for Geotechnical Explorations.

Granular Soils - The relative compactness of granular soils is described as:
ODOT A-1, A-2, A-3, A-4 (non-plastic) or USCS GW, GP, GM, GC, SW, SP, SM, SC, ML (non-plastic)

Description	Blows per foot – SPT (N_{60})		
Very Loose	Below		5
Loose	5	-	10
Medium Dense	11	-	30
Dense	31	-	50
Very Dense	Over		50

Cohesive Soils - The relative consistency of cohesive soils is described as:
ODOT A-4, A-5, A-6, A-7, A-8 or USCS ML, CL, OL, MH, CH, OH, PT

Description	Unconfined Compression (tsf)		
Very Soft	Less than		0.25
Soft	0.25	-	0.5
Medium Stiff	0.5	-	1.0
Stiff	1.0	-	2.0
Very Stiff	2.0	-	4.0
Hard	Over		4.0

Gradation - The following size-related denominations are used to describe soils:

Soil Fraction		USCS Size	ODOT Size
Boulders		Larger than 12”	Larger than 12”
Cobbles		12” to 3”	12” to 3”
Gravel	coarse	3” to ¾”	3” to ¾“
	fine	¾” to 4.75 mm (¾” to #4 Sieve)	¾” to 2.0 mm (¾” to #10 Sieve)
Sand	coarse	4.75 mm to 2.0 mm (#4 to #10 Sieve)	2.0 mm to 0.42 mm (#10 to #40 Sieve)
	medium	2.0 mm to 0.42 mm (#10 to #40 Sieve)	-
	fine	0.42 mm to 0.074 mm (#40 to #200 Sieve)	0.42 mm to 0.074 mm (#40 to #200 Sieve)
Silt		0.074 mm to 0.005 mm (#200 to 0.005 mm)	0.074 mm to 0.005 mm (#200 to 0.005 mm)
Clay		Smaller than 0.005 mm	Smaller than 0.005 mm

Modifiers of Components - Modifiers of components are as follows:

Term	Range		
Trace	0%	-	10%
Little	10%	-	20%
Some	20%	-	35%
And	35%	-	50%

Moisture Table - The following moisture-related denominations are used to describe cohesive soils:

Term	Range - USCS	Range - ODOT
Dry	0% to 10%	Well below Plastic Limit
Damp	>2% below Plastic Limit	Below Plastic Limit
Moist	2% below to 2% above Plastic Limit	Above PL to 3% below LL
Very Moist	>2% above Plastic Limit	
Wet	≥ Liquid Limit	3% below LL to above LL

Organic Content – The following terms are used to describe organic soils:

Term	Organic Content (%)
Slightly organic	2-4
Moderately organic	4-10
Highly organic	>10

Bedrock – The following terms are used to describe the relative strength of bedrock:

Description	Field Parameter
Very Weak	Can be carved with knife and scratched by fingernail. Pieces 1 in. thick can be broken by finger pressure.
Weak	Can be grooved or gouged with knife readily. Small, thin pieces can be broken by finger pressure.
Slightly Strong	Can be grooved or gouged 0.05 in deep with knife. 1 in. size pieces from hard blows of geologist hammer.
Moderately Strong	Can be scratched with knife or pick. 1/4 in. size grooves or gouges from blows of geologist hammer.
Strong	Can be scratched with knife or pick with difficulty. Hard hammer blows to detach hand specimen.
Very Strong	Cannot be scratched by knife or pick. Hard repeated blows of geologist hammer to detach hand specimen.
Extremely Strong	Cannot be scratched by knife or pick. Hard repeated blows of geologist hammer to chip hand specimen.

DESCRIPTION OF ROCK TERMS

The following terminology was used to describe the rock throughout this report and is generally adapted from ASTM D5878 and the ODOT Specifications for Geotechnical Explorations.

Weathering – Describes the degree of weathering of the rock mass:

Description	Field Parameter
Unweathered	No evidence of any chemical or mechanical alteration of the rock mass. Mineral crystals have a right appearance with no discoloration. Fractures show little or not staining on surfaces.
Slightly Weathered	Slight discoloration of the rock surface with minor alterations along discontinuities. Less than 10% of the rock volume presents alteration.
Moderately Weathered	Portions of the rock mass are discolored as evident by a dull appearance. Surfaces may have a pitted appearance with weathering "halos" evident. Isolated zones of varying rock strengths due to alteration may be present. 10 to 15% of the rock volume presents alterations.
Highly Weathered	Entire rock mass appears discolored and dull. Some pockets of slightly to moderately weathered rock may be present and some areas of severely weathered materials may be present.
Severely Weathered	Majority of the rock mass reduced to a soil-like state with relic rock structure discernable. Zones of more resistant rock may be present but the material can generally be molded and crumbled by hand pressures.

Strength of Bedrock – The following terms are used to describe the relative strength of bedrock:

Description	Field Parameter
Very Weak	Can be carved with knife and scratched by fingernail. Pieces 1 in. thick can be broken by finger pressure.
Weak	Can be grooved or gouged with knife readily. Small, thin pieces can be broken by finger pressure.
Slightly Strong	Can be grooved or gouged 0.05 in deep with knife. 1 in. size pieces from hard blows of geologist hammer.
Moderately Strong	Can be scratched with knife or pick. 1/4 in. size grooves or gouges from blows of geologist hammer.
Strong	Can be scratched with knife or pick with difficulty. Hard hammer blows to detach hand specimen.
Very Strong	Cannot be scratched by knife or pick. Hard repeated blows of geologist hammer to detach hand specimen.
Extremely Strong	Cannot be scratched by knife or pick. Hard repeated blows of geologist hammer to chip hand specimen.

Bedding Thickness – Description of bedding thickness as the average perpendicular distances between bedding surfaces:

Description	Thickness
Very Thick	Greater than 36 inches
Thick	18 to 36 inches
Medium	10 to 18 inches
Thin	2 to 10 inches
Very Thin	0.4 to 2 inches
Laminated	0.1 to 0.4 inches
Thinly Laminated	Less than 0.1 inches

Fracturing – Describes the degree and condition of fracturing (fault, joint, or shear):

Degree of Fracturing

Description	Spacing
Unfractured	Greater than 10 feet
Intact	3 to 10 feet
Slightly Fractured	1 to 3 feet
Moderately Fractured	

Aperture Width

Description	Width
Open	Greater than 0.2 inches
Narrow	0.05 to 0.2 inches
Tight	Less than 0.05 inches

Surface Roughness

Description	Criteria
Very Rough	Near vertical steps and ridges occur on surface
Slightly Rough	Asperities on the surfaces distinguishable
Slickensided	Surface has smooth, glassy finish, evidence of Striations

RQD – Rock Quality Designation (calculation shown in report) and Rock Quality (ODOT, GB 3, January 13, 2006):

RQD %	Rock Index Property Classification (based on RQD, not slake durability index)
0 – 25%	Very Poor
26 – 50%	Poor
51 – 70%	Fair
71 – 85%	Good
86 – 100%	Very Good

Appendix III

BORING LOGS:

B-001-0-22 and B-002-0-22

ROCK CORE PHOTOGRAPH

BORING LOGS

Definitions of Abbreviations

AS	=	Auger sample
GI	=	Group index as determined from the Ohio Department of Transportation classification system
HP	=	Unconfined compressive strength as determined by a hand penetrometer (tons per square foot)
LL_o	=	Oven-dried liquid limit as determined by ASTM D4318. Per ASTM D2487, if LL_o/LL is less than 75 percent, soil is classified as "organic".
LOI	=	Percent organic content (by weight) as determined by ASTM D2974 (loss on ignition test)
PID	=	Photo-ionization detector reading (parts per million)
QR	=	Unconfined compressive strength of intact rock core sample as determined by ASTM D2938 (pounds per square inch)
QU	=	Unconfined compressive strength of soil sample as determined by ASTM D2166 (pounds per square foot)
RC	=	Rock core sample
REC	=	Ratio of total length of recovered soil or rock to the total sample length, expressed as a percentage
RQD	=	Rock quality designation – estimate of the degree of jointing or fracture in a rock mass, expressed as a percentage: $\frac{\sum \text{segments equal to or longer than 4.0 inches}}{\text{core run length}} \times 100$
S	=	Sulfate content (parts per million)
SPT	=	Standard penetration test blow counts, per ASTM D1586. Driving resistance recorded in terms of blows per 6-inch interval while letting a 140-pound hammer free fall 30 inches to drive a 2-inch outer diameter (O.D.) split spoon sampler a total of 18 inches. The second and third intervals are added to obtain the number of blows per foot (N_m).
N_{60}	=	Measured blow counts corrected to an equivalent (60 percent) energy ratio (ER) by the following equation: $N_{60} = N_m*(ER/60)$
SS	=	Split spoon sample
2S	=	For instances of no recovery from standard SS interval, a 2.5 inch O.D. split spoon is driven the full length of the standard SS interval plus an additional 6.0 inches to obtain a representative sample. Only the final 6.0 inches of sample is retained. Blow counts from 2S sampling are not correlated with N_{60} values.
3S	=	Same as 2S, but using a 3.0 inch O.D. split spoon sampler.
TR	=	Top of rock
W	=	Initial water level measured during drilling
▼	=	Water level measured at completion of drilling

Classification Test Data

Gradation (as defined on Description of Soil Terms):

GR	=	% Gravel
SA	=	% Sand
SI	=	% Silt
CL	=	% Clay

Atterberg Limits:

LL	=	Liquid limit
PL	=	Plastic limit
PI	=	Plasticity Index
WC	=	Water content (%)

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-33-8.75	DRILLING FIRM / OPERATOR: RII / LH	DRILL RIG: CME 55 (386345)	STATION / OFFSET: 12+31 / 12' LT
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / J.K.	HAMMER: AUTOMATIC	ALIGNMENT: CL FRA 33
PID: 101081 SFN: NA	DRILLING METHOD: 3.25" HSA / NQ	CALIBRATION DATE: 3/21/22	ELEVATION: 791.8 (MSL) EOB: 29.3 ft.
START: 11/12/22 END: 11/12/22	SAMPLING METHOD: SPT / NQ	ENERGY RATIO (%): 87	LAT / LONG: 40.032455, -83.092505

EXPLORATION ID **B-001-0-22**

PAGE 1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 791.8
1.5'- ASPHALT (18.0")	790.3
0.4'- AGGREGATE BASE (5.0")	789.9
FILL: DENSE, BROWNISH GRAY **GRAVEL WITH SAND**, TRACE SILT, MOIST.	789.3
FILL: LOOSE TO MEDIUM DENSE, BROWN **GRAVEL WITH SAND, SILT, AND CLAY**, MOIST. -LIMESTONE FRAGMENTS IN SS-6	781.8
FILL: MEDIUM DENSE, GRAY **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP. -LIMESTONE FRAGMENTS IN SS-7	778.8
FILL: VERY STIFF, BROWNISH GRAY **SILT AND CLAY**, SOME FINE TO COARSE SAND, SOME FINE GRAVEL, DAMP.	777.3
FILL: VERY STIFF, BROWN **SILTY CLAY**, SOME FINE TO COARSE SAND, SOME FINE GRAVEL, DAMP. -CONCRETE FRAGMENTS IN SS-10	773.8
VERY STIFF TO HARD, BROWN **CLAY**, SOME FINE TO COARSE SAND, LITTLE FINE GRAVEL, MOIST.	769.3
DENSE, BROWNISH GRAY **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST.	767.8
LIMESTONE : GRAY, HIGHLY TO SLIGHTLY WEATHERED. (TR)	767.5
LIMESTONE : LIGHT BROWNISH GRAY, MODERATELY WEATHERED, WEAK, THIN BEDDED, FRACTURED, OPEN APERTURES. VERY ROUGH, VERY BLOCKY, FAIR.. -ESTIMATED UNCONFINED COMPRESSIVE STRENGTH @ 25.8'-26.0' = 1,009 PSI	762.5 (EOB)

SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
30-34-16	73	39	SS-1	-	-	-	-	-	-	-	-	-	6	A-1-b (V)
9-4-6	15	50	SS-2	-	-	-	-	-	-	-	-	-	10	A-2-6 (V)
8-5-3	12	47	SS-3	-	22	27	16	23	12	31	16	15	12	A-2-6 (1)
3-3-3	9	42	SS-4	-	-	-	-	-	-	-	-	-	17	A-2-6 (V)
3-3-4	10	44	SS-5	-	-	-	-	-	-	-	-	-	15	A-2-6 (V)
6-7-8	22	39	SS-6	-	35	23	7	25	10	30	16	14	3	A-2-6 (1)
24-7-4	16	44	SS-7	-	45	21	10	- 24 -		NP	NP	NP	4	A-1-b (0)
5-6-5	16	39	SS-8	-	-	-	-	-	-	-	-	-	8	A-1-b (V)
10-10-7	25	44	SS-9	-	21	19	11	33	16	32	19	13	13	A-6a (4)
4-4-3	10	53	SS-10	3.00	25	15	9	32	19	38	19	19	16	A-6b (6)
6-4-3	10	0	SS-11	-	-	-	-	-	-	-	-	-	-	
8	-	58	2S-SS-11A	2.50	-	-	-	-	-	-	-	-	15	A-6b (V)
6-5-7	17	89	SS-12	4.00	-	-	-	-	-	-	-	-	22	A-7-6 (V)
5-7-8	22	67	SS-13	4.25	17	12	10	39	22	43	24	19	22	A-7-6 (9)
5-5-7	17	75	SS-14	4.00	-	-	-	-	-	-	-	-	22	A-7-6 (V)
5-7-17	35	72	SS-15	-	31	36	10	19	4	25	19	6	6	A-1-b (0)
50/3"	-	17	SS-16	-	-	-	-	-	-	-	-	-	-	Rock (V)
7		60	NQ-1											CORE

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING; CAVE-IN DEPTH @ 27.2'.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 47 LBS CEMENT / 25 LBS BENTONITE POWDER / 40 GAL WATER. PAVEMENT PATCHED WITH ASPHALT COLD PATCH.

PROJECT: FRA-33-8.75	DRILLING FIRM / OPERATOR: RII / LH	DRILL RIG: CME 55 (386345)	STATION / OFFSET: 13+48 / 12' RT
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / J.K.	HAMMER: AUTOMATIC	ALIGNMENT: CL FRA 33
PID: 101081 SFN: NA	DRILLING METHOD: 3.25" HSA / NQ	CALIBRATION DATE: 3/21/22	ELEVATION: 791.3 (MSL) EOB: 36.1 ft.
START: 11/12/22 END: 11/12/22	SAMPLING METHOD: SPT / NQ	ENERGY RATIO (%): 87	LAT / LONG: 40.032777, -83.092477

EXPLORATION ID B-002-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 791.3
1.5'- ASPHALT (18.0")	789.8
0.3'- AGGREGATE BASE (4.0")	789.5
FILL: MEDIUM DENSE TO DENSE, GRAY TO BROWN **GRAVEL**, LITTLE FINE TO COARSE SAND, LITTLE SILT, DAMP. -COBBLES @ 1.8' -COBBLES @ 7.0'	783.8
FILL: STIFF TO VERY STIFF, BROWN **SILTY CLAY**, "AND" TO SOME FINE TO COARSE SAND, LITTLE TO SOME FINE GRAVEL, DAMP TO MOIST.	775.3
VERY STIFF, BROWN **SILT AND CLAY**, SOME FINE TO COARSE SAND, LITTLE FINE GRAVEL, MOIST.	773.8
STIFF TO VERY STIFF, BROWN **SILTY CLAY**, SOME FINE TO COARXSE SAND, SOME FINE GRAVEL, DAMP TO MOIST.	769.3
MEDIUM DENSE, BROWN **COARSE AND FINE SAND**, TRACE CLAY, SOME SILT, MOIST.	767.8
MEDIUM DENSE, BROWNISH GRAY **SANDY SILT**, TRACE CLAY, MOIST.	766.3
MEDIUM DENSE TO DENSE, BROWN TO BROWNISH GRAY **GRAVEL WITH SAND**, LITTLE TO SOME SILT, TRACE CLAY, MOIST.	

DEPTHS: 1 – 29

SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
29 50/4"	-	90	SS-1	-	-	-	-	-	-	-	-	-	3	A-1-a (V)
8 8 9	25	39	SS-2	-	69	12	7	- 12 -		NP	NP	NP	3	A-1-a (0)
20 14 14	41	39	SS-3	-	-	-	-	-	-	-	-	-	2	A-1-a (V)
10 6 4	15	36	SS-4	-	-	-	-	-	-	-	-	-	3	A-1-a (V)
6 4 2	9	33	SS-5	1.50	15	23	15	31	16	35	17	18	11	A-6b (5)
5 5 5	15	0	SS-6	-	-	-	-	-	-	-	-	-	-	
4	-	83	2S-6A	1.50	-	-	-	-	-	-	-	-	16	A-6b (V)
3 3 4	10	0	SS-7	-	-	-	-	-	-	-	-	-	-	
3	-	100	2S-7A	1.50	-	-	-	-	-	-	-	-	15	A-6b (V)
4 4 6	15	72	SS-8	2.00	27	16	9	29	19	40	17	23	17	A-6b (7)
4 6 6	17	67	SS-9	2.50	-	-	-	-	-	-	-	-	19	A-6b (V)
4 7 7	20	72	SS-10	2.75	14	13	10	45	18	32	20	12	20	A-6a (6)
5 6 7	19	69	SS-11	2.50	25	14	10	33	18	37	19	18	21	A-6b (6)
6 9 11	29	42	SS-12	2.00	-	-	-	-	-	-	-	-	17	A-6b (V)
7 7 8	22	39	SS-13	2.50	-	-	-	-	-	-	-	-	17	A-6b (V)
8 8 7	22	67	SS-14	-	11	8	47	30	4	NP	NP	NP	9	A-3a (0)
12 11 7	26	58	SS-15	-	0	2	58	37	3	NP	NP	NP	12	A-4a (1)
6 8 9	25	72	SS-16	-	47	21	8	21	3	NP	NP	NP	8	A-1-b (0)
5 8 7	22	58	SS-17	-	54	19	6	19	2	NP	NP	NP	7	A-1-b (0)
9 13 18	45	39	SS-18	-	-	-	-	-	-	-	-	-	7	A-1-b (V)
12														

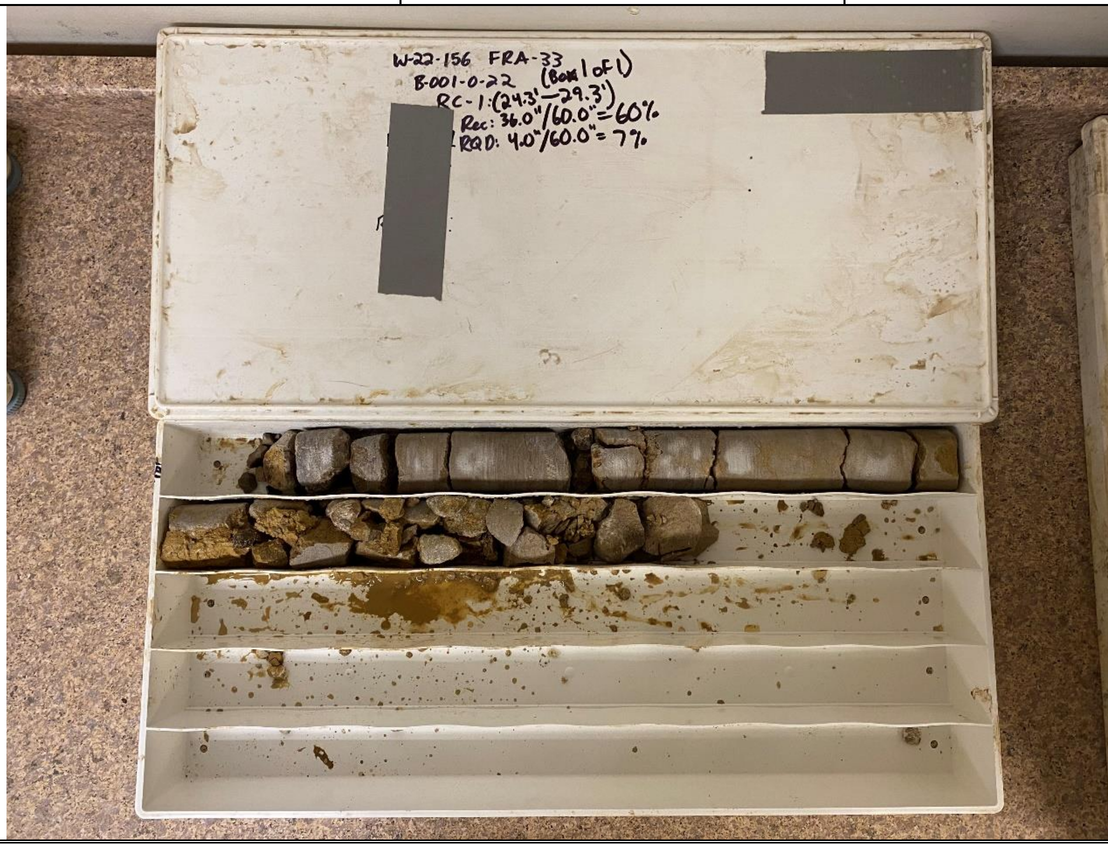
GRADATION (%): GR, CS, FS, SI, CL; ATTERBERG: LL, PL, PI; HOLE SEALED

MATERIAL DESCRIPTION AND NOTES	ELEV. 761.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
	760.3		19 17	52	0	SS-19	-	-	-	-	-	-	-	-	-	-		
VERY DENSE, BROWN TO GRAY **GRAVEL WITH SAND AND SILT**, DAMP TO MOIST.		31	14	-	100	2S-19A	-	48	12	9	- 31	-	NP	NP	NP	5	A-2-4 (0)	
		32 - 33	20 18 23	59	0	SS-20	-	-	-	-	-	-	-	-	-	-		
		34	17	-	100	2S-20A	-	-	-	-	-	-	-	-	-	13	A-2-4 (V)	
-LIMESTONE FRAGMENTS THROUGHOUT	755.2	35 - 36 ETR3	7 18 50/5"	-	12	SS-21	-	-	-	-	-	-	-	-	-	-	Rock (V)	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING; CAVE-IN DEPTH @ 19.7'. AUGER REFUSAL AT 36.1'.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 47 LBS CEMENT / 25 LBS BENTONITE POWDER / 40 GAL WATER. PAVEMENT PATCHED WITH ASPHALT COLD PATCH.

Project Name: FRA-33-8.75 Culvert Replacement	**Location:** Franklin County, Ohio	**Project No.:** Rii. W-22-156

Photo No. **1**	
Boring: B-001-0-22	
RC-1: 24.3'-29.3' REC (%):60% RQD (%):7%	

RESOURCE INTERNATIONAL, INC.

