Resource International, Inc.

FRA-70-12.68 PROJECT 4R
FRA-70-1358A
RAMP C5 OVER CSX AND NORFOLK SOUTHERN RAILROAD
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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RESOURCE INTERNATIONAL, INC.
ISO | ISO 9001:2008 Certified QMS
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Planning

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Technology

December 23, 2014 (Revised January 30, 2019)

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Re: Structure Foundation Exploration Report
FRA-70-12.68 Project 4R
FRA-70-1358A – Ramp C5 over CSX and NS Railroad
Retaining Wall 4W11
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. Engineering logs have been prepared and are attached to this report along with the results of laboratory testing. This report includes recommendations for the design and construction of the proposed FRA-70-1358A bridge structure carrying Ramp C5 over CSX and Norfolk Southern Railroad 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 structure foundation exploration or this report, please contact us.

Sincerely,

RESOURCE INTERNATIONAL, INC.

Brian R. Trenner, P.E.
Director – Geotechnical Programming

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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 the FRA-70-1358A bridge structure carrying the proposed Ramp C5 over CSX and Norfolk Southern railroads. Based on information provided by Burgess and Niple, it is understood that the proposed bridge will consist of a two-span continuous straight welded steel plate girder structure with a composite reinforced concrete deck with pile supported semi-integral stub abutments behind mechanically stabilized earth (MSE) walls and reinforced concrete wall-type pier.

Retaining Wall 4W10 will be located at the rear abutment of the proposed structure to provide the required grade separation to support the configuration. Based on plan information provided by Dynotec, it understood that only a portion of the wall will be constructed as part of Project 4R, which will be between Sta. 167+35, 196.3' Rt. (BL I-70 EB) to Sta. 6002+19, 23.0' Lt. (BL Ramp C6). The remainder of the wall will be constructed as part of Project 4A when I-70 eastbound is upgraded. The wall height will range from 4.5 feet at the beginning of the wall alignment to a maximum height of 40.2 feet at the proposed abutment, and the total wall length is approximately 135 lineal feet to the termination at Temporary Wall T2. Additionally, please note that the analysis and recommendations for the portion of Retaining Wall 4W8, between Sta. 169+29, 62.2' Rt. to 169+67, 132.0' Lt. (BL I-70 EB), at the forward abutment is presented under this report cover. It is understood that a mechanically stabilized earth (MSE) wall type is being considered as the preferred wall type for Retaining Walls 4W8 and 4W10.

Exploration and Findings

Between July 18, 2013, and February 6, 2014, five (5) structural borings, designated as B-017-3-13 through B-017-7-13, were drilled along the proposed bridge alignments at the locations shown on the boring plan provided in Appendix I of the full report. The borings were advanced to completion depths ranging from 76.3 to 96.7 feet below the existing ground surface at the respective boring location

Borings B-017-3-13 and B-017-7-13 were performed in the south shoulder of I-70 eastbound and encountered 6.0 and 11.0 inches of asphalt overlying 4.0 and 6.0 inches of aggregate base, respectively, at the ground surface. Boring B-017-4-13 and B-017-5-13 were performed in grass areas south of I-70 and west of the existing railroad tracks, just off of an access road that runs adjacent to the railroad tracks, and encountered 6.0 and 2.0 inches of topsoil at the ground surface, respectively. Boring B-017-6-13 was performed within the dirt packed access road that runs from Short Street to the railroad tracks just south of I-70.

Beneath the existing pavement, existing embankment fill was encountered in borings B-017-3-13 and B-017-7-13 extending to a depth of 32.0 and 39.0 feet below the existing ground surface, respectively. The embankment fill consisted of brown, gray, brownish gray and black gravel, gravel and sand, silt and clay, silty clay and clay (ODOT A-1-a, A-1-b, A-6a, A-6b, A-7-6) and did not contain any deleterious material.

Beneath the surface materials in borings B-017-5-13 and B-017-6-13, material identified as existing fill was encountered extending to a depth of 5.0 and 10.5 feet below the existing ground surface, respectively. The fill material consisted of gravel and sand with seams of silt and clay (ODOT A-1-b, A-6a) and contained slag, cinders and organics throughout. Wood fragments were recovered at the bottom of the existing fill in boring B-017-7-13.

Underlying the surficial materials and fill material, and below the topsoil in boring B-017-4-13, natural granular soils were predominantly present in the upper 25 to 52 feet of the soil profile overlying cohesive soils. The granular soils were generally described as brown, gray and black gravel, gravel and sand and gravel with sand and silt and coarse and fine sand (ODOT A-1-a, A-1-b, A-2-4, A-3a). The cohesive soils were described as brown, gray, reddish brown and black sandy silt, silt and clay, silty clay, elastic clay and clay (ODOT A-4a, A-6a, A-6b, A-7-5, A-7-6).

Shale bedrock was encountered across the site at a depths ranging from 53.5 to 90.0 feet below the ground surface, which corresponds to elevations ranging from 650.0 feet msl in boring B-017-5-13 to 659.3 feet msl in boring B-017-4-13. However, this weathered bedrock material was able to be augered in borings B-017-4-13 through B-017-6-13, while this material required rock coring techniques to advance the borings in borings B-017-3-13 and B-017-7-13 and for a portion of the shale encountered between limestone layers in boring B-017-4-13. Competent limestone bedrock was encountered in borings B-017-4-13 through B-017-6-13 at a depths ranging from 72.8 to 74.5 feet below the ground surface, respectively, which corresponds to elevations ranging from 640.0 feet msl in boring B-017-4-13 to 642.5 feet msl in boring B-017-5-13.

Analyses and Recommendations

Borings B-017-9-13, B-018-1-13 and B-018-2-13, which were performed for the FRA-70-1358L bridge structure as part of the FRA-70-13.10 Phase 6A project, were also referenced to further delineate the bedrock stratigraphy at the site.

Driven Pile Recommendations

Given the depth to bedrock encountered in the borings, it is recommended that steel H-piles (ODOT Item 507.06) driven to refusal on bedrock be employed for foundation support of the proposed substructure elements. Per Section 202.2.3.2a of the 2007 ODOT Bridge Design Manual, refusal is met during driving when the pile penetration is an inch or less after receiving at least 20 blows from the pile hammer. Table 7 shows the recommended pile lengths and the corresponding factored structural axial resistance ($R_{R\ max}$) of steel H-piles.

FRA-70-1358A Driven Pile Recommendations

Substructure Reference (Boring)	Ground Elevation [1]	Pile Size	Pile Elevation		Pile Length [3] (feet)	$R_{R\ max}$ [4] (kips/pile)	Sleeve Length [5]	φ [6]
			Top [2]	Tip				
Rear Abutment (B-017-3-13 / B-017-4-13)	740.3 / 712.8	HP 10x42	735.1	646.5	90	310	26.2	N/A
Pier 1 (B-017-5-13)	717.0	HP 10x42	712.5	642.5	70	310	N/A	N/A
Forward Abutment (B-017-6-13 / B-017-7-13)	714.9 / 743.1	HP 10x42	737.0	640.4	100	310	26.0	N/A

1. *Ground elevation listed is the ground elevation at the respective boring location.*
2. *The top of pile elevation corresponds to the pile cutoff elevation, which is 1.0-foot above the proposed bottom of footing elevation.*
3. *Per Section 202.3.2 of the 2007 ODOT BDM, the estimated pile length was determined as the pile cutoff elevation (top) minus the pile tip elevation, rounded up to the nearest 5.0 feet.*
4. *The factored structural axial resistance for H-piles is based on the structural limit state of the steel H-pile section per Section 202.2.3.2.a of the 2007 ODOT BDM.*
5. *Sleeve length represents the required length of pile that should be sleeved within the MSE wall backfill, including the foundation preparation.*
6. *For H-piles driven to refusal on bedrock, no geotechnical resistance factor should be applied to the factored structural axial resistance values presented, as the values presented account for the structural resistance factor, φ_c = 0.50, for H-piles subject to damage due to severe driving conditions.*

The anticipated total settlement at the facing of the wall at the rear and forward abutments is 2.07 and 6.73 inches, respectively. Results of the settlement analysis indicate that approximately 90 percent of the primary consolidation of the cohesive layers at the rear and forward abutment will be complete within sixty (60) days following the placement if the surcharge load. Therefore, if the above noted waiting period is specified following completion of construction of the MSE walls at the rear and forward abutments, downdrag forces along the piles will be eliminated.

<u>MSE Wall Recommendations</u>

Based on proposed plan and profile information provided by Burgess and Niple and Dynotec, the wall heights at the rear and forward abutment of the FRA-70-1358A structure are anticipated to be 40.2 and 40.5 feet, respectively, from the top of the leveling pad to the proposed profile grade of the roadway. Therefore, it is considered that the minimum reinforcement length and the effective foundation width (B) of the rear and forward abutment MSE walls for external and global stability calculations will be 28.1 and 28.4 feet, respectively.

The anticipated bearing materials at the abutment locations consist of natural, stiff silty clay (ODOT A-6b) at the rear abutment (Wall 4W10) and existing fill comprised of medium dense sand and gravel and stiff silt and clay (ODOT A-1-b, A-6a) with slag, cinders and organics at the forward abutment (Wall 4W8). As noted in Section 5.2 of the full report, it is recommended that the weak cohesive soil at the rear abutment (Wall 4W10) be completely over excavated to expose the competent underlying granular soils and replaced with Item 203 granular embankment. However, as noted in Section 5.2 of the full report, it is understood that ground improvement techniques will be implemented along the alignment of Retaining Wall 4W8, including where the wall crosses the forward abutment. As this is a proprietary design, the analysis for this wall considers the existing fill material will remain in place. MSE wall foundations bearing on engineered fill, placed and compacted in accordance with ODOT Item 203, or existing fill material may be proportioned for a nominal bearing resistance as indicated in the following table.

FRA-70-1358A MSE Wall Design Parameters

Substructure Unit [1] (Boring)	Wall Height Analyzed (feet)	Backslope Behind Wall	Minimum Required Reinforcement Length [2] (feet)	Bearing Resistance at Strength Limit (ksf)		Strength Limit Equivalent Bearing Pressure [4] (ksf)
				Nominal	Factored [3]	
Rear Abutment / Retaining Wall 4W10 (B-017-3-13 / B-017-4-13)	40.2	Level	28.1 (0.7H)	28.77	18.70	9.11
Forward Abutment / Retaining Wall 4W8 (B-017-6-13 / B-017-7-13)	40.5	Level	28.4 (0.7H)	8.30	5.40	9.15

1. *Stationing referenced to the baseline of the respective retaining wall.*
2. *The required foundation width is expressed as a percentage of the wall height, H.*
3. *A geotechnical resistance factor of φ_b=0.65 was considered in calculating the factored bearing resistance at the strength limit state.*
4. *The strength limit equivalent bearing pressure is the uniformly distributed pressure asserted by the wall over an effective base width based on the eccentricity of the wall system at the strength limit state.*

Total settlements of 2.75 and 11.03 inches at the center of the reinforced soil mass and 2.07 and 6.73 inches at the facing of the wall are anticipated at the rear and forward abutment, respectively. Based on the results of the analysis, 90 percent of the total settlement at the rear and forward abutment is anticipated to occur over a period of approximately 60 days.

Based on the results of the external and global stability analysis performed for the MSE wall at the rear abutment (Wall 4W10), the recommended controlling strap length is 0.7 times the maximum height of the MSE wall (measured from the top of the leveling pad to the proposed profile grade of the roadway). All remaining external and global stability calculations indicate that adequate resistance is available for support of the MSE wall at the abutment for a strap length equal to 70 percent of the wall height, provided the underlying silty clay soil is over excavated and replaced with Item 203 granular embankment.

Based on the results of the external and global stability analysis performed for the MSE wall at the forward abutment (Wall 4W8), sliding under undrained conditions as well as bearing and global stability under both drained and undrained conditions were not satisfied at a strap length equal to 0.7 times the wall height. Increasing the width of the wall up to 1.0 times the wall height still did not satisfy all of the external and global stability requirements. As noted in Section 5.2 of the full report, consideration was given to over excavating these soils and replacing it with granular embankment; however, similar conditions are anticipated along the remainder of the alignment of Retaining Wall 4W8, which makes this a very expensive and uneconomical option. Recommendations have been provided in the structure foundation exploration report for Retaining Wall 4W8 to incorporate the use of ground improvement techniques to stabilize the existing fill and underlying cohesive soils. The recommendations for this alternative should govern the design of this portion of the wall as well.

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 FRA-70-1358A bridge structure carrying the proposed Ramp C5 over CSX and Norfolk Southern railroads, as shown on the vicinity map and boring plan presented in Appendix I. Based on information provided by Burgess and Niple, it is understood that the proposed bridge will consist of a two-span continuous straight welded steel plate girder structure with a composite reinforced concrete deck with pile supported semi-integral stub abutments behind mechanically stabilized earth (MSE) walls and reinforced concrete wall-type pier. The proposed structure will have a total length of approximately 262 feet and variable width ranging from 59 to 71 feet. In addition, the roadway profile will be elevated approximately 35 feet above the existing ground surface grade.

Retaining Wall 4W10 will be located at the rear abutment of the proposed structure to provide the required grade separation to support the configuration. It is understood that a mechanically stabilized earth (MSE) wall type is being considered as the preferred wall type for Retaining Wall 4W10. Based on plan information provided by Dynotec, it understood that only a portion of the wall will be constructed as part of Project 4R, which will be between Sta. 167+35, 196.3’ Rt. (BL I-70 EB) to Sta. 6002+19, 23.0’ Lt. (BL Ramp C6). The remainder of the wall will be constructed as part of Project 4A when I-70 eastbound is upgraded. A temporary MSE wall, Retaining Wall T2, will be constructed along the north side of the rear abutment to provide support of the proposed Ramp C5 roadway until construction of the I-70 improvements are performed as part of Project 4A. The wall height will range from 4.5 feet at the beginning of the wall alignment to a maximum height of 40.2 feet at the proposed abutment, and the total wall length is approximately 135 lineal feet to the termination at Temporary Wall T2.

Additionally, please note that the analysis and recommendations for the portion of Retaining Wall 4W8, between Sta. 169+29, 62.2’ Rt. to 169+67, 132.0’ Lt. (BL I-70 EB), at the forward abutment is presented under this report cover. Design recommendations for the remaining alignment of Retaining Wall 4W8 is presented under a separate cover.

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 High Street, 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. Bedrock was encountered in borings B-017-4-13 through B-017-6-13 at elevations ranging from 650.0 and 659.3 feet msl.

2.2 Existing Conditions

The proposed FRA-70-1358A structure will be situated along the south side of I-70 eastbound, where the existing I-70 eastbound structure crosses CSX and Norfolk Southern Railroad. The existing I-70 eastbound in the vicinity of the structure is a four-lane, asphalt paved roadway that is aligned east-to-west. Two pairs of railroad tracks cross under the bridge, with the westernmost pair operated by CSX Railroad and the easternmost tracks operated by Norfolk Southern Railroad. An access road also crosses under the bridge, which provides access to the north side of I-70 between the highway and the Scioto River. The existing I-70 roadway profile grade is elevated approximately 25 feet above the railroad and surrounding terrain. The terrain along I-70 slopes gently to the west and the surrounding area is relatively flat-lying, and dense vegetation covers the existing embankment slopes at both ends of the bridge.

3.0 EXPLORATION

Between July 18, 2013, and February 6, 2014, five (5) structural borings, designated as B-017-3-13 through B-017-7-13, were drilled along the proposed bridge alignments at the locations shown on the boring plan provided in Appendix I of this report and summarized in Table 1. The borings were advanced to completion depths ranging from 76.3 to 96.7 feet below the existing ground surface at the respective boring location.

Table 1. Test Boring Summary

Boring Number	Reference Alignment	Station	Offse	Latitude	Longitude	Ground Elevation (feet msl)	Boring Depth (feet)
B-017-3-13	BL I-70 EB	166+20.53	31.8' Rt.	39.953028358	-83.008033736	740.3	87.0
B-017-4-13	BL Ramp C5	5071+46.22	58.4' Rt.	39.952700442	-83.007703124	712.8	76.3
B-017-5-13	BL I-70 EB	167+93.97	62.9' Rt.	39.953017653	-83.007412989	717.0	84.5
B-017-6-13	BL Ramp C5	5074+21.50	19.1' Rt.	39.952895767	-83.006754692	714.9	84.5
B-017-7-13	BL I-70 EB	170+79.36	23.3' Rt.	39.953200568	-83.006425064	743.1	96.7

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

The borings were drilled using a truck or all-terrain vehicle (ATV) mounted rotary drilling machine, utilizing a 3.25-inch or 4.25-inch inside diameter, continuous hollow-stem auger to advance the holes. Standard penetration test (SPT) and split spoon sampling were performed in the borings at 2.5-foot increments of depth to 30.0 feet and at 5.0-foot increments thereafter 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 Mobile B-53 truck and CME 750X ATV-mounted drill rigs used were calibrated on April 26, 2013, and have drill rod energy ratios of 77.7 and 86.8 percent, respectively.

During drilling, Rii personnel prepared field logs 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	114
Plastic and Liquid Limits	AASHTO T89, T90	35
Gradation – Sieve/Hydrometer	AASHTO T88	35
Unconfined Compressive Strength of Intact Rock	ASTM D7012	4

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.

The depth to bedrock was determined by split spoon sampler refusal or auger refusal. Split spoon sampler refusal is defined as exceeding 50 blows from the hammer with less than 6.0 inches of penetration by the split spoon sampler. Auger refusal is defined as no or insignificant observable advancement of the augers with the weight of the drill rig driving the augers.

Where borings were extended into the bedrock (after encountering auger refusal), an NQ or HQ-sized double-tube diamond bit core barrel (utilizing wire line equipment) was used to core the bedrock. Coring produced 1.85 or 2.45 inch diameter cores, for NQ and HQ-sized cores, respectively, from which the type of rock and geological characteristics were determined.

Rock cores were logged in the field and visually classified in the laboratory. They were 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:

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

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

Borings B-017-3-13 and B-017-7-13 were performed in the south shoulder of I-70 eastbound and encountered 6.0 and 11.0 inches of asphalt overlying 4.0 and 6.0 inches of aggregate base, respectively, at the ground surface. Boring B-017-4-13 and B-017-5-13 were performed in grass areas south of I-70 and west of the existing railroad tracks, just off of an access road that runs adjacent to the railroad tracks, and encountered 6.0 and 2.0 inches of topsoil at the ground surface, respectively. Boring B-017-6-13 was performed within the dirt packed access road that runs from Short Street to the railroad tracks just south of I-70.

4.2 Subsurface Soils

Beneath the existing pavement, existing embankment fill was encountered in borings B-017-3-13 and B-017-7-13 extending to a depth of 32.0 and 39.0 feet below the existing ground surface, respectively. The embankment fill consisted of brown, gray, brownish gray and black gravel, gravel and sand, silt and clay, silty clay and clay (ODOT A-1-a, A-1-b, A-6a, A-6b, A-7-6) and did not contain any deleterious material.

Beneath the surface materials in borings B-017-5-13 and B-017-6-13, material identified as existing fill was encountered extending to a depth of 5.0 and 10.5 feet below the existing ground surface, which corresponds to an elevation of 712.0 and 704.4 feet msl, respectively. The fill material consisted of gravel and sand with seams of silt and clay (ODOT A-1-b, A-6a) and contained slag, cinders and organics throughout. Wood fragments were recovered at the bottom of the existing fill in boring B-017-7-13.

Underlying the surficial materials and fill material, and below the topsoil in boring B-017-4-13, natural granular soils were predominantly present in the upper 25 to 52 feet of the soil profile overlying cohesive soils. The granular soils were generally described as brown, gray and black gravel, gravel and sand and gravel with sand and silt and coarse and fine sand (ODOT A-1-a, A-1-b, A-2-4, A-3a). The cohesive soils were described as brown, gray, reddish brown and black sandy silt, silt and clay, silty clay, elastic clay and clay (ODOT A-4a, A-6a, A-6b, A-7-5, A-7-6).

The relative density of granular soils is primarily derived from SPT blow counts (N_{60}). Based on the SPT blow counts obtained, the granular soil encountered ranged from loose ($5 \leq N_{60} \leq 10$ blows per foot [bpf]) to very dense ($N_{60} > 50$ bpf). Overall blow counts recorded from the SPT sampling ranged from 6 bpf to split spoon sampler refusal. The shear strength and consistency of the cohesive soils are primarily derived from the hand penetrometer values (HP). The cohesive soil encountered ranged from medium stiff ($0.5 < HP \leq 1.0$ tsf) to hard ($HP > 4.0$ tsf). The unconfined compressive strength of the cohesive soil samples tested, obtained from the hand penetrometer, ranged from 1.0 to over 4.5 tsf (limit of instrument).

Natural moisture contents of the soil samples tested ranged from 4 to 27 percent. A moisture content of 110 percent was obtained in sample SS-14A from boring B-017-7-13. The high moisture content is likely due to the present of wood fragments and other organics in the sample. The natural moisture content of the cohesive soil samples tested for plasticity index ranged from 14 percent below to 5 percent above their corresponding plastic limits. In general, the soil exhibited natural moisture contents considered to be significantly below to moderately above optimum moisture levels.

4.3 Bedrock

Bedrock was encountered in all of the borings as presented in Table 3.

Table 3. Top of Bedrock Elevations

Boring Number	Ground Surface Elevation (feet msl)	Top of Bedrock (Sampler Refusal)		Top of Bedrock Core (Auger Refusal)	
		Depth (feet)	Elevation (feet msl)	Depth (feet)	Elevation (feet msl)
B-017-3-13	740.3	N/A	N/A	83.5	656.8
B-017-4-13	712.8	53.5	659.3	66.3	646.5
B-017-5-13	717.0	67.0	650.0	74.5	642.5
B-017-6-13	714.9	64.3	650.6	74.5	640.4
B-017-7-13	743.1	N/A	N/A	90.0	653.1

Shale bedrock was encountered across the site at a depths ranging from 53.5 to 90.0 feet below the ground surface, which corresponds to elevations ranging from 650.0 feet msl in boring B-017-5-13 to 659.3 feet msl in boring B-017-4-13. However, this weathered bedrock material was able to be augered in borings B-017-4-13 through B-017-6-13, while this material required rock coring techniques to advance the borings in borings B-017-3-13 and B-017-7-13 and for a portion of the shale encountered between limestone layers in boring B-017-4-13. Competent limestone bedrock was encountered in borings B-017-4-13 through B-017-6-13 at a depths ranging from 72.8 to 74.5 feet below the ground surface, respectively, which corresponds to elevations ranging from 640.0 feet msl in boring B-017-4-13 to 642.5 feet msl in boring B-017-5-13. The cored limestone bedrock was described as gray, tan and gray, and light gray, moderately weathered to unweathered, moderately strong to very strong and slightly fractured to highly fractured.

The percent recovery, RQD values and unconfined compressive strengths of the bedrock core runs are summarized in Table 4.

Table 4. Rock Core Summary

Boring	Core No.	Elevation (feet msl)	Recovery (%)	RQD (%)	Unconfined Compressive Strength
B-017-3-13	RC-1	656.8 to 655.3	56	0	N/A
	RC-2	655.3 to 653.3	100	46	q_u @ 86.0' = 222 psi
B-017-4-13	RC-1	646.5 to 645.0	56	0	N/A
	RC-2	645.0 to 640.0	13	7	N/A
	RC-3	640.0 to 636.5	100	100	q_u @ 74.1' = 8,324 psi
B-017-5-13	RC-1	642.5 to 637.5	89	83	q_u @ 78.4' = 10,615 psi
	RC-2	637.5 to 632.5	93	82	N/A
B-017-6-13	RC-1	640.4 to 635.4	93	83	q_u @ 75.6' = 12,261 psi
	RC-2	635.4 to 630.4	100	100	N/A
B-017-7-13	RC-1	653.1 to 652.1	100	79	N/A
	RC-2	652.1 to 651.1	100	66	N/A
	RC-3	651.1 to 646.4	74	15	N/A

It should be noted that bedrock naturally experiences mechanical breaks during the drilling and coring processes. Rii attempted to account for fresh, manmade breaks during tabulation of the RQD analysis. The quality of the shale bedrock, according to the RQD values, was very poor (RQD ≤ 25%) to good (75% < RQD ≤ 90%) and the quality of the limestone bedrock was good to excellent (90% < RQD ≤ 100%).

4.4 Groundwater

Groundwater was encountered in the borings as presented in Table 5.

Table 5. Groundwater

Boring Number	Ground Elevation (feet msl)	Initial Groundwater		Upon Completion	
		Depth (feet)	Elevation (feet msl)	Depth (feet)	Elevation (feet msl)
B-017-3-13	740.3	58.5	681.8	N/A [1]	N/A
B-017-4-13	712.8	18.0	694.8	N/A [1]	N/A
B-017-5-13	717.0	23.5	693.5	N/A [1]	N/A
B-017-6-13	714.9	28.0	686.9	N/A [1]	N/A
B-017-7-13	743.1	57.0	686.1	N/A [1]	N/A

1. *The groundwater level at completion could not be obtained due to the addition of water as a drilling fluid.*

Groundwater was encountered initially during drilling in all of the borings at depths ranging from 18.0 to 58.5 feet below the existing ground surface. The groundwater levels at the completion of drilling could not be measured due to the addition of water as a circulating fluid during the rock coring process. Please note that short-term water level readings, especially in cohesive soils, are not necessarily an accurate indication of the actual groundwater level. In addition, groundwater levels or the presence of groundwater are considered to be dependent on seasonal fluctuations in precipitation.

A more comprehensive description of what was encountered during the drilling process may be found on the boring logs in Appendix III.

5.0 ANALYSES AND RECOMMENDATIONS

Data obtained from the subsurface exploration has been used 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 bridge, 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 bridge structure were provided by Burgess and Niple. Based on the information provided, it is understood that the proposed bridge will consist of a two-span continuous straight welded steel plate girder structure with a composite reinforced concrete deck with pile supported semi-integral stub abutments behind mechanically stabilized earth (MSE) walls and reinforced concrete wall-type pier. The proposed structure will have a total length of approximately 262 feet and variable width ranging from 59 to 71 feet. In addition, the roadway profile will be elevated approximately 35 feet above the existing ground surface grade.

Retaining Wall 4W10 will be located at the rear abutment of the proposed structure to provide the required grade separation to support the configuration. It is understood that a mechanically stabilized earth (MSE) wall type is being considered as the preferred wall type for Retaining Wall 4W10. Based on plan information provided by Dynotec, it understood that only a portion of the wall will be constructed as part of Project 4R, which will be between Sta. 167+35, 196.3’ Rt. (BL I-70 EB) to Sta. 6002+19, 23.0’ Lt. (BL Ramp C6). The remainder of the wall will be constructed as part of Project 4A when I-70 eastbound is upgraded. A temporary MSE wall, Temporary MSE Wall T2, will be constructed along the north side of the rear abutment to provide support of the proposed Ramp C5 roadway until construction of the I-70 improvements are performed as part of Project 4A. The wall height will range from 4.5 feet at the beginning of the wall alignment to a maximum height of 40.2 feet at the proposed abutment, and the total wall length is approximately 135 lineal feet to the termination at Temporary MSE Wall T2.

Retaining Wall 4W8 will be located at the forward abutment of the proposed structure to provide the required grade separation to support the configuration. It is understood that a mechanically stabilized earth (MSE) wall type is being considered as the preferred wall type for Retaining Wall 4W8. Based on plan information provided by Dynotec, it understood that only a portion of the wall will be constructed as part of Project 4R, which will be between Sta. 169+29, 62.2' Rt. to 169+67, 132.0' Lt. (BL I-70 EB). A temporary MSE wall, Temporary MSE Wall T4, will be constructed along the north side of the forward abutment to provide support of the proposed Ramp C5 roadway until construction of the I-70 improvements are performed as part of Project 4A. The maximum wall height at the proposed abutment is 40.5 feet, and the total wall length at the abutment is approximately 80 lineal feet from Temporary MSE Wall T4 to the south side of the abutment. The wall alignment will turn east on the south side of the structure and continue to the FRA-70-1373A bridge over Short Street. Design recommendations for the remaining alignment of Retaining Wall 4W8 east of Sta. 169+67, 132.0' Lt. (BL I-70 EB) is presented under a separate cover.

Proposed structural data was obtained from design details provided by Burgess and Niple and Dynotec, which are included in Table 6.

Table 6. Structure and Bridge Design Elevations

<table>
<tr><th>Substructure Reference</th><th>Structure Component [1]</th><th>Elevation [1] (feet msl)</th><th>Design Maximum Factored Load</th></tr>
<tr><td rowspan="3">Rear Abutment (B-017-3-13 / B-017-4-13)</td><td>Profile Grade</td><td>749.6</td><td rowspan="3">204 kips/pile</td></tr>
<tr><td>Bottom of Footing</td><td>734.1</td></tr>
<tr><td>Bottom of Wall (Top of Leveling Pad)</td><td>709.4</td></tr>
<tr><td>Pier 1 (B-017-5-13)</td><td>Bottom of Footing</td><td>711.5</td><td>304 kips/pile</td></tr>
<tr><td rowspan="3">Forward Abutment (B-017-6-13 / B-017-7-13)</td><td>Profile Grade</td><td>752.0</td><td rowspan="3">267 kips/pile</td></tr>
<tr><td>Bottom of Footing</td><td>736.0</td></tr>
<tr><td>Bottom of Wall (Top of Leveling Pad)</td><td>711.5</td></tr>
</table>

1. *Proposed foundation elevations and structural loading based on structure information provided by Burgess and Niple and Dynotec.*

The recommendations provided for Retaining Walls 4W8 and 4W10 should also govern the design of Temporary MSE Walls T4 and T2, respectively.

Borings B-017-9-13, B-018-1-13 and B-018-2-13, which were performed for the FRA-70-1358L bridge structure as part of the FRA-70-13.10 Phase 6A project, were also referenced to further delineate the bedrock stratigraphy at the site. A copy of these logs are also provided in Appendix III.

5.1 Driven Pile Recommendations

Given the depth to bedrock encountered in the borings, it is recommended that steel H-piles (ODOT Item 507.06) driven to refusal on bedrock be employed for foundation support of the proposed substructure elements. Per Section 202.2.3.2a of the 2007 ODOT Bridge Design Manual, refusal is met during driving when the pile penetration is an inch or less after receiving at least 20 blows from the pile hammer. Table 7 shows the recommended pile lengths and the corresponding factored structural axial resistance ($R_{R\,max}$) of steel H-piles. For H-piles driven to refusal on bedrock, no geotechnical resistance factor should be applied to the factored structural axial resistance values presented, as the values presented account for the structural resistance factor, $\varphi_c = 0.50$, for H-piles subject to damage due to severe driving conditions.

Table 7. FRA-70-1358A Driven Pile Recommendations

Substructure Reference (Boring)	Ground Elevation [1]	Pile Size	Pile Elevation		Pile Length [3] (feet)	$R_{R\,max}$ [4] (kips/pile)	Sleeve Length [5]	φ [6]
			Top [2]	Tip				
Rear Abutment (B-017-3-13 / B-017-4-13)	740.3 / 712.8	HP 10x42	735.1	646.5	90	310	26.2	N/A
Pier 1 (B-017-5-13)	717.0	HP 10x42	712.5	642.5	70	310	N/A	N/A
Forward Abutment (B-017-6-13 / B-017-7-13)	714.9 / 743.1	HP 10x42	737.0	640.4	100	310	26.0	N/A

1. *Ground elevation listed is the ground elevation at the respective boring location.*
2. *The top of pile elevation corresponds to the pile cutoff elevation, which is 1.0-foot above the proposed bottom of footing elevation.*
3. *Per Section 202.3.2 of the 2007 ODOT BDM, the estimated pile length was determined as the pile cutoff elevation (top) minus the pile tip elevation, rounded up to the nearest 5.0 feet.*
4. *The factored structural axial resistance for H-piles is based on the structural limit state of the steel H-pile section per Section 202.2.3.2.a of the 2007 ODOT BDM.*
5. *Sleeve length represents the required length of pile that should be sleeved within the MSE wall backfill, including the foundation preparation.*
6. *For H-piles driven to refusal on bedrock, no geotechnical resistance factor should be applied to the factored structural axial resistance values presented, as the values presented account for the structural resistance factor, $\varphi_c = 0.50$, for H-piles subject to damage due to severe driving conditions.*

As per Section 202.2.3.2.a of the 2007 ODOT BDM, the factored resistance for H-piles driven to refusal on bedrock is typically governed by the structural resistance of the pile element. The factored structural axial resistances listed in Table 7 consider an axially loaded pile with negligible moment, no appreciable loss of section due to deterioration throughout the life of the structure, a steel yield strength of 50 ksi, a structural resistance factor for H-piles subject to damage due to severe driving conditions (LRFD 6.5.4.2: $\varphi_c = 0.50$) and a pile fully braced along its length. **The factored structural axial**

resistance should not be used for piles that are subjected to bending moments or are not supported by soil for their entire length. Static or dynamic load testing is not required for H-piles driven to refusal on bedrock. It is anticipated that the piles will be able to be driven a short distance into the surficial bedrock before satisfying the driving conditions that meet the refusal criterion. Due to the weathered, variable nature of the upper portion of the bedrock, it is estimated that refusal will be met within the upper 3.0 to 5.0 feet of the surficial bedrock. Therefore, the recommended pile tip elevation at the forward abutment is based on a penetration of 4.0 feet into the weathered shale bedrock. Settlement is estimated to be less than 1.0 inch for H-piles driven to refusal on bedrock.

Consideration was given to the use of friction piles using cast-in-place (CIP) pipe piles; however, given the required pile reactions provided by Burgess and Niple, additional piles would be required to support the proposed substructure units, which would result in additional costs. As noted in Section 4.2, the upper soils encountered generally consisted of cohesive fill material with interbedded layers of granular soils which extended to approximate elevations of 700 to 705 feet msl, overlying medium dense to very dense granular soils consisting of gravel and gravel and sand were encountered which extended to approximate elevations of 665 to 678 feet msl. Analyses indicate that 16-inch CIP piles would only be able to be driven a short distance into the underlying medium dense to very dense granular material before reaching the maximum capacity and overstressing the piles. Given the weak and variable nature of the overlying fill material, the capacity would need to be carried almost solely in the end bearing of the pile. Additionally, as the bridge site is situated in a flood plain area, it is anticipated that the site will be inundated during the design life. Therefore, if a critical design groundwater elevation at the finished grade of the roadway is considered, there will be a significant reduction in the capacity of the piles, which would likely result in significant settlement or complete failure of the piles. Therefore, CIP pipe piles were not considered for foundation support of the proposed substructures.

5.1.1 Downdrag Considerations

The anticipated total settlement at the facing of the wall at the rear and forward abutments is 2.07 and 6.73 inches, respectively. Given the anticipated amount of settlement following construction of the embankment, downdrag loads may be induced on the pile elements if installed to the final tip elevation prior to placement of the embankment fill. To reduce the amount of downdrag induced on the piles, it is recommended that the piles be pre-driven into the soil only as far as necessary to remain vertical and that the MSE wall should be constructed around the piles and then allowed to sit for a specified holding period such that a percentage of the consolidation can occur prior to driving the piles the to the design tip elevation and reduce the amount of downdrag on the piles.

In order to consolidate the underlying soil to the required settlement, consideration should be given to the placement of a surcharge load in order to preload the site under the full weight of the MSE wall height (from the bottom of wall elevation to the profile grade). The surcharge should remain in place until approximately 90 percent of consolidation of the subsurface soils has occurred to prevent downdrag loads from developing along the pile elements. Results of the settlement analysis indicate that approximately 90 percent of the primary consolidation of the cohesive layers at the rear and forward abutment will be complete within sixty (60) days following the placement if the surcharge load. Therefore, if the above noted waiting period is specified following completion of construction of the MSE wall at the rear abutment, downdrag forces along the piles will be eliminated. However, even at 90 percent consolidation for the forward abutment, the remaining settlement still exceeds 0.4 inches, which is the relative movement that results in full mobilization of the side resistance, and thus generating downdrag loads. Since the majority of the settlement is occurring within the upper fill material and stiff silt and clay, if this material is stabilized as discussed in Section 5.2, then the total amount of settlement will be reduced, resulting in the elimination of the downdrag loading.

Settlement platforms should be installed once the embankment surcharge has been placed to monitor the settlement of the embankment over time. A shorter or longer hold period than specified may be required based on the settlement platform readings as directed by the geotechnical engineer. The required hold period may be considered complete when survey monitoring of the settlement platforms indicate that the above noted settlement has occurred for the hold period or until the survey shows less than ⅛-inch of total movement per week over a two week period **following placement of the final lifts of surcharge loading.**

5.1.2 Driveability

A drivability analysis was performed in accordance with Section 10.7.8 of the 2018 AASHTO LRFD Bridge Design Specifications (BDS) using the GRLWEAP software program, and the results are provided in Appendix V. In the driveability analysis, a Delmag 19-42 hammer with a rated energy of approximately 43,000 ft-lbs was used in conjunction with the H-pile sections. Based on the results of this analysis, driving stresses induced on the H-piles **would not exceed** 90 percent of the yield stress of the steel (f_y = 50 ksi, 0.9f_y = 45 ksi) if driven through the overburden soils to the bedrock depths provided in Table 7. Care should be taken during pile driving operations when approaching the bedrock elevations noted above, and when extending the piles into the surficial bedrock material, to ensure that the driving stresses induced on the pile elements do not exceed the maximum allowable value of 90 percent of the yield stress of the steel, subsequently damaging the pile elements. Pile driving should be terminated upon achieving the required 20 blows from the pile hammer with an inch or less of penetration to reduce the possibility of damaging the pile element.

Per Section 202.2.3.2.a of the 2007 ODOT BDM, steel pile points should not be used when the piles are driven to bear on shale. However, it should be noted that dense granular soils and cobbles and boulders were encountered throughout the surficial deposits. If there is difficulty in driving the piles to bear on the bedrock due to the dense granular soils or obstructions, then consideration should be given to the use of a pile point to aid in penetrating beyond these layers or obstructions. If a pile point is utilized, the piles may penetrate further into the shale bedrock prior to encountering refusal.

5.1.3 Lateral Design Considerations

If lateral loads or moments are expected to be applied on the foundation elements, they should be analyzed to verify the shaft or pile 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 (for drilled shafts) required to resist the lateral load for a given end condition and deflection. Table 8 lists the 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 8. 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)

5.2 MSE Wall Recommendations

It is proposed to construct an MSE wall at the rear abutment (Retaining Wall 4W10 between Sta. 167+35, 196.3' Rt., BL I-70 EB, to Sta. 6002+19, 23.0' Lt., BL Ramp C6) and forward abutment (Retaining Wall 4W8 between Sta. 169+29, 62.2' Rt. to 169+67, 132.0' Lt., BL I-70 EB) of the proposed bridge structure. MSE walls are constructed on earthen foundations at a minimum depth of 3.0 feet below grade, as defined by the top of the leveling pad to the ground surface located 4.0 feet from the face of the wall. Per Section 204.6.2.1 of the 2007 ODOT BDM, the height of the MSE wall at the bridge abutments is defined as the elevation difference between the profile grade at the face of the wall and the top of the leveling pad. However, it is noted that the reinforced soil mass only extends from the foundation bearing elevation (top of leveling pad) to the bottom of footing elevation. Additionally, per Section 303.5.1 of the 2007 ODOT BDM, a minimum of one row of soil reinforcement straps should be attached to the backside of the abutment footing to resist horizontal forces from the bridge structure and lateral pressures along the backwall of the abutment footing, and prevent any load transfer from these forces to the coping and facing panels. For portions of the wall outside the limits of the bridge abutments, the straps should be installed the full height of the wall. The width of the MSE wall foundation (B) is defined by the length of the reinforced soil mass. Per the Section 204.6.2.1 of the 2007 ODOT BDM and Supplemental Specification (SS) 840, the minimum length of the reinforced soil mass is equal to 70 percent of the height of the MSE wall or 8.0 feet whichever is greater. A non-structural bearing leveling pad consisting of a minimum of 6.0-inches of unreinforced concrete should be placed at the base of the wall facing for constructability purposes. Please note that the leveling pad is not a structural foundation.

Based on proposed plan and profile information provided by Burgess and Niple and Dynotec, the wall heights at the rear and forward abutment of the FRA-70-1358A structure are anticipated to be 40.2 and 40.5 feet, respectively, from the top of the leveling pad to the proposed profile grade of the roadway. Therefore, it is considered that the minimum reinforcement length and the effective foundation width (B) of the rear and forward abutment MSE walls for external and global stability calculations will be 28.1 and 28.4 feet, respectively. For the analysis, the foundation width was set at 70 percent of the wall height for the rear and forward abutments, respectively, and the foundation width was increased, until external and global stability requirements were satisfied.

Per Section 840.06.D of ODOT SS 840, the foundation subgrade should be inspected to verify that the subsurface conditions are the same as those anticipated in this report. Stiff silty clay (ODOT A-6b) was encountered at the proposed bearing elevation at the rear abutment (Wall 4W10), which extends to a depth of 6.5 feet below the proposed bearing elevation (El. 703 feet msl). It is recommended that this weak cohesive material be completely over excavated to expose the underlying competent natural granular soils and replaced with ODOT Item 203 granular embankment.

Existing fill material overlying was encountered at the proposed bearing elevation at the forward abutment (Wall 4W8), which extends to a depth of 7.5 feet below the proposed bearing elevation (El. 704 feet msl). The fill material consisted of medium dense sand and gravel (ODOT A-1-b) and stiff silt and clay (ODOT A-6a) and contained slag, cinders and organic material. Underlying the fill material, layers of natural stiff cohesive soils were encountered extending to a depth of 10.5 feet below the proposed bearing elevation (El. 701 feet msl). These soils are not considered suitable for foundation support for a wall of this size. Consideration was given to over excavating these soils and replacing it with granular embankment; however, similar conditions are anticipated along the remainder of the alignment of Retaining Wall 4W8, which makes this a very expensive and uneconomical option. Recommendations have been provided in the structure foundation exploration report for Retaining Wall 4W8 to incorporate the use of ground improvement techniques to stabilize the existing fill and underlying cohesive soils. The recommendations for this alternative should govern the design of this portion of the wall as well. For this report, the analysis this section of Wall 4W8 has been conducted using the soil profile as encountered in the borings.

Per ODOT SS 840, following foundation subgrade inspection and acceptance, a minimum of 12.0 inches of ODOT Item 703.16.C, Granular Material Type C, should be placed and compacted in accordance with ODOT Item 204.07.

Since the walls are located within an existing floodplain, the analyses were performed using a design groundwater level at the ground surface.

5.2.1 Strength Parameters Utilized in External and Global Stability Analyses

The shear strength parameters utilized in the external and global stability analyses for the MSE walls at the abutments are provided in Table 9.

Table 9. Shear Strength Parameters Utilized in MSE Wall Stability Analyses

Material Type	γ (pcf)	φ' (1) (°)	c' (2) (psf)	S_u (3) (psf)
MSE Wall Backfill (Select granular fill)	120	34	0	N/A
Item 203 Embankment Fill (Retained Soil at 4W10)	120	30	0	2,000
Item 203 Granular Embankment (Retained Soil at 4W8 and Over Excavation Backfill at 4W10)	130	33	0	N/A
Existing Fill: Stiff Silt and Clay (ODOT A-6a)	115	26	0	1,500
Medium Dense to Very Dense Gravel, Gravel and Sand (ODOT A-1-a, A-1-b)	125 to 135	37 to 42	0	N/A
Stiff to Very Stiff Sandy Silt (ODOT A-4a)	120	28	0	3,125
Very Stiff to Hard Silt and Clay (ODOT A-6a)	130	28	50	8,000
Very Stiff to Hard Elastic Clay (ODOT A-7-5)	125	24	0 to 50	3,375 to 8,000
Hard Clay (ODOT A-7-6)	130	26	50	8,000

1. *Per Figure 7-45, Section 7.6.9 of FHWA GEC 5 for cohesive soils and Table 10.4.6.2.4-1 of the 2018 AASHTO LRFS BDS for granular soils.*
2. *Estimated based on overconsolidated nature of soil.*
3. *$S_u = 125(N_{60})$, Terzaghi and Peck (1967).*

Shear strength parameters for the reinforced soil backfill are provided in ODOT SS 840. Per SS 840, the select granular backfill in the reinforced zone must meet the shear strength requirements provided in Table 9. Based on the design plans provided by GPD Group and Dynotec, it is understood that Item 203 granular embankment will be utilized where any new embankment will be placed behind the reinforced soil backfill at both MSE walls. Therefore, the shear strength parameters for the retained fill will be modeled using a friction angle of 33 degrees since granular embankment is being specified, instead of using the shear strength parameters provided in ODOT SS 840.

