Resource International, Inc.

FRA-70-12.68 PROJECT 4R
RETAINING WALL 4W4
PID NO. 105523
FRANKLIN COUNTY, OHIO

STRUCTURE FOUNDATION EXPLORATION REPORT

Prepared For:
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Rii Project No. W-13-045

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July 16, 2018 (Revised January 30, 2019)

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Re: Structure Foundation Exploration Report
FRA-70-12.68 Project 4R
Retaining Wall 4W4
PID No. 105523
Rii Project No. W-13-045

Mr. Luzier:

Resource International, Inc. (Rii) is pleased to submit this structure foundation exploration report for the above referenced project. This report includes recommendations for the design and construction of the proposed Retaining Wall 4W4 as part of the FRA-70-12.68 Project 4R in Columbus, Ohio.

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

Sincerely,

RESOURCE INTERNATIONAL, INC.

Peyman P. Majidi, E.I.
Staff Engineer

Jonathan P. Sterenberg, P.E.
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Enclosure: Structure Foundation Exploration Report

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EXECUTIVE SUMMARY

Resource International, Inc. (Rii) has completed a structure foundation exploration for retaining wall 4W4 as part of the FRA-70-12.68 project. The Retaining Wall 4W4 is located on south side of I-70 EB between the ramp onto W. Fulton Street and Front Street over I-70 Bridge (FRA-70-1395). Based on design information provided by GPD GROUP, It is understood that the proposed wall will be a tangent drilled shaft retaining wall, beginning approximately at Sta. 184+25.47, extending east towards bridge structure FRA-70-1395 and ending at Sta. 186+57.50. Based on design information provided by GPD GROUP, it is understood that the wall is approximately 233 feet long and a portion of the wall will be on 5 ft. diameter tangent drilled shafts and the remaining portion of the wall will be on 4 ft. diameter tangent drilled shafts.

Exploration and Findings

On September 19, 2013 and between February 11 and 14, 2015, two (2) structural borings, designated as B-026-1-13 and B-024-1-13, were drilled as part of the current investigation, to completion depth of 50.0 feet and 64.3 below the existing ground surface.

Boring B-024-1-13 was drilled in the existing I-70 eastbound ramp to Front Street and encountered 14.0 of asphalt overlying 6.0 inches of aggregate base. Boring B-026-1-13 was performed in the existing pavement along S. Ludlow Street and encountered 4.0 inches of asphalt overlying 8.0 inches of aggregate base. Surface materials were not noted in the historic 1959 boring logs.

Material identified as existing or possible fill was encountered in boring B-026-1-13 extending to a depth of 15.5 feet below the ground surface. The fill materials encountered were described as brown and gray gravel and gravel with sand and silt (ODOT A-1-a, A-2-4).

Beneath the surficial materials and/or fill, natural granular soils were encountered with intermittent seams of cohesive material. The granular soils were generally described as brown and gray gravel, gravel and sand, and coarse and fine sand (ODOT A-1-a, A-1-b, A-2-4, A-3a). The cohesive materials were described as brown and gray sandy silt, and silt and clay (ODOT A-4a, A-6a).

Groundwater was initially encountered in both borings at depths of 34.0 and 28.5 feet, respectively. No groundwater was present in the borehole of either boring B-024-1-13 at the completion of drilling. Water level readings at the completion of drilling were not able to be measured in borings B-026-1-13 due to the addition of drilling mud to counteract the heaving sands that were encountered beneath the initial groundwater level during drilling. Groundwater levels were not noted in the borings performed during the 1959 investigation.

As previously indicated, a subsurface investigation was performed in 1959 as part of the Department of as part of the original FRA-40-12.82 project for the existing Front Street bridge structure were obtained from the construction documents on record. One (1) boring, designated as B-002-F-59, was obtained along the west side of the existing bridge alignment, near the west end of the Retaining Wall 4W1 alignment. One boring, identified as B-002-F-59 from this investigation was reviewed and are referenced in this report to supplement the subsurface information obtained as part of the current investigation. The subsurface soils encountered in the borings generally consisted of granular soils comprised of loose to very dense sandy gravel and silty sandy gravel from the ground surface at approximately 754.7 feet to the termination depth at 681.8 feet below the existing ground surface. Groundwater elevations in the boreholes were not provided on the historic logs. In general, the soil strata encountered in the historic borings matched relatively closely with those encountered in the soil borings for the current investigation.

Analyses and Recommendations

Design details of the proposed retaining wall were provided by GPD GROUP. Based on the information provided, it is understood that Retaining Wall 4W4 will be a tangent drilled shaft wall type.

While the design of tangent shaft retaining wall is controlled by lateral check of the wall, the drilled shafts bearing capacity may be calculated utilizing the values provided in the following table:

Drilled Shaft Axial Design Parameters

Boring	Elevation [1] (feet msl)	Shaft Length (feet)	Soil Type	Nominal Resistance		Resistance Factor	
				End (ksf)	Side (ksf)	End	Side
B-002-F-59	726.0-723.6	0.0-2.4	A-2-4	60	2.33	0.50	0.55
	723.6-712.1	2.4-13.9	A-1-b	60	3.56	0.50	0.55
	712.1-691.1	13.9-34.9	A-1-a	60	4.54	0.50	0.55
	691.1-681.1	34.9-44.9	A-3a	60	3.08	0.50	0.55
B-024-1-13	727.0-720.9	0.0-6.1	A-4a	42	2.37	0.40	0.45
	720.9-714.4	6.1-12.6	A-6a	45	2.32	0.40	0.45
	714.4-694.4	12.6-32.6	A-1-a	60	4.30	0.50	0.55
	694.4-689.4	32.6-37.6	A-3a	52	2.01	0.50	0.55
	689.4-684.4	37.6-42.6	A-4a	72	3.60	0.40	0.45
	684.4-682.4	42.6-44.6	A-1-b	60	4.96	0.50	0.55

Boring	Elevation [1] (feet msl)	Shaft Length (feet)	Soil Type	Nominal Resistance		Resistance Factor	
				End (ksf)	Side (ksf)	End	Side
B-026-1-13	726.0-719.0	0.0-7.0	A-1-b	46	1.23	0.50	0.55
	719.0-714.0	7.0-12.0	A-1-b	60	2.00	0.50	0.55
	714.0-697.0	12.0-29.0	A-1-b	60	3.29	0.50	0.55

1. Top of shaft elevation based on structure information provided by GPD Group.

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

The overall purpose of this project is to provide detailed subsurface information and recommendations for the design and construction of the FRA-70-12.68/13.11/14.05C (Project 4R/4H/4A) projects in Columbus, Ohio. The projects represent the central portion of FRA-70-8.93 (PID 77369) I-70/71 south innerbelt improvements project. The FRA-70-12.68 (Project 4R) phase will consist of all work associated with the construction of Ramp C5, starting at the bridge over Souder Avenue and extending east to Front Street. The proposed Ramp C5 will be a two-lane to four-lane ramp that will collect and direct traffic from I-71 northbound and SR-315 southbound as well as I-70 eastbound to exit in downtown at the intersection of Front Street and W. Fulton Avenue. This project includes the construction of six (6) new bridge structures for the proposed Ramp C5 alignment and replacement of three (3) bridge structures, two along I-70 and the Front Street Structure over I-70, as well as the construction of fourteen (14) new retaining walls and a culvert structure to accommodate the new configuration.