Engineering Consultants

Point Load Strength Index of Rock Specimens

(ASTM D 5731-08)

6350 Presidential Gatew.
Columbus, OH 43231
Phone (614) 823-4949

9885 Rockside Road
Cleveland, OH 44125
Phone (216) 573-0955

4480 Lake Forest Drive
Cincinnati, Ohio 45242
Phone (513) 769-6998

Project: FRA-33-8.75 STRUCTURE REPLACEMENT

Project No.: W-22-156

Date of Testing: 12/7/2022

Test Performed by: EM/KL

Rock Description: Brownish gray Limestone

Boring No.: B-001-0-22

Station / Offset: NA

Sample No. / Depth: RC-1

Test Apparatus: Forney-LA 0080

Serial Number: A125/AZ/0014

Date of Calibration: 6/12/2022

Sample No.	Test Type	Depth (ft)	W (mm)	D (mm)	Load (N)	D_e^2 (mm^2)	D_e (mm)	F	Is (MPa)	$Is_{(50)}$ (MPa)	σ_c (MPa)
1	a ⊥	25.8-26.0	50.1	25.8	1,095	1,642	40.5	0.91	0.67	0.61	8.00
2	a ⊥	25.8-26.0	50.1	25.6	894	1,631	40.4	0.91	0.55	0.50	6.58
3	a ⊥	25.8-26.0	50.1	27.0	903	1,722	41.5	0.92	0.52	0.48	6.29

STATISTICS	
Mean $Is_{(50)}$ ⊥	0.53 MPa (77 psi)
Mean $Is_{(50)}$ ‖	
$Ia_{(50)}$	

Specific Specimen Shape:

d = diametrical

a = axial

b = block

i = irregular lump

⊥ = perpendicular to bedding plane

‖ = parallel to bedding plane

Estimated Unaxial Compression, σ_c = K*Is

K = 12

*Per Section 206.1.3 of 2011 ODOT Rock Slope Design Guide

Mean σ_c = 6.96 MPa (1,009 psi)

Remarks:

Appendix IV

PAVEMENT CORE REPORT

Pavement Core Data Summary

6350 Presidential Gateway
Columbus, Ohio 43231
Telephone: (614) 823-4949
Fax Number: (614) 823-4990

PROJECT	ODOT FRA-33-8.75 Culvert Replacement (PID No. 108081)
LOCATION	Columbus, Franklin County, Ohio
JOB No.	W-22-156
BORING/CORE No.	X-001-0-22
DATE CORE OBTAINED	11/12/2022
CORE OBTAINED BY	LH, KC & JK

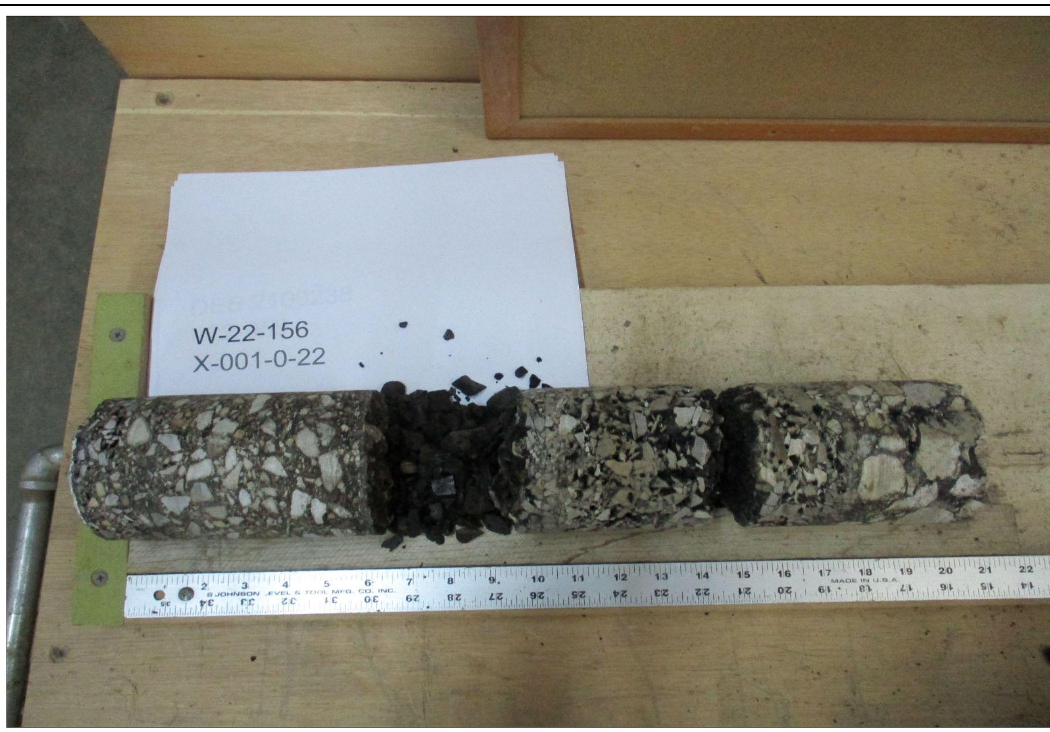
Core Composition

Core Number	Layer Thickness (in.)	Pavement Layer Number	Asphalt: Surface Binder	Intermediate Binder	Base Binder	Concrete	Aggregate/Granular Base	Other		
X-001-0-22	1.25	9	✓							
	3.75	8		✓						
	1.00	7		✓						
	0.50	6	✓							
	3.00	5		✓						
	1.25	4	✓							
	4.00	3		✓						
	2.00	2		✓						
	3.25	1			✓					
	4.00						✓			

Comments/Remarks

- Layer 9 has some voids.
- Layer 5 is highly deteriorated.
- The core separated between layers 2 & 3.
- Layers 2 & 3 have voids.
- Layer 1 has some voids.
- Aggregate Base:

Total Pavement Thickness = 20.00 in.	Total Asphalt Thickness = 20.00 in.	Total Concrete Thickness = 0.00 in.	Total Base Thickness = 4.00 in.



Appendix V

DCP LOGS:

DCP-1, DCP-2 and DCP-3

WILDCAT DYNAMIC CONE LOG

Resource International, Inc.
6350 Presdiential Gateway
Columbus, Ohio 43231

PROJECT NUMBER: W-22-156
DATE STARTED: 11-03-2022
DATE COMPLETED: 11-03-2022

HOLE #: DCP-1
CREW: TB, KC, GK
PROJECT: FRA-33-8.75
ADDRESS:
LOCATION: Columbus, Ohio

SURFACE ELEVATION: 778.5
WATER ON COMPLETION: N/E
HAMMER WEIGHT: 35 lbs.
CONE AREA: 10 sq. cm

DEPTH	BLOWS PER 10 cm	RESISTANCE Kg/cm²	GRAPH OF CONE RESISTANCE 0 50 100 150	N'	TESTED CONSISTENCY NON-COHESIVE	COHESIVE
-	2	8.9	••	2	VERY LOOSE	SOFT
-	2	8.9	••	2	VERY LOOSE	SOFT
- 1 ft	2	8.9	••	2	VERY LOOSE	SOFT
-	3	13.3	•••	3	VERY LOOSE	SOFT
-	5	22.2	••••••	6	LOOSE	MEDIUM STIFF
- 2 ft	5	22.2	••••••	6	LOOSE	MEDIUM STIFF
-	4	17.8	•••••	5	LOOSE	MEDIUM STIFF
-	3	13.3	•••	3	VERY LOOSE	SOFT
- 3 ft	6	26.6	•••••••	7	LOOSE	MEDIUM STIFF
- 1 m	4	17.8	•••••	5	LOOSE	MEDIUM STIFF
-	4	15.4	••••	4	VERY LOOSE	SOFT
- 4 ft	4	15.4	••••	4	VERY LOOSE	SOFT
-	6	23.2	••••••	6	LOOSE	MEDIUM STIFF
-	18	69.5	••••••••••••••••••••	19	MEDIUM DENSE	VERY STIFF
- 5 ft	8	30.9	••••••••	8	LOOSE	MEDIUM STIFF
-	7	27.0	•••••••	7	LOOSE	MEDIUM STIFF
-	9	34.7	••••••••••	9	LOOSE	STIFF
- 6 ft	9	34.7	••••••••••	9	LOOSE	STIFF
-	10	38.6	•••••••••••	11	MEDIUM DENSE	STIFF
- 2 m	5	19.3	•••••	5	LOOSE	MEDIUM STIFF
- 7 ft	6	20.5	•••••	5	LOOSE	MEDIUM STIFF
-	10	34.2	•••••••••	9	LOOSE	STIFF
-	33	112.9	••••••••••••••••••••••••••••••••	25+	DENSE	HARD
- 8 ft	55	188.1	••	25+	VERY DENSE	HARD
-	23	78.7	••••••••••••••••••••••	22	MEDIUM DENSE	VERY STIFF
-	18	61.6	•••••••••••••••••	17	MEDIUM DENSE	VERY STIFF
- 9 ft	19	65.0	••••••••••••••••••	18	MEDIUM DENSE	VERY STIFF
-	26	88.9	•••••••••••••••••••••••••	25	MEDIUM DENSE	VERY STIFF
-	31	106.0	••••••••••••••••••••••••••••••	25+	MEDIUM DENSE	VERY STIFF
- 3 m 10 ft	17	58.1	••••••••••••••••	16	MEDIUM DENSE	VERY STIFF
-	19	58.1	••••••••••••••••	16	MEDIUM DENSE	VERY STIFF
-	17	52.0	•••••••••••••••	14	MEDIUM DENSE	STIFF
-	15	45.9	•••••••••••••	13	MEDIUM DENSE	STIFF
- 11 ft	35	107.1	•••••••••••••••••••••••••••••••	25+	MEDIUM DENSE	VERY STIFF
-	42	128.5	•••••••••••••••••••••••••••••••••••••	25+	DENSE	HARD
-	13	39.8	•••••••••••	11	MEDIUM DENSE	STIFF
- 12 ft	10	30.6	••••••••	8	LOOSE	MEDIUM STIFF
-	13	39.8	•••••••••••	11	MEDIUM DENSE	STIFF
-	10	30.6	••••••••	8	LOOSE	MEDIUM STIFF
- 4 m 13 ft	12	36.7	••••••••••	10	LOOSE	STIFF

WILDCAT DYNAMIC CONE LOG

Resource International, Inc.
6350 Presdiential Gateway
Columbus, Ohio 43231

PROJECT NUMBER: W-22-156
DATE STARTED: 11-03-2022
DATE COMPLETED: 11-03-2022

HOLE #: DCP-2
CREW: TB, KC, GK
PROJECT: FRA-33-8.75
ADDRESS:
LOCATION: Columbus, Ohio

SURFACE ELEVATION: 773.7
WATER ON COMPLETION: N/E
HAMMER WEIGHT: 35 lbs.
CONE AREA: 10 sq. cm

DEPTH	BLOWS PER 10 cm	RESISTANCE Kg/cm²	GRAPH OF CONE RESISTANCE 0 50 100 150	N'	TESTED CONSISTENCY NON-COHESIVE	COHESIVE
-	5	22.2	••••••	6	LOOSE	MEDIUM STIFF
-	8	35.5	••••••••••	10	LOOSE	STIFF
- 1 ft	17	75.5	•••••••••••••••••••••	21	MEDIUM DENSE	VERY STIFF
-	11	48.8	••••••••••••••	13	MEDIUM DENSE	STIFF
-	14	62.2	••••••••••••••••••	17	MEDIUM DENSE	VERY STIFF
- 2 ft	16	71.0	••••••••••••••••••••	20	MEDIUM DENSE	VERY STIFF
-	20	88.8	•••••••••••••••••••••••••	25	MEDIUM DENSE	VERY STIFF
-	16	71.0	••••••••••••••••••••	20	MEDIUM DENSE	VERY STIFF
- 3 ft	18	79.9	•••••••••••••••••••••••	22	MEDIUM DENSE	VERY STIFF
- 1 m	17	75.5	•••••••••••••••••••••	21	MEDIUM DENSE	VERY STIFF
-	10	38.6	•••••••••••	11	MEDIUM DENSE	STIFF
- 4 ft	15	57.9	••••••••••••••••	16	MEDIUM DENSE	VERY STIFF
-	17	65.6	•••••••••••••••••••	18	MEDIUM DENSE	VERY STIFF
-	15	57.9	••••••••••••••••	16	MEDIUM DENSE	VERY STIFF
- 5 ft	16	61.8	•••••••••••••••••	17	MEDIUM DENSE	VERY STIFF
-	19	73.3	•••••••••••••••••••••	20	MEDIUM DENSE	VERY STIFF
-	100	386.0	•••	25+	VERY DENSE	HARD
- 6 ft						
-						
- 2 m						
- 7 ft						
-						
-						
- 8 ft						
-						
-						
- 9 ft						
-						
-						
- 3 m 10 ft						
-						
-						
-						
- 11 ft						
-						
-						
- 12 ft						
-						
-						
- 4 m 13 ft						