The shear strength parameters for the natural soils were assigned using correlations provided in FHWA Geotechnical Engineering Circular (GEC) No. 5 (FHWA-NHI-16-072) Evaluation of Soil and Rock Properties and based on past experience in the vicinity of the site with projects performed in similar subsurface profiles. However, the friction angle for the existing fill that consisted of medium dense gravel with sand and silt was conservatively assigned since there no records of the material origin or how it was placed.

5.2.2 Bearing Stability

The anticipated bearing materials at the abutment locations consist of natural, stiff silty clay (ODOT A-6b) at the rear abutment (Wall 4W10) and existing fill comprised of medium dense sand and gravel and stiff silt and clay (ODOT A-1-b, A-6a) with slag, cinders and organics at the forward abutment (Wall 4W8). As noted in Section 5.2, it is recommended that the weak cohesive soil at the rear abutment (Wall 4W10) be completely over excavated to expose the competent underlying granular soils and replaced with Item 203 granular embankment. However, as noted in Section 5.2, it is understood that ground improvement techniques will be implemented along the alignment of Retaining Wall 4W8, including where the wall crosses the forward abutment. As this is a proprietary design, the analysis for this wall considers the existing fill material will remain in place. MSE wall foundations bearing on engineered fill, placed and compacted in accordance with ODOT Item 203, or existing fill material may be proportioned for a nominal bearing resistance as indicated in Table 10. A geotechnical resistance factor of φ_b=0.65 was considered in calculating the factored nominal bearing resistance at the strength limit state.

Table 10. FRA-70-1358A MSE Wall Design Parameters

Substructure Unit [1] (Boring)	**Wall Height Analyzed (feet)**	**Backslope Behind Wall**	**Minimum Required Reinforcement Length [2] (feet)**	**Bearing Resistance at Strength Limit (ksf)**		**Strength Limit Equivalent Bearing Pressure [4] (ksf)**
				Nominal	**Factored [3]**	
Rear Abutment / Retaining Wall 4W10 (B-017-3-13 / B-017-4-13)	40.2	Level	28.1 (0.7H)	28.77	18.70	9.11
Forward Abutment / Retaining Wall 4W8 (B-017-6-13 / B-017-7-13)	40.5	Level	28.4 (0.7H)	8.30	5.40	9.15

1. *Stationing referenced to the baseline of the respective retaining wall.*
2. *The required foundation width is expressed as a percentage of the wall height, H.*
3. *A geotechnical resistance factor of φ_b=0.65 was considered in calculating the factored bearing resistance at the strength limit state.*
4. *The strength limit equivalent bearing pressure is the uniformly distributed pressure asserted by the wall over an effective base width based on the eccentricity of the wall system at the strength limit state.*

Rii performed a verification of the bearing pressure exerted on the subgrade soils for the maximum specified wall heights indicated in Table 10. Based on the minimum length of reinforced soil mass presented, the factored equivalent bearing pressure exerted below the wall **will not exceed** the factored bearing resistance at the strength limit state for Wall 4W10 at the rear abutment. However, the factored equivalent bearing pressure exerted below the wall **will exceed** the factored bearing resistance at the strength limit state for Wall 4W8, considering the wall will bear on the existing fill material.

5.2.3 Settlement Evaluation

The compressibility parameters utilized in the settlement analysis of the proposed MSE walls are provided in Table 11.

Table 11. Compressibility Parameters Utilized in Settlement Analysis

Material Type	**γ (pcf)**	***LL* (%)**	**C_c (1)**	**C_r (2)**	**e_o (3)**	**C_v (4) (ft²/yr)**	**N_{60}**	**C' (5)**
Item 203 Granular Embankment	130	N/A	N/A	N/A	N/A	N/A	30	161 to 215
Existing Fill: Stiff Silt and Clay (ODOT A-6a)	115	33	0.207	0.031	0.530	600	N/A	N/A
Medium Dense to Very Dense Granular Soils (ODOT A-1-a, A-1-b, A-3a)	125 to 135	N/A	N/A	N/A	N/A	N/A	22 to 85	76 to 340
Stiff to Very Stiff Sandy Silt (ODOT A-4a)	120	24	0.126	0.013	0.460	800	N/A	N/A
Very Stiff to Hard Silt and Clay (ODOT A-6a)	130	22	0.108	0.011	0.444	600	N/A	N/A
Very Stiff to Hard Elastic Clay (ODOT A-7-5)	125	57	0.423	0.042	0.718	100	N/A	N/A
Hard Clay (ODOT A-7-6)	130	41 to 51	0.279 to 0.369	0.028 to 0.037	0.593 to 0.671	150	N/A	N/A

1. *Per Table 6-9, Section 6.14.1 of FHWA GEC 5.*
2. *Estimated at 10% of C_c for natural soils and 15% C_c for existing fill per Section 8.11 of Holtz and Kovacs (1981).*
3. *Per Table 8-2 of Holtz and Kovacs (1981).*
4. *Per Figure 6-37, Section 6.14.2 of FHWA GEC 5.*
5. *Per Figure 10.6.2.4.2-1 of 2018 AASHTO LRFD BDS.*

Results of the settlement analysis are tabulated in Table 12. Total settlements of 2.75 and 11.03 inches at the center of the reinforced soil mass and 2.07 and 6.73 inches at the facing of the wall are anticipated at the rear and forward abutment, respectively. Based on the results of the analysis, 90 percent of the total settlement at the rear and forward abutment is anticipated to occur over a period of approximately 60 days. Please note that the consolidation settlement and time rate of consolidation are based on estimates using correlated compressibility parameters provided in Table 11 for the underlying soils. Actual settlement and time rate of consolidation should be determined by monitoring the settlement of the wall using settlement platforms.

Table 12. FRA-70-1358A MSE Wall Settlement Results

Substructure Unit [1] (Boring)	Wall Height Analyzed (feet)	Backslope Behind Wall in Analysis	Service Limit Equivalent Bearing Pressure [1] (ksf)	Total Settlement Values (inches)		Time for 90% Consolidation (Days)
				Center of Wall Mass	Facing of Wall	
Rear Abutment / Retaining Wall 4W10 (B-017-3-13 / B-017-4-13)	40.2	Level	6.57	2.749	2.073	60
Forward Abutment / Retaining Wall 4W8 (B-017-6-13 / B-017-7-13)	40.5	Level	6.47	11.027	6.729	60

1. *The service limit equivalent bearing pressure is the uniformly distributed pressure asserted by the wall over an effective base width based on the eccentricity of the wall system at the service limit state.*

Per Section 204.6.2.1 of the ODOT BDM, "the maximum allowable differential settlement in the longitudinal direction (regardless of the size of panels) is one (1) percent." Based on the total anticipated settlement at the facing of the wall, maximum differential settlement in the longitudinal direction is anticipated to be less than 1/1000 for Wall 4W10, which is within the tolerable limit of 1/100. However, give the amount of settlement anticipated at the facing along Wall 4W8, as well as the presence of existing fill material that may vary significantly over the footprint of the wall, differential settlement greater than 1/100 may occur if the fill material is not stabilized or over excavated and replaced with embankment fill.

If either the total or differential settlement predicted presents an issue with respect to the deformation tolerances that the walls can withstand, then measures should be taken to minimize the amount of settlement that will occur. This can be achieved by preloading the site and consolidating the underlying soils prior to constructing the wall. If preloading the site is not a desired option, then consideration could be given to ground improvement through the use of stone columns. Settlement calculations are provided in Appendix VII.

5.2.4 Eccentricity (Overturning Stability)

The resistance of the MSE walls to overturning will be dependent on the location of the resultant force at the bottom of the wall due to the overturning and resisting moments acting on the wall. For MSE walls, overturning stability is determined by calculating the eccentricity of the resultant force from the midpoint of the base of the wall and comparing this value to a limiting eccentricity value. Per Section 11.10.5.5 of the 2018 AASHTO LRFD BDS, for foundations bearing on soil, the location of the resultant of the reaction forces shall be within the middle two-thirds ($^2/_3$) of the base width. Therefore, the limiting eccentricity is one-third ($^1/_3$) of the base width of the wall. Rii performed a verification of the eccentricity of the resultant force for the maximum specified wall heights indicated in Table 10. Based on the minimum length of reinforced soil mass presented in Table 10 and utilizing the soil parameters listed in Section 5.2.1 for the retained embankment material, the calculated eccentricity of the resultant force **will not exceed** the limiting eccentricity at the strength limit state for either wall.

5.2.5 Sliding Stability

The resistance of the MSE walls to sliding was evaluated per Section 11.10.5.3 of the 2018 AASHTO LRFD BDS. For drained conditions, the sliding resistance is determined by multiplying a coefficient of sliding friction "f" times the total vertical force at the base of the wall. The coefficient of sliding friction is determined based on the limiting friction angle between the foundation soil and the reinforced soil backfill. Based on the soil parameters listed in Section 5.2.1 for the foundation and reinforced soil backfill, a coefficient of sliding friction of 0.65 and 0.49 was utilized for design at the rear abutment (Wall 4W10) and forward abutment (Wall 4W8), respectively. The sliding resistance at the forward abutment (Wall 4W8) was also evaluated under undrained conditions as well. For undrained conditions, the sliding resistance is taken as the limiting value between the undrained shear strength of the bearing soil and half of the vertical stress applied by the wall multiplied by the width of the MSE wall. Based on the soil parameters listed in Section 5.2.1, the undrained shear strength of the existing silt and clay fill material encountered at the proposed bearing elevation at the forward abutment (Wall 4W8) is estimated to be 1.5 ksf.

A geotechnical resistance factor of φ_{τ}=1.0 was considered in calculating the factored shear resistance between the reinforced backfill material and foundation for sliding. Based on the minimum length of reinforced soil mass presented in Table 10 and utilizing the soil parameters listed in Section 5.2.1 for the retained embankment material, the resultant horizontal forces on the back of the MSE walls **will not exceed** the factored shear resistance at the strength limit state under drained conditions for either wall. However, the resultant horizontal forces on the back of the MSE wall at the forward abutment (Wall 4W8) **will exceed** the factored shear resistance at the strength limit state under undrained conditions.

5.2.6 Overall (Global) Stability

A slope stability analysis was performed to check the global stability of the walls. As per the AASHTO LRFD BDS, safety against soil failure shall be evaluated at the service limit state by assuming the reinforced soil mass to be a rigid body. Soil parameters utilized in the global stability analyses are presented in Section 5.2.1. For the global stability condition, it was considered that the failure plane will not cross through the reinforced soil mass. The computer software program Slide 6.0 manufactured by Rocscience Inc. was utilized to perform the analyses.

Per Section 11.6.2.3 of the 2018 AASHTO LRFD BDS, overall (global) stability for MSE walls that are integrated with or 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=0.65 is greater than 1.0. Therefore, global stability is satisfied when a minimum factor of safety of 1.5 is obtained. For an MSE wall designed with the minimum strap lengths listed in Table 10, the resulting factor of safety under drained conditions (long-term stability) and undrained conditions (short-term stability) at the rear abutment (Wall 4W10) using the Spencer's analysis method was greater than 1.5. However, the resulting factor of safety under drained conditions (long-term stability) and undrained conditions (short-term stability) at the forward abutment (Wall 4W8) was less than 1.5.

5.2.7 Final MSE Wall Considerations

Based on the results of the external and global stability analysis performed for the MSE wall at the rear abutment (Wall 4W10), the recommended controlling strap length is 0.7 times the maximum height of the MSE wall (measured from the top of the leveling pad to the proposed profile grade of the roadway). All remaining external and global stability calculations indicate that adequate resistance is available for support of the MSE wall at the abutment for a strap length equal to 70 percent of the wall height, provided the underlying silty clay soil is over excavated and replaced with Item 203 granular embankment.

Based on the results of the external and global stability analysis performed for the MSE wall at the forward abutment (Wall 4W8), sliding under undrained conditions as well as bearing and global stability under both drained and undrained conditions were not satisfied at a strap length equal to 0.7 times the wall height. Increasing the width of the wall up to 1.0 times the wall height still did not satisfy all of the external and global stability requirements. As noted in Section 5.2, consideration was given to over excavating these soils and replacing it with granular embankment; however, similar conditions are anticipated along the remainder of the alignment of Retaining Wall 4W8, which makes this a very expensive and uneconomical option. Recommendations have been provided in the structure foundation exploration report for Retaining Wall 4W8 to incorporate the use of ground improvement techniques to stabilize the existing fill and underlying cohesive soils. The recommendations for this alternative should govern the design of this portion of the wall as well.

Calculations for external (bearing and sliding resistance and limiting eccentricity) and overall (global) stability of the MSE walls are provided in Appendix VII.

5.3 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 13 and Table 14.

Table 13. 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	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	130	0	33°	0.30	0.46	3.39

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

Table 14. 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	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	130	0	33°	0.26	0.46	7.41

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.

5.4 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).

5.4.1 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, 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 15. 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

5.4.2 Groundwater Considerations

Based on the groundwater observations made during drilling, groundwater is not anticipated to be encountered during construction. Where/if 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. 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 above recommendations 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 these 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 for the current investigation. 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.

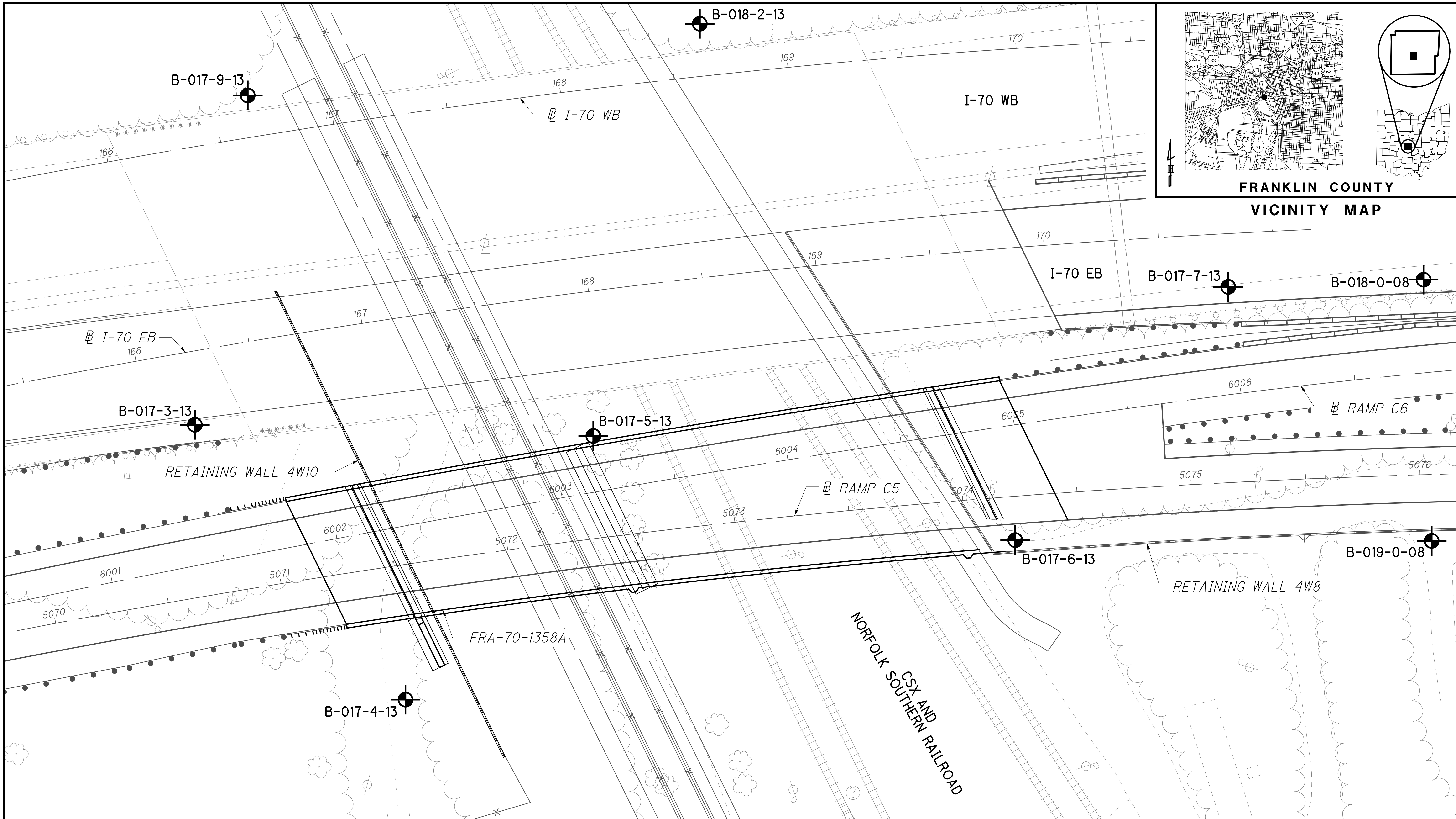
The conclusions and recommendations herein have been based upon the available soil and bedrock information and the design details furnished by a representative of the owner of the proposed project. Any revision in the plans for the proposed construction from those anticipated in this report should be 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-70-1358A AND RETAINING WALL 4W10

FRANKLIN COUNTY, OHIO

RII PROJECT NO. W-13-045

SCALE: 1"=40'

0 20 40

DRAWN RRM

REVIEWED BRT

DATE 7-13-18

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	$LL_O/LL \times 100$*	% 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.	$\leq$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 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

PROJECT BORING LOGS:

B-017-3-13 through B-018-2-13

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

<u>Classification Test Data</u>

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.B.	DRILL RIG: MOBILE B-53 (SN 624400)	STATION / OFFSET: 166+20.53 / 31.8' RT	EXPLORATION ID B-017-3-13
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / S.B.	HAMMER: AUTOMATIC	ALIGNMENT: BL I-70 EB	
PID: 77372 BR ID: FRA-70-1358R	DRILLING METHOD: 4.25" HSA / RC	CALIBRATION DATE: 4/26/13	ELEVATION: 740.3 (MSL) EOB: 87.0 ft.	PAGE 1 OF 3
START: 7/30/13 END: 8/2/13	SAMPLING METHOD: SPT / HQ	ENERGY RATIO (%): 77.7	LAT / LONG: 39.953028358, -83.008033736	

MATERIAL DESCRIPTION AND NOTES	ELEV. 740.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.5'- ASPHALT (6.0")	739.8																	
0.3'- AGGREGATE BASE (4.0")	739.5																	
FILL: STIFF TO VERY STIFF, BROWN **CLAY**, "AND" SILT, TRACE TO LITTLE FINE TO COARSE SAND, TRACE TO SOME FINE GRAVEL, DAMP TO MOIST.		1–2	4 4 10	18	78	SS-1	3.25	-	-	-	-	-	-	-	-	17	A-7-6 (V)	
		4–5	5 2 4	8	50	SS-2	1.50	26	13	6	36	19	43	16	27	16	A-7-6 (11)	
		6–7	2 3 5	10	33	SS-3	2.25	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
		9–10	3 4 5	12	44	SS-4	2.75	-	-	-	-	-	-	-	-	15	A-7-6 (V)	
		11–12	2 3 3	8	50	SS-5	2.00	-	-	-	-	-	-	-	-	16	A-7-6 (V)	
		14–15	1 3 3	8	56	SS-6	1.25	21	9	5	36	29	43	17	26	19	A-7-6 (13)	
		16–17	3 4 5	12	17	SS-7	1.25	-	-	-	-	-	-	-	-	17	A-7-6 (V)	
		17–18	4	-	67	3S-7A	1.25	-	-	-	-	-	-	-	-	16	A-7-6 (V)	
		19–20	2 7 5	16	50	SS-8	3.00	5	3	3	35	54	50	18	32	22	A-7-6 (18)	
		21–22	3 4 5	12	83	SS-9	3.00	-	-	-	-	-	-	-	-	24	A-7-6 (V)	
		24–25	3 3 5	10	89	SS-10	2.00	-	-	-	-	-	-	-	-	26	A-7-6 (V)	
	713.3	26–27	3 9 10	25	83	SS-11	3.75	-	-	-	-	-	-	-	-	21	A-7-6 (V)	
FILL: MEDIUM DENSE, BLACK **GRAVEL AND SAND**, TRACE SILT, MOIST.							-	-	-	-	-	-	-	-	-	16	A-1-b (V)	
		29	3 5 9	18	33	SS-12	-	-	-	-	-	-	-	-	-	13	A-1-b (V)	

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 3/14/15 17:34 - U:\GI8\PROJECTS\2013\W-13-045.GPJ

PID: 77372	BR ID: FRA-70-1358R	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 166+20.53 / 31.8 RT	START: 7/30/13	END: 8/2/13	PG 2 OF 3	B-017-3-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 710.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
FILL: MEDIUM DENSE, BLACK **GRAVEL AND SAND**, TRACE SILT, MOIST. *(same as above)*	708.3	31–32																
STIFF, BROWN **SILTY CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST.		34–35	1 4 7	14	67	SS-13	1.50	5	7	12	41	35	37	17	20	20	A-6b (12)	
	703.3																	
DENSE TO VERY DENSE, BROWN **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, DAMP TO MOIST.		39–40	5 13 16	38	61	SS-14	-	-	-	-	-	-	-	-	-	7	A-1-b (V)	
		44–45	20 25 20	58	94	SS-15	-	59	16	8	14	3	NP	NP	NP	6	A-1-b (0)	
		W (48.5); 49–50	13 26 26	67	56	SS-16	-	-	-	-	-	-	-	-	-	10	A-1-b (V)	
		54–55	30 25 28	69	78	SS-17	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
	683.3																	
VERY STIFF TO HARD, GRAY **SILT AND CLAY**, SOME COARSE TO FINE SAND, SOME FINE GRAVEL, DAMP.		W (58.5); 59–60	15 22 20	54	67	SS-18	3.50	28	13	18	30	11	22	11	11	10	A-6a (1)	
		61																

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 3/14/15 17:34 - U:\GI8\PROJECTS\2013\W-13-045.GPJ

PID: 77372	BR ID: FRA-70-1358R	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 166+20.53 / 31.8 RT	START: 7/30/13	END: 8/2/13	PG 3 OF 3	B-017-3-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 678.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
VERY STIFF TO HARD, GRAY **SILT AND CLAY**, SOME COARSE TO FINE SAND, SOME FINE GRAVEL, DAMP. *(same as above)*	673.3	63–67	20 25 40	84	67	SS-19	4.50	-	-	-	-	-	-	-	-	9	A-6a (V)	
VERY DENSE, BROWN AND GRAY **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, MOIST.	668.3	67–72	3 30 36	85	67	SS-20	-	-	-	-	-	-	-	-	-	9	A-1-a (V)	
HARD, BROWN TO GRAY **CLAY**, TRACE COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP.		72–83.5	4 19 19	49	72	SS-21	4.50	-	-	-	-	-	-	-	-	17	A-7-6 (V)	
			10 24 40	83	72	SS-22	4.5+	8	2	3	41	46	41	19	22	10	A-7-6 (13)	
AUGER REFUSAL @ 83.5'	656.8	TR	4 20 50/5"	-	59	SS-23	4.5+	-	-	-	-	-	-	-	-	15	A-7-6 (V)	
SHALE : BLACK AND GRAY, SLIGHTLY TO HIGHLY WEATHERED, VERY WEAK TO SLIGHTLY STRONG, THINLY LAMINATED TO THIN BEDDED, FISSILE, HIGHLY TO MODERATELY FRACTURED, OPEN APERTURE, SLIGHTLY ROUGH; RQD 26%, REC 81%. -QU @ 86.0' = 222 PSI		83.5–87	0		56	RC-1											CORE	
	653.3	EOB 87	46		100	RC-2											CORE	

NOTES: SEEPAGE ENCOUNTERED @ 48.5'; GROUNDWATER ENCOUNTERED INITIALLY @ 58.5'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 100 LBS BENTONITE CHIPS AND SOIL CUTTINGS

B-017-3-13 – RC-1 and RC-2 – Depth from 83.5 to 87.0 feet

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-12.68 - PHASE 4A	DRILLING FIRM / OPERATOR: RII / T.F.	DRILL RIG: CME-750X (SN 310218)	STATION / OFFSET: 5071+46.22 / 58.4' RT	EXPLORATION ID **B-017-4-13**
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / A.D.	HAMMER: CME AUTOMATIC	ALIGNMENT: BL RAMP C5	
PID: 77372 BR ID: FRA-70-1358A	DRILLING METHOD: 4.25" HSA / RC	CALIBRATION DATE: 4/26/13	ELEVATION: 712.8 (MSL) EOB: 76.3 ft.	PAGE 1 OF 3
START: 7/18/13 END: 7/19/13	SAMPLING METHOD: SPT / HQ	ENERGY RATIO (%): 86.8	LAT / LONG: 39.952700442, -83.007703124	

MATERIAL DESCRIPTION AND NOTES	ELEV. 712.8	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.5' - TOPSOIL (6.0")	712.3																	
STIFF, BROWN **SILTY CLAY**, SOME COARSE TO FINE SAND, SOME FINE GRAVEL, DAMP TO MOIST.		1–2	5-8-4	17	72	SS-1	2.00	-	-	-	-	-	-	-	-	22	A-6b (V)	
		4–5	4-4-5	13	72	SS-2	2.00	29	10	14	28	19	36	20	16	18	A-6b (4)	
	704.8	6–7	4-4-5	13	50	SS-3	2.00	-	-	-	-	-	-	-	-	19	A-6b (V)	
MEDIUM DENSE TO VERY DENSE, BROWN **GRAVEL AND SAND**, LITTLE TO SOME SILT, TRACE CLAY, DAMP TO MOIST.		9–10	5-7-6	19	17	SS-4	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	
		11–12	11-13-15	41	67	SS-5	-	-	-	-	-	-	-	-	-	4	A-1-b (V)	
		14–15	21-12-15	39	56	SS-6	-	59	16	7	14	4	24	19	5	9	A-1-b (0)	
-COBBLES PRESENT THROUGHOUT		16–17	16-15-10	36	56	SS-7	-	-	-	-	-	-	-	-	-	13	A-1-b (V)	
		W (18)																
		19–20	9-12-15	39	44	SS-8	-	-	-	-	-	-	-	-	-	14	A-1-b (V)	
		21–22	10-10-12	32	78	SS-9	-	39	23	13	21	4	23	22	1	10	A-1-b (0)	
		24–25	5-6-4	14	72	SS-10	-	-	-	-	-	-	-	-	-	16	A-1-b (V)	
	684.8	26–27	4-25-28	77	89	SS-11	-	-	-	-	-	-	-	-	-	20	A-1-b (V)	
DENSE TO VERY DENSE, BROWN **GRAVEL**, SOME FINE TO COARSE SAND, TRACE SILT, TRACE CLAY, MOIST.		29	24-13-12	36	83	SS-12	-	-	-	-	-	-	-	-	-	11	A-1-a (V)	

PID: 77372	BR ID: FRA-70-1358A	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 5071+46.22 / 58.4 RT	START: 7/18/13	END: 7/19/13	PG 2 OF 3	B-017-4-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 682.8	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
DENSE TO VERY DENSE, BROWN **GRAVEL**, SOME FINE TO COARSE SAND, TRACE SILT, TRACE CLAY, MOIST. *(same as above)*		31–33																
-HEAVING SANDS ENCOUNTERED @ 33.5'		34–35	10 17 20	54	56	SS-13	-	69	19	4	5	3	21	16	5	11	A-1-a (0)	
		39–40	15 24 41	94	83	SS-14	-	-	-	-	-	-	-	-	-	10	A-1-a (V)	
		44–45	17 18 11	42	89	SS-15	-	-	-	-	-	-	-	-	-	8	A-1-a (V)	
HARD, GRAY **CLAY**, SOME SILT, SOME FINE GRAVEL, TRACE FINE SAND, DRY TO DAMP.	665.8	47																
		49–50	11 16 30	67	50	SS-16	3.50	-	-	-	-	-	-	-	-	16	A-7-6 (V)	
SHALE: GRAY, HIGHLY WEATHERED, VERY WEAK.	659.3	TR 53.5	50/5"	-	100	SS-17	-	-	-	-	-	-	-	-	-	10	Rock (V)	
		58.5	50/5"	-	80	SS-18	-	-	-	-	-	-	-	-	-	10	Rock (V)	
		61																

PID: 77372	BR ID: FRA-70-1358A	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 5071+46.22 / 58.4 RT	START: 7/18/13	END: 7/19/13	PG 3 OF 3	B-017-4-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 650.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
SHALE: GRAY, HIGHLY WEATHERED, VERY WEAK. *(same as above)*		63																
		64	50/5"	-	100	SS-19	-	-	-	-	-	-	-	-	-	11	Rock (V)	
AUGER REFUSAL @ 66.3'	646.5	65, 66																
LIMESTONE : GRAY, MODERATELY WEATHERED, MODERATELY STRONG, VERY THIN TO THIN BEDDED, CALCAREOUS, FRACTURED, OPEN APERTURE, SLIGHTLY ROUGH; RQD 0%, REC 56%. -CLAY SEAM FROM 66.3' TO 66.9'	645.0	67	0		56	RC-1											CORE	
SHALE : GRAY, SLIGHTLY WEATHERED, WEAK, LAMINATED TO THIN BEDDED, CALCAREOUS, FISSILE, FRACTURED TO HIGHLY FRACTURED, OPEN APERTURE, ROUGH; RQD 7%, REC 13%.	640.0	68, 69, 70, 71, 72	7		13	RC-2											CORE	
LIMESTONE : GRAY, UNWEATHERED, STRONG, LAMINATED TO THIN BEDDED, CALCAREOUS, CHERT NODULS, PYRITIC, SLIGHTLY FRACTURED, TIGHT APERTURE, SMOOTH; RQD 100%, REC 100%. -QU @ 74.1' = 8,324 PSI	636.5	73, 74, 75, 76 EOB	100		100	RC-3											CORE	

NOTES: GROUNDWATER INITIALLY ENCOUNTERED @ 18.0'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 188 LBS CEMENT / 50 LBS BENTONITE POWDER / 50 GAL WATER

B-017-4-13 – RC-1, RC-2, and RC-3 – Depth from 66.3 to 76.3 feet

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-12.68 - PHASE 4A	DRILLING FIRM / OPERATOR: RII / J.K.	DRILL RIG: MOBILE B-53 (SN 624400)	STATION / OFFSET: 167+93.97 / 62.9' RT	EXPLORATION ID B-017-5-13
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / S.B.	HAMMER: AUTOMATIC	ALIGNMENT: BL I-70 EB	PAGE 1 OF 3
PID: 77372 BR ID: FRA-70-1358R	DRILLING METHOD: 3.25" HSA / RC	CALIBRATION DATE: 4/26/13	ELEVATION: 717.0 (MSL) EOB: 84.5 ft.	
START: 2/6/14 END: 2/7/14	SAMPLING METHOD: SPT / NQ	ENERGY RATIO (%): 77.7	LAT / LONG: 39.953017653, -83.007412989	

MATERIAL DESCRIPTION AND NOTES	ELEV. 717.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
0.2' - TOPSOIL (2.0")	716.8																	
FILL: MEDIUM DENSE TO DENSE, BLACK **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, WET. -COAL FRAGMENTS PRESENT IN SS-1		1–2	10 12 14	34	67	SS-1	-	35	23	17	17	8	NP	NP	NP	23	A-1-b (0)	
	711.5	4–5	8 5 6	14	67	SS-2	-	-	-	-	-	-	-	-	-	27	A-1-b (V)	
MEDIUM STIFF TO STIFF, BROWN **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, LITTLE FINE GRAVEL, MOIST.		6–7	1 2 3	6	72	SS-3	1.00	-	-	-	-	-	-	-	-	24	A-6a (V)	
		9–10	2 2 4	8	72	SS-4	1.00	12	11	8	31	38	33	20	13	25	A-6a (8)	
	704.0	11–12	2 2 3	6	78	SS-5	1.50	-	-	-	-	-	-	-	-	23	A-6a (V)	
BROWN **GRAVEL AND SAND**, TRACE CLAY, TRACE SILT, MOIST.	701.5	14–15			50	ST-6	-	45	30	6	9	10	NP	NP	NP	16	A-1-b (0)	
LOOSE TO DENSE, BROWN **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST.		16–17	5 4 4	10	89	SS-7	-	-	-	-	-	-	-	-	-	8	A-1-a (V)	
	696.5	19–20	10 12 13	32	72	SS-8	-	-	-	-	-	-	-	-	-	6	A-1-a (V)	
MEDIUM DENSE TO DENSE, BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, MOIST TO WET.		21–22 (W)	8 10 12	28	56	SS-9	-	36	41	10	7	6	NP	NP	NP	20	A-1-b (0)	
		23 (W), 24–25	8 14 17	40	67	SS-10	-	-	-	-	-	-	-	-	-	15	A-1-b (V)	
		26–27	5 5 6	14	89	SS-11	-	-	-	-	-	-	-	-	-	20	A-1-b (V)	
		28–29	3 3 6	12	72	SS-12	-	-	-	-	-	-	-	-	-	17	A-1-b (V)	

PID: 77372 | BR ID: FRA-70-1358R | PROJECT: FRA-70-12.68 - PHASE 4A | STATION / OFFSET: 167+93.97 / 62.9 RT | START: 2/6/14 | END: 2/7/14 | PG 2 OF 3 | B-017-5-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 687.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
-INTRODUCED MUD @ 30.0' MEDIUM DENSE TO DENSE, BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, MOIST TO WET. *(same as above)*	685.0	31, 32																
HARD, BROWN **SANDY SILT**, LITTLE CLAY, LITTLE FINE GRAVEL, DRY.		33, 34, 35	40 20 24	57	83	SS-13	4.5+	20	18	13	32	17	21	16	5	9	A-4a (3)	
	680.0	36, 37																
MEDIUM DENSE TO VERY DENSE, GRAY **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, MOIST. -COBBLES PRESENT FROM 32.0' TO 47.0'		38, 39, 40	17 20 20	52	89	SS-14	-	-	-	-	-	-	-	-	-	11	A-1-b (V)	
		41, 42, 43, 44, 45	7 10 12	28	94	SS-15	-	4	66	17	8	5	NP	NP	NP	17	A-1-b (0)	
		46, 47, 48, 49, 50	8 10 28	49	94	SS-16	-	-	-	-	-	-	-	-	-	12	A-1-b (V)	
	665.0	51, 52																
VERY STIFF, GRAY **CLAY**, LITTLE SILT, TRACE COARSE AND FINE SAND, TRACE FINE GRAVEL, DAMP.		53, 54, 55	3 6 8	18	56	SS-17	2.50	2	1	0	20	77	43	27	16	23	A-7-6 (11)	
	660.0	56, 57																
HARD, GRAY **CLAY**, SOME SILT, LITTLE FINE GRAVEL, TRACE COARSE TO FINE SAND, DAMP.		58, 59, 60	16 26 27	69	72	SS-18	4.5+	-	-	-	-	-	-	-	-	16	A-7-6 (V)	
		61																

PID: 77372	BR ID: FRA-70-1358R	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 167+93.97 / 62.9 RT	START: 2/6/14	END: 2/7/14	PG 3 OF 3	B-017-5-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 654.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
HARD, GRAY **CLAY**, SOME SILT, LITTLE FINE GRAVEL, TRACE COARSE TO FINE SAND, DAMP. *(same as above)*		63																
		64–65	17 26 40	85	83	SS-19	4.5+	12	4	3	32	49	41	24	17	17	A-7-6 (11)	
	650.0	66–67 TR																
SHALE : GRAY, HIGHLY WEATHERED, VERY WEAK.		68																
		69–70	20 36 45	105	78	SS-20	4.5+	-	-	-	-	-	-	-	-	15	Rock (V)	
		71–73																
AUGER REFUSAL @ 74.5'	642.5	74	29 50/5"	-	91	SS-21	4.5+	-	-	-	-	-	-	-	-	17	Rock (V)	
LIMESTONE : GRAY, UNWEATHERED, STRONG, VERY THICK BEDDED, CALCAREOUS, DOLOMITIC, FOSSILIFEROUS, CHERTY, PYRITIC, SLIGHTLY TO HIGHLY FRACTURED, NARROW TO OPEN APERTURES, SLIGHTLY ROUGH TO ROUGH; RQD 82%, REC 91%. -QU @ 78.4' = 10,615 PSI		75–79	83		89	RC-1											CORE	
		80–84	82		93	RC-2											CORE	
	632.5	EOB																

NOTES: SEEPAGE ENCOUNTERED @ 22.0'; GROUNDWATER ENCOUNTERED INITIALLY @ 23.5'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 188 LBS CEMENT / 50 LBS BENTONITE POWDER / 50 GAL WATER

B-017-5-13 – RC-1 and RC-2 – Depth from 74.5 to 84.5 feet

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-12.68 - PHASE 4A	DRILLING FIRM / OPERATOR: RII / J.K.	DRILL RIG: MOBILE B-53 (SN 624400)	STATION / OFFSET: 5074+21.50 / 19.1' RT
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / K.S.	HAMMER: AUTOMATIC	ALIGNMENT: BL RAMP C5
PID: 77372 BR ID: FRA-70-1358A	DRILLING METHOD: 3.25" HSA / RC	CALIBRATION DATE: 4/26/13	ELEVATION: 714.9 (MSL) EOB: 84.5 ft.
START: 12/31/13 END: 1/7/14	SAMPLING METHOD: SPT / NQ	ENERGY RATIO (%): 77.7	LAT / LONG: 39.952895767, -83.006754692

EXPLORATION ID **B-017-6-13**

MATERIAL DESCRIPTION AND NOTES	ELEV. 714.9
FILL: MEDIUM DENSE, BLACK **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, DAMP TO MOIST. -SLAG, CINDERS AND ROCK FRAGMENTS PRESENT THROUGHOUT	708.2
FILL: STIFF, BROWN **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, LITTLE FINE GRAVEL, DAMP. -ORGANICS PRESENT THROUGHOUT	705.5
FILL: MEDIUM DENSE, BROWN **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, DAMP. -SLAG, CINDERS AND ORGANICS PRESENT THROUGHOUT	704.4
STIFF, REDDISH BROWN **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST.	701.9
MEDIUM DENSE, BLACK AND BROWN **COARSE AND FINE SAND**, LITTLE SILT, TRACE CLAY, TRACE FINE GRAVEL, MOIST.	699.4
VERY STIFF, BROWN **SANDY SILT**, SOME FINE GRAVEL, TRACE CLAY, DAMP.	696.9
MEDIUM DENSE TO VERY DENSE, BROWN **GRAVEL AND SAND**, TRACE TO LITTLE SILT, TRACE CLAY, DAMP TO MOIST.	