This report is a presentation of the structure foundation exploration performed for the design and construction of the proposed Retaining Wall 4W4 located along the south side of Interstate 70 EB between the ramp onto W. Fulton Street and the Front Street bridge over I-70 (FRA-70-1395), as shown on the vicinity map and boring plan presented in Appendix I. Based on design information provided by GPD GROUP, It is understood that the proposed wall will be a tangent drilled shaft retaining wall, beginning approximately at Sta. 184+25.47, extending east towards bridge structure FRA-70-1395 and ending at Sta. 186+57.50. It is understood that the wall is approximately 233 feet long.

Please note that the design of the drilled shaft retaining wall where it will support the south abutment of the proposed FRA-70-1390 and FRA-70-1395 structures will be governed by the recommendations in the respective bridge structure reports, which are presented under separate covers.

A preliminary structure foundation exploration was performed by DLZ for the proposed retaining walls as part of the FRA-70-8.93 Final engineering project (PID No. 77369) and their findings are presented in the report dated September 24, 2009. Historic boring information from the 1959 investigation performed by the Ohio Department of Highways was also obtained from the original construction records for the existing Front Street and High Street bridges. These final engineering and historic borings were used to supplement the information obtained by Rii during the current investigation.

2.0 GEOLOGY AND OBSERVATIONS OF THE PROJECT

2.1 Site Geology

Both the Illinoian and Wisconsinan glaciers advanced over two-thirds of the State of Ohio, leaving behind glacial features such as moraines, kame deposits, lacustrine deposits and outwash terraces. The glacial and non-glacial regions comprise five physiographic sections based on geological age, depositional process and geomorphic occurrence (physical features or landforms). The project area lies within the Columbus Lowland District of the Till Plains Section. This area is characterized by flat to gently rolling ground moraine deposits from the Late Wisconsinan age. The site topography exhibits moderate to high relief. The ground moraine deposits are composed primarily of silty loam till (Darby, Bellefontaine, Centerburg, Grand Lake, Arcanum, Knightstown Tills), with smaller alluvium and outwash deposits bordering the Scioto River, its tributaries and floodplain areas. A ground moraine is the sheet of debris left after the steady retreat of glacial ice. The debris left behind ranges in composition from clay size particles to boulders (including silt, sand, and gravel). 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 in composition from silty clay size particles to cobbles, usually deposited in present and former floodplain areas.

According to the bedrock geology and topography maps obtained from the Ohio Department of Natural Resources (ODNR), the underlying bedrock consists predominantly of the Middle to Lower Devonian-aged Columbus Limestone. This formation is further subdivided into two members in the central portion of the state, known as the Delhi and Bellepoint Members. The Delhi Member consists of light gray, finely to coarsely crystalline, irregularly bedded, fossiliferous limestone. The Bellepoint Member consists of variable brown, finely crystalline, massively bedded limy dolomite. Both of these members contain chert nodules. Just east of the Scioto River, the underlying bedrock consists of the Upper Devonian Ohio Shale Formation overlying the Middle Devonian-aged Delaware Limestone Formation. The Ohio Shale formation consists of brownish black to greenish gray, thinly bedded, fissile, carbonaceous shale. The Delaware Limestone consists of bluish gray, thin to medium bedded dolomitic limestone with nodules and layers of chert. Regionally, the bedrock surface forms a broad valley aligned roughly north-to-south beneath the Scioto River. According to bedrock topography mapping, the elevation of the bedrock surface ranges from approximately 600 feet mean sea level (msl) in the valley to approximately 625 feet msl near the project limits.

2.2 Existing Conditions

The proposed Retaining Wall 4W4 is located along the south side of I-70/71 between the ramp onto W. Fulton Street and the Front Street bridge over I-70 (FRA-70-1395), approximately 0.5 miles east of the Scioto River. The existing I-70/I-71 in the vicinity of the structure is a six-lane, bi-directional, composite asphalt and concrete paved roadway that is generally east-west aligned through downtown Columbus, Ohio. The existing I-70 profile is lowered from the surrounding terrain, as the existing corridor was cut approximately 20 to 25 below the existing grade of S. Front Street and the surrounding downtown area. An existing cast-in-place concrete retaining wall extends between the two bridge structures, which steps up a graded slope as it extends toward S. High Street. This traffic volume along the project alignment is very high, and the alignment traverses primarily commercial and government properties. The surrounding terrain across the site is relatively flat-lying.

3.0 EXPLORATION

On September 19, 2013 and between February 11 and 14, 2015, two (2) structural borings, designated as B-026-1-13 and B-024-1-13, were drilled as part of the current exploration, to completion depth of 50.0 feet and 64.3 below the existing ground surface at the locations shown on the boring plan provided in Appendix I of this report and summarized in Table 1 below.

Table 1. Test Boring Summary

Boring Number	Reference Alignment	Station	Offset	Latitude	Longitude	Ground Elevation (feet msl)	Boring Depth (feet)
B-024-1-13	BL Ramp C5	5087+81.22	64.3’ Rt.	39.952930262	-83.001880690	746.4	64.3
B-026-1-13	BL I-70 EB	184+88.08	111.1’ Rt.	39.952673289	-83.001473185	747.0	50.0

The boring location was determined and located in the field by Rii representatives. Rii utilized a handheld GPS unit to obtain northing and easting coordinates of the boring location. The ground surface elevation at the boring location was interpolated using topographic mapping information provided by GPD GROUP.

The borings were performed with a truck mounted rotary drilling machine utilizing a 4.25-inch ID hollow stem auger. Standard penetration testing (SPT) and split-spoon sampling were performed in Boring B-024-1-13 was sampled in 2.5-foot increments to a depth of 30.0 feet and at 5.0 foot increments thereafter to the boring termination depth. Boring B-26-1-13 was sampled at 2.5-foot increments to a depth of 5.0 feet, than at 5.0-foot increments to a depth of 15.0 feet, then continued sampling at 2.5-foot increments to 35.0 feet, where sampling was again increased to 5.0-foot increments to the boring termination depth.

