FRA-70-22.85 FAR EAST FREEWAY
FRA-00070-23.920
BRICE ROAD OVER I-70
PID NO. 98232
FRANKLIN COUNTY, OHIO

STRUCTURE FOUNDATION EXPLORATION REPORT (REV. 1)

Prepared For:
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Columbus, OH 43054

Prepared By:
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Rii Project No. W-17-140

May 2023

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January 7, 2023 (Revised May 6, 2023)

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Re: Structure Foundation Exploration (Rev. 1)
FRA-70-22.85 Far East Freeway
FRA-00070-23.920 – Brice Road over I-70
PID 98232
Franklin County, Ohio
Rii Project No. W-17-140

Mr. Beal:

Resource International, Inc. (Rii) is pleased to submit this revised 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-00070-23.920 (SFN 2505739) bridge structure carrying Brice Road over Interstate Route 70 as part of the FRA-70-22.85 project within the City of Columbus, in Franklin County, Ohio. Please note that this revised version supersedes submission.

We sincerely appreciate the opportunity to be of continued service to you on this project. If you have any questions regarding the structure foundation exploration, or this report, please do not hesitate to contact us.

Sincerely,

RESOURCE INTERNATIONAL, INC.

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Enclosure: Structure Foundation Exploration Report (Rev. 1)

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EXECUTIVE SUMMARY

This report is a presentation of the structure foundation exploration performed for the proposed FRA-00070-23.920 bridge structure (SFN 2505739) carrying Brice Road over I-70, as shown on the vicinity map and boring plan presented in APPENDIX I. The existing structure is a four-span bridge with a maximum span length of 96 feet and a total length of approximately 297 feet. It is understood that the existing abutment and piers are supported on 12-inch diameter cast-in-place (CIP) pipe piles. The existing bridge will be replaced with the new structure.

Exploration and Findings

Between August 16 and September 21, 2020, a total of eight (8) borings were performed and analyzed for the proposed FRA-00070-23.920 bridge structure, ranging in depth from 10.0 to 75.0 feet beneath the existing ground surface. It is to be noted that Boring B-067-0-19 was terminated at 10-feet due to utility conflict. Offset boring B-067-1-19 was drilled 9.0 feet north of B-067-0-19. In addition to the borings performed for this project, Rii utilized historical borings in the area of the proposed structure available through the ODOT Transportation Information Mapping System (TIMS). Borings B-003-0-65 and B-007-0-65 were reportedly performed in the vicinity of Pier 1 and Pier 3 of the existing bridge, respectively, on the west side of the structure.

Beneath the surficial topsoil in borings B-066-0-19 through B-068-0-19 and B-070-0-19, pavement section in borings B-071-0-19 and B-072-0-19, and fill material in boring B-069-0-19, soil identified as existing fill or possible fill material was encountered in borings B-065-0-019, B-071-0-19 and B-072-0-19, down to depths ranging from approximately 5.5 to 43.0 feet below existing grade. In general, the existing fill material were described as dark brown, gravel and/or stone fragments, gravel with sand and silt, sandy silt, silt and clay, and silty clay (ODOT A-6b, A-6a, A-4a, A-2-4, A-1-b). Construction debris materials consisting of rock and brick fragments were encountered in the fill samples.

Underlying the surficial and existing fill materials, the natural soils encountered generally consisted of both cohesive soils and granular material deposits. The natural granular soils generally consisted of very loose to very dense, gravel, gravel and/or stone fragments, gravel and/or stone fragments with sand, gravel with sand, gravel with sand and silt, coarse and fine sand, (ODOT A-1-a, A-1-b, A-3a, A-2-4, A-2-6). Natural cohesive soils consisted of medium stiff to hard, sandy silt, silt and clay, silty clay and clay (ODOT A-4a, A-6a, A-6b, A-7-6). Additionally, occasional cobbles and rock fragments were encountered in borings B-065-0-019, B-070-0-19, B-071-0-19 and B-072-0-19.

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

Analyses and Recommendations

Pile Foundation Recommendations

Based upon an evaluation of the subsurface conditions encountered in the borings performed at the subject structure, it is recommended that a deep foundation system consisting of driven piles be employed for support of the proposed bridge abutment foundation elements. As per the 2020 ODOT Bridge Design Manual, cast-in-place (CIP) friction piles should be considered to support the superstructure units since bedrock was not encountered in any of the borings. Additionally, the CIP reinforced concrete pipe piles should consist of ASTM A252, Grade 3 steel (F_y = 45 ksi) with a minimum wall thickness as indicated in the following and outlined in Section 5.1.2 of the full report. It is recommended that steel CIP pipe piles (ODOT Item 507.06) be driven to the frictional capacity provided in the following table, which summarizes recommended pile lengths of CIP piles and corresponding to ultimate bearing values (UBV).

CIP-Pile Recommendations

Substructure Reference	Bottom of Footing [1] (feet msl)	Pile Size / Type	Min. Req. Pile Wall Thickness [2] (inch)	Sleeve Length [3] (feet)	Pile Elevation (feet msl)		Est. Pile Length [5] (feet)	Required UBV [6] (kips/pile)	φ_{dyn} [7]
					Top [4]	Tip			
Rear Abutment (B-066-0-19)	810.3	12” CIP	0.3125 (5/16)	17.8	811.3	743.0	70	267	0.7
Pier 1 (B-069-0-19)	790.7		0.3125 (5/16)	N/A	791.7	735.8	60	273	
Forward Abutment (B-070-0-19)	810.0		0.3125 (5/16)	17.7	811.0	760.3	55	197	

1. *Bottom of footing elevation determined from design plans provided by EMH&T.*
2. *ASTM A252, Grade 3 steel is recommended due to higher driving stresses. See Section 5.1.2 of the full report for pile wall thickness determination and drivability discussion.*
3. *Sleeve length represents the required length of pile that should be sleeved within the MSE wall backfill, including the foundation preparation.*
4. *The top of pile elevation corresponds to the pile cutoff elevation, which is considered to be 1.0-foot above the proposed bottom of footing elevation per Section 305.3.5.1 of the 2020 ODOT BDM.*
5. *Per Section 305.3.5.2 of the 2020 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.*
6. *Ultimate bearing value is the final maximum unfactored resistance that an individual pile is expected to supply. Values are based on design maximum factored structural loads provided by EMH&T.*
7. *The resistance factor listed assumes dynamic testing of the pile elements per Section 305.7.1 of the 2020 ODOT BDM.*

MSE Wall Recommendations

It is proposed to construct MSE walls at the rear abutment (Retaining Wall 6) and forward abutment (Retaining Wall 5B between Sta. 15+85 to 17+96, BL Wall 5B) of the proposed bridge structure.

Based on the subsurface conditions encountered in borings B-067-0-19 and B-003-0-65, the anticipated soils at the proposed bearing elevation along Retaining Wall 6, at the rear abutment, will consist of medium stiff silty clay (ODOT A-6b) extending to elevation 786.5 feet msl, overlying medium dense to very dense gravel with sand and silt and gravel (ODOT A-2-4, A-1-a) extending to elevation 764.0 to 771.3 feet msl, overlying very stiff to hard sandy silt, silt and clay and silty clay (ODOT A-4a, A-6a, A-6b). The upper medium stiff silty clay (ODOT A-6b) is estimated to have an undrained shear strength less than 1,000 psf and will not be suitable for support of the proposed MSE wall. Therefore, it is recommended that this material be completely over excavated to expose the underlying medium dense gravel with sand and silt (ODOT A-2-4) and replaced with ODOT Item 203 granular embankment. This stabilization measure should be performed for the entire length of the wall alignment within the footprint of the MSE wall and select granular backfill.

Based on the subsurface conditions encountered in borings B-070-0-19 and B-007-0-65, the anticipated soils at the proposed bearing elevation along Retaining Wall 5B between Sta. 15+85 to 17+96 (BL Wall 5B), at the forward abutment, will consist of stiff sandy silt (ODOT A-4a) extending to elevation 786.1 feet msl, overlying medium dense to very dense gravel with sand and silt, gravel with sand, silt and clay and gravel (ODOT A-2-4, A-2-6, A-1-a) extending to elevation 768.6 to 774.4 feet msl, overlying very stiff to hard sandy silt and silty clay (ODOT A-4a, A-6b). These soils are suitable for support of the proposed MSE wall their current condition.

Retaining Wall 5B and 6 MSE Wall Design Parameters

Substructure Unit / Wall Reference (Boring)	**Station Along Wall Alignment**		**Wall Height Analyzed (feet)**	**Back-slope Behind Wall**	**Minimum Required Reinforcement Length [2] (feet)**	**Bearing Resistance at Strength Limit (ksf)**		**Strength Limit Equivalent Bearing Pressure [4] (ksf)**
	From [1]	**To [1]**				**Nominal**	**Factored [3]**	
Rear Abutment / Retaining Wall 6 (B-067-0-19 and B-003-0-65)	10+00	12+55	29.3	Level	20.5 (0.70H)	33.20	21.58	6.97
Forward Abutment / Retaining Wall 5B (B-070-0-19 and B-007-0-65)	15+85	17+96	28.2	Level	24.0 (0.85H)	9.51	6.18	6.06

1. *Stationing referenced to the baseline of the respective retaining wall alignment.*
2. *The minimum reinforcement length is based on the maximum wall height analyzed. The value in parentheses represent the required reinforcement length 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 up to 1.20 and 2.57 inches at the center of the reinforced soil mass and 0.92 and 1.76 inches at the facing of the wall are anticipated along the alignment of Retaining Walls 6 and 5B at the rear and forward abutment, respectively. Based on the results of the analysis, 90 percent of the total settlement at the facing of the wall is anticipated to occur within 85 to 250 days following the completion of construction of the walls. However, it is estimated that the remaining settlement following completion of construction of the MSE wall at the rear abutment and following a 30 day hold period at the forward abutment will be less than 0.4 inches.

Based on the results of the external and global stability analysis performed for the MSE wall at the rear abutment (Wall 6), the recommended controlling strap length is 0.70 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 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 for this wall, provided the underlying weak, compressible soils are over excavated and replaced as outlined above and in Section 5.2 of the full report.

Based on the results of the external and global stability analysis performed for the MSE wall at the forward abutment (Wall 5B between Sta. 15+85 and 17+96, BL Wall 5B), the recommended controlling strap length is 0.85 times the maximum height of the MSE wall (measured from the top of the leveling pad to the proposed profile grade of the roadway) along that segment of the wall. Bearing resistance under undrained conditions was the controlling factor in the determination of the required strap length of 0.85 times the wall height for this section of the wall.

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 Phase 2 and 3 of the FRA-70-22.85 project. The project's proposed improvements include reconfiguration of the north half of the Brice Road interchange of westbound ramps to Interstate 270 (I-270) interchange, replacement of the Brice Road Bridge over Interstate 70 (I-70), a proposed Brice Road Bridge over new WB-CD Ramp, three (3) noise barriers, twelve (12) retaining walls, and five (5) culvert extensions.

This report is a presentation of the structure foundation exploration performed for the proposed widening of FRA-00070-23.920 bridge structure (SFN 2505739), carrying Brice Road over I-70, as shown on the vicinity map and boring plan presented in Appendix I. Based on the information received from EMH&T, it is understood that the existing structure will be removed and replaced with a widened structure to accommodate additional lane of traffic on Brice Road, to include a total of three (3) driving lanes and two (2) left turn lanes in the northbound direction, and four (4) driving and one (1) turn lane in the southbound direction of travel. Partial width outside shoulders (4-feet wide along southbound lanes and 2 feet wide along northbound lanes) and a full width (13 feet wide) sidewalk along northbound lanes, are proposed to be included in the proposed improvements. The clear roadway widths in northbound and southbound direction of travel, measured from top-of-curb are, 58 feet and 60 feet, respectively, with five (5) 11.0-foot lanes in each direction of travel. Further, partial width (1-foot wide) inside shoulders will be included along both northbound and southbound lanes with a 4-foot raised median.

The existing four-span structure will be fully removed and replaced with two-span continuous steel girder with composite reinforced concrete deck structure. The span lengths between the Rear Abutment and Center Pier, and Center Pier and Forward Abutment are 135 feet, 2 inches and 94 feet, 9 inches, respectively, measured center-to-center of the substructures. Additionally, Retaining Wall 5B, between Sta. 15+85 to 17+96 (BL Wall 5B), and Retaining Wall 6 will be constructed at the rear and forward abutments, respectively. As such, the analysis and recommendations for this section of Retaining Wall 5B and Retaining Wall 6 are presented under this report cover. Design recommendations for the remaining alignment of Retaining Wall 5B is under a separate cover.

The exploration was performed within general accordance of the Ohio Department of Transportation (ODOT) Specifications for Geotechnical Explorations (SGE).

2.0 RECONNAISSANCE AND PLANNING

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

Based on the Bedrock Geology and Bedrock Topography maps of the Columbus area, obtained from Ohio Department of Natural Resources (ODNR), the bedrock at the proposed project site consists of the Upper Devonian-aged Ohio Shale Formation. The Ohio Shale Formation is further subdivided into three primary members, in descending order: the Cleveland, Chagrin, and Huron Members. The Cleveland Member consists of black shale and is thickest in the north-central portion of the state but thins out to the south and east. The Huron Member consists of gray to greenish gray interbedded shale, siltstone, and very fine-grained sandstone, and is thickest in the northeastern portion of the state, thinning out to the southwest. The Chagrin Member grades into the overlying and underlying members and consists of black, carbonaceous shale. The entire Ohio Shale formation ranges from 250 to over 500 feet thick, with generally laminated to thin bedding and fissile partings, and is characterized by such features as having a petroliferous odor and carbonate/siderite concretions.

According to bedrock topography mapping from ODNR, the top of bedrock forms a ridge to the north of the site, generally lying just outside of the I-270 loop, and roughly underlying the cities of Gahanna and Reynoldsburg. The bedrock surface forms a narrow plateau that extends southwest from the south end of this ridge, which projects beneath the I-270 and I-70 interchange. The bedrock surface slopes down to the northwest and to the southeast from this plateau near the interchange, then generally slopes downward to the south and southeast. The bedrock near the interchange and northward along I-270 and eastward along I-70, lies at approximately elevation of 750 feet mean sea level (msl), or 27 to 33 feet below the ground surface. The bedrock surface gets only slightly deeper moving northward and approximately 50 feet deeper eastward from the interchange near the Brice Road overpass over I-70. The bedrock surface slopes upwards moving northward along Brice Road from the Brice Road overpass over I-70.

2.2 Existing Conditions

The site of the proposed FRA-00070-23.920 bridge structure is located along the east side of Columbus, in Franklin County, Ohio, with the project limits stretching from the east side approximately 1,400 feet east of the existing I-70 exit ramp to Brice Road, westward along I-70 to the I-270 northbound ramp. On the north side the project extends along Brice Road to the first intersection north of the bridge and on the south side, the project extends along Brice Road to the intersection of Chantry Drive and Brice Road. Land use surrounding the majority of the project vicinity is predominantly commercial and residential units.

Based on site reconnaissance of the project area, the areas around the existing ditch by the bridge pier and abutments appear to be mostly vegetated with grass which has been mowed and maintained. At the bridge deck, pavement distresses consisting of low to medium severity alligator cracks, pothole patches, longitudinal cracks, and transverse cracks at the abutments are evident. Concrete spalling of the curbs is also visible along the bridge.

3.0 EXPLORATION

Between August 16 and September 21, 2020, a total of eight (8) borings were performed and analyzed for the proposed FRA-00070-23.920 bridge structure, ranging in depth from 10.0 to 75.0 feet beneath the existing ground surface. It is to be noted that boring B-067-0-19 was terminated at a depth of 10-feet due to utility conflict. Offset boring B-067-1-19 was drilled 9.0 feet north of B-067-0-19. A summary of the eight (8) borings analyzed for the subject structure is presented in Table 1.

Table 1. Summary of FRA-70-22.85 Borings

Boring Number	Station [1]	Offset [1]	Latitude	Longitude	Ground Elevation [2] (feet)	Boring Depth (feet)
B-065-0-19 [3]	29+15	35' Lt.	39.932306	-82.830924	820.6	75.0
B-066-0-19	29+27	98' Rt.	39.932311	-82.830450	801.6	70.0
B-067-0-19	29+95	69' Rt.	39.932502	-82.830535	796.0	10.0
B-067-1-19	30+04	69' Rt.	39.932527	-82.830535	797.3	75.0
B-068-0-19	31+04	60' Lt.	39.932828	-82.830967	796.9	75.0
B-069-0-19	31+07	86' Rt.	39.932808	-82.830447	797.8	75.0
B-070-0-19	31+88	78' Rt.	39.933031	-82.830456	796.6	75.0
B-071-0-19	1586+63	59' Rt.	39.933291	-82.830827	820.7	75.0
B-072-0-19	32+62	43' Rt.	39.933239	-82.830560	820.8	75.0

1. *Boring B-071-0-19 referenced to baseline IR-70 WB-CD. Remaining boring locations referenced to the centerline of Brice Road centerline.*
2. *Ground surface elevations were provided by EMH&T survey.*
3. *As drilled location for B-065-0-19 was obtained from hand-held GPS unit.*

Boring locations were determined and field located by Rii personnel prior to drilling operations. During the field locating and reconnaissance, Rii utilized a handheld GPS locate the boring locations. Coordinates and ground surface elevations of the as drilled boring locations were provided by EMH&T survey team. Boring B-065-0-19 was not able to be surveyed due to the period between final survey and completion of drilling, and, therefore, approximate information from the handheld GPS locations and CAD topography are provided on the individual borings logs and noted as approximate.

The borings performed for the subject structure were drilled with either an all-terrain vehicle (ATV) or truck-mounted rotary drilling machine, utilizing 3.25- or 4.25-inch inside diameter hollow-stem augers to advance the holes between sampling attempts. In general, standard penetration testing (SPT) and split spoon sampling were performed at 2.5-foot intervals to approximately 30 feet below the existing ground surface, and at 5.0-foot intervals thereafter.

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. Driving resistance is recorded on the boring logs in terms of blows per 6-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_m) values are corrected to an equivalent (60%) energy ratio, N_{60}, by the following equation. Both values are represented on boring logs presented 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 hammers for the CME-55 and CME-750X drill rigs operated by Rii on this project were calibrated on September 14, 2020, and have drill rod energy ratios of 84.2 and 86.2 percent, respectively.

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

Upon completion of drilling, the borings were backfilled with bentonite chips and soil cuttings. Where borings penetrated the existing pavement, an equivalent thickness of quickset concrete was used to repair the pavement surface.

During drilling, field 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 recovered soil and rock samples were visually classified, and select samples from the borings performed for the subject structure 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	161
Plastic and Liquid Limits	AASHTO T89, T90	37
Gradation – Sieve/Hydrometer	AASHTO T88	37

The tests performed are necessary to classify existing soil according to the 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 and rock terms used throughout this report is presented in Appendix II.

3.1 Historical Borings

In addition to the borings performed for this project, Rii utilized historical borings in the area of the proposed structure available through the ODOT Transportation Information Mapping System (TIMS). Borings B-003-0-65 and B-007-0-65 were reportedly performed in the vicinity of the existing Pier 1 and Pier 3 of the existing bridge, respectively, on the west side of the structure. The borings were drilled to depths of 61 feet and 41 feet, respectively. The subsurface profile and material encountered in each boring is described in section 4.2.

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

The borings were generally performed in the vicinity of the proposed abutment and pier locations for the proposed widening. Borings B-066-0-19 through B-068-0-19 and B-070-0-19 encountered between 5.0 to 8.0 inches of topsoil at the existing grade. Boring B-065-0-19 was drilled through the existing outside shoulder along Brice Road southbound, and encountered 1.5 inches of asphalt. Borings B-071-0-19 and B-072-0-19 encountered asphalt ranging in thickness from 13.0 and 11.5 inches, respectively, overlying 5.0 and 4.5 inches of aggregate base material. Boring B-069-0-19 was drilled through the existing fill material consisting of loose, black to brown, gravel and/or stone fragments with sand (ODOT A-1-b), extending up to 5.0 feet below the existing ground surface.

4.2 Subsurface Soils

Beneath the surficial topsoil in borings B-066-0-19 through B-068-0-19 and B-070-0-19, pavement section in borings B-071-0-19 and B-072-0-19, and fill material in boring B-069-0-19, soil identified as existing fill or possible fill material was encountered in borings B-065-0-019, B-071-0-19 and B-072-0-19, down to depths ranging from approximately 5.5 to 43.0 feet below existing grade. In general, the existing fill material were described as dark brown, gravel and/or stone fragments, gravel with sand and silt, sandy silt, silt and clay, and silty clay (ODOT A-6b, A-6a, A-4a, A-2-4, A-1-b). Construction debris materials consisting of rock and brick fragments were encountered in the fill samples.

Underlying the surficial and existing fill materials, the natural soils encountered generally consisted of both cohesive soils and granular material deposits. The natural granular soils generally consisted of very loose to very dense, gravel, gravel and/or stone fragments, gravel and/or stone fragments with sand, gravel with sand, gravel with sand and silt, coarse and fine sand, (ODOT A-1-a, A-1-b, A-3a, A-2-4, A-2-6). Natural cohesive soils consisted of medium stiff to hard, sandy silt, silt and clay, silty clay and clay (ODOT A-4a, A-6a, A-6b, A-7-6). Additionally, occasional cobbles and rock fragments were encountered in borings B-065-0-019, B-070-0-19, B-071-0-19 and B-072-0-19.

The shear strength and consistency of the cohesive soils are primarily derived from the hand penetrometer values (HP). The cohesive soils 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 4.5 tsf (limit of instrument). The relative density of granular soils is primarily derived from SPT blow counts (N_{60}). Based on the SPT blow counts obtained, the granular soils encountered ranged from loose ($5 < N_{60} < 11$ blows per foot [bpf]) to very dense ($N_{60} \geq 50$ bpf). Blow counts recorded from the SPT sampling ranged from 9 bpf to split spoon sampler refusal. Split spoon sampler refusal is defined as exceeding 50 blows with less than 6 inches of penetration by the split spoon sampler.

Natural moisture contents of the soil samples tested ranged from 8 to 36 percent. The natural moisture contents of the cohesive soil samples tested for plasticity ranged from 12 percent below to 18 percent above their corresponding plastic limits. In general, the soil exhibited natural moisture contents considered to be significantly below to significantly above the optimum moisture levels.

4.3 Historic Borings

Rii reviewed the historic borings available through ODOT Transportation Information Mappin System (TIMS). From the historical borings, boring B-007-0-65 encountered primarily granular material identified as brown and gray sandy gravel, sandy gravelly silt and silty sandy gravel and gray gravelly clay (ODOT A-1-b, A-2-6). Boring B-003-065 encountered granular soils overlying cohesive soils. The granular materials were encountered down to approximately 20 feet below grade and were described as brown and gray sandy gravel, sandy clayey gravel, clayey sandy gravel, silty sandy gravel (ODOT A-1-b, A-2-6, A-2-4). The cohesive soils were encountered to boring termination depth of 61.0 feet below existing grade and were described as gray sandy silt, silt, silt and clay, silty clay (ODOT A-4a, A-4b, A-6a, A-6b).

4.4 Bedrock

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

4.5 Groundwater

Groundwater was encountered in the borings as presented in Table 3 below.

Table 3. Groundwater Levels

Boring Number	Ground Elevation (feet msl)	Initial Groundwater		At Completion		Cave-In Depth	
		Depth (feet)	Elevation (feet msl)	Depth (feet)	Elevation (feet msl)	Depth (feet)	Elevation (feet msl)
B-065-0-19	813.0	40.0	773.0	N/A [1]	-	N/A	-
B-066-0-19	801.6	15.3	786.3	N/A [1]	-	N/A	-
B-067-1-19	797.3	13.5	783.8	22.5	774.8	N/A	-
B-068-0-19	796.9	14.7	782.2	12.5	784.4	19.4	777.5
B-069-0-19	797.8	13.5	784.3	N/A [1]	-	N/A	-
B-070-0-19	796.6	13.5	783.1	N/A [1]	-	N/A	-
B-071-0-19	820.7	34.0	786.7	37.0	783.7	N/A	-
B-072-0-19	820.8	38.7	782.1	N/A [1]	-	N/A	-

1. *Groundwater level during and/or at the completion of drilling was not measured due to the addition of water or mud to the borehole to counteract heaving sands*

Groundwater was encountered initially during the drilling process in all of the borings at depths ranging from 13.5 feet to 40.0 feet below the existing grade, which corresponds to elevations ranging from 773.0 to 786.7 feet msl. Upon completion of drilling and after removing the augers, groundwater was encountered in borings B-067-1-19, B-068-0-19 and B-071-0-19, at depths 22.5, 12.5 and 37.0 feet, respectively, below the existing grade, which corresponds to elevations ranging from 774.8 to 784.4 feet msl. The remaining borings (including historical borings) were observed to be dry, meaning no measurable amount of water had accumulated within the borehole at the completion of drilling. Groundwater seepage was encountered initially during the drilling process in boring B-070-0-19 at the depth of 11.0 feet below the ground surface. Cave-in of the sidewalls of the borehole was observed in boring B-068-0-19, at a depth of 19.4 feet below existing grade.

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 in the boring logs in Appendix III.

5.0 ANALYSES AND RECOMMENDATIONS

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

Rii understands that the based on the information received from EMH&T the existing structure will be removed and replaced with a widened structure, to accommodate additional lane of traffic on Brice Road, to include a total of three (3) driving lanes and two (2) left turn lanes in the northbound direction, and four (4) driving and one (1) turn lane in the southbound direction of travel. The existing four-span structure will be fully removed and replaced with two-span continuous steel girder with composite reinforced concrete deck structure. The span lengths between Rear Abutment and Center Pier, and Center Pier and Forward Abutment are 135 feet, 2 inches and 94 feet, 9 inches, respectively, measured center-to-center of the substructures. Additionally, Retaining Wall 5B, between Sta. 15+85 to 17+96 (BL Wall 5B), and Retaining Wall 6 will be constructed at the rear and forward abutments, respectively, to support the semi-integral rear abutment and a jointed substructure at the forward abutment. All of the substructures are supported on cast-in-place (CIP) piles driven to frictional capacities. Bearing elevation obtained from the proposed plan and profile drawing provided by EMH&T is summarized in Table 4.

Table 4. Bridge Structure Design Elevations

Substructure Reference	Substructure Type	Structure Component	Elevation (ft. msl) [1]	Design Structure Loads [2] (kips/pile)
Rear Abutment / Retaining Wall 6 (B-065-0-19, B-066-0-19, B-067-1-19 and B-003-0-65)	Semi-Integral Abutment Behind MSE Wall	Profile Grade	821.8	144 / 187
		Bottom of Footing	810.3	
		Bottom of Wall (Top of Leveling Pad)	792.5	
Pier 1 (B-068-0-19 and B-069-0-19)	Cap and Column	Bottom of Footing	790.7	N/A / 191
Forward Abutment / Retaining Wall 5B (Sta. 15+85 to 17+96) (B-070-0-19 and B-007-0-65)	Jointed Abutment Behind MSE Wall	Profile Grade	822.0	96 / 138
		Bottom of Footing	810.0	
		Bottom of Wall (Top of Leveling Pad)	792.3	

1. *Elevations based on the proposed structure information provided by EMH&T.*
2. *Design structural loads provided by EMH&T. The first value is the service load and the second value is the strength load.*

5.1 Pile Foundation Recommendations

Based upon an evaluation of the subsurface conditions encountered in the borings performed at the subject structure, it is recommended that a deep foundation system consisting of driven piles be employed for support of the proposed bridge abutment foundation elements.

As per the 2020 ODOT Bridge Design Manual, cast-in-place (CIP) friction piles should be considered to support the superstructure units since bedrock was not encountered in any of the borings. Additionally, the CIP reinforced concrete pipe piles should consist of ASTM A252, Grade 3 steel (F_y = 45 ksi) with a minimum wall thickness as indicated in Table 5 and outlined in Section 5.1.2. Since bedrock was not encountered at the site, it is recommended that steel CIP pipe piles (ODOT Item 507.06) be driven to the frictional capacity provided in Table 5, which summarizes recommended pile lengths of CIP piles and corresponding to ultimate bearing values (UBV).

Table 5. CIP-Pile Recommendations

Substructure Reference	Bottom of Footing [1] (feet msl)	Pile Size / Type	Min. Req. Pile Wall Thickness [2] (inch)	Sleeve Length [3] (feet)	Pile Elevation (feet msl)		Est. Pile Length [5] (feet)	Required UBV [6] (kips/pile)	φ_{dyn} [7]
					Top [4]	Tip			
Rear Abutment (B-066-0-19)	810.3	12” CIP	0.3125 (5/16)	17.8	811.3	743.0	70	267	0.7
Pier 1 (B-069-0-19)	790.7		0.3125 (5/16)	N/A	791.7	735.8	60	273	
Forward Abutment (B-070-0-19)	810.0		0.3125 (5/16)	17.7	811.0	760.3	55	197	

1. *Bottom of footing elevation determined from design plans provided by EMH&T.*
2. *ASTM A252, Grade 3 steel is recommended due to higher driving stresses. See Section 5.1.2 for pile wall thickness determination and drivability discussion.*
3. *Sleeve length represents the required length of pile that should be sleeved within the MSE wall backfill, including the foundation preparation.*
4. *The top of pile elevation corresponds to the pile cutoff elevation, which is considered to be 1.0-foot above the proposed bottom of footing elevation per Section 305.3.5.1 of the 2020 ODOT BDM.*
5. *Per Section 305.3.5.2 of the 2020 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.*
6. *Ultimate bearing value is the final maximum unfactored resistance that an individual pile is expected to supply. Values are based on design maximum factored structural loads provided by EMH&T.*
7. *The resistance factor listed assumes dynamic testing of the pile elements per Section 305.7.1 of the 2020 ODOT BDM.*

The piles were analyzed using the DrivenPiles software program and the results are provided in Appendix VI. The ultimate bearing values listed in Table 5 are based on the maximum factored load per pile and were calculated in accordance with Section 305.3.2 and 305.3.4 of the 2020 ODOT BDM. Additionally, the ultimate bearing values listed in Table 5 represent the calculated values after soil setup has occurred, following a specified waiting period (at restrike). Based on the subsurface conditions encountered, it is recommended that a minimum hold period of five (5) days be specified between the end of driving the pile and the time of restrike to allow adequate soil setup to occur. However, if dynamic testing indicates that the required ultimate bearing value is achieved at the end of driving the pile, a restrike of the pile will not be required. It is recommended that a minimum of one (1) dynamic load test or restrike shall be performed at each substructure for each phase of construction. Settlement is estimated to be less than 1.0 inch for CIP pipe piles driven to the resistances provided in Table 5.

It should be noted that the pile lengths and ultimate bearing values presented in Table 5 are estimates using empirical equations based on the derived characteristics of the soils encountered in the subject borings drilled. The actual pile capacities should be verified using static or dynamic pile load testing as detailed in Sections 305.7.1 and 305.7.2 of the 2020 ODOT BDM. The most accurate method for determining pile capacities and lengths is to drive test piling at the site and perform static load testing in accordance with ASTM D1143. Dynamic pile load testing should be performed in accordance with ASTM 4945. Further installation considerations are presented in Section 5.1.3.

During the design process, consideration was given to reusing the existing piles supporting the existing pier foundations to support the proposed foundations in conjunction with new piling. However, given the uncertainty in the available capacity of the existing piling, it was determined that the proposed foundations will be supported on new piling only, and that the existing pier piles will be abandoned in place and cut off below the proposed bearing elevation of the proposed piers.

5.1.1 Downdrag Considerations

The anticipated total settlement at the facing of the MSE wall at the rear abutment is 0.92 inches and at the forward abutment is 0.88 to 1.76 inches. Given the anticipated amount of settlement at the MSE wall facing, downdrag loads may be induced on the pile elements if installed to the final tip elevation prior to construction of the walls. 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 settlement of the underlying foundation soils can occur prior to driving the piles the to the design tip elevation and reduce or eliminate 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 of the roadway) and left 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 150 to 250 days and 85 to 155 days following the placement if the surcharge load at the rear and forward abutment, respectively.

However, as outlined in Section 5.2.3, it is anticipated that the remaining settlement following completion of construction of the MSE wall at rear abutment (Wall 6) and following a 30 day hold period at the forward abutment (Wall 5B) will be less than 0.4 inches, which is the amount of relative movement that would typically result in the development of downdrag loads. Therefore, if the piles are driven to the final pile tip elevation following completion of construction of the MSE wall (including placement of a surcharge up to the roadway profile grade, as outlined in the previous paragraph) at the rear abutment (Wall 6) and following a 30 day hold period at the forward abutment (Wall 5B), downdrag forces along the piles will be eliminated.

Given the granular nature of the upper portion of the foundation soils at the rear abutment (Wall 6), and provided the upper weak, compressible soils are over excavated and replaced with granular embankment as outlined in Section 5.2, settlement platforms will not be required if it is elected to drive the piles following completion of the MSE wall.

If it is elected to drive the piles to the final tip elevation following the 30 day hold period at the forward abutment (Wall 5B), it is recommended to install settlement platforms within the MSE wall mass as close to the abutment footing as possible, with a minimum of one (1) settlement platform installed for each phase of construction. 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.

If it is elected to drive the piles to the final tip elevation prior to construction of the MSE walls or immediately following construction of the MSE wall at the forward abutment, downdrag loading will develop along the piles, and the bridge structures will need to be designed to accommodate the estimated settlement at the respective abutment. Downdrag was evaluated in accordance with Section 305.3.2.2 of the 2020 ODOT BDM. Downdrag was evaluated using the neutral plane method as outlined in Section 7.3.5.7 and 7.3.6.1 of FHWA Geotechnical Engineering Circular 12 (GEC 12) “Design and Construction of Driven Pile Foundations” (FHWA-NHI-16-009/010). Figure 1 and Figure 2 are plots of the axial load and resistance based on the bearing resistance from the DrivenPiles analysis included in Appendix VI and service load on the piles, which indicates the neutral plane depth below the bottom of footing based on fully mobilized toe resistance in accordance with Section 305.3.2.2 of the 2020 ODOT BDM.

Figure 1. Axial Load and Resistance Graph – Rear Abutment

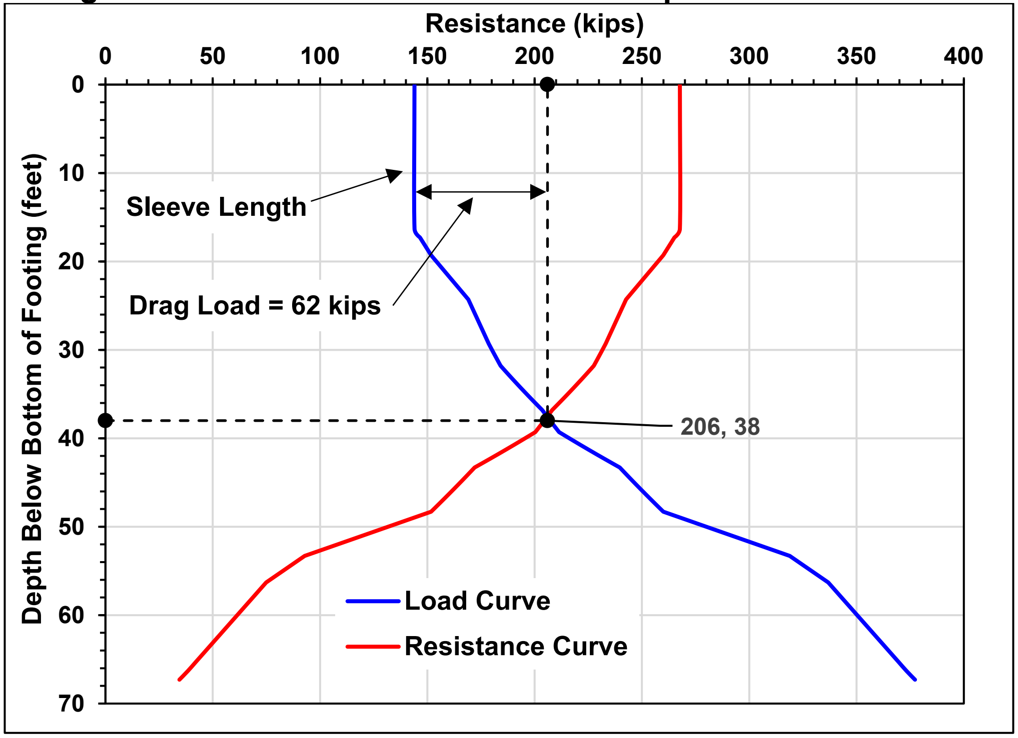
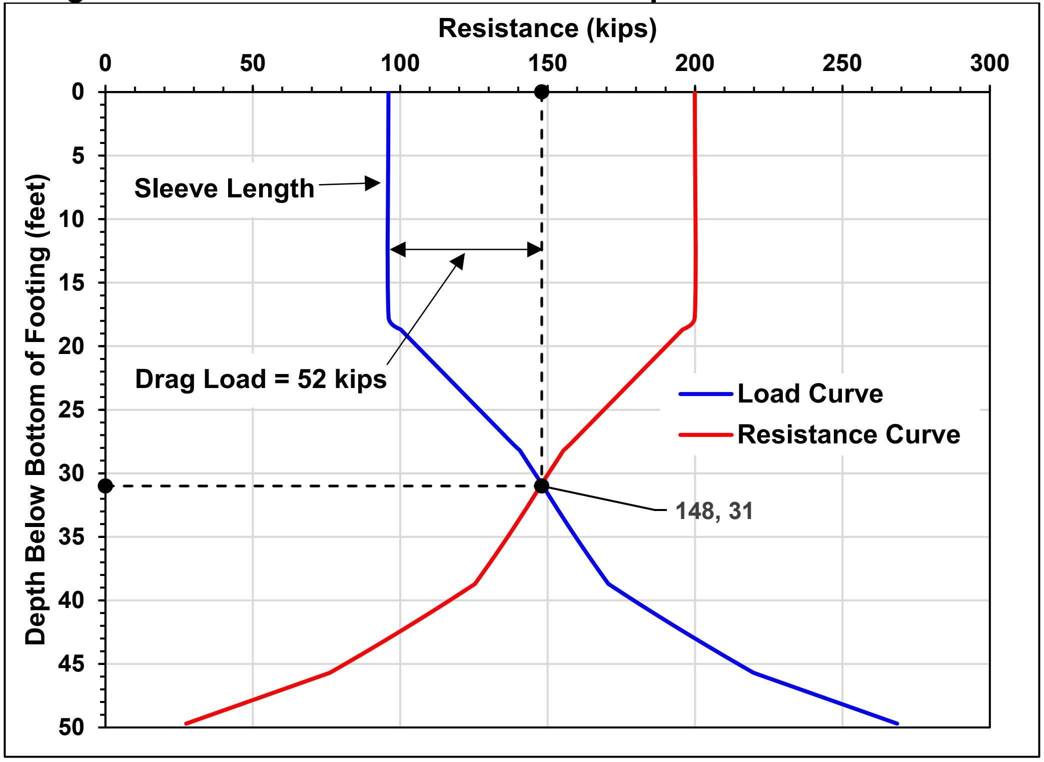


Figure 2. Axial Load and Resistance Graph – Forward Abutment



Based on the results of the bearing plots, the depth of the neutral plane is 38.0 feet and 31.0 feet below the bottom of footing elevation at the rear abutment (Wall 6) and forward abutment (Wall 5B), respectively. The calculated drag load based on the depth of the neutral plane is 62 kips at the rear abutment (Wall 6) and 52 kips at the forward abutment (Wall 5B).

Per Section 305.3.2.2 of the 2020 ODOT BDM, the factored structural axial resistance of the pile at the strength limit state shall equal or exceed the combined effect of the factored drag load and the maximum factored load per pile. For piles subject to downdrag loads, the factored structural resistance of the pile shall consider a resistance factor of 0.7, which results in a factored structural resistance of 517 kips for a 12-inch pipe pile consisting of ASTM A252, Grade 2 steel with a pile wall thickness of 0.375 (3/8) inches, or 603 kips for a 12-inch pipe pile consisting of ASTM A252, Grade 3 steel with a pile wall thickness of 0.3125 (5/16) inches (see Section 5.1.2 for pile wall thickness determination). A load factor of 1.05 should be applied to the unfactored downdrag load when determining the factored downdrag load per pile at the strength limit state and should be added to the factored load per pile from the superstructure.

Based on a maximum factored load of 187 kips/pile and a drag load of 62 kips at the rear abutment (Wall 6) and 138 kips/pile and a drag load of 52 kips at the forward abutment (Wall 5B), the combined factored load of 252 kips/pile and 193 kips/pile at the rear and forward abutment, respectively, is less than the factored structural pile resistance for either ASTM A252, Grade 2 or Grade 3 steel with the pile wall thicknesses noted.

In addition to resisting the factored drag load on the piles, the bridge design will need to accommodate the anticipated soil settlement and elastic compression of the pile due to the combined structure load and drag load under service (unfactored) loading conditions within the depth to the neutral plane. For the elastic compression of the pile, since the drag load increases with depth from 0 kips at the top of the pile to the maximum drag load at the depth of the neutral plane, the average drag load was used in the calculation. Based on a combined service load of 175 kips and 122 kips was used at the rear and forward abutment, which results in an elastic compression of 0.201 and 0.114 inches, respectively.

If consideration is given to driving the piles to the final tip elevation prior to constructing the MSE walls, settlement within the foundation soils below the wall elevation within the depth of the neutral plane are estimated to be 0.600 to 0.612 inches at the rear abutment (Wall 6) and 0.430 to 1.007 inches at the forward abutment (Wall 5B). Adding the elastic compression of the piles, the resulting total settlement is 0.801 to 0.813 inches and 0.544 to 1.121 inches, respectively. For the forward abutment (Wall 5B), if the piles are driven immediately following construction of the MSE wall, settlement within the foundation soil below the wall elevation within the depth of the neutral plane is estimated to be 0.620 inches, with a total settlement of 0.734 inches.

Based on information provided by the bridge designer, EMH&T, it is understood that the tolerable bridge movement per ODOT BDM Section 305.1.3 d for the shorter span length is 1.68 inches. Therefore, since the estimated settlement within the depth of the neutral plane if the piles are driven to the final tip elevation prior to construction of the MSE walls is less than the tolerable bridge movement, it is preferred to incorporate this option in the design to forgo to the need for a hold period or settlement monitoring.

5.1.2 Drivability

A drivability analysis was performed in accordance with Section 10.7.8 of the 2020 American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD) Bridge Design Specifications (BDS) using the GRLWEAP software program, and the results are provided in Appendix VIII. In the drivability analysis, a Delmag 19-42 hammer with a rated energy of approximately 43,000 ft-lbs was used in conjunction with the CIP pipe pile sections. The minimum wall thickness for the drivability analysis for CIP pipe piles is 0.25 inches per ODOT Item 507.06. In the drivability analysis, the piles were modeled using the minimum pile wall thickness, and the pile wall thickness was increased in 1/8-inch increments until the driving stresses induced on the piles were below 90 percent of the yield stress of the steel. Additionally, at the rear abutment and forward abutment, the portion of the pile within the sleeve length through the MSE walls was modeled using a friction angle of 28 degrees to simulate a sand backfill within the pile sleeves.

Based on the results of this analysis it appears that the driving stresses induced on the CIP pipe piles **would not exceed** 90 percent of the yield stress for A252, Grade 2 steel (f_y = 35 ksi, 0.9f_y = 31.5 ksi) if driven to the depths and corresponding ultimate bearing values provided in Table 5 using a pile wall thickness of 0.4375 (7/16), 0.375 (3/8) and 0.5 (1/2) inches at the rear abutment, pier 1 and forward abutment, respectively. If ASTM A252, Grade 3 steel (f_y = 45 ksi, 0.9f_y = 40.5 ksi) is utilized, the pile wall thicknesses can be reduced to 0.3125 (5/16) inch at all substructure locations.