DEPTHS: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29 (W at 28)

SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
5 6 8	18	44	SS-1	-	-	-	-	-	-	-	-	-	14	A-1-b (V)
9 10 11	27	100	SS-2	-	34	25	20	18	3	NP	NP	NP	19	A-1-b (0)
13 8 4	16	78	SS-3	-	-	-	-	-	-	-	-	-	5	A-1-b (V)
				2.00	13	4	13	42	28	33	18	15	17	A-6a (9)
22 13 9	28	89	SS-4	1.75	-	-	-	-	-	-	-	-	15	A-6a (V)
				-	52	15	13	15	5	NP	NP	NP	6	A-1-b (0)
4 4 5	12	33	SS-5	1.50	-	-	-	-	-	-	-	-	21	A-6a (V)
5 6 8	18	100	SS-6	-	4	28	47	16	5	NP	NP	NP	10	A-3a (0)
7 9 10	25	89	SS-7	-	27	15	14	35	9	24	19	5	14	A-4a (2)
14 10 11	27	83	SS-8	-	-	-	-	-	-	-	-	-	11	A-1-b (V)
11 14 25	51	89	SS-9	-	-	-	-	-	-	-	-	-	9	A-1-b (V)
29 26 26	67	78	SS-10	-	57	17	9	12	5	22	17	5	9	A-1-b (0)
18 16 16	41	67	SS-11	-	-	-	-	-	-	-	-	-	13	A-1-b (V)
8 9 10	25	83	SS-12	-	-	-	-	-	-	-	-	-	15	A-1-b (V)

HOLE SEALED

PID: 77372	BR ID: FRA-70-1358A	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 5074+21.50 / 19.1 RT	START: 12/31/13	END: 1/7/14	PG 2 OF 3	B-017-6-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 684.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
MEDIUM DENSE TO VERY DENSE, BROWN **GRAVEL AND SAND**, TRACE TO LITTLE SILT, TRACE CLAY, DAMP TO MOIST. *(same as above)*			2 6 12	23	67	SS-13	-	10	47	33	8	2	NP	NP	NP	19	A-1-b (0)
	677.9	37															
VERY STIFF TO HARD, GRAY **ELASTIC CLAY**, TRACE SILT, TRACE COARSE SAND, DAMP.			2 6 12	23	67	SS-14	3.00	-	-	-	-	-	-	-	-	24	A-7-5 (V)
			7 10 13	30	83	SS-15	3.75	-	-	-	-	-	-	-	-	27	A-7-5 (V)
			8 10 12	28	100	SS-16	3.75	0	1	0	10	89	57	34	23	27	A-7-5 (17)
			12 18 32	65	100	SS-17	4.50	-	-	-	-	-	-	-	-	25	A-7-5 (V)
	657.9	57															
VERY DENSE, GRAY AND BLACK **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, DAMP.			50/4"	-	75	SS-18	-	-	-	-	-	-	-	-	-	8	A-1-b (V)
	652.9																

PID: 77372	BR ID: FRA-70-1358A	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 5074+21.50 / 19.1 RT	START: 12/31/13	END: 1/7/14	PG 3 OF 3	B-017-6-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 652.8	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
HARD, GRAY **CLAY**, "AND" FINE GRAVEL, LITTLE SILT, TRACE COARSE TO FINE SAND, DRY. *(same as above)*	650.6	63–64 (TR)	32 50/3"	-	22	SS-19	4.5+	56	1	1	15	27	51	23	28	10	A-7-6 (7)	
SHALE : GRAY, HIGHLY WEATHERED, VERY WEAK.		69	33 50/3"	-	56	SS-20	-	-	-	-	-	-	-	-	-	12	Rock (V)	
		74	50/3"	-	100	SS-21	-	-	-	-	-	-	-	-	-	16	Rock (V)	
AUGER REFUSAL @ 74.5'	640.4	74.5																
LIMESTONE : LIGHT BROWN AND GRAY, UNWEATHERED, VERY STRONG, VERY THICK BEDDED, DOLOMITIC, CALCAREOUS, CHERTY, MICACEOUS, SLIGHTLY TO HIGHLY FRACTURED, OPEN APERTURES, ROUGH; RQD 92%, REC 97%. -QU @ 75.6' = 12,261 PSI		77	83		93	RC-1											CORE	
	630.4	82	100		100	RC-2											CORE	
		84.5 (EOB)																

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 28.0'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 282 LBS CEMENT / 50 LBS BENTONITE POWDER / 50 GAL WATER

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 4/2/15 17:50 - U:\GI8\PROJECTS\2013\W-13-045.GPJ

B-017-6-13 – RC-1 and RC-2 – Depth from 74.5 to 84.5 feet

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-12.68 - PHASE 4A	DRILLING FIRM / OPERATOR: RII / J.B.	DRILL RIG: MOBILE B-53 (SN 624400)	STATION / OFFSET: 170+79.36 / 23.3' RT	EXPLORATION ID B-017-7-13
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / S.B.	HAMMER: AUTOMATIC	ALIGNMENT: BL I-70 EB	
PID: 77372 BR ID: FRA-70-1358R	DRILLING METHOD: 4.25" HSA / RC	CALIBRATION DATE: 4/26/13	ELEVATION: 743.1 (MSL) EOB: 96.7 ft.	PAGE 1 OF 4
START: 8/4/13 END: 8/7/13	SAMPLING METHOD: SPT / HQ	ENERGY RATIO (%): 77.7	LAT / LONG: 39.953200568, -83.006425064	

MATERIAL DESCRIPTION AND NOTES	ELEV. 743.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.9' - ASPHALT (11.0")	742.2																	
0.5' - AGGREGATE BASE (6.0")	741.7																	
FILL: MEDIUM DENSE, GRAY **GRAVEL**, LITTLE FINE TO COARSE SAND, TRACE SILT, TRACE CLAY, MOIST.	739.1	2	4 5 6	14	67	SS-1	-	69	13	5	10	3	NP	NP	NP	7	A-1-a (0)	
		4	3 3 5	10	50	SS-2	-	-	-	-	-	-	-	-	-	9	A-1-a (V)	
FILL: STIFF TO VERY STIFF, BROWNISH GRAY TO BROWN **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP.							3.00	-	-	-	-	-	-	-	-	13	A-6a (V)	
	735.1	7	6 8 12	26	50	SS-3	2.00	-	-	-	-	-	-	-	-	12	A-6a (V)	
FILL: VERY DENSE, BROWN **GRAVEL**, TRACE SILT, DAMP.	732.6	9	18 25 25	65	44	SS-4	-	-	-	-	-	-	-	-	-	5	A-1-a (V)	
FILL: STIFF TO HARD, BROWN TO DARK BROWNISH GRAY **SILTY CLAY**, SOME FINE GRAVEL, LITTLE COARSE TO FINE SAND, DRY TO MOIST.		12	3 9 10	25	50	SS-5	2.00	-	-	-	-	-	-	-	-	12	A-6b (V)	
		14	1 2 5	9	56	SS-6	1.50	31	11	8	30	20	37	18	19	19	A-6b (6)	
		17	5 15 15	39	39	SS-7	2.00	-	-	-	-	-	-	-	-	9	A-6b (V)	
		19	15 50 28	101	39	SS-8	2.00	-	-	-	-	-	-	-	-	19	A-6b (V)	
		22	6 12 9	27	56	SS-9	1.75	-	-	-	-	-	-	-	-	20	A-6b (V)	
		24	21 6 8	18	56	SS-10	4.50	24	10	9	33	24	40	20	20	18	A-6b (8)	
		27	7 8 10	23	83	SS-11	2.50	-	-	-	-	-	-	-	-	16	A-6b (V)	
		29	WOH 2 10	16	72	SS-12	2.75	-	-	-	-	-	-	-	-	18	A-6b (V)	

PID: 77372	BR ID: FRA-70-1358R	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 170+79.36 / 23.3 RT	START: 8/4/13	END: 8/7/13	PG 2 OF 4	B-017-7-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 713.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
FILL: STIFF TO HARD, BROWN TO DARK BROWNISH GRAY **SILTY CLAY**, SOME FINE GRAVEL, LITTLE COARSE TO FINE SAND, DRY TO MOIST. *(same as above)*	711.1	31–32																
FILL: STIFF, DARK BROWN **SILT AND CLAY**, SOME COARSE TO FINE SAND, SOME FINE GRAVEL, DAMP.		34–35	4 4 5	12	50	SS-13	1.75	24	14	12	31	19	33	18	15	20	A-6a (5)	
-WOOD FRAGMENTS RECOVERED FROM 38.5' TO 39.0'	704.1	38.5–39	10				-	-	-	-	-	-	-	-	-	110		
HARD, DARK BROWN **SILTY CLAY**, SOME FINE TO COARSE SAND, SOME FINE GRAVEL, MOIST.	701.1	39–40	8 8	21	33	SS-14	4.50	-	-	-	-	-	-	-	-	13	A-6b (V)	
MEDIUM DENSE TO DENSE, BROWN **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, MOIST.		44–45	2 8 11	25	78	SS-15	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
		W 48.5																
		49–50	10 14 16	39	61	SS-16	-	52	18	10	16	4	21	18	3	10	A-1-b (0)	
	686.1	54–55	20 30 45	97	72	SS-17	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
VERY DENSE, GRAY **GRAVEL WITH SAND AND SILT**, TRACE SILT, MOIST.		W 57																
		59–60	41 21 50/4"	-	100	SS-18	-	-	-	-	-	-	-	-	-	17	A-2-4 (V)	
-COBBLES PRESENT @ 60.0'		60–61																

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 3/14/15 17:34 - U:\GI8\PROJECTS\2013\W-13-045.GPJ

MATERIAL DESCRIPTION AND NOTES	ELEV. 681.0	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, GRAY **GRAVEL WITH SAND AND SILT**, TRACE SILT, MOIST. *(same as above)*		63																
		64–65	8 20 20	52	83	SS-19	-	-	-	-	-	-	-	-	-	17	A-2-4 (V)	
	676.1	66–67																
HARD, GRAY **CLAY**, SOME SILT, TRACE COARSE TO FINE SAND, DAMP.		68																
		69–70	8 9 16	32	78	SS-20	4.5+	-	-	-	-	-	-	-	-	20	A-7-6 (V)	
		71–73																
		74–75	12 14 20	44	89	SS-21	4.5+	-	-	-	-	-	-	-	-	17	A-7-6 (V)	
		76–78																
		79–80	12 22 50	93	44	SS-22	4.5+	-	-	-	-	-	-	-	-	17	A-7-6 (V)	
		81–83																
		84–85	40 35 50/4"	-	81	SS-23	4.5+	0	2	5	34	59	54	25	29	15	A-7-6 (18)	
		86–88																
		89	25 50/4"	-	100	SS-24	4.5+	-	-	-	-	-	-	-	-	15	A-7-6 (V)	
AUGER REFUSAL @ 90.0'	653.1	TR 90																
MUDSTONE : GRAY, SLIGHTLY WEATHERED, VERY WEAK, THINLY LAMINATED TO LAMINATED, FRIABLE, FISSILE, HIGHLY FRACTURED TO FRACTURED, OPEN APERTURE, ROUGH; RQD 73%, REC 100%.		90–91	79		100	RC-1											CORE	
	651.1	91–92	66		100	RC-2											CORE	
		93–94																

PID: 77372	BR ID: FRA-70-1358R	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 170+79.36 / 23.3 RT	START: 8/4/13	END: 8/7/13	PG 4 OF 4	B-017-7-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 648.8	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
SHALE : GRAY TO BLACK, HIGHLY WEATHERED, VERY WEAK, THINLY LAMINATED TO LAMINATED, FRIABLE, MODERATELY TO HIGHLY FRACTURED, OPEN APERTURE, SLIGHTLY ROUGH TO ROUGH; RQD 15%, REC 74%. *(same as above)*	646.4	95, 96, EOB	15		74	RC-3											CORE	

NOTES: SEEPAGE ENCOUNTERED @ 48.5'; GROUNDWATER ENCOUNTERED INITIALLY @ 57.0'

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

B-017-7-13 – RC-1, RC-2, and RC-3 – Depth from 90.0 to 96.7 feet

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / J.K.	DRILL RIG: CME-750 (SN 98048)	STATION / OFFSET: 166+64.96 / 18.3' LT	EXPLORATION ID **B-017-9-13**
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / R.B.	HAMMER: CME AUTOMATIC	ALIGNMENT: BL I-70 WB	PAGE
PID: 89464 BR ID: FRA-70-1358L	DRILLING METHOD: 4.25" HSA / HQ	CALIBRATION DATE: 4/26/13	ELEVATION: 717.6 (MSL) EOB: 78.1 ft.	1 OF 3
START: 2/25/14 END: 2/26/14	SAMPLING METHOD: SPT / RC	ENERGY RATIO (%): 82.6	LAT / LONG: 39.953423434, -83.007954336	

MATERIAL DESCRIPTION AND NOTES	ELEV. 717.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
0.1' - TOPSOIL (2.0")	717.5																	
FILL: VERY LOOSE TO MEDIUM DENSE, BLACK TO BROWN **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, MOIST TO WET.		1 - 2	2 2 1	4	0	SS-1	-	-	-	-	-	-	-	-	-	-		
-ORGANICS, ROOT FIBERS AND CINDERS PRESENT IN 3S-1A		3	3	-	67	3S-1A	-	40	20	17	16	7	35	29	6	29	A-1-b (0)	
-CINDERS AND SLAG PRESENT IN SS-2	712.1	4 - 5	6 8 12	28	56	SS-2	-	-	-	-	-	-	-	-	-	18	A-1-b (V)	
FILL: MEDIUM STIFF, BROWN TO GRAY **SILTY CLAY**, SOME COARSE TO FINE SAND, LITTLE FINE GRAVEL, MOIST.	708.9	6 - 8	2 2 2	6	50	SS-3	1.00	11	10	12	35	32	40	18	22	19	A-6b (11)	
FILL: VERY LOOSE, BROWN AND BLACK **COARSE AND FINE SAND**, SOME CLAY, LITTLE FINE GRAVEL, TRACE SILT, WET. -TRACE COAL FRAGMENTS PRESENT IN SS-4B	707.1	9 - 10	1 1 2	4	33	SS-4	1.00	-	-	-	-	-	-	-	-	26	A-6b (V)	
							-	-	-	-	-	-	-	-	-	22	A-3a (V)	
STIFF, DARK BROWN **SILTY CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST.	704.6	11 - 13	WOH 1 4	7	44	SS-5	1.50	-	-	-	-	-	-	-	-	24	A-6b (V)	
MEDIUM DENSE, BROWN **GRAVEL WITH SAND, SILT, AND CLAY**, MOIST.	702.1	14 - 15	6 8 12	28	33	SS-6	-	51	11	10	14	14	-	-	-	17	A-2-6 (V)	
MEDIUM DENSE, BROWN **COARSE AND FINE SAND**, LITTLE SILT, LITTLE FINE GRAVEL, TRACE CLAY, MOIST.	699.6	16 - 18	6 6 8	19	44	SS-7	-	18	19	37	19	7	NP	NP	NP	15	A-3a (0)	
MEDIUM DENSE TO DENSE, BROWN **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, MOIST.		19 - 20	4 6 11	23	56	SS-8	-	-	-	-	-	-	-	-	-	13	A-1-b (V)	
-INTRODUCED MUD @ 20.0'		W 20																
		21 - 22	10 13 21	47	67	SS-9	-	-	-	-	-	-	-	-	-	12	A-1-b (V)	
-ROCK FRAGMENTS PRESENT THROUGHOUT		23 - 25	3 7 11	25	50	SS-10	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
-COBBLES PRESENT FROM 22.0' TO 31.0'		26 - 27	9 10 13	32	56	SS-11	-	54	17	8	15	6	24	19	5	12	A-1-b (0)	
		28 - 29	17 15 19	47	50	SS-12	-	-	-	-	-	-	-	-	-	10	A-1-b (V)	

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 5/2/15 19:17 - U:\GI8\PROJECTS\2013\W-13-072.GPJ

PID: 89464 | BR ID: FRA-70-1358L | PROJECT: FRA-70-13.10 - PHASE 6A | STATION / OFFSET: 166+64.96 / 18.3 LT | START: 2/25/14 | END: 2/26/14 | PG 2 OF 3 | B-017-9-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 687.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
MEDIUM DENSE TO DENSE, BROWN **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, MOIST. *(same as above)*	685.6	31–32																
VERY STIFF, GRAY **CLAY**, LITTLE SILT, TRACE COARSE SAND, TRACE FINE GRAVEL, MOIST.		33																
		34–35	3 7 9	22	50	SS-13	3.50	-	-	-	-	-	-	-	-	24	A-7-6 (V)	
		36–38																
		39–40	3 6 8	19	56	SS-14	2.25	0	1	0	12	87	58	23	35	30	A-7-6 (20)	
		41–43																
		44–45	5 6 10	22	72	SS-15	2.75	-	-	-	-	-	-	-	-	27	A-7-6 (V)	
		46–48																
		49–50	4 7 11	25	78	SS-16	4.00	-	-	-	-	-	-	-	-	25	A-7-6 (V)	
		51–53																
		54–55	6 10 16	36	78	SS-17	4.00	1	0	0	15	84	53	21	32	22	A-7-6 (19)	
	660.6	56																
HARD, GRAY **CLAY**, SOME SILT, TRACE FINE GRAVEL, TRACE FINE SAND, DRY.		57–58																
		59–60	11 21 50	98	56	SS-18	4.5+	-	-	-	-	-	-	-	-	15	A-7-6 (V)	
-BECOMING SHALE @ 60.0'		61																

PID: 89464	BR ID: FRA-70-1358L	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 166+64.96 / 18.3 LT	START: 2/25/14	END: 2/26/14	PG 3 OF 3	B-017-9-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 655.5	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
HARD, GRAY **CLAY**, SOME SILT, TRACE FINE GRAVEL, TRACE FINE SAND, DRY. *(same as above)*	653.2	63 – 64	21 50/5"	-	73	SS-19	4.5+	10	0	1	34	55	53	24	29	15	A-7-6 (18)	
SHALE : GRAY, HIGHLY WEATHERED, VERY WEAK. AUGER REFUSAL @ 69.6'	648.0	TR; 65 – 69	31 42 50/1"	-	69	SS-20	-	-	-	-	-	-	-	-	-	16	Rock (V)	
MUDSTONE : BROWN, HIGHLY TO SEVERLY WEATHERED, VERY WEAK TO WEAK, MEDIUM BEDDED, ARENACEOUS, CALCAREOUS, FRIABLE, PYRITIC, FISSILE, FRACTURED TO HIGHLY FRACTURED, OPEN APERTURES, ROUGH; RQD 0%, REC 62%.	643.5	70 – 73	0		50	RC-1											CORE	
LIMESTONE : GRAY, SLIGHTLY WEATHERED, VERY STRONG, THICK BEDDED, ARENACEOUS, CALCAREOUS, ARGILLACEOUS, CHERT INCLUSIONS, PYRITIC, JOINTED, MODERATELY TO HIGHLY FRACTURED, OPEN APERTURES, ROUGH; RQD 57%, REC 100%. -QU @ 74.2' = 11,707 PSI	639.5	74 – 78; EOB	38		77	RC-2											CORE	

NOTES: GROUNDWATER ENCOUNTERED INTIALLY @ 20.0'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 376 LBS CEMENT / 50 LBS BENTONITE POWDER / 80 GAL WATER

B-017-9-13 – RC-1 and RC-2 – Depth from 69.6 to 78.1 feet

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / J.B.	DRILL RIG: CME-750 (SN 98048)	STATION / OFFSET: 167+31.32 / 54.6' LT
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / TF	HAMMER: CME AUTOMATIC	ALIGNMENT: BL I-70 WB
PID: 89464 BR ID: FRA-70-1358L	DRILLING METHOD: 4.25" HSA / HQ	CALIBRATION DATE: 4/26/13	ELEVATION: 717.0 (MSL) EOB: 83.5 ft.
START: 2/6/14 END: 2/7/14	SAMPLING METHOD: SPT / RC	ENERGY RATIO (%): 82.6	LAT / LONG: 39.953550889, -83.007738627

EXPLORATION ID **B-018-1-13**

MATERIAL DESCRIPTION AND NOTES	ELEV. 717.0
1.0' - TOPSOIL (12.0")	716.0
FILL: MEDIUM DENSE, BLACK AND BROWN **GRAVEL AND SAND**, SOME SILT, TRACE CLAY, WET. -SLAG AND ORGANICS PRESENT IN SS-1 -BRICK AND COAL FRAGMENTS PRESENT IN SS-2	711.5
MEDIUM STIFF TO VERY STIFF, GRAY TO BROWN **SANDY SILT**, SOME CLAY, TRACE FINE GRAVEL, MOIST. -CONSOLIDATION TEST PERFORMED @ 10.1'	701.5
MEDIUM DENSE, BROWN **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST.	699.0
DENSE TO VERY DENSE, BROWN **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST.	694.0
STIFF, BROWN **SILT AND CLAY**, SOME COARSE TO FINE SAND, LITTLE FINE GRAVEL, DAMP.	691.5
DENSE, GRAY **GRAVEL WITH SAND, SILT, AND CLAY**, MOIST.	689.0
VERY DENSE, BROWN TO GRAY **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST.	

DEPTHS: 1–29 (W at approx. 7)

SPT/RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
3 2 8	14	61	SS-1	-	31	28	19	20	2	NP	NP	NP	30	A-1-b (0)	
9 7 6	18	56	SS-2	-	-	-	-	-	-	-	-	-	19	A-1-b (V)	
2 1 2	4	61	SS-3	1.00	-	-	-	-	-	-	-	-	29	A-4a (V)	
		75	ST-4	2.00	6	6	18	41	29	34	25	9	28	A-4a (7)	
3 2 6	11	39	SS-5	1.00	-	-	-	-	-	-	-	-	21	A-4a (V)	
2 11 13	33	44	SS-6	2.50	-	-	-	-	-	-	-	-	29	A-4a (V)	
10 9 6	21	89	SS-7	-	-	-	-	-	-	-	-	-	9	A-1-a (V)	
11 14 21	48	67	SS-8	-	68	14	7	7	4	NP	NP	NP	7	A-1-a (0)	
21 26 28	74	83	SS-9	-	-	-	-	-	-	-	-	-	6	A-1-a (V)	
26 21 17	52	33	SS-10	2.00	16	19	14	31	20	33	21	12	20	A-6a (4)	
16 14 13	37	33	SS-11	-	-	-	-	-	-	-	-	-	20	A-2-6 (V)	
17 17 20	51	61	SS-12	-	-	-	-	-	-	-	-	-	12	A-1-a (V)	

PID: 89464	BR ID: FRA-70-1358L	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 167+31.32 / 54.6 LT	START: 2/6/14	END: 2/7/14	PG 2 OF 3	B-018-1-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 687.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
VERY DENSE, BROWN TO GRAY **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST. *(same as above)*		31–33																
		34–35	17 17 20	51	61	SS-13	-	-	-	-	-	-	-	-	-	7	A-1-a (V)	
		36–38																
		39–40	21 21 36	78	89	SS-14	-	61	23	7	6	3	NP	NP	NP	7	A-1-a (0)	
	675.0	41–42																
STIFF TO VERY STIFF, GRAY **CLAY**, SOME SILT, TRACE FINE GRAVEL, TRACE COARSE TO FINE SAND, DAMP TO MOIST.		43																
		44–45	4 4 5	12	39	SS-15	1.75	-	-	-	-	-	-	-	-	26	A-7-6 (V)	
		46–48																
		49–50	3 5 8	18	78	SS-16	2.75	-	-	-	-	-	-	-	-	24	A-7-6 (V)	
	665.0	51–52																
VERY STIFF TO HARD, BROWN TO GRAY **CLAY**, SOME SILT, TRACE FINE GRAVEL, TRACE COARSE TO FINE SAND, DAMP.		53																
		54–55	12 10 16	36	50	SS-17	4.00	7	4	2	31	56	41	25	16	19	A-7-6 (11)	
		56–58																
	657.7	TR 59	23 50/3"	-	89	SS-18	4.5+	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
SHALE : GRAY, HIGHLY WEATHERED, VERY WEAK.		60–61																

PID: 89464	BR ID: FRA-70-1358L	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 167+31.32 / 54.6 LT	START: 2/6/14	END: 2/7/14	PG 3 OF 3	B-018-1-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 654.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
SHALE : GRAY, HIGHLY WEATHERED, VERY WEAK. *(same as above)*		63																
		64–65	22 32 50/5"	-	82	SS-19	-	-	-	-	-	-	-	-	-	19	Rock (V)	
		69–70	6 23 50	100	67	SS-20	-	-	-	-	-	-	-	-	-	16	Rock (V)	
AUGER REFUSAL @ 73.5'	643.5	73																
LIMESTONE : GRAY AND TAN, UNWEATHERED TO SLIGHTLY WEATHERED, STRONG, VERY THICK BEDDED, CALCAREOUS, SLIGHTLY CARBONACEOUS, CHERTY, CALCITE GROWTHS, DOLOMITIC, JOINTED, MODERATELY TO HIGHLY FRACTURED, OPEN APERTURES, ROUGH; RQD 60%, REC 93%. -QU @ 75.6' = 9,525 PSI -LOSS OF CIRCULATION @ 76.8'		73.5–78.5	97		98	RC-1											CORE	
-CHERT INCLUSIONS FROM 79.5' TO 80.0'	633.5	78.5–83.5 (EOB)	24		88	RC-2											CORE	

NOTES: SEEPAGE ENCOUNTERED @ 7.0'

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

B-018-1-13 – RC-1 and RC-2 – Depth from 73.5 to 83.5 feet

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / J.B.	DRILL RIG: CME-750 (SN 98048)	STATION / OFFSET: 168+63.72 / 22.9' LT
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / K.S.	HAMMER: CME AUTOMATIC	ALIGNMENT: BL I-70 WB
PID: 89464 BR ID: FRA-70-1358L	DRILLING METHOD: 4.25" HSA / HQ	CALIBRATION DATE: 4/26/13	ELEVATION: 715.7 (MSL) EOB: 84.5 ft.
START: 2/10/14 END: 2/13/14	SAMPLING METHOD: SPT / RC	ENERGY RATIO (%): 82.6	LAT / LONG: 39.953512324, -83.007250705

EXPLORATION ID B-018-2-13

PAGE 1 OF 3

MATERIAL DESCRIPTION AND NOTES	ELEV. 715.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
0.5' - TOPSOIL (6.0")	715.2																	
FILL: LOOSE TO MEDIUM DENSE, BROWN TO BLACK **GRAVEL WITH SAND AND SILT**, LITTLE CLAY, MOIST TO WET. -TRASH, DEBRIS, PLASTIC, CINDERS AND ROOT FIBERS PRESENT THROUGHOUT		1–3	6 4 3	10	67	SS-1	-	-	-	-	-	-	-	-	-	12	A-2-4 (V)	
	710.2	3–5	3 5 8	18	72	SS-2	-	26	25	17	22	10	NP	NP	NP	28	A-2-4 (0)	
FILL: STIFF TO VERY STIFF, BROWN **SILTY CLAY**, SOME COARSE TO FINE SAND, LITTLE FINE GRAVEL, MOIST. -TRACE CINDERS AND BRICK FRAGMENTS PRESENT THROUGHOUT		6–8	7 7 8	21	83	SS-3	2.25	-	-	-	-	-	-	-	-	26	A-6b (V)	
	705.2	8–10	4 4 3	10	61	SS-4	1.75	-	-	-	-	-	-	-	-	23	A-6b (V)	
FILL: STIFF TO VERY STIFF, BROWN TO DARK BROWN **SANDY SILT**, SOME CLAY, TRACE FINE GRAVEL, DAMP. -TRACE CINDERS PRESENT IN SS-5		11–13	6 6 8	19	78	SS-5	2.75	9	16	8	39	28	28	19	9	16	A-4a (6)	
	701.4	13–15	3 3 5	11	11	SS-6	1.50	-	-	-	-	-	-	-	-	18	A-4a (V)	
MEDIUM DENSE TO DENSE, BROWN **GRAVEL AND SAND**, TRACE CLAY, TRACE SILT, DAMP TO MOIST. -TRACE ROCK FRAGMENTS PRESENT IN SS-6B							-	-	-	-	-	-	-	-	-	11	A-1-b (V)	
		16–18	5 9 7	22	72	SS-7	-	42	37	13	1	7	NP	NP	NP	9	A-1-b (0)	
	695.2	18–20	7 9 19	39	78	SS-8	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	
DENSE TO VERY DENSE, GRAY **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, DAMP TO MOIST.		21–23	21 25 28	73	56	SS-9	-	-	-	-	-	-	-	-	-	6	A-1-a (V)	
		23–25 W	15 20 23	59	83	SS-10	-	54	29	6	6	5	NP	NP	NP	8	A-1-a (0)	
-IRON STAINING PRESENT IN SS-11		26–28	25 21 15	50	78	SS-11	-	-	-	-	-	-	-	-	-	9	A-1-a (V)	
-LIMESTONE FRAGMENTS PRESENT THROUGHOUT		28–29	23 20 23	59	83	SS-12	-	-	-	-	-	-	-	-	-	9	A-1-a (V)	

PID: 89464	BR ID: FRA-70-1358L	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 168+63.72 / 22.9 LT	START: 2/10/14	END: 2/13/14	PG 2 OF 3	B-018-2-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 685.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
DENSE TO VERY DENSE, GRAY **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, DAMP TO MOIST. *(same as above)* -COBBLES PRESENT @ 31.0'		31–33																
		34–35	48 15 18	45	56	SS-13	-	-	-	-	-	-	-	-	-	8	A-1-a (V)	
-HEAVING SAND ENCOUNTERED @ 35.0' -INTRODUCED MUD @ 35.0'	678.7	35–37																
VERY STIFF TO HARD, GRAY **CLAY**, SOME SILT, TRACE FINE GRAVEL, TRACE COARSE SAND, DRY TO DAMP.		37–38																
		39–40	7 9 18	37	39	SS-14	3.50	-	-	-	-	-	-	-	-	23	A-7-6 (V)	
		41–43																
		44–45	5 8 11	26	78	SS-15	3.50	-	-	-	-	-	-	-	-	25	A-7-6 (V)	
		46–48																
		49–50	8 11 13	33	72	SS-16	4.00	1	1	0	20	78	45	26	19	22	A-7-6 (13)	
		51–53																
		54–55	8 11 15	36	83	SS-17	4.50	-	-	-	-	-	-	-	-	24	A-7-6 (V)	
	656.9	56–58																
		59 (TR)	50/3"	-	100	SS-18	4.5+	-	-	-	-	-	-	-	-	11	A-7-6 (V)	
SHALE : GRAY, HIGHLY WEATHERED, VERY WEAK.		60–61																

PID: 89464	BR ID: FRA-70-1358L	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 168+63.72 / 22.9 LT	START: 2/10/14	END: 2/13/14	PG 3 OF 3	B-018-2-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 653.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
SHALE : GRAY, HIGHLY WEATHERED, VERY WEAK. *(same as above)*		63																
		64	12 50/5"	-	91	SS-19	-	-	-	-	-	-	-	-	-	11	Rock (V)	
		69	25 50/3"	-	100	SS-20	-	-	-	-	-	-	-	-	-	11	Rock (V)	
AUGER REFUSAL @ 74.5'	641.2	74	30 50/2"	-	100	SS-21	-	-	-	-	-	-	-	-	-	13	Rock (V)	
LIMESTONE : GRAY, UNWEATHERED TO SLIGHTLY WEATHERED, STRONG, VERY THICK BEDDED, CALCAREOUS, ARGILLACEOUS, FOSSILIFEROUS, CHERTY, DOLOMITIC, JOINTED, SLIGHTLY TO HIGHLY FRACTURED, OPEN APERTURES, SLIGHTLY ROUGH; RQD 80%, REC 100%. -0.1' TO 0.2' CLAY SEAMS PRESENT FROM 74.5' TO 75.5' -QU @ 78.5' = 10,153 PSI		77	72		100	RC-1											CORE	
		82	87		100	RC-2											CORE	
	631.2	EOB (84)																

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 25.0'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 188 LBS CEMENT / 50 LBS BENTONITE POWDER / 40 GAL WATER; COMPACTED WITH THE AUGER 300 LB. BENTONITE CHIPS AND SOIL CUTTINGS

B-018-2-13 – RC-1 – Depth from 74.5 to 79.5 feet

B-018-2-13 – RC-2 – Depth from 79.5 to 84.5 feet

APPENDIX IV

UNCONFINED COMPRESSIVE STRENGTH TEST RESULTS

RESOURCE INTERNATIONAL, INC.

Engineering Consultants

6350 Presidential Gatew.	9885 Rockside Road	4480 Lake Forest Drive
Columbus, OH 43231	Cleveland, OH 44125	Cincinnati, Ohio 45242
Phone (614) 823-4949	Phone (216) 573-0955	Phone (513) 769-6998

Unconfined Compressive Strength of Intact Rock Core Specimens (ASTM D 7012-04)

Project: FRA-70-12.68

Project No.: W-13-045

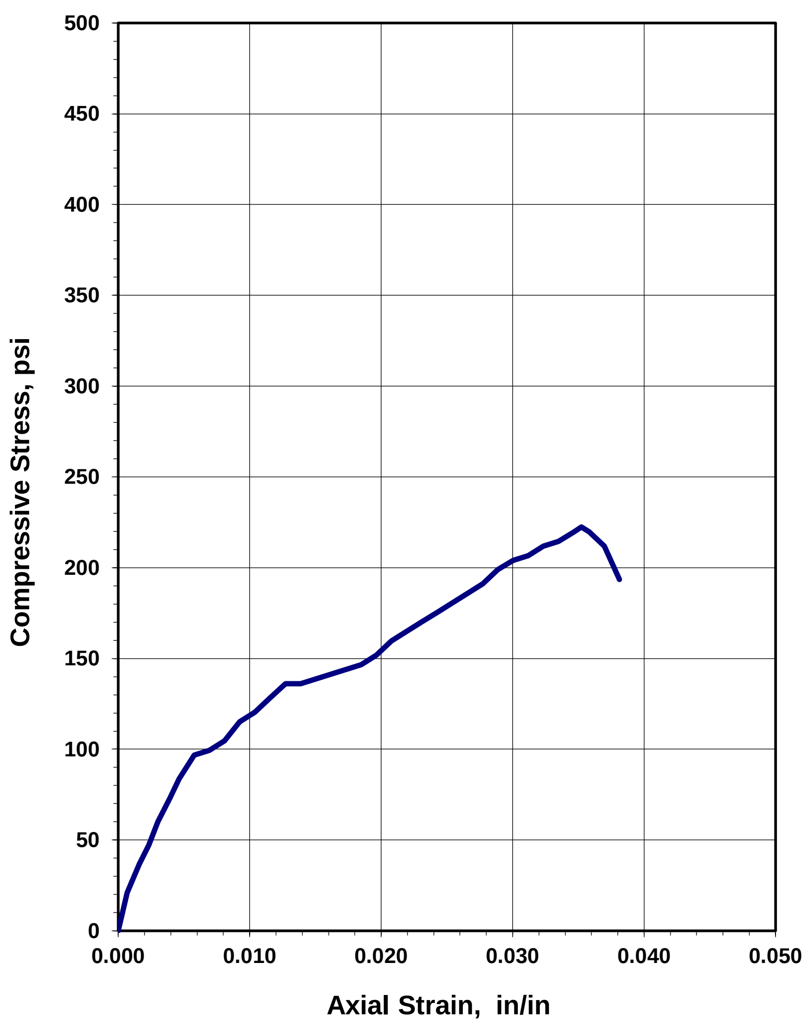
Date of Testing: 8/8/2013

Test Performed by: KR/TK

Rock Description: SHALE: Black, highly weathered, very weak.

Boring No.:	B-017-3-13	Average Length:	4.328 in
Station / Offset:	166+20.53, 31.8' Rt.	Average Diameter:	2.206 in
Sample No. / Depth:	RC-2 / 86 ft.	Length to diameter ratio:	1.962
Moisture condition:	As received	Cross Sectional Area:	3.820 in^2
Rate of Loading:	2.7 lbs/sec	Failure Load:	850 lbs
Testing Time:	310 sec	Axial Strain at Failure:	0.0352 in/in
(Rate 2-15 minutes to failure)		Stress:	222 psi

Unconfined Compression Test



Before Testing

After Failure

REMARKS: ____

RESOURCE INTERNATIONAL, INC.
Engineering Consultants

Unconfined Compressive Strength
of Intact Rock Core Specimens (ASTM D 7012-04)

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

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

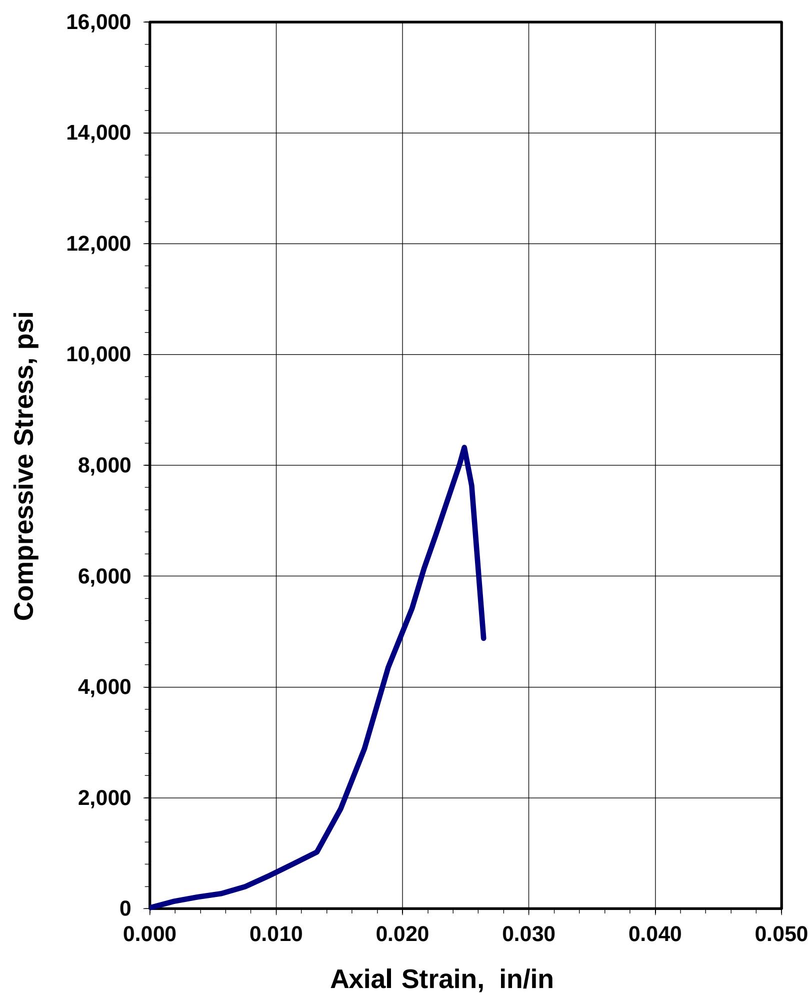
4480 Lake Forest Drive
Cincinnati, Ohio 45242
Phone (513) 769-6998

Project: FRA-70-12.68
Project No.: W-13-045
Date of Testing: 7/26/2013
Test Performed by: KR/TK

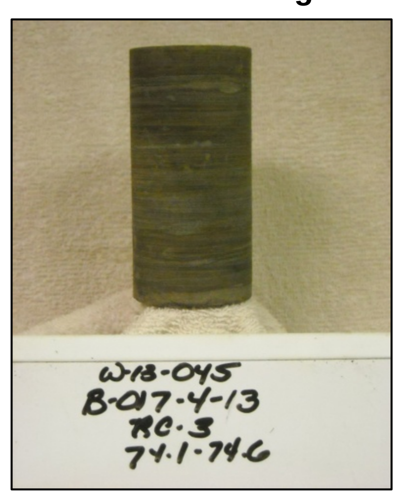
Rock Description: LIMESTONE: Gray, unweathered, strong.

Boring No.:	B-017-4-13	Average Length:	5.3 in
Station / Offset:	5071+46.22, 58.4' Rt.	Average Diameter:	2.396 in
Sample No. / Depth:	RC-3 / 74.1 ft.	Length to diameter ratio:	2.212
Moisture condition:	As received	Cross Sectional Area:	4.507 in^2
Rate of Loading:	64.1 lbs/sec	Failure Load:	37,520 lbs
Testing Time:	585 sec	Axial Strain at Failure:	0.0249 in/in
(Rate 2-15 minutes to failure)		Stress:	8,324 psi

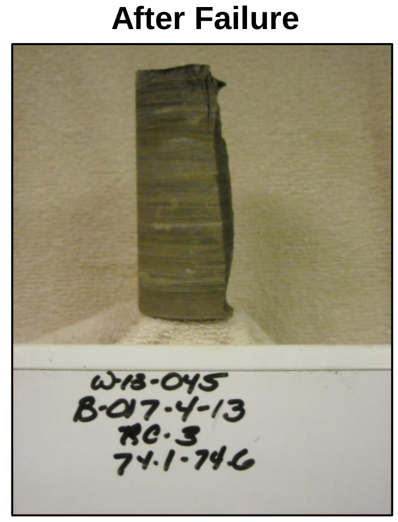
Unconfined Compression Test



Before Testing



After Failure



REMARKS:

RESOURCE INTERNATIONAL, INC.

Engineering Consultants

Unconfined Compressive Strength of Intact Rock Core Specimens (ASTM D 7012-04)

6350 Presidential Gatew.
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Phone (614) 823-4949

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

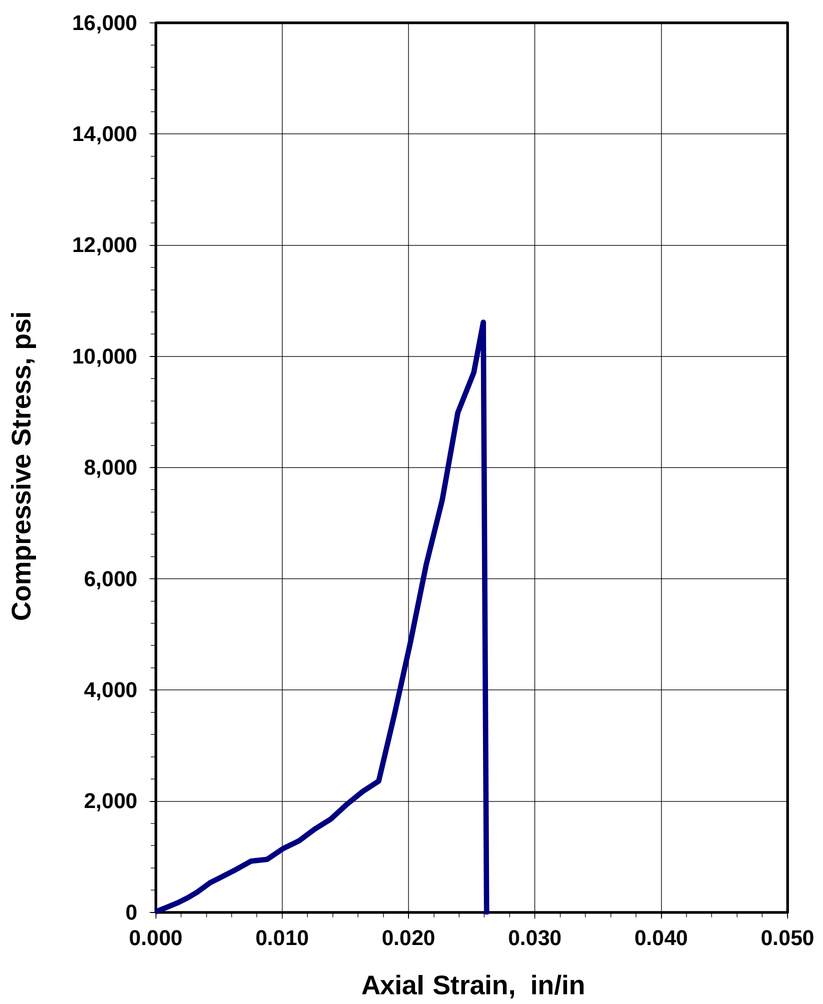
4480 Lake Forest Drive
Cincinnati, Ohio 45242
Phone (513) 769-6998

Project: FRA-70-12.68
Project No.: W-13-045
Date of Testing: 2/10/2014
Test Performed by: K.R./T.K.

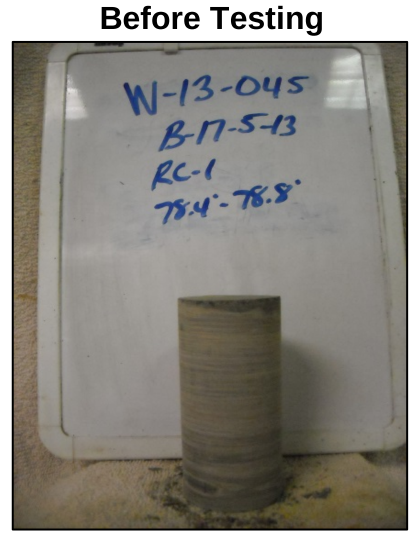
Rock Description: LIMESTONE: Gray, unweathered, strong.

Boring No.:	B-017-5-13	Average Length:	3.973 in
Station / Offset:	167+93.97, 62.9' Rt.	Average Diameter:	1.864 in
Sample No. / Depth:	RC-1 / 78.4 ft.	Length to diameter ratio:	2.131
Moisture condition:	As received	Cross Sectional Area:	2.727 in^2
Rate of Loading:	90.2 lbs/sec	Failure Load:	28,960 lbs
Testing Time:	321 sec	Axial Strain at Failure:	0.0259 in/in
(Rate 2-15 minutes to failure)		Stress:	10,615 psi

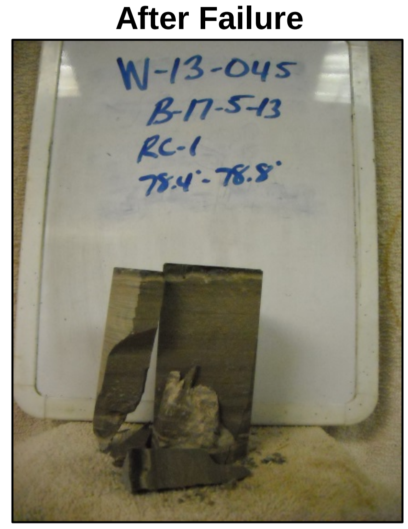
Unconfined Compression Test



Before Testing



After Failure



REMARKS:

RESOURCE INTERNATIONAL, INC.
Engineering Consultants

Unconfined Compressive Strength of Intact Rock Core Specimens (ASTM D 7012-04)

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

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

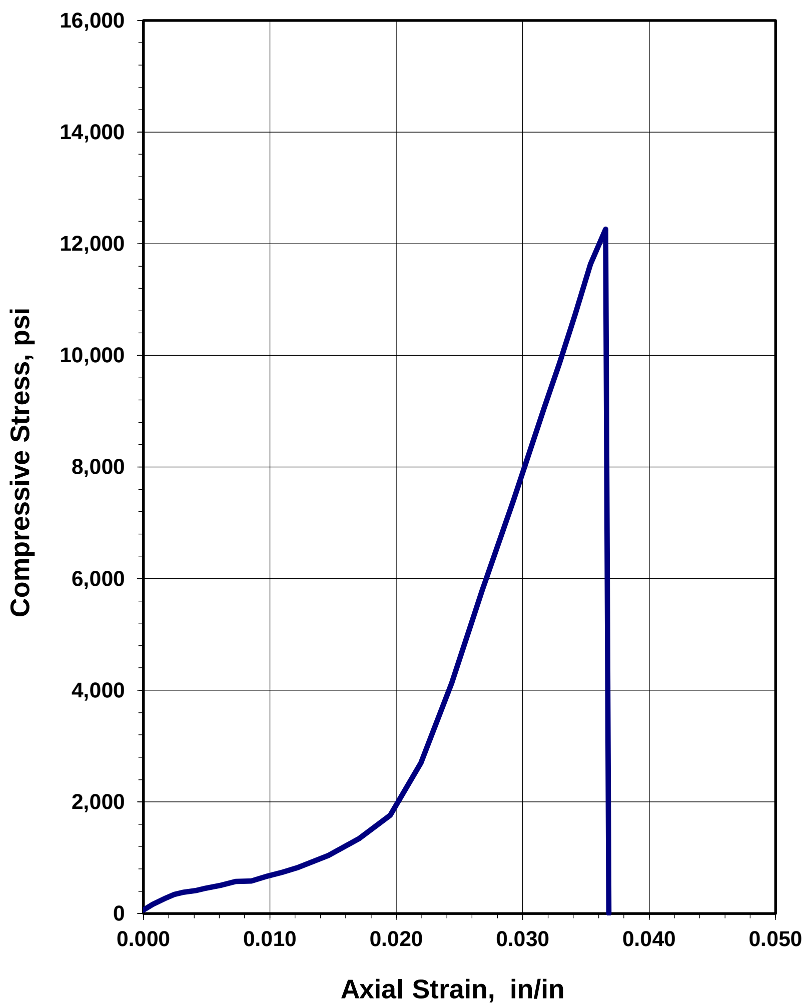
4480 Lake Forest Drive
Cincinnati, Ohio 45242
Phone (513) 769-6998

Project: FRA-70-12.68
Project No.: W-13-045
Date of Testing: 2/13/2014
Test Performed by: J.H./T.K.