WILDCAT DYNAMIC CONE LOG

Resource International, Inc.
6350 Presdiential Gateway
Columbus, Ohio 43231

PROJECT NUMBER: W-22-156
DATE STARTED: 11-03-2022
DATE COMPLETED: 11-03-2022

HOLE #: DCP-3
CREW: TB, KC, GK
PROJECT: FRA-33-8.75
ADDRESS:
LOCATION: Columbus, Ohio

SURFACE ELEVATION: 771.1
WATER ON COMPLETION: N/E
HAMMER WEIGHT: 35 lbs.
CONE AREA: 10 sq. cm

DEPTH	BLOWS PER 10 cm	RESISTANCE Kg/cm²	GRAPH OF CONE RESISTANCE 0 50 100 150	N'	TESTED CONSISTENCY NON-COHESIVE	TESTED CONSISTENCY COHESIVE
-	5	22.2	••••••	6	LOOSE	MEDIUM STIFF
-	5	22.2	••••••	6	LOOSE	MEDIUM STIFF
- 1 ft	7	31.1	•••••••••	8	LOOSE	MEDIUM STIFF
-	5	22.2	••••••	6	LOOSE	MEDIUM STIFF
-	6	26.6	•••••••	7	LOOSE	MEDIUM STIFF
- 2 ft	13	57.7	••••••••••••••••	16	MEDIUM DENSE	VERY STIFF
-	12	53.3	•••••••••••••••	15	MEDIUM DENSE	STIFF
-	18	79.9	•••••••••••••••••••••••	22	MEDIUM DENSE	VERY STIFF
- 3 ft	9	40.0	•••••••••••	11	MEDIUM DENSE	STIFF
- 1 m	7	31.1	•••••••••	8	LOOSE	MEDIUM STIFF
-	10	38.6	•••••••••••	11	MEDIUM DENSE	STIFF
- 4 ft	9	34.7	••••••••••	9	LOOSE	STIFF
-	12	46.3	•••••••••••••	13	MEDIUM DENSE	STIFF
-	10	38.6	•••••••••••	11	MEDIUM DENSE	STIFF
- 5 ft	8	30.9	••••••••	8	LOOSE	MEDIUM STIFF
-	4	15.4	••••	4	VERY LOOSE	SOFT
-	7	27.0	•••••••	7	LOOSE	MEDIUM STIFF
- 6 ft	7	27.0	•••••••	7	LOOSE	MEDIUM STIFF
-	13	50.2	••••••••••••••	14	MEDIUM DENSE	STIFF
- 2 m	18	69.5	••••••••••••••••••••	19	MEDIUM DENSE	VERY STIFF
- 7 ft	24	82.1	•••••••••••••••••••••••	23	MEDIUM DENSE	VERY STIFF
-	15	51.3	••••••••••••••	14	MEDIUM DENSE	STIFF
-	36	123.1	••••••••••••••••••••••••••••••••••	25+	DENSE	HARD
- 8 ft	250	855.0	•••	25+	VERY DENSE	HARD
-						
-						
- 9 ft						
-						
-						
- 3 m 10 ft						
-						
-						
-						
- 11 ft						
-						
-						
- 12 ft						
-						
-						
- 4 m 13 ft						

Appendix VI

ANALYSIS CALCULATIONS

W-22-156; FRA-33-8.75 ***PID: 108081***

Headwall -Shallow Foundation Bearing Resistance

Borings B-001-0-22 (outlet)

Culvert invert elevation are 765.8 feet and 764.7 feet at inlet and outlet, respectively

At and below the estimated culvert bearin9 elevation medium dense to very dense granular soils and limestone bedrock is encountered.

B =	7.0	ft	(Estimated footing width)
L =	20	ft	(Estimate footing length)
Su=	10,000	psf	(Estimated shear strength of upper weathered rock -Lower Bound)
γ =	145	pcf	(Unit weight)
D_f =	3.0	ft	(Minimum foundation embedment depth)
φ =	0	deg	(Friction angle of foundation soil)
D_w =	0.0	ft	

Nominal Bearing Resistance (q_n)

$$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \tfrac{1}{2}\gamma B N_{\gamma m} C_{w\gamma} = 55.12 \text{ ksf}$$

$$N_{cm} = N_c s_c i_c = 5.49 \qquad N_{qm} = N_q s_q d_q i_q = 1.00 \qquad N_{\gamma m} = N_\gamma s_\gamma i_\gamma = 0.00$$

N_c =	5.14
N_q =	1.00
N_γ =	0.00

s_c =	1.068
s_q =	1.000
s_γ =	0.860

i_c =	1.000
i_q =	1.000
i_γ =	1.000

d_q =	1.000
C_{wq} =	0.500
$C_{w\gamma}$ =	0.500

Factored Bearing Resistance (q_R)

$$q_R = q_n \cdot \phi_b = 30.31 \text{ ksf}$$

φ_b = 0.55

W-22-156; FRA-33-8.75 ***PID: 108081***

Headwall -Shallow Foundation Bearing Resistance

Borings B-002-0-22 (inlet)

Culvert invert elevation are 765.8 feet and 764.7 feet at inlet and outlet, respectively

At and below the estimated culvert bearing elevation medium dense to very dense granular soils and limestone bedrock is encountered.

B =	7.0	ft	(Estimated footing width)
L =	20	ft	(Estimate footing length)
Su=	0	psf	(Shear strength of foundation soil)
γ =	130	pcf	(Unit weight)
D_f =	3.0	ft	(Minimum foundation embedment depth)
φ =	32	deg	(Friction angle of foundation soil)
D_w =	0.0	ft	

Nominal Bearing Resistance (q_n)

$$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \tfrac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$$ = 12.04 ksf

$$N_{cm} = N_c s_c i_c$$ = 43.60

$$N_{qm} = N_q s_q d_q i_q$$ = 31.41

$$N_{\gamma m} = N_\gamma s_\gamma i_\gamma$$ = 25.98

N_c =	35.49
N_q =	23.18
N_γ =	30.21

s_c =	1.229
s_q =	1.219
s_γ =	0.860

i_c =	1.000
i_q =	1.000
i_γ =	1.000

d_q =	1.112
C_{wq} =	0.500
$C_{w\gamma}$ =	0.500

Factored Bearing Resistance (q_R)

$$q_R = q_n \cdot \phi_b$$ = 6.62 ksf

φ_b = 0.55

W-21-097 FRA-70-7.38 ***PID: 108081***

Calculated By: AG Date: 2.11.2023

Checked By: DEK Date: 2.11.2023

Settlement - CONTINUOUS SPREAD FOOTINGS

Boring B-002-0-22

Existing groundsurface elevation at proposed wall= 767 feet

Approximate bearing elevation= 765.8 feet (Inlet)

Overburden Pressure 150 psf

B = 7.0 ft (Footing Width for Continuous Footing)

D_w = 0.0 ft (Depth to Groundwater) (Assumed at or near creek bed)

q = 6,620 psf (Foundation Pressure)

Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Elevation (ft. msl)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' (1) (psf)	LL	C_c (2)	C_r (3)	e_o (4)	N_{60}	$(N1)_{60}$ (5)	C' (6)	Z_f/B	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	S_c (9,10) (ft)	S_c (in)
1	A-1-b	G	0.0	4.0	765.8	761.8	4.0	2.0	125	650	400	275						34	57	199	0.29	0.94	6,248	6,523	0.028	0.332
2	A-2-4	G	4.0	9.0	761.8	756.8	5.0	6.5	125	1,275	963	557						52	74	293	0.93	0.580	3,841	4,398	0.015	0.184
																								Total Settlement:		***0.516 in***

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 4,000 psf for moderately overconsolidated soil deposit; Ref. Table 11.2, Coduto 2003
2. $C_c = 0.009(LL-10)$; Ref. Table 26, FHWA GEC 5
3. $C_r = 0.15(C_c)$ for medium stiff to stiff natural soil deposits and existing fill material, 0.075 to 0.10(C_c) for very stiff to hard natural soil deposits, and 0.05(Cc) for new embankment fill; Ref. Section 5.4.2.5 of FHWA GEC 5
4. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
5. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
6. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
7. Influence factor for continuous footing
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$ for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesive soil layers)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)

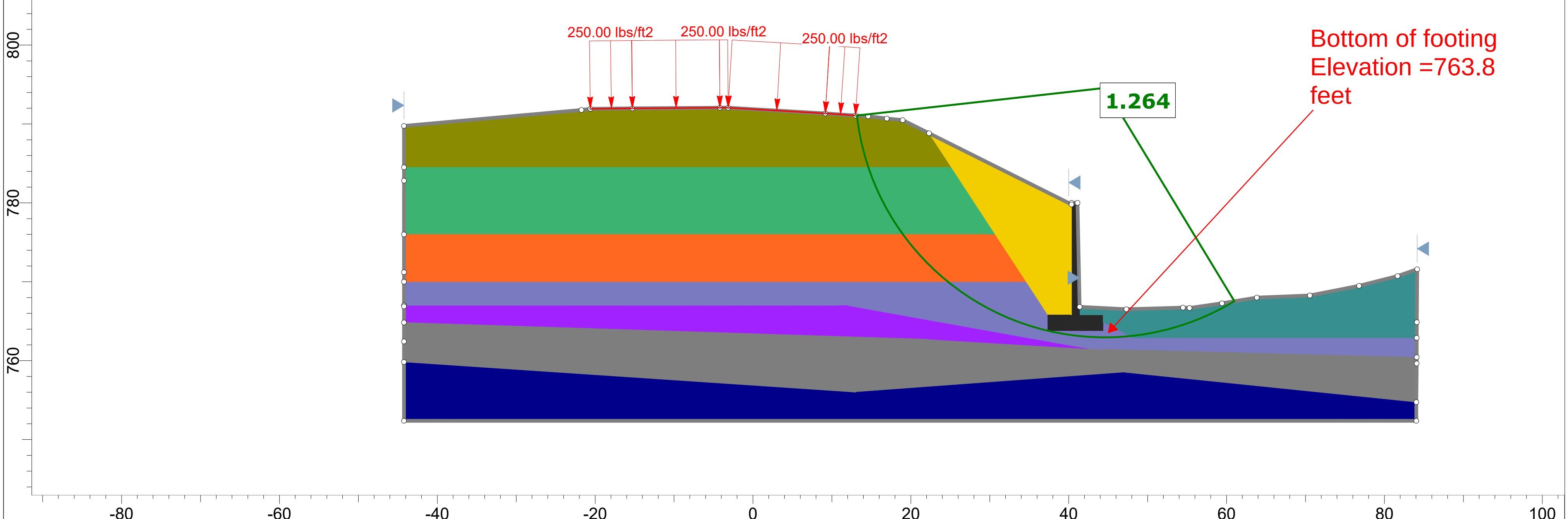
Appendix VII

GLOBAL STABILITY ANALYSIS

SECTION - "XX"

New Slope with Retaining Wall

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Retaining Wall		150	Infinite strength		
Item 203 Embankment (Retained Soil)		120	Mohr-Coulomb	0	30
A-1-a		130	Mohr-Coulomb	0	33
A-6b		120	Mohr-Coulomb	0	26
A-6a/A-6b		120	Mohr-Coulomb	0	26
A-3a/A-4a		125	Mohr-Coulomb	0	31
A-1-b		130	Mohr-Coulomb	0	33
M. Stiff Soils		120	Mohr-Coulomb	0	26
A-2-4		135	Mohr-Coulomb	0	36
Bedrock		145	Mohr-Coulomb	3000	30