The SPT, per the American Society for Testing and Materials (ASTM) designation D1586, is conducted using a 140-pound hammer 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 blow 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). Standard penetration blow counts aid in determining soil properties applicable in foundation system design. Measured blow count (N) values are corrected to an equivalent (60%) 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 for the truck-mounted drill rig used for the B-024-1-13 was calibrated on October 20, 2014, with a drill rod energy ratio of 92.0 percent. The hammer for the truck mounted drill rig used for B-026-1-13 was calibrated on April 26, 2013 with a drill rod energy ratio of 77.7 percent. No calibration factor was applied to the blow counts presented on the historic boring logs, as these were performed using a manual hammer.

During drilling for the borings, field logs were prepared by Rii personnel showing the encountered subsurface conditions. Soil samples obtained from the drilling operation were preserved and sealed in 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	ASTM D 2216	34
Plastic and Liquid Limits	AASHTO T89, T90	11
Gradation – Sieve/Hydrometer	AASHTO T88	11

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. Results of the laboratory testing are presented on the boring logs in Appendix III. A description of the soil terms used throughout this report is presented in Appendix II.

Hand penetrometer readings, which provide a rough estimate of the unconfined compressive strength 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.

In addition to the borings performed as part of the current exploration, historic borings performed in 1959 by the Department of Highways as part of the original FRA-40-12.82 project for the existing Front Street bridge structure were obtained from the construction documents on record. One (1) boring, designated as B-002-F-59, was obtained along the west side of the existing bridge alignment, near the west end of the proposed Retaining Wall 4W1 alignment, on the west side of the Front Street bridge south abutment. Based on the elevation provided on the boring log, it is anticipated that the boring was performed from the then-existing ground surface and that the profile for the then-proposed US 40 (existing I-70/71) was lowered to provide sufficient clearance for the bridge to be constructed at the then-existing ground surface. The boring was extended to a depth of 73.0 feet below the ground surface at the time the boring was obtained.

Rii has included a plan showing the current and historic soil borings performed in the project area in Appendix I.

4.0 FINDINGS

Interpreted engineering logs have been prepared based on the field logs, visual examination of samples and laboratory test results. Classification follows the respective version of the ODOT Specifications for Geotechnical Explorations (SGE) at the time the exploration borings were performed. The following is a summary of what was found in the test borings and what is represented on the boring logs.

4.1 Surface Materials

Boring B-024-1-13 was drilled in the existing I-70 eastbound ramp to Front Street and encountered 14.0 of asphalt overlying 6.0 inches of aggregate base. Boring B-026-1-13 was performed in the existing pavement along S. Ludlow Street and encountered 4.0 inches of asphalt overlying 8.0 inches of aggregate base. Surface materials were not noted in the historic 1959 boring logs.

4.2 Subsurface Soils

Material identified as existing or possible fill was encountered in boring B-026-1-13 extending to a depth of 15.5 feet below the ground surface. The fill materials encountered were described as brown and gray gravel and gravel with sand and silt (ODOT A-1-a, A-2-4).

Beneath the surficial materials and/or fill, natural granular soils were encountered with intermittent seams of cohesive material. The granular soils were generally described as brown and gray gravel, gravel and sand, and coarse and fine sand (ODOT A-1-a, A-1-b, A-2-4, A-3a). The cohesive materials were described as brown and gray sandy silt, and silt and clay (ODOT A-4a, A-6a).

4.3 Bedrock

Bedrock was not encountered in any of the borings performed for this exploration.

4.4 Groundwater

Groundwater was initially encountered in both borings at depths of 34.0 and 28.5 feet, respectively. No groundwater was present in the borehole of either boring B-024-1-13 at the completion of drilling. Water level readings at the completion of drilling were not able to be measured in borings B-026-1-13 due to the addition of drilling mud to counteract the heaving sands that were encountered beneath the initial groundwater level during drilling. Groundwater levels were not noted in the borings performed during the 1959 investigation.

4.5 Historic Borings

As previously indicated, a subsurface investigation was performed in 1959 as part of the Department of as part of the original FRA-40-12.82 project for the existing Front Street bridge structure were obtained from the construction documents on record. One (1) boring, designated as B-002-F-59, was obtained along the west side of the existing bridge alignment, near the west end of the Retaining Wall 4W1 alignment. One boring, identified as B-002-F-59 from this investigation was reviewed and are referenced in this report to supplement the subsurface information obtained as part of the current investigation. The subsurface soils encountered in the borings generally consisted of granular soils comprised of loose to very dense sandy gravel and silty sandy gravel from the ground surface at approximately 754.7 feet to the termination depth at 681.8 feet below the existing ground surface. Groundwater elevations in the boreholes were not provided on the historic logs. In general, the soil strata encountered in the historic borings matched relatively closely with those encountered in the soil borings for the current investigation. A copy of the historic boring logs is provided in Appendix IV, and the historic boring locations are shown on the boring plan in Appendix I.

5.0 ANALYSES AND RECOMMENDATIONS

Data obtained from the review of existing geotechnical information has been used in conjunction with data obtained during the current exploration to determine the foundation support capabilities and the settlement potential for the soil encountered at the site. These parameters have been used to provide guidelines for the design of foundation systems for the subject retaining wall, as well as the construction specifications related to the placement of foundation systems and general earthwork recommendations, which are discussed in the following paragraphs.

Design details of the proposed retaining wall were provided by GPD GROUP. Based on the information provided, it is understood that Retaining Wall 4W4 will be a tangent drilled shaft wall type.

5.1 Drilled Shaft Recommendations

While the design of tangent shaft retaining wall is controlled by lateral check of the wall, the drilled shafts bearing capacity may be calculated utilizing the values provided in Table 3.

Table 3. Drilled Shaft Axial Design Parameters

Boring	Elevation [1] (feet msl)	Shaft Length (feet)	Soil Type	Nominal Resistance		Resistance Factor	
				End (ksf)	Side (ksf)	End	Side
B-002-F-59	726.0-723.6	0.0-2.4	A-2-4	60	2.33	0.50	0.55
	723.6-712.1	2.4-13.9	A-1-b	60	3.56	0.50	0.55
	712.1-691.1	13.9-34.9	A-1-a	60	4.54	0.50	0.55
	691.1-681.1	34.9-44.9	A-3a	60	3.08	0.50	0.55
B-024-1-13	727.0-720.9	0.0-6.1	A-4a	42	2.37	0.40	0.45
	720.9-714.4	6.1-12.6	A-6a	45	2.32	0.40	0.45
	714.4-694.4	12.6-32.6	A-1-a	60	4.30	0.50	0.55
	694.4-689.4	32.6-37.6	A-3a	52	2.01	0.50	0.55
	689.4-684.4	37.6-42.6	A-4a	72	3.60	0.40	0.45
	684.4-682.4	42.6-44.6	A-1-b	60	4.96	0.50	0.55
B-026-1-13	726.0-719.0	0.0-7.0	A-1-b	46	1.23	0.50	0.55
	719.0-714.0	7.0-12.0	A-1-b	60	2.00	0.50	0.55
	714.0-697.0	12.0-29.0	A-1-b	60	3.29	0.50	0.55