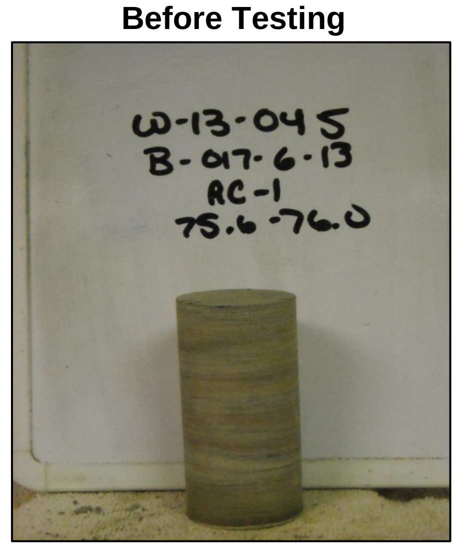
Rock Description: LIMESTONE: Light brown, unweathered, very strong.

Boring No.:	B-017-6-13	Average Length:	4.102 in
Station / Offset:	5074+21.50, 19.1' Rt.	Average Diameter:	1.87 in
Sample No. / Depth:	RC-1 / 75.6 ft.	Length to diameter ratio:	2.194
Moisture condition:	As received	Cross Sectional Area:	2.745 in^2
Rate of Loading:	62.1 lbs/sec	Failure Load:	33,670 lbs
Testing Time:	542 sec	Axial Strain at Failure:	0.0366 in/in
(Rate 2-15 minutes to failure)		Stress:	12,261 psi

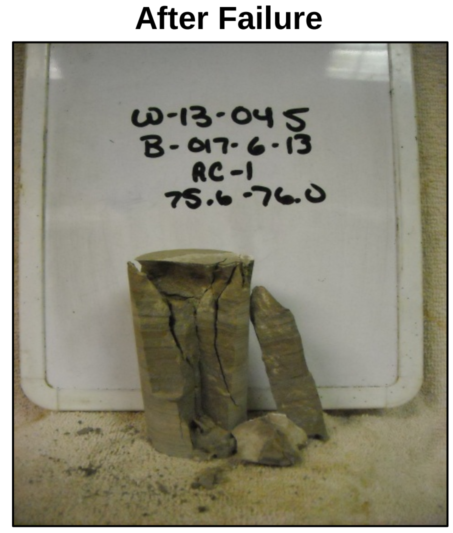
Unconfined Compression Test



Before Testing



After Failure



REMARKS:

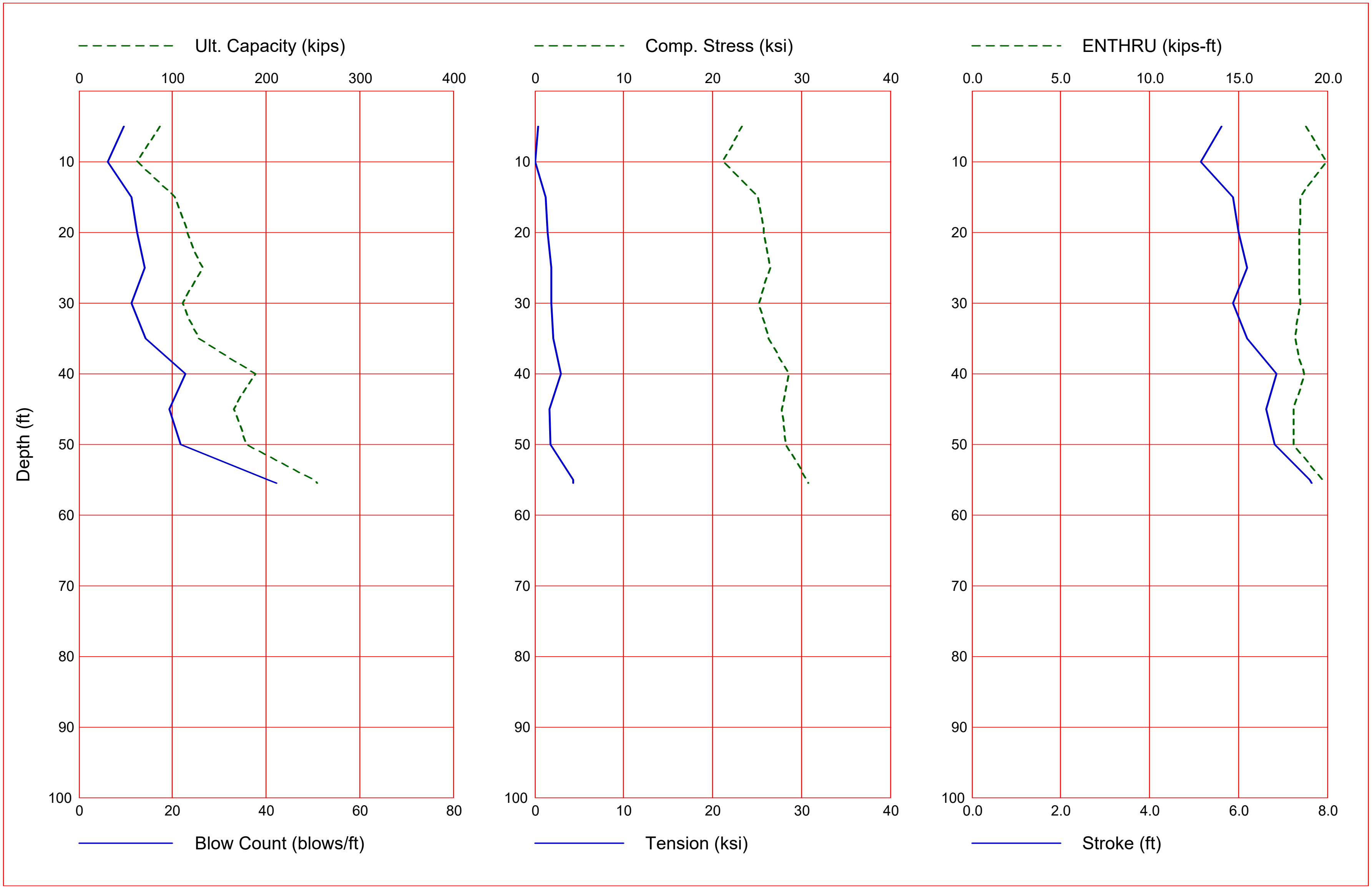
APPENDIX V

GRLWEAP DRIVEABILITY ANALYSIS OUTPUTS

Resource International Inc
FRA-70-1358A - RA - B-017-3-13- HP10x42

Jul 08 2018
GRLWEAP Version 2010

Gain/Loss 1 at Shaft and Toe 0.500 / 1.000



Gain/Loss 1 at Shaft and Toe 0.500 / 1.000

Depth ft	Ultimate Capacity kips	Friction kips	End Bearing kips	Blow Count blows/ft	Comp. Stress ksi	Tension Stress ksi	Stroke ft	ENTHRU kips-ft
5.0	86.3	1.3	85.0	9.6	23.350	-0.412	5.62	18.8
10.0	62.0	8.1	53.9	6.1	21.141	0.000	5.16	19.9
15.0	103.1	18.1	85.0	11.2	25.085	-1.207	5.87	18.5
20.0	115.8	30.8	85.0	12.5	25.780	-1.450	6.01	18.4
25.0	132.1	47.1	85.0	14.1	26.485	-1.898	6.19	18.4
30.0	110.7	64.7	45.9	11.3	25.178	-1.859	5.88	18.5
35.0	127.9	81.9	45.9	14.3	26.346	-2.128	6.19	18.2
40.0	188.6	103.6	85.0	22.7	28.545	-2.928	6.86	18.7
45.0	165.8	119.9	45.9	19.3	27.797	-1.671	6.63	18.1
50.0	178.7	132.8	45.9	21.7	28.244	-1.765	6.81	18.1
55.0	250.4	165.5	84.8	40.4	30.613	-4.296	7.60	19.7
55.5	254.5	169.6	84.8	42.2	30.753	-4.353	7.65	19.8

Total Continuous Driving Time 18.00 minutes; Total Number of Blows 833

GRLWEAP - Version 2010
WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS

written by GRL Engineers, Inc. (formerly Goble Rausche Likins
and Associates, Inc.) with cooperation from Pile Dynamics, Inc.

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

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

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

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

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

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

```
 Input  File: J:\GEOTECH\PROJECTS\2013\W-13-045 FRA-70-13.54 PROJECT 4A\ANALYSIS\FRA-70-1358A\DRIVEBILITY\B-017-3-13 - REAR
ABUTMENT\B-017-3-13 - REAR ABUTMENT.GWW
 Hammer File: C:\ProgramData\PDI\GRLWEAP\2010\Resource\HAMMER2003.GW
 Hammer File Version:  2003 (2/22/2013)

                       Input File Contents
     FRA-70-1358A - RA - B-017-3-13- HP10x42
 OUT OSG HAM STR FUL PEL  N SPL N-U P-D %SK ISM  0 PHI RSA ITR H-D MXT     DEx
-100   0  41   0   1   0  0   0   0   0   0   0  0   0   0   0   0   0   0.000
    Pile g  Hammer g  Toe Area Pile Size          Pile Type
    32.170    32.170    97.720    10.070             H Pile
      W Cp      A Cp      E Cp      T Cp       CoR      ROut      StCp
     1.900   227.000     530.0     2.000     0.800     0.010       0.0
      A Cu      E Cu      T Cu       CoR      ROut      StCu
     0.000       0.0     0.000     0.000     0.000       0.0
      LPle      APle      EPle      WPle      Peri        CI       CoR      ROut
    85.000     12.40   30000.0   492.000     3.295         0     0.850     0.010
 Manufac  Hmr Name  HmrType No Seg-s
 DELMAG   D 19-42         1        5
    Ram Wt     Ram L   Ram Dia   MaxStrk   RtdStrk    Efficy
      4.00    129.10     12.60     11.86     10.81      0.80
    IB. Wt     IB. L    IB.Dia    IB CoR     IB RO
      0.75     25.30     12.60     0.900     0.010
  CompStrk A Chamber V Chamber   C Delay  C Duratn Exp Coeff VolCStart  Vol CEnd
     16.65    124.70    157.70     0.002     0.002     1.250      0.00      0.00
     P atm        P1        P2        P3        P4        P5
     14.70   1520.00   1368.00   1231.00   1108.00      0.00
    Stroke    Effic.  Pressure  R-Weight   T-Delay Exp-Coeff   Eps-Str  Total-AW
```

10.8100	0.8000	1520.0000	0.0000	0.0000	0.0000	0.0100	0.0000

Qs	Qt	Js	Jt	Qx	Jx	Rati	Dept
0.100	0.100	0.153	0.150	0.000	0.000	0.000	0.000

Research Soil Model: Atoe, Plug, Gap, Q-fac
0.000 0.000 0.000 0.000
Research Soil Model: RD-skn: m, d, toe: m, d
0.000 0.000 0.000 0.000
Res. Distribution

Dpth	Rskn	Rtoe	Qs	Qt	Js	Jt	SU F	LimD	SU T
0.00	0.00	85.04	0.10	0.17	0.05	0.15	1.00	6.56	1.0
6.50	0.20	85.04	0.10	0.17	0.05	0.15	1.00	6.56	1.0
6.50	0.41	53.86	0.10	0.17	0.05	0.15	1.00	6.56	1.0
11.50	0.71	53.86	0.10	0.17	0.05	0.15	1.00	6.56	1.0
11.50	0.50	85.04	0.10	0.10	0.05	0.15	1.00	6.56	1.0
26.50	1.17	85.04	0.10	0.10	0.05	0.15	1.00	6.56	1.0
26.50	1.57	45.92	0.10	0.10	0.20	0.15	1.50	6.56	168.0
36.50	1.57	45.92	0.10	0.10	0.20	0.15	1.50	6.56	168.0
36.50	1.39	85.04	0.10	0.10	0.05	0.15	1.00	6.56	1.0
41.50	1.50	85.04	0.10	0.10	0.05	0.15	1.00	6.56	1.0
41.50	1.57	45.92	0.10	0.10	0.20	0.15	2.00	6.56	168.0
51.50	1.57	45.92	0.10	0.10	0.20	0.15	2.00	6.56	168.0
51.50	5.00	84.83	0.10	0.10	0.20	0.15	0.00	6.56	0.0
61.50	5.00	84.83	0.10	0.10	0.20	0.15	0.00	6.56	0.0
61.50	10.00	271.44	0.10	0.10	0.05	0.15	0.00	6.56	0.0
71.50	10.00	271.44	0.10	0.10	0.05	0.15	0.00	6.56	0.0
85.00	10.00	271.44	0.10	0.10	0.05	0.15	0.00	6.56	0.0

Gain/Loss factors: shaft and toe

0.50000	0.00000	0.00000	0.00000	0.00000
1.00000	0.00000	0.00000	0.00000	0.00000

Dpth	L	Wait	Strk	Pmx%	Eff.	Stff	CoR
5.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
10.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
15.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
20.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
25.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
30.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
35.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
40.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
45.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
50.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
55.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
55.50	0.00	0.00	0.000	0.000	0.000	0.000	0.000
0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000

1 0 10.81000 11.86000

GRLWEAP: WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS
Version 2010
English Units

FRA-70-1358A - RA - B-017-3-13- HP10x42

Hammer Model: D 19-42 Made by: DELMAG

No.	Weight kips	Stiffn k/inch	CoR	C-Slk ft	Dampg k/ft/s
1	0.800				
2	0.800	140046.7	1.000	0.0100	
3	0.800	140046.7	1.000	0.0100	
4	0.800	140046.7	1.000	0.0100	
5	0.800	140046.7	1.000	0.0100	
Imp Block	0.753	70735.6	0.900	0.0100	
Helmet	1.900	60155.0	0.800	0.0100	5.8
Combined Pile Top		9482.4			

HAMMER OPTIONS:

Hammer File ID No.	41	Hammer Type	OE Diesel
Stroke Option	FxdP-VarS	Stroke Convergence Crit.	0.010
Fuel Pump Setting	Maximum		

HAMMER DATA:

Ram Weight	(kips)	4.00	Ram Length	(inch)	129.10
Maximum Stroke	(ft)	11.86			
Rated Stroke	(ft)	10.81	Efficiency		0.800
Maximum Pressure	(psi)	1520.00	Actual Pressure	(psi)	1520.00

```
 Compression Exponent           1.350  Expansion Exponent            1.250
 Ram Diameter        (inch)     12.60
 Combustion Delay       (s)   0.00200  Ignition Duration      (s)   0.00200

        The Hammer Data Includes Estimated (NON-MEASURED) Quantities
        ____________________________________________________________


 HAMMER CUSHION                        PILE CUSHION
 Cross Sect. Area     (in2)    227.00  Cross Sect. Area     (in2)      0.00
 Elastic-Modulus      (ksi)     530.0  Elastic-Modulus      (ksi)       0.0
 Thickness           (inch)      2.00  Thickness           (inch)      0.00
 Coeff of Restitution             0.8  Coeff of Restitution             1.0
 RoundOut              (ft)       0.0  RoundOut              (ft)       0.0
 Stiffness        (kips/in)   60155.0  Stiffness        (kips/in)       0.0
```



```
 Depth                 (ft)       5.0
 Shaft Gain/Loss Factor         0.500  Toe Gain/Loss Factor          1.000

 PILE PROFILE:
 Toe Area            (in2)     97.720  Pile Type                    H Pile
 Pile Size          (inch)     10.070

  L b Top     Area    E-Mod  Spec Wt    Perim  C Index  Wave Sp      EA/c
      ft      in2      ksi   lb/ft3       ft              ft/s     k/ft/s
     0.0    12.40   30000.    492.0      3.3        0    16807.      22.1
    85.0    12.40   30000.    492.0      3.3        0    16807.      22.1

 Wave Travel Time 2L/c (ms)    10.115

       Pile and Soil Model           Total Capacity Rut  (kips)      86.3
No. Weight   Stiffn C-Slk T-Slk  CoR  Soil-S  Soil-D Quake  LbTop Perim    Area
      kips     k/in    ft    ft         kips    s/ft  inch     ft    ft     in2
  1  0.139     9482 0.010 0.000 0.85     0.0   0.000 0.100   3.27   3.3    12.4
  2  0.139     9482 0.000 0.000 1.00     0.0   0.000 0.100   6.54   3.3    12.4
 25  0.139     9482 0.000 0.000 1.00     0.2   0.050 0.100  81.73   3.3    12.4
 26  0.139     9482 0.000 0.000 1.00     1.1   0.050 0.100  85.00   3.3    12.4
Toe                                     85.0   0.150 0.167

     3.601 kips total unreduced pile weight (g= 32.17 ft/s2)
     3.601 kips total reduced pile weight   (g= 32.17 ft/s2)

 PILE, SOIL, ANALYSIS OPTIONS:
 Uniform pile                          Pile Segments: Automatic
 No. of Slacks/Splices              0  Pile Damping           (%)         1
                                       Pile Damping Fact.(k/ft/s)     0.443
 Driveability Analysis
 Soil Damping Option            Smith
 Max No Analysis Iterations         0  Time Increment/Critical          160
 Output Time Interval               1  Analysis Time-Input   (ms)         0
 Output Level: Normal
 Gravity Mass, Pile, Hammer:   32.170    32.170    32.170
 Output Segment Generation: Automatic

    Depth    Stroke  Pressure    Efficy
       ft        ft     Ratio
     5.00     10.81      1.00     0.800
```



```
    Rut   Bl Ct   Stroke (ft) Ten Str   i   t Comp Str   i   t ENTHRU   Bl Rt
   kips    b/ft   down     up     ksi               ksi         kip-ft   b/min
   86.3     9.6   5.62   5.66   -0.41  18  47    23.35  22   6   18.8    49.5
         1          0   10.81000       11.86000
```



```
 Depth                 (ft)      10.0
```

B-017-3-13 - REAR ABUTMENT

Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:

Toe Area (in2) 97.720 Pile Type H Pile

Pile Size (inch) 10.070

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
85.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 10.115

Pile and Soil Model Total Capacity Rut (kips) 62.0

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.139	9482	0.010	0.000	0.85	0.0	0.000	0.100	3.27	3.3	12.4
2	0.139	9482	0.000	0.000	1.00	0.0	0.000	0.100	6.54	3.3	12.4
23	0.139	9482	0.000	0.000	1.00	0.0	0.050	0.100	75.19	3.3	12.4
24	0.139	9482	0.000	0.000	1.00	0.6	0.050	0.100	78.46	3.3	12.4
25	0.139	9482	0.000	0.000	1.00	1.9	0.050	0.100	81.73	3.3	12.4
26	0.139	9482	0.000	0.000	1.00	5.6	0.050	0.100	85.00	3.3	12.4
Toe						53.9	0.150	0.168			

3.601 kips total unreduced pile weight (g= 32.17 ft/s2)

3.601 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
10.00	10.81	1.00	0.800

↑

FRA-70-1358A - RA - B-017-3-13- HP10x42 07/08/2018

Resource International Inc GRLWEAP Version 2010

Rut	Bl Ct	Stroke (ft) down	Stroke (ft) up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
62.0	6.1	5.16	5.14	0.00	1	0	21.14	22	6	19.9	51.9

1 0 10.81000 11.86000

↑

FRA-70-1358A - RA - B-017-3-13- HP10x42 07/08/2018

Resource International Inc GRLWEAP Version 2010

Depth (ft) 15.0

Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:

Toe Area (in2) 97.720 Pile Type H Pile

Pile Size (inch) 10.070

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
85.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 10.115

Pile and Soil Model Total Capacity Rut (kips) 103.1

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.139	9482	0.010	0.000	0.85	0.0	0.000	0.100	3.27	3.3	12.4
2	0.139	9482	0.000	0.000	1.00	0.0	0.000	0.100	6.54	3.3	12.4
22	0.139	9482	0.000	0.000	1.00	0.2	0.050	0.100	71.92	3.3	12.4
23	0.139	9482	0.000	0.000	1.00	1.2	0.050	0.100	75.19	3.3	12.4
24	0.139	9482	0.000	0.000	1.00	3.8	0.050	0.100	78.46	3.3	12.4
25	0.139	9482	0.000	0.000	1.00	6.6	0.050	0.100	81.73	3.3	12.4
26	0.139	9482	0.000	0.000	1.00	6.3	0.050	0.100	85.00	3.3	12.4
Toe						85.0	0.150	0.100			

3.601 kips total unreduced pile weight (g= 32.17 ft/s2)

3.601 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	

15.00	10.81	1.00	0.800

FRA-70-1358A - RA - B-017-3-13- HP10x42 07/08/2018
Resource International Inc GRLWEAP Version 2010

Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
103.1	11.2	5.87	5.90	-1.21	19	50	25.08	22	6	18.5	48.5

1 0 10.81000 11.86000

FRA-70-1358A - RA - B-017-3-13- HP10x42 07/08/2018
Resource International Inc GRLWEAP Version 2010

Depth (ft) 20.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
85.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 10.115

Pile and Soil Model Total Capacity Rut (kips) 115.8

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.139	9482	0.010	0.000	0.85	0.0	0.000	0.100	3.27	3.3	12.4
2	0.139	9482	0.000	0.000	1.00	0.0	0.000	0.100	6.54	3.3	12.4
20	0.139	9482	0.000	0.000	1.00	0.0	0.050	0.100	65.38	3.3	12.4
21	0.139	9482	0.000	0.000	1.00	0.7	0.050	0.100	68.65	3.3	12.4
22	0.139	9482	0.000	0.000	1.00	2.1	0.050	0.100	71.92	3.3	12.4
23	0.139	9482	0.000	0.000	1.00	5.8	0.050	0.100	75.19	3.3	12.4
24	0.139	9482	0.000	0.000	1.00	6.4	0.050	0.100	78.46	3.3	12.4
25	0.139	9482	0.000	0.000	1.00	7.1	0.050	0.100	81.73	3.3	12.4
26	0.139	9482	0.000	0.000	1.00	8.7	0.050	0.100	85.00	3.3	12.4
Toe						85.0	0.150	0.100			

3.601 kips total unreduced pile weight (g= 32.17 ft/s2)
3.601 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
20.00	10.81	1.00	0.800

FRA-70-1358A - RA - B-017-3-13- HP10x42 07/08/2018
Resource International Inc GRLWEAP Version 2010

Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
115.8	12.5	6.01	6.03	-1.45	22	43	25.78	22	6	18.4	47.9

1 0 10.81000 11.86000

FRA-70-1358A - RA - B-017-3-13- HP10x42 07/08/2018
Resource International Inc GRLWEAP Version 2010

Depth (ft) 25.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
85.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 10.115

Pile and Soil Model Total Capacity Rut (kips) 132.1

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.139	9482	0.010	0.000	0.85	0.0	0.000	0.100	3.27	3.3	12.4
2	0.139	9482	0.000	0.000	1.00	0.0	0.000	0.100	6.54	3.3	12.4
19	0.139	9482	0.000	0.000	1.00	0.2	0.050	0.100	62.12	3.3	12.4
20	0.139	9482	0.000	0.000	1.00	1.3	0.050	0.100	65.38	3.3	12.4
21	0.139	9482	0.000	0.000	1.00	4.1	0.050	0.100	68.65	3.3	12.4
22	0.139	9482	0.000	0.000	1.00	6.6	0.050	0.100	71.92	3.3	12.4
23	0.139	9482	0.000	0.000	1.00	6.4	0.050	0.100	75.19	3.3	12.4
24	0.139	9482	0.000	0.000	1.00	8.0	0.050	0.100	78.46	3.3	12.4
25	0.139	9482	0.000	0.000	1.00	9.5	0.050	0.100	81.73	3.3	12.4
26	0.139	9482	0.000	0.000	1.00	11.1	0.050	0.100	85.00	3.3	12.4
Toe						85.0	0.150	0.100			

3.601 kips total unreduced pile weight (g= 32.17 ft/s2)
3.601 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
25.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft) down	Stroke (ft) up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
132.1	14.1	6.19	6.19	-1.90	20	39	26.49	21	6	18.4	47.2

1 0 10.81000 11.86000

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Depth (ft) 30.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
85.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 10.115

Pile and Soil Model Total Capacity Rut (kips) 110.7

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.139	9482	0.010	0.000	0.85	0.0	0.000	0.100	3.27	3.3	12.4
2	0.139	9482	0.000	0.000	1.00	0.0	0.000	0.100	6.54	3.3	12.4
17	0.139	9482	0.000	0.000	1.00	0.0	0.050	0.100	55.58	3.3	12.4
18	0.139	9482	0.000	0.000	1.00	0.7	0.050	0.100	58.85	3.3	12.4
19	0.139	9482	0.000	0.000	1.00	2.3	0.050	0.100	62.12	3.3	12.4
20	0.139	9482	0.000	0.000	1.00	5.9	0.050	0.100	65.38	3.3	12.4
21	0.139	9482	0.000	0.000	1.00	6.4	0.050	0.100	68.65	3.3	12.4
22	0.139	9482	0.000	0.000	1.00	7.2	0.050	0.100	71.92	3.3	12.4
23	0.139	9482	0.000	0.000	1.00	8.8	0.050	0.100	75.19	3.3	12.4
24	0.139	9482	0.000	0.000	1.00	10.3	0.050	0.100	78.46	3.3	12.4
25	0.139	9482	0.000	0.000	1.00	11.8	0.065	0.100	81.73	3.3	12.4
26	0.139	9482	0.000	0.000	1.00	11.2	0.200	0.100	85.00	3.3	12.4
Toe						45.9	0.150	0.100			

3.601 kips total unreduced pile weight (g= 32.17 ft/s2)
3.601 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
30.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
110.7	11.3	5.88	5.91	-1.86	19	42	25.18	20	6	18.5	48.4

1 0 10.81000 11.86000

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Depth (ft) 35.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
85.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 10.115

Pile and Soil Model Total Capacity Rut (kips) 127.9

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.139	9482	0.010	0.000	0.85	0.0	0.000	0.100	3.27	3.3	12.4
2	0.139	9482	0.000	0.000	1.00	0.0	0.000	0.100	6.54	3.3	12.4
16	0.139	9482	0.000	0.000	1.00	0.3	0.050	0.100	52.31	3.3	12.4
17	0.139	9482	0.000	0.000	1.00	1.3	0.050	0.100	55.58	3.3	12.4
18	0.139	9482	0.000	0.000	1.00	4.3	0.050	0.100	58.85	3.3	12.4
19	0.139	9482	0.000	0.000	1.00	6.6	0.050	0.100	62.12	3.3	12.4
20	0.139	9482	0.000	0.000	1.00	6.5	0.050	0.100	65.38	3.3	12.4
21	0.139	9482	0.000	0.000	1.00	8.0	0.050	0.100	68.65	3.3	12.4
22	0.139	9482	0.000	0.000	1.00	9.6	0.050	0.100	71.92	3.3	12.4
23	0.139	9482	0.000	0.000	1.00	11.2	0.050	0.100	75.19	3.3	12.4
24	0.139	9482	0.000	0.000	1.00	11.7	0.151	0.100	78.46	3.3	12.4
25	0.139	9482	0.000	0.000	1.00	11.2	0.200	0.100	81.73	3.3	12.4
26	0.139	9482	0.000	0.000	1.00	11.2	0.200	0.100	85.00	3.3	12.4
Toe						45.9	0.150	0.100			

3.601 kips total unreduced pile weight (g= 32.17 ft/s2)
3.601 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
35.00	10.81	1.00	0.800

Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
127.9	14.3	6.19	6.20	-2.13	17	39	26.35	18	5	18.2	47.2

1 0 10.81000 11.86000

Depth (ft) 40.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
85.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 10.115

Pile and Soil Model Total Capacity Rut (kips) 188.6

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area

	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.139	9482	0.010	0.000	0.85	0.0	0.000	0.100	3.27	3.3	12.4
2	0.139	9482	0.000	0.000	1.00	0.0	0.000	0.100	6.54	3.3	12.4
14	0.139	9482	0.000	0.000	1.00	0.0	0.050	0.100	45.77	3.3	12.4
15	0.139	9482	0.000	0.000	1.00	0.8	0.050	0.100	49.04	3.3	12.4
16	0.139	9482	0.000	0.000	1.00	2.5	0.050	0.100	52.31	3.3	12.4
17	0.139	9482	0.000	0.000	1.00	6.0	0.050	0.100	55.58	3.3	12.4
18	0.139	9482	0.000	0.000	1.00	6.4	0.050	0.100	58.85	3.3	12.4
19	0.139	9482	0.000	0.000	1.00	7.3	0.050	0.100	62.12	3.3	12.4
20	0.139	9482	0.000	0.000	1.00	8.9	0.050	0.100	65.38	3.3	12.4
21	0.139	9482	0.000	0.000	1.00	10.4	0.050	0.100	68.65	3.3	12.4
22	0.139	9482	0.000	0.000	1.00	11.8	0.076	0.100	71.92	3.3	12.4
23	0.139	9482	0.000	0.000	1.00	11.2	0.200	0.100	75.19	3.3	12.4
25	0.139	9482	0.000	0.000	1.00	11.5	0.191	0.100	81.73	3.3	12.4
26	0.139	9482	0.000	0.000	1.00	15.4	0.050	0.100	85.00	3.3	12.4
Toe						85.0	0.150	0.100			

3.601 kips total unreduced pile weight (g= 32.17 ft/s2)
3.601 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
40.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
188.6	22.7	6.86	6.82	-2.93	16	30	28.55	17	5	18.7	45.0

1 0 10.81000 11.86000

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Depth (ft) 45.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
85.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 10.115

Pile and Soil Model Total Capacity Rut (kips) 165.8

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.139	9482	0.010	0.000	0.85	0.0	0.000	0.100	3.27	3.3	12.4
2	0.139	9482	0.000	0.000	1.00	0.0	0.000	0.100	6.54	3.3	12.4
13	0.139	9482	0.000	0.000	1.00	0.3	0.050	0.100	42.50	3.3	12.4
14	0.139	9482	0.000	0.000	1.00	1.4	0.050	0.100	45.77	3.3	12.4
15	0.139	9482	0.000	0.000	1.00	4.5	0.050	0.100	49.04	3.3	12.4
16	0.139	9482	0.000	0.000	1.00	6.6	0.050	0.100	52.31	3.3	12.4
17	0.139	9482	0.000	0.000	1.00	6.6	0.050	0.100	55.58	3.3	12.4
18	0.139	9482	0.000	0.000	1.00	8.1	0.050	0.100	58.85	3.3	12.4
19	0.139	9482	0.000	0.000	1.00	9.7	0.050	0.100	62.12	3.3	12.4
20	0.139	9482	0.000	0.000	1.00	11.3	0.050	0.100	65.38	3.3	12.4
21	0.139	9482	0.000	0.000	1.00	11.6	0.159	0.100	68.65	3.3	12.4
22	0.139	9482	0.000	0.000	1.00	11.2	0.200	0.100	71.92	3.3	12.4
24	0.139	9482	0.000	0.000	1.00	13.6	0.114	0.100	78.46	3.3	12.4
25	0.139	9482	0.000	0.000	1.00	15.3	0.061	0.100	81.73	3.3	12.4
26	0.139	9482	0.000	0.000	1.00	8.4	0.200	0.100	85.00	3.3	12.4
Toe						45.9	0.150	0.100			

3.601 kips total unreduced pile weight (g= 32.17 ft/s2)
3.601 kips total reduced pile weight (g= 32.17 ft/s2)

Depth Stroke Pressure Efficy

ft	ft	Ratio	
45.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
165.8	19.3	6.63	6.58	-1.67	15	34	27.80	15	5	18.1	45.8
	1		0	10.81000			11.86000				

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Depth (ft) 50.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
85.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 10.115

Pile and Soil Model Total Capacity Rut (kips) 178.7

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.139	9482	0.010	0.000	0.85	0.0	0.000	0.100	3.27	3.3	12.4
2	0.139	9482	0.000	0.000	1.00	0.0	0.000	0.100	6.54	3.3	12.4
11	0.139	9482	0.000	0.000	1.00	0.0	0.050	0.100	35.96	3.3	12.4
12	0.139	9482	0.000	0.000	1.00	0.9	0.050	0.100	39.23	3.3	12.4
13	0.139	9482	0.000	0.000	1.00	2.7	0.050	0.100	42.50	3.3	12.4
14	0.139	9482	0.000	0.000	1.00	6.1	0.050	0.100	45.77	3.3	12.4
15	0.139	9482	0.000	0.000	1.00	6.3	0.050	0.100	49.04	3.3	12.4
16	0.139	9482	0.000	0.000	1.00	7.4	0.050	0.100	52.31	3.3	12.4
17	0.139	9482	0.000	0.000	1.00	9.0	0.050	0.100	55.58	3.3	12.4
18	0.139	9482	0.000	0.000	1.00	10.5	0.050	0.100	58.85	3.3	12.4
19	0.139	9482	0.000	0.000	1.00	11.8	0.087	0.100	62.12	3.3	12.4
20	0.139	9482	0.000	0.000	1.00	11.2	0.200	0.100	65.38	3.3	12.4
22	0.139	9482	0.000	0.000	1.00	11.7	0.182	0.100	71.92	3.3	12.4
23	0.139	9482	0.000	0.000	1.00	15.5	0.050	0.100	75.19	3.3	12.4
24	0.139	9482	0.000	0.000	1.00	11.5	0.142	0.100	78.46	3.3	12.4
25	0.139	9482	0.000	0.000	1.00	8.4	0.200	0.100	81.73	3.3	12.4
26	0.139	9482	0.000	0.000	1.00	8.4	0.200	0.100	85.00	3.3	12.4
Toe						45.9	0.150	0.100			

3.601 kips total unreduced pile weight (g= 32.17 ft/s2)
3.601 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
50.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
178.7	21.7	6.81	6.79	-1.76	13	30	28.24	14	4	18.1	45.2
	1		0	10.81000			11.86000				

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Depth (ft) 55.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
85.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 10.115

Pile and Soil Model — Total Capacity Rut (kips) 250.4

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.139	9482	0.010	0.000	0.85	0.0	0.000	0.100	3.27	3.3	12.4
2	0.139	9482	0.000	0.000	1.00	0.0	0.000	0.100	6.54	3.3	12.4
10	0.139	9482	0.000	0.000	1.00	0.4	0.050	0.100	32.69	3.3	12.4
11	0.139	9482	0.000	0.000	1.00	1.5	0.050	0.100	35.96	3.3	12.4
12	0.139	9482	0.000	0.000	1.00	4.8	0.050	0.100	39.23	3.3	12.4
13	0.139	9482	0.000	0.000	1.00	6.5	0.050	0.100	42.50	3.3	12.4
14	0.139	9482	0.000	0.000	1.00	6.7	0.050	0.100	45.77	3.3	12.4
15	0.139	9482	0.000	0.000	1.00	8.2	0.050	0.100	49.04	3.3	12.4
16	0.139	9482	0.000	0.000	1.00	9.8	0.050	0.100	52.31	3.3	12.4
17	0.139	9482	0.000	0.000	1.00	11.4	0.050	0.100	55.58	3.3	12.4
18	0.139	9482	0.000	0.000	1.00	11.6	0.166	0.100	58.85	3.3	12.4
19	0.139	9482	0.000	0.000	1.00	11.2	0.200	0.100	62.12	3.3	12.4
21	0.139	9482	0.000	0.000	1.00	13.9	0.105	0.100	68.65	3.3	12.4
22	0.139	9482	0.000	0.000	1.00	14.9	0.071	0.100	71.92	3.3	12.4
23	0.139	9482	0.000	0.000	1.00	8.4	0.200	0.100	75.19	3.3	12.4
25	0.139	9482	0.000	0.000	1.00	9.7	0.200	0.100	81.73	3.3	12.4
26	0.139	9482	0.000	0.000	1.00	26.9	0.200	0.100	85.00	3.3	12.4
Toe						84.8	0.150	0.100			

3.601 kips total unreduced pile weight (g= 32.17 ft/s2)
3.601 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
55.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft) down	Stroke (ft) up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
250.4	40.4	7.60	7.59	-4.30	12	26	30.61	12	4	19.7	42.7

1 0 10.81000 11.86000

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Depth (ft) 55.5
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
85.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 10.115

Pile and Soil Model — Total Capacity Rut (kips) 254.5

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.139	9482	0.010	0.000	0.85	0.0	0.000	0.100	3.27	3.3	12.4
2	0.139	9482	0.000	0.000	1.00	0.0	0.000	0.100	6.54	3.3	12.4
10	0.139	9482	0.000	0.000	1.00	0.5	0.050	0.100	32.69	3.3	12.4
11	0.139	9482	0.000	0.000	1.00	1.6	0.050	0.100	35.96	3.3	12.4
12	0.139	9482	0.000	0.000	1.00	5.4	0.050	0.100	39.23	3.3	12.4
13	0.139	9482	0.000	0.000	1.00	6.5	0.050	0.100	42.50	3.3	12.4
14	0.139	9482	0.000	0.000	1.00	6.9	0.050	0.100	45.77	3.3	12.4
15	0.139	9482	0.000	0.000	1.00	8.5	0.050	0.100	49.04	3.3	12.4
16	0.139	9482	0.000	0.000	1.00	10.0	0.050	0.100	52.31	3.3	12.4

17	0.139	9482	0.000	0.000	1.00	11.6	0.050	0.100	55.58	3.3	12.4
18	0.139	9482	0.000	0.000	1.00	11.4	0.185	0.100	58.85	3.3	12.4
19	0.139	9482	0.000	0.000	1.00	11.2	0.200	0.100	62.12	3.3	12.4
21	0.139	9482	0.000	0.000	1.00	14.5	0.081	0.100	68.65	3.3	12.4
22	0.139	9482	0.000	0.000	1.00	13.8	0.094	0.100	71.92	3.3	12.4
23	0.139	9482	0.000	0.000	1.00	8.4	0.200	0.100	75.19	3.3	12.4
25	0.139	9482	0.000	0.000	1.00	12.6	0.200	0.100	81.73	3.3	12.4
26	0.139	9482	0.000	0.000	1.00	26.9	0.200	0.100	85.00	3.3	12.4
Toe						84.8	0.150	0.100			

3.601 kips total unreduced pile weight (g= 32.17 ft/s2)
3.601 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
55.50	10.81	1.00	0.800

FRA-70-1358A - RA - B-017-3-13- HP10x42 07/08/2018
Resource International Inc GRLWEAP Version 2010

Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
254.5	42.2	7.65	7.65	-4.35	12	25	30.75	12	4	19.8	42.6

FRA-70-1358A - RA - B-017-3-13- HP10x42 07/08/2018
Resource International Inc GRLWEAP Version 2010

SUMMARY OVER DEPTHS

G/L at Shaft and Toe: 0.500 1.000

Depth ft	Rut kips	Frictn kips	End Bg kips	Bl Ct bl/ft	Com Str ksi	Ten Str ksi	Stroke ft	ENTHRU kip-ft
5.0	86.3	1.3	85.0	9.6	23.350	-0.412	5.62	18.8
10.0	62.0	8.1	53.9	6.1	21.141	0.000	5.16	19.9
15.0	103.1	18.1	85.0	11.2	25.085	-1.207	5.87	18.5
20.0	115.8	30.8	85.0	12.5	25.780	-1.450	6.01	18.4
25.0	132.1	47.1	85.0	14.1	26.485	-1.898	6.19	18.4
30.0	110.7	64.7	45.9	11.3	25.178	-1.859	5.88	18.5
35.0	127.9	81.9	45.9	14.3	26.346	-2.128	6.19	18.2
40.0	188.6	103.6	85.0	22.7	28.545	-2.928	6.86	18.7
45.0	165.8	119.9	45.9	19.3	27.797	-1.671	6.63	18.1
50.0	178.7	132.8	45.9	21.7	28.244	-1.765	6.81	18.1
55.0	250.4	165.5	84.8	40.4	30.613	-4.296	7.60	19.7
55.5	254.5	169.6	84.8	42.2	30.753	-4.353	7.65	19.8

Total Driving Time 18 minutes; Total No. of Blows 833

FRA-70-1358A - RA - B-017-3-13- HP10x42 07/08/2018
Resource International Inc GRLWEAP Version 2010

Table of Depths Analyzed with Driving System Modifiers

Depth ft	Temp. Length ft	Wait Time hr	Equivalent Stroke ft	Pressure Ratio	Efficy.	Stiffn. Factor	Cushion CoR
5.00	85.00	0.00	10.81	1.00	0.80	1.00	1.00
10.00	85.00	0.00	10.81	1.00	0.80	1.00	1.00
15.00	85.00	0.00	10.81	1.00	0.80	1.00	1.00
20.00	85.00	0.00	10.81	1.00	0.80	1.00	1.00
25.00	85.00	0.00	10.81	1.00	0.80	1.00	1.00
30.00	85.00	0.00	10.81	1.00	0.80	1.00	1.00
35.00	85.00	0.00	10.81	1.00	0.80	1.00	1.00
40.00	85.00	0.00	10.81	1.00	0.80	1.00	1.00
45.00	85.00	0.00	10.81	1.00	0.80	1.00	1.00
50.00	85.00	0.00	10.81	1.00	0.80	1.00	1.00
55.00	85.00	0.00	10.81	1.00	0.80	1.00	1.00
55.50	85.00	0.00	10.81	1.00	0.80	1.00	1.00

Soil Layer Resistance Values

Depth ft	Shaft Res. k/ft2	End Bearing kips	Shaft Quake inch	Toe Quake inch	Shaft Damping s/ft	Toe Damping s/ft	Soil Setup Normlzd	Limit Distance ft	Setup Time hrs

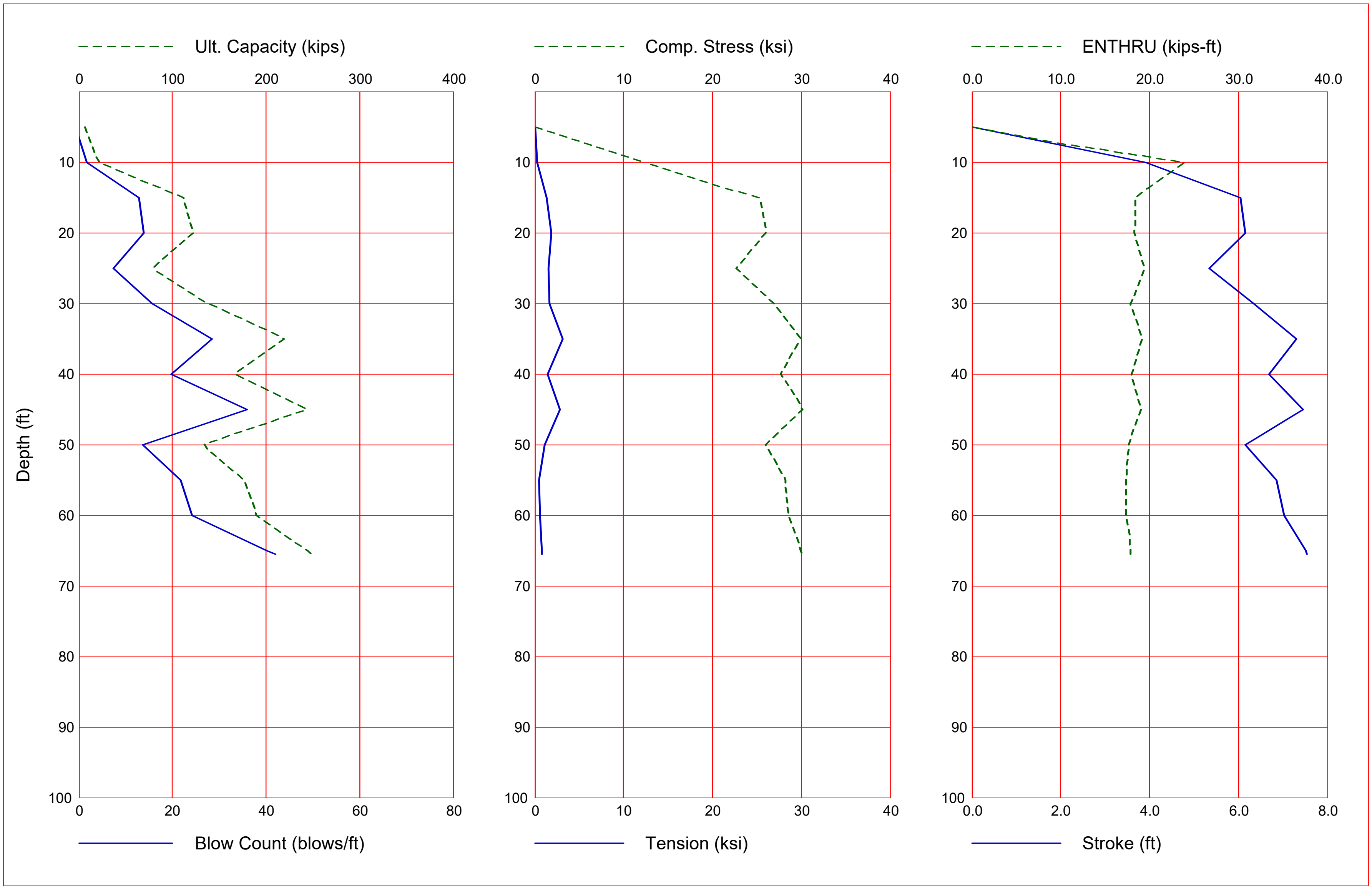
B-017-3-13 - REAR ABUTMENT

0.00	0.00	85.04	0.100	0.167	0.050	0.150	0.000	6.560	1.000
6.50	0.20	85.04	0.100	0.167	0.050	0.150	0.000	6.560	1.000
6.50	0.41	53.86	0.100	0.168	0.050	0.150	0.000	6.560	1.000
11.50	0.71	53.86	0.100	0.168	0.050	0.150	0.000	6.560	1.000
11.50	0.50	85.04	0.100	0.100	0.050	0.150	0.000	6.560	1.000
26.50	1.17	85.04	0.100	0.100	0.050	0.150	0.000	6.560	1.000
26.50	1.57	45.92	0.100	0.100	0.200	0.150	0.667	6.560	168.000
36.50	1.57	45.92	0.100	0.100	0.200	0.150	0.667	6.560	168.000
36.50	1.39	85.04	0.100	0.100	0.050	0.150	0.000	6.560	1.000
41.50	1.50	85.04	0.100	0.100	0.050	0.150	0.000	6.560	1.000
41.50	1.57	45.92	0.100	0.100	0.200	0.150	1.000	6.560	168.000
51.50	1.57	45.92	0.100	0.100	0.200	0.150	1.000	6.560	168.000
51.50	5.00	84.83	0.100	0.100	0.200	0.150	1.000	6.560	168.000
61.50	5.00	84.83	0.100	0.100	0.200	0.150	1.000	6.560	168.000
61.50	10.00	271.44	0.100	0.100	0.050	0.150	1.000	6.560	168.000
71.50	10.00	271.44	0.100	0.100	0.050	0.150	1.000	6.560	168.000
85.00	10.00	271.44	0.100	0.100	0.050	0.150	1.000	6.560	168.000

Resource International Inc
FRA-70-1358A-Pier - B-017-5-13 - HP10x42

Jul 08 2018
GRLWEAP Version 2010

Gain/Loss 1 at Shaft and Toe 0.500 / 1.000



Gain/Loss 1 at Shaft and Toe 0.500 / 1.000

Depth ft	Ultimate Capacity kips	Friction kips	End Bearing kips	Blow Count blows/ft	Comp. Stress ksi	Tension Stress ksi	Stroke ft	ENTHRU kips-ft
5.0	6.5	1.2	5.4	-1.0	0.000	0.000	0.00	0.0
10.0	21.4	7.2	14.2	1.8	12.435	-0.287	3.91	23.9
15.0	112.1	18.6	93.5	12.8	25.385	-1.343	6.04	18.4
20.0	122.0	28.5	93.5	13.9	25.983	-1.846	6.15	18.3
25.0	78.8	42.0	36.8	7.3	22.700	-1.567	5.34	19.5
30.0	138.3	57.4	80.9	15.7	26.882	-1.600	6.34	17.9
35.0	219.0	71.6	147.4	28.4	29.922	-3.199	7.31	19.1
40.0	166.9	87.5	79.4	19.8	27.732	-1.404	6.68	18.0
45.0	243.5	104.6	138.9	36.0	30.097	-2.801	7.46	19.0
50.0	132.3	118.5	13.8	13.7	26.000	-1.095	6.16	17.7
55.0	177.2	131.2	45.9	21.8	28.169	-0.448	6.86	17.3
60.0	190.1	144.1	45.9	24.3	28.581	-0.596	7.02	17.3
65.0	244.7	176.8	67.9	40.2	29.916	-0.796	7.51	17.9
65.5	248.8	181.0	67.9	42.1	30.007	-0.753	7.54	17.9

Total Continuous Driving Time 24.00 minutes; Total Number of Blows 1095

GRLWEAP - Version 2010
WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS

written by GRL Engineers, Inc. (formerly Goble Rausche Likins and Associates, Inc.) with cooperation from Pile Dynamics, Inc.