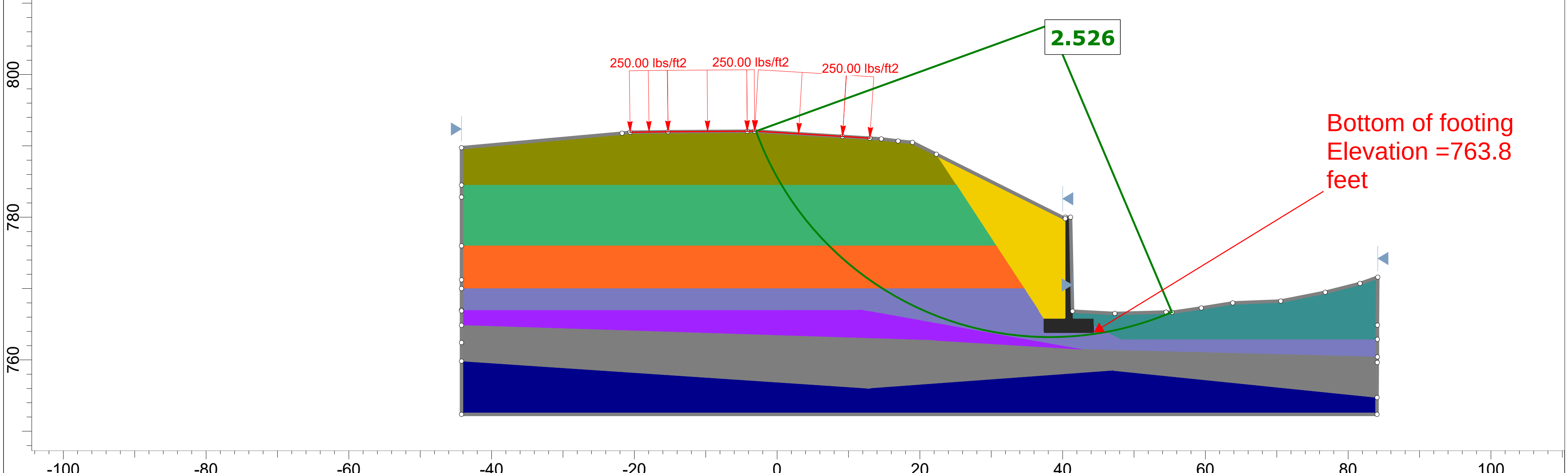


RESOURCE INTERNATIONAL, INC. An ISO 9001:2015 QMS certified firm	*Project* FRA-33-8.75 Culvert Replacement		
	Analysis Description Stability Analysis - Long Term		
	Drawn By AG	*Scale* 1:226	*Company* Resource International Inc,
SLIDEINTERPRET 9.009	*Date* 2/8/2023, 8:32:24 AM		*File Name* Stability Analysis-long term_first.slmd

SECTION - "XX"

New Slope with Retaining Wall

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Retaining Wall		150	Infinite strength		
Item 203 Embankment (Retained Soil)		120	Mohr-Coulomb	2500	0
A-1-a		130	Mohr-Coulomb	0	33
A-6b		120	Mohr-Coulomb	1625	0
A-6a/A-6b		120	Mohr-Coulomb	2750	0
A-3a/A-4a		125	Mohr-Coulomb	0	31
A-1-b		130	Mohr-Coulomb	0	33
M. Stiff Soils		120	Mohr-Coulomb	1000	0
A-2-4		135	Mohr-Coulomb	0	36
Bedrock		145	Mohr-Coulomb	3000	30



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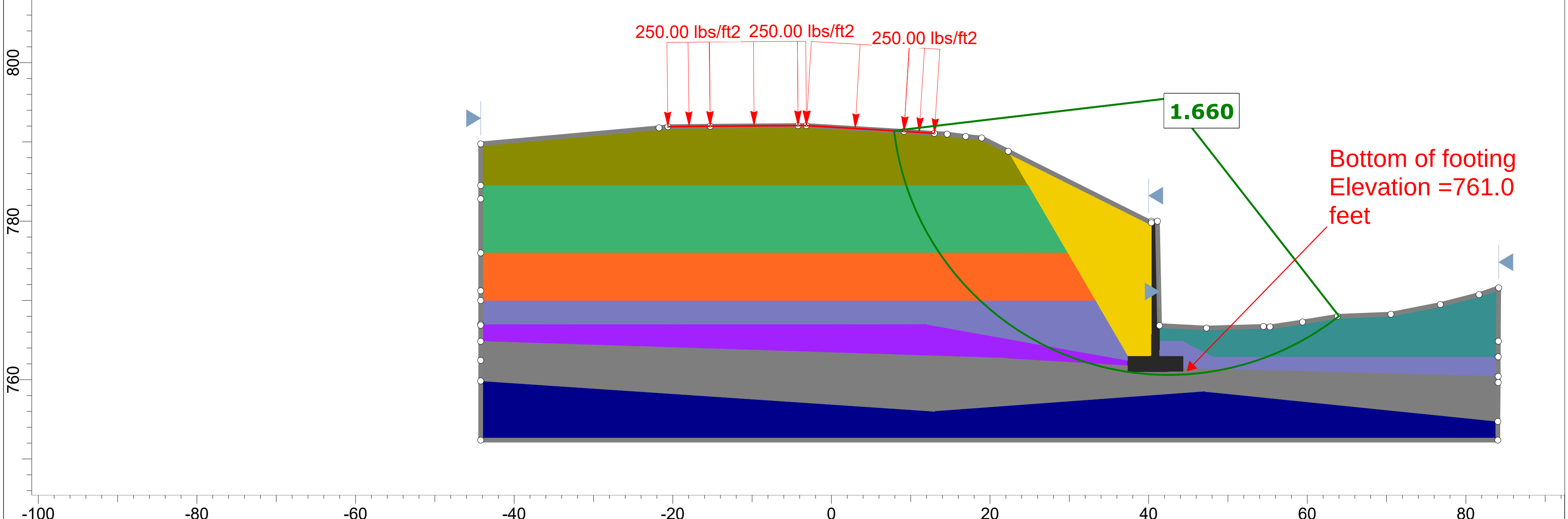
Project	FRA-33-8.75 Culvert Replacement
Analysis Description	Stability Analysis - Short Term
Drawn By	AG
Scale	1:250
Company	Resource International Inc,
Date	2/8/2023, 8:32:24 AM
File Name	Stability Analysis-short term.slmd

SECTION - "XX"

New Slope with Retaining Wall

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Retaining Wall		150	Infinite strength		
Item 203 Embankment (Retained Soil)		120	Mohr-Coulomb	0	30
A-1-a		130	Mohr-Coulomb	0	33
A-6b		120	Mohr-Coulomb	0	26
A-6a/A-6b		120	Mohr-Coulomb	0	26
A-3a/A-4a		125	Mohr-Coulomb	0	31
A-1-b		130	Mohr-Coulomb	0	33
M. Stiff Soils		120	Mohr-Coulomb	0	26
A-2-4		135	Mohr-Coulomb	0	36
Bedrock		145	Mohr-Coulomb	3000	30



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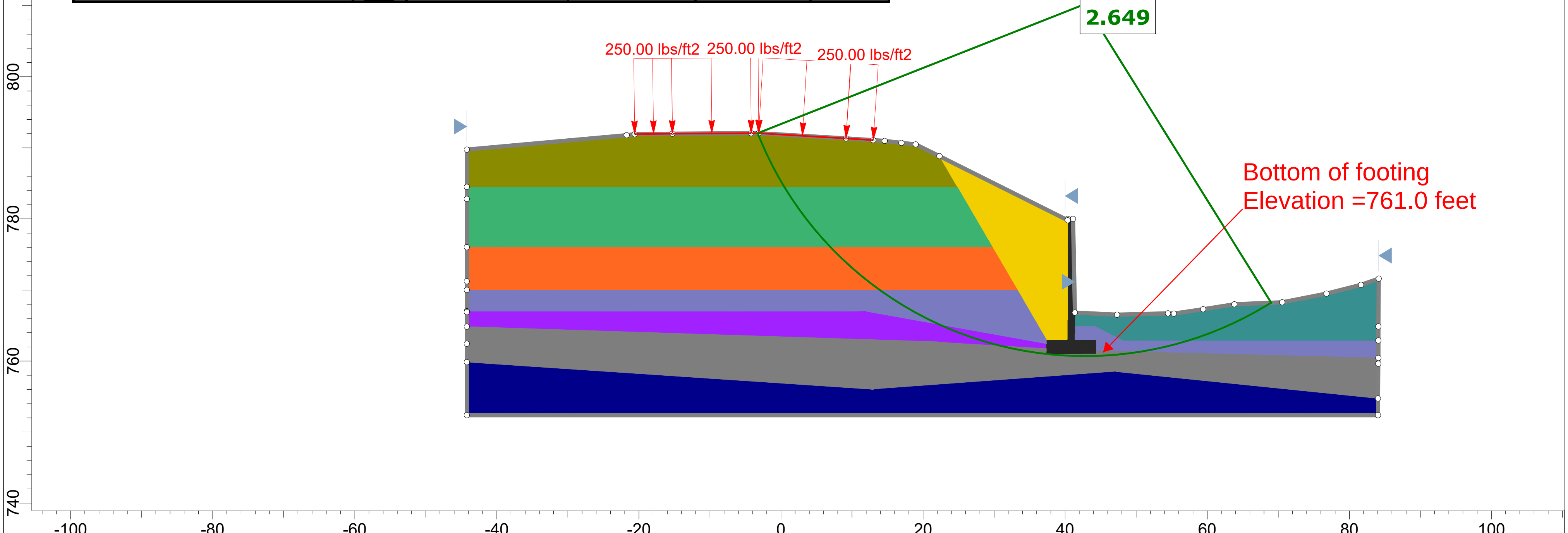
Project	FRA-33-8.75 Culvert Replacement
Analysis Description	Stability Analysis - Long Term
Drawn By	AG
Scale	1:225
Company	Resource International Inc,
Date	2/8/2023, 8:32:24 AM
File Name	Stability Analysis-long term.slmd

SECTION - "XX"

New Slope with Retaining Wall

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Retaining Wall		150	Infinite strength		
Item 203 Embankment (Retained Soil)		120	Mohr-Coulomb	0	30
A-1-a		130	Mohr-Coulomb	0	33
A-6b		120	Mohr-Coulomb	1625	0
A-6a/A-6b		120	Mohr-Coulomb	2750	0
A-3a/A-4a		125	Mohr-Coulomb	0	31
A-1-b		130	Mohr-Coulomb	0	33
M. Stiff Soils		120	Mohr-Coulomb	1000	0
A-2-4		135	Mohr-Coulomb	0	36
Bedrock		145	Mohr-Coulomb	3000	30



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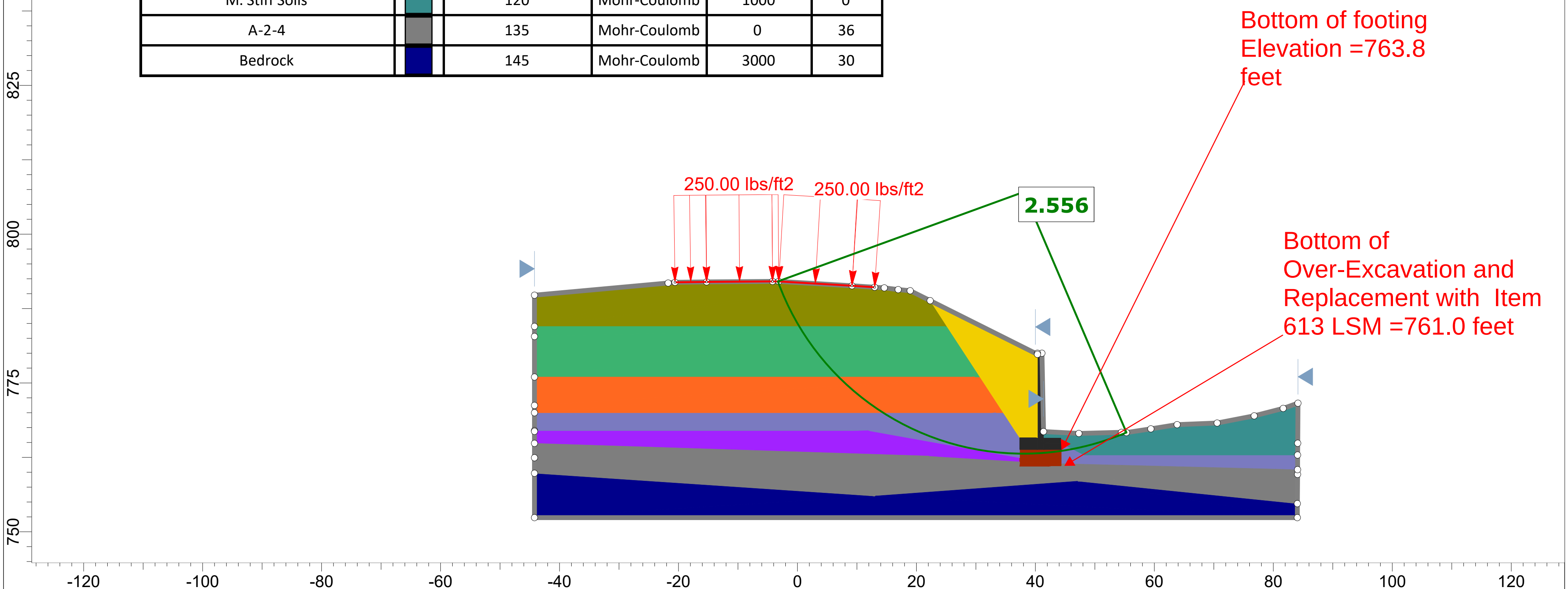
Project	FRA-33-8.75 Culvert Replacement
Analysis Description	Stability Analysis - Short Term
Drawn By	AG
Scale	1:251
Company	Resource International Inc,
Date	2/8/2023, 8:32:24 AM
File Name	Stability Analysis-short term_761.slmd