1. *Top of shaft elevation based on structure information provided by GPD Group.*

Drilled shaft lengths should measure a minimum of three (3) times the shaft diameter. Per Section 10.8.3.5.3 of the 2017 AASHTO LRFD Bridge Design Specifications (BDS), where drilled shafts are extended to end bear in a strong soil layer overlying a weaker soil layer, the end bearing resistance shall be reduced if the tip elevation is within 1.5 times the diameter of the drilled shaft above the top of the weaker soil layer. A weighted average that varies linearly from the full end bearing resistance in the overlying strong soil layer at a distance of 1.5 times the diameter of the drilled shaft above the top of the weak soil layer to the end bearing resistance of the weak soil layer at the top of the weak soil layer should be used to determine the end bearing resistance utilized in the design. Therefore, the end bearing resistance utilized in the design will need to be adjusted accordingly if the tip elevation of the drilled shafts will be within 1.5 times the diameter of the drilled shaft above the underlying weaker soil layer.

It is anticipated that 100 percent of the side friction resistance will be mobilized at a displacement of 1.0 percent of the diameter of the shaft, which is approximately 0.4 inches for a 3.5-foot diameter shaft. At this displacement, approximately 30 percent of the end bearing resistance will be mobilized. Therefore, if the drilled shafts are designed using a combination of side and end bearing resistance, the nominal end bearing resistance noted in Table 3 should be reduced to 30 percent of the values provided for the respective tip elevation in the determination of the design shaft resistance. Drilled shaft calculations are provided in Appendix V.

5.1.1 Group Efficiency

The axial resistance of a group of shafts may be less than the sum of the individual shaft resistance within a group of shafts. Per Section 10.8.3.6.3 of the 2017 AASHTO LRFD BDS, for soil profiles that consist of primarily granular soils, the individual nominal resistance of each drilled shaft shall be reduced by applying an adjustment factor, η, as defined in Table 10.8.3.6.1-1 of the 2017 AASHTO LRFD BDS. The following criteria are recommended for the group resistance of any shaft groups:

- η = 0.9 for a center-to-center spacing of 2.0 diameters,
- η = 1.0 for a center-to-center spacing of 3.0 diameters or greater,
- For intermediate spacing, the value of η may be determined by liner interpolation.

Please note that the adjustment factor should be applied to the total individual nominal shaft resistance (including both end bearing side resistance along the shaft length).

Given that the drilled shafts will be constructed tangent to each other, the shaft group capacity should also be checked using the block failure mechanism. Since the soil profile consists primarily of dense granular soils, the analysis should be performed considering the entire drilled shaft group as an equivalent strip footing with a length equal to the length of the tangent shaft wall and equivalent width equal to the total end area of the drilled shafts divided by the length of the drilled shaft wall. A resistance factor of φ_b = 0.45 should be utilized in calculating the factored bearing resistance for the this failure mode at the strength limit state.

The total group resistance shall be the lesser of the sum of the individual drilled shafts multiplied by the applicable group efficiency factor, η, or the factored resistance of the group in block failure mode.

5.1.2 Lateral Design

If lateral load or moments are expected to be applied on the foundation elements, they should be analyzed to verify the shaft has enough lateral and bending resistance against these loads. A boring-by-boring tabulation of parameters that should be used for lateral loading design is provided in Appendix VI. 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 required to resist the lateral load for a given end condition and deflection. Table 4 lists the eleven different soil types internal to the LPILE program. These strata were utilized to define the soil strata in the soil profile for each boring provided in Appendix VI.

Table 4. Subsurface 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)

For the case of closely spaced drilled shafts, a pile group reduction factor will need to be applied to the p-y curves that are internally generated by the lateral analysis software. Reese, Isenhower, and Wang published an equation for the pile group p-reduction factor, otherwise known as p-multiplier (β_a), for a single row of piles placed side by side in the publication “Analysis and Design of Shallow and Deep Foundations” (2006), as follows:

$$\beta_a = 0.64(S/D)^{0.34}$$

In which:

$$1 \leq S/D < 3.75 \text{ and } 0.5 \leq \beta_a \leq 1.0$$

Where:
S = center to center spacing of the drilled shafts
D = diameter of drilled shafts

It is understood that GPD GROUP has performed an analysis of the lateral loading on the drilled shaft elements, which were utilized to determine the shaft tip elevation provided in the Stage 2 design plans.

5.2 Lateral Earth Pressure

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 5 and Table 6.

Table 5. Estimated Undrained (Short-term) Soil Parameters for Design

Soil Type	γ (pcf) [1]	c (psf)	φ	k_a	k_o	k_p
Soft to Stiff Cohesive Soil	115	0	26°	0.35	0.56	4.53
Very Stiff to Hard Cohesive Soil	125	50	28°	0.32	0.53	5.07
Loose Granular Soil	120	0	28°	0.32	0.53	5.07
Medium Dense Granular Soil	125	0	32°	0.27	0.47	6.82
Dense to Very Dense Granular Soil	130	0	36°	0.23	0.41	9.09
Compacted Cohesive Engineered Fill	120	0	30°	0.30	0.50	5.58
Compacted Granular Engineered Fill	120	0	32°	0.27	0.47	6.82

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

Table 6. Estimated Drained (Long-term) Soil Parameters for Design

Soil Type	γ (pcf) [1]	c (psf)	φ'	k_a	k_o	k_p
Soft to Stiff Cohesive Soil	115	1,500	0°	N/A	N/A	N/A
Very Stiff to Hard Cohesive Soil	125	3,000	0°	N/A	N/A	N/A
Loose Granular Soil	120	0	28°	0.32	0.53	5.07
Medium Dense Granular Soil	125	0	32°	0.27	0.47	6.82
Dense to Very Dense Granular Soil	130	0	36°	0.23	0.41	9.09
Compacted Cohesive Engineered Fill	120	2,000	0°	N/A	N/A	N/A
Compacted Granular Engineered Fill	120	0	32°	0.27	0.47	6.82

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

These parameters are considered appropriate for the design of all subsurface structures and any excavation support systems. Subsurface structures (where the top of the structure is restrained from movement) should be designed based on at-rest conditions (k_o). For proposed temporary retaining structures (where the top of the structure is allowed to move), earth pressure distributions should be based on active (k_a) and passive (k_p) conditions. 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 considered). Earth pressures on excavation support systems will be dependent on the type of sheeting and method of bracing or anchorage.

5.3 Construction Considerations

All site work shall conform to local codes and to the latest ODOT Construction and Materials Specifications (CMS), including that all excavation and embankment preparation and construction should follow ODOT Item 200 (Earthwork).