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

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

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

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

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

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

```
 Input  File: J:\GEOTECH\PROJECTS\2013\W-13-045 FRA-70-13.54 PROJECT 4A\ANALYSIS\FRA-70-1358A\DRIVEBILITY\B-017-5-13 -
PIER\B-017-5-13 - PIER.GWW
 Hammer File: C:\ProgramData\PDI\GRLWEAP\2010\Resource\HAMMER2003.GW
 Hammer File Version:  2003 (2/22/2013)

                       Input File Contents
    FRA-70-1358A-Pier - B-017-5-13 - HP10x42
 OUT OSG HAM STR FUL PEL  N SPL N-U P-D %SK ISM  0 PHI RSA ITR H-D MXT     DEx
-100   0  41   0   1   0  0   0   0   0   0   0  0   0   0   0   0   0   0.000
   Pile g  Hammer g  Toe Area Pile Size          Pile Type
   32.170    32.170    97.720    10.070             H Pile
     W Cp      A Cp      E Cp      T Cp       CoR      ROut      StCp
    1.900   227.000     530.0     2.000     0.800     0.010       0.0
     A Cu      E Cu      T Cu       CoR      ROut      StCu
    0.000       0.0     0.000     0.000     0.000       0.0
     LPle      APle      EPle      WPle      Peri        CI       CoR      ROut
   70.000     12.40   30000.0   492.000     3.295         0     0.850     0.010
 Manufac  Hmr Name  HmrType No Seg-s
 DELMAG   D 19-42         1        5
   Ram Wt     Ram L   Ram Dia   MaxStrk   RtdStrk    Efficy
     4.00    129.10     12.60     11.86     10.81      0.80
   IB. Wt     IB. L    IB.Dia    IB CoR     IB RO
     0.75     25.30     12.60     0.900     0.010
  CompStrk A Chamber V Chamber   C Delay  C Duratn Exp Coeff VolCStart  Vol CEnd
    16.65    124.70    157.70     0.002     0.002     1.250      0.00      0.00
    P atm        P1        P2        P3        P4        P5
    14.70   1520.00   1368.00   1231.00   1108.00      0.00
   Stroke    Effic.  Pressure  R-Weight   T-Delay Exp-Coeff   Eps-Str  Total-AW
```

B-017-5-13 - PIER

10.8100	0.8000	1520.0000	0.0000	0.0000	0.0000	0.0100	0.0000

Qs	Qt	Js	Jt	Qx	Jx	Rati	Dept
0.100	0.100	0.146	0.150	0.000	0.000	0.000	0.000

Research Soil Model: Atoe, Plug, Gap, Q-fac

0.000	0.000	0.000	0.000

Research Soil Model: RD-skn: m, d, toe: m, d

0.000	0.000	0.000	0.000

Res. Distribution

Dpth	Rskn	Rtoe	Qs	Qt	Js	Jt	SU F	LimD	SU T
0.00	0.00	5.36	0.10	0.17	0.20	0.15	1.50	6.56	168.0
8.00	0.34	5.36	0.10	0.17	0.20	0.15	1.50	6.56	168.0
8.00	0.56	14.17	0.10	0.17	0.05	0.15	1.00	6.56	1.0
13.00	0.93	14.17	0.10	0.17	0.05	0.15	1.00	6.56	1.0
13.00	0.45	93.54	0.10	0.17	0.05	0.15	1.00	6.56	1.0
20.50	0.70	93.54	0.10	0.17	0.05	0.15	1.00	6.56	1.0
20.50	0.79	36.85	0.10	0.17	0.05	0.15	1.00	6.56	1.0
27.00	0.92	36.85	0.10	0.17	0.05	0.15	1.00	6.56	1.0
27.00	1.39	75.38	0.10	0.10	0.20	0.15	1.50	6.56	84.0
32.00	1.56	84.56	0.10	0.10	0.20	0.15	1.50	6.56	84.0
32.00	0.73	147.40	0.10	0.10	0.05	0.15	1.00	6.56	1.0
37.00	0.82	147.40	0.10	0.10	0.05	0.15	1.00	6.56	1.0
37.00	1.05	79.37	0.10	0.17	0.05	0.15	1.00	6.56	1.0
42.00	1.15	79.37	0.10	0.17	0.05	0.15	1.00	6.56	1.0
42.00	0.95	138.90	0.10	0.17	0.05	0.15	1.00	6.56	1.0
47.00	1.04	138.90	0.10	0.17	0.05	0.15	1.00	6.56	1.0
47.00	1.43	13.78	0.10	0.17	0.20	0.15	2.00	6.56	168.0
52.00	1.53	13.78	0.10	0.17	0.20	0.15	2.00	6.56	168.0
52.00	1.57	45.92	0.10	0.10	0.20	0.15	2.00	6.56	168.0
61.50	1.57	45.92	0.10	0.10	0.20	0.15	2.00	6.56	168.0
61.50	5.00	67.86	0.10	0.10	0.20	0.15	0.00	6.56	0.0
69.00	5.00	67.86	0.10	0.10	0.20	0.15	0.00	6.56	0.0
69.00	10.00	271.44	0.10	0.10	0.05	0.15	0.00	6.56	0.0
70.00	10.00	271.44	0.10	0.10	0.05	0.15	0.00	6.56	0.0

Gain/Loss factors: shaft and toe

0.50000	0.00000	0.00000	0.00000	0.00000
1.00000	0.00000	0.00000	0.00000	0.00000

Dpth	L	Wait	Strk	Pmx%	Eff.	Stff	CoR
5.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
10.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
15.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
20.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
25.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
30.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
35.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
40.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
45.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
50.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
55.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
60.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
65.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
65.50	0.00	0.00	0.000	0.000	0.000	0.000	0.000
0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000

1 0 10.81000 11.86000

GRLWEAP: WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS
Version 2010
English Units

FRA-70-1358A-Pier - B-017-5-13 - HP10x42

Hammer Model: D 19-42 Made by: DELMAG

No.	Weight kips	Stiffn k/inch	CoR	C-Slk ft	Dampg k/ft/s
1	0.800				
2	0.800	140046.7	1.000	0.0100	
3	0.800	140046.7	1.000	0.0100	
4	0.800	140046.7	1.000	0.0100	
5	0.800	140046.7	1.000	0.0100	
Imp Block	0.753	70735.6	0.900	0.0100	
Helmet	1.900	60155.0	0.800	0.0100	5.8
Combined Pile Top		9300.0			

HAMMER OPTIONS:
Hammer File ID No. 41 Hammer Type OE Diesel

```
 Stroke Option             FxdP-VarS  Stroke Convergence Crit.       0.010
 Fuel Pump Setting           Maximum

HAMMER DATA:
 Ram Weight          (kips)      4.00  Ram Length          (inch)    129.10
 Maximum Stroke        (ft)     11.86
 Rated Stroke          (ft)     10.81  Efficiency                     0.800

 Maximum Pressure     (psi)   1520.00  Actual Pressure      (psi)   1520.00
 Compression Exponent           1.350  Expansion Exponent             1.250
 Ram Diameter        (inch)     12.60
 Combustion Delay       (s)   0.00200  Ignition Duration      (s)   0.00200

        The Hammer Data Includes Estimated (NON-MEASURED) Quantities


 HAMMER CUSHION                        PILE CUSHION
 Cross Sect. Area     (in2)    227.00  Cross Sect. Area     (in2)      0.00
 Elastic-Modulus      (ksi)     530.0  Elastic-Modulus      (ksi)       0.0
 Thickness           (inch)      2.00  Thickness           (inch)      0.00
 Coeff of Restitution             0.8  Coeff of Restitution             1.0
 RoundOut              (ft)       0.0  RoundOut              (ft)       0.0
 Stiffness       (kips/in)    60155.0  Stiffness       (kips/in)       0.0
```



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 Depth                 (ft)       5.0
 Shaft Gain/Loss Factor         0.500  Toe Gain/Loss Factor           1.000

 PILE PROFILE:
 Toe Area             (in2)    97.720  Pile Type                     H Pile
 Pile Size           (inch)    10.070

  L b Top     Area    E-Mod  Spec Wt    Perim  C Index  Wave Sp      EA/c
      ft      in2      ksi   lb/ft3       ft              ft/s    k/ft/s
     0.0    12.40   30000.    492.0      3.3        0    16807.     22.1
    70.0    12.40   30000.    492.0      3.3        0    16807.     22.1

 Wave Travel Time 2L/c (ms)     8.330

       Pile and Soil Model            Total Capacity Rut  (kips)       6.5
No. Weight   Stiffn C-Slk T-Slk  CoR  Soil-S  Soil-D Quake  LbTop Perim    Area
      kips     k/in    ft    ft         kips    s/ft  inch     ft    ft     in2
  1  0.141     9300 0.010 0.000 0.85     0.0   0.000 0.100   3.33   3.3    12.4
  2  0.141     9300 0.000 0.000 1.00     0.0   0.000 0.100   6.67   3.3    12.4
 20  0.141     9300 0.000 0.000 1.00     0.1   0.200 0.100  66.67   3.3    12.4
 21  0.141     9300 0.000 0.000 1.00     1.0   0.200 0.100  70.00   3.3    12.4
Toe                                      5.4   0.150 0.167

     2.966 kips total unreduced pile weight (g= 32.17 ft/s2)
     2.966 kips total reduced pile weight   (g= 32.17 ft/s2)

 PILE, SOIL, ANALYSIS OPTIONS:
 Uniform pile                          Pile Segments: Automatic
 No. of Slacks/Splices              0  Pile Damping          (%)          1
                                       Pile Damping Fact.(k/ft/s)     0.443
 Driveability Analysis
 Soil Damping Option            Smith
 Max No Analysis Iterations         0  Time Increment/Critical          160
 Output Time Interval               1  Analysis Time-Input   (ms)         0
 Output Level: Normal
 Gravity Mass, Pile, Hammer:   32.170    32.170    32.170
 Output Segment Generation: Automatic

    Depth    Stroke  Pressure    Efficy
       ft        ft     Ratio
     5.00     10.81      1.00     0.800
```

B-017-5-13 - PIER

Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
6.5	Hammer did not run										

1 0 10.81000 11.86000

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FRA-70-1358A-Pier - B-017-5-13 - HP10x42 07/08/2018
Resource International Inc GRLWEAP Version 2010

Depth (ft) 10.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
70.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 8.330

Pile and Soil Model Total Capacity Rut (kips) 21.4

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.141	9300	0.010	0.000	0.85	0.0	0.000	0.100	3.33	3.3	12.4
2	0.141	9300	0.000	0.000	1.00	0.0	0.000	0.100	6.67	3.3	12.4
19	0.141	9300	0.000	0.000	1.00	0.5	0.200	0.100	63.33	3.3	12.4
20	0.141	9300	0.000	0.000	1.00	1.6	0.200	0.100	66.67	3.3	12.4
21	0.141	9300	0.000	0.000	1.00	5.1	0.087	0.100	70.00	3.3	12.4
Toe						14.2	0.150	0.167			

2.966 kips total unreduced pile weight (g= 32.17 ft/s2)
2.966 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
10.00	10.81	1.00	0.800

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FRA-70-1358A-Pier - B-017-5-13 - HP10x42 07/08/2018
Resource International Inc GRLWEAP Version 2010

Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
21.4	1.8	3.91	3.92	-0.29	9	13	12.43	1	2	23.9	59.9

1 0 10.81000 11.86000

↑

FRA-70-1358A-Pier - B-017-5-13 - HP10x42 07/08/2018
Resource International Inc GRLWEAP Version 2010

Depth (ft) 15.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
70.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 8.330

Pile and Soil Model Total Capacity Rut (kips) 112.1

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.141	9300	0.010	0.000	0.85	0.0	0.000	0.100	3.33	3.3	12.4
2	0.141	9300	0.000	0.000	1.00	0.0	0.000	0.100	6.67	3.3	12.4
17	0.141	9300	0.000	0.000	1.00	0.1	0.200	0.100	56.67	3.3	12.4
18	0.141	9300	0.000	0.000	1.00	1.0	0.200	0.100	60.00	3.3	12.4
19	0.141	9300	0.000	0.000	1.00	2.5	0.172	0.100	63.33	3.3	12.4
20	0.141	9300	0.000	0.000	1.00	7.8	0.050	0.100	66.67	3.3	12.4
21	0.141	9300	0.000	0.000	1.00	7.1	0.050	0.100	70.00	3.3	12.4

Toe		93.5	0.150	0.167

2.966 kips total unreduced pile weight (g= 32.17 ft/s2)
2.966 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
15.00	10.81	1.00	0.800

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Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
112.1	12.8	6.04	6.05	-1.34	18	42	25.39	18	5	18.4	47.8

1 0 10.81000 11.86000

FRA-70-1358A-Pier - B-017-5-13 - HP10x42 07/08/2018
Resource International Inc GRLWEAP Version 2010

Depth (ft) 20.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
70.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 8.330

Pile and Soil Model Total Capacity Rut (kips) 122.0

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.141	9300	0.010	0.000	0.85	0.0	0.000	0.100	3.33	3.3	12.4
2	0.141	9300	0.000	0.000	1.00	0.0	0.000	0.100	6.67	3.3	12.4
16	0.141	9300	0.000	0.000	1.00	0.5	0.200	0.100	53.33	3.3	12.4
17	0.141	9300	0.000	0.000	1.00	1.6	0.200	0.100	56.67	3.3	12.4
18	0.141	9300	0.000	0.000	1.00	5.1	0.087	0.100	60.00	3.3	12.4
19	0.141	9300	0.000	0.000	1.00	8.6	0.050	0.100	63.33	3.3	12.4
20	0.141	9300	0.000	0.000	1.00	5.7	0.050	0.100	66.67	3.3	12.4
21	0.141	9300	0.000	0.000	1.00	6.9	0.050	0.100	70.00	3.3	12.4
Toe						93.5	0.150	0.167			

2.966 kips total unreduced pile weight (g= 32.17 ft/s2)
2.966 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
20.00	10.81	1.00	0.800

FRA-70-1358A-Pier - B-017-5-13 - HP10x42 07/08/2018
Resource International Inc GRLWEAP Version 2010

Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
122.0	13.9	6.15	6.16	-1.85	17	39	25.98	17	5	18.3	47.4

1 0 10.81000 11.86000

FRA-70-1358A-Pier - B-017-5-13 - HP10x42 07/08/2018
Resource International Inc GRLWEAP Version 2010

Depth (ft) 25.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c

B-017-5-13 - PIER

ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
70.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 8.330

Pile and Soil Model — Total Capacity Rut (kips) 78.8

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.141	9300	0.010	0.000	0.85	0.0	0.000	0.100	3.33	3.3	12.4
2	0.141	9300	0.000	0.000	1.00	0.0	0.000	0.100	6.67	3.3	12.4
14	0.141	9300	0.000	0.000	1.00	0.1	0.200	0.100	46.67	3.3	12.4
15	0.141	9300	0.000	0.000	1.00	1.0	0.200	0.100	50.00	3.3	12.4
16	0.141	9300	0.000	0.000	1.00	2.5	0.172	0.100	53.33	3.3	12.4
17	0.141	9300	0.000	0.000	1.00	7.8	0.050	0.100	56.67	3.3	12.4
18	0.141	9300	0.000	0.000	1.00	7.1	0.050	0.100	60.00	3.3	12.4
19	0.141	9300	0.000	0.000	1.00	6.3	0.050	0.100	63.33	3.3	12.4
20	0.141	9300	0.000	0.000	1.00	7.8	0.050	0.100	66.67	3.3	12.4
21	0.141	9300	0.000	0.000	1.00	9.3	0.050	0.100	70.00	3.3	12.4
Toe						36.8	0.150	0.167			

2.966 kips total unreduced pile weight (g= 32.17 ft/s2)
2.966 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
25.00	10.81	1.00	0.800

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FRA-70-1358A-Pier - B-017-5-13 - HP10x42 07/08/2018
Resource International Inc GRLWEAP Version 2010

Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
78.8	7.3	5.34	5.32	-1.57	15	50	22.70	15	5	19.5	51.0

1 0 10.81000 11.86000

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FRA-70-1358A-Pier - B-017-5-13 - HP10x42 07/08/2018
Resource International Inc GRLWEAP Version 2010

Depth (ft) 30.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
70.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 8.330

Pile and Soil Model — Total Capacity Rut (kips) 138.3

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.141	9300	0.010	0.000	0.85	0.0	0.000	0.100	3.33	3.3	12.4
2	0.141	9300	0.000	0.000	1.00	0.0	0.000	0.100	6.67	3.3	12.4
13	0.141	9300	0.000	0.000	1.00	0.5	0.200	0.100	43.33	3.3	12.4
14	0.141	9300	0.000	0.000	1.00	1.6	0.200	0.100	46.67	3.3	12.4
15	0.141	9300	0.000	0.000	1.00	5.1	0.087	0.100	50.00	3.3	12.4
16	0.141	9300	0.000	0.000	1.00	8.6	0.050	0.100	53.33	3.3	12.4
17	0.141	9300	0.000	0.000	1.00	5.7	0.050	0.100	56.67	3.3	12.4
18	0.141	9300	0.000	0.000	1.00	6.9	0.050	0.100	60.00	3.3	12.4
19	0.141	9300	0.000	0.000	1.00	8.8	0.050	0.100	63.33	3.3	12.4
20	0.141	9300	0.000	0.000	1.00	9.7	0.050	0.100	66.67	3.3	12.4
21	0.141	9300	0.000	0.000	1.00	10.5	0.190	0.100	70.00	3.3	12.4
Toe						80.9	0.150	0.100			

2.966 kips total unreduced pile weight (g= 32.17 ft/s2)
2.966 kips total reduced pile weight (g= 32.17 ft/s2)

Depth Stroke Pressure Efficy

ft	ft	Ratio	
30.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft) down	up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
138.3	15.7	6.34	6.35	-1.60	14	35	26.88	14	5	17.9	46.7

1 0 10.81000 11.86000

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Resource International Inc GRLWEAP Version 2010

Depth (ft) 35.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
70.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 8.330

Pile and Soil Model Total Capacity Rut (kips) 219.0

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.141	9300	0.010	0.000	0.85	0.0	0.000	0.100	3.33	3.3	12.4
2	0.141	9300	0.000	0.000	1.00	0.0	0.000	0.100	6.67	3.3	12.4
11	0.141	9300	0.000	0.000	1.00	0.1	0.200	0.100	36.67	3.3	12.4
12	0.141	9300	0.000	0.000	1.00	1.0	0.200	0.100	40.00	3.3	12.4
13	0.141	9300	0.000	0.000	1.00	2.5	0.172	0.100	43.33	3.3	12.4
14	0.141	9300	0.000	0.000	1.00	7.8	0.050	0.100	46.67	3.3	12.4
15	0.141	9300	0.000	0.000	1.00	7.1	0.050	0.100	50.00	3.3	12.4
16	0.141	9300	0.000	0.000	1.00	6.3	0.050	0.100	53.33	3.3	12.4
17	0.141	9300	0.000	0.000	1.00	7.8	0.050	0.100	56.67	3.3	12.4
18	0.141	9300	0.000	0.000	1.00	9.3	0.050	0.100	60.00	3.3	12.4
19	0.141	9300	0.000	0.000	1.00	10.1	0.127	0.100	63.33	3.3	12.4
20	0.141	9300	0.000	0.000	1.00	10.9	0.200	0.100	66.67	3.3	12.4
21	0.141	9300	0.000	0.000	1.00	8.6	0.078	0.100	70.00	3.3	12.4
Toe						147.4	0.150	0.100			

2.966 kips total unreduced pile weight (g= 32.17 ft/s2)
2.966 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
35.00	10.81	1.00	0.800

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Resource International Inc GRLWEAP Version 2010

Rut	Bl Ct	Stroke (ft) down	up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
219.0	28.4	7.31	7.29	-3.20	13	26	29.92	13	4	19.1	43.5

1 0 10.81000 11.86000

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Resource International Inc GRLWEAP Version 2010

Depth (ft) 40.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1

70.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 8.330

Pile and Soil Model — Total Capacity Rut (kips) 166.9

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.141	9300	0.010	0.000	0.85	0.0	0.000	0.100	3.33	3.3	12.4
2	0.141	9300	0.000	0.000	1.00	0.0	0.000	0.100	6.67	3.3	12.4
10	0.141	9300	0.000	0.000	1.00	0.5	0.200	0.100	33.33	3.3	12.4
11	0.141	9300	0.000	0.000	1.00	1.6	0.200	0.100	36.67	3.3	12.4
12	0.141	9300	0.000	0.000	1.00	5.1	0.087	0.100	40.00	3.3	12.4
13	0.141	9300	0.000	0.000	1.00	8.6	0.050	0.100	43.33	3.3	12.4
14	0.141	9300	0.000	0.000	1.00	5.7	0.050	0.100	46.67	3.3	12.4
15	0.141	9300	0.000	0.000	1.00	6.9	0.050	0.100	50.00	3.3	12.4
16	0.141	9300	0.000	0.000	1.00	8.8	0.050	0.100	53.33	3.3	12.4
17	0.141	9300	0.000	0.000	1.00	9.7	0.050	0.100	56.67	3.3	12.4
18	0.141	9300	0.000	0.000	1.00	10.5	0.190	0.100	60.00	3.3	12.4
19	0.141	9300	0.000	0.000	1.00	10.0	0.163	0.100	63.33	3.3	12.4
20	0.141	9300	0.000	0.000	1.00	8.6	0.050	0.100	66.67	3.3	12.4
21	0.141	9300	0.000	0.000	1.00	11.5	0.050	0.100	70.00	3.3	12.4
Toe						79.4	0.150	0.167			

2.966 kips total unreduced pile weight (g= 32.17 ft/s2)
2.966 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
40.00	10.81	1.00	0.800

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FRA-70-1358A-Pier - B-017-5-13 - HP10x42 07/08/2018
Resource International Inc GRLWEAP Version 2010

Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
166.9	19.8	6.68	6.63	-1.40	11	31	27.73	11	4	18.0	45.6

1 0 10.81000 11.86000

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FRA-70-1358A-Pier - B-017-5-13 - HP10x42 07/08/2018
Resource International Inc GRLWEAP Version 2010

Depth (ft) 45.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
70.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 8.330

Pile and Soil Model — Total Capacity Rut (kips) 243.5

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.141	9300	0.010	0.000	0.85	0.0	0.000	0.100	3.33	3.3	12.4
2	0.141	9300	0.000	0.000	1.00	0.0	0.000	0.100	6.67	3.3	12.4
8	0.141	9300	0.000	0.000	1.00	0.1	0.200	0.100	26.67	3.3	12.4
9	0.141	9300	0.000	0.000	1.00	1.0	0.200	0.100	30.00	3.3	12.4
10	0.141	9300	0.000	0.000	1.00	2.5	0.172	0.100	33.33	3.3	12.4
11	0.141	9300	0.000	0.000	1.00	7.8	0.050	0.100	36.67	3.3	12.4
12	0.141	9300	0.000	0.000	1.00	7.1	0.050	0.100	40.00	3.3	12.4
13	0.141	9300	0.000	0.000	1.00	6.3	0.050	0.100	43.33	3.3	12.4
14	0.141	9300	0.000	0.000	1.00	7.8	0.050	0.100	46.67	3.3	12.4
15	0.141	9300	0.000	0.000	1.00	9.3	0.050	0.100	50.00	3.3	12.4
16	0.141	9300	0.000	0.000	1.00	10.1	0.127	0.100	53.33	3.3	12.4
17	0.141	9300	0.000	0.000	1.00	10.9	0.200	0.100	56.67	3.3	12.4
18	0.141	9300	0.000	0.000	1.00	8.6	0.078	0.100	60.00	3.3	12.4
19	0.141	9300	0.000	0.000	1.00	9.9	0.050	0.100	63.33	3.3	12.4
20	0.141	9300	0.000	0.000	1.00	12.2	0.050	0.100	66.67	3.3	12.4
21	0.141	9300	0.000	0.000	1.00	10.9	0.050	0.100	70.00	3.3	12.4

Toe	138.9	0.150	0.167

2.966 kips total unreduced pile weight (g= 32.17 ft/s2)
2.966 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
45.00	10.81	1.00	0.800

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Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
243.5	36.0	7.46	7.46	-2.80	10	25	30.10	10	4	19.0	43.1

1 0 10.81000 11.86000

FRA-70-1358A-Pier - B-017-5-13 - HP10x42 07/08/2018
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Depth (ft) 50.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
70.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 8.330

Pile and Soil Model — Total Capacity Rut (kips) 132.3

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.141	9300	0.010	0.000	0.85	0.0	0.000	0.100	3.33	3.3	12.4
2	0.141	9300	0.000	0.000	1.00	0.0	0.000	0.100	6.67	3.3	12.4
7	0.141	9300	0.000	0.000	1.00	0.5	0.200	0.100	23.33	3.3	12.4
8	0.141	9300	0.000	0.000	1.00	1.6	0.200	0.100	26.67	3.3	12.4
9	0.141	9300	0.000	0.000	1.00	5.1	0.087	0.100	30.00	3.3	12.4
10	0.141	9300	0.000	0.000	1.00	8.6	0.050	0.100	33.33	3.3	12.4
11	0.141	9300	0.000	0.000	1.00	5.7	0.050	0.100	36.67	3.3	12.4
12	0.141	9300	0.000	0.000	1.00	6.9	0.050	0.100	40.00	3.3	12.4
13	0.141	9300	0.000	0.000	1.00	8.8	0.050	0.100	43.33	3.3	12.4
14	0.141	9300	0.000	0.000	1.00	9.7	0.050	0.100	46.67	3.3	12.4
15	0.141	9300	0.000	0.000	1.00	10.5	0.190	0.100	50.00	3.3	12.4
16	0.141	9300	0.000	0.000	1.00	10.0	0.163	0.100	53.33	3.3	12.4
17	0.141	9300	0.000	0.000	1.00	8.6	0.050	0.100	56.67	3.3	12.4
18	0.141	9300	0.000	0.000	1.00	11.5	0.050	0.100	60.00	3.3	12.4
19	0.141	9300	0.000	0.000	1.00	11.6	0.050	0.100	63.33	3.3	12.4
20	0.141	9300	0.000	0.000	1.00	11.0	0.050	0.100	66.67	3.3	12.4
21	0.141	9300	0.000	0.000	1.00	8.4	0.189	0.100	70.00	3.3	12.4
Toe						13.8	0.150	0.167			

2.966 kips total unreduced pile weight (g= 32.17 ft/s2)
2.966 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
50.00	10.81	1.00	0.800

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Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
132.3	13.7	6.16	6.19	-1.10	7	34	26.00	8	3	17.7	47.3

1 0 10.81000 11.86000

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Depth (ft) 55.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
70.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 8.330

Pile and Soil Model   Total Capacity Rut (kips) 177.2

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.141	9300	0.010	0.000	0.85	0.0	0.000	0.100	3.33	3.3	12.4
2	0.141	9300	0.000	0.000	1.00	0.0	0.000	0.100	6.67	3.3	12.4
5	0.141	9300	0.000	0.000	1.00	0.1	0.200	0.100	16.67	3.3	12.4
6	0.141	9300	0.000	0.000	1.00	1.0	0.200	0.100	20.00	3.3	12.4
7	0.141	9300	0.000	0.000	1.00	2.5	0.172	0.100	23.33	3.3	12.4
8	0.141	9300	0.000	0.000	1.00	7.8	0.050	0.100	26.67	3.3	12.4
9	0.141	9300	0.000	0.000	1.00	7.1	0.050	0.100	30.00	3.3	12.4
10	0.141	9300	0.000	0.000	1.00	6.3	0.050	0.100	33.33	3.3	12.4
11	0.141	9300	0.000	0.000	1.00	7.8	0.050	0.100	36.67	3.3	12.4
12	0.141	9300	0.000	0.000	1.00	9.3	0.050	0.100	40.00	3.3	12.4
13	0.141	9300	0.000	0.000	1.00	10.1	0.127	0.100	43.33	3.3	12.4
14	0.141	9300	0.000	0.000	1.00	10.9	0.200	0.100	46.67	3.3	12.4
15	0.141	9300	0.000	0.000	1.00	8.6	0.078	0.100	50.00	3.3	12.4
16	0.141	9300	0.000	0.000	1.00	9.9	0.050	0.100	53.33	3.3	12.4
17	0.141	9300	0.000	0.000	1.00	12.2	0.050	0.100	56.67	3.3	12.4
18	0.141	9300	0.000	0.000	1.00	10.9	0.050	0.100	60.00	3.3	12.4
19	0.141	9300	0.000	0.000	1.00	9.9	0.123	0.100	63.33	3.3	12.4
20	0.141	9300	0.000	0.000	1.00	8.2	0.200	0.100	66.67	3.3	12.4
21	0.141	9300	0.000	0.000	1.00	8.6	0.200	0.100	70.00	3.3	12.4
Toe						45.9	0.150	0.100			

2.966 kips total unreduced pile weight (g= 32.17 ft/s2)
2.966 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
55.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
177.2	21.8	6.86	6.83	-0.45	7	30	28.17	7	3	17.3	45.0

1 0 10.81000 11.86000

FRA-70-1358A-Pier - B-017-5-13 - HP10x42   07/08/2018
Resource International Inc   GRLWEAP Version 2010

Depth (ft) 60.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
70.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 8.330

Pile and Soil Model   Total Capacity Rut (kips) 190.1

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2

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1	0.141	9300	0.010	0.000	0.85	0.0	0.000	0.100	3.33	3.3	12.4
2	0.141	9300	0.000	0.000	1.00	0.0	0.000	0.100	6.67	3.3	12.4
4	0.141	9300	0.000	0.000	1.00	0.5	0.200	0.100	13.33	3.3	12.4
5	0.141	9300	0.000	0.000	1.00	1.6	0.200	0.100	16.67	3.3	12.4
6	0.141	9300	0.000	0.000	1.00	5.1	0.087	0.100	20.00	3.3	12.4
7	0.141	9300	0.000	0.000	1.00	8.6	0.050	0.100	23.33	3.3	12.4
8	0.141	9300	0.000	0.000	1.00	5.7	0.050	0.100	26.67	3.3	12.4
9	0.141	9300	0.000	0.000	1.00	6.9	0.050	0.100	30.00	3.3	12.4
10	0.141	9300	0.000	0.000	1.00	8.8	0.050	0.100	33.33	3.3	12.4
11	0.141	9300	0.000	0.000	1.00	9.7	0.050	0.100	36.67	3.3	12.4
12	0.141	9300	0.000	0.000	1.00	10.5	0.190	0.100	40.00	3.3	12.4
13	0.141	9300	0.000	0.000	1.00	10.0	0.163	0.100	43.33	3.3	12.4
14	0.141	9300	0.000	0.000	1.00	8.6	0.050	0.100	46.67	3.3	12.4
15	0.141	9300	0.000	0.000	1.00	11.5	0.050	0.100	50.00	3.3	12.4
16	0.141	9300	0.000	0.000	1.00	11.6	0.050	0.100	53.33	3.3	12.4
17	0.141	9300	0.000	0.000	1.00	11.0	0.050	0.100	56.67	3.3	12.4
18	0.141	9300	0.000	0.000	1.00	8.4	0.189	0.100	60.00	3.3	12.4
19	0.141	9300	0.000	0.000	1.00	8.4	0.200	0.100	63.33	3.3	12.4
20	0.141	9300	0.000	0.000	1.00	8.6	0.200	0.100	66.67	3.3	12.4
21	0.141	9300	0.000	0.000	1.00	8.6	0.200	0.100	70.00	3.3	12.4
Toe						45.9	0.150	0.100			

2.966 kips total unreduced pile weight (g= 32.17 ft/s2)
2.966 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
60.00	10.81	1.00	0.800

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Rut kips	Bl Ct b/ft	Stroke (ft) down	Stroke (ft) up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
190.1	24.3	7.02	6.99	-0.60	6	50	28.58	6	3	17.3	44.5

1 0 10.81000 11.86000

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Resource International Inc GRLWEAP Version 2010

Depth (ft) 65.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
70.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 8.330

Pile and Soil Model Total Capacity Rut (kips) 244.7

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.141	9300	0.010	0.000	0.85	0.0	0.000	0.100	3.33	3.3	12.4
2	0.141	9300	0.000	0.000	1.00	0.1	0.200	0.100	6.67	3.3	12.4
3	0.141	9300	0.000	0.000	1.00	1.0	0.200	0.100	10.00	3.3	12.4
4	0.141	9300	0.000	0.000	1.00	2.5	0.172	0.100	13.33	3.3	12.4
5	0.141	9300	0.000	0.000	1.00	7.8	0.050	0.100	16.67	3.3	12.4
6	0.141	9300	0.000	0.000	1.00	7.1	0.050	0.100	20.00	3.3	12.4
7	0.141	9300	0.000	0.000	1.00	6.3	0.050	0.100	23.33	3.3	12.4
8	0.141	9300	0.000	0.000	1.00	7.8	0.050	0.100	26.67	3.3	12.4
9	0.141	9300	0.000	0.000	1.00	9.3	0.050	0.100	30.00	3.3	12.4
10	0.141	9300	0.000	0.000	1.00	10.1	0.127	0.100	33.33	3.3	12.4
11	0.141	9300	0.000	0.000	1.00	10.9	0.200	0.100	36.67	3.3	12.4
12	0.141	9300	0.000	0.000	1.00	8.6	0.078	0.100	40.00	3.3	12.4
13	0.141	9300	0.000	0.000	1.00	9.9	0.050	0.100	43.33	3.3	12.4
14	0.141	9300	0.000	0.000	1.00	12.2	0.050	0.100	46.67	3.3	12.4
15	0.141	9300	0.000	0.000	1.00	10.9	0.050	0.100	50.00	3.3	12.4
16	0.141	9300	0.000	0.000	1.00	9.9	0.123	0.100	53.33	3.3	12.4
17	0.141	9300	0.000	0.000	1.00	8.2	0.200	0.100	56.67	3.3	12.4

18	0.141	9300	0.000	0.000	1.00	8.6	0.200	0.100	60.00	3.3	12.4
19	0.141	9300	0.000	0.000	1.00	8.6	0.200	0.100	63.33	3.3	12.4
20	0.141	9300	0.000	0.000	1.00	9.5	0.200	0.100	66.67	3.3	12.4
21	0.141	9300	0.000	0.000	1.00	27.5	0.200	0.100	70.00	3.3	12.4
Toe						67.9	0.150	0.100			

2.966 kips total unreduced pile weight (g= 32.17 ft/s2)
2.966 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
65.00	10.81	1.00	0.800

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Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
244.7	40.2	7.51	7.50	-0.80	5	44	29.92	4	3	17.9	43.0

1 0 10.81000 11.86000

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Resource International Inc GRLWEAP Version 2010

Depth (ft) 65.5
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
70.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 8.330

Pile and Soil Model Total Capacity Rut (kips) 248.8

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.141	9300	0.010	0.000	0.85	0.0	0.000	0.100	3.33	3.3	12.4
2	0.141	9300	0.000	0.000	1.00	0.2	0.200	0.100	6.67	3.3	12.4
3	0.141	9300	0.000	0.000	1.00	1.2	0.200	0.100	10.00	3.3	12.4
4	0.141	9300	0.000	0.000	1.00	3.2	0.139	0.100	13.33	3.3	12.4
5	0.141	9300	0.000	0.000	1.00	8.2	0.050	0.100	16.67	3.3	12.4
6	0.141	9300	0.000	0.000	1.00	6.5	0.050	0.100	20.00	3.3	12.4
7	0.141	9300	0.000	0.000	1.00	6.5	0.050	0.100	23.33	3.3	12.4
8	0.141	9300	0.000	0.000	1.00	8.1	0.050	0.100	26.67	3.3	12.4
9	0.141	9300	0.000	0.000	1.00	9.4	0.050	0.100	30.00	3.3	12.4
10	0.141	9300	0.000	0.000	1.00	10.2	0.149	0.100	33.33	3.3	12.4
11	0.141	9300	0.000	0.000	1.00	10.9	0.196	0.100	36.67	3.3	12.4
12	0.141	9300	0.000	0.000	1.00	8.4	0.050	0.100	40.00	3.3	12.4
13	0.141	9300	0.000	0.000	1.00	10.4	0.050	0.100	43.33	3.3	12.4
14	0.141	9300	0.000	0.000	1.00	12.2	0.050	0.100	46.67	3.3	12.4
15	0.141	9300	0.000	0.000	1.00	10.8	0.050	0.100	50.00	3.3	12.4
16	0.141	9300	0.000	0.000	1.00	9.5	0.145	0.100	53.33	3.3	12.4
17	0.141	9300	0.000	0.000	1.00	8.3	0.200	0.100	56.67	3.3	12.4
18	0.141	9300	0.000	0.000	1.00	8.6	0.200	0.100	60.00	3.3	12.4
20	0.141	9300	0.000	0.000	1.00	12.4	0.200	0.100	66.67	3.3	12.4
21	0.141	9300	0.000	0.000	1.00	27.5	0.200	0.100	70.00	3.3	12.4
Toe						67.9	0.150	0.100			

2.966 kips total unreduced pile weight (g= 32.17 ft/s2)
2.966 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
65.50	10.81	1.00	0.800

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Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
248.8	42.1	7.54	7.54	-0.75	4	43	30.01	4	3	17.9	42.9

SUMMARY OVER DEPTHS

G/L at Shaft and Toe: 0.500 1.000

Depth ft	Rut kips	Frictn kips	End Bg kips	Bl Ct bl/ft	Com Str ksi	Ten Str ksi	Stroke ft	ENTHRU kip-ft
5.0	6.5	1.2	5.4	Hammer did not run				
10.0	21.4	7.2	14.2	1.8	12.435	-0.287	3.91	23.9
15.0	112.1	18.6	93.5	12.8	25.385	-1.343	6.04	18.4
20.0	122.0	28.5	93.5	13.9	25.983	-1.846	6.15	18.3
25.0	78.8	42.0	36.8	7.3	22.700	-1.567	5.34	19.5
30.0	138.3	57.4	80.9	15.7	26.882	-1.600	6.34	17.9
35.0	219.0	71.6	147.4	28.4	29.922	-3.199	7.31	19.1
40.0	166.9	87.5	79.4	19.8	27.732	-1.404	6.68	18.0
45.0	243.5	104.6	138.9	36.0	30.097	-2.801	7.46	19.0
50.0	132.3	118.5	13.8	13.7	26.000	-1.095	6.16	17.7
55.0	177.2	131.2	45.9	21.8	28.169	-0.448	6.86	17.3
60.0	190.1	144.1	45.9	24.3	28.581	-0.596	7.02	17.3
65.0	244.7	176.8	67.9	40.2	29.916	-0.796	7.51	17.9
65.5	248.8	181.0	67.9	42.1	30.007	-0.753	7.54	17.9

Total Driving Time 24 minutes; Total No. of Blows 1095

Table of Depths Analyzed with Driving System Modifiers

Depth ft	Temp. Length ft	Wait Time hr	Equivalent Stroke ft	Pressure Ratio	Efficy.	Stiffn. Factor	Cushion CoR
5.00	70.00	0.00	10.81	1.00	0.80	1.00	1.00
10.00	70.00	0.00	10.81	1.00	0.80	1.00	1.00
15.00	70.00	0.00	10.81	1.00	0.80	1.00	1.00
20.00	70.00	0.00	10.81	1.00	0.80	1.00	1.00
25.00	70.00	0.00	10.81	1.00	0.80	1.00	1.00
30.00	70.00	0.00	10.81	1.00	0.80	1.00	1.00
35.00	70.00	0.00	10.81	1.00	0.80	1.00	1.00
40.00	70.00	0.00	10.81	1.00	0.80	1.00	1.00
45.00	70.00	0.00	10.81	1.00	0.80	1.00	1.00
50.00	70.00	0.00	10.81	1.00	0.80	1.00	1.00
55.00	70.00	0.00	10.81	1.00	0.80	1.00	1.00
60.00	70.00	0.00	10.81	1.00	0.80	1.00	1.00
65.00	70.00	0.00	10.81	1.00	0.80	1.00	1.00
65.50	70.00	0.00	10.81	1.00	0.80	1.00	1.00

Soil Layer Resistance Values

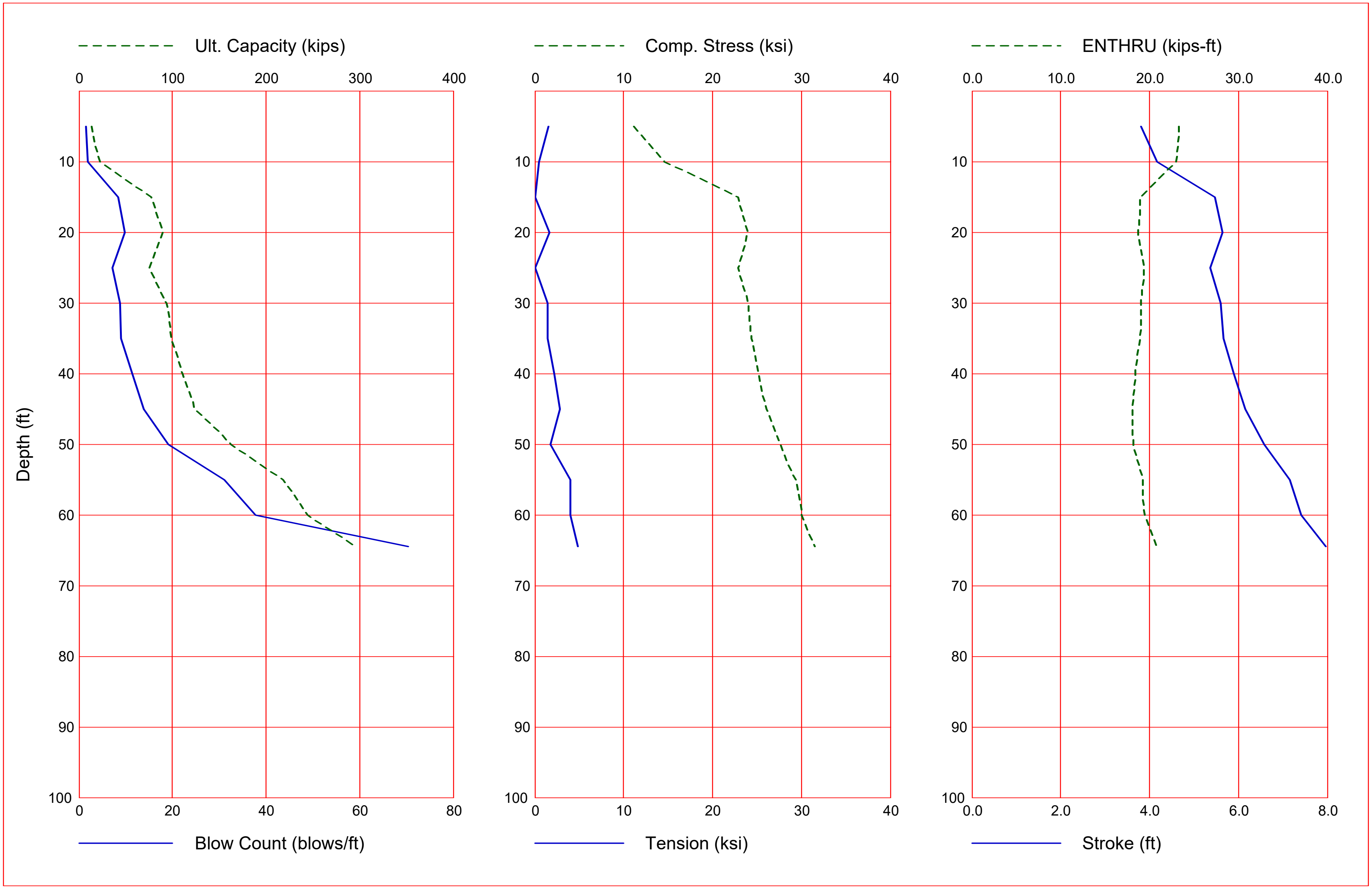
Depth ft	Shaft Res. k/ft2	End Bearing kips	Shaft Quake inch	Toe Quake inch	Shaft Damping s/ft	Toe Damping s/ft	Soil Setup Normlzd	Limit Distance ft	Setup Time hrs
0.00	0.00	5.36	0.100	0.167	0.200	0.150	0.667	6.560	168.000
8.00	0.34	5.36	0.100	0.167	0.200	0.150	0.667	6.560	168.000
8.00	0.56	14.17	0.100	0.167	0.050	0.150	0.000	6.560	1.000
13.00	0.93	14.17	0.100	0.167	0.050	0.150	0.000	6.560	1.000
13.00	0.45	93.54	0.100	0.167	0.050	0.150	0.000	6.560	1.000
20.50	0.70	93.54	0.100	0.167	0.050	0.150	0.000	6.560	1.000
20.50	0.79	36.85	0.100	0.167	0.050	0.150	0.000	6.560	1.000
27.00	0.92	36.85	0.100	0.167	0.050	0.150	0.000	6.560	1.000
27.00	1.39	75.38	0.100	0.100	0.200	0.150	0.667	6.560	84.000
32.00	1.56	84.56	0.100	0.100	0.200	0.150	0.667	6.560	84.000
32.00	0.73	147.40	0.100	0.100	0.050	0.150	0.000	6.560	1.000
37.00	0.82	147.40	0.100	0.100	0.050	0.150	0.000	6.560	1.000
37.00	1.05	79.37	0.100	0.167	0.050	0.150	0.000	6.560	1.000
42.00	1.15	79.37	0.100	0.167	0.050	0.150	0.000	6.560	1.000
42.00	0.95	138.90	0.100	0.167	0.050	0.150	0.000	6.560	1.000
47.00	1.04	138.90	0.100	0.167	0.050	0.150	0.000	6.560	1.000
47.00	1.43	13.78	0.100	0.167	0.200	0.150	1.000	6.560	168.000

52.00	1.53	13.78	0.100	0.167	0.200	0.150	1.000	6.560	168.000
52.00	1.57	45.92	0.100	0.100	0.200	0.150	1.000	6.560	168.000
61.50	1.57	45.92	0.100	0.100	0.200	0.150	1.000	6.560	168.000
61.50	5.00	67.86	0.100	0.100	0.200	0.150	1.000	6.560	168.000
69.00	5.00	67.86	0.100	0.100	0.200	0.150	1.000	6.560	168.000
69.00	10.00	271.44	0.100	0.100	0.050	0.150	1.000	6.560	168.000
70.00	10.00	271.44	0.100	0.100	0.050	0.150	1.000	6.560	168.000

Resource International Inc
FRA-70-1358A - FA - B-017-6-13 - HP10x42

Jul 08 2018
GRLWEAP Version 2010

Gain/Loss 1 at Shaft and Toe 0.500 / 1.000



Gain/Loss 1 at Shaft and Toe 0.500 / 1.000

Depth ft	Ultimate Capacity kips	Friction kips	End Bearing kips	Blow Count blows/ft	Comp. Stress ksi	Tension Stress ksi	Stroke ft	ENTHRU kips-ft
5.0	14.0	1.8	12.2	1.5	11.163	-1.558	3.81	23.3
10.0	22.4	5.7	16.7	2.0	14.554	-0.455	4.16	23.0
15.0	77.1	11.9	65.2	8.5	22.884	-0.105	5.47	18.9
20.0	89.9	24.7	65.2	9.8	23.954	-1.680	5.64	18.7
25.0	75.2	41.2	34.0	7.1	22.854	0.000	5.36	19.4
30.0	93.8	59.7	34.0	8.8	24.066	-1.401	5.61	19.0
35.0	98.3	77.6	20.7	9.0	24.323	-1.432	5.66	18.9
40.0	111.2	90.5	20.7	11.5	25.206	-2.236	5.89	18.4
45.0	124.1	103.4	20.7	13.9	26.131	-2.830	6.15	18.1
50.0	162.3	116.3	45.9	19.1	27.674	-1.759	6.59	18.2
55.0	218.1	133.1	85.0	31.0	29.362	-3.961	7.15	19.2
60.0	245.0	159.9	85.0	37.8	30.070	-3.981	7.41	19.5
64.5	296.5	228.6	67.9	70.3	31.520	-4.811	7.96	20.7

Total Continuous Driving Time 21.00 minutes; Total Number of Blows 950

GRLWEAP - Version 2010
WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS

written by GRL Engineers, Inc. (formerly Goble Rausche Likins and Associates, Inc.) with cooperation from Pile Dynamics, Inc.

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

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

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

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

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

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