Additionally, due to the presence of cobbles and boulders, per Section 305.3.5.6 of the 2020 ODOT BDM it is recommended that pile points be installed to improve penetration and protect the piles during driving.

5.1.3 Driven Pile Considerations

Proper pile installation is as important as pile design in order to obtain a cost effective and safe product. Driven piles must be installed to develop adequate soil resistance without structural damage. Because piles cannot be visually inspected after installation, direct quality control of the finished product is impossible. Consequently, substantial control must be exercised over peripheral operations leading to the pile placement within the foundation. Construction monitoring should be employed in (1) pile materials, (2) installation equipment, and (3) the estimation of the static load capacity.

It is recommended that the contractor submit a wave equation analysis (bearing graph) of his driving equipment, or the necessary pile driving and equipment data to perform the wave equation analysis, for hammer approval. A constant capacity wave equation analysis (inspector’s chart) should also be performed to assist field personnel during inspection in accordance with the 2007 ODOT BDM.

5.1.4 Lateral Design

If lateral loads or moments are expected to be applied on the foundation elements, they should be analyzed to verify the 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 VIII. In order to evaluate the lateral capacity, it is recommended that a derivation of COM624, such as LPILE, be utilized to determine the embedment depth provided is adequate to resist the lateral loading for a given end condition and deflection. Table 6 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 VIII.

Table 6. 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 MSE walls at the rear abutment (Retaining Wall 6) and forward abutment (Retaining Wall 5B between Sta. 15+85 to 17+96, BL Wall 5B) 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 840.04.A of ODOT Supplemental Specification 840 (SS 840), the height of the MSE wall at the bridge abutment is defined as the elevation difference between the profile grade at the face of the wall and the top of the leveling pad, and where the wall does not cross in front of the abutment, the height of the wall is defined as the elevation difference between the top of coping and the top of the leveling pad. However, at the abutment, 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 201.4.1.C.7 of the 2020 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 back wall of the abutment footing, and prevent any load transfer from these forces to the coping and facing panels.

The width of the MSE wall foundation (B) is defined by the length of the reinforced soil mass. Per the 307.4.A of the 2020 ODOT BDM and Section 840.04.A.2 of ODOT 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 upon the proposed plan information, the maximum wall height at the rear and forward abutment is 29.3 and 28.2 feet, respectively, as measured from the top of the leveling pad to the proposed profile grade of the roadway. For the analysis, the foundation width was set at 70 percent of the maximum wall height for the rear and forward abutments, respectively, and the foundation width was increased, if required, 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.

Based on the subsurface conditions encountered in borings B-067-0-19 and B-003-0-65, the anticipated soils at the proposed bearing elevation along Retaining Wall 6, at the rear abutment, will consist of medium stiff silty clay (ODOT A-6b) extending to elevation 786.5 feet msl (approximately 4.5 feet below the Type C Granular MSE wall base), overlying medium dense to very dense gravel with sand and silt and gravel (ODOT A-2-4, A-1-a) extending to elevation 764.0 to 771.3 feet msl, overlying very stiff to hard sandy silt, silt and clay and silty clay (ODOT A-4a, A-6a, A-6b). The upper medium stiff silty clay (ODOT A-6b) is estimated to have an undrained shear strength less than 1,000 psf and will not be suitable for support of the proposed MSE wall. Therefore, it is recommended that this material be completely over excavated to expose the underlying medium dense gravel with sand and silt (ODOT A-2-4) and replaced with ODOT Item 203 granular embankment. This stabilization measure should be performed for the entire length of the wall alignment within the footprint of the MSE wall and select granular backfill.

Based on the subsurface conditions encountered in borings B-070-0-19 and B-007-0-65, the anticipated soils at the proposed bearing elevation along Retaining Wall 5B between Sta. 15+85 to 17+96 (BL Wall 5B), at the forward abutment, will consist of stiff sandy silt (ODOT A-4a) extending to elevation 786.1 feet msl, overlying medium dense to very dense gravel with sand and silt, gravel with sand, silt and clay and gravel (ODOT A-2-4, A-2-6, A-1-a) extending to elevation 768.6 to 774.4 feet msl, overlying very stiff to hard sandy silt and silty clay (ODOT A-4a, A-6b). These soils are suitable for support of the proposed MSE wall their current condition.

Per Section 307.4.C of the 2020 AASHTO LRFD BDS and Section 840.06.D of 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.

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 7.

Table 7. 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 (Retained soil)	120	30	0	2,000
Item 203 Granular Embankment (Over excavation backfill)	120	32	0	N/A
Existing Embankment Fill: Stiff to Very Stiff Silt and Clay and Silty Clay (ODOT A-6a, A-6b)	120	26 to 27	0	1,625 to 2,750
Medium Stiff Silty Clay (ODOT A-6b)	115	25	0	750
Stiff Sandy Silt (ODOT A-4a)	120	29	0	1,750
Medium Dense to Very Dense Granular Soils (ODOT A-1-a, A-2-4, A-2-6, A-3a, A-4b)	125 to 135	30 to 38	0	N/A
Very Stiff to Hard Sandy Silt (ODOT A-4a)	120 to 130	30	0 to 100	3,000 to 8,000
Very Stiff to Hard Silty and Clay (ODOT A-6a)	125 to 130	28	25 to 50	3,875 to 5,625
Very Stiff to Hard Silty Clay (ODOT A-6b)	120 to 130	26 to 27	0 to 25	2,750 to 4,375

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 2020 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 and retained embankment are provided in Table 307-1 of the 2020 ODOT BDM and Section 840.04.A.3 of ODOT SS 840. Per these specifications, the select granular backfill in the reinforced zone and the retained embankment must meet the shear strength requirements provided in Table 7.

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, the 2020 AASHTO LRFD BDS and based on past experience in the vicinity of the site with projects performed in similar subsurface profiles. A tabulation of the correlated shear strength parameters for each boring is provided in Appendix VIII.

5.2.2 Bearing Stability

The anticipated bearing materials at the rear abutment (Wall 6) and at the forward abutment (Wall 5B) consist of medium stiff silty clay (ODOT A-6b) and stiff sandy silt (ODOT A-4a), respectively, overlying medium dense to very dense gravel with sand and silt, gravel with sand, silt and clay and gravel (ODOT A-2-4, A-2-6, A-1-a), overlying very stiff to hard sandy silt, silt and clay and silty clay (ODOT A-4a, A-6a, A-6b). As noted in Section 5.2, it is recommended to over excavate the upper medium stiff silty clay (ODOT A-6b) within the entire footprint of Retaining Wall 6 at the rear abutment and replace with ODOT Item 203 granular embankment.

MSE wall foundations bearing these natural soils or granular embankment, placed and compacted in accordance with ODOT Item 203, may be proportioned for a factored bearing resistance as indicated in Table 8. A geotechnical resistance factor of φ_b=0.65 was considered in calculating the factored bearing resistance at the strength limit state. Given that the bearing soils at the forward abutment (Wall 5B) will consist of cohesive soils, the bearing resistance was evaluated under both drained and undrained conditions. The reinforcement length presented in Table 8 represents the minimum foundation width required to satisfy external and global stability requirements, expressed as a percentage of the wall height.

Table 8. Retaining Wall 5B and 6 MSE Wall Design Parameters

Substructure Unit / Wall Reference (Boring)	**Station Along Wall Alignment**		**Wall Height Analyzed (feet)**	**Back-slope Behind Wall**	**Minimum Required Reinforcement Length [2] (feet)**	**Bearing Resistance at Strength Limit (ksf)**		**Strength Limit Equivalent Bearing Pressure [4] (ksf)**
	From [1]	**To [1]**				**Nominal**	**Factored [3]**	
Rear Abutment / Retaining Wall 6 (B-067-1-19 and B-003-0-65)	10+00	12+55	29.3	Level	20.5 (0.70H)	33.20	21.58	6.97
Forward Abutment / Retaining Wall 5B (B-070-0-19 and B-007-0-65)	15+85	17+96	28.2	Level	24.0 (0.85H)	9.51	6.18	6.06

1. *Stationing referenced to the baseline of the respective retaining wall alignment.*
2. *The minimum reinforcement length is based on the maximum wall height analyzed. The value in parentheses represent the required reinforcement length 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 material for the specified wall heights indicated in Table 8. Based on the minimum length of reinforced soil mass presented, the factored equivalent bearing pressure exerted below the walls **will not exceed** the factored bearing resistance at the strength limit state.

5.2.3 Settlement Evaluation

The compressibility parameters utilized in the settlement analyses of the proposed MSE wall are provided in Table 9.

Table 9. Compressibility Parameters Utilized in Settlement Analysis

Material Type	**γ (pcf)**	**LL (%)**	**C_c (1)**	**C_r (2)**	**e_o (3)**	**C_v (4) (ft^2/yr)**	**N_{60}**	**C' (5)**
Item 203 Granular Embankment (Over excavation backfill)	120	N/A	N/A	N/A	N/A	N/A	30	138 to 207
Stiff Sandy Silt (ODOT A-4a)	120	25	0.135	0.014	0.467	400	N/A	N/A
Medium Dense to Very Dense Granular Soils (ODOT A-1-a, A-2-4, A-2-6, A-3a, A-4b)	125 to 135	N/A	N/A	N/A	N/A	N/A	25 to 100	43 to 300
Very Stiff to Hard Sandy Silt (ODOT A-4a)	120 to 130	22 to 25	0.108 to 0.135	0.011 to 0.014	0.444 to 0.467	400	N/A	N/A
Very Stiff to Hard Silty and Clay (ODOT A-6a)	125 to 130	26 to 32	0.144 to 0.198	0.014 to 0.020	0.475 to 0.522	300	N/A	N/A
Very Stiff to Hard Silty Clay (ODOT A-6b)	120 to 130	32 to 39	0.198 to 0.261	0.020 to 0.026	0.569 to 0.577	200	N/A	N/A

1. *Per Table 6-9, Section 6.14.1 of FHWA GEC 5.*
2. *Estimated at 10% of C_c 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 10.6.2.4.2b-1 of 2020 AASHTO LRFD BDS.*

The settlement analysis was performed considering the unit weight and height (H) of the select granular backfill over the width of the wall (B) at the service limit state. For Wall 6 at the rear abutment, the net pressure was used in the settlement analysis, which considered the presence of the existing spill through slope using an average existing grade elevation of 805 feet msl (800 feet msl at the wall face and 810 feet msl at the back of the wall mass).

Results of the settlement analysis are tabulated in Table 10. Total settlements of up to 1.20 and 2.57 inches at the center of the reinforced soil mass and 0.92 and 1.76 inches at the facing of the wall are anticipated along the alignment of Retaining Walls 6 and 5B at the rear and forward abutment, respectively. Based on the results of the analysis, 90 percent of the total settlement at the facing of the wall is anticipated to occur within 85 to 250 days following the completion of construction of the walls. However, it is estimated that the remaining settlement following completion of construction of the MSE wall at the rear abutment and following a 30 day hold period at the forward abutment will be less than 0.4 inches.

Table 10. MSE Retaining Wall Settlement Values

Substructure Unit / Wall Reference (Boring)	Station Along Wall Alignment		Total Settlement Values (inches)		Differential Settlement Along Wall Facing (inches)	Time for 90% Consolidation (Days)
	From [1]	To [1]	Center of Wall Mass	Facing of Wall		
Rear Abutment / Retaining Wall 6 (B-067-1-19 and B-003-0-65)	10+00	12+55	1.200 to 1.206	0.919 to 0.920	Less than 1 in. / 1,000 ft.	150 to 250
Forward Abutment / Retaining Wall 5B (B-070-0-19 and B-007-0-65)	15+85	17+96	1.148 to 2.567	0.879 to 1.763	Less than 1 in. / 160 ft.	85 to 155

1. *Stationing referenced to the baseline of the respective retaining wall alignment.*

Please note that the consolidation settlement and time rate of consolidation are based on estimates using correlated compressibility parameters provided in Table 9 for the underlying soils. Actual settlement and time rate of consolidation may be determined by monitoring the settlement of the wall using settlement platforms.

Per Section 307.1.6 of the 2020 ODOT BDM, the maximum allowable differential settlement in the longitudinal direction (regardless of the size of panels) is one (1) percent (1 in. / 100 ft.). Based on the total anticipated settlement at the facing of Retaining Walls 6 and 5B, maximum differential settlement in the longitudinal direction is anticipated to be less than 1 in. / 1,000 ft. (1/1,000) and 1 in. / 160 ft. (1/160), which is within the tolerable limit of 1/100. If the total or differential settlement values predicted for the proposed walls present 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 using a surcharge and consolidating the underlying soils prior to constructing the walls.

5.2.4 Eccentricity (Overturning Stability)

The resistance of the MSE walls to overturning will be dependent on the 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 2020 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 specified wall height indicated in Table 8. Based on the minimum length of reinforced soil mass presented in Table 8 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.

5.2.5 Sliding Stability

The resistance of the MSE walls to sliding was evaluated per Section 11.10.5.3 of the 2020 AASHTO LRFD BDS. Given that the bearing soils along Retaining Wall 5B consist of cohesive material, the sliding resistance was evaluated under both drained and undrained conditions. 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 soil and the reinforced soil backfill, a coefficient of sliding friction of 0.55 to 0.62 was utilized for design. 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 bearing material along Retaining Wall 5B is 1.75 ksf.

A geotechnical resistance factor of φ_{τ}=1.0 was considered in calculating the factored shear resistance between the reinforced soil mass and foundation for sliding. Based on the minimum length of reinforced soil mass presented in Table 8 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.

5.2.6 Overall (Global) Stability

A slope stability analysis was performed to check the global stability of walls at the rear and forward abutments. As per Section 11.6.2.3 of the 2020 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 external 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 masses. The computer software program Slide, manufactured by Rocscience Inc., was utilized to perform the analyses.

Per Section 307.1.2 of the 2020 ODOT BDM and Section 11.6.2.3 of the 2020 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 MSE walls designed with the minimum strap lengths listed in Table 8, the resulting factor of safety under drained conditions (long-term stability) and undrained conditions (short-term stability) at the rear abutment (Wall 6) and forward abutment (Wall 5B) using the Spencer’s analysis method was greater 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 6), the recommended controlling strap length is 0.70 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 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 for this wall, provided the underlying weak, compressible soils are over excavated and replaced as outlined in Section 5.2.

Based on the results of the external and global stability analysis performed for the MSE wall at the forward abutment (Wall 5B between Sta. 15+85 and 17+96, BL Wall 5B), the recommended controlling strap length is 0.85 times the maximum height of the MSE wall (measured from the top of the leveling pad to the proposed profile grade of the roadway) along that segment of the wall. Bearing resistance under undrained conditions was the controlling factor in the determination of the required strap length of 0.85 times the wall height for this section of the wall.

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

5.3 Lateral Earth Pressure Parameters

For the soil types encountered in the borings, the "in-situ" unit weight (γ), cohesion (c), effective angle of friction (φ'), and lateral earth pressure coefficients for at-rest conditions (k_o), active conditions (k_a), and passive conditions (k_p) have been estimated and are provided in Table 11 and Table 12. These parameters are applicable for short-term and long-term conditions at the proposed bridge structure site.

Table 11. Estimated Undrained Soil Parameters for Design

Soil Type	γ (pcf) [1]	c (psf)	φ	k_a	k_o	k_p
Soft to Medium Stiff Cohesive Soil	115	750	0°	N/A	N/A	N/A
Stiff Cohesive Soil	120	1,500	0°	N/A	N/A	N/A
Very Stiff to Hard Cohesive Soil	125	3,000	0°	N/A	N/A	N/A
Loose Granular Soil	120	0	28°	0.32	0.53	5.07
Medium Dense Granular Soil	125	0	32°	0.27	0.47	6.82
Dense to Very Dense Granular Soil	130	0	36°	0.23	0.41	9.09
Compacted Cohesive Engineered Fill	120	2,000	0°	N/A	N/A	N/A
Compacted Granular Engineered Fill	120	0	32°	0.27	0.47	6.82

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

Table 12. Estimated Drained Soil Parameters for Design

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

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

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. Active earth pressure is developed as the structure moves away from the backfill or retained soil, while passive pressure is developed as the structure moves towards the backfill. A relatively small amount of lateral movement is needed to reach the active condition (≥ 0.1 percent of the height), whereas the movements required to engage the passive condition are approximately ten times greater than those required to develop active earth pressure. The values in this table have been estimated from correlation charts based on minimum standards specified for compacted engineered fill materials.

These recommendations do not take into consideration the effect of any surcharge loading or a sloped ground surface (a flat surface is assumed). Earth pressures on excavation support systems will be dependent on the type of sheeting and method of bracing or anchorage. Surcharge loads, such as that imposed by traffic loading, will create additional lateral loading on the subsurface structures and excavation support systems. The resulting lateral earth pressure should be evaluated based on active (k_a) and at-rest (k_o) conditions and the anticipated magnitude of the loading.

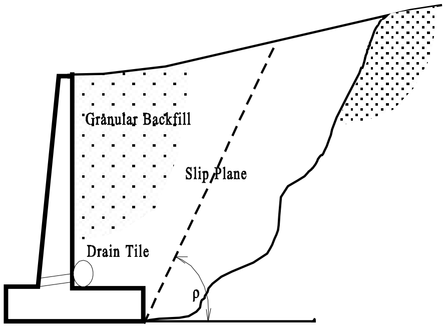
Temporary retaining structures should be designed using the undrained soil parameters provided in Table 11, and the design should follow all applicable guidelines for the type of retaining structure utilized. Permanent retaining structures should be design using the drained soil parameters provided in Table 12. A boring-by-boring tabulation of shear strength parameters for each soil layer encountered in provided in Appendix VIII. Lateral earth pressure coefficients can be determined from Table 11 and Table 12 based on the soil type and shear strength provided for each layer.

Regardless of whether the retaining structure is temporary or permanent, the effective unit weight ($\gamma' = \gamma$ - 62.4 pcf) plus the hydrostatic water pressure ($\gamma_w * h_w$, where h_w is the height of water behind the wall above the base of the wall) should be utilized below the design groundwater level. The lateral earth pressure coefficients should only be applied to the horizontal pressure resulting from the effective overburden pressure, and should not be applied to the hydrostatic water pressure.

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

The 2.0 feet of free draining material placed behind the wall prevents the formation of hydrostatic pressures as noted above. However, unless the free draining granular backfill is placed beyond the slip plane (see Figure 3), it has no influence on the equivalent fluid weight of the soil. If free-draining granular fill (meeting the requirements listed above) is to be placed beyond the slip plane (ρ=45° for at-rest conditions; ρ=45°+φ/2 for active conditions), the values presented for the compacted granular engineered fill can be employed, consequently lowering the pressures on the wall.

Figure 3. Slip Plane



Backfill Rankine Zone with Select Backfill

5.4 Construction Considerations

All site work shall conform to local codes, and to the latest ODOT 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 13. 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

Temporary shoring can be design using the lateral earth pressures defined in Section 5.3 as well as the design parameters provided in Appendix VIII.

5.4.2 Groundwater Considerations

Based on the groundwater observations made during drilling, groundwater seepage is anticipated during construction. Where groundwater is encountered, proper groundwater control should be employed and maintained to prevent disturbance to excavation bottoms consisting of cohesive soil, and to prevent the possible development of a quick or "boiling" condition where soft silts and/or fine sands are encountered. It is preferable that the groundwater level, if encountered, be maintained at least 36 inches below the deepest excavation. Any seepage or groundwater encountered at this site should be able to be controlled by pumping from temporary sumps. However, if any excavations extend in the underlying granular soil layer, additional dewatering measures such as point wells or deep well point may be required to maintain a dry, stable condition. Further, 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 our recommendations.

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

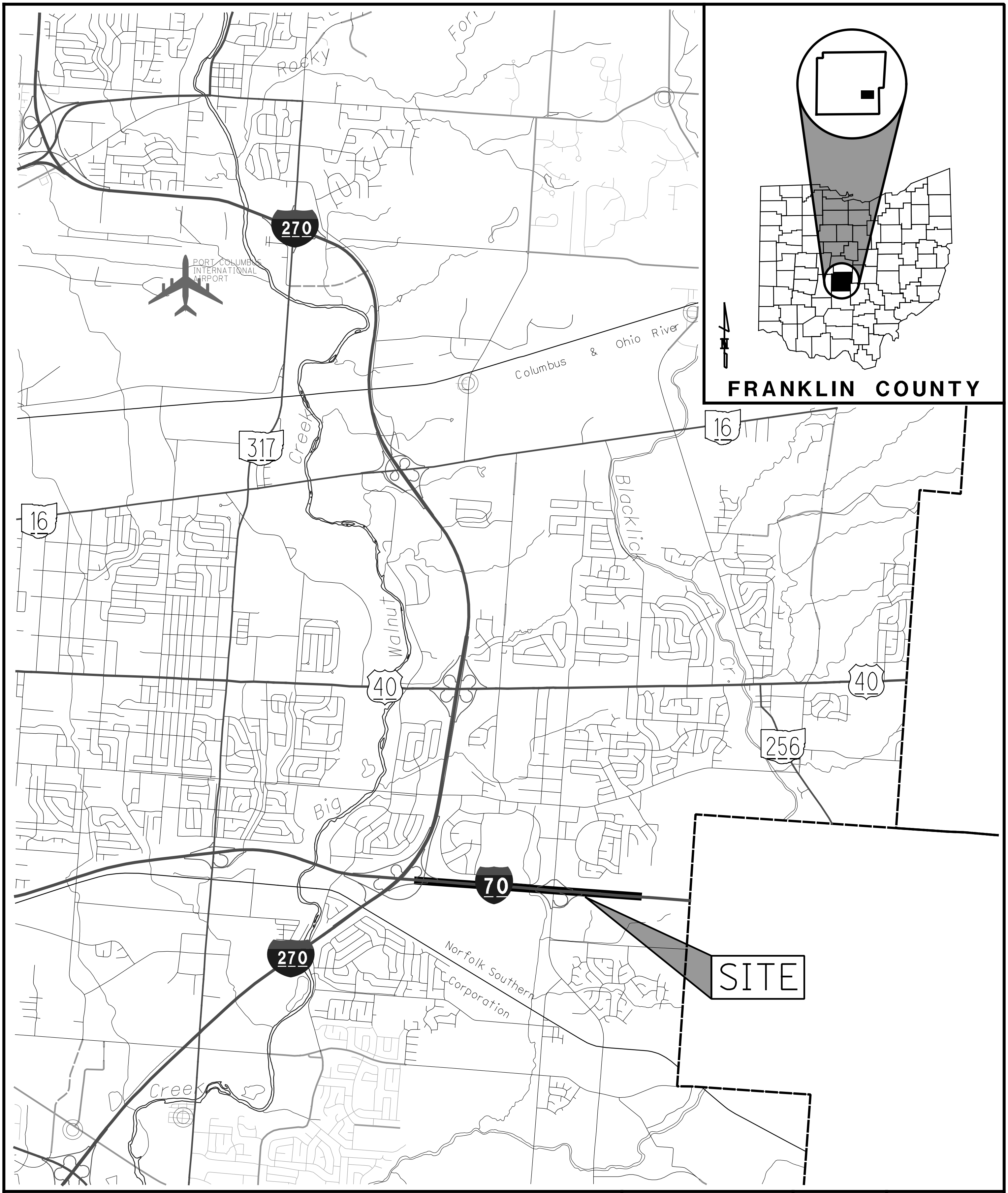
The conclusions and recommendations herein have been based upon the available soil information and the preliminary design details furnished by a representative of the owner of the proposed project. Any revision in the plans for the proposed construction from those anticipated in this report should be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

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

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

APPENDIX I

VICINITY MAP AND BORING PLAN



VICINITY MAP

FRA-70-22.85

COLUMBUS, OHIO

RII PROJECT NO.
W-17-140

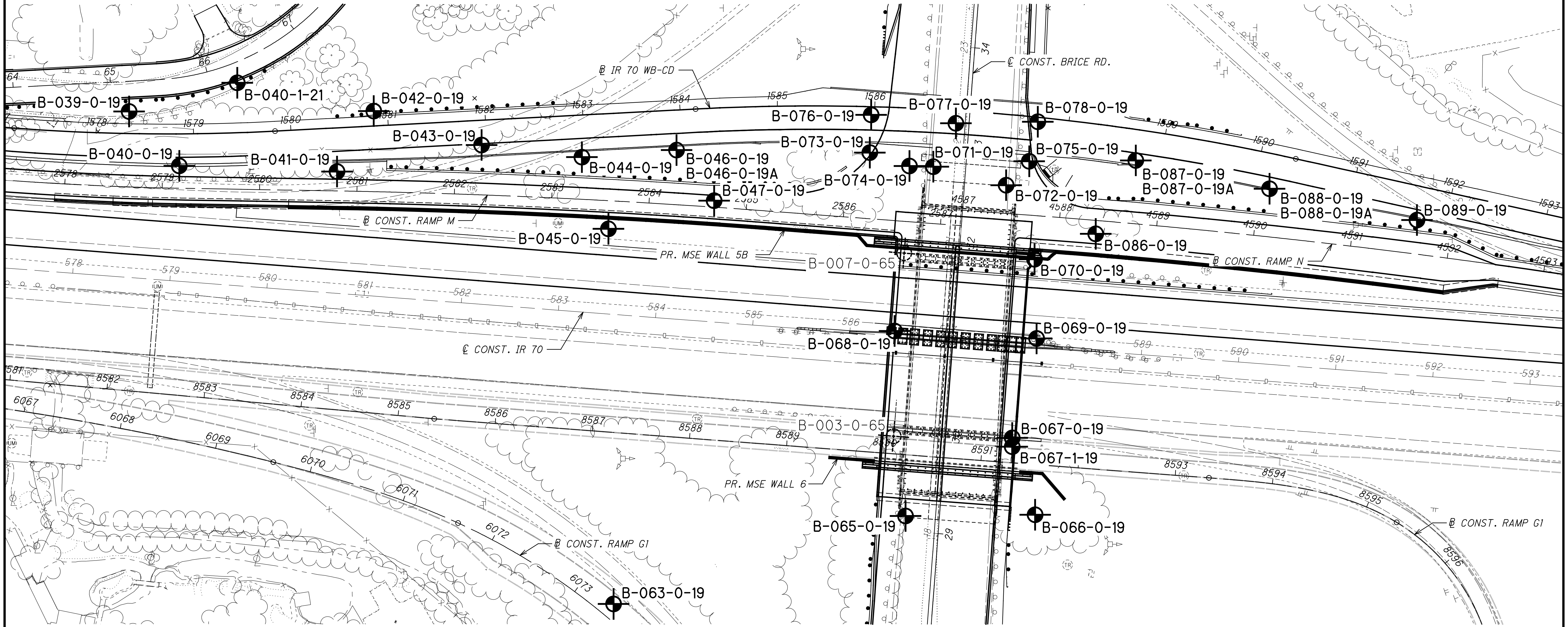
SCALE: 1″=5000′
0 2500 5000

DRAWN
JAS

REVIEWED
PPM

DATE
1/15/2021

RESOURCE INTERNATIONAL
Rii



BORING PLAN

FRA-00070-23.920

FRANKLIN COUNTY, OHIO

RII PROJECT NO.
W-17-140

SCALE: 1"=100'
0 50 100

N

DRAWN
RRM

REVIEWED
BRT

DATE
4/02/22

RESOURCE INTERNATIONAL

APPENDIX II

DESCRIPTION OF SOIL AND ROCK TERMS

CLASSIFICATION OF SOILS

Ohio Department of Transportation

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

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

MATERIAL CLASSIFIED BY VISUAL INSPECTION

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

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

DESCRIPTION OF SOIL TERMS

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

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

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

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

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

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

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

Modifiers of Components - Modifiers of components are as follows:

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

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

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

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

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

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

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

DESCRIPTION OF ROCK TERMS

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

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

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

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

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

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

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

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

Degree of Fracturing

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

Aperture Width

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

Surface Roughness

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

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

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

APPENDIX III

BORING LOGS:

B-065-0-19 through B-072-0-19

BORING LOGS

Definitions of Abbreviations

AS = Auger sample

GI = Group index as determined from the Ohio Department of Transportation classification system

HP = Unconfined compressive strength as determined by a hand penetrometer (tons per square foot)

LL_o = Oven-dried liquid limit as determined by ASTM D4318. Per ASTM D2487, if LL_o/LL is less than 75 percent, soil is classified as “organic”.

LOI = Percent organic content (by weight) as determined by ASTM D2974 (loss on ignition test)

PID = Photo-ionization detector reading (parts per million)

QR = Unconfined compressive strength of intact rock core sample as determined by ASTM D2938 (pounds per square inch)

QU = Unconfined compressive strength of soil sample as determined by ASTM D2166 (pounds per square foot)

RC = Rock core sample

REC = Ratio of total length of recovered soil or rock to the total sample length, expressed as a percentage

RQD = Rock quality designation – estimate of the degree of jointing or fracture in a rock mass, expressed as a percentage:

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

S = Sulfate content (parts per million)

SPT = Standard penetration test blow counts, per ASTM D1586. Driving resistance recorded in terms of blows per 6-inch interval while letting a 140-pound hammer free fall 30 inches to drive a 2-inch outer diameter (O.D.) split spoon sampler a total of 18 inches. The second and third intervals are added to obtain the number of blows per foot (N_m).

N_{60} = Measured blow counts corrected to an equivalent (60 percent) energy ratio (ER) by the following equation: $N_{60} = N_m{*}(ER/60)$

SS = Split spoon sample

2S = For instances of no recovery from standard SS interval, a 2.5 inch O.D. split spoon is driven the full length of the standard SS interval plus an additional 6.0 inches to obtain a representative sample. Only the final 6.0 inches of sample is retained. Blow counts from 2S sampling are not correlated with N_{60} values.

3S = Same as 2S, but using a 3.0 inch O.D. split spoon sampler.

TR = Top of rock

W = Initial water level measured during drilling

▼ = Water level measured at completion of drilling

Classification Test Data

Gradation (as defined on Description of Soil Terms):

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

Atterberg Limits:

LL = Liquid limit
PL = Plastic limit
PI = Plasticity Index

WC = Water content (%)

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-070-22.85
TYPE: BRIDGE
PID: 98232 SFN: 2505738
START: 9/16/20 END: 9/16/20

DRILLING FIRM / OPERATOR: RII / LARRY
SAMPLING FIRM / LOGGER: DHDC / GANESH
DRILLING METHOD: 4.25" HSA
SAMPLING METHOD: SPT

DRILL RIG: CME 55 (386345)
HAMMER: AUTOMATIC
CALIBRATION DATE: 9/4/18
ENERGY RATIO (%): 90

STATION / OFFSET: 29+15.47 / 34.7' LT
ALIGNMENT: CL CONST. BRICE RD
ELEVATION: 820.6 (MSL) EOB: 75.0 ft.
LAT / LONG: 39.932306, -82.830924

EXPLORATION ID
B-065-0-19

PAGE
1 OF 3

MATERIAL DESCRIPTION AND NOTES	ELEV. 820.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
ASPHALT (1.5")	820.4						-	-	-	-	-	-	-	-	-	-		
FILL: VERY STIFF, DARK GRAYISH BROWN AND BLACKISH GRAY, **SILTY CLAY**, TRACE TO LITTLE SAND, TRACE GRAVEL, DAMP TO MOIST ---ROCK FRAGMENTS IN SAMPLE--- @3.5'-5.0'; LIGHT ORGANIC ODOR IN SAMPLE		1 2 3	5 4 5	14	75	SS-1	3.00	-	-	-	-	-	-	-	-	18	A-6b (V)	
		4 5	4 4 5	14	89	SS-2	2.50	-	-	-	-	-	-	-	-	21	A-6b (V)	
	812.6	6 7 8	4 5 8	20	89	SS-3	2.50	-	-	-	-	-	-	-	-	21	A-6b (V)	
FILL: VERY STIFF, DARK BROWN WITH TRACE GRAY, **SILT AND CLAY**, LITTLE SAND, LITTLE GRAVEL, MOIST @10.0'; 2S SPLIT SPOON DROVE TO RECOVER SAMPLE		9	4 6 8	21	0	SS-4A	-	-	-	-	-	-	-	-	-	-	A-6a (V)	
	810.1	10	9	-	100	SS-4B	3.50	-	-	-	-	-	-	-	-	12	A-6a (V)	
FILL: VERY STIFF, BROWN AND GRAY, **SILTY CLAY**, SOME SAND, TRACE GRAVEL, MOIST ---ROCK FRAGMENTS IN SAMPLE--- @13.5'-15.0'; LIGHT ORGANIC ODOR IN SAMPLE		11 12 13	4 4 5	14	81	SS-5	3.00	7	8	15	32	38	34	18	16	20	A-6b (9)	
	805.1	14 15	3 5 7	18	69	SS-6	4.00	-	-	-	-	-	-	-	-	15	A-6b (V)	
FILL: VERY STIFF, DARK BROWN TO BROWN WITH BLUISH GRAY STAINING, **SILT AND CLAY**, SOME SAND, LITTLE GRAVEL, MOIST ---LIGHT ORGANIC ODOR IN SAMPLE--- ---OCCASIONAL ROCK FRAGMENTS IN SAMPLE--- @21.0'-22.5', DAMP		16 17 18	3 5 7	18	89	SS-7	4.00	-	-	-	-	-	-	-	-	26	A-6a (V)	
		19 20	3 5 7	18	67	SS-8	3.00	-	-	-	-	-	-	-	-	21	A-6a (V)	
		21 22 23	3 7 11	27	72	SS-9	3.00	19	17	12	25	27	35	24	11	12	A-6a (4)	
	793.6	24 25 26 27	9 9 10	29	72	SS-10	3.00	-	-	-	-	-	-	-	-	20	A-6a (V)	
FILL: HARD TO VERY STIFF, DARK BROWN, **SILTY CLAY**, SOME SAND, TRACE GRAVEL, MOIST ---OCCASIONAL ROCK FRAGMENTS---		28 29	9 14 18	48	72	SS-11	3.00	-	-	-	-	-	-	-	-	13	A-6b (V)	

00-2021 NEW STA ODOT BORING LOG (8.5X11) - OH DOT.GDT - 4/4/22 11:30 - U:\GI8\PROJECTS\2017\W-17-140.GPJ

PID: 98232 | SFN: | PROJECT: FRA-070-22.85 | STATION / OFFSET: 2915.47, 35' LT. | START: 9/16/20 | END: 9/16/20 | PG 2 OF 3 | B-065-0-19

MATERIAL DESCRIPTION AND NOTES	ELEV. 790.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
		▽ 789.4 31																
	788.6	32																
HARD, DARK BROWN, **SILTY CLAY**, SOME SAND, TRACE GRAVEL, DAMP TO MOIST		33																
		34 35	5 7 13	30	89	SS-12	3.00	7	10	12	29	42	40	20	20	24	A-6b (11)	
		36 37 38																
		39 40	12 21 22	65	69	SS-13	2.00	-	-	-	-	-	-	-	-	19	A-6b (V)	
	778.6	41 42																
DENSE TO VERY DENSE, GRAY, **GRAVEL AND/OR STONE FRAGMENTS WITH SAND**, WET COBBLES AT 42.0'-57.0'		43																
		44 45	3 14 24	57	44	SS-14	-	-	-	-	-	-	-	-	-	19	A-1-b (V)	
		46 47 48																
		49 50	7 11 14	38	61	SS-15	-	51	21	8	- 20 -		NP	NP	NP	13	A-1-b (0)	
		51 52 53																
		54 55	18 14 20	51	89	SS-16	-	-	-	-	-	-	-	-	-	11	A-1-b (V)	
	763.6	56 57																
HARD, GRAY, **SILT AND CLAY**, SOME SAND, LITTLE GRAVEL, DAMP		58																
		59 60	13 8 14	33	78	SS-17	3.00	-	-	-	-	-	-	-	-	11	A-6a (V)	
		61																

PID: 98232	SFN:	PROJECT: FRA-070-22.85	STATION / OFFSET: 2915.47, 35' LT.	START: 9/16/20	END: 9/16/20	PG 3 OF 3	B-065-0-19

MATERIAL DESCRIPTION AND NOTES	ELEV. 758.4	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL
								GR	CS	FS	SI	CL	LL	PL	PI			
HARD, GRAY, **SILT AND CLAY**, SOME SAND, LITTLE GRAVEL, DAMP *(continued)*		63																
		64 65	11 9 13	33	89	SS-18	3.00	19	12	13	30	26	36	23	13	12	A-6a (5)	
		66 67 68																
		69 70	16 18 18	54	44	SS-19	2.00	-	-	-	-	-	-	-	-	13	A-6a (V)	
		71 72 73																
	745.6	74 EOB 75	11 9 14	35	89	SS-20	2.00	-	-	-	-	-	-	-	-	12	A-6a (V)	

NOTE: WATER WAS INTRODUCED IN BOREHOLE AT ABOUT 40.0 FEET TO ADVANCE THE BOREHOLE. SAMPLES EXTRACTED BEYOND 43.5 FEET ARE WET. POSSIBLE PRESENCE OF PERCHED OR TRAPPED GROUNDWATER WITHIN THE GRANULAR MATERIALS ENCOUNTERED AT A DEPTH OF ABOUT 42.0 FEET TO 57.0 FEET.

DURING DRILLING REBAR WAS ENCOUNTERED AT A DEPTH OF 8.0 FEET. HENCE BORING WAS OFFSET TO THE SOUTH TO ADVANCE THE BOREHOLE.

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: USED ASPHALT PATCH; POURED BENTONITE GROUT

00-2021 NEW STA ODOT BORING LOG (8.5X11) - OH DOT.GDT - 4/4/22 11:30 - U:\GI8\PROJECTS\2017\W-17-140.GPJ

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-070-22.85
TYPE: BRIDGE
PID: 98232 SFN: 2505738
START: 9/8/20 END: 9/8/20

DRILLING FIRM / OPERATOR: RII / SB
SAMPLING FIRM / LOGGER: RII / TG
DRILLING METHOD: 3.25" HSA
SAMPLING METHOD: SPT

DRILL RIG: CME 750X (SN 310218)
HAMMER: AUTOMATIC
CALIBRATION DATE: 9/14/20
ENERGY RATIO (%): 86.2

STATION / OFFSET: 29+26.77 / 97.9' RT
ALIGNMENT: CL CONST. BRICE RD
ELEVATION: 801.7 (MSL) EOB: 70.0 ft.
LAT / LONG: 39.932311, -82.830450

EXPLORATION ID
B-066-0-19

PAGE
1 OF 3

MATERIAL DESCRIPTION AND NOTES	ELEV. 801.7	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")	801.2																	
MEDIUM STIFF, BROWN **SANDY SILT**, LITTLE CLAY, TRACE FINE GRAVEL, DAMP.	798.7		1 2 3	7	72	SS-1	1.00	-	-	-	-	-	-	-	-	23	A-4a (V)	
STIFF TO VERY STIFF, BROWN **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST.			3 2 3	7	39	SS-2	1.50	-	-	-	-	-	-	-	-	19	A-6a (V)	
	793.7		3 4 6	14	81	SS-3	2.50	-	-	-	-	-	-	-	-	20	A-6a (V)	
VERY STIFF, BROWN **SANDY SILT**, SOME CLAY, TRACE FINE GRAVEL, MOIST TO WET.			2 3 2	7	89	SS-4	0.75	-	-	-	-	-	-	-	-	22	A-4a (V)	
	788.7		2 1 2	4	89	SS-5	0.25	1	15	24	36	24	24	18	6	29	A-4a (5)	
MEDIUM DENSE, GRAY **COARSE AND FINE SAND**, TRACE SILT, WET.	786.2	W 786.4	4 5 6	16	78	SS-6	-	-	-	-	-	-	-	-	-	15	A-3a (V)	
DENSE, GRAY **GRAVEL WITH SAND**, TRACE SILT, WET.			5 10 14	34	69	SS-7	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
	781.2		11 14 16	43	83	SS-8	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	
MEDIUM DENSE, GRAY **COARSE AND FINE SAND**, TRACE SILT, WET.	778.7		7 7 12	27	81	SS-9	-	-	-	-	-	-	-	-	-	17	A-3a (V)	
MEDIUM DENSE TO VERY DENSE, GRAY **GRAVEL WITH SAND**, TRACE SILT, WET. -COBBLES @ 23.0'			21 40 50/5"	-	65	SS-10	-	-	-	-	-	-	-	-	-	13	A-1-b (V)	
			6 8 9	24	36	SS-11	1.50	-	-	-	-	-	-	-	-	12	A-1-b (V)	

PID: 98232	SFN:	PROJECT: FRA-070-22.85	STATION / OFFSET: 2926.77, 98' RT.	START: 9/8/20	END: 9/8/20	PG 2 OF 3	B-066-0-19

MATERIAL DESCRIPTION AND NOTES	ELEV. 771.7	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
MEDIUM DENSE TO VERY DENSE, GRAY **GRAVEL WITH SAND**, TRACE SILT, WET. *(continued)*	769.7	31 32																
VERY STIFF TO HARD, GRAY **SANDY SILT**, SOME CLAY, TRACE FINE GRAVEL, MOIST.		33 34 35	10 9 14	33	64	SS-12	3.75	2	8	16	40	34	24	15	9	14	A-4a (8)	
	761.7	36 37 38 39	19 20 30	72	0	SS-13	-	-	-	-	-	-	-	-	-	-		
VERY STIFF TO HARD, GRAY **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST.		40	26	-	75	2S-13A	4.5+	-	-	-	-	-	-	-	-	15	A-6a (V)	
-COBBLES @ 42.8'		41 42 43 44 45	40 14 15	42	81	SS-14	4.5+	-	-	-	-	-	-	-	-	13	A-6a (V)	
		46 47 48 49 50	28 12 12	34	53	SS-15	4.5+	-	-	-	-	-	-	-	-	14	A-6a (V)	
		51 52 53 54 55	31 15 22	53	89	SS-16	4.25	9	6	9	31	45	29	17	12	16	A-6a (9)	
		56 57 58 59	50/3"	-	100	SS-17	3.50	-	-	-	-	-	-	-	-	16	A-6a (V)	
	739.7	60 61																

PID: 98232	SFN:	PROJECT: FRA-070-22.85	STATION / OFFSET: 2926.77, 98' RT.	START: 9/8/20	END: 9/8/20	PG 3 OF 3	B-066-0-19

MATERIAL DESCRIPTION AND NOTES	ELEV. 739.5	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	HOLE SEALED
								GR	CS	FS	SI	CL	LL	PL	PI			
HARD, GRAY **SANDY SILT**, SOME CLAY, TRACE FINE GRAVEL, DAMP. *(continued)*		63																
		64	50/5"	-	0	SS-18	-	-	-	-	-	-	-	-	-	-		
		65	27	-	100	2S-18A	4.5+	-	-	-	-	-	-	-	-	11	A-4a (V)	
		66																
		67																
		68																
		69	33 19 17	52	72	SS-19	4.5+	-	-	-	-	-	-	-	-	11	A-4a (V)	
	731.7	EOB 70																

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 15.3'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 94 LBS CEMENT / 25 LBS BENTONITE POWDER / 30 GAL WATER .