5.3.1 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, sheeting boxes 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 7. Excavation Back Slopes

Soil	Maximum Back Slope	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
Rock to 3.0' +/- below Auger Refusal	0.75 : 1.0	Above Ground Water Table and No Seepage
Stable Rock	Vertical	Above Ground Water Table and No Seepage

5.3.2 Groundwater Considerations

Based on the groundwater observations made during drilling in borings B-026-1-13 and B-024-1-13, groundwater may be encountered during construction of the drilled shafts. Where groundwater is encountered, proper groundwater control should be employed and maintained to prevent disturbance to excavation bottoms consisting of cohesive soil, and to prevent the possible development of a quick or "boiling" condition where soft silts and/or fine sands are encountered. It is preferable that the groundwater level, if encountered, be maintained at least 36 inches below the deepest excavation. In the case of drilled shafts, the utilization of casing will be required below the water table to maintain an open hole and prevent the sidewalls from collapse. In addition, concrete placed below the water table should be placed by tremie method using a rigid tremie pipe. Any seepage or groundwater encountered at this site should be able to be controlled by pumping from temporary sumps. Additional measures may be required depending on seasonal fluctuations of the groundwater level. Note that determining and maintaining actual groundwater levels during construction is the responsibility of the contractor.

6.0 LIMITATIONS OF STUDY

The recommendations 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 historic and current test borings that were made at the proposed site. Resource International is not responsible for the data, conclusions, opinions or recommendations made by others during previous investigations at this 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.

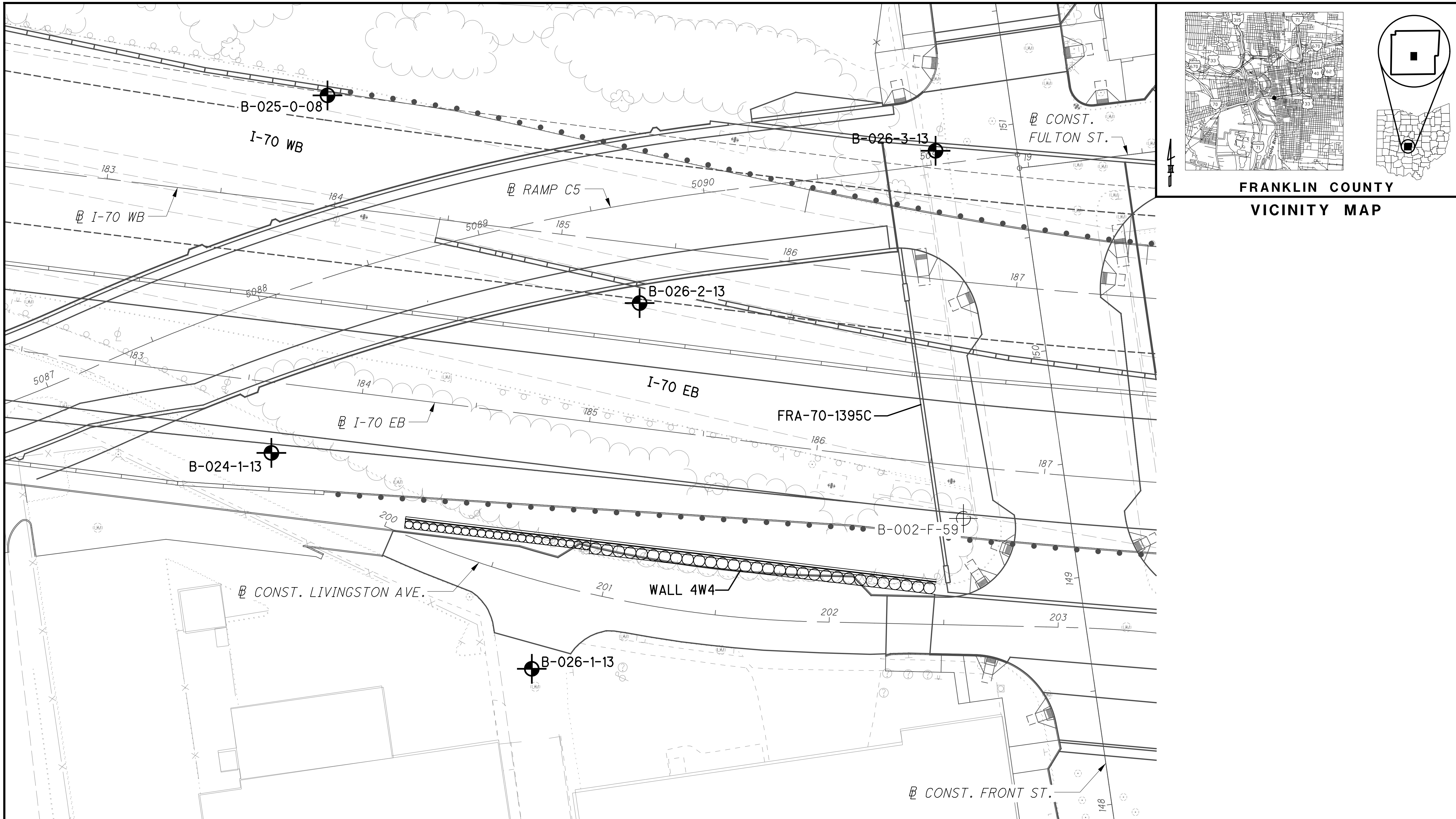
The conclusions and recommendations herein have been based upon the available soil and bedrock information and the design details furnished by a representative of the owner of the proposed project. Any revision in the plans for the proposed construction from those anticipated in this report should be 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 of 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



BORING PLAN

FRA-70-12.68 - RETAINING WALL 4W4

FRANKLIN COUNTY, OHIO

RII PROJECT NO. W-13-045

SCALE: 1"=40'

0 20 40

DRAWN RRM

REVIEWED BRT

DATE 7-11-18

RESOURCE INTERNATIONAL, INC.

APPENDIX II

DESCRIPTION OF SOIL TERMS

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 – ODOT A-1, A-2, A-3, A-4 (non-plastic)
The relative compactness of granular soils is described as:

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 – ODOT A-4, A-5, A-6, A-7, A-8
The relative consistency of cohesive soils is described as:

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		Size
Boulders		Larger than 12”
Cobbles		12” to 3”
Gravel	coarse	3” to ¾“
	fine	¾” to 2.0 mm (¾” to #10 Sieve)
Sand	coarse	2.0 mm to 0.42 mm (#10 to #40 Sieve)
	fine	0.42 mm to 0.074 mm (#40 to #200 Sieve)
Silt		0.074 mm to 0.005 mm (#200 to 0.005 mm)
Clay		Smaller than 0.005 mm

Modifiers of Components - The following modifiers indicate the range of percentages of the minor soil components:

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 - ODOT
Dry	Well below Plastic Limit
Damp	Below Plastic Limit
Moist	Above PL to 3% below LL
Wet	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.