```
 Input  File: J:\GEOTECH\PROJECTS\2013\W-13-045 FRA-70-13.54 PROJECT 4A\ANALYSIS\FRA-70-1358A\DRIVEBILITY\B-017-6-13 - FORWARD ABUTMENT\B-017-6-13 - FORWARD ABUTMENT.GWW
 Hammer File: C:\ProgramData\PDI\GRLWEAP\2010\Resource\HAMMER2003.GW
 Hammer File Version:  2003 (2/22/2013)

                       Input File Contents
     FRA-70-1358A - FA - B-017-6-13 - HP10x42
 OUT OSG HAM STR FUL PEL  N SPL N-U P-D %SK ISM  0 PHI RSA ITR H-D MXT     DEx
-100   0  41   0   1   0  0   0   0   0   0   0  0   0   0   0   0   0   0.000
    Pile g  Hammer g  Toe Area Pile Size           Pile Type
    32.170    32.170    97.720    10.070              H Pile
      W Cp      A Cp      E Cp      T Cp       CoR      ROut      StCp
     1.900   227.000     530.0     2.000     0.800     0.010       0.0
      A Cu      E Cu      T Cu       CoR      ROut      StCu
     0.000       0.0     0.000     0.000     0.000       0.0
      LPle      APle      EPle      WPle      Peri        CI       CoR      ROut
    95.000     12.40   30000.0   492.000     3.295         0     0.850     0.010
 Manufac  Hmr Name  HmrType No Seg-s
 DELMAG   D 19-42         1       5
    Ram Wt     Ram L   Ram Dia   MaxStrk   RtdStrk    Efficy
      4.00    129.10     12.60     11.86     10.81      0.80
    IB. Wt     IB. L    IB.Dia    IB CoR     IB RO
      0.75     25.30     12.60     0.900     0.010
  CompStrk A Chamber V Chamber   C Delay  C Duratn Exp Coeff VolCStart  Vol CEnd
     16.65    124.70    157.70     0.002     0.002     1.250      0.00      0.00
     P atm        P1        P2        P3        P4        P5
     14.70   1520.00   1368.00   1231.00   1108.00      0.00
    Stroke    Effic.  Pressure  R-Weight   T-Delay Exp-Coeff   Eps-Str  Total-AW
```

```
  10.8100    0.8000 1520.0000    0.0000    0.0000    0.0000    0.0100    0.0000
       Qs        Qt        Js        Jt        Qx        Jx      Rati      Dept
    0.100     0.100     0.146     0.150     0.000     0.000     0.000     0.000
 Research Soil Model: Atoe, Plug,  Gap, Q-fac
    0.000     0.000     0.000     0.000
 Research Soil Model: RD-skn: m, d, toe: m, d
    0.000     0.000     0.000     0.000
 Res. Distribution
   Dpth    Rskn      Rtoe      Qs      Qt      Js      Jt    SU F    LimD    SU T
   0.00    0.00     76.53    0.10    0.17    0.05    0.15    1.00    6.56     1.0
   3.00    0.15     76.53    0.10    0.17    0.05    0.15    1.00    6.56     1.0
   3.00    0.18     12.25    0.10    0.17    0.20    0.15    1.50    6.56     1.0
   7.00    0.41     12.25    0.10    0.17    0.20    0.15    1.50    6.56     1.0
   7.00    0.23     11.81    0.10    0.17    0.20    0.15    1.17    6.56    84.0
  14.50    0.48     24.02    0.10    0.17    0.20    0.15    1.17    6.56    84.0
  14.50    0.63     65.20    0.10    0.17    0.05    0.15    1.00    6.56     1.0
  24.50    1.10     65.20    0.10    0.17    0.05    0.15    1.00    6.56     1.0
  24.50    1.06     34.02    0.10    0.17    0.05    0.15    1.00    6.56     1.0
  33.50    1.25     34.02    0.10    0.17    0.05    0.15    1.00    6.56     1.0
  33.50    1.57     20.66    0.10    0.17    0.20    0.15    2.00    6.56   168.0
  48.50    1.57     20.66    0.10    0.17    0.20    0.15    2.00    6.56   168.0
  48.50    1.57     45.92    0.10    0.10    0.20    0.15    2.00    6.56   168.0
  53.50    1.57     45.92    0.10    0.10    0.20    0.15    2.00    6.56   168.0
  53.50    1.54     85.04    0.10    0.10    0.05    0.15    1.00    6.56     1.0
  60.50    1.70     85.04    0.10    0.10    0.05    0.15    1.00    6.56     1.0
  60.50    5.00     67.86    0.10    0.10    0.20    0.15    0.00    6.56     0.0
  71.00    5.00     67.86    0.10    0.10    0.20    0.15    0.00    6.56     0.0
  71.00   10.00    271.44    0.10    0.10    0.05    0.15    0.00    6.56     0.0
  81.00   10.00    271.44    0.10    0.10    0.05    0.15    0.00    6.56     0.0
  95.00   10.00    271.44    0.10    0.10    0.05    0.15    0.00    6.56     0.0
 Gain/Loss factors: shaft and toe
  0.50000   0.00000   0.00000   0.00000   0.00000
  1.00000   0.00000   0.00000   0.00000   0.00000
     Dpth         L      Wait      Strk      Pmx%      Eff.      Stff       CoR
     5.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    10.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    15.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    20.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    25.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    30.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    35.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    40.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    45.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    50.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    55.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    60.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    64.50      0.00      0.00     0.000     0.000     0.000     0.000     0.000
     0.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
         1          0   10.81000       11.86000
```

GRLWEAP: WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS
Version 2010
English Units

FRA-70-1358A - FA - B-017-6-13 - HP10x42

Hammer Model: D 19-42 Made by: DELMAG

No.	Weight kips	Stiffn k/inch	CoR	C-Slk ft	Dampg k/ft/s
1	0.800				
2	0.800	140046.7	1.000	0.0100	
3	0.800	140046.7	1.000	0.0100	
4	0.800	140046.7	1.000	0.0100	
5	0.800	140046.7	1.000	0.0100	
Imp Block	0.753	70735.6	0.900	0.0100	
Helmet	1.900	60155.0	0.800	0.0100	5.8
Combined Pile Top		9463.2			

HAMMER OPTIONS:

Hammer File ID No.	41	Hammer Type	OE Diesel
Stroke Option	FxdP-VarS	Stroke Convergence Crit.	0.010
Fuel Pump Setting	Maximum		

HAMMER DATA:

Ram Weight	(kips)	4.00	Ram Length	(inch)	129.10
Maximum Stroke	(ft)	11.86			
Rated Stroke	(ft)	10.81	Efficiency		0.800
Maximum Pressure	(psi)	1520.00	Actual Pressure	(psi)	1520.00
Compression Exponent		1.350	Expansion Exponent		1.250
Ram Diameter	(inch)	12.60			
Combustion Delay	(s)	0.00200	Ignition Duration	(s)	0.00200

The Hammer Data Includes Estimated (NON-MEASURED) Quantities

HAMMER CUSHION			PILE CUSHION		
Cross Sect. Area	(in2)	227.00	Cross Sect. Area	(in2)	0.00
Elastic-Modulus	(ksi)	530.0	Elastic-Modulus	(ksi)	0.0
Thickness	(inch)	2.00	Thickness	(inch)	0.00
Coeff of Restitution		0.8	Coeff of Restitution		1.0
RoundOut	(ft)	0.0	RoundOut	(ft)	0.0
Stiffness	(kips/in)	60155.0	Stiffness	(kips/in)	0.0

Depth	(ft)	5.0			
Shaft Gain/Loss Factor		0.500	Toe Gain/Loss Factor		1.000

PILE PROFILE:

Toe Area	(in2)	97.720	Pile Type		H Pile
Pile Size	(inch)	10.070			

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
95.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 11.305

Pile and Soil Model — Total Capacity Rut (kips) 14.0

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.139	9463	0.010	0.000	0.85	0.0	0.000	0.100	3.28	3.3	12.4
2	0.139	9463	0.000	0.000	1.00	0.0	0.000	0.100	6.55	3.3	12.4
28	0.139	9463	0.000	0.000	1.00	0.2	0.050	0.100	91.72	3.3	12.4
29	0.139	9463	0.000	0.000	1.00	1.5	0.164	0.100	95.00	3.3	12.4
Toe						12.2	0.150	0.167			

4.025 kips total unreduced pile weight (g= 32.17 ft/s2)
4.025 kips total reduced pile weight (g= 32.17 ft/s2)

PILE, SOIL, ANALYSIS OPTIONS:

Uniform pile		Pile Segments: Automatic	
No. of Slacks/Splices	0	Pile Damping (%)	1
		Pile Damping Fact.(k/ft/s)	0.443
Driveability Analysis			
Soil Damping Option	Smith		
Max No Analysis Iterations	0	Time Increment/Critical	160
Output Time Interval	1	Analysis Time-Input (ms)	0
Output Level: Normal			

Gravity Mass, Pile, Hammer: 32.170 32.170 32.170
Output Segment Generation: Automatic

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
5.00	10.81	1.00	0.800

Rut	Bl Ct	Stroke (ft) down	up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft			ksi			ksi			kip-ft	b/min
14.0	1.5	3.81	3.83	-1.56	9	16	11.16	1	7	23.3	60.7

1 0 10.81000 11.86000

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FRA-70-1358A - FA - B-017-6-13 - HP10x42                       07/08/2018
Resource International Inc                                GRLWEAP Version 2010

 Depth                (ft)      10.0
 Shaft Gain/Loss Factor         0.500  Toe Gain/Loss Factor          1.000

 PILE PROFILE:
 Toe Area            (in2)    97.720  Pile Type                    H Pile
 Pile Size          (inch)    10.070

  L b Top     Area    E-Mod  Spec Wt    Perim  C Index  Wave Sp      EA/c
      ft      in2      ksi   lb/ft3      ft              ft/s    k/ft/s
     0.0    12.40   30000.    492.0      3.3       0    16807.     22.1
    95.0    12.40   30000.    492.0      3.3       0    16807.     22.1

 Wave Travel Time 2L/c (ms)    11.305

        Pile and Soil Model           Total Capacity Rut  (kips)      22.4
No. Weight   Stiffn C-Slk T-Slk  CoR  Soil-S  Soil-D Quake  LbTop Perim    Area
      kips     k/in    ft    ft        kips    s/ft  inch     ft    ft     in2
  1  0.139     9463 0.010 0.000 0.85     0.0   0.000 0.100   3.28   3.3    12.4
  2  0.139     9463 0.000 0.000 1.00     0.0   0.000 0.100   6.55   3.3    12.4
 26  0.139     9463 0.000 0.000 1.00     0.0   0.050 0.100  85.17   3.3    12.4
 27  0.139     9463 0.000 0.000 1.00     0.9   0.092 0.100  88.45   3.3    12.4
 28  0.139     9463 0.000 0.000 1.00     2.2   0.200 0.100  91.72   3.3    12.4
 29  0.139     9463 0.000 0.000 1.00     2.6   0.200 0.100  95.00   3.3    12.4
Toe                                     16.7   0.150 0.167

     4.025 kips total unreduced pile weight (g= 32.17 ft/s2)
     4.025 kips total reduced pile weight   (g= 32.17 ft/s2)


    Depth    Stroke  Pressure    Efficy
       ft        ft     Ratio
    10.00     10.81      1.00     0.800
```

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FRA-70-1358A - FA - B-017-6-13 - HP10x42                       07/08/2018
Resource International Inc                                GRLWEAP Version 2010

    Rut   Bl Ct   Stroke (ft) Ten Str   i   t Comp Str   i   t ENTHRU   Bl Rt
   kips    b/ft   down     up     ksi              ksi         kip-ft   b/min
   22.4     2.0   4.16   4.20   -0.45   4  16    14.55   1   2   23.0    57.9
          1          0   10.81000       11.86000
```

```
FRA-70-1358A - FA - B-017-6-13 - HP10x42                       07/08/2018
Resource International Inc                                GRLWEAP Version 2010

 Depth                (ft)      15.0
 Shaft Gain/Loss Factor         0.500  Toe Gain/Loss Factor          1.000

 PILE PROFILE:
 Toe Area            (in2)    97.720  Pile Type                    H Pile
 Pile Size          (inch)    10.070

  L b Top     Area    E-Mod  Spec Wt    Perim  C Index  Wave Sp      EA/c
      ft      in2      ksi   lb/ft3      ft              ft/s    k/ft/s
     0.0    12.40   30000.    492.0      3.3       0    16807.     22.1
    95.0    12.40   30000.    492.0      3.3       0    16807.     22.1

 Wave Travel Time 2L/c (ms)    11.305

        Pile and Soil Model           Total Capacity Rut  (kips)      77.1
No. Weight   Stiffn C-Slk T-Slk  CoR  Soil-S  Soil-D Quake  LbTop Perim    Area
      kips     k/in    ft    ft        kips    s/ft  inch     ft    ft     in2
  1  0.139     9463 0.010 0.000 0.85     0.0   0.000 0.100   3.28   3.3    12.4
  2  0.139     9463 0.000 0.000 1.00     0.0   0.000 0.100   6.55   3.3    12.4
 25  0.139     9463 0.000 0.000 1.00     0.3   0.050 0.100  81.90   3.3    12.4
 26  0.139     9463 0.000 0.000 1.00     1.6   0.170 0.100  85.17   3.3    12.4
 27  0.139     9463 0.000 0.000 1.00     2.5   0.200 0.100  88.45   3.3    12.4
 28  0.139     9463 0.000 0.000 1.00     3.1   0.200 0.100  91.72   3.3    12.4
 29  0.139     9463 0.000 0.000 1.00     4.5   0.168 0.100  95.00   3.3    12.4
Toe                                     65.2   0.150 0.167

     4.025 kips total unreduced pile weight (g= 32.17 ft/s2)
```

4.025 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
15.00	10.81	1.00	0.800

Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
77.1	8.5	5.47	5.52	-0.10	25	50	22.88	25	7	18.9	50.1

1 0 10.81000 11.86000

Depth (ft) 20.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
95.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 11.305

Pile and Soil Model Total Capacity Rut (kips) 89.9

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.139	9463	0.010	0.000	0.85	0.0	0.000	0.100	3.28	3.3	12.4
2	0.139	9463	0.000	0.000	1.00	0.0	0.000	0.100	6.55	3.3	12.4
23	0.139	9463	0.000	0.000	1.00	0.0	0.050	0.100	75.34	3.3	12.4
24	0.139	9463	0.000	0.000	1.00	1.0	0.104	0.100	78.62	3.3	12.4
25	0.139	9463	0.000	0.000	1.00	2.2	0.200	0.100	81.90	3.3	12.4
26	0.139	9463	0.000	0.000	1.00	2.7	0.200	0.100	85.17	3.3	12.4
27	0.139	9463	0.000	0.000	1.00	3.6	0.200	0.100	88.45	3.3	12.4
28	0.139	9463	0.000	0.000	1.00	6.4	0.086	0.100	91.72	3.3	12.4
29	0.139	9463	0.000	0.000	1.00	8.8	0.050	0.100	95.00	3.3	12.4
Toe						65.2	0.150	0.167			

4.025 kips total unreduced pile weight (g= 32.17 ft/s2)
4.025 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
20.00	10.81	1.00	0.800

Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
89.9	9.8	5.64	5.69	-1.68	24	50	23.95	25	7	18.7	49.4

1 0 10.81000 11.86000

Depth (ft) 25.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1

```
     95.0    12.40   30000.    492.0      3.3        0    16807.     22.1

 Wave Travel Time 2L/c (ms)    11.305

        Pile and Soil Model            Total Capacity Rut  (kips)      75.2
No. Weight    Stiffn C-Slk T-Slk  CoR  Soil-S  Soil-D Quake  LbTop Perim    Area
      kips      k/in    ft    ft         kips    s/ft  inch     ft    ft     in2
  1  0.139      9463 0.010 0.000 0.85     0.0   0.000 0.100   3.28   3.3    12.4
  2  0.139      9463 0.000 0.000 1.00     0.0   0.000 0.100   6.55   3.3    12.4
 22  0.139      9463 0.000 0.000 1.00     0.4   0.050 0.100  72.07   3.3    12.4
 23  0.139      9463 0.000 0.000 1.00     1.7   0.175 0.100  75.34   3.3    12.4
 24  0.139      9463 0.000 0.000 1.00     2.5   0.200 0.100  78.62   3.3    12.4
 25  0.139      9463 0.000 0.000 1.00     3.1   0.200 0.100  81.90   3.3    12.4
 26  0.139      9463 0.000 0.000 1.00     4.6   0.158 0.100  85.17   3.3    12.4
 27  0.139      9463 0.000 0.000 1.00     8.0   0.050 0.100  88.45   3.3    12.4
 28  0.139      9463 0.000 0.000 1.00     9.7   0.050 0.100  91.72   3.3    12.4
 29  0.139      9463 0.000 0.000 1.00    11.2   0.050 0.100  95.00   3.3    12.4
Toe                                      34.0   0.150 0.167

     4.025 kips total unreduced pile weight (g= 32.17 ft/s2)
     4.025 kips total reduced pile weight   (g= 32.17 ft/s2)


    Depth    Stroke  Pressure    Efficy
       ft        ft     Ratio
    25.00     10.81      1.00     0.800
```

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```
    Rut   Bl Ct   Stroke (ft) Ten Str   i   t Comp Str   i   t ENTHRU   Bl Rt
   kips    b/ft   down     up     ksi             ksi         kip-ft   b/min
   75.2     7.1   5.36   5.34    0.00   1   0    22.85  23   6   19.4    50.9
          1           0   10.81000       11.86000
```

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```
 Depth                (ft)      30.0
 Shaft Gain/Loss Factor         0.500  Toe Gain/Loss Factor          1.000

 PILE PROFILE:
 Toe Area            (in2)    97.720  Pile Type                    H Pile
 Pile Size          (inch)    10.070

  L b Top     Area    E-Mod  Spec Wt    Perim  C Index  Wave Sp      EA/c
      ft      in2      ksi   lb/ft3       ft             ft/s    k/ft/s
      0.0    12.40   30000.    492.0      3.3        0    16807.     22.1
     95.0    12.40   30000.    492.0      3.3        0    16807.     22.1

 Wave Travel Time 2L/c (ms)    11.305

        Pile and Soil Model            Total Capacity Rut  (kips)      93.8
No. Weight    Stiffn C-Slk T-Slk  CoR  Soil-S  Soil-D Quake  LbTop Perim    Area
      kips      k/in    ft    ft         kips    s/ft  inch     ft    ft     in2
  1  0.139      9463 0.010 0.000 0.85     0.0   0.000 0.100   3.28   3.3    12.4
  2  0.139      9463 0.000 0.000 1.00     0.0   0.000 0.100   6.55   3.3    12.4
 20  0.139      9463 0.000 0.000 1.00     0.0   0.050 0.100  65.52   3.3    12.4
 21  0.139      9463 0.000 0.000 1.00     1.1   0.114 0.100  68.79   3.3    12.4
 22  0.139      9463 0.000 0.000 1.00     2.3   0.200 0.100  72.07   3.3    12.4
 23  0.139      9463 0.000 0.000 1.00     2.7   0.200 0.100  75.34   3.3    12.4
 24  0.139      9463 0.000 0.000 1.00     3.7   0.200 0.100  78.62   3.3    12.4
 25  0.139      9463 0.000 0.000 1.00     6.6   0.080 0.100  81.90   3.3    12.4
 26  0.139      9463 0.000 0.000 1.00     8.9   0.050 0.100  85.17   3.3    12.4
 27  0.139      9463 0.000 0.000 1.00    10.5   0.050 0.100  88.45   3.3    12.4
 28  0.139      9463 0.000 0.000 1.00    11.7   0.050 0.100  91.72   3.3    12.4
 29  0.139      9463 0.000 0.000 1.00    12.3   0.050 0.100  95.00   3.3    12.4
Toe                                      34.0   0.150 0.167

     4.025 kips total unreduced pile weight (g= 32.17 ft/s2)
     4.025 kips total reduced pile weight   (g= 32.17 ft/s2)


    Depth    Stroke  Pressure    Efficy
       ft        ft     Ratio
```

```
   30.00     10.81      1.00     0.800
```

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```
    Rut   Bl Ct   Stroke (ft) Ten Str   i   t Comp Str   i   t ENTHRU   Bl Rt
   kips    b/ft   down     up     ksi            ksi           kip-ft   b/min
   93.8     8.8   5.61   5.59   -1.40  21  47    24.07  22   6   19.0    49.7
         1           0   10.81000       11.86000
```

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```
 Depth                (ft)      35.0
 Shaft Gain/Loss Factor        0.500  Toe Gain/Loss Factor          1.000

 PILE PROFILE:
 Toe Area            (in2)    97.720  Pile Type                   H Pile
 Pile Size          (inch)    10.070

  L b Top     Area    E-Mod  Spec Wt    Perim  C Index  Wave Sp      EA/c
       ft      in2      ksi   lb/ft3       ft             ft/s    k/ft/s
      0.0    12.40   30000.    492.0      3.3        0    16807.     22.1
     95.0    12.40   30000.    492.0      3.3        0    16807.     22.1

 Wave Travel Time 2L/c (ms)    11.305

       Pile and Soil Model           Total Capacity Rut  (kips)      98.3
No. Weight   Stiffn C-Slk T-Slk  CoR  Soil-S  Soil-D Quake  LbTop Perim    Area
      kips     k/in    ft    ft        kips    s/ft  inch     ft    ft     in2
  1  0.139     9463 0.010 0.000 0.85     0.0   0.000 0.100   3.28   3.3    12.4
  2  0.139     9463 0.000 0.000 1.00     0.0   0.000 0.100   6.55   3.3    12.4
 19  0.139     9463 0.000 0.000 1.00     0.4   0.050 0.100  62.24   3.3    12.4
 20  0.139     9463 0.000 0.000 1.00     1.7   0.180 0.100  65.52   3.3    12.4
 21  0.139     9463 0.000 0.000 1.00     2.5   0.200 0.100  68.79   3.3    12.4
 22  0.139     9463 0.000 0.000 1.00     3.2   0.200 0.100  72.07   3.3    12.4
 23  0.139     9463 0.000 0.000 1.00     4.8   0.149 0.100  75.34   3.3    12.4
 24  0.139     9463 0.000 0.000 1.00     8.1   0.050 0.100  78.62   3.3    12.4
 25  0.139     9463 0.000 0.000 1.00     9.8   0.050 0.100  81.90   3.3    12.4
 26  0.139     9463 0.000 0.000 1.00    11.3   0.050 0.100  85.17   3.3    12.4
 27  0.139     9463 0.000 0.000 1.00    12.0   0.050 0.100  88.45   3.3    12.4
 28  0.139     9463 0.000 0.000 1.00    12.7   0.050 0.100  91.72   3.3    12.4
 29  0.139     9463 0.000 0.000 1.00    11.1   0.128 0.100  95.00   3.3    12.4
Toe                                     20.7   0.150 0.167

     4.025 kips total unreduced pile weight (g= 32.17 ft/s2)
     4.025 kips total reduced pile weight   (g= 32.17 ft/s2)


    Depth    Stroke  Pressure    Efficy
       ft        ft     Ratio
    35.00     10.81      1.00     0.800
```

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```
    Rut   Bl Ct   Stroke (ft) Ten Str   i   t Comp Str   i   t ENTHRU   Bl Rt
   kips    b/ft   down     up     ksi            ksi           kip-ft   b/min
   98.3     9.0   5.66   5.65   -1.43  21  47    24.32  20   6   18.9    49.4
         1           0   10.81000       11.86000
```

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```
 Depth                (ft)      40.0
 Shaft Gain/Loss Factor        0.500  Toe Gain/Loss Factor          1.000

 PILE PROFILE:
 Toe Area            (in2)    97.720  Pile Type                   H Pile
 Pile Size          (inch)    10.070