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Retaining Wall		150	Infinite strength		
Item 203 Embankment (Retained Soil)		120	Mohr-Coulomb	0	30
Item 613 Low Strength Mortar		140	Mohr-Coulomb	250	28
A-1-a		130	Mohr-Coulomb	0	33
A-6b		120	Mohr-Coulomb	1625	0
A-6a/A-6b		120	Mohr-Coulomb	2750	0
A-3a/A-4a		125	Mohr-Coulomb	0	31
A-1-b		130	Mohr-Coulomb	0	33
M. Stiff Soils		120	Mohr-Coulomb	1000	0
A-2-4		135	Mohr-Coulomb	0	36
Bedrock		145	Mohr-Coulomb	3000	30

SECTION - "XX"

New Slope with Retaining Wall



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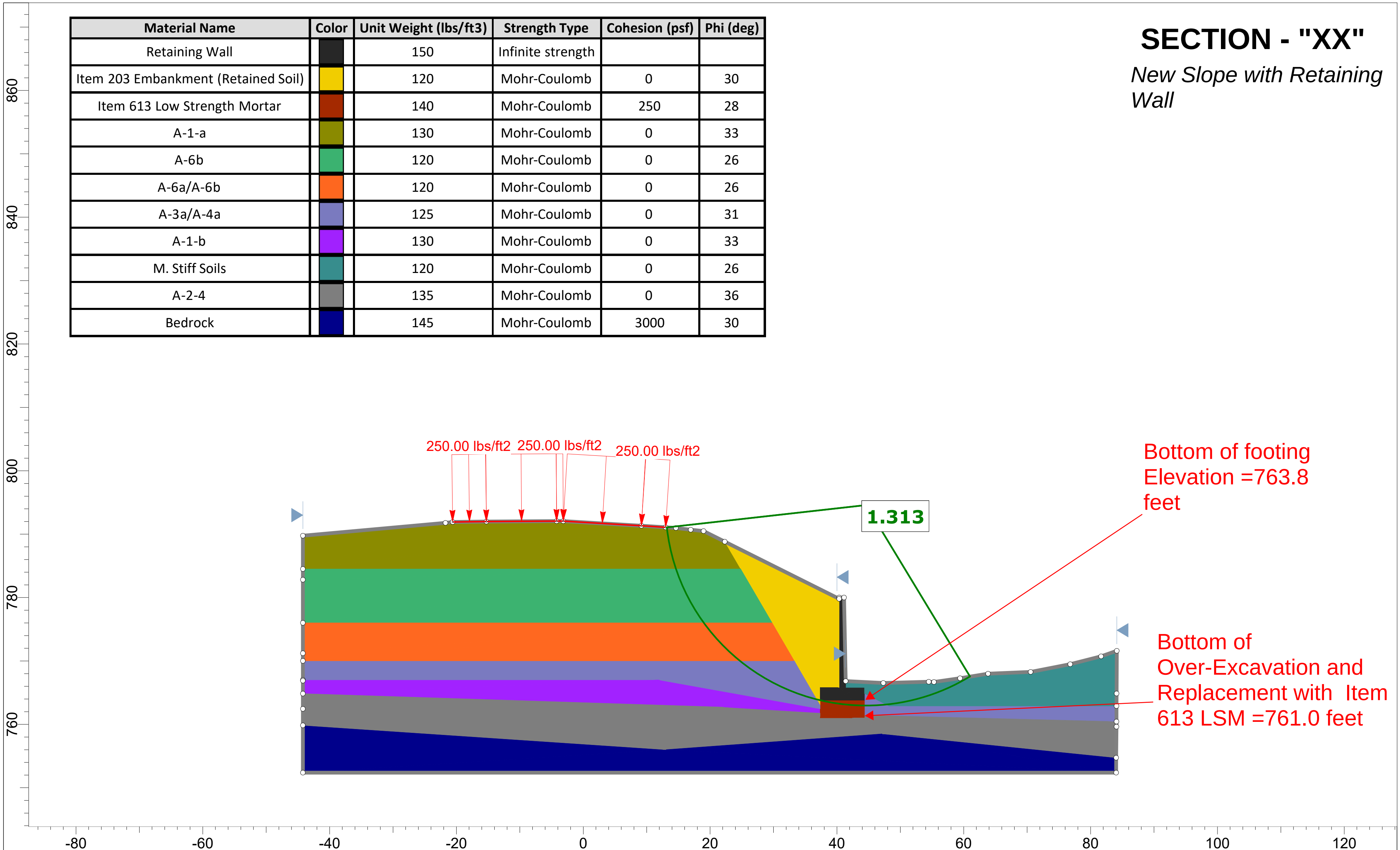
Project	FRA-33-8.75 Culvert Replacement
Analysis Description	Stability Analysis - Short Term
Drawn By	AG
Scale	1:300
Company	Resource International Inc,
Date	2/8/2023, 8:32:24 AM
File Name	Stability Analysis-long term_761_Engineered Fill - Undrained.slmd

SLIDEINTERPRET 9.009

SECTION - "XX"

New Slope with Retaining Wall

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Retaining Wall		150	Infinite strength		
Item 203 Embankment (Retained Soil)		120	Mohr-Coulomb	0	30
Item 613 Low Strength Mortar		140	Mohr-Coulomb	250	28
A-1-a		130	Mohr-Coulomb	0	33
A-6b		120	Mohr-Coulomb	0	26
A-6a/A-6b		120	Mohr-Coulomb	0	26
A-3a/A-4a		125	Mohr-Coulomb	0	31
A-1-b		130	Mohr-Coulomb	0	33
M. Stiff Soils		120	Mohr-Coulomb	0	26
A-2-4		135	Mohr-Coulomb	0	36
Bedrock		145	Mohr-Coulomb	3000	30



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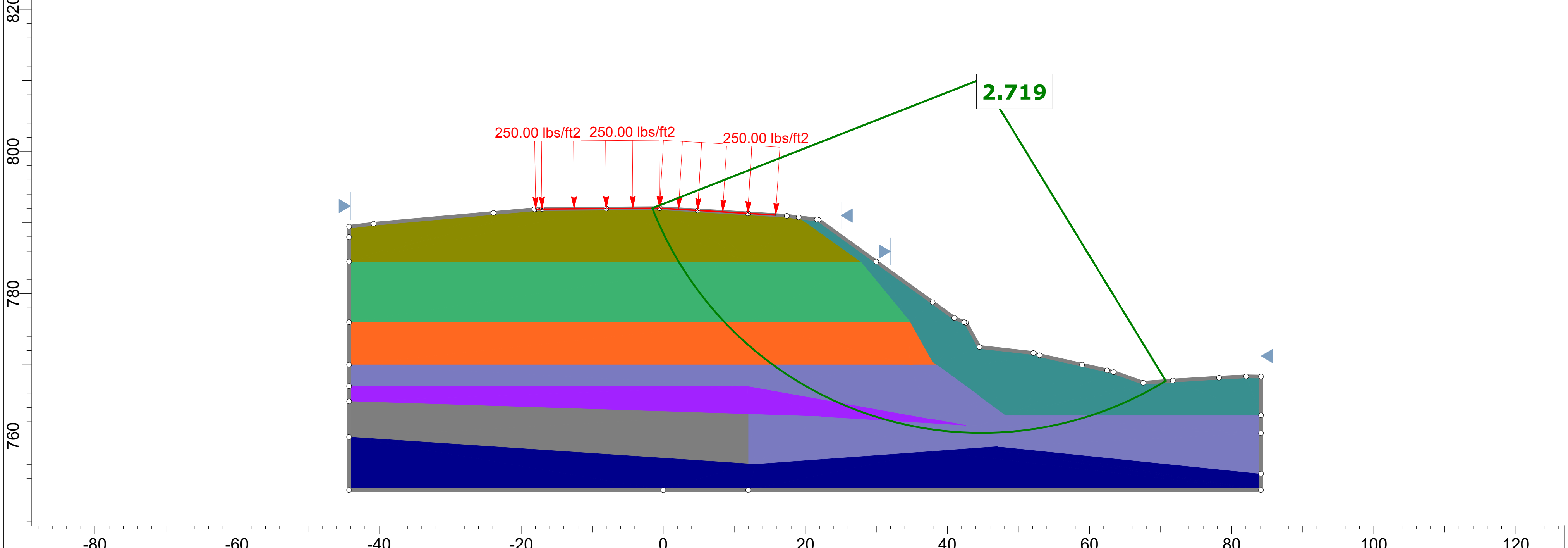
Project	FRA-33-8.75 Culvert Replacement		
Analysis Description	Stability Analysis - Long Term		
Drawn By AG	*Scale* 1:251	*Company*	Resource International Inc,
Date	2/8/2023, 8:32:24 AM	*File Name*	Stability Analysis-long term_761_Engineered Fill.slmd

SLIDEINTERPRET 9.009

SECTION - "YY"

Existing Slope

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
A-1-a		130	Mohr-Coulomb	0	33
A-6b		120	Mohr-Coulomb	1625	0
A-6a/A-6b		120	Mohr-Coulomb	2750	0
A-3a/A-4a		125	Mohr-Coulomb	0	31
A-1-b		130	Mohr-Coulomb	0	33
M. Stiff Soils		120	Mohr-Coulomb	1000	0
A-2-4		135	Mohr-Coulomb	0	36
Bedrock		145	Mohr-Coulomb	3000	30