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 AASHTO	Classifcation OHIO	LL_O/LL × 100*	% Pass #40	% Pass #200	Liquid Limit (LL)	Plastic Index (PI)	Group Index Max.	REMARKS
	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.

APPENDIX III

PROJECT BORING LOGS:

B-026-0-13 and B-024-1-13

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-70-12.68 - PHASE 4A	DRILLING FIRM / OPERATOR: RII / J.K.	DRILL RIG: CME 55 (SN 386345)	STATION / OFFSET: 5087+81.22 / 64.3' RT
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / C.D.	HAMMER: CME AUTOMATIC	ALIGNMENT: BL RAMP C5
PID: 77372 BR ID: FRA-70-1390	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 10/20/14	ELEVATION: 746.4 (MSL) EOB: 64.3 ft.
START: 2/11/15 END: 2/14/15	SAMPLING METHOD: SPT	ENERGY RATIO (%): 92	LAT / LONG: 39.952930262, -83.001880690

EXPLORATION ID **B-024-1-13**

MATERIAL DESCRIPTION AND NOTES	ELEV. 746.4	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
1.2' - ASPHALT (14.0")	745.2																	
0.5' - AGGREGATE BASE (6.0")	744.7																	
VERY STIFF TO HARD, BROWN **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, TRACE TO LITTLE FINE GRAVEL, DAMP.			8 6 5	17	33	SS-1	4.50	-	-	-	-	-	-	-	-	12	A-6a (V)	
	740.9		2 6 7	20	100	SS-2	3.50	-	-	-	-	-	-	-	-	15	A-6a (V)	
VERY DENSE, GRAY **GRAVEL**, TRACE COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, DAMP.	738.4		9 19 20	60	33	SS-3	-	83	7	3	5	2	NP	NP	NP	3	A-1-a (0)	
HARD, GRAY **SANDY SILT**, SOME FINE GRAVEL, LITTLE CLAY, DAMP.	735.9		12 17 13	46	89	SS-4	4.5+	23	13	14	31	19	23	13	10	8	A-4a (3)	
DENSE, GRAY **GRAVEL**, TRACE COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, DAMP.	733.4		19 16 13	44	39	SS-5	-	-	-	-	-	-	-	-	-	3	A-1-a (V)	
HARD, GRAY TO DARK GRAY **SANDY SILT**, LITTLE CLAY, LITTLE FINE GRAVEL, DRY TO DAMP. -SS-6: SULFATE CONCENTRATION = 1,447 PPM			9 10 13	35	100	SS-6	4.5+	-	-	-	-	-	-	-	-	5	A-4a (V)	
			16 22 18	61	39	SS-7	-	-	-	-	-	-	-	-	-	7	A-4a (V)	
			6 13 11	37	67	SS-8	4.5+	18	14	17	32	19	22	13	9	9	A-4a (3)	
	723.4		9 8 10	28	100	SS-9	4.50	-	-	-	-	-	-	-	-	10	A-4a (V)	
VERY DENSE, DARK GRAY **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, DAMP.	720.9		14 30 19	75	100	SS-10	-	31	28	27	9	5	NP	NP	NP	5	A-1-b (0)	
HARD, GRAY **SILT AND CLAY**, TRACE FINE SAND, MOIST.			7 10 18	43	100	SS-11	4.5+	-	-	-	-	-	-	-	-	18	A-6a (V)	
			6 10 15	38	100	SS-12	4.5+	0	0	3	49	48	30	15	15	18	A-6a (10)	

PID: 77372 | BR ID: FRA-70-1390 | PROJECT: FRA-70-12.68 - PHASE 4A | STATION / OFFSET: 5087+81.22 / 64.3 RT | START: 2/11/15 | END: 2/14/15 | | B-024-1-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 716.4	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
HARD, GRAY **SILT AND CLAY**, TRACE FINE SAND, MOIST. *(same as above)*	714.4	31–32																
VERY DENSE, DARK GRAY **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST.		W 34	21 30 24	83	89	SS-13	-	-	-	-	-	-	-	-	-	8	A-1-a (V)	
		39	4 15 50/4"	-	81	SS-14	-	72	16	5	4	3	17	13	4	8	A-1-a (0)	
		44	14 50/3"	-	44	SS-15	-	-	-	-	-	-	-	-	-	8	A-1-a (V)	
		49	50/3"	-	100	SS-16	-	-	-	-	-	-	-	-	-	5	A-1-a (V)	
	694.4	52																
DENSE, GRAY **COARSE AND FINE SAND**, SOME FINE GRAVEL, TRACE SILT, TRACE CLAY, MOIST. -HEAVING SANDS ENCOUNTERED @ 53.5' -INTRODUCED WATER @ 53.5' -PETROLEUM ODOR PRESENT IN SS-17		54	12 14 15	44	89	SS-17	-	-	-	-	-	-	-	-	-	13	A-3a (V)	
	689.4	57																
HARD, GRAY **SILT AND CLAY**, SOME FINE GRAVEL, SOME COARSE TO FINE SAND, DAMP.		59	50/5"	-	80	SS-18	4.5+	34	14	13	25	14	23	13	10	6	A-4a (1)	
	684.4	62																

PID: 77372	BR ID: FRA-70-1390	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 5087+81.22 / 64.3 RT	START: 2/11/15	END: 2/14/15	PG 3 OF 3	B-024-1-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 684.3	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
VERY DENSE, BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, MOIST. *(same as above)*		63																
	682.1	EOB 64	47 50/3"	-	100	SS-19	-	-	-	-	-	-	-	-	-	11	A-1-b (V)	

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 3/28/15 22:00 - U:\GI8\PROJECTS\2013\W-13-045.GPJ

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 34.0'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 188 LBS CEMENT / 50 LABS BENTONITE POWDER / 40 GAL WATER

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-12.68 - PHASE 4A	DRILLING FIRM / OPERATOR: RII / T.F.	DRILL RIG: MOBILE B-53 (SN 624400)	STATION / OFFSET: 184+88.08 / 111.1' RT
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / S.M.	HAMMER: AUTOMATIC	ALIGNMENT: BL I-70 EB
PID: 77372 BR ID: N/A	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 4/26/13	ELEVATION: 747.0 (MSL) EOB: 50.0 ft.
START: 9/19/13 END: 9/19/13	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.7	LAT / LONG: 39.952673289, -83.001473185