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-070-22.85
TYPE: BRIDGE
PID: 98232 SFN: 2505738
START: 8/1/20 END: 8/1/20

DRILLING FIRM / OPERATOR: RII / LH
SAMPLING FIRM / LOGGER: RII / JP
DRILLING METHOD: 3.25" HSA
SAMPLING METHOD: SPT

DRILL RIG: CME 55 (SN 386345)
HAMMER: AUTOMATIC
CALIBRATION DATE: 9/14/20
ENERGY RATIO (%): 84.2

STATION / OFFSET: 29+94.66 / 69.2' RT
ALIGNMENT: CL CONST. BRICE RD
ELEVATION: 796.0 (MSL) EOB: 10.0 ft.
LAT / LONG: 39.932502, -82.830535

EXPLORATION ID
B-067-0-19

PAGE
1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 796.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.4' - TOPSOIL (5.0")	795.6																	
VERY STIFF TO HARD, BROWN **SILT AND CLAY**, LITTTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP TO MOIST.		2.5	5 5	15	0	SS-1	-	-	-	-	-	-	-	-	-	-		
			6	-	100	2S-1A	4.5+	-	-	-	-	-	-	-	-	-	A-6a (V)	
	790.5	5.0	8	11	100	SS-2	4.00	-	-	-	-	-	-	-	-	-	A-6a (V)	
HARD, BROWN AND TAN **SANDY SILT**, SOME CLAY, TRACE FINE GRAVEL, DAMP.			9															
	788.0	7.5	4 4	22	44	SS-3	4.5+	-	-	-	-	-	-	-	-	-	A-4a (V)	
MEDIUM DENSE, DARK BROWN AND DARK GRAY **GRAVEL WITH SAND AND SILT**, TRACE CLAY, DAMP.			5															
	786.0	EOB 10.0	7 9	18	56	SS-4	-	-	-	-	-	-	-	-	-	-	A-2-4 (V)	
			5 7 6															

-BORING TERMINATED @ 10.0' DUE TO UTILITY CONFLICT. OFFSET BORING B-067-0-19A IS DRILLED 9' NORTH OF THIS LOCATION

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 25 LBS BENTONITE CHIPS AND SOIL CUTTINGS .

00-2021 NEW STA ODOT BORING LOG (8.5X11) - OH DOT.GDT - 11/23/22 13:26 - U:\GI8\PROJECTS\2017\W-17-140.GPJ

PROJECT: FRA-070-22.85	DRILLING FIRM / OPERATOR: RII / LH	DRILL RIG: CME 55 (SN 386345)	STATION / OFFSET: 30+03.63 / 68.5' RT	EXPLORATION ID B-067-1-19
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: RII / JP	HAMMER: AUTOMATIC	ALIGNMENT: CL CONST. BRICE RD	
PID: 98232 SFN: 2505738	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 9/14/20	ELEVATION: 797.3 (MSL) EOB: 75.0 ft.	PAGE 1 OF 2
START: 9/1/20 END: 9/1/20	SAMPLING METHOD: SPT	ENERGY RATIO (%): 84.2	LAT / LONG: 39.932527, -82.830535	

MATERIAL DESCRIPTION AND NOTES	ELEV. 797.3	DEPTHS
0.4' - TOPSOIL (5.0")	796.9	
VERY STIFF, BROWN **SILTY CLAY**, SOME COARSE TO FINE SAND, LITTLE FINE GRAVEL, MOIST.	787.8	
MEDIUM DENSE TO DENSE, GRAY **GRAVEL WITH SAND AND SILT**, TRACE CLAY, MOIST TO WET.	774.3	W 783.8 ▽ 774.8
VERY DENSE, GRAY **GRAVEL**, TRACE COARSE TO FINE SAND, TRACE SILT, WET.	770.3	
DENSE, GRAY **GRAVEL WITH SAND AND SILT**, WET.	765.3	
VERY STIFF TO HARD, GRAY **SANDY SILT**, LITTLE TO SOME CLAY, LITTLE FINE GRAVEL, MOIST.	740.3	
HARD, GRAY **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST.		

DEPTHS: 2.5, 5.0, 7.5, 10.0, 12.5, 15.0, 17.5, 20.0, 22.5, 25.0, 27.5, 30.0, 32.5, 35.0, 37.5, 40.0, 42.5, 45.0, 47.5, 50.0, 52.5, 55.0, 57.5

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
3 2 3	7	78	SS-1	2.50	-	-	-	-	-	-	-	-	18	A-6b (V)	
3 3 2	7	67	SS-2	2.50	-	-	-	-	-	-	-	-	19	A-6b (V)	
2 2 2	6	72	SS-3	2.00	14	18	20	24	24	37	20	17	23	A-6b (5)	
3 5 7	17	44	SS-4A	2.50	-	-	-	-	-	-	-	-	24	A-6b (V)	
			SS-4B	-	-	-	-	-	-	-	-	-	15	A-2-4 (V)	
3 7 9	22	33	SS-5	-	-	-	-	-	-	-	-	-	14	A-2-4 (V)	
6 9 9	25	50	SS-6	-	-	-	-	-	-	-	-	-	10	A-2-4 (V)	
9 7 15	31	39	SS-7	-	-	-	-	-	-	-	-	-	8	A-2-4 (V)	
15 15 18	46	33	SS-8	-	-	-	-	-	-	-	-	-	9	A-2-4 (V)	
15 17 16	46	44	SS-9	-	-	-	-	-	-	-	-	-	10	A-2-4 (V)	
38 50/5"	-	64	SS-10	-	-	-	-	-	-	-	-	-	12	A-1-a (V)	
15 17 16	46	44	SS-11	-	-	-	-	-	-	-	-	-	15	A-2-4 (V)	
11 26 14	56	61	SS-12	2.25	20	11	18	32	19	25	16	9	14	A-4a (3)	
14 12 23	49	72	SS-13	4.25	-	-	-	-	-	-	-	-	9	A-4a (V)	
8 19 19	53	44	SS-14	4.5+	-	-	-	-	-	-	-	-	11	A-4a (V)	
13 28 27	77	56	SS-15	4.25	18	13	15	32	22	22	14	8	11	A-4a (4)	
5 12 17	41	67	SS-16	4.5+	-	-	-	-	-	-	-	-	10	A-4a (V)	
14	34	61	SS-17	4.5+	-	-	-	-	-	-	-	-	20	A-4a (V)	

PID: 98232 | SFN: | PROJECT: FRA-070-22.85 | STATION / OFFSET: 3003.63, 69' RT. | START: 9/1/20 | END: 9/1/20 | PG 2 OF 2 | B-067-1-19

MATERIAL DESCRIPTION AND NOTES	ELEV. 737.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	HOLE SEALED
								GR	CS	FS	SI	CL	LL	PL	PI			
HARD, GRAY **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST. *(continued)*		62.5	8 16															
	730.3	65.0	22 28 24	73	44	SS-18	4.25	-	-	-	-	-	-	-	-	22	A-4a (V)	
VERY STIFF, GRAY **SILTY CLAY**, TRACE FINE SAND, MOIST.		67.5 70.0	6 8 10	25	78	SS-19	3.25	0	0	1	36	63	38	22	16	25	A-6b (10)	
	722.3	72.5 EOB 75.0	5 6 9	21	72	SS-20	3.25	-	-	-	-	-	-	-	-	26	A-6b (V)	

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 13.5' AND AT COMPLETION @ 22.5'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 94 LBS CEMENT / 25 LBS BENTONITE POWDER / 30 GAL WATER .

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-070-22.85
TYPE: BRIDGE
PID: 98232 SFN: 2505738
START: 9/2/20 END: 9/2/20

DRILLING FIRM / OPERATOR: RII / LH
SAMPLING FIRM / LOGGER: RII / JK
DRILLING METHOD: 3.25" HSA
SAMPLING METHOD: SPT

DRILL RIG: CME 55 (SN 386345)
HAMMER: AUTOMATIC
CALIBRATION DATE: 9/14/20
ENERGY RATIO (%): 84.2

STATION / OFFSET: 31+04.08 / 60.3' LT
ALIGNMENT: CL CONST. BRICE RD
ELEVATION: 796.9 (MSL) EOB: 75.0 ft.
LAT / LONG: 39.932828, -82.830967

EXPLORATION ID
B-068-0-19

PAGE
1 OF 3

MATERIAL DESCRIPTION AND NOTES	ELEV. 796.9	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
0.6' - TOPSOIL (7.0")	796.3																	
VERY STIFF, BROWN TO GRAY **SILT AND CLAY**, SOME COARSE TO FINE SAND, LITTLE FINE GRAVEL, MOIST.		1 2	3 3 5	11	56	SS-1	3.00	-	-	-	-	-	-	-	-	15	A-6a (V)	
		3 4 5	3 5 4	13	78	SS-2	3.00	12	15	17	28	28	32	17	15	15	A-6a (6)	
	788.9	6 7 8	3 6 9	21	100	SS-3	3.25	-	-	-	-	-	-	-	-	17	A-6a (V)	
STIFF, DARK GRAY **CLAY**, "AND" SAND, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST. -TRACE ORGANICS PRESENT IN SS-4	786.4	9 10	3 3 5	11	69	SS-4	2.00	4	7	8	44	37	43	25	18	29	A-7-6 (12)	
MEDIUM DENSE TO DENSE, GRAY **GRAVEL WITH SAND AND SILT**, TRACE CLAY, MOIST. -COBBLES @ 12.0'		11 ▽ 784.4 12 13	3 7 9	22	56	SS-5	-	-	-	-	-	-	-	-	-	13	A-2-4 (V)	
		14 W 782.2 15	23 17 17	48	61	SS-6	-	-	-	-	-	-	-	-	-	10	A-2-4 (V)	
		16 17 18	13 15 18	46	83	SS-7	-	-	-	-	-	-	-	-	-	9	A-2-4 (V)	
	776.4	19 20	14 11 12	32	61	SS-8	-	-	-	-	-	-	-	-	-	10	A-2-4 (V)	
VERY DENSE, GRAY **COARSE AND FINE SAND**, TRACE SILT, WET.	773.9	21 22 23	26 19 29	67	50	SS-9	-	-	-	-	-	-	-	-	-	19	A-3a (V)	
VERY DENSE, GRAY **GRAVEL WITH SAND AND SILT**, MOIST.	769.9	24 25 26	16 15 22	52	50	SS-10	-	-	-	-	-	-	-	-	-	9	A-2-4 (V)	
VERY STIFF TO HARD, GRAY **SANDY SILT**, SOME CLAY, SOME FINE GRAVEL, DAMP TO MOIST.		27 28 29	14 12 19	44	44	SS-11	4.5+	-	-	-	-	-	-	-	-	13	A-4a (V)	

00-2021 NEW STA ODOT BORING LOG (8.5X11) - OH DOT.GDT - 4/4/22 11:30 - U:\GI8\PROJECTS\2017\W-17-140.GPJ

PID: 98232 | SFN: | PROJECT: FRA-070-22.85 | STATION / OFFSET: 3104.08, 60' LT. | START: 9/2/20 | END: 9/2/20 | PG 2 OF 3 | B-068-0-19

MATERIAL DESCRIPTION AND NOTES	ELEV. 766.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	HOLE SEALED
								GR	CS	FS	SI	CL	LL	PL	PI			
VERY STIFF TO HARD, GRAY **SANDY SILT**, SOME CLAY, SOME FINE GRAVEL, DAMP TO MOIST. *(continued)*		31 32 33																
		34 35	15 17 27	62	47	SS-12	2.50	31	13	13	22	21	22	15	7	14	A-4a (2)	
		36 37 38																
		39 40	14 15 14	41	44	SS-13	3.00	-	-	-	-	-	-	-	-	11	A-4a (V)	
		41 42 43																
		44 45	15 20 22	59	36	SS-14	2.50	-	-	-	-	-	-	-	-	14	A-4a (V)	
		46 47 48																
		49	10 14 23	52	11	SS-15	2.00	-	-	-	-	-	-	-	-	-	A-4a (V)	
		50	18	-	50	2S-15A	4.25	-	-	-	-	-	-	-	-	10	A-4a (V)	
	743.9	51 52																
VERY STIFF TO HARD, GRAY **SILT AND CLAY**, TRACE FINE GRAVEL, MOIST.		53																
		54 55	12 14 19	46	72	SS-16	4.25	-	-	-	-	-	-	-	-	12	A-6a (V)	
		56 57 58																
		59 60	7 5 9	20	42	SS-17	3.50	1	0	0	33	66	35	21	14	22	A-6a (10)	
		61																

PID: 98232 | SFN: | PROJECT: FRA-070-22.85 | STATION / OFFSET: 3104.08, 60' LT. | START: 9/2/20 | END: 9/2/20 | PG 3 OF 3 | B-068-0-19

MATERIAL DESCRIPTION AND NOTES	ELEV. 734.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG				ODOT CLASS (GI)	HOLE SEALED
								GR	CS	FS	SI	CL	LL	PL	PI	WC		
VERY STIFF TO HARD, GRAY **SILT AND CLAY**, TRACE FINE GRAVEL, MOIST. *(continued)*		63																
		64 65	5 8 15	32	44	SS-18	3.00	-	-	-	-	-	-	-	-	22	A-6a (V)	
		66 67 68																
		69 70	5 5 10	21	100	SS-19	3.00	-	-	-	-	-	-	-	-	25	A-6a (V)	
		71 72 73																
	721.9	74 EOB 75	5 7 10	24	100	SS-20	3.25	-	-	-	-	-	-	-	-	29	A-6a (V)	

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 14.7' AND AT COMPLETION @ 12.5'; CAVE-IN DEPTH @ 19.4'.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 94 LBS CEMENT / 25 LBS BENTONITE POWDER / 20 GAL WATER .

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-070-22.85
TYPE: BRIDGE
PID: 98232 SFN: 2505738
START: 9/11/20 END: 9/11/20

DRILLING FIRM / OPERATOR: RII / LARRY
SAMPLING FIRM / LOGGER: DHDC / GANESH
DRILLING METHOD: 4.25" HSA
SAMPLING METHOD: SPT

DRILL RIG: CME 55 (386345)
HAMMER: AUTOMATIC
CALIBRATION DATE: 9/4/18
ENERGY RATIO (%): 90

STATION / OFFSET: 31+07.36 / 85.8' RT
ALIGNMENT: CL CONST. BRICE RD
ELEVATION: 797.8 (MSL) EOB: 75.0 ft.
LAT / LONG: 39.932808, -82.830447

EXPLORATION ID
B-069-0-19

PAGE
1 OF 3

MATERIAL DESCRIPTION AND NOTES	ELEV. 797.8	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
POSSIBLE FILL: LOOSE, BLACK TO BROWN, **GRAVEL AND/OR STONE FRAGMENTS WITH SAND**, MOIST			7 3 4	11	33	SS-1	-	-	-	-	-	-	-	-	-	11	A-1-b (V)	
	792.3		6 3 3	9	42	SS-2	-	36	27	12	- 25 -		NP	NP	NP	13	A-1-b (0)	
LOOSE, BROWN AND GRAY, **SANDY SILT**, LITTLE TO SOME GRAVEL, MOIST			6 3 4	11	86	SS-3	-	-	-	-	-	-	-	-	-	14	A-4a (V)	
			4 4 2	9	72	SS-4	-	-	-	-	-	-	-	-	-	16	A-4a (V)	
	785.3		3 4 3	11	69	SS-5	-	-	-	-	-	-	-	-	-	17	A-4a (V)	
LOOSE, BROWN AND GRAY, **GRAVEL AND/OR STONE FRAGMENTS WITH SAND AND SILT**, MOIST	782.8	▼	7 3 3	9	22	SS-6A	-	-	-	-	-	-	-	-	-	13	A-2-4 (V)	
MEDIUM DENSE, GRAY, **GRAVEL AND/OR STONE FRAGMENTS WITH SAND**, TRACE SILT, TRACE CLAY, WET			9	-	100	SS-6B	-	-	-	-	-	-	-	-	-	12	A-1-b (V)	
			8 5 5	15	53	SS-7	-	-	-	-	-	-	-	-	-	12	A-1-b (V)	
	777.3		7 5 4	14	67	SS-8	-	42	43	6	- 9 -		NP	NP	NP	13	A-1-b (0)	
MEDIUM DENSE TO DENSE, GRAY, **GRAVEL AND/OR STONE FRAGMENTS WITH SAND, SILT AND CLAY**, WET			12 11 9	30	44	SS-9	-	-	-	-	-	-	-	-	-	15	A-2-6 (V)	
	770.8		17 12 12	36	61	SS-10	-	-	-	-	-	-	-	-	-	12	A-2-6 (V)	
VERY STIFF, DARK BLACKISH BROWN TO BLUISH GRAY, **SILT AND CLAY**, SOME TO LITTLE SAND, TRACE TO LITTLE GRAVEL, DAMP TO MOIST ---LIGHT ORGANIC ODOR AND OCCASIONAL STAINING---			10 7 10	26	64	SS-11	3.00	2	5	17	41	35	33	18	15	36	A-6a (10)	

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

PID: 98232	SFN:	PROJECT: FRA-070-22.85	STATION / OFFSET: 3107.36, 86' RT.	START: 9/11/20	END: 9/11/20	PG 2 OF 3	B-069-0-19

MATERIAL DESCRIPTION AND NOTES	ELEV. 767.8	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
VERY STIFF, DARK BLACKISH BROWN TO BLUISH GRAY, **SILT AND CLAY**, SOME TO LITTLE SAND, TRACE TO LITTLE GRAVEL, DAMP TO MOIST ---LIGHT ORGANIC ODOR AND OCCASIONAL STAINING--- *(continued)*	760.8	31 32 33 34 35 36	3 5 12	26	78	SS-12	4.00	12	6	9	34	39	38	23	15	17	A-6a (10)	
VERY STIFF, GRAY, **SILT AND CLAY**, LITTLE SAND, LITTLE GRAVEL, DAMP	754.8	37 38 39 40 41 42	9 21 12	50	44	SS-13	4.00	-	-	-	-	-	-	-	-	11	A-6a (V)	
VERY DENSE, GRAY, **GRAVEL AND/OR STONE FRAGMENTS WITH SAND, SILT AND CLAY**, WET	751.3	43 44 45 46	20 50/4"	-	70	SS-14	-	-	-	-	-	-	-	-	-	12	A-2-6 (V)	
VERY STIFF, GRAY, **SILT AND CLAY**, SOME SAND, LITTLE GRAVEL, DAMP		47 48 49 50 51 52	11 40 50/4"	-	56	SS-15	3.00	18	16	15	27	24	36	23	13	11	A-6a (4)	
		53 54 55 56 57	11 19 15	51	69	SS-16	4.00	-	-	-	-	-	-	-	-	13	A-6a (V)	
		58 59 60 61	11 10 21	47	72	SS-17	4.00	-	-	-	-	-	-	-	-	10	A-6a (V)	

PID: 98232 | SFN: | PROJECT: FRA-070-22.85 | STATION / OFFSET: 3107.36, 86' RT. | START: 9/11/20 | END: 9/11/20 | PG 3 OF 3 | B-069-0-19

MATERIAL DESCRIPTION AND NOTES	ELEV. 735.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG				ODOT CLASS (GI)	BACK FILL
								GR	CS	FS	SI	CL	LL	PL	PI	WC		
VERY STIFF, GRAY, **SILT AND CLAY**, SOME SAND, LITTLE GRAVEL, DAMP *(continued)*		63 64 65	11 15 13	42	56	SS-18	4.00	-	-	-	-	-	-	-	-	22	A-6a (V)	
	730.8	66																
VERY STIFF, BROWNISH GRAY, **CLAY**, SOME SILT, TRACE GRAVEL, MOIST TO WET ---VARVED LAYERS---		67 68 69 70	5 7 10	26	100	SS-19	3.00	1	0	0	25	74	47	23	24	24	A-7-6 (15)	
		71 72 73																
	722.8	74 EOB 75	4 5 8	20	100	SS-20	2.50	-	-	-	-	-	-	-	-	30	A-7-6 (V)	

NOTES: BORING WAS RELOCATED 12.0 FEET NORTH, 21.0 FEET EAST DUE TO INACCESSIBLE BORING LOCATION

ABANDONMENT METHODS, MATERIALS, QUANTITIES: POURED BENTONITE GROUT

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-070-22.85	DRILLING FIRM / OPERATOR: RII / SB	DRILL RIG: CME 750X (SN 310218)	STATION / OFFSET: 31+88.29 / 77.5' RT	**EXPLORATION ID** **B-070-0-19**
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: RII / KS	HAMMER: AUTOMATIC	ALIGNMENT: CL CONST. BRICE RD	
PID: 98232 SFN: 2505738	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 9/14/20	ELEVATION: 796.6 (MSL) EOB: 75.0 ft.	PAGE
START: 8/25/20 END: 8/25/20	SAMPLING METHOD: SPT	ENERGY RATIO (%): 86.2	LAT / LONG: 39.933031, -82.830456	1 OF 3

MATERIAL DESCRIPTION AND NOTES	ELEV. 796.6	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
0.7' - TOPSOIL (8.0")	795.9																	
VERY STIFF TO HARD, BROWN **SANDY SILT**, SOME FINE GRAVEL, LITTLE CLAY, DAMP TO MOIST.		1 2	4 3 4	10	61	SS-1	4.50	-	-	-	-	-	-	-	-	10	A-4a (V)	
		3 4 5	5 4 5	13	44	SS-2	4.00	-	-	-	-	-	-	-	-	19	A-4a (V)	
		6 7	6 5 4	13	83	SS-3	4.50	21	18	10	32	19	25	17	8	13	A-4a (3)	
	786.1	8 9 10	8 7 6	19	67	SS-4	3.00	-	-	-	-	-	-	-	-	13	A-4a (V)	
MEDIUM DENSE, GRAY **GRAVEL WITH SAND AND SILT**, TRACE CLAY, MOIST. -COBBLES @ 13.0'	783.6	W 11 12	10 8 9	24	61	SS-5	-	-	-	-	-	-	-	-	-	8	A-2-4 (V)	
MEDIUM DENSE TO DENSE, GRAY **GRAVEL WITH SAND, SILT, AND CLAY**, MOIST TO WET.		W 783.1 13 14 15	12 10 24	49	67	SS-6	-	-	-	-	-	-	-	-	-	11	A-2-6 (V)	
		16 17	8 9 6	22	50	SS-7	-	-	-	-	-	-	-	-	-	12	A-2-6 (V)	
		18 19	9 8 10	26	0	SS-8	-	-	-	-	-	-	-	-	-	-	A-2-6 (V)	
-SANDSTONE FRAGMENTS IN SS-8A	775.6	20	10	-	100	2S-8A	-	-	-	-	-	-	-	-	-	-		
MEDIUM DENSE, GRAY **COARSE AND FINE SAND**, TRACE FINE GRAVEL, TRACE SILT, WET.	773.6	21 22	17 9 8	24	44	SS-9	-	-	-	-	-	-	-	-	-	11	A-3a (V)	
MEDIUM DENSE TO VERY DENSE, GRAY **GRAVEL**, TRACE COARSE TO FINE SAND, TRACE SILT, WET.		23 24 25	33 22 25	68	44	SS-10	-	-	-	-	-	-	-	-	-	11	A-1-a (V)	
	768.6	26 27	3 14 8	32	61	SS-11	-	-	-	-	-	-	-	-	-	12	A-1-a (V)	
VERY STIFF TO HARD, GRAY **SANDY SILT**, SOME FINE GRAVEL, LITTLE CLAY, DAMP TO MOIST.		28 29	6 7 10	24	94	SS-12	4.50	-	-	-	-	-	-	-	-	13	A-4a (V)	

PID: 98232	SFN:	PROJECT: FRA-070-22.85	STATION / OFFSET: 3188.29, 78' RT.	START: 8/25/20	END: 8/25/20	PG 2 OF 3	B-070-0-19

MATERIAL DESCRIPTION AND NOTES	ELEV. 766.6	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
VERY STIFF TO HARD, GRAY **SANDY SILT**, SOME FINE GRAVEL, LITTLE CLAY, DAMP TO MOIST. *(continued)*		31 32 33																
		34 35	6 9 12	30	89	SS-13	4.00	-	-	-	-	-	-	-	-	14	A-4a (V)	
		36 37 38																
		39 40	21 14 11	36	72	SS-14	4.50	23	13	14	31	19	22	15	7	12	A-4a (3)	
-COBBLES @ 42.5'	754.6	41 42																
VERY STIFF TO HARD, GRAY **SANDY SILT**, SOME CLAY, TRACE TO LITTLE FINE GRAVEL, DAMP TO MOIST.		43																
		44 45	33 14 10	34	67	SS-15	4.50	-	-	-	-	-	-	-	-	12	A-4a (V)	
		46 47 48																
		49 50	12 16 49	93	72	SS-16	4.50	6	13	15	38	28	23	15	8	10	A-4a (6)	
-COBBLES @ 51.0'		51 52 53																
		54 55	30 30 36	95	33	SS-17	2.00	-	-	-	-	-	-	-	-	15	A-4a (V)	
		56 57 58																
		59 60	47 38 35	105	78	SS-18	4.50	-	-	-	-	-	-	-	-	9	A-4a (V)	
		61																

PID: 98232 | SFN: | PROJECT: FRA-070-22.85 | STATION / OFFSET: 3188.29, 78' RT. | START: 8/25/20 | END: 8/25/20 | PG 3 OF 3 | B-070-0-19

MATERIAL DESCRIPTION AND NOTES	ELEV. 734.5	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG				ODOT CLASS (GI)	HOLE SEALED
								GR	CS	FS	SI	CL	LL	PL	PI	WC		
VERY STIFF TO HARD, GRAY **SANDY SILT**, SOME CLAY, TRACE TO LITTLE FINE GRAVEL, DAMP TO MOIST. *(continued)*		63 64 65	9 10 13	33	50	SS-19	3.50	13	12	16	31	28	24	14	10	17	A-4a (5)	
	729.6	66 67																
VERY STIFF TO HARD, GRAY **SILTY CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST.		68 69 70	6 9 11	29	83	SS-20	4.50	-	-	-	-	-	-	-	-	27	A-6b (V)	
		71 72 73																
	721.6	74 EOB 75	6 8 10	26	50	SS-21	2.50	-	-	-	-	-	-	-	-	19	A-6b (V)	

NOTES: SEEPAGE @ 11.0'; GROUNDWATER ENCOUNTERED INITIALLY @ 13.5'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 94 LBS CEMENT / 50 LBS BENTONITE POWDER / 20 GAL WATER .

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-070-22.85	DRILLING FIRM / OPERATOR: RII / LARRY	DRILL RIG: CME 55 (386345)	STATION / OFFSET: 1586+63.41 / 59' RT
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: DHDC / GANESH	HAMMER: AUTOMATIC	ALIGNMENT: BL IR 70 WB-CD
PID: 98232 SFN: 2505738	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 9/4/18	ELEVATION: 820.7 (MSL) EOB: 75.0 ft.
START: 9/21/20 END: 9/21/20	SAMPLING METHOD: SPT	ENERGY RATIO (%): 90	LAT / LONG: 39.933291, -82.830827

EXPLORATION ID
B-071-0-19

PAGE
1 OF 3

MATERIAL DESCRIPTION AND NOTES	ELEV. 820.7	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
ASPHALT (13") & **GRANULAR BASE** (5")	819.2	1																
FILL: VERY STIFF, DARK BROWN OR BROWN, **SILTY CLAY**, LITTLE TO SOOME SAND, TRACE TO LITTLE GRAVEL, MOIST ---CONTAINS BLUISH GRAY STAINING--- ---CONTAINS ROCK FRAGMENTS--- @18.5'-22.5'; ROCK FRAGMENTS		2 3	6 5 8	20	58	SS-1	4.00	-	-	-	-	-	-	-	-	13	A-6b (V)	
		4 5	3 5 5	15	56	SS-2	4.00	-	-	-	-	-	-	-	-	13	A-6b (V)	
		6 7	5 6 9	23	22	SS-3A	4.00	-	-	-	-	-	-	-	-	14	A-6b (V)	
		8	10	-	100	SS-3B	4.00	-	-	-	-	-	-	-	-	15	A-6b (V)	
		9 10	9 10 13	35	67	SS-4	4.00	-	-	-	-	-	-	-	-	12	A-6b (V)	
		11 12 13	3 4 8	18	64	SS-5	4.00	11	10	15	32	32	35	19	16	13	A-6b (8)	
		14	12 10 10	30	0	SS-6A	-	-	-	-	-	-	-	-	-	-	A-6b (V)	
		15	7	-	58	SS-6B	4.00	-	-	-	-	-	-	-	-	16	A-6b (V)	
		16 17 18	7 7 11	27	33	SS-7	4.00	-	-	-	-	-	-	-	-	10	A-6b (V)	
		19 20	50/5"	-	100	SS-8	4.00	-	-	-	-	-	-	-	-	12	A-6b (V)	
		21 22	15 10 18	42	0	SS-9A	-	-	-	-	-	-	-	-	-	-	A-6b (V)	
	797.2	23	11	-	33	SS-9B	-	-	-	-	-	-	-	-	-	10	A-6b (V)	
FILL: VERY STIIFF, GRAY, **SILT AND CLAY**, SOME SAND, LITTLE GRAVEL, WET		24 25 26 27 28	11 18 18	54	78	SS-10	4.00	11	10	16	32	31	34	19	15	11	A-6a (8)	
		29	6 10 11	32	67	SS-11	4.00	-	-	-	-	-	-	-	-	12	A-6a (V)	

PID: 98232	SFN:	PROJECT: FRA-070-22.85	STATION / OFFSET: 158663.41, 59' RT.	START: 9/21/20	END: 9/21/20	PG 2 OF 3	B-071-0-19

MATERIAL DESCRIPTION AND NOTES	ELEV. 790.7	DEPTHS		SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL
									GR	CS	FS	SI	CL	LL	PL	PI			
FILL: VERY STIIFF, GRAY, **SILT AND CLAY**, SOME SAND, LITTLE GRAVEL, WET *(continued)*	788.7		31 32																
STIFF, GRAY, **SILT AND CLAY**, LITTLE SAND, LITTLE GRAVEL, WET		W 786.7	33 34 35	10 13 11	36	72	SS-12	1.50	-	-	-	-	-	-	-	-	19	A-6a (V)	
	783.7	▼	36 37																
DENSE, GRAY, **GRAVEL AND/OR STONE FRAGMENTS** WITH SAND AND SILT, WET			38 39 40	11 13 12	38	89	SS-13	-	-	-	-	-	-	-	-	-	12	A-2-4 (V)	
			41 42 43 44 45	14 10 12	33	89	SS-14	-	30	37	4	- 29 -		NP	NP	NP	14	A-2-4 (0)	
			46 47 48 49 50	14 15 15	45	72	SS-15	-	-	-	-	-	-	-	-	-	12	A-2-4 (V)	
	768.7		51 52																
VERY STIFF, GREENISH GRAY TO GRAY, **SILTY CLAY**, AND SAND, LITTLE GRAVEL, DAMP			53 54 55	16 5 9	21	61	SS-16	3.50	-	-	-	-	-	-	-	-	17	A-6b (V)	
			56 57 58 59 60	4 9 9	27	44	SS-17	2.50	10	13	24	29	24	39	21	18	18	A-6b (7)	
			61																

PID: 98232 | SFN: | PROJECT: FRA-070-22.85 | STATION / OFFSET: 158663.41, 59' RT. | START: 9/21/20 | END: 9/21/20 | PG 3 OF 3 | B-071-0-19

MATERIAL DESCRIPTION AND NOTES	ELEV. 758.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL
								GR	CS	FS	SI	CL	LL	PL	PI			
VERY STIFF, GREENISH GRAY TO GRAY, **SILTY CLAY**, AND SAND, LITTLE GRAVEL, DAMP *(continued)*		63																
		64 – 65	8 14 24	57	56	SS-18	4.00	-	-	-	-	-	-	-	-	13	A-6b (V)	
		66 67 68																
		69 – 70	15 13 16	44	67	SS-19	4.00	14	10	13	32	31	34	18	16	12	A-6b (8)	
		71 72 73																
	745.7	74 – EOB 75	14 15 15	45	44	SS-20	4.00	-	-	-	-	-	-	-	-	17	A-6b (V)	

NOTES: BORING WAS RELOCATED 32.0 FEET NORTH AND 5.0 FEET EAST DUE TO OVERHEAD UTILITIES AND OBSTRUCTIONS.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: USED ASPHALT PATCH; POURED BENTONITE GROUT

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-070-22.85	DRILLING FIRM / OPERATOR: RII / LARRY	DRILL RIG: CME 55 (386345)	STATION / OFFSET: 32+61.92 / 42.7' RT
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: DHDC / GANESH	HAMMER: AUTOMATIC	ALIGNMENT: CL CONST. BRICE RD
PID: 98232 SFN: 2505738	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 9/4/18	ELEVATION: 820.8 (MSL) EOB: 75.0 ft.
START: 9/21/20 END: 9/22/20	SAMPLING METHOD: SPT	ENERGY RATIO (%): 90	LAT / LONG: 39.933239, -82.830560

EXPLORATION ID
B-072-0-19

PAGE
1 OF 3

MATERIAL DESCRIPTION AND NOTES	ELEV. 820.8	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
ASPHALT (11.5") & **GRANULAR BASE** (4.5")	819.4	1																
FILL: VERY STIFF, DARK BROWN TO GRAYISH BROWN, **SILT AND CLAY**, LITTLE TO SOME SAND, TRACE TO LITTLE GRAVEL, MOIST ---ROCK FRAGMENTS IN SAMPLE---		2 3	6 7 9	24	86	SS-1	4.00	-	-	-	-	-	-	-	-	11	A-6a (V)	
		4 5	8 6 12	27	56	SS-2	4.00	-	-	-	-	-	-	-	-	14	A-6a (V)	
		6 7	10 4 7	17	64	SS-3	4.00	-	-	-	-	-	-	-	-	20	A-6a (V)	
		8 9 10	5 7 7	21	89	SS-4	4.00	-	-	-	-	-	-	-	-	10	A-6a (V)	
		11 12 13	5 6 8	21	100	SS-5	4.00	11	9	15	32	33	35	20	15	18	A-6a (8)	
		14 15	5 5 8	20	72	SS-6	4.00	-	-	-	-	-	-	-	-	14	A-6a (V)	
		16 17 18	7 7 10	26	72	SS-7	4.00	-	-	-	-	-	-	-	-	17	A-6a (V)	
		19 20	7 9 10	29	64	SS-8	4.00	-	-	-	-	-	-	-	-	11	A-6a (V)	
@22.0'; POSSIBLE ROCK FRAGMENTS		21 22 23	6 32 12	66	33	SS-9	4.00	11	12	16	31	30	36	23	13	17	A-6a (6)	
@23.5'-25.0'; BRICK FRAGMENTS IN SAMPLE		24 25	6 8 13	32	67	SS-10	4.00	-	-	-	-	-	-	-	-	21	A-6a (V)	
	793.3	26 27																
VERY STIFF, MOTTLED BROWN AND GRAY, **SILT AND CLAY**, AND SAND, TRACE GRAVEL, MOIST		28 29	10 8 11	29	72	SS-11	4.00	3	29	9	24	35	35	22	13	17	A-6a (6)	

PID: 98232	SFN:	PROJECT: FRA-070-22.85	STATION / OFFSET: 3261.92, 43' RT.	START: 9/21/20	END: 9/22/20	PG 2 OF 3	B-072-0-19

MATERIAL DESCRIPTION AND NOTES	ELEV. 790.8	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
VERY STIFF, MOTTLED BROWN AND GRAY, **SILT AND CLAY**, AND SAND, TRACE GRAVEL, MOIST *(continued)*	789.3	31																
MEDIUM DENSE, MOTTLED BROWN AND GRAY, **GRAVEL AND/OR STONE FRAGMENTS WITH SAND AND SILT**, MOIST	783.8	34	3 4 8	18	56	SS-12	-	-	-	-	-	-	-	-	-	15	A-2-4 (V)	
DENSE, BROWN AND GRAY TO GRAY, **GRAVEL AND/OR STONE FRAGMENTS WITH SAND**, TRACE SILT, TRACE CLAY, WET ---SAMPLES ARE MOSTLY STONE FRAGMENTS---	773.8	W 782.1 39	5 12 10	33	56	SS-13	-	38	28	9	- 25 -		NP	NP	NP	18	A-1-b (0)	
		44	5 10 12	33	78	SS-14	-	-	-	-	-	-	-	-	-	10	A-1-b (V)	
VERY DENSE, BLACKISH GRAY, **GRAVEL AND/OR STONE FRAGMENTS WITH SAND AND SILT**, WET ---SHALE FRAGMENTS IN SAMPLE---	768.8	49	17 12 36	72	89	SS-15	-	-	-	-	-	-	-	-	-	13	A-2-4 (V)	
HARD, GRAY, **SILT AND CLAY**, SOME SAND, TRACE GRAVEL, WET	763.8	54	15 12 20	48	78	SS-16	4.00	10	8	20	39	23	31	18	13	12	A-6a (7)	
VERY STIFF, GRAY, **SANDY SILT**, TRACE GRAVEL, WET ---BLACK ORGANICS IN SAMPLE---	758.8	59	4 5 12	26	89	SS-17	4.00	-	-	-	-	-	-	-	-	20	A-4a (V)	

PID: 98232	SFN:	PROJECT: FRA-070-22.85	STATION / OFFSET: 3261.92, 43' RT.	START: 9/21/20	END: 9/22/20	PG 3 OF 3	B-072-0-19

MATERIAL DESCRIPTION AND NOTES	ELEV. 758.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
VERY DENSE, GRAY, **GRAVEL AND/OR STONE FRAGMENTS WITH SAND AND SILT**, TRACE CLAY, WET CONTAIINS SANDY SILT SEAMS *(continued)* @63.0'; POSSIBLE BOULDER		63																
		64 65	15 47 24	107	72	SS-18	-	32	20	15	- 33 -		NP	NP	NP	15	A-2-4 (0)	
		66 67 68																
		69	50/5"	-	0	SS-19	-	-	-	-	-	-	-	-	-	-	A-2-4 (V)	
		70 71 72 73																
		74	50/4"	-	75	SS-20	-	-	-	-	-	-	-	-	-	16	A-2-4 (V)	
	745.8	EOB 75																

NOTES: BORING WAS RELOCATED 20.0 FEET NORTH, 1.0 FEET WEST DUE TO OVERHEAD UTILITIES.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: USED ASPHALT PATCH; POURED BENTONITE GROUT

APPENDIX IV

HISTORIC BORING LOGS:

B-003-0-65 and B-007-0-65

LOG OF BORING

Date Started 4-23-65
Date Completed 4-27-65
Boring No. B-3

Sampler Type SS Dia. 1 3/8"
Casing: Length 20' Dia. 3 1/2"
Station & Offset 19+04, 48' Lt (REAR PIER)

Water Elev.
Surface Elev. 790.8'

Elev.	Depth	Std. Pen. (N)	Rec. ft.	Loss ft.	Description	Sample No.	Physical Characteristics % Agg.	% C.S.	% F.S.	% Silt	% Clay	L.L.	P.I.	W.C.	SHTL Class.
790.8	0														
	2														
	4														
785.8	6	16/10			Brown Sandy Clayey Gravel	1	V	I	S U	A	L			12	
783.3	8	14/10			Brown Clayey Sandy Gravel	2	V	I	S U	A	L			27	
780.8	10	16/10			Gray Silty Sandy Gravel	3	52	18	10	-20-		NP	NP	11	
778.3	12	18/19			Gray Sandy Gravel	4	80	18	1	-1-		NP	NP	9	
	14														
775.8	16	50* (0.8')			Gray Silty Sandy Gravel	5	66	15	6	-13-		NP	NP	4	
773.3	18	36/48			Gray Silty Gravel	6	76	10	4	-10-		NP	NP	14	
770.8	20	10/13			Gray Gravelly Sandy Silt	7	21	9	14	26	30	24	9	18	
768.3	22	11/13			Gray Sandy Gravelly Silt	8	25	9	12	27	27	22	6	10	
	24														
765.8	26	11/15			Gray Gravelly Sandy Silt	9	17	7	13	33	30	22	6	11	
	28														
760.8	30	12/22			Gray Silt and Clay	10	9	2	8	32	49	29	11	10	
	32														
	34														
755.8	36	17/19			Gray Sandy Silt	11	11	5	18	34	32	24	9	11	
	38														
750.8	40	14/20			Gray Sandy Silt	12	11	8	13	32	36	24	8	6	
	42	B-3													
	44														
745.8	46	12/19			Gray Gravelly Clay	13	27	5	6	23	39	30	12	13	
	48														
740.8	50	15/20			Gray Silty Clay	14	0	2	2	31	65	39	18	16	
	52														
	54														
735.8	56	16/15			Gray Silt	15	0	0	1	63	36	NP	NP	15	
	58														
730.8	60				BOTTOM OF BORING										
729.8		16/22			Gray Sandy Clay	16	14	8	12	31	35	26	12	21	

*Refusal

No. 10 sieve

LOG OF BORING

Date Started 4-27-65
Date Completed 4-28-65
Boring No. B-7

Sampler Type SS Dia. 1 3/8"
Casing: Length 25' Dia. 3 1/2"
Station & Offset 20+81, 48' Lt (FORWARD PIER)

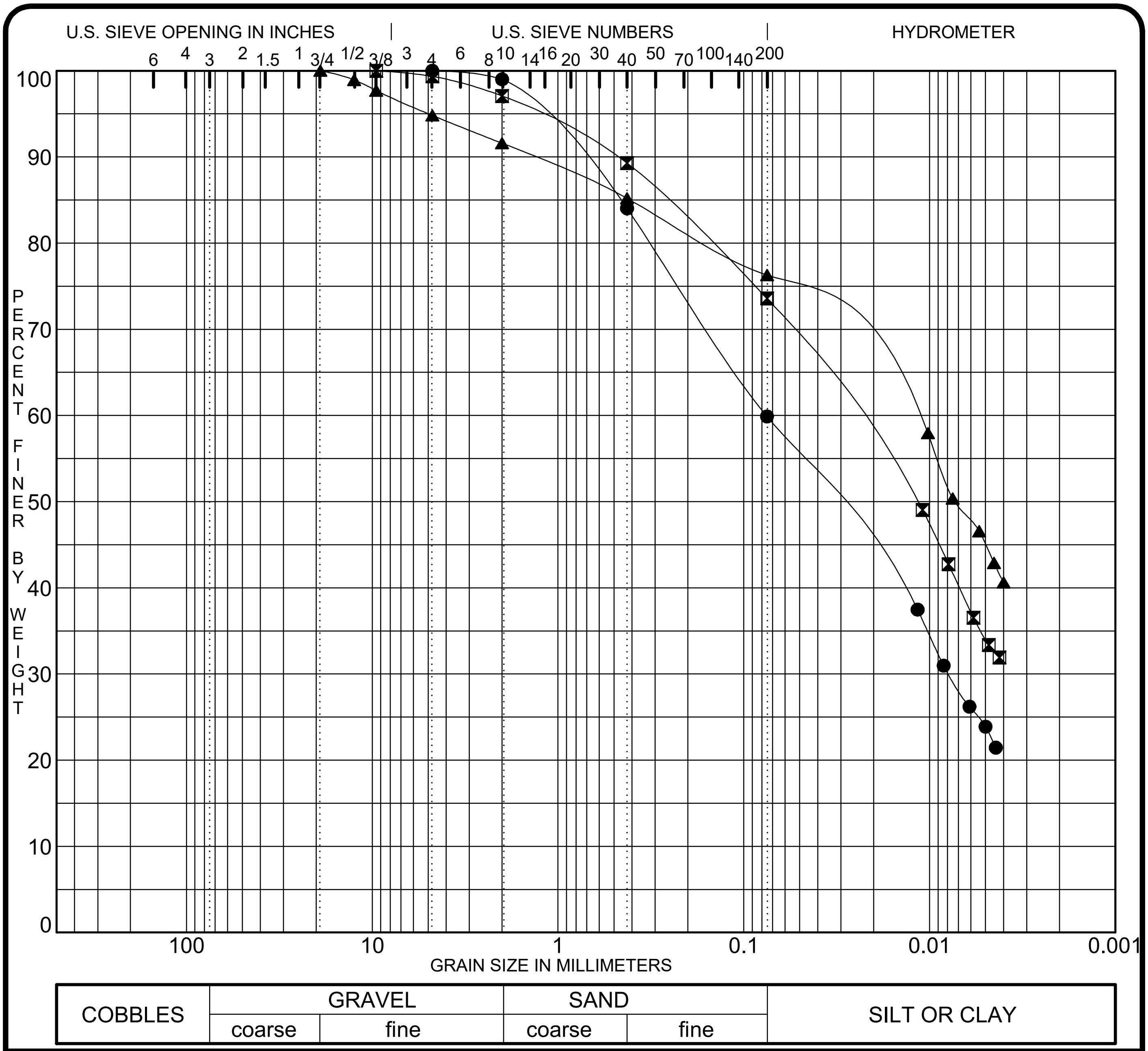
Water Elev.
Surface Elev. 793.4'