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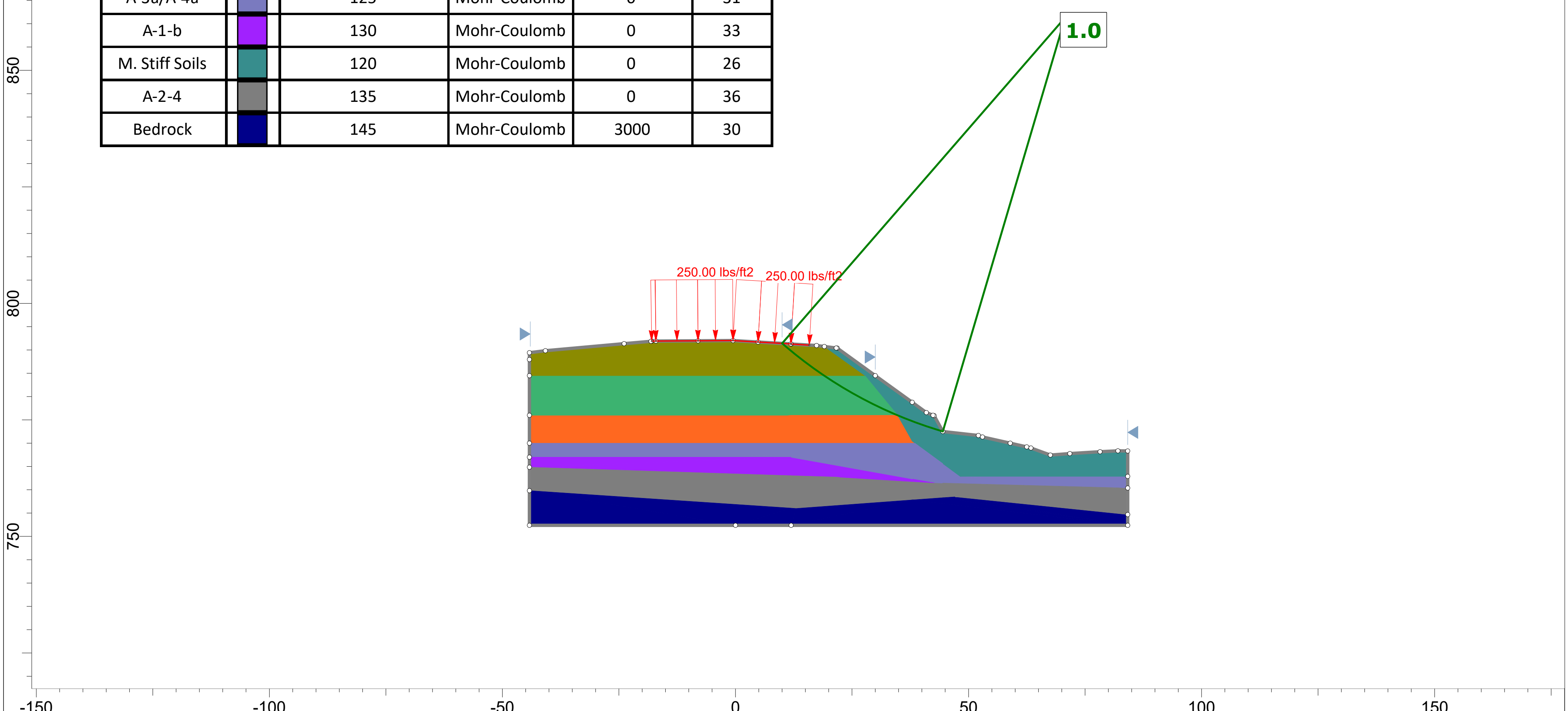
SLIDEINTERPRET 9.009

Project	FRA-33-8.75 Culvert Replacement		
Analysis Description	Stability Analysis - Short Term		
Drawn By AG	*Scale* 1:251	*Company*	Resource International Inc,
Date	2/8/2023, 8:32:24 AM	*File Name*	Stability Analysis-Section-2_Short term.slmd

SECTION - "YY"

Existing Slope

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
A-1-a		130	Mohr-Coulomb	0	33
A-6b		120	Mohr-Coulomb	0	26
A-6a/A-6b		120	Mohr-Coulomb	0	26
A-3a/A-4a		125	Mohr-Coulomb	0	31
A-1-b		130	Mohr-Coulomb	0	33
M. Stiff Soils		120	Mohr-Coulomb	0	26
A-2-4		135	Mohr-Coulomb	0	36
Bedrock		145	Mohr-Coulomb	3000	30



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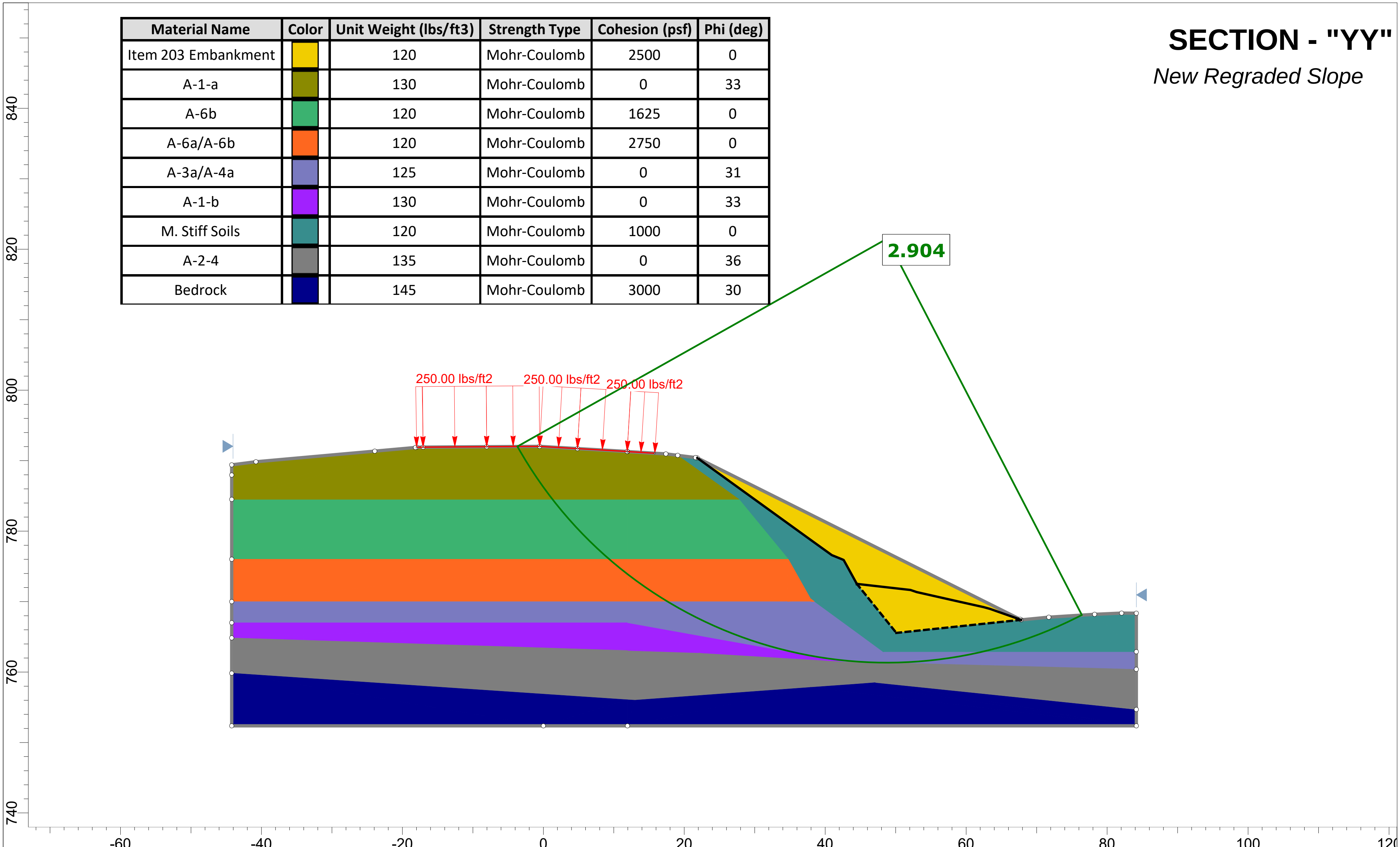
Project	FRA-33-8.75 Culvert Replacement		
Analysis Description	Stability Analysis - Long Term		
Drawn By AG	*Scale* 1:383	*Company*	Resource International Inc,
Date	2/8/2023, 8:32:24 AM	*File Name*	Stability Analysis-Section-2 -Drained.slmd

SLIDEINTERPRET 9.009

SECTION - "YY"

New Regraded Slope

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Item 203 Embankment		120	Mohr-Coulomb	2500	0
A-1-a		130	Mohr-Coulomb	0	33
A-6b		120	Mohr-Coulomb	1625	0
A-6a/A-6b		120	Mohr-Coulomb	2750	0
A-3a/A-4a		125	Mohr-Coulomb	0	31
A-1-b		130	Mohr-Coulomb	0	33
M. Stiff Soils		120	Mohr-Coulomb	1000	0
A-2-4		135	Mohr-Coulomb	0	36
Bedrock		145	Mohr-Coulomb	3000	30



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SLIDEINTERPRET 9.009

Project	FRA-33-8.75 Culvert Replacement
Analysis Description	Stability Analysis - Short Term
Drawn By	AG
Scale	1:226
Company	Resource International Inc,
Date	2/21/2023, 8:32:24 AM
File Name	Stability Analysis-Section-2 -Undrained.slmd

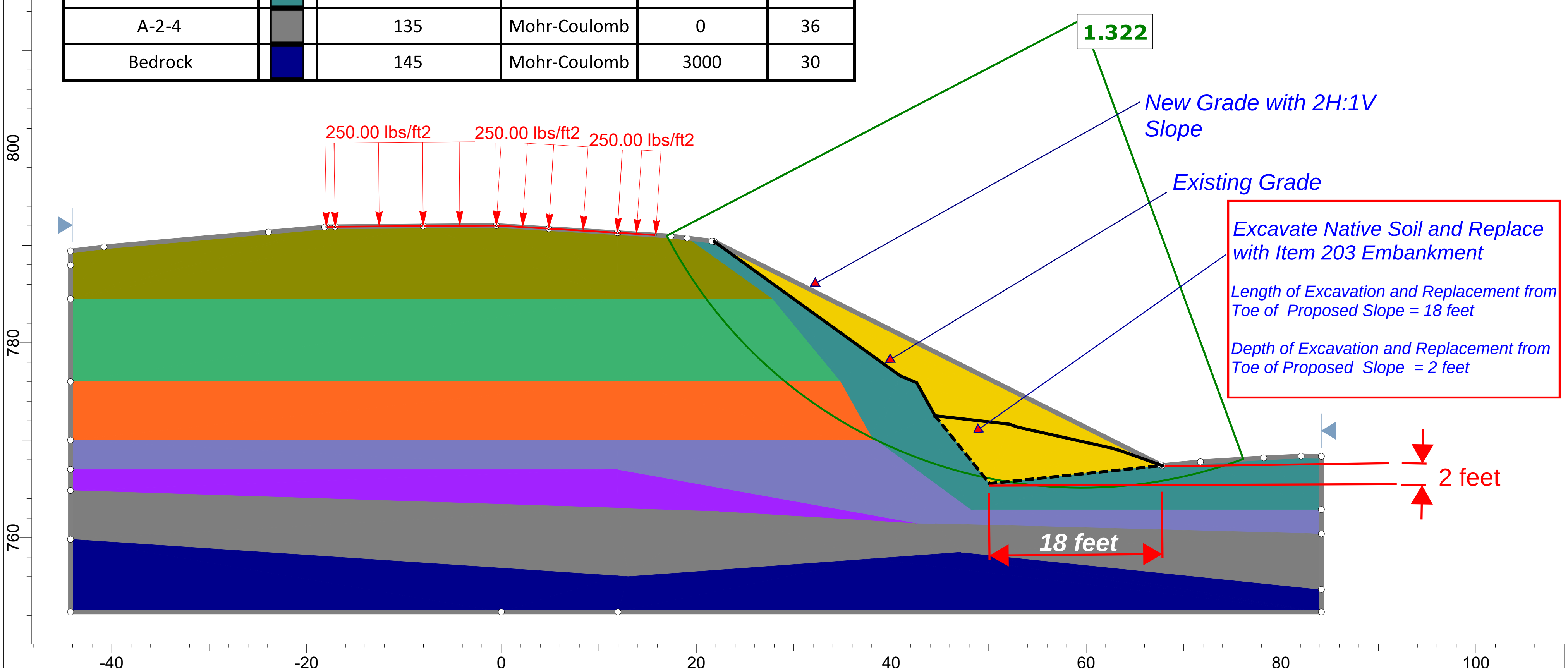
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Item 203 Embankment		120	Mohr-Coulomb	250	28
A-1-a		130	Mohr-Coulomb	0	33
A-6b		120	Mohr-Coulomb	0	26
A-6a/A-6b		120	Mohr-Coulomb	0	26
A-3a/A-4a		125	Mohr-Coulomb	0	31
A-1-b		130	Mohr-Coulomb	0	33
M. Stiff Soils		120	Mohr-Coulomb	0	26
A-2-4		135	Mohr-Coulomb	0	36
Bedrock		145	Mohr-Coulomb	3000	30