EXPLORATION ID: B-026-1-13

PAGE 1 OF 2

MATERIAL DESCRIPTION AND NOTES	ELEV. 747.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.3' - ASPHALT (4.0")	746.7																	
0.7' - AGGREGATE BASE (8.0")	746.0	1																
FILL: MEDIUM DENSE TO VERY DENSE, GRAY TO BROWN **GRAVEL WITH SAND AND SILT**, TRACE CLAY, DAMP.		2	23 / 14 / 7	27	50	SS-1	-	-	-	-	-	-	-	-	-	9	A-2-4 (V)	
		3																
		4	4 / 9 / 9	23	50	SS-2	-	17	34	14	26	9	27	22	5	10	A-2-4 (0)	
		5																
		6																
		7																
		8																
		9	12 / 27 / 27	70	61	SS-3	-	-	-	-	-	-	-	-	-	8	A-2-4 (V)	
		10																
		11																
	735.0																	
FILL: DENSE, GRAY AND BROWN **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, DAMP.		12																
		13																
		14	12 / 17 / 19	47	33	SS-4	-	63	16	6	10	5	22	18	4	4	A-1-a (0)	
		15																
	731.5																	
MEDIUM DENSE TO DENSE, BROWN TO GRAY **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, DAMP TO MOIST.		16																
		17	11 / 14 / 20	44	50	SS-5	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	
		18																
		19	9 / 12 / 12	31	44	SS-6	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	
		20																
		21																
		22	7 / 9 / 14	30	56	SS-7	-	31	32	14	19	4	21	18	3	7	A-1-b (0)	
		23																
		24	13 / 15 / 17	41	61	SS-8	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	
		25																
		26																
		27	9 / 16 / 17	43	50	SS-9	-	-	-	-	-	-	-	-	-	10	A-1-b (V)	
	719.0																	
VERY DENSE, BROWN **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, DAMP TO MOIST.		W 28																
		29	15 / 17 / 25	54	33	SS-10	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	

PID: 77372	BR ID: N/A	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 184+88.08 / 111.1 RT	START: 9/19/13	END: 9/19/13	PG 2 OF 2	B-026-1-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 717.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
VERY DENSE, BROWN **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, DAMP TO MOIST. *(same as above)*		31–32	16 16 23	51	33	SS-11	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
		33–35	30 32 33	84	39	SS-12	-	70	10	0	18	2	20	16	4	6	A-1-b (0)	
		38.5–40	27 29 33	80	50	SS-13	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	
		43.5–45	27 25 32	74	67	SS-14	-	-	-	-	-	-	-	-	-	7	A-1-b (V)	
	697.0	48.5–50 EOB	25 26 27	69	72	SS-15	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 28.5'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 50 LBS BENTONITE CHIPS AND SOIL CUTTINGS

APPENDIX IV

HISTORIC BORING LOG

B-002-F-59

SHEET 4

STATE OF OHIO
DEPARTMENT OF HIGHWAYS
TESTING LABORATORY

LOG OF BORING

CO., RT. NO., SEC. FRA-40-12.82 REAR ABUTMENT BRIDGE NO. FRA-40-1300 SOUTH INNERBELT UNDER FRONT STREET

LOCATION: T.H. 2B STA. 49+33 OFFSET 46'LT FED. NO.

ELEV.	DEPTH	NO. BLOWS	SAMPLE NO.	DESCRIPTION
754.7	0			
	2			
	4			
749.7	6	3/5	19858	Brown Silty Sandy Gravel
	8			
744.7	10			
	12	15/14	19859	Brown Silty Sandy Gravel
	14			
739.7	16	19/25	19860	Brown Silty Sandy Gravel
	18			
734.7	20			
	22	15/26	19861	Brown Silty Sandy Gravel
732.2	24	100/*	19862	Brown Sandy Gravel
729.7	26	18/21	19863	Brown Silty Sandy Gravel
727.2	28	38/59	19864	Brown Silty Sandy Gravel
724.7	30			
	32	34/31	19865	Brown Silty Sandy Gravel
722.2	34	42/*	19866	Brown Silty Sandy Gravel
719.7	36	21/57	19867	Gray Silty Sandy Gravel

*Refusal

BM
6.26.59

B-002-F-59

LOG OF BORING (CONTINUED)

SHEET 5

BRIDGE NO. FRA-40-1300 T.H. 2 B

ELEV.	DEPTH	NO. BLOWS	SAMPLE NO.	DESCRIPTION
717.2	38	35/62	19868	Gray Sandy Gravel
714.7	40	60/128	19869	Gray Silty Sandy Gravel
712.2	42			
	44	47/70	19870	Gray Silty Sandy Gravel
709.7	46	45/52	19871	Gray Silty Sandy Gravel
	48			
704.7	50			
	52	75/108	19872	Gray Sandy Gravel
	54			
699.7	56	77/150	------	Gray Silty Sandy Gravel
	58			
694.7	60			
	62	138/*	19873	Gray Silty Sandy Gravel
	64			
689.7	66	62/109	19874	Gray Silty Gravelly Sand
	68			
684.7	70			
	72	138/*	-----	Gray Silty Gravelly Sand
682.2		70/*	19875	Gray Silty Sandy Gravel
681.7	74			BOTTOM OF BORING
	76			
	78			
	80			
	82			

*Refusal

APPENDIX V

DRILLED SHAFT CALCULATION

Boring	Proposed Top of Shaft Elevation (ft msl)	D_w (ft)	Shaft Diameter, D (ft)	Soil Class.	Material Type [1]	Stratum Depth, z (ft)	Stratum Thickness (ft)	Bottom Elevation (ft msl)	γ (pcf)	σ_v' (Midpoint) (psf)	σ_v (Bottom) (psf)	S_u [2] (psf)	N_c [3]	α [4]	N_{60} [5]	$(N_1)_{60}$ [6]	φ'_f [7]	σ_p' [8] (psf)	β [9]
B-002-F-59	726.0	6.0	5.0	A-2-4	G	2.4	2.4	723.6	135	162	324				79	65	41	25,122	8.18
				A-1-b	G	13.9	11.5	712.1	135	966	1,877				88	64	42	27,984	2.83
				A-1-a	G	34.9	21.0	691.1	135	2,146	4,712				100	65	43	31,800	1.86
				A-3a	G	44.9	10.0	681.1	135	3,271	6,062				100	59	40	15,792	0.82
B-024-1-13	727.0	14.6	3.5	A-4a	C	6.1	6.1	720.9	130	397	793	5,250	8.1	0.45					
				A-6a	C	12.6	6.5	714.4	130	1,216	1,638	5,000	9.0	0.46					
				A-1-a	G	32.6	20.0	694.4	135	2,489	4,338				100	70	43	31,800	1.69
				A-3a	G	37.6	5.0	689.4	130	3,384	4,988				44	28	37	9,650	0.56
				A-4a	C	42.6	5.0	684.4	130	3,722	5,638	8,000	9.0	0.45					
				A-1-b	G	44.6	2.0	682.4	135	3,963	5,908				100	61	42	31,800	1.20
B-026-1-13	726.0	7.5	5.0	A-1-b	G	7.0	7.0	719.0	130	455	910				39	36	40	12,402	2.51
				A-1-b	G	12.0	5.0	714.0	125	1,098	1,535				52	41	41	16,536	1.77
				A-1-b	G	29.0	17.0	697.0	135	1,871	3,830				77	56	42	24,486	1.66