Elev.	Depth	Std. Pen. (N)	Rec. ft.	Loss ft.	Description	Sample No.	% Agg.	% C.S.	% F.S.	% Silt	% Clay	L.L.	P.I.	W.C.	SHTL Class.
793.4	0														
	2														
	4														
788.4	6	23/20			Brown Silty Sandy Gravel	1	63	15	3	11	8	28	8	13	
785.9	8	13/18			Brown Sandy Gravel	2	79	15	3	-3-		NP	NP	9	
783.4	10														
		33/32			Brown Sandy Gravel	3	74	15	4	-7-		NP	NP	11	
780.9	12	50* (0.4')			Gray Sandy Gravel	4	68	18	6	-8-		NP	NP	3	
	14														
778.4															
	16	17/31			Gray Silty Sandy Gravel	5	64	18	5	-13-		NP	NP	9	
775.9	18				No Sample Recovered - Boulder.										
773.4	20														
		13/24			Gray Gravelly Clay	6	V	I	S	U	A	L	31	16	7	
770.9	22														
	24	12/21			Brown Gravelly Clay	7	V	I	S	U	A	L	32	16	10	
768.4															
	26	16/17			Brown Silty Sandy Gravel	8	V	I	S	U	A	L			8	
	28														
763.4	30														
	32	22/31			Gray Sandy Gravelly Silt	9	27	9	14	31	19	22	8	11	
	34														
758.4	36	21/34			Gray Silty Sandy Gravel	10	47	8	9	17	19	22	6	10	
	38														
753.4	40				BOTTOM OF BORING										
752.4		13/26			Gray Gravelly Silt	11	30	9	5	30	26	23	9	11	

*Refusal

APPENDIX V

LAB TEST RESULTS



	Specimen Identification	Depth	Classification	MC%	LL	PL	PI	Cz	Cu
●	**B-066-0-19**	**11.0**	**A-4a**	**29**	**24**	**18**	**6**		
☒	**B-066-0-19**	**33.5**	**A-4a**	**14**	**24**	**15**	**9**		
▲	**B-066-0-19**	**53.5**	**A-6a**	**16**	**29**	**17**	**12**		

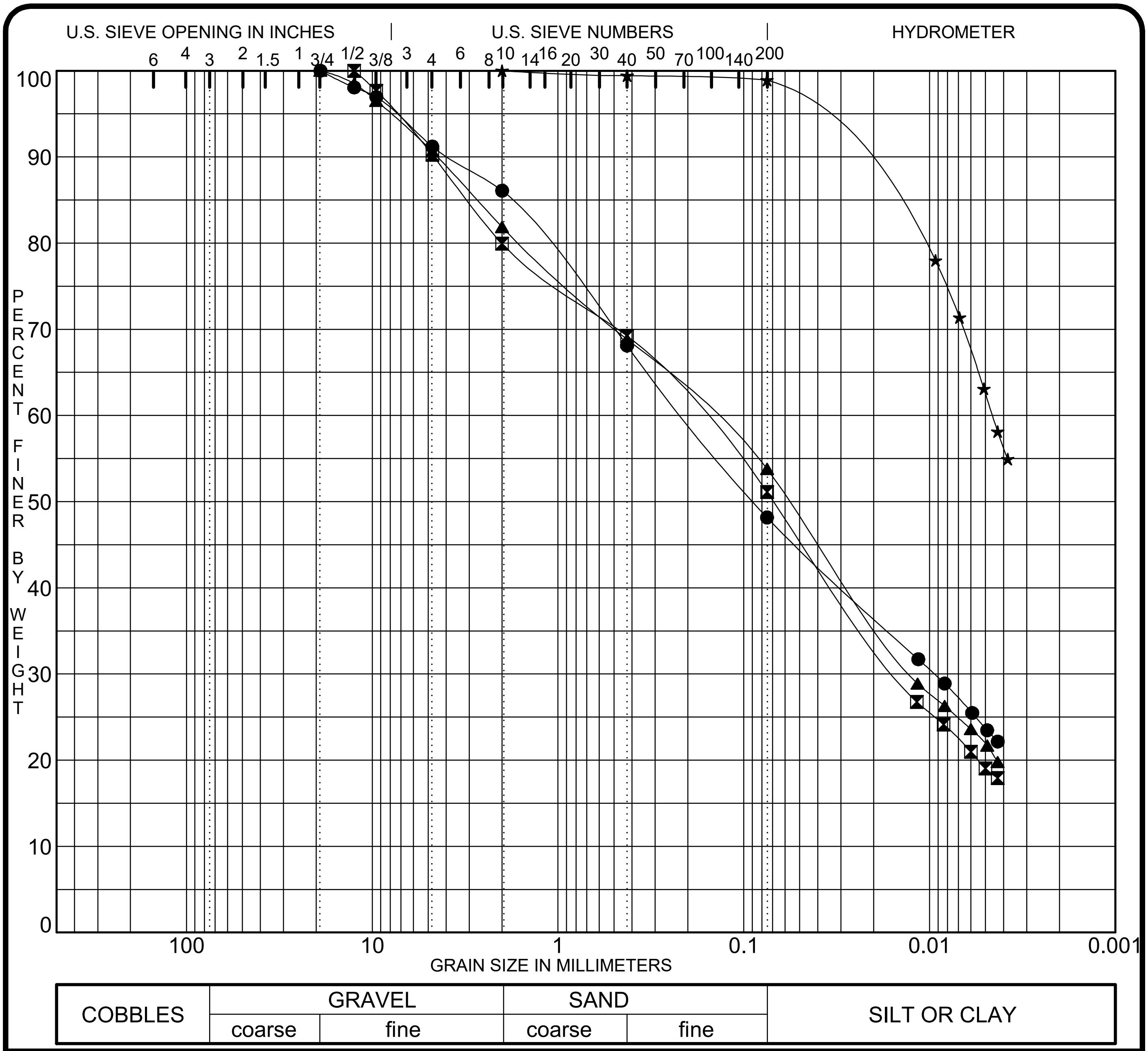
	Specimen Identification	D60	D50	D30	D10	%Gravel		%Sand		%Silt	%Clay
						coarse	fine	coarse	fine		
●	**B-066-0-19**	**0.469**	**0.033**	**0.008**		**0.0**	**1.0**	**15.0**	**24.2**	**36.0**	**23.9**
☒	**B-066-0-19**	**0.265**	**0.012**			**0.0**	**2.9**	**7.8**	**15.7**	**39.5**	**34.1**
▲	**B-066-0-19**	**0.409**	**0.007**			**0.0**	**8.4**	**6.4**	**8.9**	**31.3**	**45.0**

PROJECT **FRA-070-22.85**

PROJECT NO. **W-17-140**

GRADATION CURVES

RESOURCE INTERNATIONAL, INC



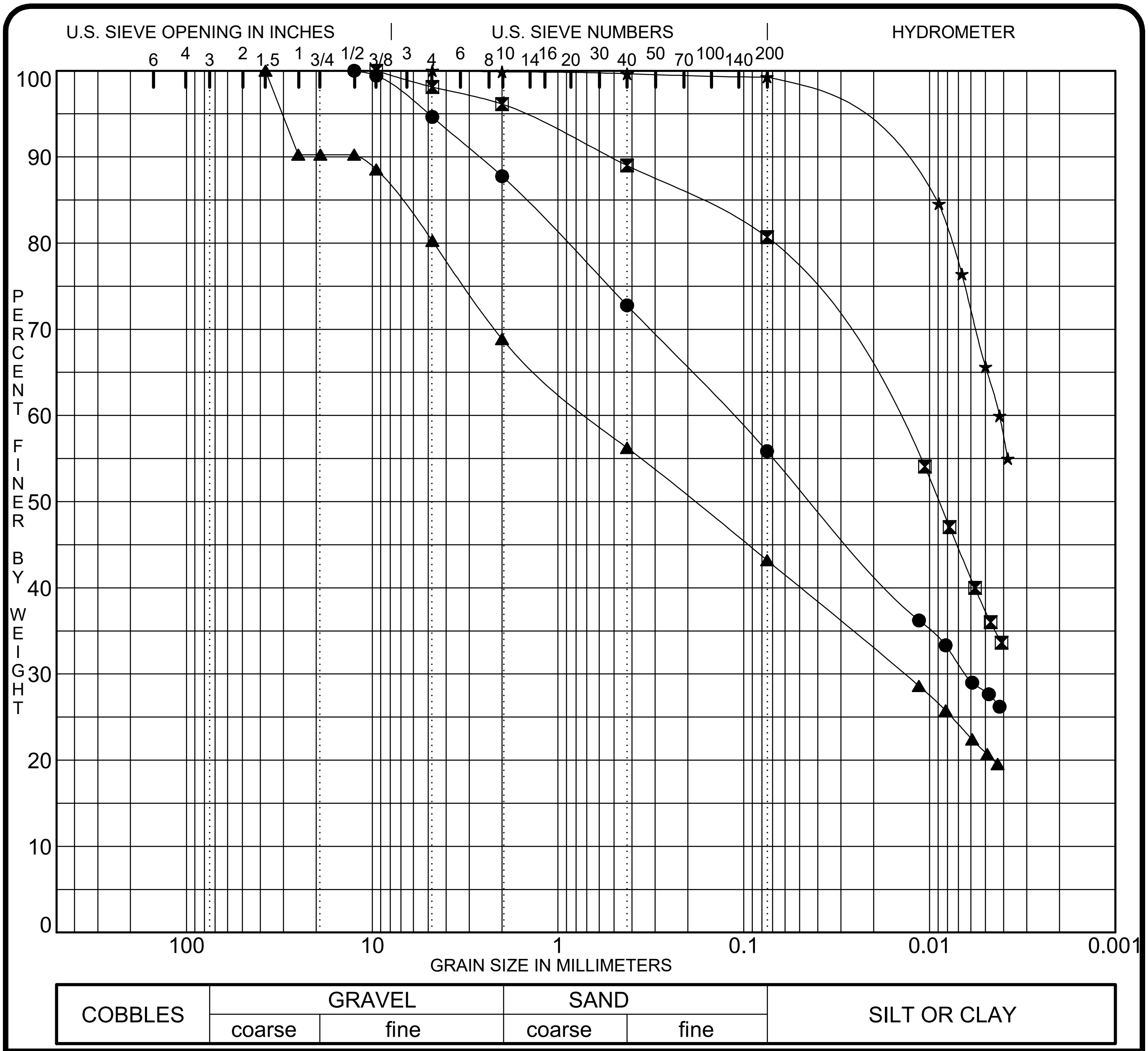
Specimen Identification		Depth	Classification	MC%	LL	PL	PI	Cz	Cu
●	**B-067-0-19A**	**6.0**	**A-6b**	**23**	**37**	**20**	**17**		
⧗	**B-067-0-19A**	**33.5**	**A-4a**	**14**	**25**	**16**	**9**		
▲	**B-067-0-19A**	**48.5**	**A-4a**	**11**	**22**	**14**	**8**		
★	**B-067-0-19A**	**68.5**	**A-6b**	**25**	**38**	**22**	**16**		

Specimen Identification		D60	D50	D30	D10	%Gravel		%Sand		%Silt	%Clay
						coarse	fine	coarse	fine		
●	**B-067-0-19A**	**1.822**	**0.088**	**0.009**		**0.0**	**13.9**	**18.0**	**19.9**	**24.5**	**23.7**
⧗	**B-067-0-19A**	**3.058**	**0.069**	**0.015**		**0.0**	**20.1**	**10.7**	**18.1**	**32.1**	**19.0**
▲	**B-067-0-19A**	**2.727**	**0.056**	**0.013**		**0.0**	**18.1**	**13.0**	**15.0**	**31.9**	**21.9**
★	**B-067-0-19A**	**0.019**				**0.0**	**0.0**	**0.6**	**0.5**	**36.4**	**62.5**

PROJECT **FRA-070-22.85** PROJECT NO. **W-17-140**

GRADATION CURVES

RESOURCE INTERNATIONAL, INC



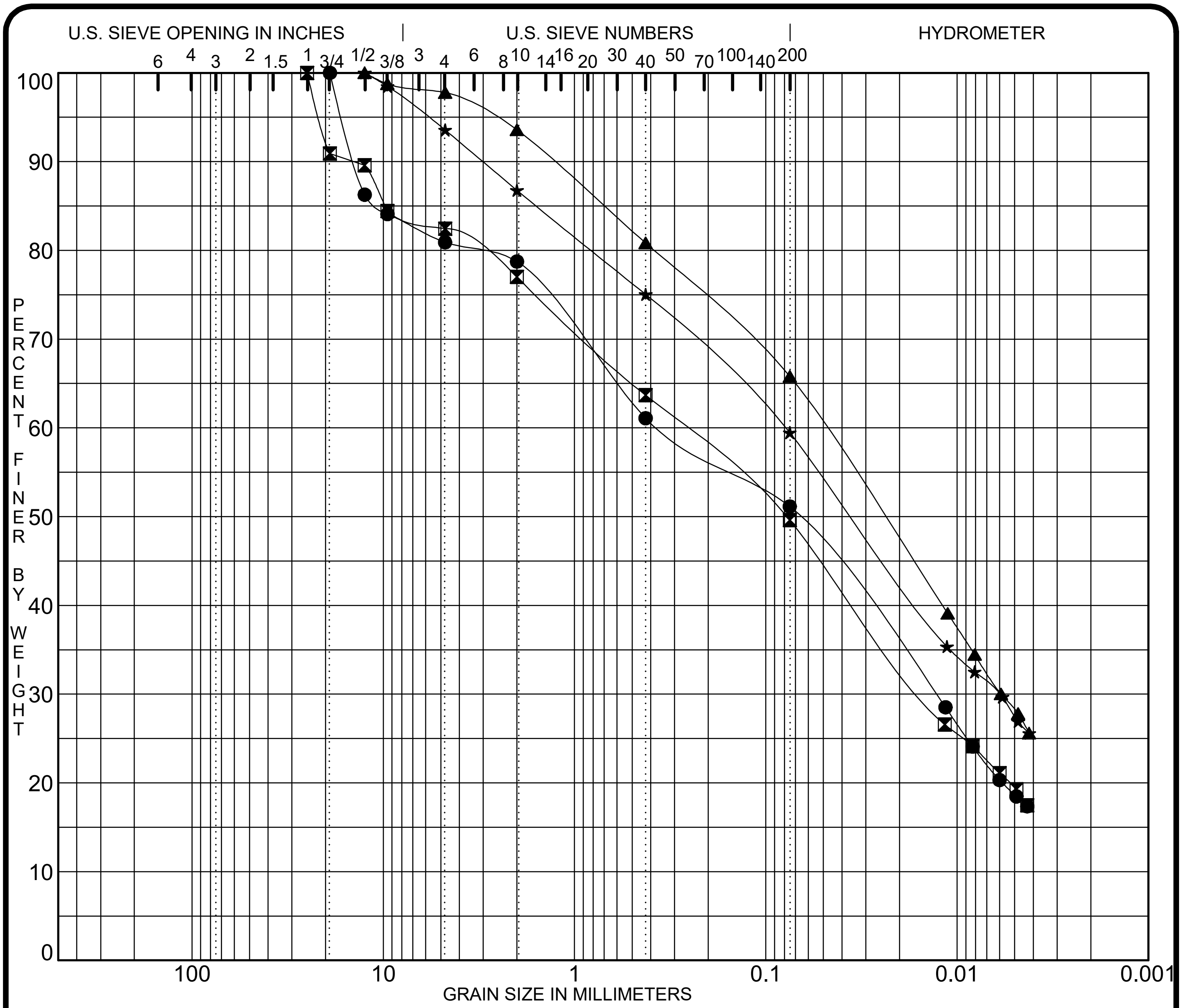
Specimen Identification		Depth	Classification	MC%	LL	PL	PI	Cz	Cu
●	**B-068-0-19**	**3.5**	**A-6a**	**15**	**32**	**17**	**15**		
⧗	**B-068-0-19**	**8.5**	**A-7-6**	**29**	**43**	**25**	**18**		
▲	**B-068-0-19**	**33.5**	**A-4a**	**14**	**22**	**15**	**7**		
★	**B-068-0-19**	**58.5**	**A-6a**	**22**	**35**	**21**	**14**		

Specimen Identification		D60	D50	D30	D10	%Gravel		%Sand		%Silt	%Clay
						coarse	fine	coarse	fine		
●	**B-068-0-19**	**1.504**	**0.043**	**0.006**		**0.0**	**12.2**	**15.0**	**16.9**	**27.9**	**27.9**
⧗	**B-068-0-19**	**0.184**	**0.009**			**0.0**	**3.9**	**7.1**	**8.3**	**43.4**	**37.3**
▲	**B-068-0-19**	**7.059**	**0.185**	**0.014**		**9.7**	**21.4**	**12.6**	**13.0**	**22.3**	**20.9**
★	**B-068-0-19**	**0.009**				**0.0**	**0.1**	**0.2**	**0.4**	**33.6**	**65.6**

PROJECT **FRA-070-22.85** PROJECT NO. **W-17-140**

GRADATION CURVES

RESOURCE INTERNATIONAL, INC



COBBLES	GRAVEL		SAND		SILT OR CLAY
	coarse	fine	coarse	fine	

	Specimen Identification	Depth	Classification	MC%	LL	PL	PI	Cz	Cu
●	**B-070-0-19**	**6.0**	**A-4a**	**13**	**25**	**17**	**8**		
⧗	**B-070-0-19**	**38.5**	**A-4a**	**12**	**22**	**15**	**7**		
▲	**B-070-0-19**	**48.5**	**A-4a**	**10**	**23**	**15**	**8**		
★	**B-070-0-19**	**63.5**	**A-4a**	**17**	**24**	**14**	**10**		

	Specimen Identification	D60	D50	D30	D10	%Gravel		%Sand		%Silt	%Clay
						coarse	fine	coarse	fine		
●	**B-070-0-19**	**10.655**	**0.068**	**0.013**		**0.0**	**21.3**	**17.7**	**9.9**	**32.5**	**18.7**
⧗	**B-070-0-19**	**9.793**	**0.079**	**0.015**		**9.1**	**13.9**	**13.3**	**14.1**	**30.1**	**19.5**
▲	**B-070-0-19**	**0.705**	**0.024**	**0.006**		**0.0**	**6.4**	**12.7**	**15.0**	**37.6**	**28.2**
★	**B-070-0-19**	**1.583**	**0.036**	**0.006**		**0.0**	**13.2**	**11.7**	**15.6**	**32.0**	**27.5**

PROJECT **FRA-070-22.85** PROJECT NO. **W-17-140**

GRADATION CURVES

RESOURCE INTERNATIONAL, INC

APPENDIX VI

DRIVENPILES ANALYSIS OUTPUT

Rear Abutment
Boring B-066-0-19

DrivenPiles - Report

General Project Information

Filename: ...CE-04342 (Brice Road Bridge over IR 70)\FRA-00070-23.920 Brice Rd Bridge - RA (B-066-0-19).dvn
Project Name: FRA-00070-23.920 Brice Rd Bridge over IR-70 - Rear Abutment (B-066-0-19)
Project Client: EMH&T
Prepared By: Hanu S. Kulkarni, Ph.D., P.E.
Project Manager: Johnnatan P. Sterenberg, P.E.

Pile Information

Pile Type: Pipe Pile - Closed End
Top of Pile: 0.00 ft
Diameter of Pile: 12.00 in

Nominal Considerations

Water Table Depth At Time Of:

Drilling:	15.30 ft
Driving/Restrike:	15.30 ft
Nominal:	15.30 ft

Nominal Considations:

Local Scour:	0.00 ft
Long Term Scour:	0.00 ft
Soft Soil:	0.00 ft

Nominal Profile

Layer	Soil Type	Thickness	Setup Factor	Unit Weight	Strength	Nominal Curve
1	Cohesionless	16.30 ft	1.000	125.00 pcf	0.0/0.0	Nordlund
2	Cohesive	3.00 ft	1.500	115.00 pcf	875.00 psf	T-80 Same
3	Cohesive	5.00 ft	1.500	125.00 pcf	1250.00 psf	T-80 Same
4	Cohesive	5.00 ft	1.500	110.00 pcf	625.00 psf	T-80 Same
5	Cohesionless	2.50 ft	1.000	125.00 pcf	29.0/29.0	Nordlund
6	Cohesionless	5.00 ft	1.000	130.00 pcf	34.0/34.0	Nordlund
7	Cohesionless	2.50 ft	1.000	125.00 pcf	31.0/31.0	Nordlund
8	Cohesionless	4.00 ft	1.000	135.00 pcf	38.0/38.0	Nordlund
9	Cohesionless	5.00 ft	1.000	125.00 pcf	32.0/32.0	Nordlund
10	Cohesive	5.00 ft	1.500	125.00 pcf	3750.00 psf	T-80 Sand
11	Cohesive	3.00 ft	1.500	130.00 pcf	8000.00 psf	T-80 Same
12	Cohesive	17.00 ft	1.500	125.00 pcf	4875.00 psf	T-80 Same
13	Cohesive	13.00 ft	1.500	130.00 pcf	6250.00 psf	T-80 Same

Restrike: 267.7 kips
Driving: 217.07 kips

Factored Structural Load: 138 kips
Required UBV: 197 kips

Estimated Ground Surface Elevation: 801.7 ft-msl
Bottom of Footing Elevation: 810.3 ft-msl
Bottom of Wall (Top of Leveling Pad) Elevation: 794.0 ft-msl

Estimated Pile Top Elevation: 811.3 ft-msl
Estimated Pile Tip Elevation: 743.0 ft-msl

Embedment Depth Below Bottom of Footing Elevation: 67.3 ft

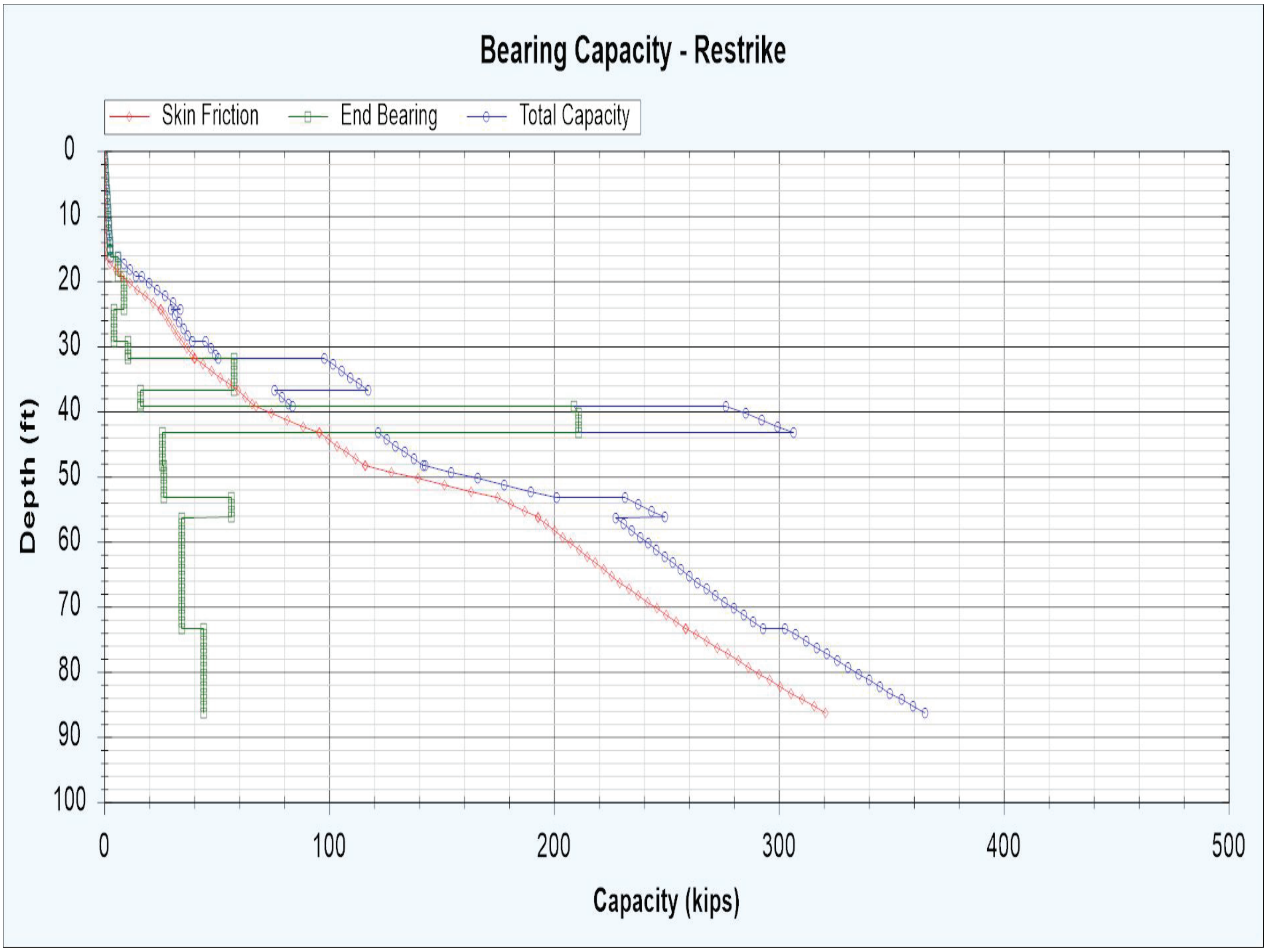
Estimated Pile Length: 70.0 ft

Restrike - Summary of Capacities

Depth	Skin Friction	End Bearing	Total Capacity
0.01 ft	0.00 kips	0.00 kips	0.00 kips
1.00 ft	0.00 kips	0.17 kips	0.17 kips
2.00 ft	0.00 kips	0.34 kips	0.34 kips
3.00 ft	0.00 kips	0.52 kips	0.52 kips
4.00 ft	0.00 kips	0.69 kips	0.69 kips
5.00 ft	0.00 kips	0.86 kips	0.86 kips
6.00 ft	0.00 kips	1.03 kips	1.03 kips
7.00 ft	0.00 kips	1.20 kips	1.20 kips
8.00 ft	0.00 kips	1.38 kips	1.38 kips
9.00 ft	0.00 kips	1.55 kips	1.55 kips
10.00 ft	0.00 kips	1.72 kips	1.72 kips
11.00 ft	0.00 kips	1.89 kips	1.89 kips
12.00 ft	0.00 kips	2.06 kips	2.06 kips
13.00 ft	0.00 kips	2.24 kips	2.24 kips
14.00 ft	0.00 kips	2.41 kips	2.41 kips
15.00 ft	0.00 kips	2.58 kips	2.58 kips
15.29 ft	0.00 kips	2.63 kips	2.63 kips
15.31 ft	0.00 kips	2.63 kips	2.63 kips
16.29 ft	0.00 kips	2.72 kips	2.72 kips
16.31 ft	0.03 kips	6.19 kips	6.21 kips
17.30 ft	2.59 kips	6.19 kips	8.77 kips
18.30 ft	5.18 kips	6.19 kips	11.36 kips
19.29 ft	7.74 kips	6.19 kips	13.93 kips
19.31 ft	7.80 kips	8.84 kips	16.64 kips
20.30 ft	11.24 kips	8.84 kips	20.07 kips
21.30 ft	14.70 kips	8.84 kips	23.54 kips
22.30 ft	18.17 kips	8.84 kips	27.01 kips
23.30 ft	21.64 kips	8.84 kips	30.47 kips
24.29 ft	25.07 kips	8.84 kips	33.91 kips
24.31 ft	25.12 kips	4.42 kips	29.54 kips
25.30 ft	27.00 kips	4.42 kips	31.42 kips
26.30 ft	28.90 kips	4.42 kips	33.32 kips
27.30 ft	30.80 kips	4.42 kips	35.22 kips
28.30 ft	32.70 kips	4.42 kips	37.12 kips
29.29 ft	34.58 kips	4.42 kips	39.00 kips
29.31 ft	34.62 kips	10.46 kips	45.08 kips
30.30 ft	36.78 kips	10.46 kips	47.24 kips
31.30 ft	39.01 kips	10.46 kips	49.47 kips
31.79 ft	40.12 kips	10.46 kips	50.58 kips
31.81 ft	40.18 kips	57.74 kips	97.92 kips
32.80 ft	43.84 kips	57.74 kips	101.58 kips
33.80 ft	47.63 kips	57.74 kips	105.37 kips

Depth	Skin Friction	End Bearing	Total Capacity
34.80 ft	51.50 kips	57.74 kips	109.24 kips
35.80 ft	55.46 kips	57.74 kips	113.20 kips
36.79 ft	59.47 kips	57.74 kips	117.21 kips
36.81 ft	59.54 kips	16.23 kips	75.77 kips
37.80 ft	62.61 kips	16.23 kips	78.84 kips
38.80 ft	65.78 kips	16.23 kips	82.01 kips
39.29 ft	67.36 kips	16.23 kips	83.59 kips
39.31 ft	67.46 kips	208.82 kips	276.28 kips
40.30 ft	74.24 kips	210.96 kips	285.19 kips
41.30 ft	81.23 kips	210.96 kips	292.19 kips
42.30 ft	88.37 kips	210.96 kips	299.33 kips
43.29 ft	95.58 kips	210.96 kips	306.54 kips
43.31 ft	95.70 kips	25.92 kips	121.61 kips
44.30 ft	99.58 kips	25.92 kips	125.50 kips
45.30 ft	103.57 kips	25.92 kips	129.49 kips
46.30 ft	107.63 kips	25.92 kips	133.55 kips
47.30 ft	111.76 kips	25.92 kips	137.68 kips
48.29 ft	115.91 kips	25.92 kips	141.83 kips
48.31 ft	116.07 kips	26.51 kips	142.58 kips
49.30 ft	127.73 kips	26.51 kips	154.24 kips
50.30 ft	139.51 kips	26.51 kips	166.02 kips
51.30 ft	151.29 kips	26.51 kips	177.80 kips
52.30 ft	163.07 kips	26.51 kips	189.58 kips
53.29 ft	174.74 kips	26.51 kips	201.24 kips
53.31 ft	174.92 kips	56.55 kips	231.46 kips
54.30 ft	180.84 kips	56.55 kips	237.39 kips
55.30 ft	186.82 kips	56.55 kips	243.37 kips
56.29 ft	192.74 kips	56.55 kips	249.29 kips
56.31 ft	192.84 kips	34.46 kips	227.30 kips
57.30 ft	196.45 kips	34.46 kips	230.90 kips
58.30 ft	200.09 kips	34.46 kips	234.55 kips
59.30 ft	203.74 kips	34.46 kips	238.19 kips
60.30 ft	207.38 kips	34.46 kips	241.84 kips
61.30 ft	211.03 kips	34.46 kips	245.48 kips
62.30 ft	214.67 kips	34.46 kips	249.13 kips
63.30 ft	218.32 kips	34.46 kips	252.77 kips
64.30 ft	221.96 kips	34.46 kips	256.42 kips
65.30 ft	225.61 kips	34.46 kips	260.06 kips
66.30 ft	229.25 kips	34.46 kips	263.71 kips
67.30 ft	233.24 kips	34.46 kips	267.70 kips
68.30 ft	237.29 kips	34.46 kips	271.75 kips
69.30 ft	241.40 kips	34.46 kips	275.86 kips

Depth	Skin Friction	End Bearing	Total Capacity
70.30 ft	245.57 kips	34.46 kips	280.03 kips
71.30 ft	249.81 kips	34.46 kips	284.27 kips
72.30 ft	254.11 kips	34.46 kips	288.57 kips
73.29 ft	258.43 kips	34.46 kips	292.89 kips
73.31 ft	258.52 kips	44.18 kips	302.70 kips
74.30 ft	263.14 kips	44.18 kips	307.32 kips
75.30 ft	267.82 kips	44.18 kips	312.00 kips
76.30 ft	272.49 kips	44.18 kips	316.67 kips
77.30 ft	277.16 kips	44.18 kips	321.34 kips
78.30 ft	281.84 kips	44.18 kips	326.02 kips
79.30 ft	286.51 kips	44.18 kips	330.69 kips
80.30 ft	291.18 kips	44.18 kips	335.36 kips
81.30 ft	295.86 kips	44.18 kips	340.03 kips
82.30 ft	300.53 kips	44.18 kips	344.71 kips
83.30 ft	305.20 kips	44.18 kips	349.38 kips
84.30 ft	310.31 kips	44.18 kips	354.49 kips
85.30 ft	315.51 kips	44.18 kips	359.69 kips
86.29 ft	320.73 kips	44.18 kips	364.90 kips

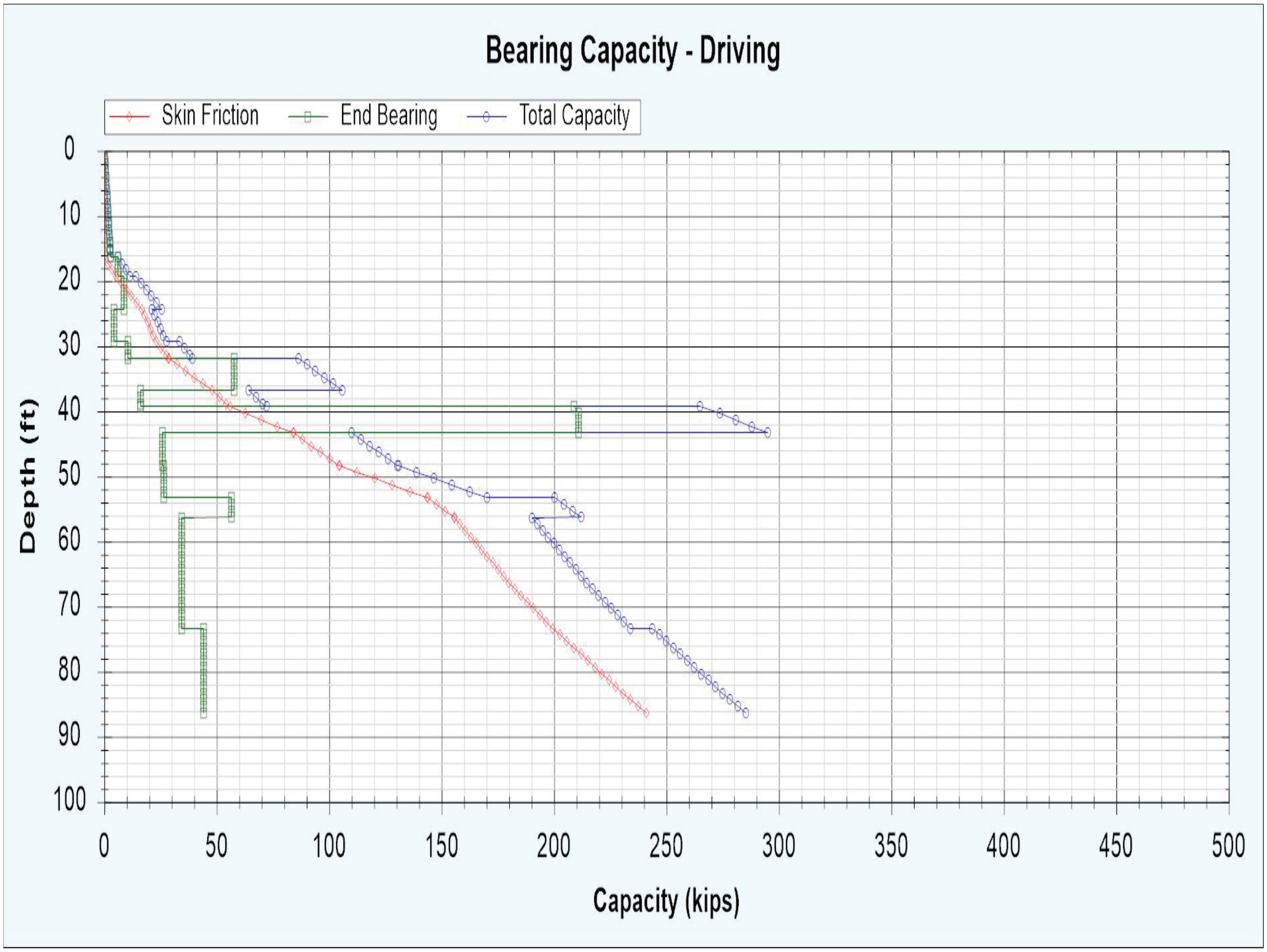

Bearing Capacity - Restrike
Skin Friction
End Bearing
Total Capacity
Depth (ft)
0
10
20
30
40
50
60
70
80
90
100
0
100
200
300
400
500
Capacity (kips)

Driving - Summary of Capacities

Depth	Skin Friction	End Bearing	Total Capacity
0.01 ft	0.00 kips	0.00 kips	0.00 kips
1.00 ft	0.00 kips	0.17 kips	0.17 kips
2.00 ft	0.00 kips	0.34 kips	0.34 kips
3.00 ft	0.00 kips	0.52 kips	0.52 kips
4.00 ft	0.00 kips	0.69 kips	0.69 kips
5.00 ft	0.00 kips	0.86 kips	0.86 kips
6.00 ft	0.00 kips	1.03 kips	1.03 kips
7.00 ft	0.00 kips	1.20 kips	1.20 kips
8.00 ft	0.00 kips	1.38 kips	1.38 kips
9.00 ft	0.00 kips	1.55 kips	1.55 kips
10.00 ft	0.00 kips	1.72 kips	1.72 kips
11.00 ft	0.00 kips	1.89 kips	1.89 kips
12.00 ft	0.00 kips	2.06 kips	2.06 kips
13.00 ft	0.00 kips	2.24 kips	2.24 kips
14.00 ft	0.00 kips	2.41 kips	2.41 kips
15.00 ft	0.00 kips	2.58 kips	2.58 kips
15.29 ft	0.00 kips	2.63 kips	2.63 kips
15.31 ft	0.00 kips	2.63 kips	2.63 kips
16.29 ft	0.00 kips	2.72 kips	2.72 kips
16.31 ft	0.02 kips	6.19 kips	6.20 kips
17.30 ft	1.73 kips	6.19 kips	7.91 kips
18.30 ft	3.45 kips	6.19 kips	9.64 kips
19.29 ft	5.16 kips	6.19 kips	11.35 kips
19.31 ft	5.20 kips	8.84 kips	14.04 kips
20.30 ft	7.49 kips	8.84 kips	16.33 kips
21.30 ft	9.80 kips	8.84 kips	18.64 kips
22.30 ft	12.11 kips	8.84 kips	20.95 kips
23.30 ft	14.43 kips	8.84 kips	23.26 kips
24.29 ft	16.71 kips	8.84 kips	25.55 kips
24.31 ft	16.75 kips	4.42 kips	21.17 kips
25.30 ft	18.00 kips	4.42 kips	22.42 kips
26.30 ft	19.27 kips	4.42 kips	23.69 kips
27.30 ft	20.54 kips	4.42 kips	24.95 kips
28.30 ft	21.80 kips	4.42 kips	26.22 kips
29.29 ft	23.06 kips	4.42 kips	27.47 kips
29.31 ft	23.09 kips	10.46 kips	33.55 kips
30.30 ft	25.25 kips	10.46 kips	35.71 kips
31.30 ft	27.47 kips	10.46 kips	37.94 kips
31.79 ft	28.58 kips	10.46 kips	39.05 kips
31.81 ft	28.64 kips	57.74 kips	86.39 kips
32.80 ft	32.31 kips	57.74 kips	90.05 kips
33.80 ft	36.09 kips	57.74 kips	93.84 kips

Depth	Skin Friction	End Bearing	Total Capacity
34.80 ft	39.97 kips	57.74 kips	97.71 kips
35.80 ft	43.93 kips	57.74 kips	101.67 kips
36.79 ft	47.93 kips	57.74 kips	105.68 kips
36.81 ft	48.01 kips	16.23 kips	64.23 kips
37.80 ft	51.08 kips	16.23 kips	67.31 kips
38.80 ft	54.25 kips	16.23 kips	70.48 kips
39.29 ft	55.83 kips	16.23 kips	72.06 kips
39.31 ft	55.93 kips	208.82 kips	264.75 kips
40.30 ft	62.70 kips	210.96 kips	273.66 kips
41.30 ft	69.70 kips	210.96 kips	280.65 kips
42.30 ft	76.84 kips	210.96 kips	287.79 kips
43.29 ft	84.05 kips	210.96 kips	295.01 kips
43.31 ft	84.16 kips	25.92 kips	110.08 kips
44.30 ft	88.05 kips	25.92 kips	113.97 kips
45.30 ft	92.04 kips	25.92 kips	117.96 kips
46.30 ft	96.10 kips	25.92 kips	122.02 kips
47.30 ft	100.22 kips	25.92 kips	126.14 kips
48.29 ft	104.38 kips	25.92 kips	130.29 kips
48.31 ft	104.50 kips	26.51 kips	131.00 kips
49.30 ft	112.27 kips	26.51 kips	138.78 kips
50.30 ft	120.13 kips	26.51 kips	146.63 kips
51.30 ft	127.98 kips	26.51 kips	154.49 kips
52.30 ft	135.84 kips	26.51 kips	162.34 kips
53.29 ft	143.61 kips	26.51 kips	170.12 kips
53.31 ft	143.73 kips	56.55 kips	200.28 kips
54.30 ft	147.68 kips	56.55 kips	204.23 kips
55.30 ft	151.67 kips	56.55 kips	208.21 kips
56.29 ft	155.61 kips	56.55 kips	212.16 kips
56.31 ft	155.68 kips	34.46 kips	190.14 kips
57.30 ft	158.08 kips	34.46 kips	192.54 kips
58.30 ft	160.51 kips	34.46 kips	194.97 kips
59.30 ft	162.94 kips	34.46 kips	197.40 kips
60.30 ft	165.37 kips	34.46 kips	199.83 kips
61.30 ft	167.80 kips	34.46 kips	202.26 kips
62.30 ft	170.23 kips	34.46 kips	204.69 kips
63.30 ft	172.66 kips	34.46 kips	207.12 kips
64.30 ft	175.09 kips	34.46 kips	209.55 kips
65.30 ft	177.52 kips	34.46 kips	211.98 kips
66.30 ft	179.95 kips	34.46 kips	214.41 kips
67.30 ft	182.61 kips	34.46 kips	217.07 kips
68.30 ft	185.31 kips	34.46 kips	219.77 kips
69.30 ft	188.06 kips	34.46 kips	222.51 kips

Depth	Skin Friction	End Bearing	Total Capacity
70.30 ft	190.84 kips	34.46 kips	225.30 kips
71.30 ft	193.66 kips	34.46 kips	228.12 kips
72.30 ft	196.53 kips	34.46 kips	230.99 kips
73.29 ft	199.41 kips	34.46 kips	233.87 kips
73.31 ft	199.47 kips	44.18 kips	243.65 kips
74.30 ft	202.55 kips	44.18 kips	246.73 kips
75.30 ft	205.67 kips	44.18 kips	249.85 kips
76.30 ft	208.78 kips	44.18 kips	252.96 kips
77.30 ft	211.90 kips	44.18 kips	256.08 kips
78.30 ft	215.01 kips	44.18 kips	259.19 kips
79.30 ft	218.13 kips	44.18 kips	262.31 kips
80.30 ft	221.25 kips	44.18 kips	265.42 kips
81.30 ft	224.36 kips	44.18 kips	268.54 kips
82.30 ft	227.48 kips	44.18 kips	271.66 kips
83.30 ft	230.59 kips	44.18 kips	274.77 kips
84.30 ft	234.00 kips	44.18 kips	278.18 kips
85.30 ft	237.46 kips	44.18 kips	281.64 kips
86.29 ft	240.94 kips	44.18 kips	285.12 kips