SECTION - "YY"

New Regraded Slope

Note:

Elevation at Crest of Proposed Slope = 790.4 feet msl
Elevation at Toe of Proposed Slope = 767.4 feet msl
Total Height of Slope = 23 feet
Minimum Horizontal Needed Beyond the Crest of Slope = 46 feet



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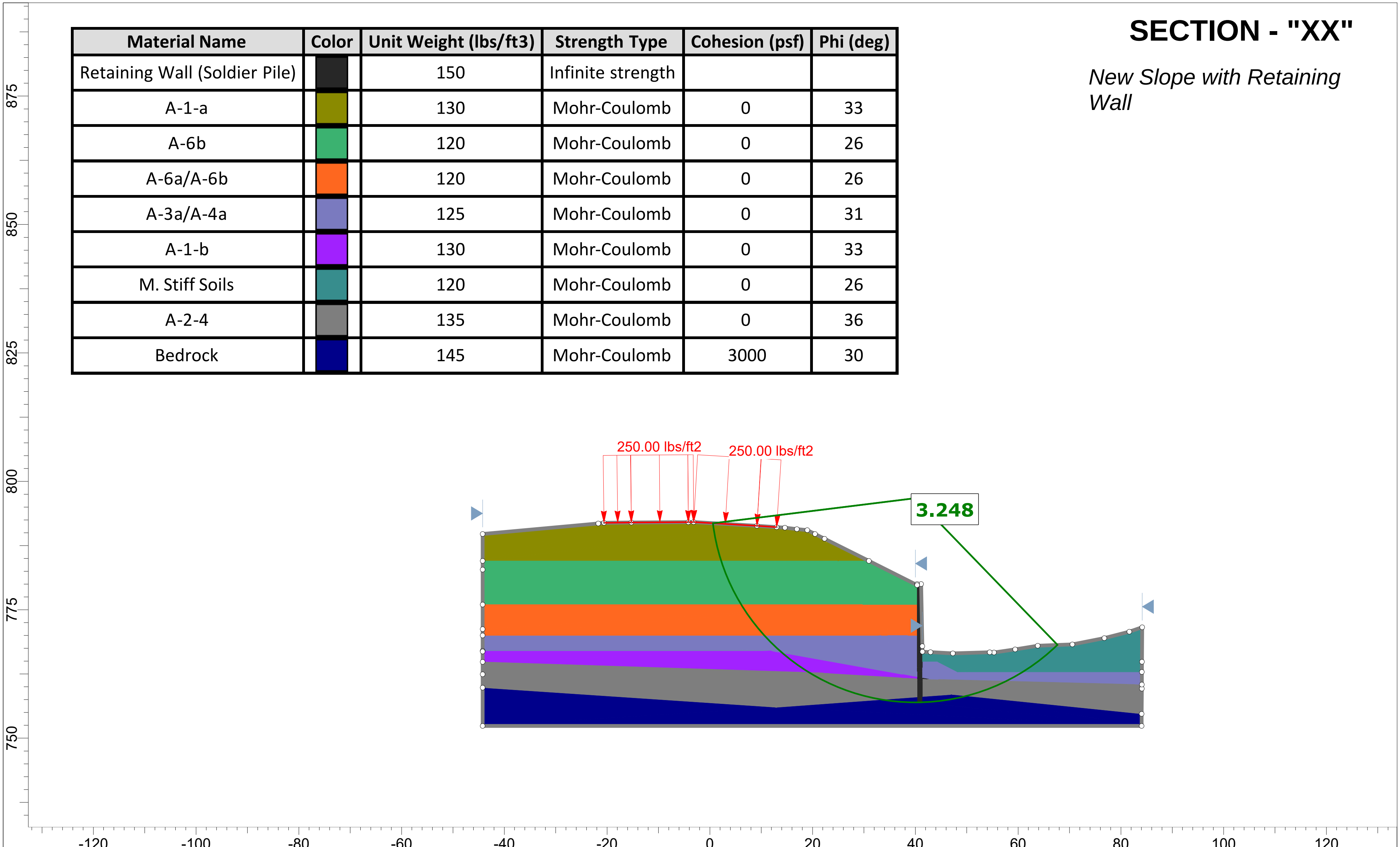
Project	FRA-33-8.75 Culvert Replacement		
Analysis Description	Stability Analysis - Long Term		
Drawn By AG	*Scale* 1:183	*Company*	Resource International Inc,
Date	2/21/2023, 8:32:24 AM	*File Name*	Stability Analysis-Section-2 -Drained_Stabilization.slmd

SLIDEINTERPRET 9.009

SECTION - "XX"

New Slope with Retaining Wall

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Retaining Wall (Soldier Pile)		150	Infinite strength		
A-1-a		130	Mohr-Coulomb	0	33
A-6b		120	Mohr-Coulomb	0	26
A-6a/A-6b		120	Mohr-Coulomb	0	26
A-3a/A-4a		125	Mohr-Coulomb	0	31
A-1-b		130	Mohr-Coulomb	0	33
M. Stiff Soils		120	Mohr-Coulomb	0	26
A-2-4		135	Mohr-Coulomb	0	36
Bedrock		145	Mohr-Coulomb	3000	30

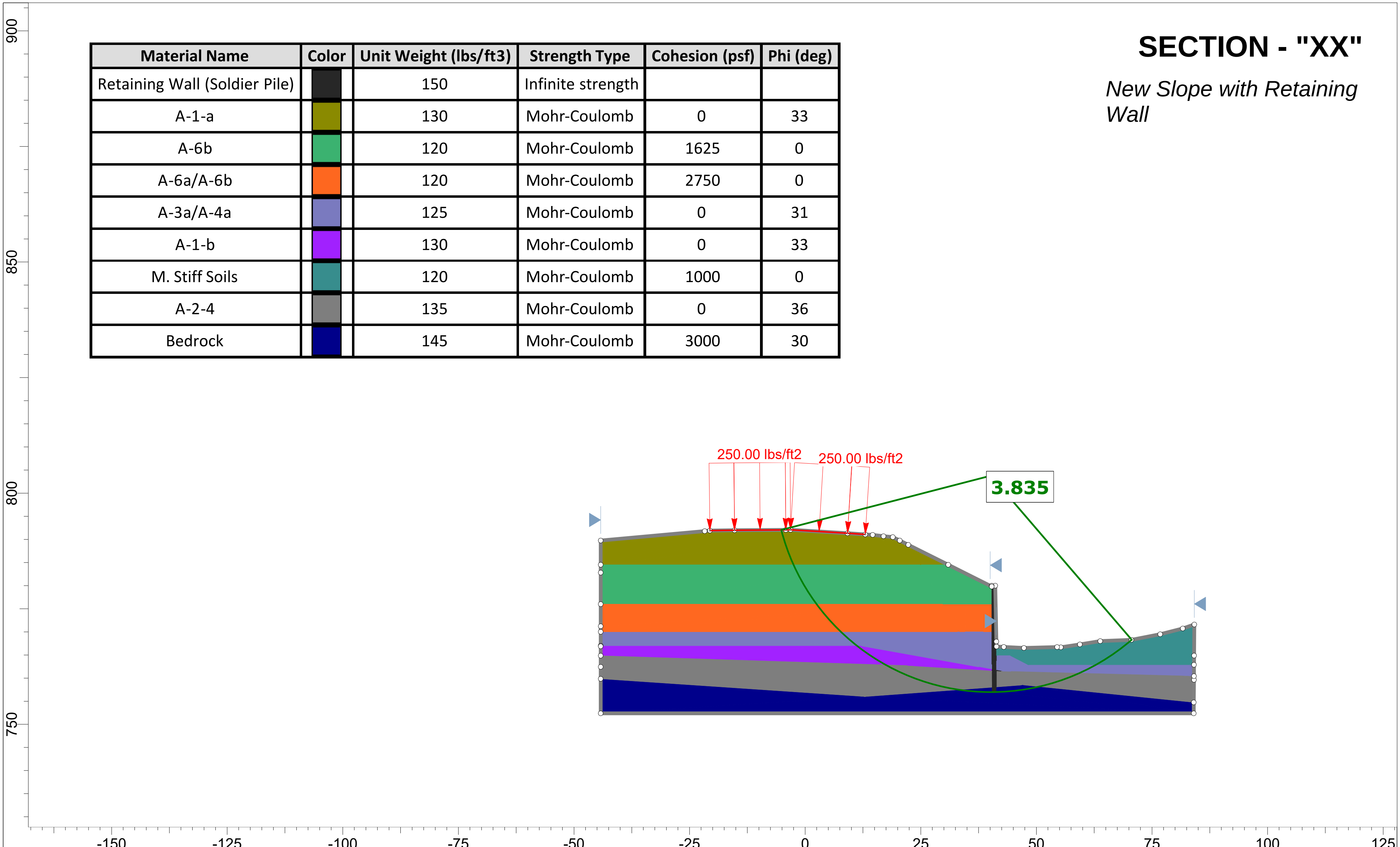


RESOURCE INTERNATIONAL, INC. An ISO 9001:2015 QMS certified firm	*Project* FRA-33-8.75 Culvert Replacement		
	Analysis Description Stability Analysis - Long Term (Soldier Pile Wall with Lagging)		
	Drawn By AG	*Scale* 1:310	*Company* Resource International Inc,
SLIDEINTERPRET 9.009	*Date* 2/8/2023, 8:32:24 AM		*File Name* Stability Analysis-long term_Soldier Pile - Copy.slmd

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Retaining Wall (Soldier Pile)		150	Infinite strength		
A-1-a		130	Mohr-Coulomb	0	33
A-6b		120	Mohr-Coulomb	1625	0
A-6a/A-6b		120	Mohr-Coulomb	2750	0
A-3a/A-4a		125	Mohr-Coulomb	0	31
A-1-b		130	Mohr-Coulomb	0	33
M. Stiff Soils		120	Mohr-Coulomb	1000	0
A-2-4		135	Mohr-Coulomb	0	36
Bedrock		145	Mohr-Coulomb	3000	30

SECTION - "XX"

New Slope with Retaining Wall



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Project	FRA-33-8.75 Culvert Replacement		
Analysis Description	Stability Analysis - Short Term (Soldier Pile Wall with Lagging)		
Drawn By AG	*Scale* 1:345	*Company*	Resource International Inc,
Date	2/8/2023, 8:32:24 AM	*File Name*	Stability Analysis-short term_Soldier Pile.slmd

SLIDEINTERPRET 9.009

Appendix VIII

SOIL AND ROCK DESIGN PARAMETERS

FRA-33-8.75 , PID No: 108081
Structure Replacement
Rii Project Number: W-22-156

(Soil and Rock Parameters for Soldier Pile Wall Design)

Substructure Unit (Boring)	Elevation (feet msl)	Soil Class.	Soil Type	Strata	N_{60}	γ (pcf)	Strength Parameter	k (soil) k_{rm} (rock)	ε_{50} (soil) E_r (rock)	RQD (rock)
B-002-0-22	791.3 to 783.8	A-1-a	G	4	33	130	φ = 32°	115 pci	-	-
	783.8 to 775.3	A-6b	C	3	13	120	Su = 1,625 psf	540 pci	0.0068	-
	775.3 to 769.3	A-6b	C	3	22	120	Su = 2,750 psf	915 pci	0.0053	-
	769.3 to 766.3	A-3a	G	4	24	125	φ = 31°	65 pci	-	-
	766.3 to 760.3	A-1-b	G	4	30	130	φ = 33°	90 pci	-	-
	760.3 to 755.3	A-2-4	G	4	59	135	φ = 37°	225 pci	-	-
	755.3 to 750.3	Weathered Limestone	R	9	-	150	Qu = 500 psi	0.0005	45,000 psi	7