  L b Top     Area    E-Mod  Spec Wt    Perim  C Index  Wave Sp      EA/c
       ft      in2      ksi   lb/ft3       ft             ft/s    k/ft/s
      0.0    12.40   30000.    492.0      3.3        0    16807.     22.1
     95.0    12.40   30000.    492.0      3.3        0    16807.     22.1
```

Wave Travel Time 2L/c (ms) 11.305

Pile and Soil Model — Total Capacity Rut (kips) 111.2

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.139	9463	0.010	0.000	0.85	0.0	0.000	0.100	3.28	3.3	12.4
2	0.139	9463	0.000	0.000	1.00	0.0	0.000	0.100	6.55	3.3	12.4
17	0.139	9463	0.000	0.000	1.00	0.0	0.050	0.100	55.69	3.3	12.4
18	0.139	9463	0.000	0.000	1.00	1.1	0.123	0.100	58.97	3.3	12.4
19	0.139	9463	0.000	0.000	1.00	2.3	0.200	0.100	62.24	3.3	12.4
20	0.139	9463	0.000	0.000	1.00	2.7	0.200	0.100	65.52	3.3	12.4
21	0.139	9463	0.000	0.000	1.00	3.7	0.200	0.100	68.79	3.3	12.4
22	0.139	9463	0.000	0.000	1.00	6.8	0.073	0.100	72.07	3.3	12.4
23	0.139	9463	0.000	0.000	1.00	9.0	0.050	0.100	75.34	3.3	12.4
24	0.139	9463	0.000	0.000	1.00	10.6	0.050	0.100	78.62	3.3	12.4
25	0.139	9463	0.000	0.000	1.00	11.7	0.050	0.100	81.90	3.3	12.4
26	0.139	9463	0.000	0.000	1.00	12.4	0.050	0.100	85.17	3.3	12.4
27	0.139	9463	0.000	0.000	1.00	13.1	0.050	0.100	88.45	3.3	12.4
28	0.139	9463	0.000	0.000	1.00	8.5	0.198	0.100	91.72	3.3	12.4
29	0.139	9463	0.000	0.000	1.00	8.5	0.200	0.100	95.00	3.3	12.4
Toe						20.7	0.150	0.167			

4.025 kips total unreduced pile weight (g= 32.17 ft/s2)
4.025 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
40.00	10.81	1.00	0.800

↑
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Rut	Bl Ct	Stroke (ft) down	up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
111.2	11.5	5.89	5.93	-2.24	18	42	25.21	19	6	18.4	48.4

1 0 10.81000 11.86000

↑
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Depth (ft) 45.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
95.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 11.305

Pile and Soil Model — Total Capacity Rut (kips) 124.1

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.139	9463	0.010	0.000	0.85	0.0	0.000	0.100	3.28	3.3	12.4
2	0.139	9463	0.000	0.000	1.00	0.0	0.000	0.100	6.55	3.3	12.4
16	0.139	9463	0.000	0.000	1.00	0.5	0.050	0.100	52.41	3.3	12.4
17	0.139	9463	0.000	0.000	1.00	1.8	0.185	0.100	55.69	3.3	12.4
18	0.139	9463	0.000	0.000	1.00	2.5	0.200	0.100	58.97	3.3	12.4
19	0.139	9463	0.000	0.000	1.00	3.2	0.200	0.100	62.24	3.3	12.4
20	0.139	9463	0.000	0.000	1.00	5.0	0.140	0.100	65.52	3.3	12.4
21	0.139	9463	0.000	0.000	1.00	8.2	0.050	0.100	68.79	3.3	12.4
22	0.139	9463	0.000	0.000	1.00	9.8	0.050	0.100	72.07	3.3	12.4
23	0.139	9463	0.000	0.000	1.00	11.3	0.050	0.100	75.34	3.3	12.4
24	0.139	9463	0.000	0.000	1.00	12.0	0.050	0.100	78.62	3.3	12.4
25	0.139	9463	0.000	0.000	1.00	12.8	0.050	0.100	81.90	3.3	12.4
26	0.139	9463	0.000	0.000	1.00	10.8	0.135	0.100	85.17	3.3	12.4
27	0.139	9463	0.000	0.000	1.00	8.5	0.200	0.100	88.45	3.3	12.4
29	0.139	9463	0.000	0.000	1.00	8.5	0.200	0.100	95.00	3.3	12.4
Toe						20.7	0.150	0.167			

4.025 kips total unreduced pile weight (g= 32.17 ft/s2)
4.025 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
45.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft) down	Stroke (ft) up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
124.1	13.9	6.15	6.16	-2.83	16	41	26.13	17	5	18.1	47.4

1 0 10.81000 11.86000

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Depth (ft) 50.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
95.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 11.305

Pile and Soil Model — Total Capacity Rut (kips) 162.3

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.139	9463	0.010	0.000	0.85	0.0	0.000	0.100	3.28	3.3	12.4
2	0.139	9463	0.000	0.000	1.00	0.0	0.000	0.100	6.55	3.3	12.4
14	0.139	9463	0.000	0.000	1.00	0.1	0.050	0.100	45.86	3.3	12.4
15	0.139	9463	0.000	0.000	1.00	1.2	0.131	0.100	49.14	3.3	12.4
16	0.139	9463	0.000	0.000	1.00	2.3	0.200	0.100	52.41	3.3	12.4
17	0.139	9463	0.000	0.000	1.00	2.8	0.200	0.100	55.69	3.3	12.4
18	0.139	9463	0.000	0.000	1.00	3.8	0.200	0.100	58.97	3.3	12.4
19	0.139	9463	0.000	0.000	1.00	7.0	0.067	0.100	62.24	3.3	12.4
20	0.139	9463	0.000	0.000	1.00	9.1	0.050	0.100	65.52	3.3	12.4
21	0.139	9463	0.000	0.000	1.00	10.7	0.050	0.100	68.79	3.3	12.4
22	0.139	9463	0.000	0.000	1.00	11.7	0.050	0.100	72.07	3.3	12.4
23	0.139	9463	0.000	0.000	1.00	12.4	0.050	0.100	75.34	3.3	12.4
24	0.139	9463	0.000	0.000	1.00	13.0	0.057	0.100	78.62	3.3	12.4
25	0.139	9463	0.000	0.000	1.00	8.5	0.200	0.100	81.90	3.3	12.4
29	0.139	9463	0.000	0.000	1.00	8.5	0.200	0.100	95.00	3.3	12.4
Toe						45.9	0.150	0.100			

4.025 kips total unreduced pile weight (g= 32.17 ft/s2)
4.025 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
50.00	10.81	1.00	0.800

FRA-70-1358A - FA - B-017-6-13 - HP10x42 07/08/2018
Resource International Inc GRLWEAP Version 2010

Rut	Bl Ct	Stroke (ft) down	Stroke (ft) up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
162.3	19.1	6.59	6.55	-1.76	15	34	27.67	16	5	18.2	45.9

1 0 10.81000 11.86000

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Depth (ft) 55.0
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:

Toe Area	(in2)	97.720	Pile Type	H Pile
Pile Size	(inch)	10.070		

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
95.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 11.305

Pile and Soil Model — Total Capacity Rut (kips) 218.1

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.139	9463	0.010	0.000	0.85	0.0	0.000	0.100	3.28	3.3	12.4
2	0.139	9463	0.000	0.000	1.00	0.0	0.000	0.100	6.55	3.3	12.4
13	0.139	9463	0.000	0.000	1.00	0.5	0.050	0.100	42.59	3.3	12.4
14	0.139	9463	0.000	0.000	1.00	1.8	0.189	0.100	45.86	3.3	12.4
15	0.139	9463	0.000	0.000	1.00	2.6	0.200	0.100	49.14	3.3	12.4
16	0.139	9463	0.000	0.000	1.00	3.3	0.200	0.100	52.41	3.3	12.4
17	0.139	9463	0.000	0.000	1.00	5.2	0.131	0.100	55.69	3.3	12.4
18	0.139	9463	0.000	0.000	1.00	8.3	0.050	0.100	58.97	3.3	12.4
19	0.139	9463	0.000	0.000	1.00	9.9	0.050	0.100	62.24	3.3	12.4
20	0.139	9463	0.000	0.000	1.00	11.4	0.050	0.100	65.52	3.3	12.4
21	0.139	9463	0.000	0.000	1.00	12.1	0.050	0.100	68.79	3.3	12.4
22	0.139	9463	0.000	0.000	1.00	12.8	0.050	0.100	72.07	3.3	12.4
23	0.139	9463	0.000	0.000	1.00	10.6	0.143	0.100	75.34	3.3	12.4
24	0.139	9463	0.000	0.000	1.00	8.5	0.200	0.100	78.62	3.3	12.4
29	0.139	9463	0.000	0.000	1.00	12.3	0.132	0.100	95.00	3.3	12.4
Toe						85.0	0.150	0.100			

4.025 kips total unreduced pile weight (g= 32.17 ft/s2)
4.025 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
55.00	10.81	1.00	0.800

↑
FRA-70-1358A - FA - B-017-6-13 - HP10x42 07/08/2018
Resource International Inc GRLWEAP Version 2010

Rut	Bl Ct	Stroke (ft) down	up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
218.1	31.0	7.15	7.14	-3.96	14	29	29.36	14	4	19.2	44.0

1 0 10.81000 11.86000

↑
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Resource International Inc GRLWEAP Version 2010

Depth	(ft)	60.0		
Shaft Gain/Loss Factor		0.500	Toe Gain/Loss Factor	1.000

PILE PROFILE:

Toe Area	(in2)	97.720	Pile Type	H Pile
Pile Size	(inch)	10.070		

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
95.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 11.305

Pile and Soil Model — Total Capacity Rut (kips) 245.0

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.139	9463	0.010	0.000	0.85	0.0	0.000	0.100	3.28	3.3	12.4
2	0.139	9463	0.000	0.000	1.00	0.0	0.000	0.100	6.55	3.3	12.4
11	0.139	9463	0.000	0.000	1.00	0.1	0.050	0.100	36.03	3.3	12.4
12	0.139	9463	0.000	0.000	1.00	1.3	0.139	0.100	39.31	3.3	12.4
13	0.139	9463	0.000	0.000	1.00	2.4	0.200	0.100	42.59	3.3	12.4
14	0.139	9463	0.000	0.000	1.00	2.8	0.200	0.100	45.86	3.3	12.4
15	0.139	9463	0.000	0.000	1.00	3.8	0.200	0.100	49.14	3.3	12.4

16	0.139	9463	0.000	0.000	1.00	7.2	0.062	0.100	52.41	3.3	12.4
17	0.139	9463	0.000	0.000	1.00	9.1	0.050	0.100	55.69	3.3	12.4
18	0.139	9463	0.000	0.000	1.00	10.8	0.050	0.100	58.97	3.3	12.4
19	0.139	9463	0.000	0.000	1.00	11.8	0.050	0.100	62.24	3.3	12.4
20	0.139	9463	0.000	0.000	1.00	12.5	0.050	0.100	65.52	3.3	12.4
21	0.139	9463	0.000	0.000	1.00	12.8	0.067	0.100	68.79	3.3	12.4
22	0.139	9463	0.000	0.000	1.00	8.5	0.200	0.100	72.07	3.3	12.4
28	0.139	9463	0.000	0.000	1.00	16.9	0.052	0.100	91.72	3.3	12.4
29	0.139	9463	0.000	0.000	1.00	17.8	0.050	0.100	95.00	3.3	12.4
Toe						85.0	0.150	0.100			

4.025 kips total unreduced pile weight (g= 32.17 ft/s2)
4.025 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
60.00	10.81	1.00	0.800

FRA-70-1358A - FA - B-017-6-13 - HP10x42 07/08/2018
Resource International Inc GRLWEAP Version 2010

Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
245.0	37.8	7.41	7.42	-3.98	13	27	30.07	13	4	19.5	43.2
	1	0	10.81000		11.86000						

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Resource International Inc GRLWEAP Version 2010

Depth (ft) 64.5
Shaft Gain/Loss Factor 0.500 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 97.720 Pile Type H Pile
Pile Size (inch) 10.070

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	12.40	30000.	492.0	3.3	0	16807.	22.1
95.0	12.40	30000.	492.0	3.3	0	16807.	22.1

Wave Travel Time 2L/c (ms) 11.305

Pile and Soil Model — Total Capacity Rut (kips) 296.5

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.139	9463	0.010	0.000	0.85	0.0	0.000	0.100	3.28	3.3	12.4
2	0.139	9463	0.000	0.000	1.00	0.0	0.000	0.100	6.55	3.3	12.4
10	0.139	9463	0.000	0.000	1.00	0.4	0.050	0.100	32.76	3.3	12.4
11	0.139	9463	0.000	0.000	1.00	1.7	0.180	0.100	36.03	3.3	12.4
12	0.139	9463	0.000	0.000	1.00	2.5	0.200	0.100	39.31	3.3	12.4
13	0.139	9463	0.000	0.000	1.00	3.2	0.200	0.100	42.59	3.3	12.4
14	0.139	9463	0.000	0.000	1.00	4.8	0.148	0.100	45.86	3.3	12.4
15	0.139	9463	0.000	0.000	1.00	8.1	0.050	0.100	49.14	3.3	12.4
16	0.139	9463	0.000	0.000	1.00	9.8	0.050	0.100	52.41	3.3	12.4
17	0.139	9463	0.000	0.000	1.00	11.3	0.050	0.100	55.69	3.3	12.4
18	0.139	9463	0.000	0.000	1.00	12.0	0.050	0.100	58.97	3.3	12.4
19	0.139	9463	0.000	0.000	1.00	12.7	0.050	0.100	62.24	3.3	12.4
20	0.139	9463	0.000	0.000	1.00	11.1	0.128	0.100	65.52	3.3	12.4
21	0.139	9463	0.000	0.000	1.00	8.5	0.200	0.100	68.79	3.3	12.4
26	0.139	9463	0.000	0.000	1.00	11.4	0.147	0.100	85.17	3.3	12.4
27	0.139	9463	0.000	0.000	1.00	17.3	0.050	0.100	88.45	3.3	12.4
28	0.139	9463	0.000	0.000	1.00	26.0	0.119	0.100	91.72	3.3	12.4
29	0.139	9463	0.000	0.000	1.00	54.0	0.200	0.100	95.00	3.3	12.4
Toe						67.9	0.150	0.100			

4.025 kips total unreduced pile weight (g= 32.17 ft/s2)
4.025 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
64.50	10.81	1.00	0.800

B-017-6-13 - FORWARD ABUTMENT

FRA-70-1358A - FA - B-017-6-13 - HP10x42 07/08/2018

Resource International Inc GRLWEAP Version 2010

Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
296.5	70.3	7.96	7.96	-4.81	13	26	31.52	12	4	20.7	41.7

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Resource International Inc GRLWEAP Version 2010

SUMMARY OVER DEPTHS

G/L at Shaft and Toe: 0.500 1.000

Depth	Rut	Frictn	End Bg	Bl Ct	Com Str	Ten Str	Stroke	ENTHRU
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft
5.0	14.0	1.8	12.2	1.5	11.163	-1.558	3.81	23.3
10.0	22.4	5.7	16.7	2.0	14.554	-0.455	4.16	23.0
15.0	77.1	11.9	65.2	8.5	22.884	-0.105	5.47	18.9
20.0	89.9	24.7	65.2	9.8	23.954	-1.680	5.64	18.7
25.0	75.2	41.2	34.0	7.1	22.854	0.000	5.36	19.4
30.0	93.8	59.7	34.0	8.8	24.066	-1.401	5.61	19.0
35.0	98.3	77.6	20.7	9.0	24.323	-1.432	5.66	18.9
40.0	111.2	90.5	20.7	11.5	25.206	-2.236	5.89	18.4
45.0	124.1	103.4	20.7	13.9	26.131	-2.830	6.15	18.1
50.0	162.3	116.3	45.9	19.1	27.674	-1.759	6.59	18.2
55.0	218.1	133.1	85.0	31.0	29.362	-3.961	7.15	19.2
60.0	245.0	159.9	85.0	37.8	30.070	-3.981	7.41	19.5
64.5	296.5	228.6	67.9	70.3	31.520	-4.811	7.96	20.7

Total Driving Time 21 minutes; Total No. of Blows 950

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Table of Depths Analyzed with Driving System Modifiers

Depth	Temp. Length	Wait Time	Equivalent Stroke	Pressure Ratio	Efficy.	Stiffn. Factor	Cushion CoR
ft	ft	hr	ft				
5.00	95.00	0.00	10.81	1.00	0.80	1.00	1.00
10.00	95.00	0.00	10.81	1.00	0.80	1.00	1.00
15.00	95.00	0.00	10.81	1.00	0.80	1.00	1.00
20.00	95.00	0.00	10.81	1.00	0.80	1.00	1.00
25.00	95.00	0.00	10.81	1.00	0.80	1.00	1.00
30.00	95.00	0.00	10.81	1.00	0.80	1.00	1.00
35.00	95.00	0.00	10.81	1.00	0.80	1.00	1.00
40.00	95.00	0.00	10.81	1.00	0.80	1.00	1.00
45.00	95.00	0.00	10.81	1.00	0.80	1.00	1.00
50.00	95.00	0.00	10.81	1.00	0.80	1.00	1.00
55.00	95.00	0.00	10.81	1.00	0.80	1.00	1.00
60.00	95.00	0.00	10.81	1.00	0.80	1.00	1.00
64.50	95.00	0.00	10.81	1.00	0.80	1.00	1.00

Soil Layer Resistance Values

Depth	Shaft Res.	End Bearing	Shaft Quake	Toe Quake	Shaft Damping	Toe Damping	Soil Setup	Limit Distance	Setup Time
ft	k/ft2	kips	inch	inch	s/ft	s/ft	Normlzd	ft	hrs
0.00	0.00	76.53	0.100	0.167	0.050	0.150	0.000	6.560	1.000
3.00	0.15	76.53	0.100	0.167	0.050	0.150	0.000	6.560	1.000
3.00	0.18	12.25	0.100	0.167	0.200	0.150	0.667	6.560	1.000
7.00	0.41	12.25	0.100	0.167	0.200	0.150	0.667	6.560	1.000
7.00	0.23	11.81	0.100	0.167	0.200	0.150	0.291	6.560	84.000
14.50	0.48	24.02	0.100	0.167	0.200	0.150	0.291	6.560	84.000
14.50	0.63	65.20	0.100	0.167	0.050	0.150	0.000	6.560	1.000
24.50	1.10	65.20	0.100	0.167	0.050	0.150	0.000	6.560	1.000
24.50	1.06	34.02	0.100	0.167	0.050	0.150	0.000	6.560	1.000
33.50	1.25	34.02	0.100	0.167	0.050	0.150	0.000	6.560	1.000
33.50	1.57	20.66	0.100	0.167	0.200	0.150	1.000	6.560	168.000
48.50	1.57	20.66	0.100	0.167	0.200	0.150	1.000	6.560	168.000
48.50	1.57	45.92	0.100	0.100	0.200	0.150	1.000	6.560	168.000
53.50	1.57	45.92	0.100	0.100	0.200	0.150	1.000	6.560	168.000
53.50	1.54	85.04	0.100	0.100	0.050	0.150	0.000	6.560	1.000
60.50	1.70	85.04	0.100	0.100	0.050	0.150	0.000	6.560	1.000

60.50	5.00	67.86	0.100	0.100	0.200	0.150	0.000	6.560	1.000
71.00	5.00	67.86	0.100	0.100	0.200	0.150	0.000	6.560	1.000
71.00	10.00	271.44	0.100	0.100	0.050	0.150	0.000	6.560	1.000
81.00	10.00	271.44	0.100	0.100	0.050	0.150	0.000	6.560	1.000
95.00	10.00	271.44	0.100	0.100	0.050	0.150	0.000	6.560	1.000

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-017-3-13	740.3 to 713.3	A-7-6	C	3	11	11	115 psf	115 psf	Su = 1,375 psf	435 pci	0.0075	-
	713.3 to 708.3	A-1-b	G	4	18	15	125 psf	125 psf	φ = 36°	160 pci	-	-
	708.3 to 703.3	A-6b	C	3	14	14	120 psf	120 psf	Su = 1,750 psf	585 pci	0.0067	-
	703.3 to 698.3	A-1-b	G	4	38	27	130 psf	130 psf	φ = 39°	250 pci	-	-
	698.3 to 683.3	A-1-b	G	4	63	40	135 psf	72.6 psf	φ = 40°	155 pci	-	-
	683.3 to 673.3	A-6a	C	2	69	69	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	673.3 to 668.3	A-1-a	G	4	85	48	135 psf	72.6 psf	φ = 42°	195 pci	-	-
	668.3 to 656.8	A-7-6	C	2	66	66	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	656.8 to 653.3	Shale	R	9	-	-	150 psf	87.6 psf	Qu = 750 psi	0.00025	68,000 psi	26
B-017-4-13	712.8 to 704.8	A-6b	C	3	14	14	120 psf	120 psf	Su = 1,750 psf	585 pci	0.0067	-
	704.8 to 684.8	A-1-b	G	4	37	36	130 psf	67.6 psf	φ = 40°	155 pci	-	-
	684.8 to 680.8	A-1-a	G	4	36	31	130 psf	67.6 psf	φ = 40°	155 pci	-	-
	680.8 to 670.8	A-1-a	G	4	74	60	135 psf	72.6 psf	φ = 43°	215 pci	-	-
	670.8 to 665.8	A-1-a	G	4	42	32	130 psf	67.6 psf	φ = 40°	155 pci	-	-
	665.8 to 659.3	A-7-6	C	2	67	67	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	659.3 to 646.5	Shale	R	9	-	-	150 psf	87.6 psf	Qu = 200 psi	0.0005	20,000 psi	20
	646.5 to 640.0	Shale	R	9	-	-	150 psf	87.6 psf	Qu = 750 psi	0.00025	68,000 psi	7
	640.0 to 636.5	Limestone	R	9	-	-	165 psf	102.6 psf	Qu = 10,000 psi	0.00005	1,000,000 psi	100
B-017-5-13	717.0 to 711.5	A-1-b	G	4	24	38	125 psf	125 psf	φ = 40°	280 pci	-	-
	711.5 to 704.0	A-6a	C	1	7	7	115 psf	115 psf	Su = 875 psf	165 pci	0.0095	-
	704.0 to 701.5	A-1-b	G	4	10	11	120 psf	120 psf	φ = 35°	135 pci	-	-
	701.5 to 696.5	A-1-a	G	4	21	20	125 psf	125 psf	φ = 38°	215 pci	-	-
	696.5 to 691.5	A-1-b	G	4	34	30	130 psf	130 psf	φ = 39°	250 pci	-	-
	691.5 to 685.0	A-1-b	G	4	13	11	125 psf	62.6 psf	φ = 35°	85 pci	-	-
	685.0 to 680.0	A-4a	C	2	57	57	130 psf	67.6 psf	Su = 7,125 psf	2,375 pci	0.0036	-
	680.0 to 675.0	A-1-b	G	4	52	40	135 psf	72.6 psf	φ = 40°	155 pci	-	-
	675.0 to 670.0	A-1-b	G	4	28	21	130 psf	67.6 psf	φ = 38°	125 pci	-	-
	670.0 to 665.0	A-1-b	G	4	49	35	135 psf	72.6 psf	φ = 40°	155 pci	-	-
	665.0 to 660.0	A-7-6	C	2	18	18	120 psf	57.6 psf	Su = 2,250 psf	750 pci	0.0060	-
	660.0 to 650.0	A-7-6	C	2	77	77	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	650.0 to 642.5	Shale	R	9	-	-	150 psf	87.6 psf	Qu = 200 psi	0.0005	20,000 psi	20
	642.5 to 632.5	Limestone	R	9	-	-	165 psf	102.6 psf	Qu = 10,000 psi	0.00005	1,000,000 psi	82

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-017-6-13	714.9 to 708.2	A-1-b	G	4	23	35	125 psf	125 psf	φ = 29°	30 pci	-	-
	708.2 to 704.4	A-6a	C	3	22	22	120 psf	120 psf	Su = 2,750 psf	915 pci	0.0053	-
	704.4 to 701.9	A-6a	C	3	12	12	115 psf	115 psf	Su = 1,500 psf	500 pci	0.0070	-
	701.9 to 699.4	A-3a	G	4	18	19	125 psf	125 psf	φ = 35°	135 pci	-	-
	699.4 to 696.9	A-4a	C	3	25	25	120 psf	120 psf	Su = 3,125 psf	1,040 pci	0.0050	-
	696.9 to 686.9	A-1-b	G	4	46	41	130 psf	130 psf	φ = 41°	315 pci	-	-
	686.9 to 677.9	A-1-b	G	4	24	19	125 psf	62.6 psf	φ = 37°	110 pci	-	-
	677.9 to 662.9	A-7-5	C	2	27	27	125 psf	62.6 psf	Su = 3,375 psf	1,125 pci	0.0049	-
	662.9 to 657.9	A-7-5	C	2	65	65	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	657.9 to 652.9	A-1-b	G	4	120	80	135 psf	72.6 psf	φ = 42°	195 pci	-	-
	652.9 to 650.6	A-7-6	C	2	120	120	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	650.6 to 640.4	Shale	R	9	-	-	150 psf	87.6 psf	Qu = 200 psi	0.0005	20,000 psi	20
	640.4 to 630.4	Limestone	R	9	-	-	165 psf	102.6 psf	Qu = 10,000 psi	0.00005	1,000,000 psi	92
B-017-7-13	743.1 to 739.1	A-1-a	G	4	14	24	120 psf	120 psf	φ = 39°	250 pci	-	-
	739.1 to 735.1	A-6a	C	3	18	18	120 psf	120 psf	Su = 2,250 psf	750 pci	0.0060	-
	735.1 to 732.6	A-1-a	G	4	65	78	135 psf	135 psf	φ = 43°	395 pci	-	-
	732.6 to 711.1	A-6b	C	3	25	25	120 psf	120 psf	Su = 3,125 psf	1,040 pci	0.0050	-
	711.1 to 704.1	A-6a	C	3	12	12	115 psf	115 psf	Su = 1,500 psf	500 pci	0.0070	-
	704.1 to 701.1	A-6b	C	3	21	21	120 psf	120 psf	Su = 2,625 psf	875 pci	0.0055	-
	701.1 to 691.1	A-1-b	G	4	32	21	130 psf	130 psf	φ = 38°	215 pci	-	-
	691.1 to 686.1	A-1-b	G	4	97	58	135 psf	135 psf	φ = 42°	355 pci	-	-
	686.1 to 676.1	A-2-4	G	4	86	49	135 psf	72.6 psf	φ = 40°	155 pci	-	-
	676.1 to 666.1	A-7-6	C	2	38	38	125 psf	62.6 psf	Su = 4,750 psf	1,585 pci	0.0044	-
	666.1 to 653.1	A-7-6	C	2	111	111	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	653.1 to 646.4	Shale	R	9	-	-	150 psf	87.6 psf	Qu = 360 psi	0.0005	32,000 psi	15

APPENDIX VII

MSE WALL CALCULATIONS

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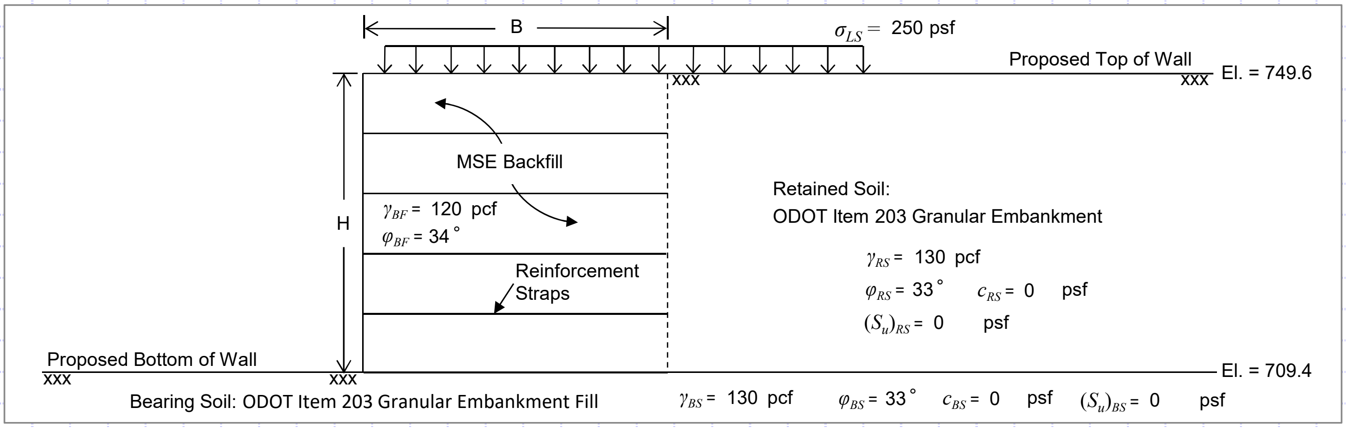
FRA-70-1358A - Retaining Wall 4W10 - MSE Wall - Rear Abutment - B-017-3-13 and B-017-4-13 - 40.2 ft. Wall Height



MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	40.2	ft
MSE Wall Width (Reinforcement Length), (B) =	28.1	ft
MSE Wall Length, (L) =	135	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion [1], (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	130	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	33	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(S_u)_{BS}]$ =	0	psf
Embedment Depth, (D_f) =	3.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

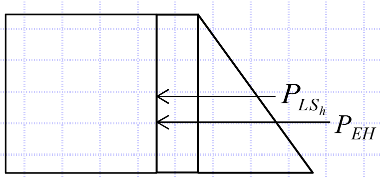
LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.3

Sliding Force:



$$P_H = P_{EH} + P_{LS_h}$$

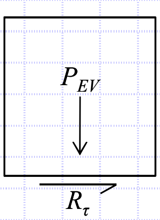
$$P_{EH} = \tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH} = \text{½(130 pcf)(40.2 ft)²(0.264)(1.5)} = 41.6 \text{ kip/ft}$$

$$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS} = \text{(250 psf)(40.2 ft)(0.264)(1.75)} = 4.64 \text{ kip/ft}$$

$$P_H = \text{41.6 kip/ft + 4.64 kip/ft} = 46.24 \text{ kip/ft}$$

Check Sliding Resistance - Drained Condition

Nominal Sliding Resistance:



$$R_\tau = P_{EV} \cdot \tan\delta$$

$$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} = \text{(120 pcf)(40.2 ft)(28.1 ft)(1.00)} = 135.55 \text{ kip/ft}$$

$$\tan\delta = (\tan\varphi_{BS} \le \tan\varphi_{BF})$$

$$\tan\delta = \tan(33) \le \tan(34) \longrightarrow 0.65 \le 0.67 \longrightarrow \tan\delta = 0.65$$

$$R_\tau = \text{(135.55 kip/ft)(0.65)} = 88.11 \text{ kip/ft}$$

Verify Sliding Force Less Than Factored Sliding Resistance - Drained Condition

$$P_H \le R_\tau \cdot \phi_\tau \longrightarrow \text{46.24 kip/ft} \le \text{(88.11 kip/ft)(1.0) = 88.11 kip/ft} \longrightarrow \text{46.24 kip/ft} \le \text{88.11 kip/ft}$$

OK

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

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MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	40.2	ft
MSE Wall Width (Reinforcement Length), (B) =	28.1	ft
MSE Wall Length, (L) =	135	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	130	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	33	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	0	psf
Embedment Depth, (D_f) =	3.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

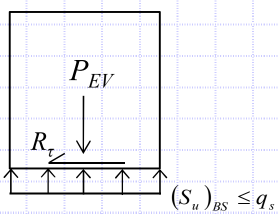
	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.3 *(Continued)*

Check Sliding Resistance - Undrained Condition

Nominal Sliding Resisting: $R_\tau = ((S_u)_{BS} \leq q_s) \cdot B$



$(S_u)_{BS} =$ N/A ksf

$q_s = \sigma_v / 2$ = (4.82 ksf) / 2 = 2.41 ksf

$\sigma_v = P_{EV} / B$ = (135.55 kip/ft) / (28.1 ft) = 4.82 ksf

R_τ = (N/A ksf ≤ 2.41 ksf)(28.1 ft) = N/A kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition

$P_H \leq R_\tau \cdot \phi_\tau$ ⟶ N/A ⟶ N/A

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

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MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	40.2	ft
MSE Wall Width (Reinforcement Length), (B) =	28.1	ft
MSE Wall Length, (L) =	135	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

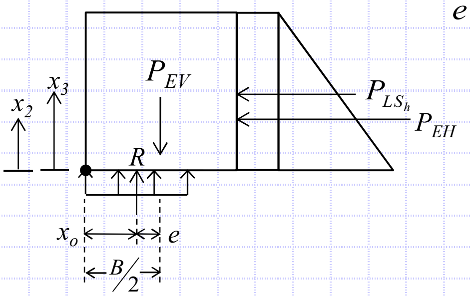
Bearing Soil Unit Weight, (γ_{BS}) =	130	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	33	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	0	psf
Embedment Depth, (D_f) =	3.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Eccentricity (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.5



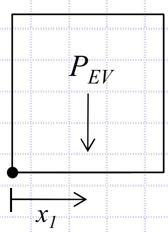
$$e = B/2 - x_o$$

$$x_o = \frac{M_{EV} - M_H}{P_{EV}}$$ = (1904.48 kip·ft/ft - 650.7 kip·ft/ft) / (135.55 kip/ft) = 9.25 ft

M_{EV}	=	1904.48	kip·ft/ft	Defined below
M_H	=	650.7	kip·ft/ft	
P_{EV}	=	135.55	kip/ft	

$e =$ (28.1 ft)/2 - 9.25 ft = 4.80 ft

Resisting Moment, M_{EV}:



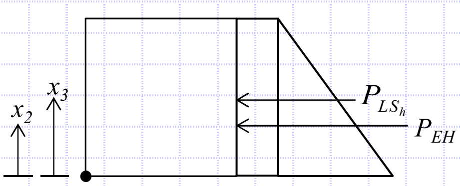
$$M_{EV} = P_{EV}(x_1)$$

$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(40.2 ft)(28.1 ft)(1.00) = 135.55 kip/ft

$x_1 = B/2$ = (28.1 ft) / 2 = 14.05 ft

M_{EV} = (135.55 kip/ft)(14.05 ft) = 1904.48 kip·ft/ft

Overturning Moment, M_H:



$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3)$$

$P_{EH} = \frac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH}$ = ½(130 pcf)(40.2 ft)²(0.264)(1.5) = 41.60 kip/ft

$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS}$ = (250 psf)(40.2 ft)(0.264)(1.75) = 4.64 kip/ft

$x_2 = H/3$ = (40.2 ft) / 3 = 13.40 ft

$x_3 = H/2$ = (40.2 ft) / 2 = 20.10 ft

M_H = (41.6 kip/ft)(13.4 ft) + (4.64 kip/ft)(20.10 ft) = 650.7 kip·ft/ft

Check Eccentricity

$e < e_{max} \longrightarrow$ 4.80 ft < 9.37 ft **OK**

Limiting Eccentricity: $e_{max} = B/3 \longrightarrow e_{max}$ = (28.1 ft) / 3 = 9.37 ft

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MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	40.2	ft
MSE Wall Width (Reinforcement Length), (B) =	28.1	ft
MSE Wall Length, (L) =	135	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

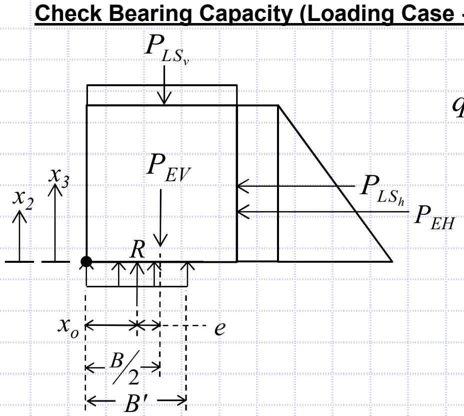
Bearing Soil Unit Weight, (γ_{BS}) =	130	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	33	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	0	psf
Embedment Depth, (D_f) =	3.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Section 11.10.5.4



$$q_{eq} = P_V / B'$$

$B' = B - 2e$ = 28.1 ft - 2(3.33 ft) = 21.44 ft

$e = B/2 - x_o$ = (28.1 ft) / 2 - 10.72 ft = 3.33 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (2743.86 kip·ft/ft - 650.72 kip·ft/ft) / 195.29 kip/ft = 10.72 ft

q_{eq} = (195.29 kip/ft) / (21.44 ft) = 9.11 ksf

$$M_V = P_{EV}(x_1) + P_{LS_v}(x_1) = (\gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV})(x_1) + (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$$

M_V = [(120 pcf)(40.2 ft)(28.1 ft)(1.35)](14.05 ft) + [(250 psf)(28.1 ft)(1.75)](14.05 ft) = 2743.86 kip·ft/ft

$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3) = (\tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH})(x_2) + (\sigma_{LS} H K_a \gamma_{LS})(x_3)$$

M_H = [½(130 pcf)(40.2 ft)²(0.264)(1.5)](13.4 ft) + [(250 psf)(40.2 ft)(0.264)(1.75)](20.1 ft) = 650.72 kip·ft/ft

$$P_V = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} + \sigma_{LS} \cdot B \cdot \gamma_{LS}$$

P_V = (120 pcf)(40.2 ft)(28.1 ft)(1.35) + (250 psf)(28.1 ft)(1.75) = 195.29 kip/ft

Check Bearing Resistance - Drained Condition

Nominal Bearing Resistance: $q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \tfrac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$

$N_{cm} = N_c s_c i_c$ = 42.77

N_c = 38.64

s_c = 1+(21.44 ft/135 ft)(26.09/38.64) = 1.107

i_c = 1.000 (Assumed)

$N_{qm} = N_q s_q d_q i_q$ = 29.84

N_q = 26.09

s_q = 1.103

d_q = 1+2tan(33°)[1-sin(33°)]²tan⁻¹(3.0 ft/21.44 ft) = 1.037

i_q = 1.000 (Assumed)

C_{wq} = 0.0 ft > 3.0 ft = 0.500

$N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 32.94

N_γ = 35.19

s_γ = 0.936

i_γ = 1.000 (Assumed)

$C_{w\gamma}$ = 0.0 ft < 1.5(21.44 ft) + 3.0 ft = 0.500

q_n = (0 psf)(42.774) + (130 pcf)(3.0 ft)(29.842)(0.500) + ½(130 pcf)(21.4 ft)(32.938)(0.500) = 28.77 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

$q_{eq} \le q_n \cdot \phi_b$ ⟶ 9.11 ksf ≤ (28.77 ksf)(0.65) = 18.70 ksf ⟶ 9.11 ksf ≤ 18.70 ksf **OK**

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	40.2	ft
MSE Wall Width (Reinforcement Length), (B) =	28.1	ft
MSE Wall Length, (L) =	135	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	130	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	33	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	0	psf
Embedment Depth, (D_f) =	3.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Section 11.10.5.4 ***(Continued)***

Check Bearing Resistance - Undrained Condition

Nominal Bearing Resistance: $$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \tfrac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$$

$N_{cm} = N_c s_c i_c$ = 5.300

- N_c = 5.140
- s_c = 1+(21.44 ft/[(5)(135 ft)]) = 1.032
- i_c = 1.000 (Assumed)

$N_{qm} = N_q s_q d_q i_q$ = 1.000

- N_q = 1.000
- s_q = 1.000
- d_q = 1+2tan(0°)[1-sin(0°)]²tan⁻¹(3.0 ft/21.44 ft) = 1.000
- i_q = 1.000 (Assumed)
- C_{wq} = 0.0 ft > 3.0 ft = 0.500

$N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 0.000

- N_γ = 0.000
- s_γ = 1.000
- i_γ = 1.000 (Assumed)
- $C_{w\gamma}$ = 0.0 ft < 1.5(21.44 ft) + 3.0 ft = 0.500

$q_n =$ (0 psf)(5.300) + (130 pcf)(3.0 ft)(1.000)(0.500) + ½(130 pcf)(21.4 ft)(0.000)(0.500) = N/A ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

$q_{eq} \le q_n \cdot \phi_b$ ⟶ 9.11 ksf ≤ (N/A ksf)(0.65) = N/A ksf ⟶ N/A

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

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JOB	FRA-70-12.68	NO.	W-13-045
SHEET NO.	6	OF	6
CALCULATED BY	BRT	DATE	7/7/2018
CHECKED BY	JPS	DATE	7/9/2018

FRA-70-1358A - Rear Abutment - Wall 4W10

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	40.2	ft
MSE Wall Width (Reinforcement Length), (B) =	28.1	ft
MSE Wall Length, (L) =	135	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

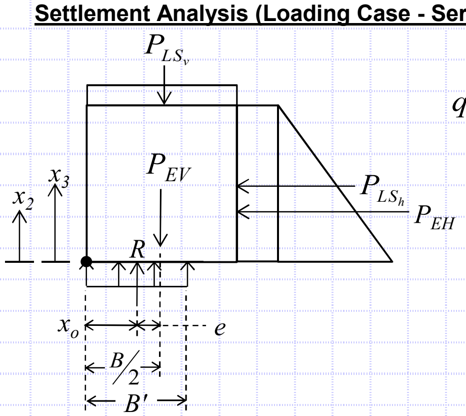
Bearing Soil Unit Weight, (γ_{BS}) =	130	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	33	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	0	psf
Embedment Depth, (D_f) =	3.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Settlement Analysis (Loading Case - Service I) - AASHTO LRFD BDM Section 11.10.4.1



$$q_{eq} = P_V / B'$$

$$B' = B - 2e \quad = \quad 28.1\text{ ft} - 2(2.98\text{ ft}) \quad = \quad 22.14 \quad \text{ft}$$