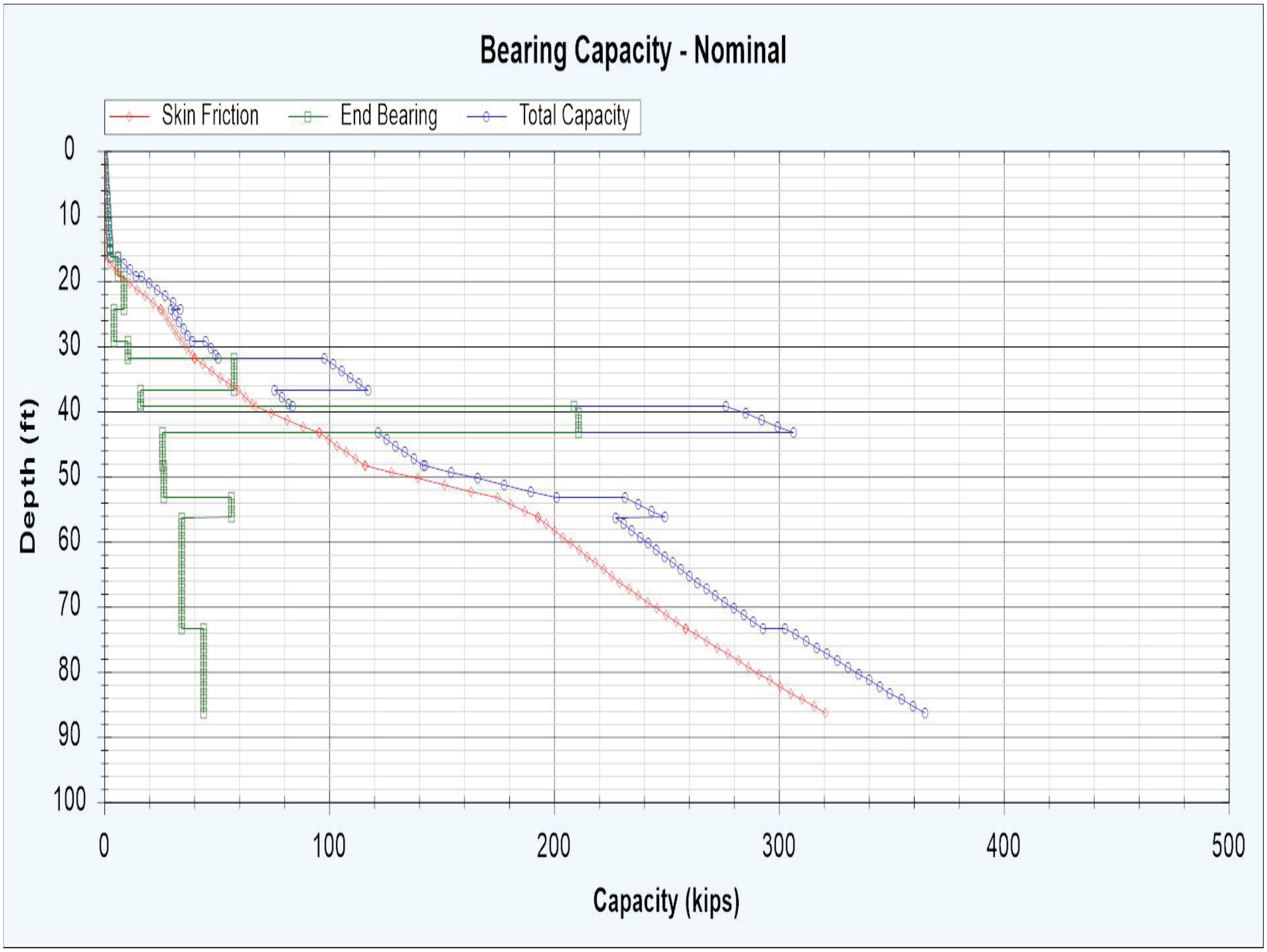

Bearing Capacity - Driving
Skin Friction
End Bearing
Total Capacity
Depth (ft)
0
10
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
300
350
400
450
500
Capacity (kips)

Nominal - Summary of Capacities

Depth	Skin Friction	End Bearing	Total Capacity
0.01 ft	0.00 kips	0.00 kips	0.00 kips
1.00 ft	0.00 kips	0.17 kips	0.17 kips
2.00 ft	0.00 kips	0.34 kips	0.34 kips
3.00 ft	0.00 kips	0.52 kips	0.52 kips
4.00 ft	0.00 kips	0.69 kips	0.69 kips
5.00 ft	0.00 kips	0.86 kips	0.86 kips
6.00 ft	0.00 kips	1.03 kips	1.03 kips
7.00 ft	0.00 kips	1.20 kips	1.20 kips
8.00 ft	0.00 kips	1.38 kips	1.38 kips
9.00 ft	0.00 kips	1.55 kips	1.55 kips
10.00 ft	0.00 kips	1.72 kips	1.72 kips
11.00 ft	0.00 kips	1.89 kips	1.89 kips
12.00 ft	0.00 kips	2.06 kips	2.06 kips
13.00 ft	0.00 kips	2.24 kips	2.24 kips
14.00 ft	0.00 kips	2.41 kips	2.41 kips
15.00 ft	0.00 kips	2.58 kips	2.58 kips
15.29 ft	0.00 kips	2.63 kips	2.63 kips
15.31 ft	0.00 kips	2.63 kips	2.63 kips
16.29 ft	0.00 kips	2.72 kips	2.72 kips
16.31 ft	0.03 kips	6.19 kips	6.21 kips
17.30 ft	2.59 kips	6.19 kips	8.77 kips
18.30 ft	5.18 kips	6.19 kips	11.36 kips
19.29 ft	7.74 kips	6.19 kips	13.93 kips
19.31 ft	7.80 kips	8.84 kips	16.64 kips
20.30 ft	11.24 kips	8.84 kips	20.07 kips
21.30 ft	14.70 kips	8.84 kips	23.54 kips
22.30 ft	18.17 kips	8.84 kips	27.01 kips
23.30 ft	21.64 kips	8.84 kips	30.47 kips
24.29 ft	25.07 kips	8.84 kips	33.91 kips
24.31 ft	25.12 kips	4.42 kips	29.54 kips
25.30 ft	27.00 kips	4.42 kips	31.42 kips
26.30 ft	28.90 kips	4.42 kips	33.32 kips
27.30 ft	30.80 kips	4.42 kips	35.22 kips
28.30 ft	32.70 kips	4.42 kips	37.12 kips
29.29 ft	34.58 kips	4.42 kips	39.00 kips
29.31 ft	34.62 kips	10.46 kips	45.08 kips
30.30 ft	36.78 kips	10.46 kips	47.24 kips
31.30 ft	39.01 kips	10.46 kips	49.47 kips
31.79 ft	40.12 kips	10.46 kips	50.58 kips
31.81 ft	40.18 kips	57.74 kips	97.92 kips
32.80 ft	43.84 kips	57.74 kips	101.58 kips
33.80 ft	47.63 kips	57.74 kips	105.37 kips

Depth	Skin Friction	End Bearing	Total Capacity
34.80 ft	51.50 kips	57.74 kips	109.24 kips
35.80 ft	55.46 kips	57.74 kips	113.20 kips
36.79 ft	59.47 kips	57.74 kips	117.21 kips
36.81 ft	59.54 kips	16.23 kips	75.77 kips
37.80 ft	62.61 kips	16.23 kips	78.84 kips
38.80 ft	65.78 kips	16.23 kips	82.01 kips
39.29 ft	67.36 kips	16.23 kips	83.59 kips
39.31 ft	67.46 kips	208.82 kips	276.28 kips
40.30 ft	74.24 kips	210.96 kips	285.19 kips
41.30 ft	81.23 kips	210.96 kips	292.19 kips
42.30 ft	88.37 kips	210.96 kips	299.33 kips
43.29 ft	95.58 kips	210.96 kips	306.54 kips
43.31 ft	95.70 kips	25.92 kips	121.61 kips
44.30 ft	99.58 kips	25.92 kips	125.50 kips
45.30 ft	103.57 kips	25.92 kips	129.49 kips
46.30 ft	107.63 kips	25.92 kips	133.55 kips
47.30 ft	111.76 kips	25.92 kips	137.68 kips
48.29 ft	115.91 kips	25.92 kips	141.83 kips
48.31 ft	116.07 kips	26.51 kips	142.58 kips
49.30 ft	127.73 kips	26.51 kips	154.24 kips
50.30 ft	139.51 kips	26.51 kips	166.02 kips
51.30 ft	151.29 kips	26.51 kips	177.80 kips
52.30 ft	163.07 kips	26.51 kips	189.58 kips
53.29 ft	174.74 kips	26.51 kips	201.24 kips
53.31 ft	174.92 kips	56.55 kips	231.46 kips
54.30 ft	180.84 kips	56.55 kips	237.39 kips
55.30 ft	186.82 kips	56.55 kips	243.37 kips
56.29 ft	192.74 kips	56.55 kips	249.29 kips
56.31 ft	192.84 kips	34.46 kips	227.30 kips
57.30 ft	196.45 kips	34.46 kips	230.90 kips
58.30 ft	200.09 kips	34.46 kips	234.55 kips
59.30 ft	203.74 kips	34.46 kips	238.19 kips
60.30 ft	207.38 kips	34.46 kips	241.84 kips
61.30 ft	211.03 kips	34.46 kips	245.48 kips
62.30 ft	214.67 kips	34.46 kips	249.13 kips
63.30 ft	218.32 kips	34.46 kips	252.77 kips
64.30 ft	221.96 kips	34.46 kips	256.42 kips
65.30 ft	225.61 kips	34.46 kips	260.06 kips
66.30 ft	229.25 kips	34.46 kips	263.71 kips
67.30 ft	233.24 kips	34.46 kips	267.70 kips
68.30 ft	237.29 kips	34.46 kips	271.75 kips
69.30 ft	241.40 kips	34.46 kips	275.86 kips

Depth	Skin Friction	End Bearing	Total Capacity
70.30 ft	245.57 kips	34.46 kips	280.03 kips
71.30 ft	249.81 kips	34.46 kips	284.27 kips
72.30 ft	254.11 kips	34.46 kips	288.57 kips
73.29 ft	258.43 kips	34.46 kips	292.89 kips
73.31 ft	258.52 kips	44.18 kips	302.70 kips
74.30 ft	263.14 kips	44.18 kips	307.32 kips
75.30 ft	267.82 kips	44.18 kips	312.00 kips
76.30 ft	272.49 kips	44.18 kips	316.67 kips
77.30 ft	277.16 kips	44.18 kips	321.34 kips
78.30 ft	281.84 kips	44.18 kips	326.02 kips
79.30 ft	286.51 kips	44.18 kips	330.69 kips
80.30 ft	291.18 kips	44.18 kips	335.36 kips
81.30 ft	295.86 kips	44.18 kips	340.03 kips
82.30 ft	300.53 kips	44.18 kips	344.71 kips
83.30 ft	305.20 kips	44.18 kips	349.38 kips
84.30 ft	310.31 kips	44.18 kips	354.49 kips
85.30 ft	315.51 kips	44.18 kips	359.69 kips
86.29 ft	320.73 kips	44.18 kips	364.90 kips


Bearing Capacity - Nominal
Skin Friction
End Bearing
Total Capacity
Depth (ft)
0
10
20
30
40
50
60
70
80
90
100
Capacity (kips)
0
100
200
300
400
500

Intermediate Pier
Boring B-069-0-19

DrivenPiles - Report

General Project Information

Filename: ...E-04342 (Brice Road Bridge over IR 70)\FRA-00070-23.920 Brice Rd Bridge - Pier (B-069-0-19).dvn
Project Name: FRA-00070-23.920 Brice Rd Bridge over IR-70 - Intermediate Pier (B-069-0-19)
Project Client: EMH&T
Prepared By: Hanu S. Kulkarni, Ph.D., P.E.
Project Manager: Jonathan P. Sterenberg, P.E.

Pile Information

Pile Type: Pipe Pile - Closed End
Top of Pile: 6.70 ft
Diameter of Pile: 12.00 in

Nominal Considerations

Water Table Depth At Time Of:

Drilling:	13.50 ft
Driving/Restrike:	13.50 ft
Nominal:	13.50 ft

Nominal Considations:

Local Scour:	0.00 ft
Long Term Scour:	0.00 ft
Soft Soil:	0.00 ft

Nominal Profile

Layer	Soil Type	Thickness	Setup Factor	Unit Weight	Strength	Nominal Curve
1	Cohesionless	5.50 ft	1.000	125.00 pcf	30.0/30.0	Nordlund
2	Cohesionless	7.00 ft	1.200	120.00 pcf	27.0/27.0	Nordlund
3	Cohesionless	8.00 ft	1.200	125.00 pcf	29.0/29.0	Nordlund
4	Cohesionless	6.50 ft	1.200	125.00 pcf	32.0/32.0	Nordlund
5	Cohesive	10.00 ft	1.500	120.00 pcf	3000.00 psf	T-80 Sand
6	Cohesive	6.00 ft	1.500	120.00 pcf	5750.00 psf	T-80 Same
7	Cohesionless	3.50 ft	1.200	135.00 pcf	36.0/36.0	Nordlund
8	Cohesive	5.50 ft	1.500	130.00 pcf	6250.00 psf	T-80 Same
9	Cohesive	15.00 ft	1.500	130.00 pcf	5375.00 psf	T-80 Same
10	Cohesive	8.00 ft	2.000	120.00 pcf	2625.00 psf	T-80 Same

Restrike: 276.3 kips
Driving: 205.6 kips

Factored Structural Load: 191 kips
Required UBV: 273 kips

Estimated Ground Surface Elevation: 797.8 ft-msl
Bottom of Footing Elevation: 790.7 ft-msl

Estimated Pile Top Elevation: 791.7 ft-msl
Estimated Pile Tip Elevation: 735.8 ft-msl

Embedment Depth Below Bottom of Footing Elevation: 54.9 ft

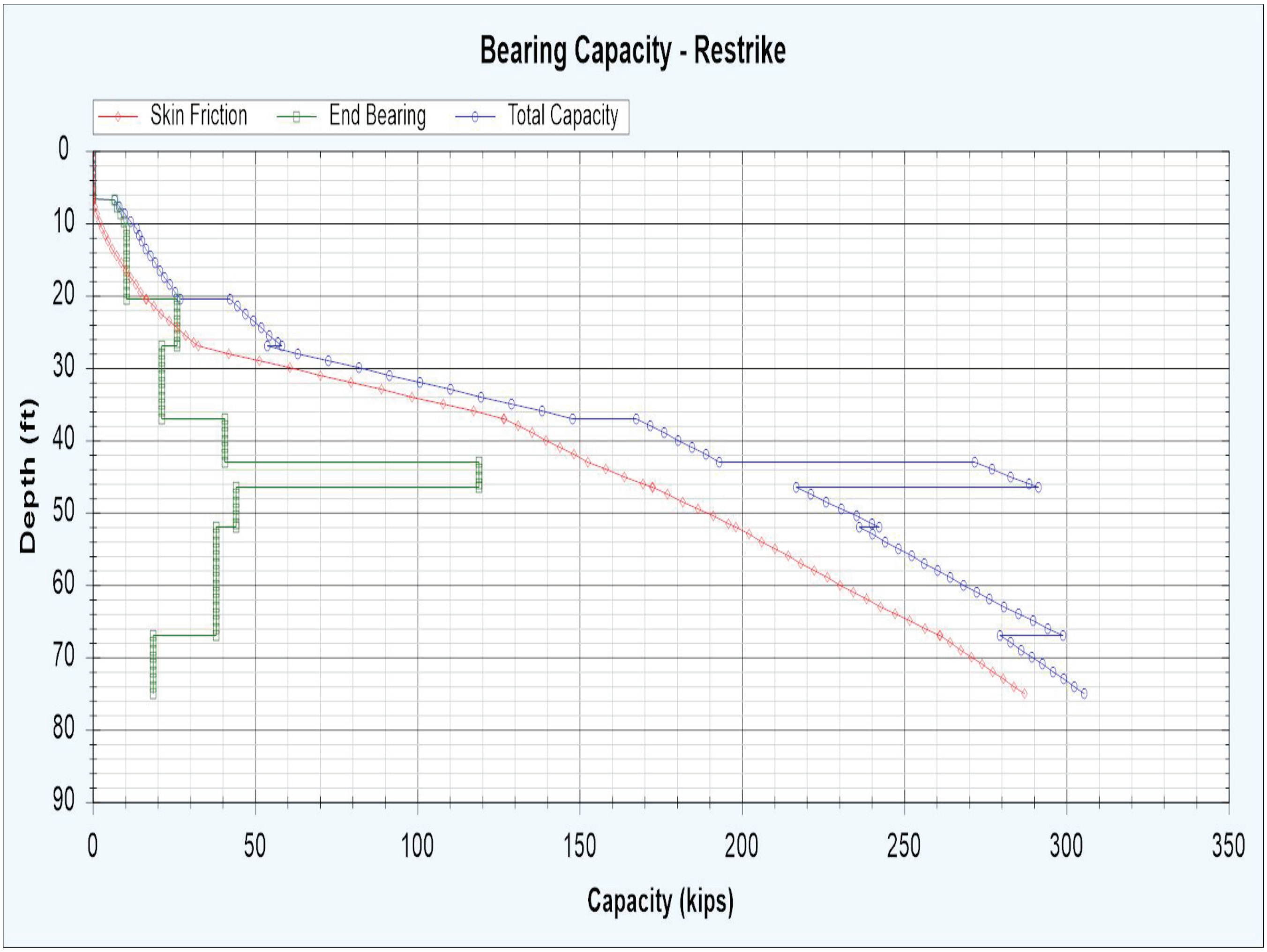
Estimated Pile Length: 60.0 ft

Restrike - Summary of Capacities

Depth	Skin Friction	End Bearing	Total Capacity
0.01 ft	0.00 kips	0.00 kips	0.00 kips
1.00 ft	0.00 kips	0.00 kips	0.00 kips
2.00 ft	0.00 kips	0.00 kips	0.00 kips
3.00 ft	0.00 kips	0.00 kips	0.00 kips
4.00 ft	0.00 kips	0.00 kips	0.00 kips
5.00 ft	0.00 kips	0.00 kips	0.00 kips
5.49 ft	0.00 kips	0.00 kips	0.00 kips
5.51 ft	0.00 kips	0.00 kips	0.00 kips
6.50 ft	0.00 kips	0.00 kips	0.00 kips
6.69 ft	0.00 kips	0.00 kips	0.00 kips
6.71 ft	0.01 kips	6.66 kips	6.66 kips
7.70 ft	0.61 kips	7.61 kips	8.21 kips
8.70 ft	1.30 kips	8.56 kips	9.86 kips
9.70 ft	2.07 kips	9.52 kips	11.59 kips
10.70 ft	2.92 kips	10.46 kips	13.38 kips
11.70 ft	3.85 kips	10.46 kips	14.31 kips
12.49 ft	4.65 kips	10.46 kips	15.11 kips
12.51 ft	4.67 kips	10.46 kips	15.13 kips
13.49 ft	5.92 kips	10.46 kips	16.38 kips
13.51 ft	5.95 kips	10.46 kips	16.41 kips
14.50 ft	7.28 kips	10.46 kips	17.74 kips
15.50 ft	8.68 kips	10.46 kips	19.15 kips
16.50 ft	10.14 kips	10.46 kips	20.60 kips
17.50 ft	11.64 kips	10.46 kips	22.10 kips
18.50 ft	13.19 kips	10.46 kips	23.65 kips
19.50 ft	14.79 kips	10.46 kips	25.25 kips
20.49 ft	16.42 kips	10.46 kips	26.89 kips
20.51 ft	16.46 kips	25.92 kips	42.38 kips
21.50 ft	18.72 kips	25.92 kips	44.64 kips
22.50 ft	21.06 kips	25.92 kips	46.98 kips
23.50 ft	23.47 kips	25.92 kips	49.39 kips
24.50 ft	25.95 kips	25.92 kips	51.87 kips
25.50 ft	28.50 kips	25.92 kips	54.42 kips
26.50 ft	31.11 kips	25.92 kips	57.03 kips
26.99 ft	32.42 kips	25.92 kips	58.34 kips
27.01 ft	32.54 kips	21.21 kips	53.75 kips
28.00 ft	41.87 kips	21.21 kips	63.08 kips
29.00 ft	51.29 kips	21.21 kips	72.50 kips
30.00 ft	60.72 kips	21.21 kips	81.93 kips
31.00 ft	70.14 kips	21.21 kips	91.35 kips
32.00 ft	79.57 kips	21.21 kips	100.77 kips
33.00 ft	88.99 kips	21.21 kips	110.20 kips

Depth	Skin Friction	End Bearing	Total Capacity
34.00 ft	98.42 kips	21.21 kips	119.62 kips
35.00 ft	107.84 kips	21.21 kips	129.05 kips
36.00 ft	117.27 kips	21.21 kips	138.47 kips
36.99 ft	126.60 kips	21.21 kips	147.80 kips
37.01 ft	126.74 kips	40.64 kips	167.38 kips
38.00 ft	130.99 kips	40.64 kips	171.64 kips
39.00 ft	135.29 kips	40.64 kips	175.94 kips
40.00 ft	139.59 kips	40.64 kips	180.24 kips
41.00 ft	143.89 kips	40.64 kips	184.53 kips
42.00 ft	148.19 kips	40.64 kips	188.83 kips
42.99 ft	152.45 kips	40.64 kips	193.09 kips
43.01 ft	152.54 kips	119.07 kips	271.61 kips
44.00 ft	158.04 kips	119.07 kips	277.10 kips
45.00 ft	163.70 kips	119.07 kips	282.77 kips
46.00 ft	169.48 kips	119.07 kips	288.55 kips
46.49 ft	172.35 kips	119.07 kips	291.42 kips
46.51 ft	172.46 kips	44.18 kips	216.64 kips
47.50 ft	177.09 kips	44.18 kips	221.26 kips
48.50 ft	181.76 kips	44.18 kips	225.94 kips
49.50 ft	186.43 kips	44.18 kips	230.61 kips
50.50 ft	191.11 kips	44.18 kips	235.28 kips
51.50 ft	195.78 kips	44.18 kips	239.96 kips
51.99 ft	198.07 kips	44.18 kips	242.25 kips
52.01 ft	198.15 kips	37.99 kips	236.15 kips
53.00 ft	202.13 kips	37.99 kips	240.13 kips
54.00 ft	206.15 kips	37.99 kips	244.15 kips
55.00 ft	210.17 kips	37.99 kips	248.16 kips
56.00 ft	214.19 kips	37.99 kips	252.18 kips
57.00 ft	218.21 kips	37.99 kips	256.20 kips
58.00 ft	222.23 kips	37.99 kips	260.22 kips
59.00 ft	226.25 kips	37.99 kips	264.24 kips
60.00 ft	230.27 kips	37.99 kips	268.26 kips
61.00 ft	234.28 kips	37.99 kips	272.28 kips
62.00 ft	238.30 kips	37.99 kips	276.30 kips
63.00 ft	242.70 kips	37.99 kips	280.69 kips
64.00 ft	247.17 kips	37.99 kips	285.16 kips
65.00 ft	251.70 kips	37.99 kips	289.69 kips
66.00 ft	256.30 kips	37.99 kips	294.30 kips
66.99 ft	260.93 kips	37.99 kips	298.92 kips
67.01 ft	261.01 kips	18.56 kips	279.56 kips
68.00 ft	264.22 kips	18.56 kips	282.78 kips
69.00 ft	267.48 kips	18.56 kips	286.03 kips

Depth	Skin Friction	End Bearing	Total Capacity
70.00 ft	270.73 kips	18.56 kips	289.28 kips
71.00 ft	273.98 kips	18.56 kips	292.53 kips
72.00 ft	277.23 kips	18.56 kips	295.78 kips
73.00 ft	280.48 kips	18.56 kips	299.03 kips
74.00 ft	283.73 kips	18.56 kips	302.29 kips
74.99 ft	286.95 kips	18.56 kips	305.50 kips

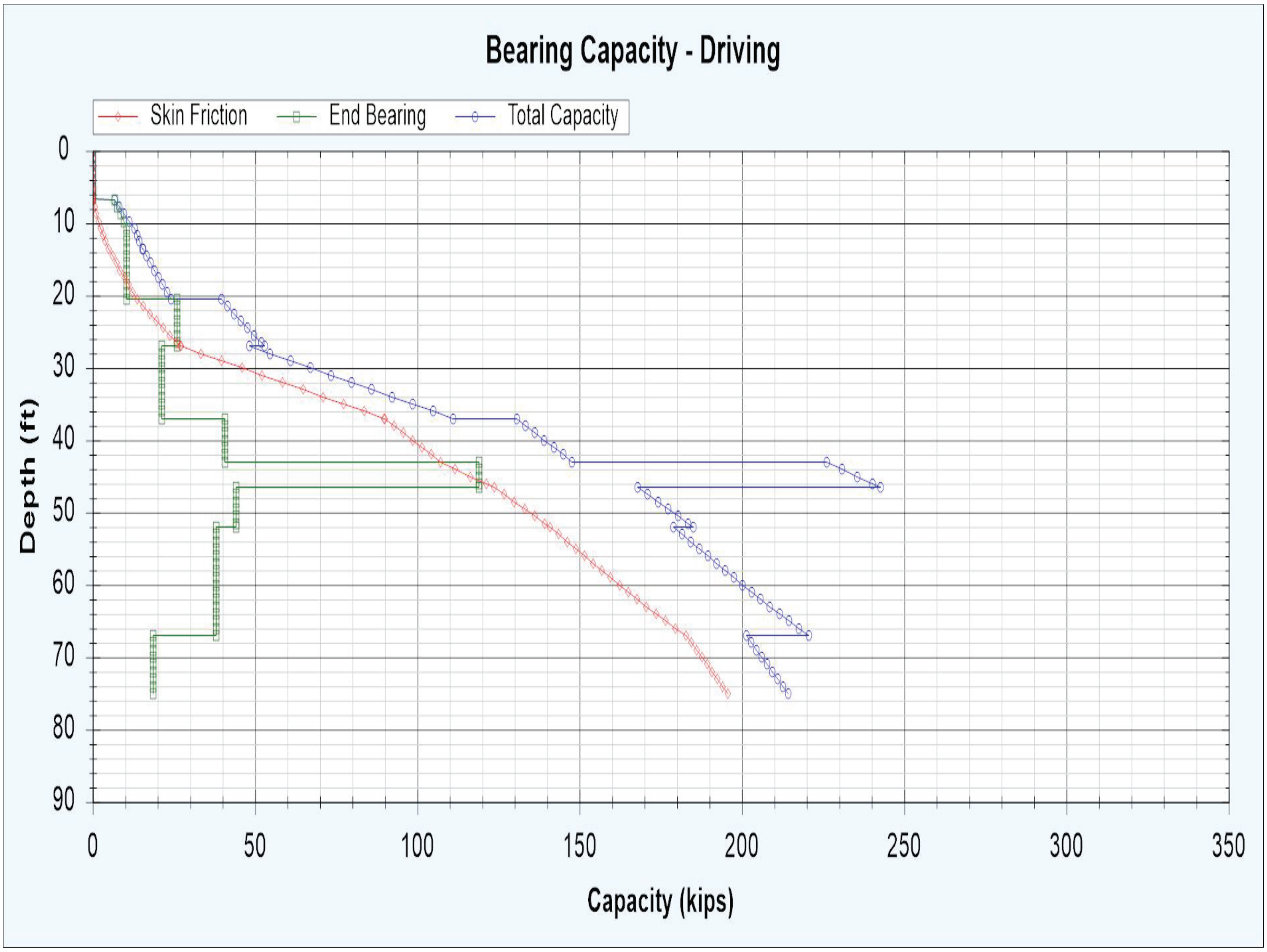
Bearing Capacity - Restrike
Skin Friction
End Bearing
Total Capacity
Depth (ft)
0
10
20
30
40
50
60
70
80
90
Capacity (kips)
0
50
100
150
200
250
300
350

Driving - Summary of Capacities

Depth	Skin Friction	End Bearing	Total Capacity
0.01 ft	0.00 kips	0.00 kips	0.00 kips
1.00 ft	0.00 kips	0.00 kips	0.00 kips
2.00 ft	0.00 kips	0.00 kips	0.00 kips
3.00 ft	0.00 kips	0.00 kips	0.00 kips
4.00 ft	0.00 kips	0.00 kips	0.00 kips
5.00 ft	0.00 kips	0.00 kips	0.00 kips
5.49 ft	0.00 kips	0.00 kips	0.00 kips
5.51 ft	0.00 kips	0.00 kips	0.00 kips
6.50 ft	0.00 kips	0.00 kips	0.00 kips
6.69 ft	0.00 kips	0.00 kips	0.00 kips
6.71 ft	0.00 kips	6.66 kips	6.66 kips
7.70 ft	0.51 kips	7.61 kips	8.11 kips
8.70 ft	1.08 kips	8.56 kips	9.64 kips
9.70 ft	1.72 kips	9.52 kips	11.25 kips
10.70 ft	2.43 kips	10.46 kips	12.89 kips
11.70 ft	3.21 kips	10.46 kips	13.67 kips
12.49 ft	3.87 kips	10.46 kips	14.33 kips
12.51 ft	3.89 kips	10.46 kips	14.35 kips
13.49 ft	4.93 kips	10.46 kips	15.39 kips
13.51 ft	4.96 kips	10.46 kips	15.42 kips
14.50 ft	6.07 kips	10.46 kips	16.53 kips
15.50 ft	7.24 kips	10.46 kips	17.70 kips
16.50 ft	8.45 kips	10.46 kips	18.91 kips
17.50 ft	9.70 kips	10.46 kips	20.16 kips
18.50 ft	10.99 kips	10.46 kips	21.45 kips
19.50 ft	12.32 kips	10.46 kips	22.79 kips
20.49 ft	13.69 kips	10.46 kips	24.15 kips
20.51 ft	13.72 kips	25.92 kips	39.64 kips
21.50 ft	15.60 kips	25.92 kips	41.52 kips
22.50 ft	17.55 kips	25.92 kips	43.47 kips
23.50 ft	19.56 kips	25.92 kips	45.48 kips
24.50 ft	21.63 kips	25.92 kips	47.55 kips
25.50 ft	23.75 kips	25.92 kips	49.67 kips
26.50 ft	25.93 kips	25.92 kips	51.85 kips
26.99 ft	27.01 kips	25.92 kips	52.93 kips
27.01 ft	27.10 kips	21.21 kips	48.31 kips
28.00 ft	33.32 kips	21.21 kips	54.53 kips
29.00 ft	39.60 kips	21.21 kips	60.81 kips
30.00 ft	45.89 kips	21.21 kips	67.09 kips
31.00 ft	52.17 kips	21.21 kips	73.38 kips
32.00 ft	58.45 kips	21.21 kips	79.66 kips
33.00 ft	64.74 kips	21.21 kips	85.94 kips

Depth	Skin Friction	End Bearing	Total Capacity
34.00 ft	71.02 kips	21.21 kips	92.23 kips
35.00 ft	77.30 kips	21.21 kips	98.51 kips
36.00 ft	83.59 kips	21.21 kips	104.79 kips
36.99 ft	89.81 kips	21.21 kips	111.01 kips
37.01 ft	89.90 kips	40.64 kips	130.54 kips
38.00 ft	92.74 kips	40.64 kips	133.38 kips
39.00 ft	95.60 kips	40.64 kips	136.25 kips
40.00 ft	98.47 kips	40.64 kips	139.11 kips
41.00 ft	101.33 kips	40.64 kips	141.98 kips
42.00 ft	104.20 kips	40.64 kips	144.84 kips
42.99 ft	107.04 kips	40.64 kips	147.68 kips
43.01 ft	107.11 kips	119.07 kips	226.18 kips
44.00 ft	111.69 kips	119.07 kips	230.75 kips
45.00 ft	116.41 kips	119.07 kips	235.47 kips
46.00 ft	121.22 kips	119.07 kips	240.29 kips
46.49 ft	123.62 kips	119.07 kips	242.69 kips
46.51 ft	123.70 kips	44.18 kips	167.88 kips
47.50 ft	126.78 kips	44.18 kips	170.96 kips
48.50 ft	129.90 kips	44.18 kips	174.08 kips
49.50 ft	133.02 kips	44.18 kips	177.19 kips
50.50 ft	136.13 kips	44.18 kips	180.31 kips
51.50 ft	139.25 kips	44.18 kips	183.43 kips
51.99 ft	140.77 kips	44.18 kips	184.95 kips
52.01 ft	140.83 kips	37.99 kips	178.82 kips
53.00 ft	143.48 kips	37.99 kips	181.48 kips
54.00 ft	146.16 kips	37.99 kips	184.16 kips
55.00 ft	148.84 kips	37.99 kips	186.84 kips
56.00 ft	151.52 kips	37.99 kips	189.51 kips
57.00 ft	154.20 kips	37.99 kips	192.19 kips
58.00 ft	156.88 kips	37.99 kips	194.87 kips
59.00 ft	159.56 kips	37.99 kips	197.55 kips
60.00 ft	162.24 kips	37.99 kips	200.23 kips
61.00 ft	164.92 kips	37.99 kips	202.91 kips
62.00 ft	167.60 kips	37.99 kips	205.59 kips
63.00 ft	170.53 kips	37.99 kips	208.52 kips
64.00 ft	173.50 kips	37.99 kips	211.50 kips
65.00 ft	176.53 kips	37.99 kips	214.52 kips
66.00 ft	179.60 kips	37.99 kips	217.59 kips
66.99 ft	182.68 kips	37.99 kips	220.67 kips
67.01 ft	182.73 kips	18.56 kips	201.28 kips
68.00 ft	184.34 kips	18.56 kips	202.89 kips
69.00 ft	185.96 kips	18.56 kips	204.52 kips

Depth	Skin Friction	End Bearing	Total Capacity
70.00 ft	187.59 kips	18.56 kips	206.14 kips
71.00 ft	189.21 kips	18.56 kips	207.77 kips
72.00 ft	190.84 kips	18.56 kips	209.39 kips
73.00 ft	192.46 kips	18.56 kips	211.02 kips
74.00 ft	194.09 kips	18.56 kips	212.64 kips
74.99 ft	195.70 kips	18.56 kips	214.25 kips

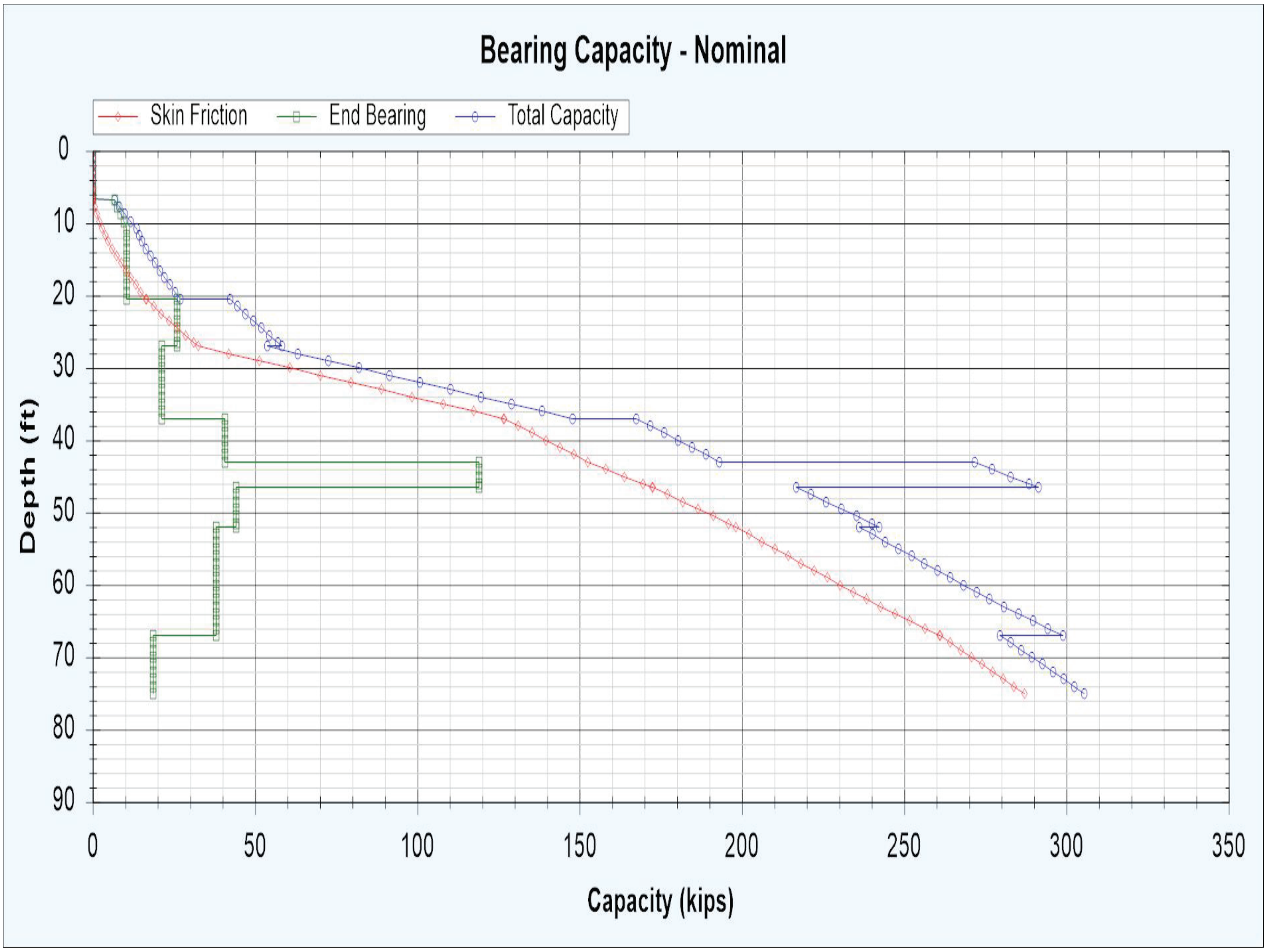

Bearing Capacity - Driving
Skin Friction
End Bearing
Total Capacity
Depth (ft)
0
10
20
30
40
50
60
70
80
90
Capacity (kips)
0
50
100
150
200
250
300
350

Nominal - Summary of Capacities

Depth	Skin Friction	End Bearing	Total Capacity
0.01 ft	0.00 kips	0.00 kips	0.00 kips
1.00 ft	0.00 kips	0.00 kips	0.00 kips
2.00 ft	0.00 kips	0.00 kips	0.00 kips
3.00 ft	0.00 kips	0.00 kips	0.00 kips
4.00 ft	0.00 kips	0.00 kips	0.00 kips
5.00 ft	0.00 kips	0.00 kips	0.00 kips
5.49 ft	0.00 kips	0.00 kips	0.00 kips
5.51 ft	0.00 kips	0.00 kips	0.00 kips
6.50 ft	0.00 kips	0.00 kips	0.00 kips
6.69 ft	0.00 kips	0.00 kips	0.00 kips
6.71 ft	0.01 kips	6.66 kips	6.66 kips
7.70 ft	0.61 kips	7.61 kips	8.21 kips
8.70 ft	1.30 kips	8.56 kips	9.86 kips
9.70 ft	2.07 kips	9.52 kips	11.59 kips
10.70 ft	2.92 kips	10.46 kips	13.38 kips
11.70 ft	3.85 kips	10.46 kips	14.31 kips
12.49 ft	4.65 kips	10.46 kips	15.11 kips
12.51 ft	4.67 kips	10.46 kips	15.13 kips
13.49 ft	5.92 kips	10.46 kips	16.38 kips
13.51 ft	5.95 kips	10.46 kips	16.41 kips
14.50 ft	7.28 kips	10.46 kips	17.74 kips
15.50 ft	8.68 kips	10.46 kips	19.15 kips
16.50 ft	10.14 kips	10.46 kips	20.60 kips
17.50 ft	11.64 kips	10.46 kips	22.10 kips
18.50 ft	13.19 kips	10.46 kips	23.65 kips
19.50 ft	14.79 kips	10.46 kips	25.25 kips
20.49 ft	16.42 kips	10.46 kips	26.89 kips
20.51 ft	16.46 kips	25.92 kips	42.38 kips
21.50 ft	18.72 kips	25.92 kips	44.64 kips
22.50 ft	21.06 kips	25.92 kips	46.98 kips
23.50 ft	23.47 kips	25.92 kips	49.39 kips
24.50 ft	25.95 kips	25.92 kips	51.87 kips
25.50 ft	28.50 kips	25.92 kips	54.42 kips
26.50 ft	31.11 kips	25.92 kips	57.03 kips
26.99 ft	32.42 kips	25.92 kips	58.34 kips
27.01 ft	32.54 kips	21.21 kips	53.75 kips
28.00 ft	41.87 kips	21.21 kips	63.08 kips
29.00 ft	51.29 kips	21.21 kips	72.50 kips
30.00 ft	60.72 kips	21.21 kips	81.93 kips
31.00 ft	70.14 kips	21.21 kips	91.35 kips
32.00 ft	79.57 kips	21.21 kips	100.77 kips
33.00 ft	88.99 kips	21.21 kips	110.20 kips

Depth	Skin Friction	End Bearing	Total Capacity
34.00 ft	98.42 kips	21.21 kips	119.62 kips
35.00 ft	107.84 kips	21.21 kips	129.05 kips
36.00 ft	117.27 kips	21.21 kips	138.47 kips
36.99 ft	126.60 kips	21.21 kips	147.80 kips
37.01 ft	126.74 kips	40.64 kips	167.38 kips
38.00 ft	130.99 kips	40.64 kips	171.64 kips
39.00 ft	135.29 kips	40.64 kips	175.94 kips
40.00 ft	139.59 kips	40.64 kips	180.24 kips
41.00 ft	143.89 kips	40.64 kips	184.53 kips
42.00 ft	148.19 kips	40.64 kips	188.83 kips
42.99 ft	152.45 kips	40.64 kips	193.09 kips
43.01 ft	152.54 kips	119.07 kips	271.61 kips
44.00 ft	158.04 kips	119.07 kips	277.10 kips
45.00 ft	163.70 kips	119.07 kips	282.77 kips
46.00 ft	169.48 kips	119.07 kips	288.55 kips
46.49 ft	172.35 kips	119.07 kips	291.42 kips
46.51 ft	172.46 kips	44.18 kips	216.64 kips
47.50 ft	177.09 kips	44.18 kips	221.26 kips
48.50 ft	181.76 kips	44.18 kips	225.94 kips
49.50 ft	186.43 kips	44.18 kips	230.61 kips
50.50 ft	191.11 kips	44.18 kips	235.28 kips
51.50 ft	195.78 kips	44.18 kips	239.96 kips
51.99 ft	198.07 kips	44.18 kips	242.25 kips
52.01 ft	198.15 kips	37.99 kips	236.15 kips
53.00 ft	202.13 kips	37.99 kips	240.13 kips
54.00 ft	206.15 kips	37.99 kips	244.15 kips
55.00 ft	210.17 kips	37.99 kips	248.16 kips
56.00 ft	214.19 kips	37.99 kips	252.18 kips
57.00 ft	218.21 kips	37.99 kips	256.20 kips
58.00 ft	222.23 kips	37.99 kips	260.22 kips
59.00 ft	226.25 kips	37.99 kips	264.24 kips
60.00 ft	230.27 kips	37.99 kips	268.26 kips
61.00 ft	234.28 kips	37.99 kips	272.28 kips
62.00 ft	238.30 kips	37.99 kips	276.30 kips
63.00 ft	242.70 kips	37.99 kips	280.69 kips
64.00 ft	247.17 kips	37.99 kips	285.16 kips
65.00 ft	251.70 kips	37.99 kips	289.69 kips
66.00 ft	256.30 kips	37.99 kips	294.30 kips
66.99 ft	260.93 kips	37.99 kips	298.92 kips
67.01 ft	261.01 kips	18.56 kips	279.56 kips
68.00 ft	264.22 kips	18.56 kips	282.78 kips
69.00 ft	267.48 kips	18.56 kips	286.03 kips

Depth	Skin Friction	End Bearing	Total Capacity
70.00 ft	270.73 kips	18.56 kips	289.28 kips
71.00 ft	273.98 kips	18.56 kips	292.53 kips
72.00 ft	277.23 kips	18.56 kips	295.78 kips
73.00 ft	280.48 kips	18.56 kips	299.03 kips
74.00 ft	283.73 kips	18.56 kips	302.29 kips
74.99 ft	286.95 kips	18.56 kips	305.50 kips


Bearing Capacity - Nominal
Skin Friction
End Bearing
Total Capacity
Depth (ft)
0
10
20
30
40
50
60
70
80
90
0
50
100
150
200
250
300
350
Capacity (kips)

Forward Abutment
Boring B-070-0-19

DrivenPiles - Report

General Project Information

Filename: ...ICE-04342 (Brice Road Bridge over IR 70)\FRA-00070-23.920 Brice Rd Bridge - FA (B-070-0-19).dvn
Project Name: FRA-00070-23.920 Brice Rd Bridge over IR-70 - Forward Abutment (B-070-0-19)
Project Client: EMH&T
Prepared By: Hanu S. Kulkarni, Ph.D., P.E.
Project Manager: Johnatan P. Sterenberg, P.E.