Boring	Elevation (ft msl)	Shaft Length (ft)	Nominal Tip Resistance, q_p [10,11] (ksf)	Nominal Side Resistance, q_s [12,13] (ksf)	φ_{qp} [14]	φ_{qs} [15]
B-002-F-59	726.0-723.6	0.0-2.4	60	1.32	0.50	0.55
	723.6-712.1	2.4-13.9	60	2.73	0.50	0.55
	712.1-691.1	13.9-34.9	60	4.00	0.50	0.55
	691.1-681.1	34.9-44.9	60	2.69	0.50	0.55
B-024-1-13	727.0-720.9	0.0-6.1	42	2.37	0.40	0.45
	720.9-714.4	6.1-12.6	45	2.32	0.40	0.45
	714.4-694.4	12.6-32.6	60	4.19	0.50	0.55
	694.4-689.4	32.6-37.6	52	1.90	0.50	0.55
	689.4-684.4	37.6-42.6	72	3.60	0.40	0.45
	684.4-682.4	42.6-44.6	60	4.75	0.50	0.55
B-026-1-13	726.0-719.0	0.0-7.0	46	1.14	0.50	0.55
	719.0-714.0	7.0-12.0	60	1.94	0.50	0.55
	714.0-697.0	12.0-29.0	60	3.11	0.50	0.55

1. C = cohesive soil stratum; G = granular soil stratum
2. $S_u = 125(N_{60}) \leq 8{,}000$ psf (cohesive soil layers)
3. $N_C = 6[1+0.2(Z/D)] \leq 9$; Ref. Section 10.8.3.5.1c, AASHTO LRFD BDS (cohesive soil layers)
4. $\alpha = 0.55$ for $S_u/P_a \leq 1.5$; $\alpha = 0.55-0.1(S_u/P_a-1.5)$ for $1.5 \leq S_u/P_a \leq 2.5$, where P_a = 2.12 ksf = 2,120 psf; Ref. Section 10.8.3.5.1b AASHTO LRFD BDS (cohesive soil layers)
5. N_{60} = average energy corrected N-values over stratum thickness (granular soil layers)
6. $(N_1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_v')] \leq 2.0$ ksf, where σ_v' = vetical effective stress at midpoint of soil layer with respect to the entire soil profile for the respective boring; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS (granular soil layers)
7. φ'_f estimated per Table 10.4.6.2.4-1; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS (granular soil layers)
8. $\sigma_p' = n(N_{60})^m(P_a)$, where n = 0.15 and m = 1.0 for A-1-a/1-b and A-2-4/2-6, n = 0.47 and m = 0.6 for A-3/3a, n = 0.47 and m = 0.8 for A-4a/4b soils, and P_a = 2.12 ksf = 2,120 psf; Ref. Section 10.8.3.5.2b, AASHTO LRFD BDS (granular soil layers)
9. $\beta = \tan\varphi'_f(1-\sin\varphi'_f)(\sigma_p'/\sigma_v')$^$(\sin\varphi'_f)$, where σ_v' = vetical effective stress at midpoint of soil layer; Ref. Section 10.8.3.5.2b, AASHTO LRFD BDS (granular soil layers)
10. $q_p = N_C S_u \leq 80.0$ ksf; Ref. Section 10.8.3.5.1c, AASHTO LRFD BDS (cohesive soil layers)
11. $q_p = 1.2N_{60} \leq 60$ ksf; Ref. Section 10.8.3.5.2c, AASHTO LRFD BDS (granular soil layers)
12. $q_s = \alpha S_u$; Ref. Section 10.8.3.5.1b, AASHTO LRFD BDS (cohesive soil layers)
13. $q_s = \beta\sigma_v'$, where σ_v' = vetical effective stress at midpoint of soil layer; Ref. Section 10.8.3.5.2b, AASHTO LRFD BDS (granular soil layers)
14. φ_{qp} = 0.50 for granular soils layers and 0.40 for cohesive soil layers; Ref. Table 10.5.5.2.4-1, AASHTO LRFD BDS
15. φ_{qs} = 0.55 for granular soils layers and 0.45 for cohesive soil layers; Ref. Table 10.5.5.2.4-1, AASHTO LRFD BDS

APPENDIX VI

LATERAL DESIGN PARAMETERS

Boring No.	Elevation (feet msl)	Soil Class.	Soil Type	Strata	N_{60}	$N1_{60}$	γ (pcf)	γ' (pcf)	Strength Parameter	k (soil) k_{rm} (rock)	ε_{50} (soil) E_r (rock)	RQD (rock)
B-002-F-59	754.1 to 746.1	A-1-a	G	4	8	12	120	120	φ = 36°	160 pci	-	-
	746.1 to 732.1	A-1-b	G	4	38	39	130	130	φ = 40°	280 pci	-	-
	732.1 to 723.6	A-2-4	G	4	79	65	135	135	φ = 41°	315 pci	-	-
	723.6 to 712.1	A-1-b	G	4	88	64	135	72.6	φ = 42°	195 pci	-	-
	712.1 to 691.1	A-1-a	G	4	100	65	135	72.6	φ = 43°	215 pci	-	-
	691.1 to 681.1	A-3a	G	4	100	59	135	72.6	φ = 40°	155 pci	-	-
B-024-1-13	746.4 to 738.4	A-6a	C	3	18	18	120	120	Su = 2,250 psf	750 pci	0.0060	-
	738.4 to 720.9	A-4a	C	3	42	42	130	130	Su = 5,250 psf	1,750 pci	0.0043	-
	720.9 to 714.4	A-6a	C	3	40	40	130	130	Su = 5,000 psf	1,665 pci	0.0043	-
	714.4 to 694.4	A-1-a	G	4	100	70	135	72.6	φ = 43°	215 pci	-	-
	694.4 to 689.4	A-3a	G	4	44	28	130	67.6	φ = 37°	110 pci	-	-
	689.4 to 684.4	A-4a	C	2	100	100	130	67.6	Su = 8,000 psf	2,665 pci	0.0033	-
	684.4 to 682.4	A-1-b	G	4	100	61	135	72.6	φ = 42°	195 pci	-	-
B-026-1-13	747.0 to 740.0	A-2-4	G	4	25	38	125	125	φ = 39°	250 pci	-	-
	740.0 to 735.0	A-2-4	G	4	70	82	135	135	φ = 41°	315 pci	-	-
	735.0 to 719.0	A-1-b	G	4	39	36	130	130	φ = 40°	280 pci	-	-
	719.0 to 714.0	A-1-b	G	4	52	41	125	62.6	φ = 41°	175 pci	-	-
	714.0 to 697.0	A-1-b	G	4	77	56	135	72.6	φ = 42°	195 pci	-	-