$$e = B/2 - x_o \quad = \quad (28.1\text{ ft}) / 2 - 11.07\text{ ft} \quad = \quad 2.98 \quad \text{ft}$$

$$x_o = \frac{M_V - M_H}{P_V} \quad = \quad (2003.24\text{ kip·ft/ft} - 424.93\text{ kip·ft/ft}) / 142.58\text{ kip/ft} \quad = \quad 11.07 \quad \text{ft}$$

$$q_{eq} = \quad (142.58\text{ kip/ft}) / (22.14\text{ ft}) \quad = \quad 6.44 \quad \text{ksf}$$

$$M_V = P_{EV}(x_1) + P_{LS_v}(x_1) = (\gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV})(x_1) + (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$$

$$M_V = \quad [(120\text{ pcf})(40.2\text{ ft})(28.1\text{ ft})(1.00)](14.1\text{ ft}) + [(250\text{ psf})(28.1\text{ ft})(1.00)](14.1\text{ ft}) \quad = \quad 2003.24 \quad \text{kip·ft/ft}$$

$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3) = (\tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH})(x_2) + (\sigma_{LS} H K_a \gamma_{LS})(x_3)$$

$$M_H = \quad [\tfrac{1}{2}(130\text{ pcf})(40.2\text{ ft})^2(0.264)(1.00)](13.4\text{ ft}) + [(250\text{ psf})(40.2\text{ ft})(0.264)(1.00)](20.1\text{ ft}) \quad = \quad 424.93 \quad \text{kip·ft/ft}$$

$$P_V = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} + \sigma_{LS} \cdot B \cdot \gamma_{LS}$$

$$P_V = \quad (120\text{ pcf})(40.2\text{ ft})(28.1\text{ ft})(1.00) + (250\text{ psf})(28.1\text{ ft})(1.00) \quad = \quad 142.58 \quad \text{kip/ft}$$

Settlement (To be calculated at Stage 2 Detailed Design):

Total Settlement at Center of Reinforced Soil Mass:	S_t =	2.749	in
Total Settlement at Wall Facing:	S_t =	2.073	in

Time Rate of Consolidation and Downdrag Depths and Loads:

Hold Period	Degree of Consolidation	Settlement Remaining at Completion of Hold Period	Depth of Downdrag
60 days	90 %	0.224 in	0.0 ft

W-13-045 - FRA-70-12.68 - FRA-70-1358A

MSE Wall Settlement - Rear Abutment - Retaining Wall 4W10

Calculated By: BRT Date: 7/7/2018

Checked By: JPS Date: 7/9/2018

Boring B-017-3-13

H=	42.0	ft	Total wall height
B'=	21.8	ft	Effective footing width due to eccentricity
D_w =	0.0	ft	Depth below bottom of footing
q_e =	6,570	psf	Equivalent bearing pressure at bottom of wall

Layer	Soil Class.	Soil Type	Layer Depth (ft)		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	Total Settlement at Center of Reinforced Soil Mass: I [7]	$\Delta\sigma_v$ [8] (psf)	σ_{vf}' Midpoint (psf)	S_c [9,10] (ft)	S_c (in)	Total Settlement at Facing of Wall: I [7]	$\Delta\sigma_v$ [8] (psf)	σ_{vf}' Midpoint (psf)	S_c [9,10] (ft)	S_c (in)
1 (Gra. Emb. Fill)	A-1-b	G	0.0	2.0	2.0	1.0	130	260	130	68	2,068					30	60	215	0.05	1.000	6,568	6,635	0.019	0.222	0.500	3,285	3,352	0.016	0.189
	A-1-b	G	2.0	4.0	2.0	3.0	130	520	390	203	2,203					30	53	182	0.14	0.992	6,517	6,720	0.017	0.200	0.499	3,281	3,484	0.014	0.163
	A-1-b	G	4.0	6.5	2.5	5.3	130	845	683	355	2,355					30	47	159	0.24	0.963	6,328	6,683	0.020	0.241	0.497	3,267	3,622	0.016	0.191
2	A-1-b	G	6.5	11.5	5.0	9.0	130	1,495	1,170	608	2,608					38	53	183	0.41	0.873	5,737	6,345	0.028	0.334	0.488	3,204	3,812	0.022	0.261
	A-1-b	G	11.5	16.5	5.0	14.0	135	2,170	1,833	959	2,959					65	81	335	0.64	0.730	4,794	5,753	0.012	0.139	0.463	3,042	4,001	0.009	0.111
	A-1-b	G	16.5	21.5	5.0	19.0	135	2,845	2,508	1,322	3,322					65	74	292	0.87	0.606	3,984	5,306	0.010	0.124	0.429	2,822	4,144	0.009	0.102
	A-1-b	G	21.5	26.5	5.0	24.0	135	3,520	3,183	1,685	3,685					65	69	261	1.10	0.511	3,358	5,043	0.009	0.109	0.393	2,583	4,268	0.008	0.093
3	A-6a	C	26.5	31.5	5.0	29.0	130	4,170	3,845	2,035	4,035	22	0.108	0.011	0.444				1.33	0.439	2,881	4,917	0.043	0.518	0.358	2,353	4,388	0.025	0.297
	A-6a	C	31.5	36.5	5.0	34.0	130	4,820	4,495	2,373	4,373	22	0.108	0.011	0.444				1.56	0.383	2,514	4,887	0.028	0.336	0.326	2,143	4,516	0.015	0.182
4	A-1-a	G	36.5	41.5	5.0	39.0	135	5,495	5,158	2,724	4,724					85	76	305	1.79	0.339	2,224	4,948	0.004	0.051	0.298	1,957	4,681	0.004	0.046
5	A-7-6	C	41.5	46.5	5.0	44.0	130	6,145	5,820	3,074	5,074	41	0.279	0.028	0.593				2.02	0.303	1,992	5,066	0.019	0.228	0.273	1,794	4,868	0.017	0.210
	A-7-6	C	46.5	53.0	6.5	49.8	130	6,990	6,568	3,463	5,463	41	0.279	0.028	0.593				2.28	0.270	1,777	5,240	0.020	0.246	0.248	1,632	5,096	0.019	0.229
																					Total Settlement:			2.749 in		Total Settlement:			2.073 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 2,000 psf for slightly to moderately overconsolidated soil deposit; Ref. Table 11.2, Coduto 2003
2. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
3. $C_r = 0.10(C_c)$; Ref. Section 8.11, Holtz and Kovacs 1981
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 strip loaded 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 (Cohesiv 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)

W-13-045 - FRA-70-12.68 - FRA-70-1358A
MSE Wall Settlement - Rear Abutment - Retaining Wall 4W10

Calculated By: BRT Date: 07/07/2018
Checked By: JPS Date: 07/09/2018

Boring B-017-3-13

H=	42.0	ft	Total wall height
B'=	21.8	ft	Effective footing width due to eccentricity
D_w =	0.0	ft	Depth below bottom of footing
q_e =	6,570	psf	Equivalent bearing pressure at bottom of wall

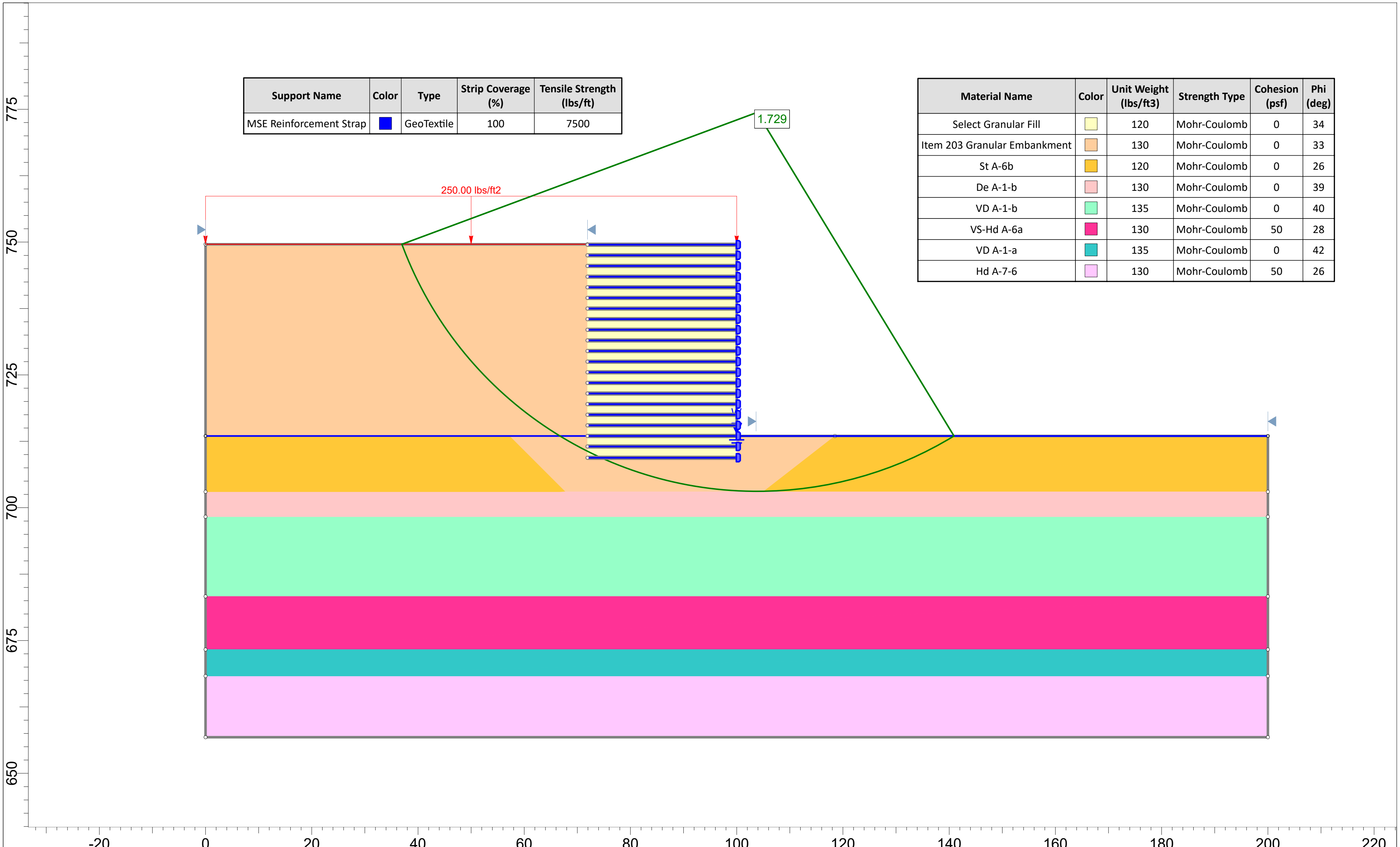
	A-6a	A-7-6			
c_v =	600	150	NA	ft^2/yr	Coefficient of consolidation
t =	60	60	60	days	Time following completion of construction
H_{dr} =	5	11.5	NA	ft	Length of longest drainage path considered
T_v =	3.945	0.186	NA		Time factor
U =	100	49	NA	%	Degree of consolidation

$(S_c)_t$ = 1.849 in Settlement complete at 89% of primary consolidation

																									Total Settlement at Facing of Wall			Settlement Complete at 89% of Primary Consolidation	
Layer	Soil Type	Soil Type	Layer Depth (ft)		Layer Thickness (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)	Layer Settlement (in)	$(S_c)_t$ [11] (in)	Layer Settlement (in)
1 (Gra. Emb. Fill)	A-1-b	G	0.0	2.0	2.0	1.0	130	260	130	68	2,068					30	60	215	0.05	0.00	1.52	0.500	3,285	3,352	0.016	0.189		0.189	
	A-1-b	G	2.0	4.0	2.0	3.0	130	520	390	203	2,203					30	53	182	0.14	0.00	1.43	0.499	3,281	3,484	0.014	0.163	0.543	0.163	0.543
	A-1-b	G	4.0	6.5	2.5	5.3	130	845	683	355	2,355					30	47	159	0.24	0.00	1.33	0.497	3,267	3,622	0.016	0.191		0.191	
2	A-1-b	G	6.5	11.5	5.0	9.0	130	1,495	1,170	608	2,608					38	53	183	0.41	0.00	1.18	0.488	3,204	3,812	0.022	0.261		0.261	
	A-1-b	G	11.5	16.5	5.0	14.0	135	2,170	1,833	959	2,959					65	81	335	0.64	0.00	1.00	0.463	3,042	4,001	0.009	0.111	0.567	0.111	0.567
	A-1-b	G	16.5	21.5	5.0	19.0	135	2,845	2,508	1,322	3,322					65	74	292	0.87	0.00	0.85	0.429	2,822	4,144	0.009	0.102		0.102	
	A-1-b	G	21.5	26.5	5.0	24.0	135	3,520	3,183	1,685	3,685					65	69	261	1.10	0.00	0.74	0.393	2,583	4,268	0.008	0.093		0.093	
3	A-6a	C	26.5	31.5	5.0	29.0	130	4,170	3,845	2,035	4,035	22	0.108	0.011	0.444				1.33	0.00	0.64	0.358	2,353	4,388	0.025	0.297	0.478	0.297	0.478
	A-6a	C	31.5	36.5	5.0	34.0	130	4,820	4,495	2,373	4,373	22	0.108	0.011	0.444				1.56	0.00	0.57	0.326	2,143	4,516	0.015	0.182		0.182	
4	A-1-a	G	36.5	41.5	5.0	39.0	135	5,495	5,158	2,724	4,724					85	76	305	1.79	0.00	0.51	0.298	1,957	4,681	0.004	0.046	0.046	0.046	0.046
5	A-7-6	C	41.5	46.5	5.0	44.0	130	6,145	5,820	3,074	5,074	41	0.279	0.028	0.593				2.02	0.00	0.46	0.273	1,794	4,868	0.017	0.210	0.439	0.103	0.215
	A-7-6	C	46.5	53.0	6.5	49.8	130	6,990	6,568	3,463	5,463	41	0.279	0.028	0.593				2.28	0.00	0.41	0.248	1,632	5,096	0.019	0.229		0.112	

Settlement Remaining After Hold Period: 0.224 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. $C_r = 0.10(C_c)$; 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 strip loaded 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 (Cohesiv 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)
11. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0

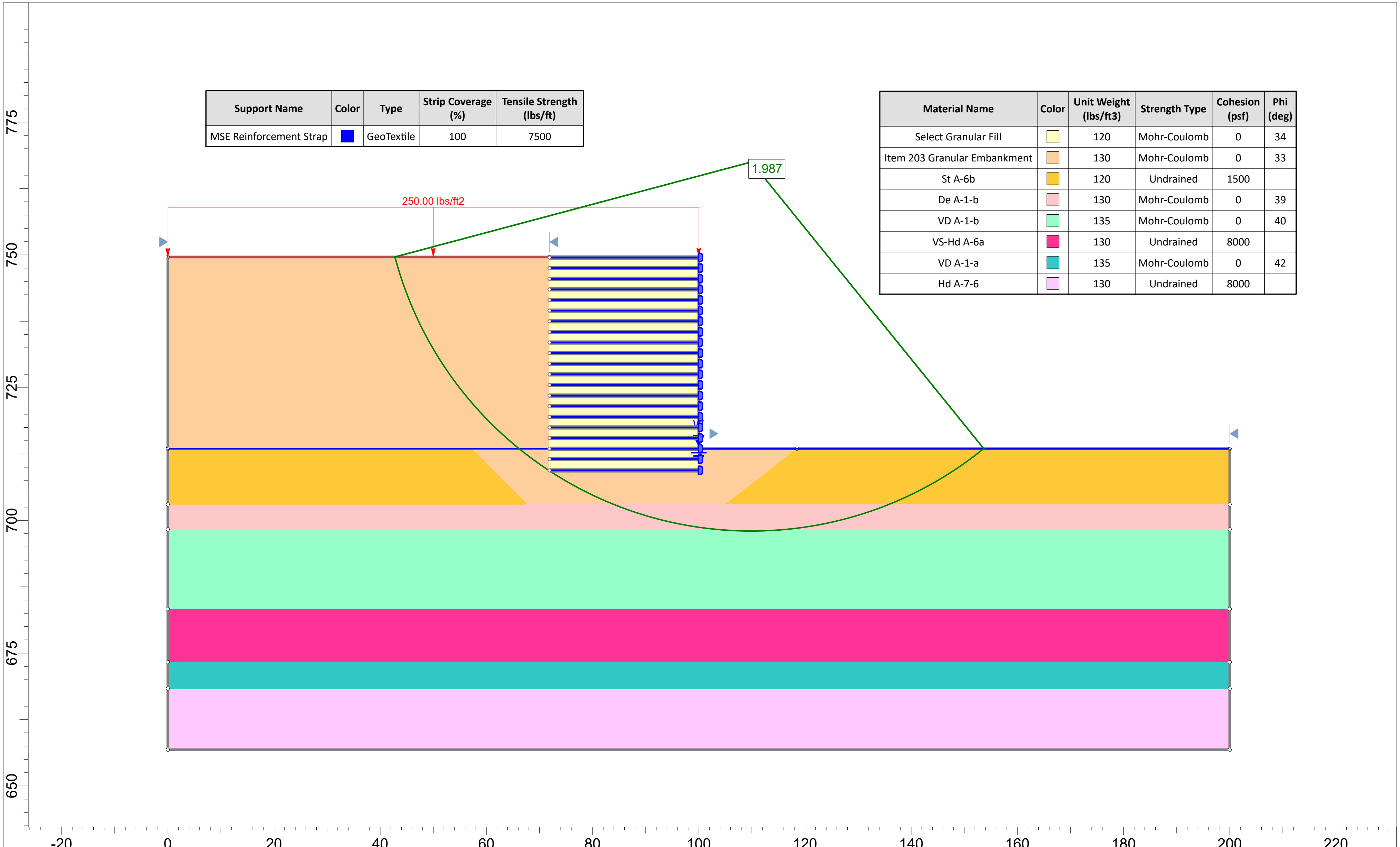


Support Name	Color	Type	Strip Coverage (%)	Tensile Strength (lbs/ft)
MSE Reinforcement Strap		GeoTextile	100	7500

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Select Granular Fill		120	Mohr-Coulomb	0	34
Item 203 Granular Embankment		130	Mohr-Coulomb	0	33
St A-6b		120	Mohr-Coulomb	0	26
De A-1-b		130	Mohr-Coulomb	0	39
VD A-1-b		135	Mohr-Coulomb	0	40
VS-Hd A-6a		130	Mohr-Coulomb	50	28
VD A-1-a		135	Mohr-Coulomb	0	42
Hd A-7-6		130	Mohr-Coulomb	50	26

Project	FRA-70-12.68 - FRA-70-1358A - Retaining Wall 4W10 - MSE Wall Global Stability		
Analysis Description	Rear Abutment - 40.2 ft Wall Height - Drained - Circular - Spencer		
Drawn By	BRT	*Scale*	1:300
Company	Resource International, Inc.		
Date	07/07/2018	*File Name*	FRA-70-1358A - Rear Abutment - Global Stability.slim

SLIDEINTERPRET 7.020



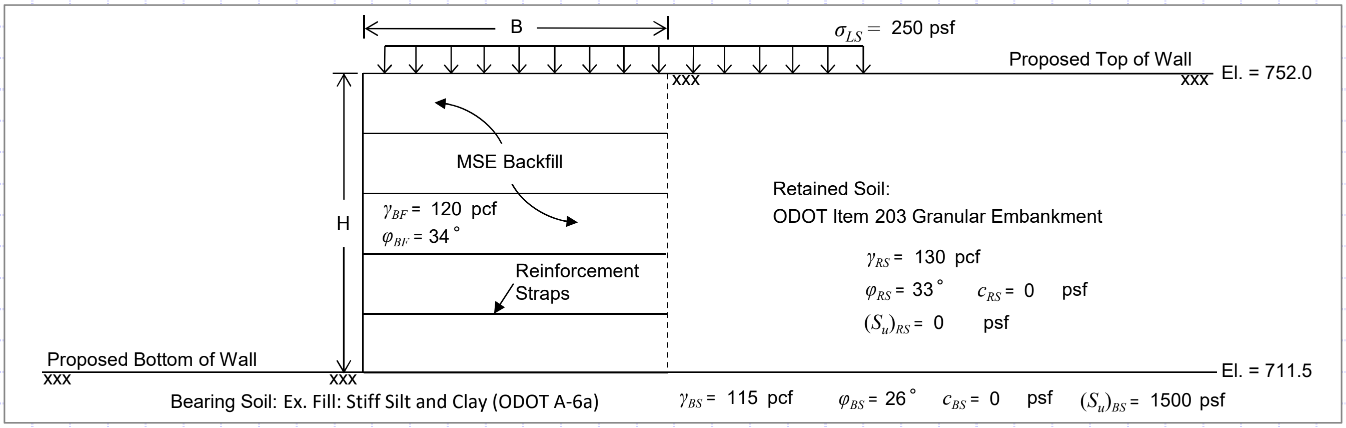
Support Name	Color	Type	Strip Coverage (%)	Tensile Strength (lbs/ft)
MSE Reinforcement Strap		GeoTextile	100	7500

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Select Granular Fill		120	Mohr-Coulomb	0	34
Item 203 Granular Embankment		130	Mohr-Coulomb	0	33
St A-6b		120	Undrained	1500	
De A-1-b		130	Mohr-Coulomb	0	39
VD A-1-b		135	Mohr-Coulomb	0	40
VS-Hd A-6a		130	Undrained	8000	
VD A-1-a		135	Mohr-Coulomb	0	42
Hd A-7-6		130	Undrained	8000	

Project	FRA-70-12.68 - FRA-70-1358A - Retaining Wall 4W10 - MSE Wall Global Stability		
Analysis Description	Rear Abutment - 40.2 ft Wall Height - Undrained - Circular - Spencer		
Drawn By	BRT	*Scale*	1:300
Company	Resource International, Inc.		
Date	07/07/2018	*File Name*	FRA-70-1358A - Rear Abutment - Global Stability.slim

SLIDEINTERPRET 7.020

FRA-70-1358A - Retaining Wall 4W8 - MSE Wall - Forward Abutment - B-017-6-13 and B-017-7-13 - 40.2 ft. Wall Height



MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	40.5	ft
MSE Wall Width (Reinforcement Length), (B) =	28.4	ft
MSE Wall Length, (L) =	80	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion [1], (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	115	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(S_u)_{BS}]$ =	1500	psf
Embedment Depth, (D_f) =	3.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

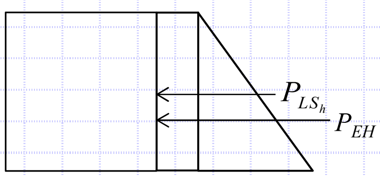
LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.3

Sliding Force:



$$P_H = P_{EH} + P_{LS_h}$$

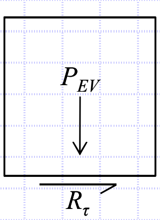
$$P_{EH} = \tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH} = \text{½(130 pcf)(40.5 ft)²(0.264)(1.5)} = 42.22 \text{ kip/ft}$$

$$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS} = \text{(250 psf)(40.5 ft)(0.264)(1.75)} = 4.68 \text{ kip/ft}$$

$$P_H = \text{42.22 kip/ft + 4.68 kip/ft} = 46.90 \text{ kip/ft}$$

Check Sliding Resistance - Drained Condition

Nominal Sliding Resistance:



$$R_\tau = P_{EV} \cdot \tan\delta$$

$$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} = \text{(120 pcf)(40.5 ft)(28.4 ft)(1.00)} = 138.02 \text{ kip/ft}$$

$$\tan\delta = (\tan\varphi_{BS} \le \tan\varphi_{BF})$$

$$\tan\delta = \tan(26) \le \tan(34) \longrightarrow 0.49 \le 0.67 \longrightarrow \tan\delta = 0.49$$

$$R_\tau = \text{(138.02 kip/ft)(0.49)} = 67.63 \text{ kip/ft}$$

Verify Sliding Force Less Than Factored Sliding Resistance - Drained Condition

$P_H \le R_\tau \cdot \phi_\tau$ ⟶ 46.90 kip/ft ≤ (67.63 kip/ft)(1.0) = 67.63 kip/ft ⟶ 46.90 kip/ft ≤ 67.63 kip/ft **OK**

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	40.5	ft
MSE Wall Width (Reinforcement Length), (B) =	28.4	ft
MSE Wall Length, (L) =	80	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	115	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	1500	psf
Embedment Depth, (D_f) =	3.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

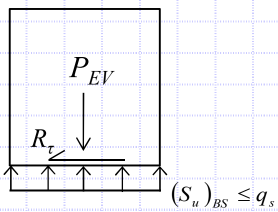
	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.3 *(Continued)*

Check Sliding Resistance - Undrained Condition

Nominal Sliding Resisting: $$R_\tau = ((S_u)_{BS} \le q_s) \cdot B$$



$(S_u)_{BS} =$ 1.50 ksf

$q_s = \sigma_v / 2$ = (4.86 ksf) / 2 = 2.43 ksf

$\sigma_v = P_{EV} / B$ = (138.02 kip/ft) / (28.4 ft) = 4.86 ksf

R_τ = (1.50 ksf ≤ 2.43 ksf)(28.4 ft) = 42.60 kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition

$P_H \le R_\tau \cdot \phi_\tau$ ⟶ 46.90 kip/ft ≤ (42.60 kip/ft)(1.0) = 42.60 kip/ft ⟶ 46.90 kip/ft ≤ 42.60 kip/ft **ERROR!!**

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	40.5	ft
MSE Wall Width (Reinforcement Length), (B) =	28.4	ft
MSE Wall Length, (L) =	80	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

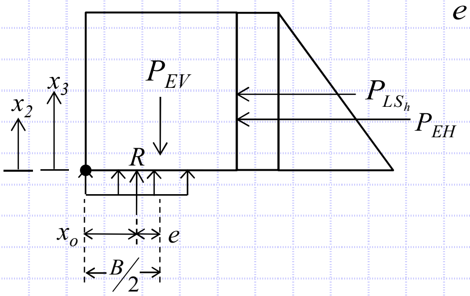
Bearing Soil Unit Weight, (γ_{BS}) =	115	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	1500	psf
Embedment Depth, (D_f) =	3.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Eccentricity (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.5



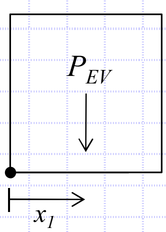
$$e = B/2 - x_o$$

$$x_o = \frac{M_{EV} - M_H}{P_{EV}}$$ = (1959.88 kip·ft/ft - 664.74 kip·ft/ft) / (138.02 kip/ft) = 9.38 ft

M_{EV}	=	1959.88	kip·ft/ft	Defined below
M_H	=	664.74	kip·ft/ft	
P_{EV}	=	138.02	kip/ft	

$e =$ (28.4 ft)/2 - 9.38 ft = 4.82 ft

Resisting Moment, M_{EV}:



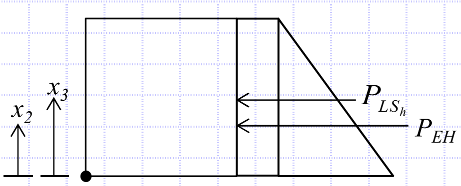
$$M_{EV} = P_{EV}(x_1)$$

$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(40.5 ft)(28.4 ft)(1.00) = 138.02 kip/ft

$x_1 = B/2$ = (28.4 ft) / 2 = 14.20 ft

$M_{EV} =$ (138.02 kip/ft)(14.20 ft) = 1959.88 kip·ft/ft

Overturning Moment, M_H:



$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3)$$

$P_{EH} = \frac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH}$ = ½(130 pcf)(40.5 ft)²(0.264)(1.5) = 42.22 kip/ft

$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS}$ = (250 psf)(40.5 ft)(0.264)(1.75) = 4.68 kip/ft

$x_2 = H/3$ = (40.5 ft) / 3 = 13.50 ft

$x_3 = H/2$ = (40.5 ft) / 2 = 20.25 ft

$M_H =$ (42.22 kip/ft)(13.5 ft) + (4.68 kip/ft)(20.25 ft) = 664.74 kip·ft/ft

Check Eccentricity

$e < e_{max} \longrightarrow$ 4.82 ft < 9.47 ft **OK**

Limiting Eccentricity: $e_{max} = B/3 \longrightarrow e_{max} =$ (28.4 ft) / 3 = 9.47 ft

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	40.5	ft
MSE Wall Width (Reinforcement Length), (B) =	28.4	ft
MSE Wall Length, (L) =	80	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

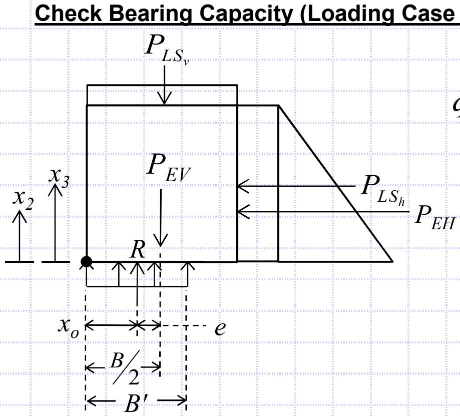
Bearing Soil Unit Weight, (γ_{BS}) =	115	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	1500	psf
Embedment Depth, (D_f) =	3.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Section 11.10.5.4



$$q_{eq} = P_V / B'$$

$B' = B - 2e$ = 28.4 ft - 2(3.34 ft) = 21.72 ft

$e = B/2 - x_o$ = (28.4 ft) / 2 - 10.86 ft = 3.34 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (2822.36 kip·ft/ft - 664.69 kip·ft/ft) / 198.76 kip/ft = 10.86 ft

q_{eq} = (198.76 kip/ft) / (21.72 ft) = 9.15 ksf

$$M_V = P_{EV}(x_1) + P_{LS_v}(x_1) = (\gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV})(x_1) + (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$$

M_V = [(120 pcf)(40.5 ft)(28.4 ft)(1.35)](14.2 ft) + [(250 psf)(28.4 ft)(1.75)](14.2 ft) = 2822.36 kip·ft/ft

$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3) = (\tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH})(x_2) + (\sigma_{LS} H K_a \gamma_{LS})(x_3)$$

M_H = [½(130 pcf)(40.5 ft)²(0.264)(1.5)](13.5 ft) + [(250 psf)(40.5 ft)(0.264)(1.75)](20.25 ft) = 664.69 kip·ft/ft

$$P_V = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} + \sigma_{LS} \cdot B \cdot \gamma_{LS}$$

P_V = (120 pcf)(40.5 ft)(28.4 ft)(1.35) + (250 psf)(28.4 ft)(1.75) = 198.76 kip/ft

Check Bearing Resistance - Drained Condition

Nominal Bearing Resistance: $q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \tfrac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$

$N_{cm} = N_c s_c i_c$ = 25.48

- N_c = 22.25
- s_c = 1+(21.72 ft/80 ft)(11.85/22.25)
- = 1.145
- i_c = 1.000 (Assumed)

$N_{qm} = N_q s_q d_q i_q$ = 13.98

- N_q = 11.85
- s_q = 1.132
- d_q = 1+2tan(26°)[1-sin(26°)]²tan⁻¹(3.0 ft/21.72 ft)
- 1.042
- i_q = 1.000 (Assumed)
- C_{wq} = 0.0 ft > 3.0 ft = 0.500

$N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 11.17

- N_γ = 12.54
- s_γ = 0.891
- i_γ = 1.000 (Assumed)
- $C_{w\gamma}$ = 0.0 ft < 1.5(21.72 ft) + 3.0 ft = 0.500

q_n = (0 psf)(25.476) + (115 pcf)(3.0 ft)(13.978)(0.500) + ½(115 pcf)(21.7 ft)(11.173)(0.500) = 9.39 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

$q_{eq} \leq q_n \cdot \phi_b$ ⟶ 9.15 ksf ≤ (9.39 ksf)(0.65) = 6.10 ksf ⟶ 9.15 ksf ≤ 6.10 ksf **ERROR!!**

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	40.5	ft
MSE Wall Width (Reinforcement Length), (B) =	28.4	ft
MSE Wall Length, (L) =	80	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	115	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	1500	psf
Embedment Depth, (D_f) =	3.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Section 11.10.5.4 *(Continued)*

Check Bearing Resistance - Undrained Condition

Nominal Bearing Resistance: $$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \tfrac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$$

$N_{cm} = N_c s_c i_c$ = 5.420

- N_c = 5.140
- s_c = 1+(21.72 ft/[(5)(80 ft)]) = 1.054
- i_c = 1.000 (Assumed)

$N_{qm} = N_q s_q d_q i_q$ = 1.000

- N_q = 1.000
- s_q = 1.000
- d_q = 1+2tan(0°)[1-sin(0°)]²tan⁻¹(3.0 ft/21.72 ft) = 1.000
- i_q = 1.000 (Assumed)
- C_{wq} = 0.0 ft > 3.0 ft = 0.500

$N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 0.000

- N_γ = 0.000
- s_γ = 1.000
- i_γ = 1.000 (Assumed)
- $C_{w\gamma}$ = 0.0 ft < 1.5(21.72 ft) + 3.0 ft = 0.500

q_n = (1500 psf)(5.420) + (115 pcf)(3.0 ft)(1.000)(0.500) + ½(115 pcf)(21.7 ft)(0.000)(0.500) = 8.30 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

$q_{eq} \le q_n \cdot \phi_b$ ⟶ 9.15 ksf ≤ (8.30 ksf)(0.65) = 5.40 ksf ⟶ 9.15 ksf ≤ 5.40 ksf **ERROR!!**

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

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JOB	FRA-70-12.68	NO.	W-13-045
SHEET NO.	6	OF	6
CALCULATED BY	BRT	DATE	7/7/2018
CHECKED BY	JPS	DATE	7/9/2018

FRA-70-1358A - Forward Abutment - Wall 4W8

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	40.5	ft
MSE Wall Width (Reinforcement Length), (B) =	28.4	ft
MSE Wall Length, (L) =	80	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion, (c_{RS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

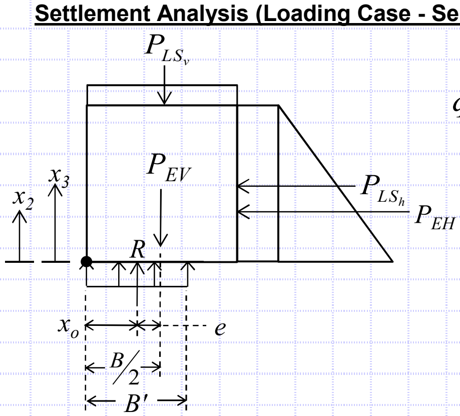
Bearing Soil Unit Weight, (γ_{BS}) =	115	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	1500	psf
Embedment Depth, (D_f) =	3.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Settlement Analysis (Loading Case - Service I) - AASHTO LRFD BDM Section 11.10.4.1



$$q_{eq} = P_V / B'$$

$$B' = B - 2e \quad = \quad \text{28.4 ft - 2(2.99 ft)} \quad = \quad 22.42 \quad \text{ft}$$

$$e = B/2 - x_o \quad = \quad \text{(28.4 ft) / 2 - 11.21 ft} \quad = \quad 2.99 \quad \text{ft}$$

$$x_o = \frac{M_V - M_H}{P_V} \quad = \quad \text{(2060.76 kip·ft/ft - 434.11 kip·ft/ft) / 145.12 kip/ft} \quad = \quad 11.21 \quad \text{ft}$$

$$q_{eq} = \text{(145.12 kip/ft) / (22.42 ft)} \quad = \quad 6.47 \quad \text{ksf}$$

$$M_V = P_{EV}(x_1) + P_{LS_v}(x_1) = (\gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV})(x_1) + (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$$

$$M_V = \text{[(120 pcf)(40.5 ft)(28.4 ft)(1.00)](14.2 ft) + [(250 psf)(28.4 ft)(1.00)](14.2 ft)} \quad = \quad 2060.76 \quad \text{kip·ft/ft}$$

$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3) = (\tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH})(x_2) + (\sigma_{LS} H K_a \gamma_{LS})(x_3)$$

$$M_H = \text{[½(130 pcf)(40.5 ft)²(0.264)(1.00)](13.5 ft) + [(250 psf)(40.5 ft)(0.264)(1.00)](20.25 ft)} \quad = \quad 434.11 \quad \text{kip·ft/ft}$$

$$P_V = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} + \sigma_{LS} \cdot B \cdot \gamma_{LS}$$

$$P_V = \text{(120 pcf)(40.5 ft)(28.4 ft)(1.00) + (250 psf)(28.4 ft)(1.00)} \quad = \quad 145.12 \quad \text{kip/ft}$$

Settlement (To be calculated at Stage 2 Detailed Design):

Total Settlement at Center of Reinforced Soil Mass:	S_t =	**11.027**	in
Total Settlement at Wall Facing:	S_t =	**6.729**	in

Time Rate of Consolidation and Downdrag Depths and Loads:

Hold Period	Degree of Consolidation	Settlement Remaining at Completion of Hold Period	Depth of Downdrag
60 days	90 %	0.693 in	0.0 ft

W-13-045 - FRA-70-12.68 - FRA-70-1358A

MSE Wall Settlement - Forward Abutment - Retaining Wall 4W8

Calculated By: BRT Date: 7/7/2018

Checked By: JPS Date: 7/9/2018

Boring B-017-6-13

H=	40.5	ft	Total wall height
B'=	22.4	ft	Effective footing width due to eccentricity
D_w =	0.0	ft	Depth below bottom of footing
q_e =	6,470	psf	Equivalent bearing pressure at bottom of wall

Layer	Soil Class.	Soil Type	Layer Depth (ft)		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	Total Settlement at Center of Reinforced Soil Mass: I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	S_c (9,10) (ft)	S_c (in)	Total Settlement at Facing of Wall: 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	3.5	3.5	1.8	125	438	219	110	2,110					22	43	143	0.08	0.998	6,460	6,569	0.044	0.522	0.500	3,234	3,344	0.036	0.436
2	A-6a	C	3.5	5.5	2.0	4.5	115	668	553	272	2,272	33	0.207	0.031	0.530				0.20	0.977	6,321	6,593	0.163	1.952	0.498	3,224	3,496	0.088	1.057
	A-6a	C	5.5	7.5	2.0	6.5	115	898	783	377	2,377	33	0.207	0.031	0.530				0.29	0.942	6,092	6,469	0.150	1.801	0.495	3,205	3,581	0.081	0.968
	A-6a	C	7.5	10.0	2.5	8.8	115	1,185	1,041	495	2,495	33	0.207	0.031	0.530				0.39	0.887	5,737	6,232	0.170	2.041	0.489	3,166	3,661	0.092	1.103
3	A-3a	G	10.0	12.5	2.5	11.3	125	1,498	1,341	639	2,639					18	25	76	0.50	0.817	5,285	5,925	0.032	0.381	0.480	3,102	3,742	0.025	0.302
4	A-4a	C	12.5	16.0	3.5	14.3	120	1,918	1,708	818	2,818	24	0.126	0.013	0.460				0.64	0.733	4,745	5,563	0.105	1.266	0.464	3,001	3,819	0.056	0.673
5	A-1-b	G	16.0	20.5	4.5	18.3	135	2,525	2,221	1,082	3,082					46	56	194	0.81	0.634	4,103	5,186	0.016	0.190	0.438	2,836	3,918	0.013	0.156
	A-1-b	G	20.5	25.0	4.5	22.8	135	3,133	2,829	1,409	3,409					46	51	176	1.02	0.544	3,516	4,926	0.014	0.167	0.407	2,631	4,040	0.012	0.141
6	A-1-b	G	25.0	29.5	4.5	27.3	125	3,695	3,414	1,713	3,713					24	25	86	1.22	0.472	3,054	4,768	0.023	0.278	0.375	2,427	4,141	0.020	0.239
	A-1-b	G	29.5	34.0	4.5	31.8	125	4,258	3,976	1,995	3,995					24	24	83	1.42	0.416	2,689	4,684	0.020	0.240	0.346	2,235	4,231	0.018	0.211
7	A-7-5	C	34.0	44.0	10.0	39.0	125	5,508	4,883	2,449	4,449	57	0.423	0.042	0.718				1.74	0.347	2,245	4,694	0.121	1.453	0.303	1,963	4,412	0.063	0.755
	A-7-5	C	44.0	54.0	10.0	49.0	125	6,758	6,133	3,075	5,075	57	0.423	0.042	0.718				2.19	0.281	1,820	4,895	0.050	0.597	0.257	1,662	4,737	0.046	0.554
8	A-1-b	G	54.0	58.0	4.0	56.0	135	7,298	7,028	3,533	5,533					100	81	335	2.50	0.248	1,605	5,138	0.002	0.023	0.231	1,494	5,027	0.002	0.022
9	A-7-6	C	58.0	61.0	3.0	59.5	130	7,688	7,493	3,780	5,780	51	0.369	0.037	0.671				2.66	0.234	1,515	5,295	0.010	0.116	0.220	1,421	5,200	0.009	0.110
																						Total Settlement:		11.027 in			Total Settlement:		6.729 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 6-9, FHWA GEC 5
3. C_r = 0.15(Cc) for the existing fill and 0.10(Cc) for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
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 strip loaded 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 (Cohesiv 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)

W-13-045 - FRA-70-12.68 - FRA-70-1358A

MSE Wall Settlement - Forward Abutment - Retaining Wall 4W8

Calculated By: BRT Date: 07/07/2018

Checked By: JPS Date: 07/09/2018

Boring B-017-6-13

H=	40.5	ft	Total wall height
B'=	22.4	ft	Effective footing width due to eccentricity
D_w =	0.0	ft	Depth below bottom of footing
q_e =	6,470	psf	Equivalent bearing pressure at bottom of wall

	A-6a	A-4a	A-7-5	A-7-6		
c_v =	600	800	100	150	ft^2/yr	Coefficient of consolidation
t =	60	60	60	60	days	Time following completion of construction
H_{dr} =	4	2	10	3	ft	Length of longest drainage path considered
T_v =	6.164	32.877	0.164	2.740		Time factor
U =	100	100	46	100	%	Degree of consolidation

$(S_c)_t$ = 6.007 in Settlement complete at 90% of primary consolidation

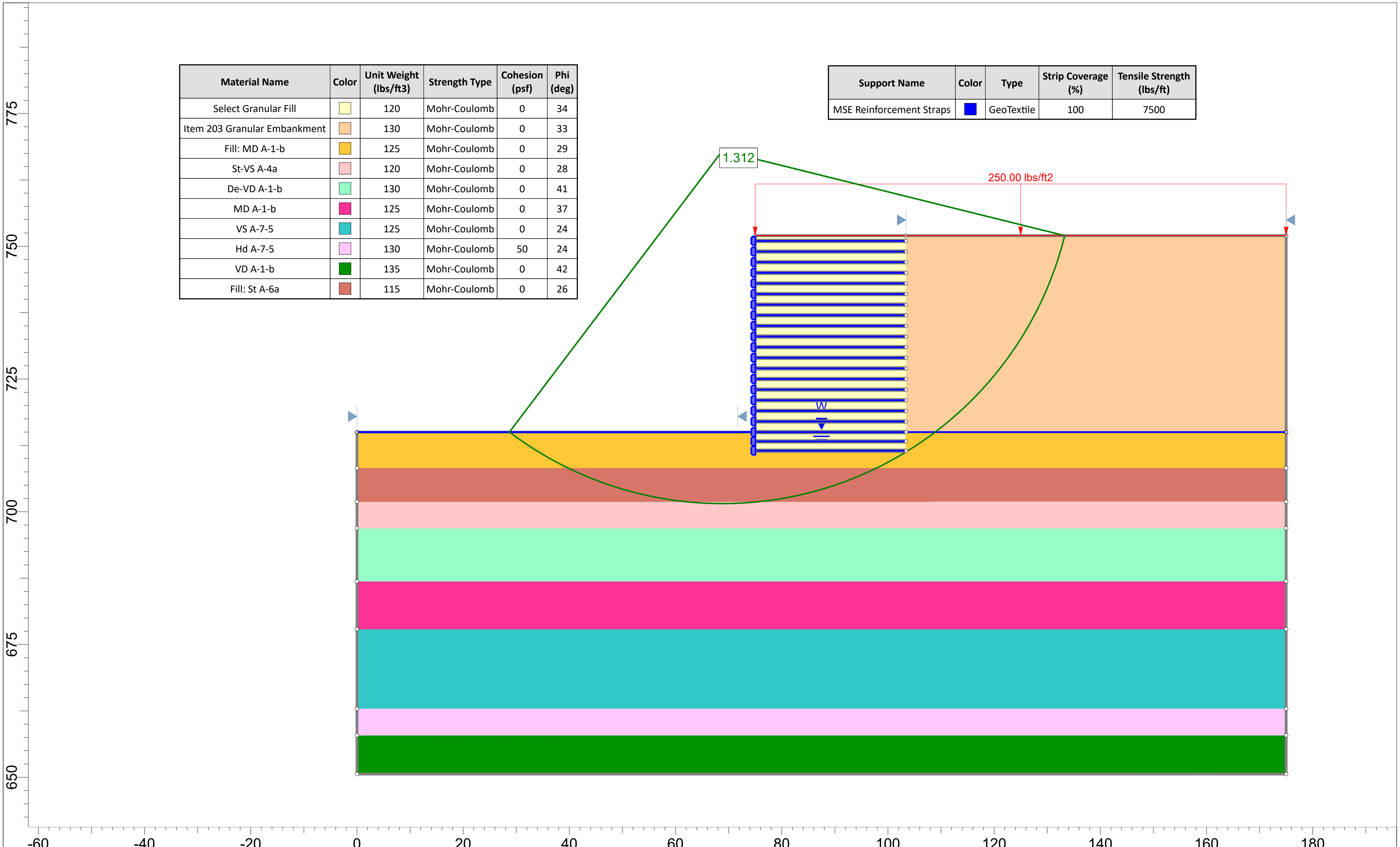
Layer	Soil Type	Soil Type	Layer Depth (ft)		Layer Thickness (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' (1) (psf)	LL	C_c (2)	C_r (3)	e_o (4)	N_{60}	$(N1)_{60}$ (5)	C' (6)	z_f/B	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	Total Settlement at Facing of Wall: S_c (9,10) (ft)	S_c (in)	Layer Settlement (in)	Settlement Complete at 90% of Primary Consolidation: $(S_c)_t$ (11) (in)	Layer Settlement (in)
1	A-1-b	G	0.0	3.5	3.5	1.8	125	438	219	110	2,110					22	43	143	0.08	0.500	3,234	3,344	0.036	0.436	0.436	0.436	0.436
2	A-6a	C	3.5	5.5	2.0	4.5	115	668	553	272	2,272	33	0.207	0.031	0.530				0.20	0.498	3,224	3,496	0.088	1.057	3.128	1.057	3.128
	A-6a	C	5.5	7.5	2.0	6.5	115	898	783	377	2,377	33	0.207	0.031	0.530				0.29	0.495	3,205	3,581	0.081	0.968		0.968	
	A-6a	C	7.5	10.0	2.5	8.8	115	1,185	1,041	495	2,495	33	0.207	0.031	0.530				0.39	0.489	3,166	3,661	0.092	1.103		1.103	
3	A-3a	G	10.0	12.5	2.5	11.3	125	1,498	1,341	639	2,639					18	25	76	0.50	0.480	3,102	3,742	0.025	0.302	0.302	0.302	0.302
4	A-4a	C	12.5	16.0	3.5	14.3	120	1,918	1,708	818	2,818	24	0.126	0.013	0.460				0.64	0.464	3,001	3,819	0.056	0.673	0.673	0.673	0.673
5	A-1-b	G	16.0	20.5	4.5	18.3	135	2,525	2,221	1,082	3,082					46	56	194	0.81	0.438	2,836	3,918	0.013	0.156	0.296	0.156	0.296
	A-1-b	G	20.5	25.0	4.5	22.8	135	3,133	2,829	1,409	3,409					46	51	176	1.02	0.407	2,631	4,040	0.012	0.141		0.141	
6	A-1-b	G	25.0	29.5	4.5	27.3	125	3,695	3,414	1,713	3,713					24	25	86	1.22	0.375	2,427	4,141	0.020	0.239	0.451	0.239	0.451
	A-1-b	G	29.5	34.0	4.5	31.8	125	4,258	3,976	1,995	3,995					24	24	83	1.42	0.346	2,235	4,231	0.018	0.211		0.211	
7	A-7-5	C	34.0	44.0	10.0	39.0	135	5,608	4,933	2,499	4,499	57	0.423	0.042	0.718				1.74	0.303	1,963	4,462	0.062	0.744	1.284	0.342	0.591
	A-7-5	C	44.0	54.0	10.0	49.0	125	6,858	6,233	3,175	5,175	57	0.423	0.042	0.718				2.19	0.257	1,662	4,837	0.045	0.540		0.248	
8	A-1-b	G	54.0	58.0	4.0	56.0	135	7,398	7,128	3,633	5,633					100	80	329	2.50	0.231	1,494	5,127	0.002	0.022	0.022	0.022	0.022
9	A-7-6	C	58.0	61.0	3.0	59.5	130	7,788	7,593	3,880	5,880	51	0.369	0.037	0.671				2.66	0.220	1,421	5,300	0.009	0.108	0.108	0.108	0.108

Settlement Remaining After Hold Period: 0.693 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 6-9, FHWA GEC 5
3. $C_r = 0.15(Cc)$ for the existing fill and 0.10(Cc) for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
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 strip loaded 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 (Cohesiv 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)
11. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Select Granular Fill		120	Mohr-Coulomb	0	34
Item 203 Granular Embankment		130	Mohr-Coulomb	0	33
Fill: MD A-1-b		125	Mohr-Coulomb	0	29
St-VS A-4a		120	Mohr-Coulomb	0	28
De-VD A-1-b		130	Mohr-Coulomb	0	41
MD A-1-b		125	Mohr-Coulomb	0	37
VS A-7-5		125	Mohr-Coulomb	0	24
Hd A-7-5		130	Mohr-Coulomb	50	24
VD A-1-b		135	Mohr-Coulomb	0	42
Fill: St A-6a		115	Mohr-Coulomb	0	26

Support Name	Color	Type	Strip Coverage (%)	Tensile Strength (lbs/ft)
MSE Reinforcement Straps		GeoTextile	100	7500

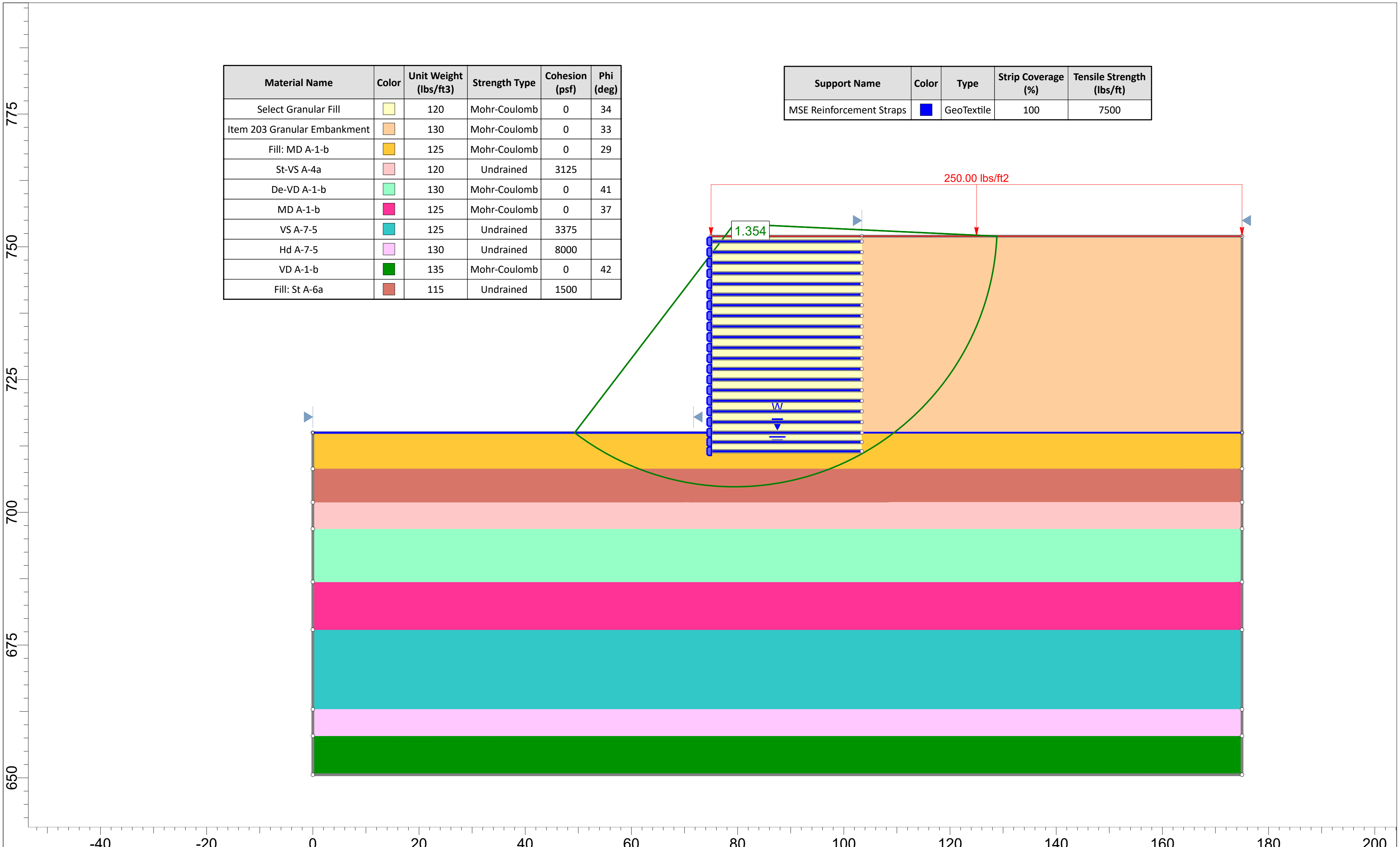


Project	FRA-70-12.68 - FRA-70-1358A - Retaining Wall 4W8 - MSE Wall Global Stability		
Analysis Description	Forward Abutment - 40.5 ft Wall Height - Drained - Circular - Spencer		
Drawn By	BRT	Scale	1:300
Company	Resource International, Inc.		
Date	07/07/18	File Name	FRA-70-1358A - Forward Abutment - Global Stability.slim

SLIDEINTERPRET 7.020

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Select Granular Fill		120	Mohr-Coulomb	0	34
Item 203 Granular Embankment		130	Mohr-Coulomb	0	33
Fill: MD A-1-b		125	Mohr-Coulomb	0	29
St-VS A-4a		120	Undrained	3125	
De-VD A-1-b		130	Mohr-Coulomb	0	41
MD A-1-b		125	Mohr-Coulomb	0	37
VS A-7-5		125	Undrained	3375	
Hd A-7-5		130	Undrained	8000	
VD A-1-b		135	Mohr-Coulomb	0	42
Fill: St A-6a		115	Undrained	1500	

Support Name	Color	Type	Strip Coverage (%)	Tensile Strength (lbs/ft)
MSE Reinforcement Straps		GeoTextile	100	7500



Project	FRA-70-12.68 - FRA-70-1358A - Retaining Wall 4W8 - MSE Wall Global Stability		
Analysis Description	Forward Abutment - 40.5 ft Wall Height - Undrained - Circular - Spencer		
Drawn By BRT	*Scale* 1:300	*Company*	Resource International, Inc.
Date 07/07/18		*File Name*	FRA-70-1358A - Forward Abutment - Global Stability.slim

SLIDEINTERPRET 7.020