Pile Information

Pile Type: Pipe Pile - Closed End
Top of Pile: 0.00 ft
Diameter of Pile: 12.00 in

Nominal Considerations

Water Table Depth At Time Of:

Drilling:	13.50 ft
Driving/Restrike:	13.50 ft
Nominal:	13.50 ft

Nominal Considations:

Local Scour:	0.00 ft
Long Term Scour:	0.00 ft
Soft Soil:	0.00 ft

Nominal Profile

Layer	Soil Type	Thickness	Setup Factor	Unit Weight	Strength	Nominal Curve
1	Cohesionless	17.70 ft	1.000	125.00 pcf	0.0/0.0	Nordlund
2	Cohesive	10.50 ft	1.500	120.00 pcf	1750.00 psf	T-80 Same
3	Cohesionless	2.50 ft	1.200	125.00 pcf	32.0/32.0	Nordlund
4	Cohesionless	8.00 ft	1.200	125.00 pcf	31.0/31.0	Nordlund
5	Cohesionless	7.00 ft	1.000	135.00 pcf	38.0/38.0	Nordlund
6	Cohesive	19.00 ft	1.500	125.00 pcf	3875.00 psf	T-80 Sand
7	Cohesive	20.00 ft	1.500	125.00 pcf	4125.00 psf	T-80 Same
8	Cohesive	8.00 ft	1.500	125.00 pcf	3375.00 psf	T-80 Same

Restrike: 199.9 kips
Driving: 163.8 kips

Factored Structural Load: 138 kips
Required UBV: 197 kips

Estimated Ground Surface Elevation: 796.6 ft-msl
Bottom of Footing Elevation: 810.0 ft-msl

Bottom of Wall (Top of Leveling Pad) Elevation: 792.3 ft-msl

Estimated Pile Top Elevation: 811.0 ft-msl
Estimated Pile Tip Elevation: 760.3 ft-msl

Embedment Depth Below Bottom of Footing Elevation: 49.7 ft

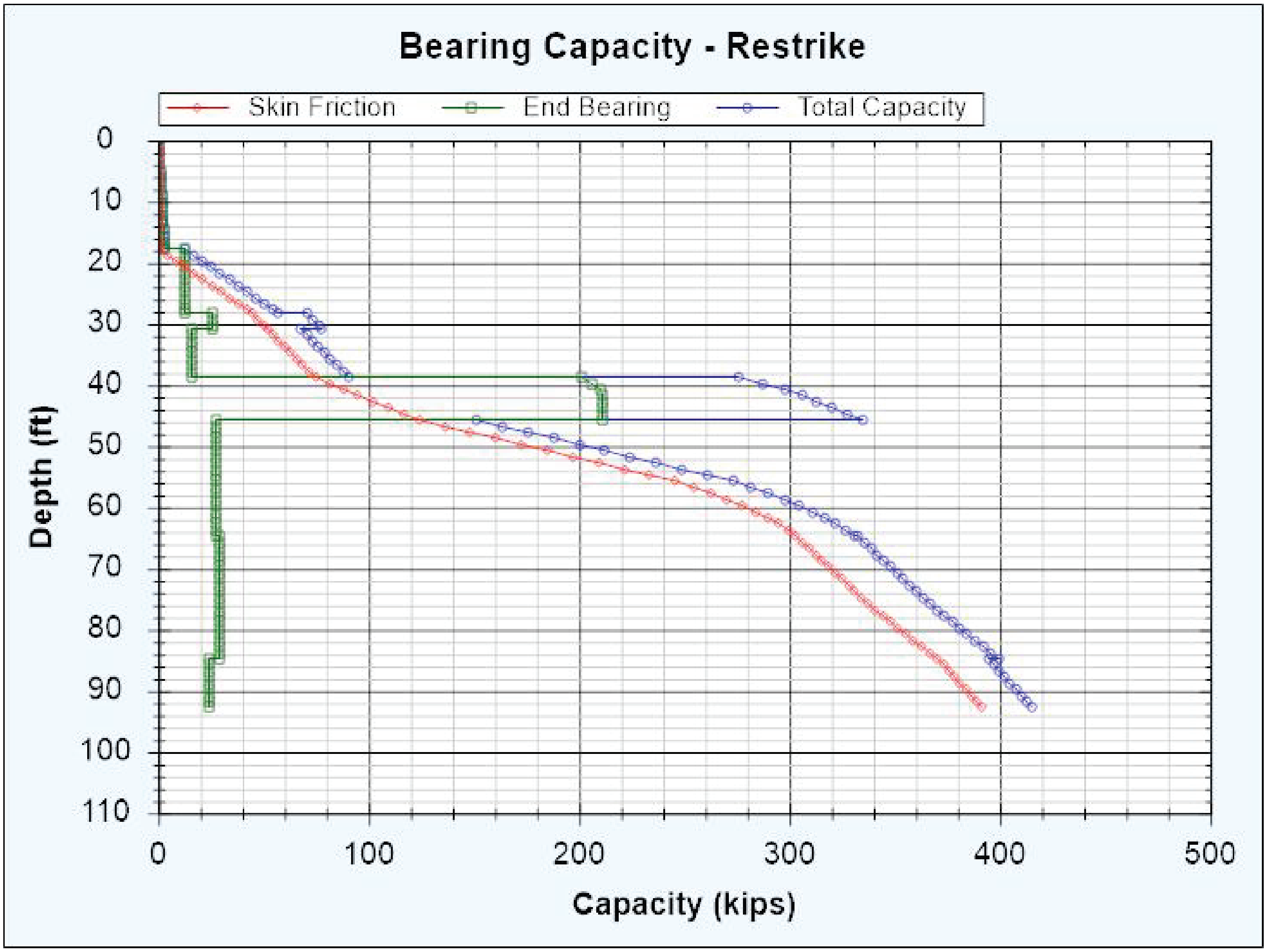
Estimated Pile Length: 55.0 ft

Restrike - Summary of Capacities

Depth	Skin Friction	End Bearing	Total Capacity
0.01 ft	0.00 kips	0.00 kips	0.00 kips
1.00 ft	0.00 kips	0.17 kips	0.17 kips
2.00 ft	0.00 kips	0.34 kips	0.34 kips
3.00 ft	0.00 kips	0.52 kips	0.52 kips
4.00 ft	0.00 kips	0.69 kips	0.69 kips
5.00 ft	0.00 kips	0.86 kips	0.86 kips
6.00 ft	0.00 kips	1.03 kips	1.03 kips
7.00 ft	0.00 kips	1.20 kips	1.20 kips
8.00 ft	0.00 kips	1.38 kips	1.38 kips
9.00 ft	0.00 kips	1.55 kips	1.55 kips
10.00 ft	0.00 kips	1.72 kips	1.72 kips
11.00 ft	0.00 kips	1.89 kips	1.89 kips
12.00 ft	0.00 kips	2.06 kips	2.06 kips
13.00 ft	0.00 kips	2.24 kips	2.24 kips
13.49 ft	0.00 kips	2.32 kips	2.32 kips
13.51 ft	0.00 kips	2.32 kips	2.32 kips
14.50 ft	0.00 kips	2.41 kips	2.41 kips
15.50 ft	0.00 kips	2.49 kips	2.49 kips
16.50 ft	0.00 kips	2.58 kips	2.58 kips
17.50 ft	0.00 kips	2.67 kips	2.67 kips
17.69 ft	0.00 kips	2.68 kips	2.68 kips
17.71 ft	0.04 kips	12.37 kips	12.41 kips
18.70 ft	4.23 kips	12.37 kips	16.60 kips
19.70 ft	8.45 kips	12.37 kips	20.82 kips
20.70 ft	12.68 kips	12.37 kips	25.05 kips
21.70 ft	16.91 kips	12.37 kips	29.28 kips
22.70 ft	21.14 kips	12.37 kips	33.51 kips
23.70 ft	25.36 kips	12.37 kips	37.73 kips
24.70 ft	29.59 kips	12.37 kips	41.96 kips
25.70 ft	33.82 kips	12.37 kips	46.19 kips
26.70 ft	38.05 kips	12.37 kips	50.42 kips
27.70 ft	42.27 kips	12.37 kips	54.64 kips
28.19 ft	44.53 kips	12.37 kips	56.90 kips
28.21 ft	44.61 kips	25.92 kips	70.53 kips
29.20 ft	47.36 kips	25.92 kips	73.27 kips
30.20 ft	50.20 kips	25.92 kips	76.12 kips
30.69 ft	51.62 kips	25.92 kips	77.54 kips
30.71 ft	51.67 kips	16.23 kips	67.90 kips
31.70 ft	54.30 kips	16.23 kips	70.53 kips
32.70 ft	57.02 kips	16.23 kips	73.25 kips
33.70 ft	59.80 kips	16.23 kips	76.03 kips
34.70 ft	62.63 kips	16.23 kips	78.86 kips

Depth	Skin Friction	End Bearing	Total Capacity
35.70 ft	65.53 kips	16.23 kips	81.76 kips
36.70 ft	68.49 kips	16.23 kips	84.72 kips
37.70 ft	71.51 kips	16.23 kips	87.74 kips
38.69 ft	74.56 kips	16.23 kips	90.79 kips
38.71 ft	74.66 kips	201.16 kips	275.82 kips
39.70 ft	81.19 kips	205.66 kips	286.85 kips
40.70 ft	87.93 kips	210.20 kips	298.14 kips
41.70 ft	94.82 kips	210.96 kips	305.78 kips
42.70 ft	101.86 kips	210.96 kips	312.82 kips
43.70 ft	109.05 kips	210.96 kips	320.01 kips
44.70 ft	116.38 kips	210.96 kips	327.34 kips
45.69 ft	123.79 kips	210.96 kips	334.75 kips
45.71 ft	123.99 kips	27.39 kips	151.38 kips
46.70 ft	136.04 kips	27.39 kips	163.43 kips
47.70 ft	148.21 kips	27.39 kips	175.60 kips
48.70 ft	160.39 kips	27.39 kips	187.78 kips
49.70 ft	172.56 kips	27.39 kips	199.95 kips
50.70 ft	184.73 kips	27.39 kips	212.12 kips
51.70 ft	196.91 kips	27.39 kips	224.30 kips
52.70 ft	209.08 kips	27.39 kips	236.47 kips
53.70 ft	221.25 kips	27.39 kips	248.65 kips
54.70 ft	233.43 kips	27.39 kips	260.82 kips
55.70 ft	245.60 kips	27.39 kips	272.99 kips
56.70 ft	254.43 kips	27.39 kips	281.82 kips
57.70 ft	262.64 kips	27.39 kips	290.04 kips
58.70 ft	270.25 kips	27.39 kips	297.64 kips
59.70 ft	277.25 kips	27.39 kips	304.64 kips
60.70 ft	283.64 kips	27.39 kips	311.04 kips
61.70 ft	289.43 kips	27.39 kips	316.82 kips
62.70 ft	294.60 kips	27.39 kips	321.99 kips
63.70 ft	299.17 kips	27.39 kips	326.56 kips
64.69 ft	303.09 kips	27.39 kips	330.48 kips
64.71 ft	303.15 kips	29.16 kips	332.31 kips
65.70 ft	306.21 kips	29.16 kips	335.36 kips
66.70 ft	309.29 kips	29.16 kips	338.45 kips
67.70 ft	312.37 kips	29.16 kips	341.53 kips
68.70 ft	315.46 kips	29.16 kips	344.62 kips
69.70 ft	318.54 kips	29.16 kips	347.70 kips
70.70 ft	321.63 kips	29.16 kips	350.79 kips
71.70 ft	324.71 kips	29.16 kips	353.87 kips
72.70 ft	327.80 kips	29.16 kips	356.95 kips
73.70 ft	330.88 kips	29.16 kips	360.04 kips

Depth	Skin Friction	End Bearing	Total Capacity
74.70 ft	333.96 kips	29.16 kips	363.12 kips
75.70 ft	337.35 kips	29.16 kips	366.51 kips
76.70 ft	340.80 kips	29.16 kips	369.95 kips
77.70 ft	344.29 kips	29.16 kips	373.45 kips
78.70 ft	347.85 kips	29.16 kips	377.01 kips
79.70 ft	351.46 kips	29.16 kips	380.61 kips
80.70 ft	355.12 kips	29.16 kips	384.28 kips
81.70 ft	358.84 kips	29.16 kips	388.00 kips
82.70 ft	362.61 kips	29.16 kips	391.77 kips
83.70 ft	366.44 kips	29.16 kips	395.60 kips
84.69 ft	370.29 kips	29.16 kips	399.45 kips
84.71 ft	370.36 kips	23.86 kips	394.21 kips
85.70 ft	372.97 kips	23.86 kips	396.83 kips
86.70 ft	375.62 kips	23.86 kips	399.48 kips
87.70 ft	378.27 kips	23.86 kips	402.12 kips
88.70 ft	380.91 kips	23.86 kips	404.77 kips
89.70 ft	383.56 kips	23.86 kips	407.41 kips
90.70 ft	386.20 kips	23.86 kips	410.06 kips
91.70 ft	388.85 kips	23.86 kips	412.70 kips
92.69 ft	391.46 kips	23.86 kips	415.32 kips

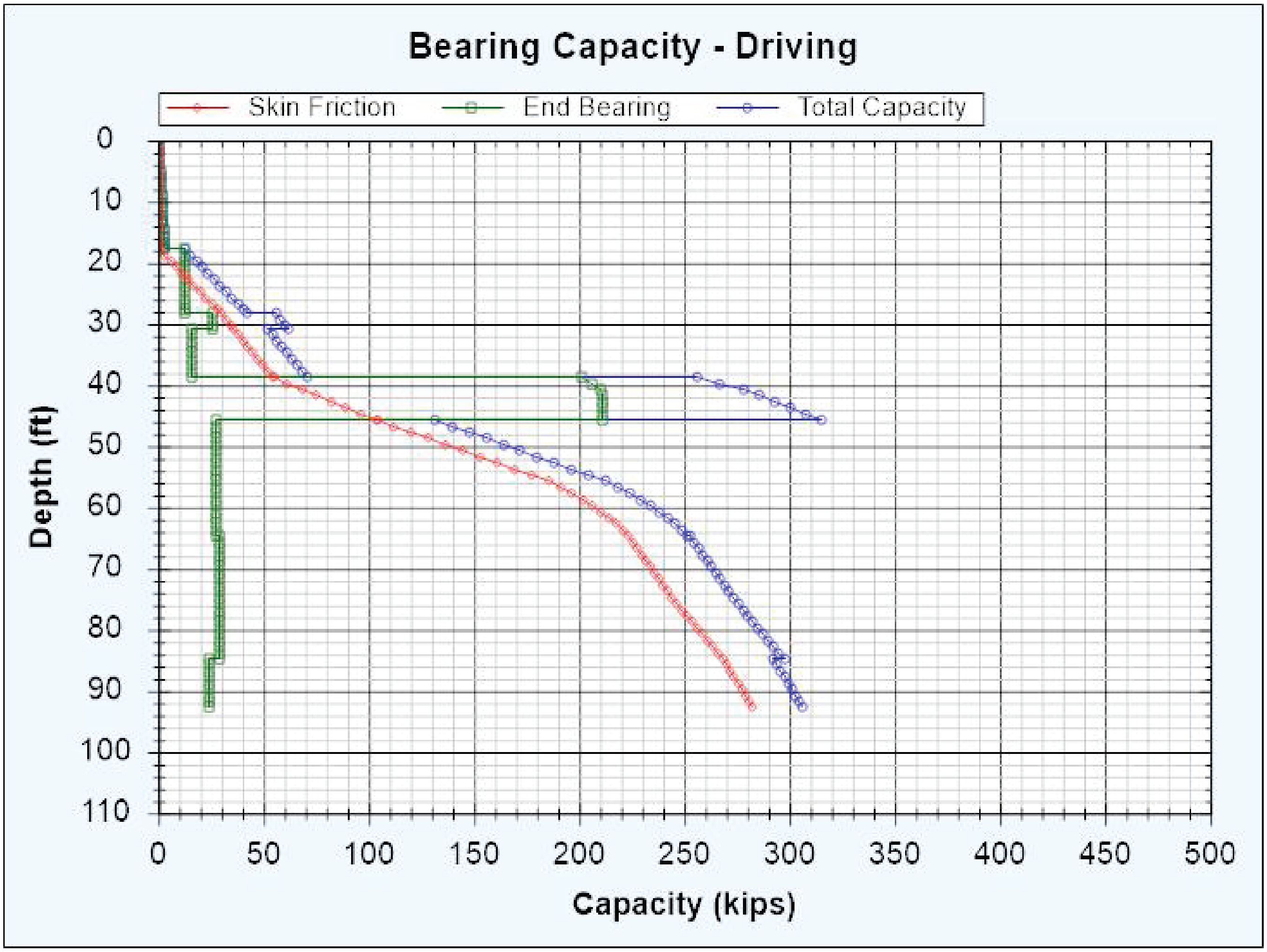

Bearing Capacity - Restrike
Skin Friction
End Bearing
Total Capacity
Depth (ft)
0
10
20
30
40
50
60
70
80
90
100
110
0
100
200
300
400
500
Capacity (kips)

Driving - Summary of Capacities

Depth	Skin Friction	End Bearing	Total Capacity
0.01 ft	0.00 kips	0.00 kips	0.00 kips
1.00 ft	0.00 kips	0.17 kips	0.17 kips
2.00 ft	0.00 kips	0.34 kips	0.34 kips
3.00 ft	0.00 kips	0.52 kips	0.52 kips
4.00 ft	0.00 kips	0.69 kips	0.69 kips
5.00 ft	0.00 kips	0.86 kips	0.86 kips
6.00 ft	0.00 kips	1.03 kips	1.03 kips
7.00 ft	0.00 kips	1.20 kips	1.20 kips
8.00 ft	0.00 kips	1.38 kips	1.38 kips
9.00 ft	0.00 kips	1.55 kips	1.55 kips
10.00 ft	0.00 kips	1.72 kips	1.72 kips
11.00 ft	0.00 kips	1.89 kips	1.89 kips
12.00 ft	0.00 kips	2.06 kips	2.06 kips
13.00 ft	0.00 kips	2.24 kips	2.24 kips
13.49 ft	0.00 kips	2.32 kips	2.32 kips
13.51 ft	0.00 kips	2.32 kips	2.32 kips
14.50 ft	0.00 kips	2.41 kips	2.41 kips
15.50 ft	0.00 kips	2.49 kips	2.49 kips
16.50 ft	0.00 kips	2.58 kips	2.58 kips
17.50 ft	0.00 kips	2.67 kips	2.67 kips
17.69 ft	0.00 kips	2.68 kips	2.68 kips
17.71 ft	0.03 kips	12.37 kips	12.40 kips
18.70 ft	2.82 kips	12.37 kips	15.19 kips
19.70 ft	5.64 kips	12.37 kips	18.01 kips
20.70 ft	8.45 kips	12.37 kips	20.82 kips
21.70 ft	11.27 kips	12.37 kips	23.64 kips
22.70 ft	14.09 kips	12.37 kips	26.46 kips
23.70 ft	16.91 kips	12.37 kips	29.28 kips
24.70 ft	19.73 kips	12.37 kips	32.10 kips
25.70 ft	22.55 kips	12.37 kips	34.92 kips
26.70 ft	25.36 kips	12.37 kips	37.73 kips
27.70 ft	28.18 kips	12.37 kips	40.55 kips
28.19 ft	29.69 kips	12.37 kips	42.06 kips
28.21 ft	29.74 kips	25.92 kips	55.66 kips
29.20 ft	32.04 kips	25.92 kips	57.95 kips
30.20 ft	34.40 kips	25.92 kips	60.32 kips
30.69 ft	35.59 kips	25.92 kips	61.50 kips
30.71 ft	35.63 kips	16.23 kips	51.86 kips
31.70 ft	37.82 kips	16.23 kips	54.05 kips
32.70 ft	40.09 kips	16.23 kips	56.32 kips
33.70 ft	42.40 kips	16.23 kips	58.63 kips
34.70 ft	44.77 kips	16.23 kips	61.00 kips

Depth	Skin Friction	End Bearing	Total Capacity
35.70 ft	47.18 kips	16.23 kips	63.41 kips
36.70 ft	49.65 kips	16.23 kips	65.88 kips
37.70 ft	52.16 kips	16.23 kips	68.39 kips
38.69 ft	54.70 kips	16.23 kips	70.93 kips
38.71 ft	54.80 kips	201.16 kips	255.95 kips
39.70 ft	61.33 kips	205.66 kips	266.99 kips
40.70 ft	68.07 kips	210.20 kips	278.27 kips
41.70 ft	74.96 kips	210.96 kips	285.92 kips
42.70 ft	82.00 kips	210.96 kips	292.96 kips
43.70 ft	89.19 kips	210.96 kips	300.15 kips
44.70 ft	96.52 kips	210.96 kips	307.48 kips
45.69 ft	103.93 kips	210.96 kips	314.89 kips
45.71 ft	104.08 kips	27.39 kips	131.48 kips
46.70 ft	112.12 kips	27.39 kips	139.51 kips
47.70 ft	120.24 kips	27.39 kips	147.63 kips
48.70 ft	128.35 kips	27.39 kips	155.74 kips
49.70 ft	136.47 kips	27.39 kips	163.86 kips
50.70 ft	144.58 kips	27.39 kips	171.98 kips
51.70 ft	152.70 kips	27.39 kips	180.09 kips
52.70 ft	160.82 kips	27.39 kips	188.21 kips
53.70 ft	168.93 kips	27.39 kips	196.32 kips
54.70 ft	177.05 kips	27.39 kips	204.44 kips
55.70 ft	185.17 kips	27.39 kips	212.56 kips
56.70 ft	191.05 kips	27.39 kips	218.44 kips
57.70 ft	196.53 kips	27.39 kips	223.92 kips
58.70 ft	201.60 kips	27.39 kips	228.99 kips
59.70 ft	206.27 kips	27.39 kips	233.66 kips
60.70 ft	210.53 kips	27.39 kips	237.92 kips
61.70 ft	214.38 kips	27.39 kips	241.77 kips
62.70 ft	217.83 kips	27.39 kips	245.22 kips
63.70 ft	220.88 kips	27.39 kips	248.27 kips
64.69 ft	223.49 kips	27.39 kips	250.88 kips
64.71 ft	223.53 kips	29.16 kips	252.69 kips
65.70 ft	225.57 kips	29.16 kips	254.73 kips
66.70 ft	227.63 kips	29.16 kips	256.78 kips
67.70 ft	229.68 kips	29.16 kips	258.84 kips
68.70 ft	231.74 kips	29.16 kips	260.90 kips
69.70 ft	233.80 kips	29.16 kips	262.95 kips
70.70 ft	235.85 kips	29.16 kips	265.01 kips
71.70 ft	237.91 kips	29.16 kips	267.07 kips
72.70 ft	239.96 kips	29.16 kips	269.12 kips
73.70 ft	242.02 kips	29.16 kips	271.18 kips

Depth	Skin Friction	End Bearing	Total Capacity
74.70 ft	244.08 kips	29.16 kips	273.23 kips
75.70 ft	246.34 kips	29.16 kips	275.49 kips
76.70 ft	248.63 kips	29.16 kips	277.79 kips
77.70 ft	250.96 kips	29.16 kips	280.12 kips
78.70 ft	253.33 kips	29.16 kips	282.49 kips
79.70 ft	255.74 kips	29.16 kips	284.90 kips
80.70 ft	258.18 kips	29.16 kips	287.34 kips
81.70 ft	260.66 kips	29.16 kips	289.82 kips
82.70 ft	263.18 kips	29.16 kips	292.34 kips
83.70 ft	265.73 kips	29.16 kips	294.89 kips
84.69 ft	268.30 kips	29.16 kips	297.45 kips
84.71 ft	268.34 kips	23.86 kips	292.20 kips
85.70 ft	270.08 kips	23.86 kips	293.94 kips
86.70 ft	271.85 kips	23.86 kips	295.70 kips
87.70 ft	273.61 kips	23.86 kips	297.47 kips
88.70 ft	275.38 kips	23.86 kips	299.23 kips
89.70 ft	277.14 kips	23.86 kips	301.00 kips
90.70 ft	278.90 kips	23.86 kips	302.76 kips
91.70 ft	280.67 kips	23.86 kips	304.52 kips
92.69 ft	282.41 kips	23.86 kips	306.27 kips

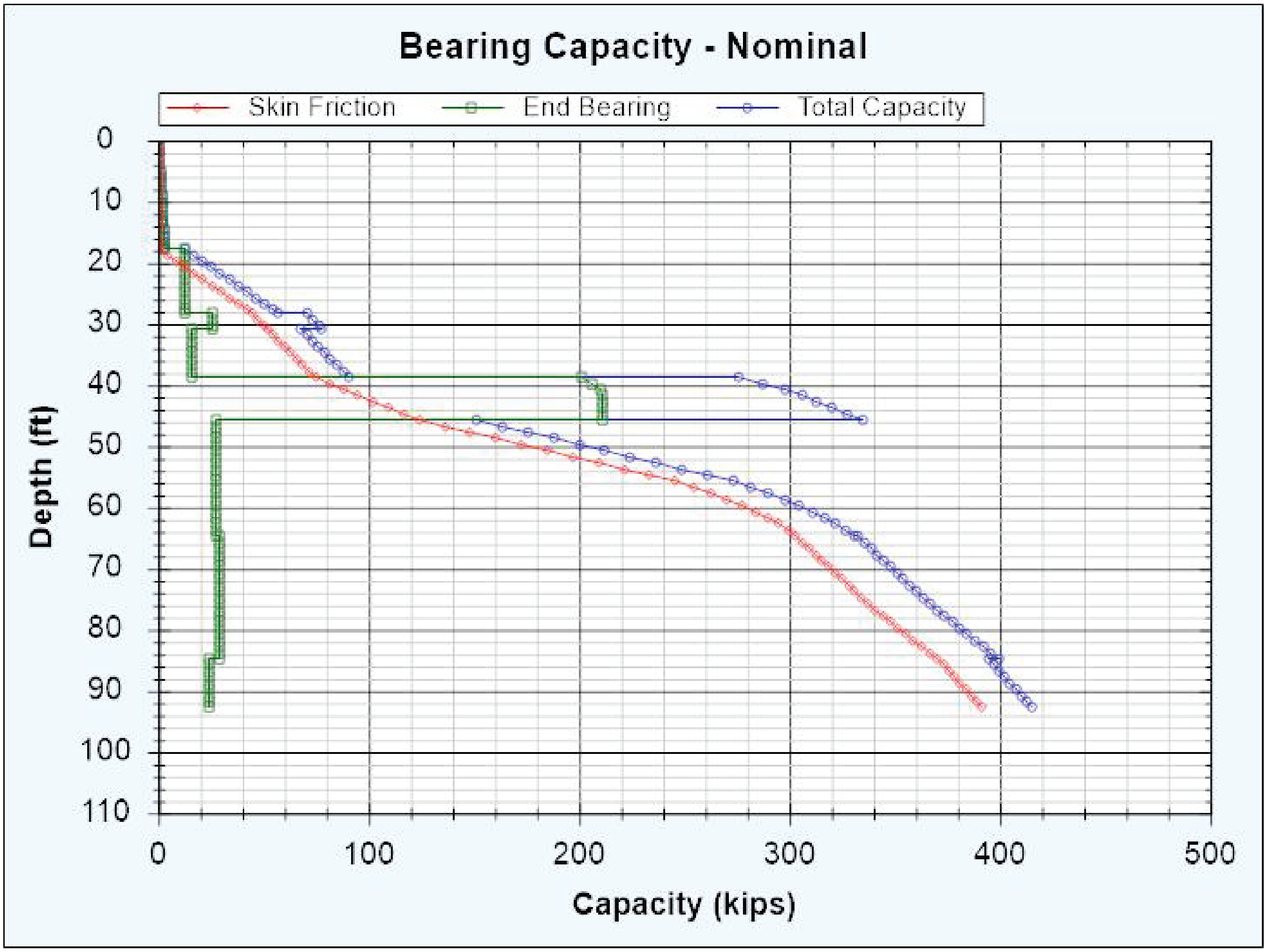

Bearing Capacity - Driving
Skin Friction
End Bearing
Total Capacity
Depth (ft)
0
10
20
30
40
50
60
70
80
90
100
110
Capacity (kips)
0
50
100
150
200
250
300
350
400
450
500

Nominal - Summary of Capacities

Depth	Skin Friction	End Bearing	Total Capacity
0.01 ft	0.00 kips	0.00 kips	0.00 kips
1.00 ft	0.00 kips	0.17 kips	0.17 kips
2.00 ft	0.00 kips	0.34 kips	0.34 kips
3.00 ft	0.00 kips	0.52 kips	0.52 kips
4.00 ft	0.00 kips	0.69 kips	0.69 kips
5.00 ft	0.00 kips	0.86 kips	0.86 kips
6.00 ft	0.00 kips	1.03 kips	1.03 kips
7.00 ft	0.00 kips	1.20 kips	1.20 kips
8.00 ft	0.00 kips	1.38 kips	1.38 kips
9.00 ft	0.00 kips	1.55 kips	1.55 kips
10.00 ft	0.00 kips	1.72 kips	1.72 kips
11.00 ft	0.00 kips	1.89 kips	1.89 kips
12.00 ft	0.00 kips	2.06 kips	2.06 kips
13.00 ft	0.00 kips	2.24 kips	2.24 kips
13.49 ft	0.00 kips	2.32 kips	2.32 kips
13.51 ft	0.00 kips	2.32 kips	2.32 kips
14.50 ft	0.00 kips	2.41 kips	2.41 kips
15.50 ft	0.00 kips	2.49 kips	2.49 kips
16.50 ft	0.00 kips	2.58 kips	2.58 kips
17.50 ft	0.00 kips	2.67 kips	2.67 kips
17.69 ft	0.00 kips	2.68 kips	2.68 kips
17.71 ft	0.04 kips	12.37 kips	12.41 kips
18.70 ft	4.23 kips	12.37 kips	16.60 kips
19.70 ft	8.45 kips	12.37 kips	20.82 kips
20.70 ft	12.68 kips	12.37 kips	25.05 kips
21.70 ft	16.91 kips	12.37 kips	29.28 kips
22.70 ft	21.14 kips	12.37 kips	33.51 kips
23.70 ft	25.36 kips	12.37 kips	37.73 kips
24.70 ft	29.59 kips	12.37 kips	41.96 kips
25.70 ft	33.82 kips	12.37 kips	46.19 kips
26.70 ft	38.05 kips	12.37 kips	50.42 kips
27.70 ft	42.27 kips	12.37 kips	54.64 kips
28.19 ft	44.53 kips	12.37 kips	56.90 kips
28.21 ft	44.61 kips	25.92 kips	70.53 kips
29.20 ft	47.36 kips	25.92 kips	73.27 kips
30.20 ft	50.20 kips	25.92 kips	76.12 kips
30.69 ft	51.62 kips	25.92 kips	77.54 kips
30.71 ft	51.67 kips	16.23 kips	67.90 kips
31.70 ft	54.30 kips	16.23 kips	70.53 kips
32.70 ft	57.02 kips	16.23 kips	73.25 kips
33.70 ft	59.80 kips	16.23 kips	76.03 kips
34.70 ft	62.63 kips	16.23 kips	78.86 kips

Depth	Skin Friction	End Bearing	Total Capacity
35.70 ft	65.53 kips	16.23 kips	81.76 kips
36.70 ft	68.49 kips	16.23 kips	84.72 kips
37.70 ft	71.51 kips	16.23 kips	87.74 kips
38.69 ft	74.56 kips	16.23 kips	90.79 kips
38.71 ft	74.66 kips	201.16 kips	275.82 kips
39.70 ft	81.19 kips	205.66 kips	286.85 kips
40.70 ft	87.93 kips	210.20 kips	298.14 kips
41.70 ft	94.82 kips	210.96 kips	305.78 kips
42.70 ft	101.86 kips	210.96 kips	312.82 kips
43.70 ft	109.05 kips	210.96 kips	320.01 kips
44.70 ft	116.38 kips	210.96 kips	327.34 kips
45.69 ft	123.79 kips	210.96 kips	334.75 kips
45.71 ft	123.99 kips	27.39 kips	151.38 kips
46.70 ft	136.04 kips	27.39 kips	163.43 kips
47.70 ft	148.21 kips	27.39 kips	175.60 kips
48.70 ft	160.39 kips	27.39 kips	187.78 kips
49.70 ft	172.56 kips	27.39 kips	199.95 kips
50.70 ft	184.73 kips	27.39 kips	212.12 kips
51.70 ft	196.91 kips	27.39 kips	224.30 kips
52.70 ft	209.08 kips	27.39 kips	236.47 kips
53.70 ft	221.25 kips	27.39 kips	248.65 kips
54.70 ft	233.43 kips	27.39 kips	260.82 kips
55.70 ft	245.60 kips	27.39 kips	272.99 kips
56.70 ft	254.43 kips	27.39 kips	281.82 kips
57.70 ft	262.64 kips	27.39 kips	290.04 kips
58.70 ft	270.25 kips	27.39 kips	297.64 kips
59.70 ft	277.25 kips	27.39 kips	304.64 kips
60.70 ft	283.64 kips	27.39 kips	311.04 kips
61.70 ft	289.43 kips	27.39 kips	316.82 kips
62.70 ft	294.60 kips	27.39 kips	321.99 kips
63.70 ft	299.17 kips	27.39 kips	326.56 kips
64.69 ft	303.09 kips	27.39 kips	330.48 kips
64.71 ft	303.15 kips	29.16 kips	332.31 kips
65.70 ft	306.21 kips	29.16 kips	335.36 kips
66.70 ft	309.29 kips	29.16 kips	338.45 kips
67.70 ft	312.37 kips	29.16 kips	341.53 kips
68.70 ft	315.46 kips	29.16 kips	344.62 kips
69.70 ft	318.54 kips	29.16 kips	347.70 kips
70.70 ft	321.63 kips	29.16 kips	350.79 kips
71.70 ft	324.71 kips	29.16 kips	353.87 kips
72.70 ft	327.80 kips	29.16 kips	356.95 kips
73.70 ft	330.88 kips	29.16 kips	360.04 kips

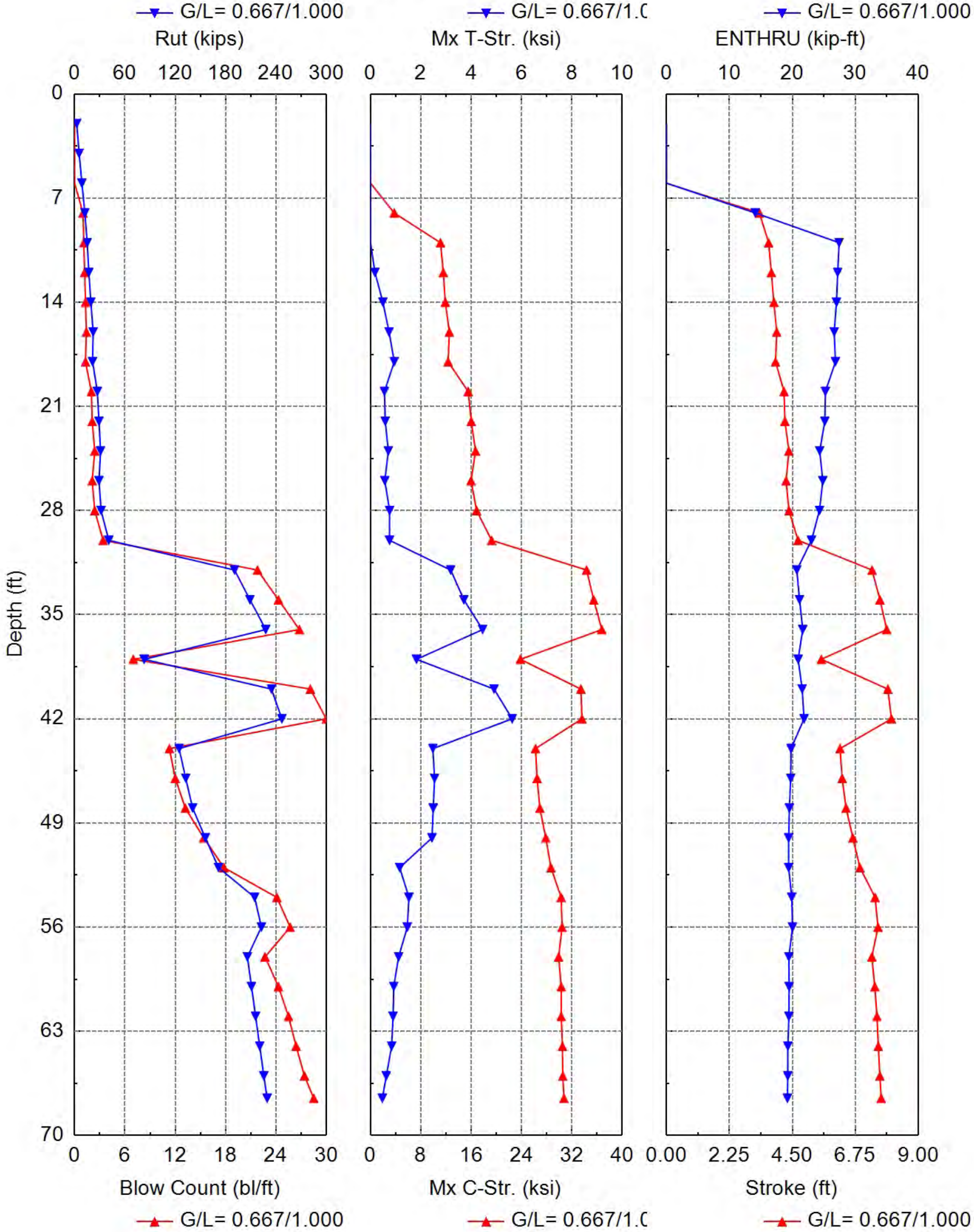
Depth	Skin Friction	End Bearing	Total Capacity
74.70 ft	333.96 kips	29.16 kips	363.12 kips
75.70 ft	337.35 kips	29.16 kips	366.51 kips
76.70 ft	340.80 kips	29.16 kips	369.95 kips
77.70 ft	344.29 kips	29.16 kips	373.45 kips
78.70 ft	347.85 kips	29.16 kips	377.01 kips
79.70 ft	351.46 kips	29.16 kips	380.61 kips
80.70 ft	355.12 kips	29.16 kips	384.28 kips
81.70 ft	358.84 kips	29.16 kips	388.00 kips
82.70 ft	362.61 kips	29.16 kips	391.77 kips
83.70 ft	366.44 kips	29.16 kips	395.60 kips
84.69 ft	370.29 kips	29.16 kips	399.45 kips
84.71 ft	370.36 kips	23.86 kips	394.21 kips
85.70 ft	372.97 kips	23.86 kips	396.83 kips
86.70 ft	375.62 kips	23.86 kips	399.48 kips
87.70 ft	378.27 kips	23.86 kips	402.12 kips
88.70 ft	380.91 kips	23.86 kips	404.77 kips
89.70 ft	383.56 kips	23.86 kips	407.41 kips
90.70 ft	386.20 kips	23.86 kips	410.06 kips
91.70 ft	388.85 kips	23.86 kips	412.70 kips
92.69 ft	391.46 kips	23.86 kips	415.32 kips

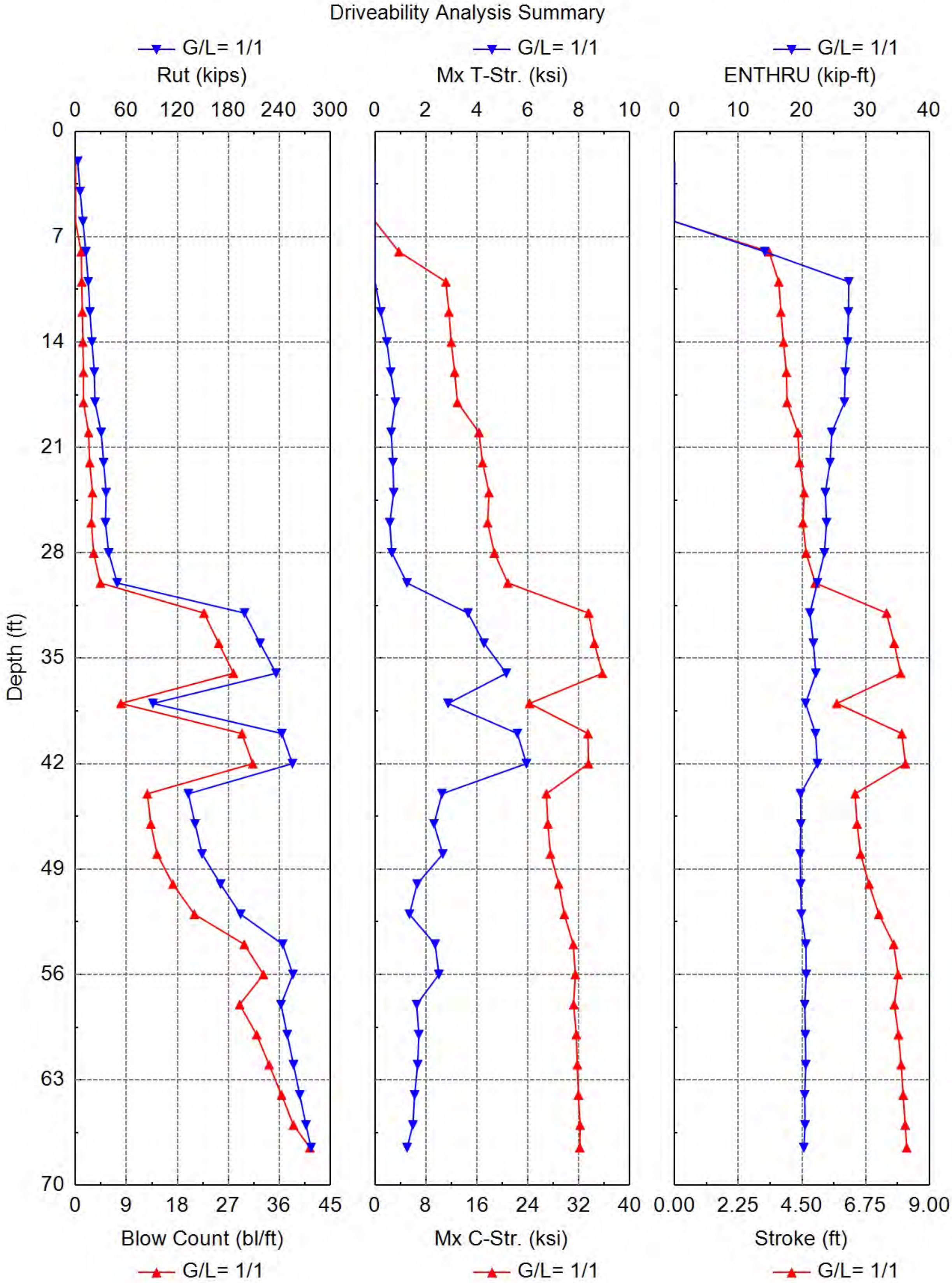

Bearing Capacity - Nominal
Skin Friction
End Bearing
Total Capacity
Depth (ft)
0
10
20
30
40
50
60
70
80
90
100
110
Capacity (kips)
0
100
200
300
400
500

APPENDIX VII

GRLWEAP DRIVABILITY ANALYSIS OUTPUTS

Driveability Analysis Summary




Driveability Analysis Summary
G/L= 1/1
Rut (kips)
0
60
120
180
240
300
G/L= 1/1
Mx T-Str. (ksi)
0
2
4
6
8
10
G/L= 1/1
ENTHRU (kip-ft)
0
10
20
30
40
Depth (ft)
0
7
14
21
28
35
42
49
56
63
70
0
9
18
27
36
45
Blow Count (bl/ft)
G/L= 1/1
0
8
16
24
32
40
Mx C-Str. (ksi)
G/L= 1/1
0.00
2.25
4.50
6.75
9.00
Stroke (ft)
G/L= 1/1

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

Depth ft	Rut kips	Rshaft kips	Rtoe kips	Blow Ct bl/ft	Mx C-Str. ksi	Mx T-Str. ksi	Stroke ft	ENTHRU kip-ft	Hammer -
2.0	2.5	0.2	2.3	0.3	0.000	0.000	10.81	0.0	D 19-42
4.0	5.4	0.7	4.7	0.0	0.000	0.000	0.00	0.0	D 19-42
6.0	8.7	1.6	7.0	0.0	0.000	0.000	0.00	0.0	D 19-42
8.0	12.2	2.9	9.3	1.0	3.761	0.000	3.32	14.1	D 19-42
10.0	15.0	4.6	10.5	1.1	11.115	0.000	3.65	27.4	D 19-42
12.0	17.0	6.6	10.5	1.2	11.565	0.175	3.75	27.2	D 19-42
14.0	19.4	8.9	10.5	1.3	11.885	0.490	3.84	27.0	D 19-42
16.0	22.1	11.7	10.5	1.4	12.531	0.736	3.94	26.7	D 19-42
18.0	21.4	15.2	6.2	1.3	12.325	0.942	3.90	26.9	D 19-42
20.0	27.1	18.3	8.8	2.0	15.524	0.552	4.20	25.3	D 19-42
22.0	29.1	20.2	8.8	2.1	16.010	0.584	4.24	25.2	D 19-42
24.0	31.0	22.2	8.8	2.4	16.693	0.708	4.38	24.4	D 19-42
26.0	29.0	24.6	4.4	2.1	15.973	0.566	4.28	24.8	D 19-42
28.0	31.6	27.2	4.4	2.4	16.853	0.758	4.38	24.3	D 19-42
30.0	40.8	30.3	10.5	3.4	19.245	0.756	4.70	23.0	D 19-42
32.0	190.7	35.4	155.3	21.8	34.342	3.184	7.35	20.7	D 19-42
34.0	209.0	46.5	162.5	24.3	35.467	3.709	7.63	21.1	D 19-42
36.0	227.9	58.2	169.7	26.8	36.758	4.453	7.88	21.7	D 19-42
38.0	82.9	66.7	16.3	7.0	23.812	1.827	5.54	20.9	D 19-42
40.0	234.7	75.0	159.6	28.1	33.429	4.907	7.92	21.6	D 19-42
42.0	247.1	87.5	159.6	30.0	33.609	5.627	8.04	21.9	D 19-42
44.0	124.5	98.6	26.0	11.3	26.218	2.476	6.21	19.8	D 19-42
46.0	132.5	106.5	26.0	12.0	26.469	2.542	6.28	19.7	D 19-42
48.0	140.7	114.7	26.0	13.2	26.909	2.491	6.42	19.5	D 19-42
50.0	155.8	129.3	26.5	15.4	27.856	2.441	6.67	19.4	D 19-42
52.0	171.6	145.0	26.5	17.8	28.677	1.157	6.92	19.4	D 19-42
54.0	214.6	158.1	56.5	24.1	30.295	1.524	7.46	19.9	D 19-42
56.0	222.7	166.1	56.5	25.7	30.449	1.461	7.56	20.0	D 19-42
58.0	206.0	171.5	34.5	22.7	29.886	1.115	7.34	19.5	D 19-42
60.0	210.9	176.4	34.5	24.3	30.309	0.922	7.45	19.5	D 19-42
62.0	215.8	181.3	34.5	25.5	30.307	0.897	7.53	19.5	D 19-42
64.0	220.7	186.2	34.5	26.4	30.496	0.839	7.57	19.3	D 19-42
66.0	225.6	191.1	34.5	27.4	30.555	0.626	7.63	19.3	D 19-42
67.5	229.5	195.1	34.5	28.5	30.740	0.469	7.68	19.2	D 19-42

Summary_Total driving time: 19 minutes; Total Number of Blows: 825 (starting at penetration 2.0 ft)

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

Depth ft	Rut kips	Rshaft kips	Rtoe kips	Blow Ct bl/ft	Mx C-Str. ksi	Mx T-Str. ksi	Stroke ft	ENTHRU kip-ft	Hammer -
2.0	2.5	0.2	2.3	0.3	0.000	0.000	10.81	0.0	D 19-42
4.0	5.4	0.7	4.7	0.0	0.000	0.000	0.00	0.0	D 19-42
6.0	8.7	1.6	7.0	0.0	0.000	0.000	0.00	0.0	D 19-42
8.0	12.2	2.9	9.3	1.0	3.742	0.000	3.33	14.2	D 19-42
10.0	15.0	4.6	10.5	1.1	11.119	0.000	3.68	27.3	D 19-42
12.0	17.0	6.6	10.5	1.2	11.600	0.224	3.75	27.3	D 19-42

14.0	19.4	8.9	10.5	1.3	11.960	0.462	3.85	27.1	D 19-42
16.0	22.1	11.7	10.5	1.4	12.492	0.616	3.95	26.8	D 19-42
18.0	23.0	16.8	6.2	1.4	12.934	0.798	3.98	26.7	D 19-42
20.0	30.2	21.4	8.8	2.3	16.310	0.633	4.35	24.7	D 19-42
22.0	33.1	24.3	8.8	2.5	16.878	0.702	4.41	24.4	D 19-42
24.0	36.0	27.2	8.8	3.0	17.890	0.734	4.58	23.7	D 19-42
26.0	35.3	30.9	4.4	2.8	17.683	0.580	4.53	23.8	D 19-42
28.0	39.1	34.7	4.4	3.2	18.731	0.660	4.65	23.5	D 19-42
30.0	49.1	38.7	10.5	4.4	20.849	1.253	4.97	22.4	D 19-42
32.0	199.0	43.7	155.3	22.7	33.541	3.649	7.49	21.3	D 19-42
34.0	217.4	54.9	162.5	25.3	34.427	4.278	7.76	21.8	D 19-42
36.0	236.2	66.5	169.7	27.9	35.703	5.153	7.99	22.2	D 19-42
38.0	91.3	75.0	16.3	8.0	24.265	2.867	5.73	20.6	D 19-42
40.0	243.0	83.3	159.6	29.4	33.422	5.586	8.02	22.1	D 19-42
42.0	255.5	95.8	159.6	31.3	33.513	5.941	8.16	22.4	D 19-42
44.0	132.9	106.9	26.0	12.7	26.901	2.628	6.38	19.8	D 19-42
46.0	140.8	114.8	26.0	13.3	27.134	2.312	6.45	19.8	D 19-42
48.0	149.0	123.1	26.0	14.4	27.539	2.659	6.57	19.7	D 19-42
50.0	170.8	144.3	26.5	17.2	28.842	1.651	6.87	19.8	D 19-42
52.0	194.4	167.9	26.5	21.0	29.704	1.350	7.22	19.9	D 19-42
54.0	244.0	187.4	56.5	29.8	31.126	2.358	7.74	20.6	D 19-42
56.0	256.1	199.5	56.5	33.2	31.449	2.508	7.89	20.7	D 19-42
58.0	242.0	207.6	34.5	29.0	31.177	1.633	7.76	20.4	D 19-42
60.0	249.4	214.9	34.5	32.0	31.600	1.719	7.91	20.5	D 19-42
62.0	256.7	222.3	34.5	34.2	31.757	1.672	8.00	20.6	D 19-42
64.0	264.1	229.6	34.5	36.4	31.930	1.554	8.07	20.4	D 19-42
66.0	271.4	237.0	34.5	38.5	32.192	1.484	8.15	20.5	D 19-42
67.5	277.4	242.9	34.5	41.4	32.150	1.259	8.20	20.3	D 19-42

Summary_Total driving time: 23 minutes; Total Number of Blows: 985 (starting at penetration 2.0 ft)

GRLWEAP: Wave Equation Analysis of Pile Foundations

FRA-00070-23.920 - RA (B-066-0-19) + 12" CIP - 0.3125" Wall Thick 11/30/2022
RESOURCE INTERNATIONAL INC GRLWEAP 14.1.15.0

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

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

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

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

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

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

SOIL PROFILE

Depth ft	Soil Type -	Spec. Wt lb/ft^3	Su ksf	Phi °	Unit Rs ksf	Unit Rt ksf
0.0	Sand	125.0	0.0	28.0	0.00	0.00
16.3	Sand	125.0	0.0	28.0	0.47	13.32
16.3	Clay	115.0	0.9	0.0	0.87	7.87
19.3	Clay	115.0	0.9	0.0	0.87	7.87
19.3	Clay	115.0	1.2	0.0	0.46	11.25
24.3	Clay	115.0	1.2	0.0	0.46	11.25
24.3	Clay	110.0	0.6	0.0	0.61	5.62
29.3	Clay	110.0	0.6	0.0	0.61	5.62
29.3	Sand	125.0	0.0	29.0	0.68	13.32
31.8	Sand	125.0	0.0	29.0	0.72	13.32
31.8	Sand	127.3	0.0	37.5	1.73	196.83
36.8	Sand	127.3	0.0	37.5	1.93	219.72
36.8	Sand	125.0	0.0	31.0	0.97	20.71
39.3	Sand	125.0	0.0	31.0	1.02	20.71
39.3	Sand	135.0	0.0	37.0	1.91	203.27
43.3	Sand	135.0	0.0	37.0	2.08	203.27
43.3	Sand	125.0	0.0	32.0	1.23	33.09
48.3	Sand	125.0	0.0	32.0	1.34	33.09
48.3	Clay	130.5	3.7	32.0	3.75	33.75
53.3	Clay	130.5	3.7	32.0	3.75	33.75
53.3	Clay	130.0	8.0	0.0	1.92	72.00
56.3	Clay	130.0	8.0	0.0	1.92	72.00
56.3	Clay	125.0	4.9	0.0	1.18	43.87
73.3	Clay	125.0	4.9	0.0	1.18	43.87
73.3	Clay	130.0	6.2	0.0	1.50	56.25
86.3	Clay	130.0	6.2	0.0	1.50	56.25

PILE INPUT

Uniform Pile		Pile Type:	Pipe
Pile Length: (ft)	70.000	Pile Penetration: (ft)	67.500
Pile Size: (ft)	1.00	Toe Area: (in^2)	113.10

Pile Profile

Lb Top ft	X-Area in^2	E-Modulus ksi	Spec. Wt lb/ft^3	Perim. ft	Crit. Index -
0.0	11.5	30,000.0	492.0	3.1	0
70.0	11.5	30,000.0	492.0	3.1	0

HAMMER INPUT

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

Hammer Data

ID -	Ram Wt kips	Ram L. in	Ram Ar. in^2	Rtd. Stk ft	Effic. -	Rtd. Energy kip-ft
41	4.000	129.1	124.7	10.8	0.80	43.2

DRIVE SYSTEM FOR DELMAG D 19-42-OED

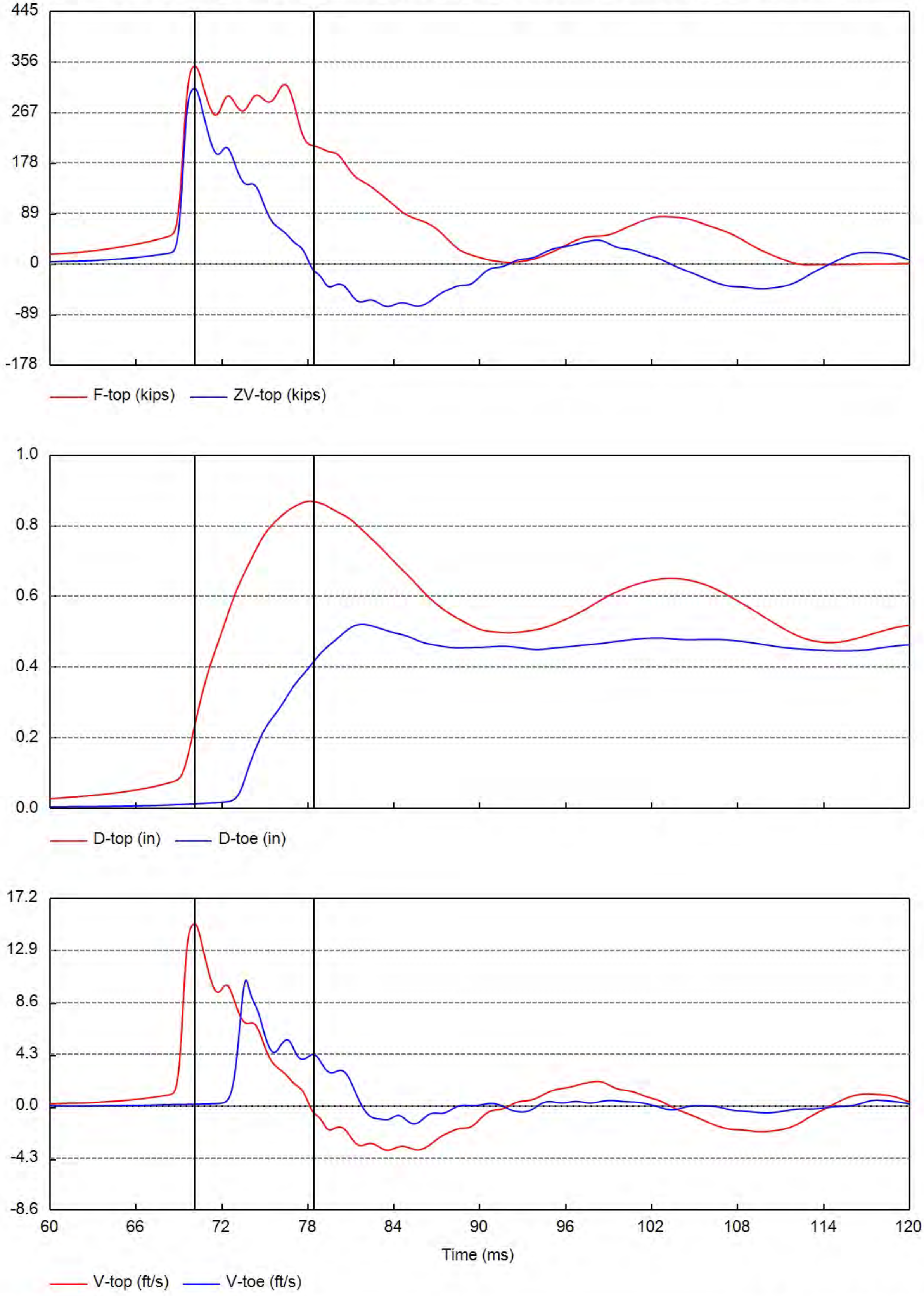
Type -	X-Area in²	E-Modulus ksi	Thickness in	COR -	Round-out in	Stiffness kips/in
Hammer C.	227.000	530.000	2.000	0.800	0.120	60155.550
Helmet Wt.	1.900	kips				

SOIL RESISTANCE DISTRIBUTION

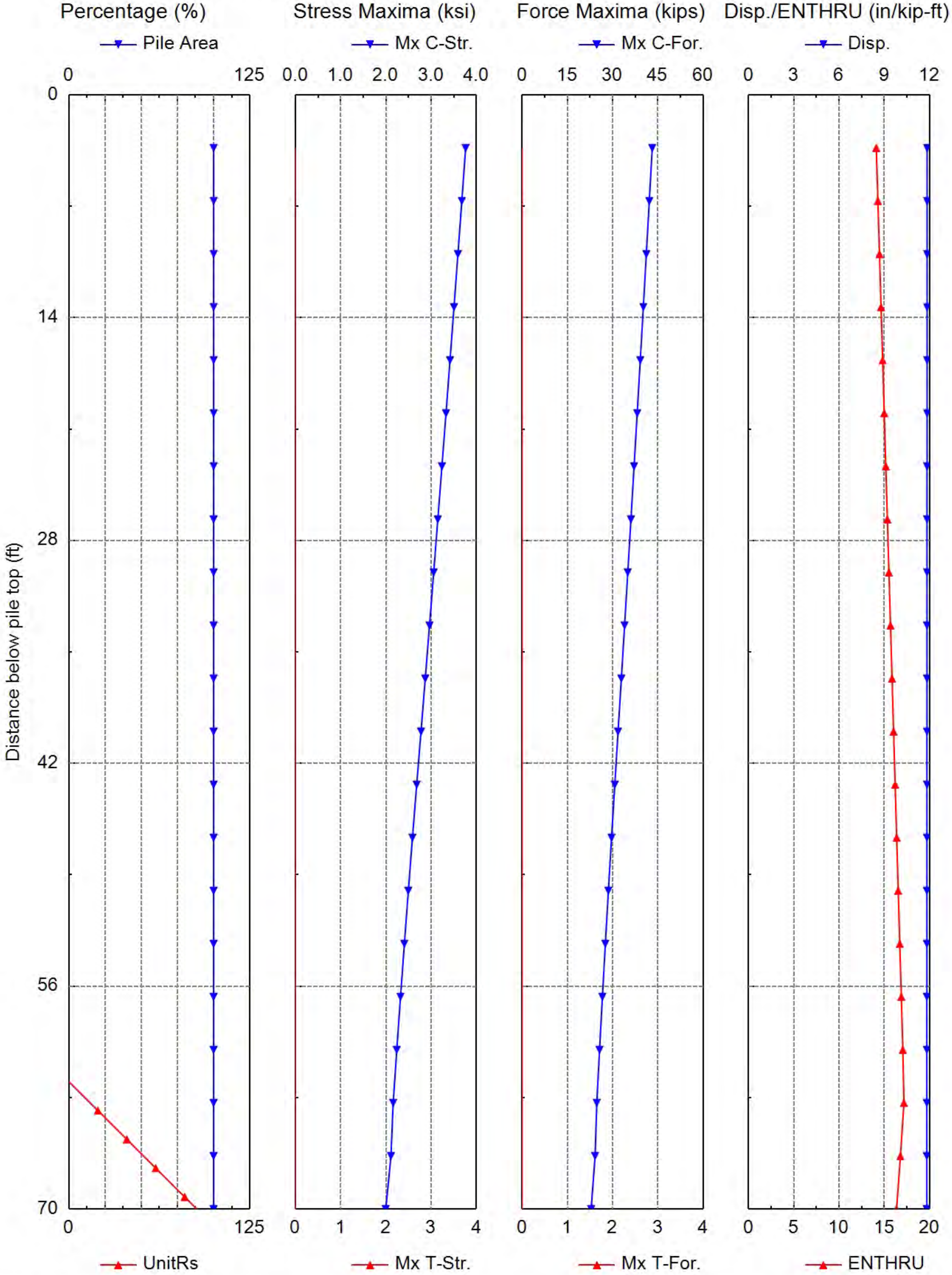
Depth ft	Unit Rs ksf	Unit Rt ksf	Qs in	Qt in	Js s/ft	Jt s/ft	Set. F. -	Limit D. ft	Set. T. Hours	EB Area in²
0.0	0.0	0.0	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
1.8	0.1	2.7	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
3.6	0.1	5.4	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
5.4	0.2	8.1	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
7.2	0.2	10.8	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
9.1	0.3	13.3	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
10.9	0.3	13.3	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
12.7	0.4	13.3	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
14.5	0.4	13.3	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
16.3	0.5	13.3	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
16.3	0.9	7.9	0.10	0.20	0.15	0.15	1.5	6.6	168.0	113.1
17.8	0.9	7.9	0.10	0.20	0.15	0.15	1.5	6.6	168.0	113.1
19.3	0.9	7.9	0.10	0.20	0.15	0.15	1.5	6.6	168.0	113.1
19.3	0.5	11.2	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
21.0	0.5	11.2	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
22.6	0.5	11.2	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
24.3	0.5	11.2	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
24.3	0.6	5.6	0.10	0.20	0.15	0.15	1.5	6.6	168.0	113.1
26.0	0.6	5.6	0.10	0.20	0.15	0.15	1.5	6.6	168.0	113.1
27.6	0.6	5.6	0.10	0.20	0.15	0.15	1.5	6.6	168.0	113.1
29.3	0.6	5.6	0.10	0.20	0.15	0.15	1.5	6.6	168.0	113.1
29.3	0.7	13.3	0.10	0.15	0.05	0.15	1.0	6.6	1.0	113.1
30.5	0.7	13.3	0.10	0.15	0.05	0.15	1.0	6.6	1.0	113.1
31.8	0.7	13.3	0.10	0.15	0.05	0.15	1.0	6.6	1.0	113.1
31.8	1.7	196.8	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
33.5	1.8	204.5	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
35.1	1.9	212.1	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
36.8	1.9	219.7	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
36.8	1.0	20.7	0.10	0.15	0.05	0.15	1.0	6.6	1.0	113.1
38.0	1.0	20.7	0.10	0.15	0.05	0.15	1.0	6.6	1.0	113.1
39.3	1.0	20.7	0.10	0.15	0.05	0.15	1.0	6.6	1.0	113.1
39.3	1.9	203.3	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
41.3	2.0	203.3	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
43.3	2.1	203.3	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
43.3	1.2	33.1	0.10	0.15	0.05	0.15	1.0	6.6	1.0	113.1
45.0	1.3	33.1	0.10	0.15	0.05	0.15	1.0	6.6	1.0	113.1
46.6	1.3	33.1	0.10	0.15	0.05	0.15	1.0	6.6	1.0	113.1
48.3	1.3	33.1	0.10	0.15	0.05	0.15	1.0	6.6	1.0	113.1
48.3	3.7	33.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1

50.0	3.7	33.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
51.6	3.7	33.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
53.3	3.7	33.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
53.3	1.9	72.0	0.10	0.10	0.15	0.15	1.5	6.6	168.0	113.1
54.8	1.9	72.0	0.10	0.10	0.15	0.15	1.5	6.6	168.0	113.1
56.3	1.9	72.0	0.10	0.10	0.15	0.15	1.5	6.6	168.0	113.1
56.3	1.2	43.9	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
58.0	1.2	43.9	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
59.7	1.2	43.9	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
61.4	1.2	43.9	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
63.1	1.2	43.9	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
64.8	1.2	43.9	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
66.5	1.2	43.9	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
68.2	1.2	43.9	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1

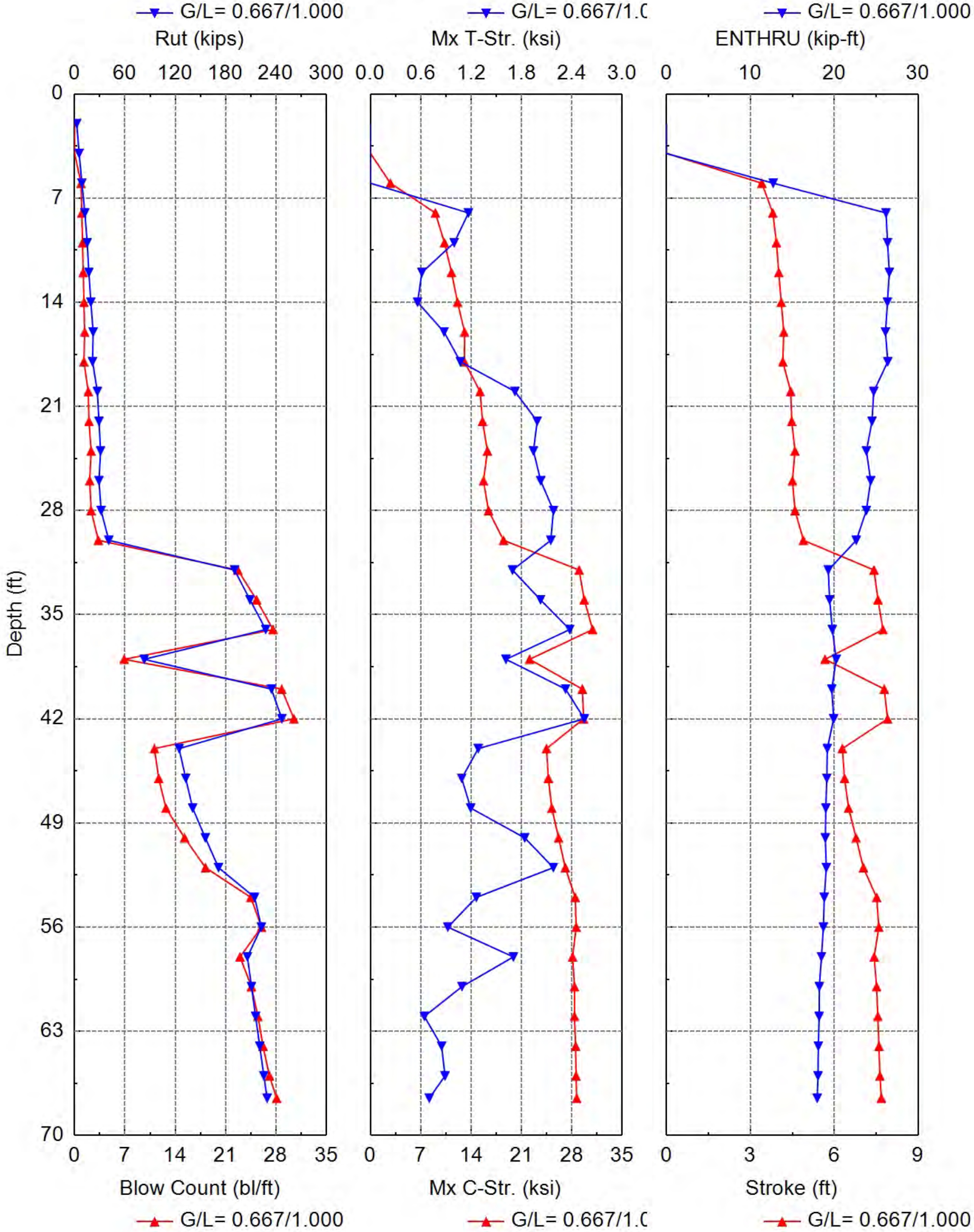
Variable Time Hisotry with DELMAG D 19-42; Depth = 67.50ft; Shaft/Toe G/L = 0.667/1.000



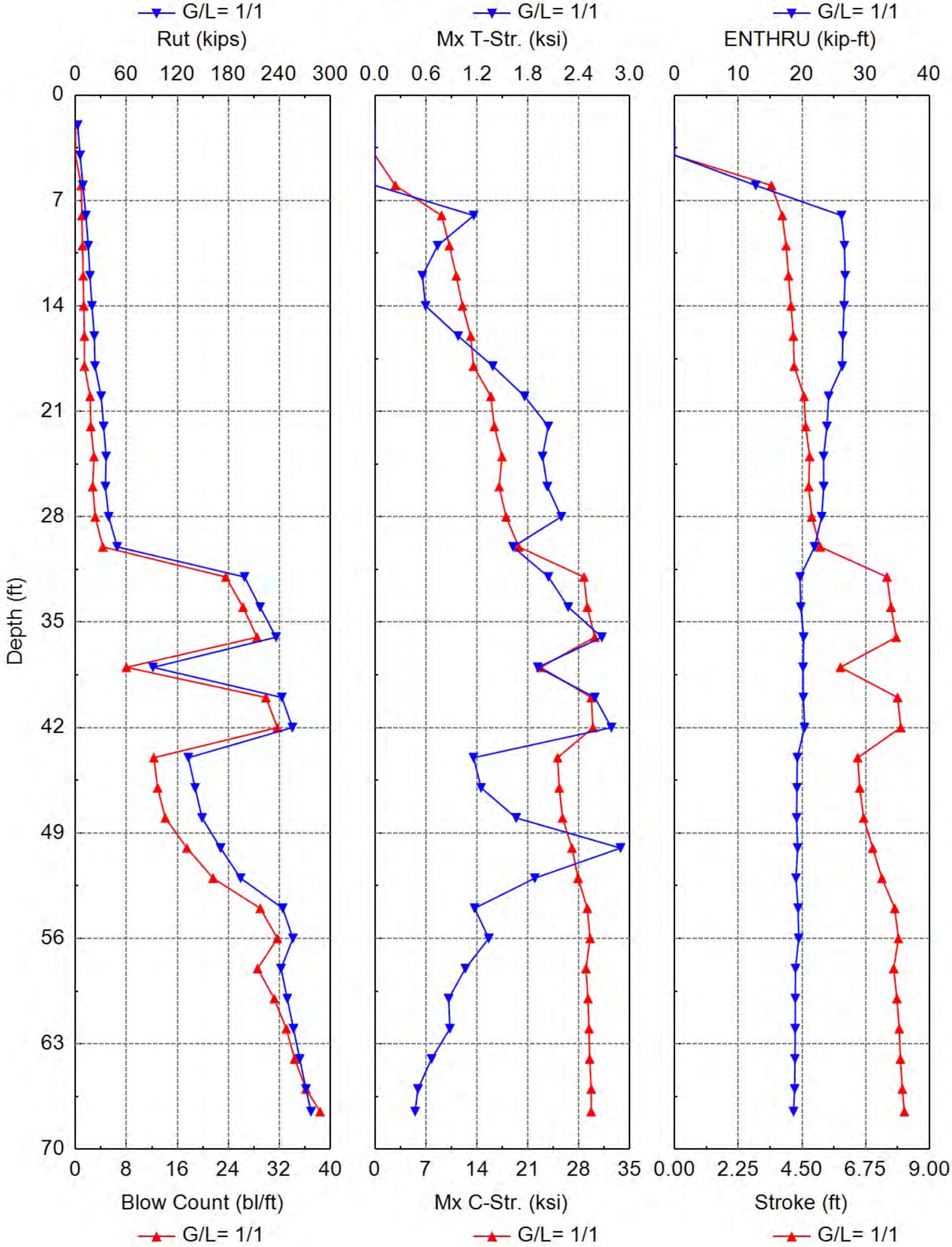
Extrema Results of Gain/Loss at Shaft/Toe = 0.667/1.000 and Depth = 8.00 ft



Driveability Analysis Summary



Driveability Analysis Summary



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

Depth ft	Rut kips	Rshaft kips	Rtoe kips	Blow Ct bl/ft	Mx C-Str. ksi	Mx T-Str. ksi	Stroke ft	ENTHRU kip-ft	Hammer -
2.0	2.5	0.2	2.3	0.3	0.000	0.000	10.81	0.0	D 19-42
4.0	5.4	0.7	4.7	0.3	0.000	0.000	10.81	0.0	D 19-42
6.0	8.7	1.6	7.0	0.9	2.763	0.000	3.41	12.7	D 19-42
8.0	12.2	2.9	9.3	1.0	9.013	1.167	3.80	26.2	D 19-42
10.0	15.0	4.6	10.5	1.1	10.280	0.997	3.93	26.3	D 19-42
12.0	17.0	6.6	10.5	1.2	11.262	0.612	4.01	26.6	D 19-42
14.0	19.4	8.9	10.5	1.3	12.098	0.561	4.10	26.3	D 19-42
16.0	22.1	11.7	10.5	1.4	13.079	0.877	4.19	26.1	D 19-42
18.0	21.4	15.2	6.2	1.3	13.056	1.071	4.16	26.4	D 19-42
20.0	27.1	18.3	8.8	1.9	15.234	1.721	4.44	24.7	D 19-42
22.0	29.1	20.2	8.8	2.0	15.574	1.986	4.48	24.5	D 19-42
24.0	31.0	22.2	8.8	2.3	16.255	1.942	4.59	23.8	D 19-42
26.0	29.0	24.6	4.4	2.1	15.704	2.028	4.50	24.3	D 19-42
28.0	31.6	27.2	4.4	2.3	16.406	2.180	4.60	23.8	D 19-42
30.0	40.8	30.3	10.5	3.3	18.495	2.149	4.90	22.6	D 19-42
32.0	190.7	35.4	155.3	22.7	29.002	1.692	7.42	19.3	D 19-42
34.0	209.0	46.5	162.5	25.3	29.724	2.026	7.56	19.4	D 19-42
36.0	227.9	58.2	169.7	27.6	30.882	2.375	7.74	19.8	D 19-42
38.0	82.9	66.7	16.3	6.9	22.127	1.615	5.67	20.2	D 19-42
40.0	234.7	75.0	159.6	28.8	29.449	2.324	7.79	19.7	D 19-42
42.0	247.1	87.5	159.6	30.5	29.635	2.548	7.91	19.9	D 19-42
44.0	124.6	98.6	26.0	11.1	24.470	1.284	6.29	19.2	D 19-42
46.0	132.5	106.5	26.0	11.7	24.729	1.087	6.37	19.1	D 19-42
48.0	140.7	114.7	26.0	12.7	25.203	1.194	6.51	19.0	D 19-42
50.0	155.8	129.3	26.5	15.3	26.154	1.838	6.78	18.9	D 19-42
52.0	171.6	145.0	26.5	18.2	27.085	2.179	7.04	19.1	D 19-42
54.0	214.6	158.1	56.5	24.5	28.463	1.261	7.51	18.8	D 19-42
56.0	222.7	166.1	56.5	26.0	28.593	0.921	7.59	18.7	D 19-42
58.0	206.0	171.5	34.5	23.0	28.104	1.703	7.43	18.5	D 19-42
60.0	210.9	176.4	34.5	24.6	28.363	1.090	7.51	18.2	D 19-42
62.0	215.8	181.3	34.5	25.5	28.366	0.642	7.56	18.2	D 19-42
64.0	220.7	186.2	34.5	26.2	28.517	0.847	7.60	18.1	D 19-42
66.0	225.6	191.1	34.5	27.1	28.574	0.887	7.63	18.1	D 19-42
67.5	229.5	195.1	34.5	28.1	28.673	0.700	7.68	18.0	D 19-42

Summary_Total driving time: 19 minutes; Total Number of Blows: 835 (starting at penetration 2.0 ft)

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

Depth ft	Rut kips	Rshaft kips	Rtoe kips	Blow Ct bl/ft	Mx C-Str. ksi	Mx T-Str. ksi	Stroke ft	ENTHRU kip-ft	Hammer -
2.0	2.5	0.2	2.3	0.3	0.000	0.000	10.81	0.0	D 19-42
4.0	5.4	0.7	4.7	0.3	0.000	0.000	10.81	0.0	D 19-42
6.0	8.7	1.6	7.0	0.9	2.776	0.000	3.42	12.7	D 19-42
8.0	12.2	2.9	9.3	1.0	9.147	1.162	3.80	26.2	D 19-42
10.0	15.0	4.6	10.5	1.1	10.216	0.736	3.94	26.7	D 19-42
12.0	17.0	6.6	10.5	1.2	11.157	0.558	4.02	26.8	D 19-42

14.0	19.4	8.9	10.5	1.3	12.020	0.595	4.11	26.6	D 19-42
16.0	22.1	11.7	10.5	1.4	13.144	0.979	4.20	26.4	D 19-42
18.0	23.0	16.8	6.2	1.4	13.520	1.387	4.22	26.3	D 19-42
20.0	30.2	21.4	8.8	2.3	15.898	1.760	4.57	24.2	D 19-42
22.0	33.1	24.3	8.8	2.4	16.384	2.040	4.63	23.9	D 19-42
24.0	36.0	27.2	8.8	2.9	17.445	1.972	4.77	23.4	D 19-42
26.0	35.3	30.9	4.4	2.7	17.056	2.029	4.74	23.4	D 19-42
28.0	39.1	34.7	4.4	3.1	18.000	2.193	4.84	23.1	D 19-42
30.0	49.1	38.7	10.5	4.3	19.736	1.625	5.14	22.0	D 19-42
32.0	199.0	43.7	155.3	23.6	28.695	2.042	7.50	19.7	D 19-42
34.0	217.4	54.9	162.5	26.3	29.155	2.275	7.65	19.8	D 19-42
36.0	236.2	66.5	169.7	28.5	30.191	2.671	7.83	20.3	D 19-42
38.0	91.3	75.0	16.3	8.0	22.746	1.917	5.86	20.2	D 19-42
40.0	243.0	83.3	159.6	29.9	29.711	2.589	7.88	20.2	D 19-42
42.0	255.5	95.8	159.6	31.7	29.940	2.783	7.99	20.4	D 19-42
44.0	132.9	106.9	26.0	12.3	25.076	1.160	6.47	19.3	D 19-42
46.0	140.8	114.8	26.0	12.9	25.315	1.249	6.54	19.2	D 19-42
48.0	149.0	123.1	26.0	14.1	25.756	1.661	6.68	19.2	D 19-42
50.0	170.8	144.3	26.5	17.5	27.062	2.891	7.00	19.3	D 19-42
52.0	194.4	167.9	26.5	21.6	27.890	1.881	7.32	19.1	D 19-42
54.0	244.0	187.4	56.5	29.0	29.159	1.172	7.78	19.4	D 19-42
56.0	256.1	199.5	56.5	31.7	29.545	1.340	7.91	19.5	D 19-42
58.0	242.0	207.6	34.5	28.6	28.981	1.063	7.74	19.0	D 19-42
60.0	249.4	214.9	34.5	31.2	29.255	0.867	7.86	19.0	D 19-42
62.0	256.7	222.3	34.5	33.1	29.400	0.881	7.94	18.9	D 19-42
64.0	264.1	229.6	34.5	34.4	29.482	0.665	7.98	18.9	D 19-42
66.0	271.4	237.0	34.5	36.2	29.702	0.505	8.05	18.8	D 19-42
67.5	277.4	242.9	34.5	38.4	29.679	0.472	8.12	18.7	D 19-42

Summary_Total driving time: 22 minutes; Total Number of Blows: 973 (starting at penetration 2.0 ft)

GRLWEAP: Wave Equation Analysis of Pile Foundations

FRA-00070-23.920 - RA (B-066-0-19) + 12" CIP - 0.4375" Wall Thick 12/3/2022
RESOURCE INTERNATIONAL INC GRLWEAP 14.1.15.0

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

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

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

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

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

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

SOIL PROFILE

Depth ft	Soil Type -	Spec. Wt lb/ft³	Su ksf	Phi °	Unit Rs ksf	Unit Rt ksf
0.0	Sand	125.0	0.0	28.0	0.00	0.00
16.3	Sand	125.0	0.0	28.0	0.47	13.32
16.3	Clay	115.0	0.9	0.0	0.87	7.87
19.3	Clay	115.0	0.9	0.0	0.87	7.87
19.3	Clay	115.0	1.2	0.0	0.46	11.25
24.3	Clay	115.0	1.2	0.0	0.46	11.25
24.3	Clay	110.0	0.6	0.0	0.61	5.62
29.3	Clay	110.0	0.6	0.0	0.61	5.62
29.3	Sand	125.0	0.0	29.0	0.68	13.32
31.8	Sand	125.0	0.0	29.0	0.72	13.32
31.8	Sand	127.3	0.0	37.5	1.73	196.83
36.8	Sand	127.3	0.0	37.5	1.93	219.72
36.8	Sand	125.0	0.0	31.0	0.97	20.71
39.3	Sand	125.0	0.0	31.0	1.02	20.71
39.3	Sand	135.0	0.0	37.0	1.91	203.27
43.3	Sand	135.0	0.0	37.0	2.08	203.27
43.3	Sand	125.0	0.0	32.0	1.23	33.09
48.3	Sand	125.0	0.0	32.0	1.34	33.09
48.3	Clay	130.5	3.7	32.0	3.75	33.75
53.3	Clay	130.5	3.7	32.0	3.75	33.75
53.3	Clay	130.0	8.0	0.0	1.92	72.00
56.3	Clay	130.0	8.0	0.0	1.92	72.00
56.3	Clay	125.0	4.9	0.0	1.18	43.87
73.3	Clay	125.0	4.9	0.0	1.18	43.87
73.3	Clay	130.0	6.2	0.0	1.50	56.25
86.3	Clay	130.0	6.2	0.0	1.50	56.25

PILE INPUT

Uniform Pile		Pile Type:	Pipe
Pile Length: (ft)	70.000	Pile Penetration: (ft)	67.500
Pile Size: (ft)	1.00	Toe Area: (in²)	113.10

Pile Profile

Lb Top ft	X-Area in²	E-Modulus ksi	Spec. Wt lb/ft³	Perim. ft	Crit. Index -
0.0	15.9	30,000.0	492.0	3.1	0
70.0	15.9	30,000.0	492.0	3.1	0

HAMMER INPUT

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

Hammer Data

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

DRIVE SYSTEM FOR DELMAG D 19-42-OED

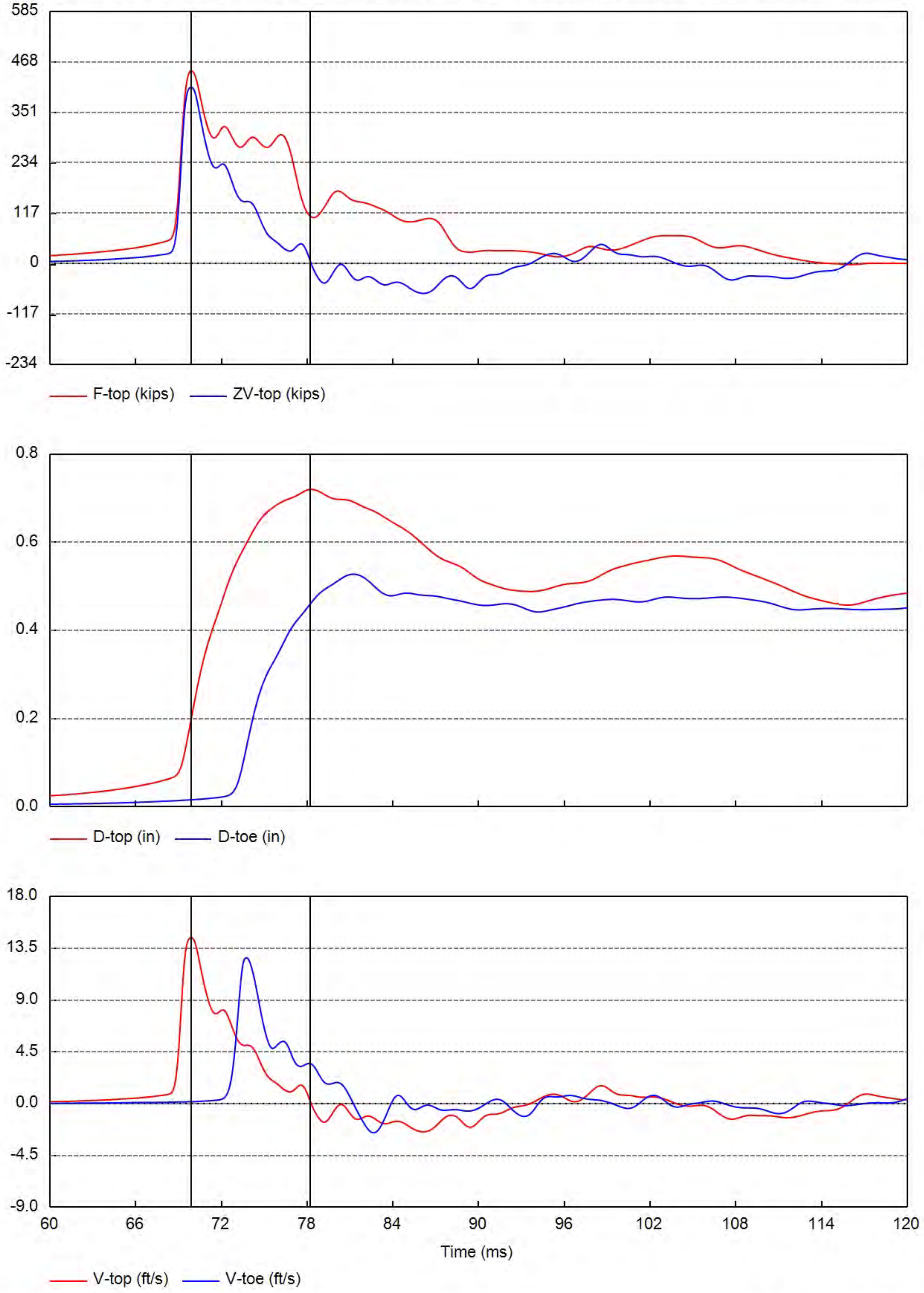
Type	X-Area	E-Modulus	Thickness	COR	Round-out	Stiffness
-	in²	ksi	in	-	in	kips/in
Hammer C.	227.000	530.000	2.000	0.800	0.120	60155.550
Helmet Wt.	1.900	kips				

SOIL RESISTANCE DISTRIBUTION

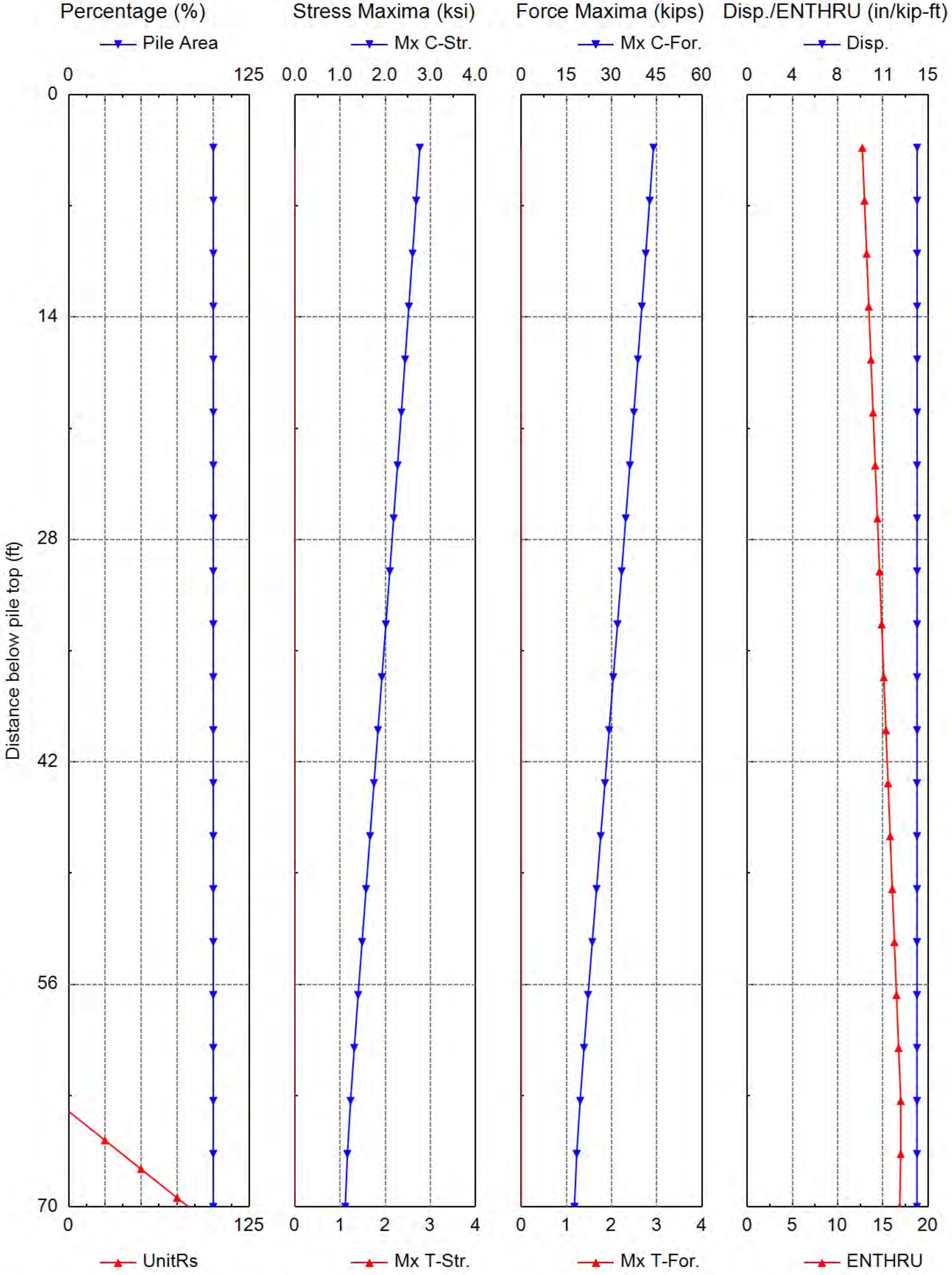
Depth	Unit Rs	Unit Rt	Qs	Qt	Js	Jt	Set. F.	Limit D.	Set. T.	EB Area
ft	ksf	ksf	in	in	s/ft	s/ft	-	ft	Hours	in²
0.0	0.0	0.0	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
1.8	0.1	2.7	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
3.6	0.1	5.4	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
5.4	0.2	8.1	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
7.2	0.2	10.8	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
9.1	0.3	13.3	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
10.9	0.3	13.3	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
12.7	0.4	13.3	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
14.5	0.4	13.3	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
16.3	0.5	13.3	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
16.3	0.9	7.9	0.10	0.20	0.15	0.15	1.5	6.6	168.0	113.1
17.8	0.9	7.9	0.10	0.20	0.15	0.15	1.5	6.6	168.0	113.1
19.3	0.9	7.9	0.10	0.20	0.15	0.15	1.5	6.6	168.0	113.1
19.3	0.5	11.2	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
21.0	0.5	11.2	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
22.6	0.5	11.2	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
24.3	0.5	11.2	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
24.3	0.6	5.6	0.10	0.20	0.15	0.15	1.5	6.6	168.0	113.1
26.0	0.6	5.6	0.10	0.20	0.15	0.15	1.5	6.6	168.0	113.1
27.6	0.6	5.6	0.10	0.20	0.15	0.15	1.5	6.6	168.0	113.1
29.3	0.6	5.6	0.10	0.20	0.15	0.15	1.5	6.6	168.0	113.1
29.3	0.7	13.3	0.10	0.15	0.05	0.15	1.0	6.6	1.0	113.1
30.5	0.7	13.3	0.10	0.15	0.05	0.15	1.0	6.6	1.0	113.1
31.8	0.7	13.3	0.10	0.15	0.05	0.15	1.0	6.6	1.0	113.1
31.8	1.7	196.8	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
33.5	1.8	204.5	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
35.1	1.9	212.1	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
36.8	1.9	219.7	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
36.8	1.0	20.7	0.10	0.15	0.05	0.15	1.0	6.6	1.0	113.1
38.0	1.0	20.7	0.10	0.15	0.05	0.15	1.0	6.6	1.0	113.1
39.3	1.0	20.7	0.10	0.15	0.05	0.15	1.0	6.6	1.0	113.1
39.3	1.9	203.3	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
41.3	2.0	203.3	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
43.3	2.1	203.3	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
43.3	1.2	33.1	0.10	0.15	0.05	0.15	1.0	6.6	1.0	113.1
45.0	1.3	33.1	0.10	0.15	0.05	0.15	1.0	6.6	1.0	113.1
46.6	1.3	33.1	0.10	0.15	0.05	0.15	1.0	6.6	1.0	113.1
48.3	1.3	33.1	0.10	0.15	0.05	0.15	1.0	6.6	1.0	113.1
48.3	3.7	33.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1

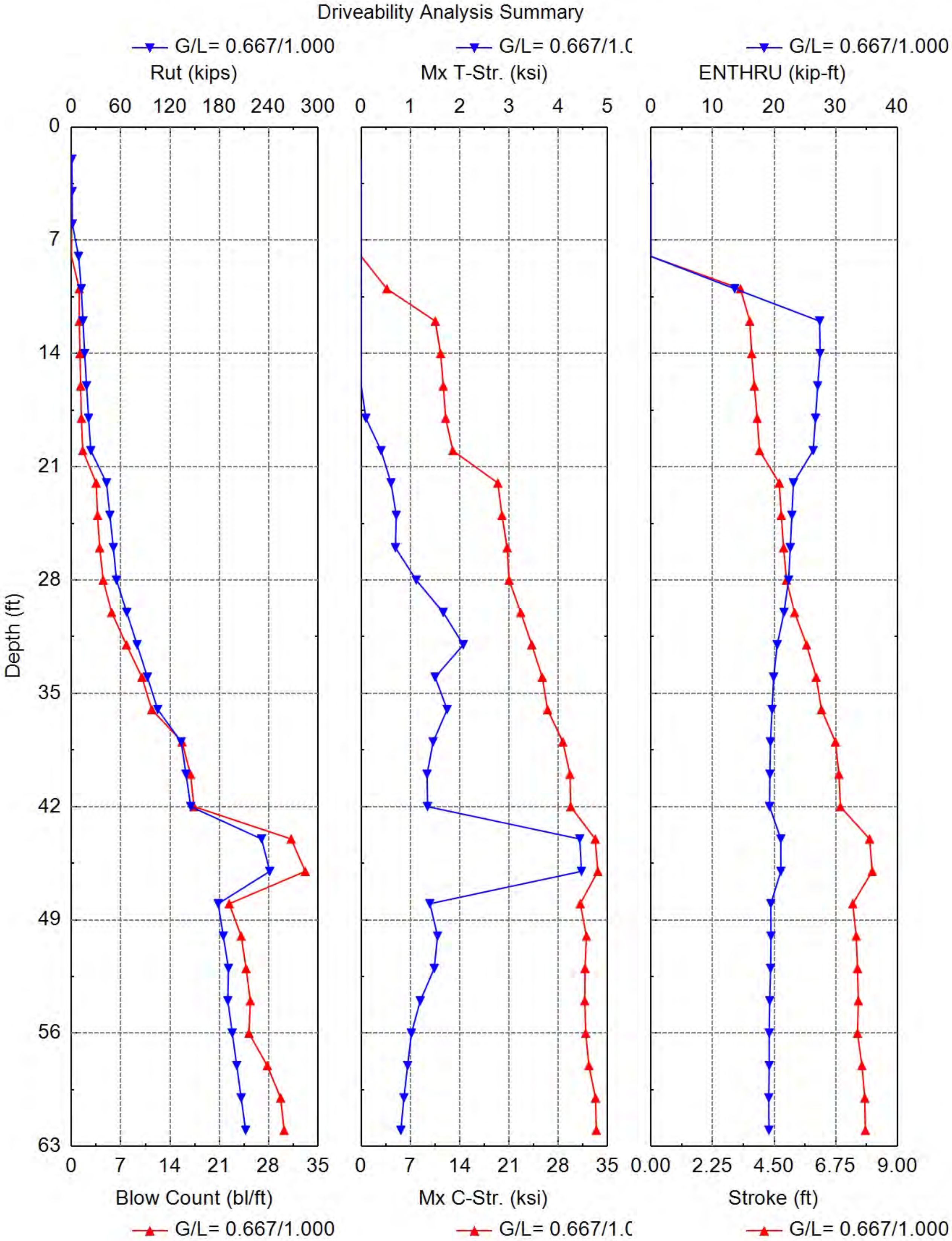
50.0	3.7	33.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
51.6	3.7	33.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
53.3	3.7	33.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
53.3	1.9	72.0	0.10	0.10	0.15	0.15	1.5	6.6	168.0	113.1
54.8	1.9	72.0	0.10	0.10	0.15	0.15	1.5	6.6	168.0	113.1
56.3	1.9	72.0	0.10	0.10	0.15	0.15	1.5	6.6	168.0	113.1
56.3	1.2	43.9	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
58.0	1.2	43.9	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
59.7	1.2	43.9	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
61.4	1.2	43.9	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
63.1	1.2	43.9	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
64.8	1.2	43.9	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
66.5	1.2	43.9	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
68.2	1.2	43.9	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1

Variable Time Hisotry with DELMAG D 19-42; Depth = 67.50ft; Shaft/Toe G/L = 0.667/1.000

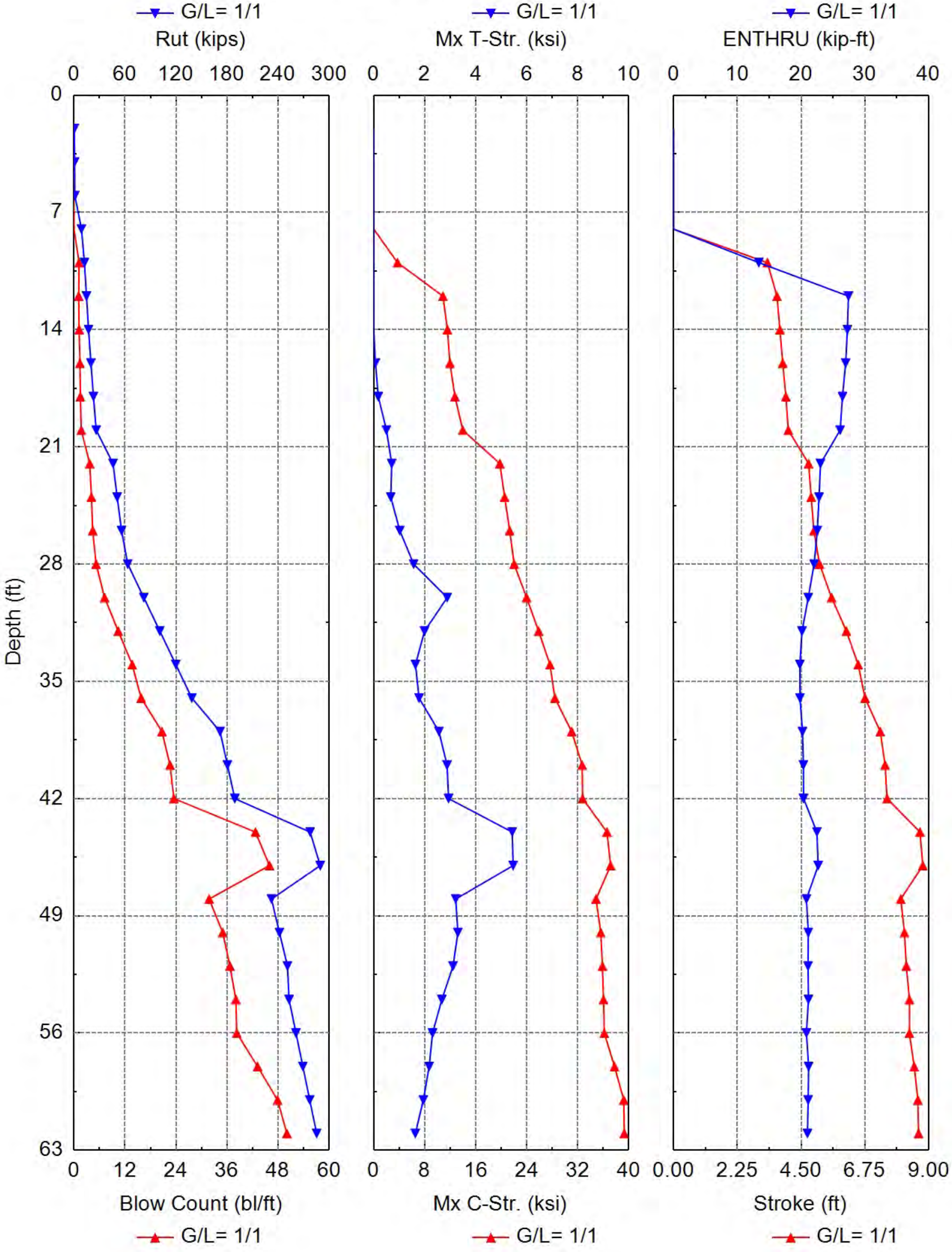


Extrema Results of Gain/Loss at Shaft/Toe = 0.667/1.000 and Depth = 6.00 ft




Driveability Analysis Summary
G/L= 0.667/1.000
Rut (kips)
0 60 120 180 240 300
G/L= 0.667/1.(
Mx T-Str. (ksi)
0 1 2 3 4 5
G/L= 0.667/1.000
ENTHRU (kip-ft)
0 10 20 30 40
Depth (ft)
0 7 14 21 28 35 42 49 56 63
Blow Count (bl/ft)
0 7 14 21 28 35
G/L= 0.667/1.000
Mx C-Str. (ksi)
0 7 14 21 28 35
G/L= 0.667/1.(
Stroke (ft)
0.00 2.25 4.50 6.75 9.00
G/L= 0.667/1.000

Driveability Analysis Summary



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

Depth ft	Rut kips	Rshaft kips	Rtoe kips	Blow Ct bl/ft	Mx C-Str. ksi	Mx T-Str. ksi	Stroke ft	ENTHRU kip-ft	Hammer -
2.0	0.3	0.0	0.3	0.3	0.000	0.000	10.81	0.0	D 19-42
4.0	0.7	0.0	0.7	0.3	0.000	0.000	10.81	0.0	D 19-42
6.0	1.0	0.0	1.0	0.3	0.000	0.000	10.81	0.0	D 19-42
8.0	8.7	0.7	8.0	0.0	0.000	0.000	0.00	0.0	D 19-42
10.0	11.9	2.0	9.9	1.1	3.632	0.000	3.27	13.6	D 19-42
12.0	14.0	3.5	10.5	1.1	10.520	0.000	3.61	27.4	D 19-42
14.0	16.0	5.6	10.5	1.2	11.269	0.000	3.68	27.5	D 19-42
16.0	18.3	7.9	10.5	1.3	11.664	0.000	3.78	27.1	D 19-42
18.0	20.8	10.4	10.5	1.4	11.991	0.093	3.88	26.7	D 19-42
20.0	23.5	13.0	10.5	1.6	13.007	0.403	3.96	26.3	D 19-42
22.0	42.6	16.6	26.0	3.5	19.400	0.605	4.69	23.1	D 19-42
24.0	46.7	20.7	26.0	3.7	19.993	0.711	4.76	22.9	D 19-42
26.0	51.0	25.0	26.0	4.0	20.726	0.694	4.85	22.6	D 19-42
28.0	54.7	33.5	21.2	4.5	20.998	1.116	4.95	22.3	D 19-42
30.0	67.3	46.1	21.2	5.7	22.662	1.664	5.25	21.6	D 19-42
32.0	79.8	58.6	21.2	7.8	24.222	2.071	5.68	20.5	D 19-42
34.0	92.4	71.2	21.2	10.0	25.709	1.499	6.03	19.9	D 19-42
36.0	105.0	83.8	21.2	11.4	26.467	1.744	6.23	19.7	D 19-42
38.0	133.6	93.0	40.6	15.7	28.644	1.459	6.74	19.4	D 19-42
40.0	139.4	98.7	40.6	16.9	29.651	1.336	6.87	19.3	D 19-42
42.0	145.2	104.5	40.6	17.4	29.750	1.346	6.92	19.3	D 19-42
44.0	231.4	112.2	119.2	31.2	33.239	4.434	7.99	21.1	D 19-42
46.0	241.3	122.1	119.2	33.2	33.606	4.468	8.08	21.1	D 19-42
48.0	178.5	134.4	44.2	22.4	31.111	1.393	7.37	19.5	D 19-42
50.0	184.8	140.6	44.2	24.1	31.992	1.549	7.50	19.5	D 19-42
52.0	191.1	146.9	44.2	24.8	31.790	1.482	7.54	19.4	D 19-42
54.0	190.3	152.3	38.0	25.4	31.757	1.198	7.57	19.3	D 19-42
56.0	195.7	157.7	38.0	25.2	31.888	1.019	7.54	19.2	D 19-42
58.0	201.1	163.2	38.0	27.8	32.339	0.941	7.71	19.2	D 19-42
60.0	206.6	168.6	38.0	29.7	33.283	0.866	7.81	19.1	D 19-42
62.0	212.0	174.0	38.0	30.2	33.392	0.803	7.83	19.1	D 19-42

Summary_Total driving time: 17 minutes; Total Number of Blows: 736 (starting at penetration 2.0 ft)

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

Depth ft	Rut kips	Rshaft kips	Rtoe kips	Blow Ct bl/ft	Mx C-Str. ksi	Mx T-Str. ksi	Stroke ft	ENTHRU kip-ft	Hammer -
2.0	0.3	0.0	0.3	0.3	0.000	0.000	10.81	0.0	D 19-42
4.0	0.7	0.0	0.7	0.3	0.000	0.000	10.81	0.0	D 19-42
6.0	1.0	0.0	1.0	0.3	0.000	0.000	10.81	0.0	D 19-42
8.0	8.8	0.8	8.0	0.0	0.000	0.000	0.00	0.0	D 19-42
10.0	12.3	2.4	9.9	1.2	3.724	0.000	3.31	13.4	D 19-42
12.0	14.7	4.2	10.5	1.1	10.845	0.000	3.65	27.4	D 19-42
14.0	17.1	6.7	10.5	1.2	11.543	0.000	3.75	27.3	D 19-42
16.0	19.9	9.4	10.5	1.4	11.945	0.064	3.85	27.0	D 19-42
18.0	22.9	12.4	10.5	1.5	12.727	0.177	3.96	26.5	D 19-42

20.0	26.1	15.6	10.5	1.7	13.963	0.495	4.05	26.1	D 19-42
22.0	45.9	20.0	26.0	3.7	19.777	0.703	4.77	23.0	D 19-42
24.0	50.8	24.8	26.0	4.1	20.521	0.666	4.86	22.8	D 19-42
26.0	56.0	30.0	26.0	4.4	21.322	1.020	4.95	22.5	D 19-42
28.0	63.3	42.1	21.2	5.2	22.021	1.564	5.15	22.0	D 19-42
30.0	82.1	60.9	21.2	7.2	23.966	2.879	5.58	21.1	D 19-42
32.0	101.0	79.8	21.2	10.4	25.853	1.989	6.10	20.1	D 19-42
34.0	119.8	98.6	21.2	13.7	27.640	1.635	6.52	19.8	D 19-42
36.0	138.7	117.5	21.2	15.8	28.406	1.775	6.76	19.8	D 19-42
38.0	171.9	131.2	40.6	20.7	31.042	2.555	7.30	20.2	D 19-42
40.0	180.5	139.9	40.6	22.6	32.698	2.873	7.47	20.4	D 19-42
42.0	189.2	148.6	40.6	23.5	32.764	2.932	7.54	20.4	D 19-42
44.0	277.8	158.7	119.2	42.7	36.585	5.428	8.70	22.5	D 19-42
46.0	289.7	170.6	119.2	46.0	37.151	5.466	8.80	22.7	D 19-42
48.0	232.3	188.1	44.2	31.8	34.864	3.213	8.02	20.8	D 19-42
50.0	241.7	197.6	44.2	35.0	35.609	3.297	8.15	21.1	D 19-42
52.0	251.2	207.0	44.2	36.7	35.869	3.109	8.21	21.1	D 19-42
54.0	253.1	215.1	38.0	38.1	36.042	2.668	8.33	21.2	D 19-42
56.0	261.2	223.2	38.0	38.3	36.160	2.304	8.32	20.8	D 19-42
58.0	269.3	231.3	38.0	43.2	37.765	2.171	8.49	21.2	D 19-42
60.0	277.4	239.4	38.0	47.9	39.224	1.943	8.62	21.1	D 19-42
62.0	285.5	247.5	38.0	50.1	39.295	1.628	8.65	21.0	D 19-42

Summary_Total driving time: 25 minutes; Total Number of Blows: 1050 (starting at penetration 2.0 ft)

GRLWEAP: Wave Equation Analysis of Pile Foundations

FRA-00070-23.920 - P1 (B-069-0-19) + 12" CIP - 0.3125" Wall Thick 11/30/2022
RESOURCE INTERNATIONAL INC GRLWEAP 14.1.15.0

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

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

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

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

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

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

SOIL PROFILE

Depth ft	Soil Type -	Spec. Wt lb/ft³	Su ksf	Phi °	Unit Rs ksf	Unit Rt ksf
0.0	Sand	125.0	0.0	0.0	0.00	0.00
5.5	Sand	125.0	0.0	0.0	0.00	1.22
5.5	Sand	120.0	0.0	0.0	0.00	1.22
6.7	Sand	120.0	0.0	0.0	0.00	1.48
6.7	Sand	120.0	0.0	27.0	0.18	8.55
12.5	Sand	120.0	0.0	27.0	0.34	13.32
12.5	Sand	125.0	0.0	29.0	0.39	13.32
20.5	Sand	125.0	0.0	29.0	0.54	13.32
20.5	Sand	125.0	0.0	32.0	0.72	33.09
27.0	Sand	125.0	0.0	32.0	0.86	33.09
27.0	Clay	130.5	3.0	0.0	3.00	27.00
37.0	Clay	130.5	3.0	0.0	3.00	27.00
37.0	Clay	120.0	5.7	0.0	1.38	51.75
43.0	Clay	120.0	5.7	0.0	1.38	51.75
43.0	Sand	135.0	0.0	36.0	1.82	151.75
46.5	Sand	135.0	0.0	36.0	1.95	151.75
46.5	Clay	130.0	6.2	0.0	6.25	56.25
47.0	Clay	130.0	6.2	0.0	6.25	56.25
47.0	Clay	130.0	6.2	0.0	1.50	56.25
52.0	Clay	130.0	6.2	0.0	1.50	56.25
52.0	Clay	130.0	5.4	0.0	1.29	48.37
67.0	Clay	130.0	5.4	0.0	1.29	48.37
67.0	Clay	120.0	2.6	0.0	1.04	23.62
75.0	Clay	120.0	2.6	0.0	1.04	23.62

PILE INPUT

Uniform Pile		Pile Type:	Pipe
Pile Length: (ft)	65.000	Pile Penetration: (ft)	62.000
Pile Size: (ft)	1.00	Toe Area: (in²)	113.10

Pile Profile

Lb Top ft	X-Area in²	E-Modulus ksi	Spec. Wt lb/ft³	Perim. ft	Crit. Index -
0.0	11.5	30,000.0	492.0	3.1	0
65.0	11.5	30,000.0	492.0	3.1	0

HAMMER INPUT

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

Hammer Data

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

DRIVE SYSTEM FOR DELMAG D 19-42-OED

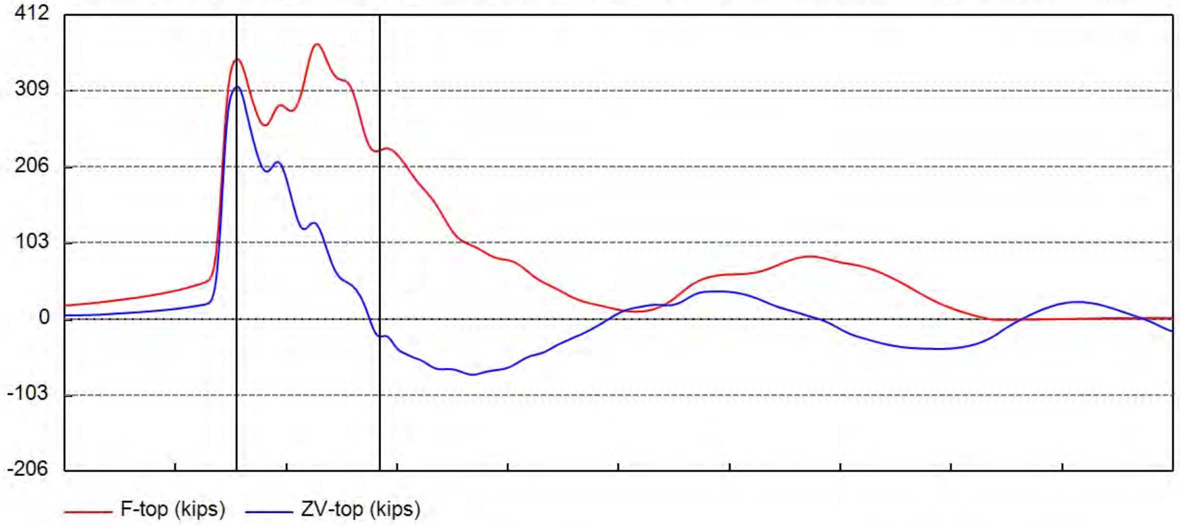
Type	X-Area	E-Modulus	Thickness	COR	Round-out	Stiffness
-	in²	ksi	in	-	in	kips/in
Hammer C.	227.000	530.000	2.000	0.800	0.120	60155.550
Helmet Wt.	1.900	kips				

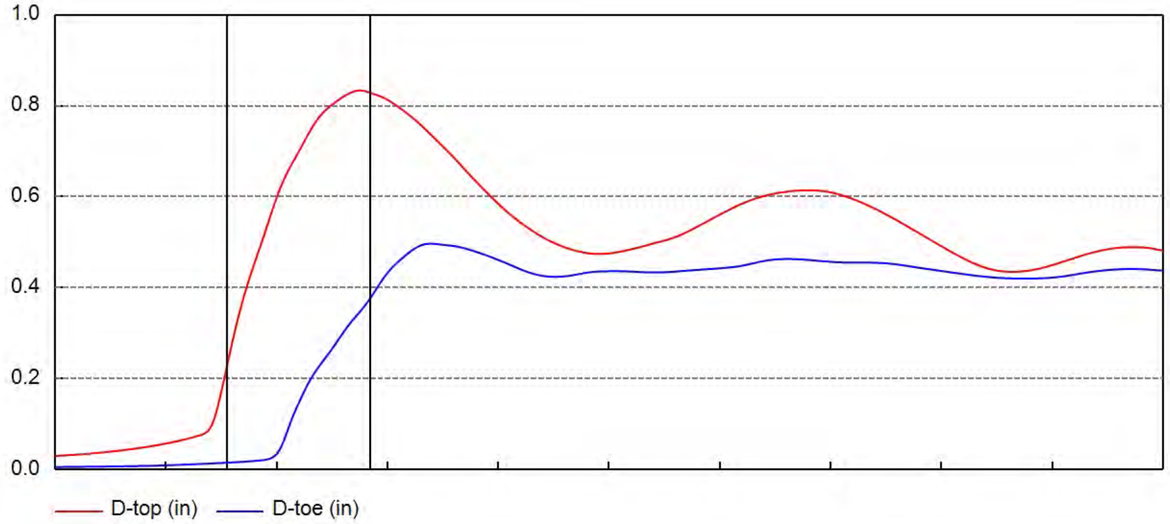
SOIL RESISTANCE DISTRIBUTION

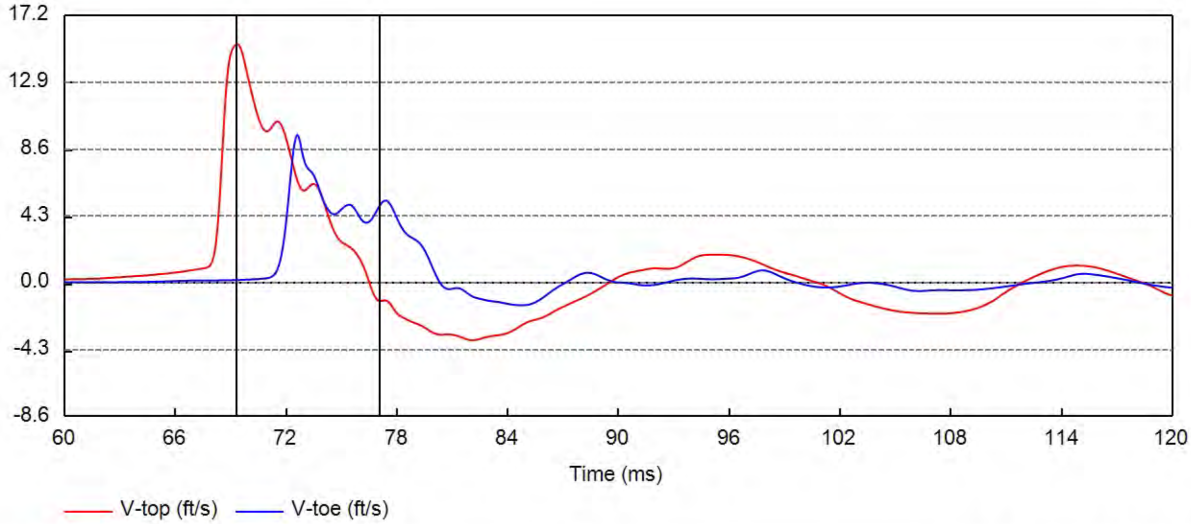
Depth	Unit Rs	Unit Rt	Qs	Qt	Js	Jt	Set. F.	Limit D.	Set. T.	EB Area
ft	ksf	ksf	in	in	s/ft	s/ft	-	ft	Hours	in²
0.0	0.0	0.0	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
1.8	0.0	0.4	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
3.7	0.0	0.8	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
5.5	0.0	1.2	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
5.5	0.0	1.2	0.10	0.20	0.10	0.15	1.2	6.6	1.0	113.1
6.7	0.0	1.5	0.10	0.20	0.10	0.15	1.2	6.6	1.0	113.1
6.7	0.2	8.5	0.10	0.20	0.10	0.15	1.2	6.6	1.0	113.1
8.6	0.2	10.9	0.10	0.20	0.10	0.15	1.2	6.6	1.0	113.1
10.6	0.3	13.3	0.10	0.20	0.10	0.15	1.2	6.6	1.0	113.1
12.5	0.3	13.3	0.10	0.20	0.10	0.15	1.2	6.6	1.0	113.1
12.5	0.4	13.3	0.10	0.20	0.05	0.15	1.2	6.6	1.0	113.1
14.5	0.4	13.3	0.10	0.20	0.05	0.15	1.2	6.6	1.0	113.1
16.5	0.5	13.3	0.10	0.20	0.05	0.15	1.2	6.6	1.0	113.1
18.5	0.5	13.3	0.10	0.20	0.05	0.15	1.2	6.6	1.0	113.1
20.5	0.5	13.3	0.10	0.20	0.05	0.15	1.2	6.6	1.0	113.1
20.5	0.7	33.1	0.10	0.10	0.05	0.15	1.2	6.6	1.0	113.1
22.7	0.8	33.1	0.10	0.10	0.05	0.15	1.2	6.6	1.0	113.1
24.8	0.8	33.1	0.10	0.10	0.05	0.15	1.2	6.6	1.0	113.1
27.0	0.9	33.1	0.10	0.10	0.05	0.15	1.2	6.6	1.0	113.1
27.0	3.0	27.0	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
28.7	3.0	27.0	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
30.3	3.0	27.0	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
32.0	3.0	27.0	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
33.7	3.0	27.0	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
35.3	3.0	27.0	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
37.0	3.0	27.0	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
37.0	1.4	51.7	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
39.0	1.4	51.7	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
41.0	1.4	51.7	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
43.0	1.4	51.7	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
43.0	1.8	151.8	0.10	0.10	0.05	0.15	1.2	6.6	1.0	113.1
44.7	1.9	151.8	0.10	0.10	0.05	0.15	1.2	6.6	1.0	113.1
46.5	1.9	151.8	0.10	0.10	0.05	0.15	1.2	6.6	1.0	113.1
46.5	6.2	56.2	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
47.0	6.2	56.2	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
47.0	1.5	56.2	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
48.7	1.5	56.2	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
50.3	1.5	56.2	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
52.0	1.5	56.2	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
52.0	1.3	48.4	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
53.7	1.3	48.4	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1

55.3	1.3	48.4	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
57.0	1.3	48.4	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
58.7	1.3	48.4	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
60.3	1.3	48.4	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
62.0	1.3	48.4	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1

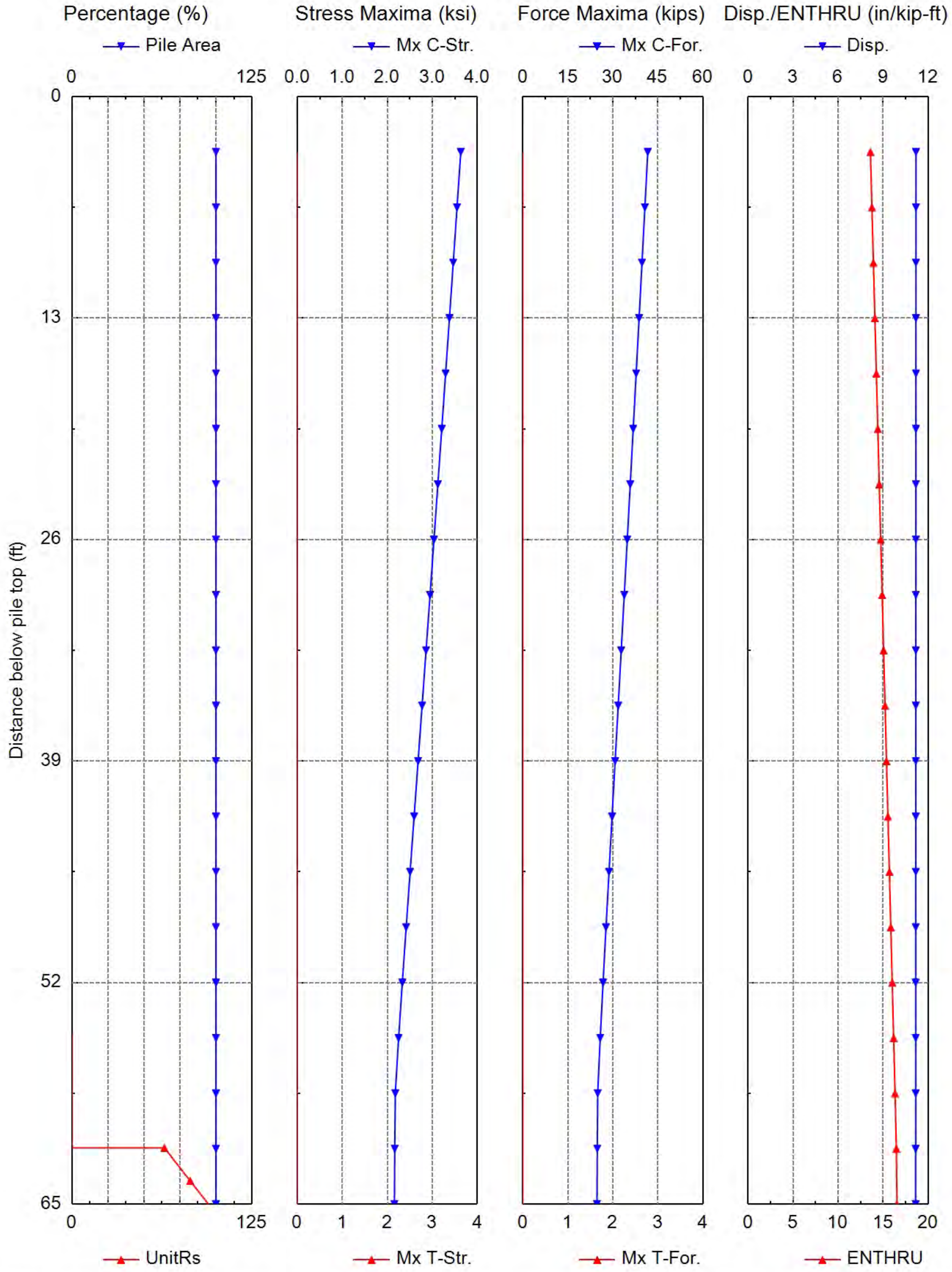
Variable Time Hisotry with DELMAG D 19-42; Depth = 62.00ft; Shaft/Toe G/L = 0.667/1.000



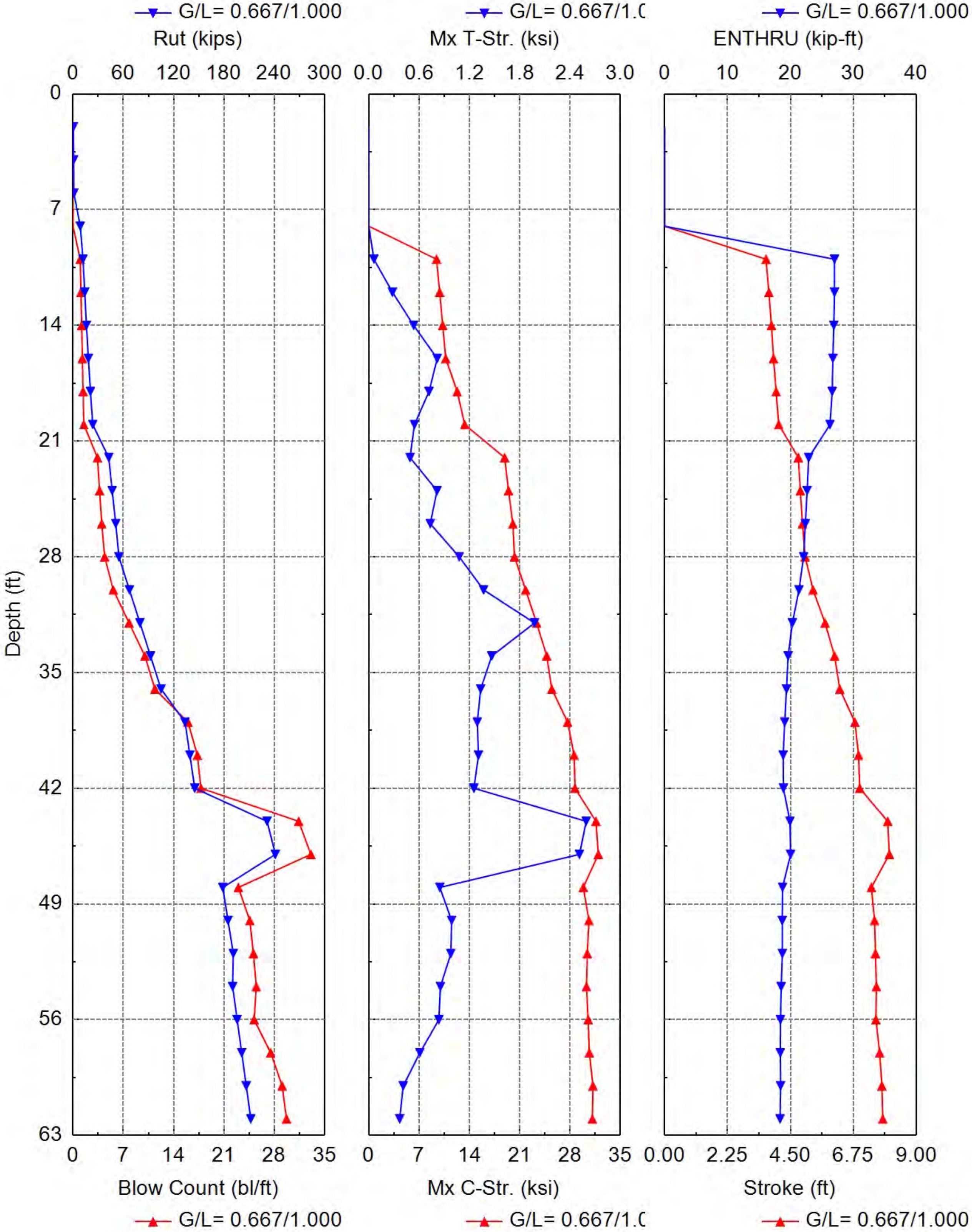


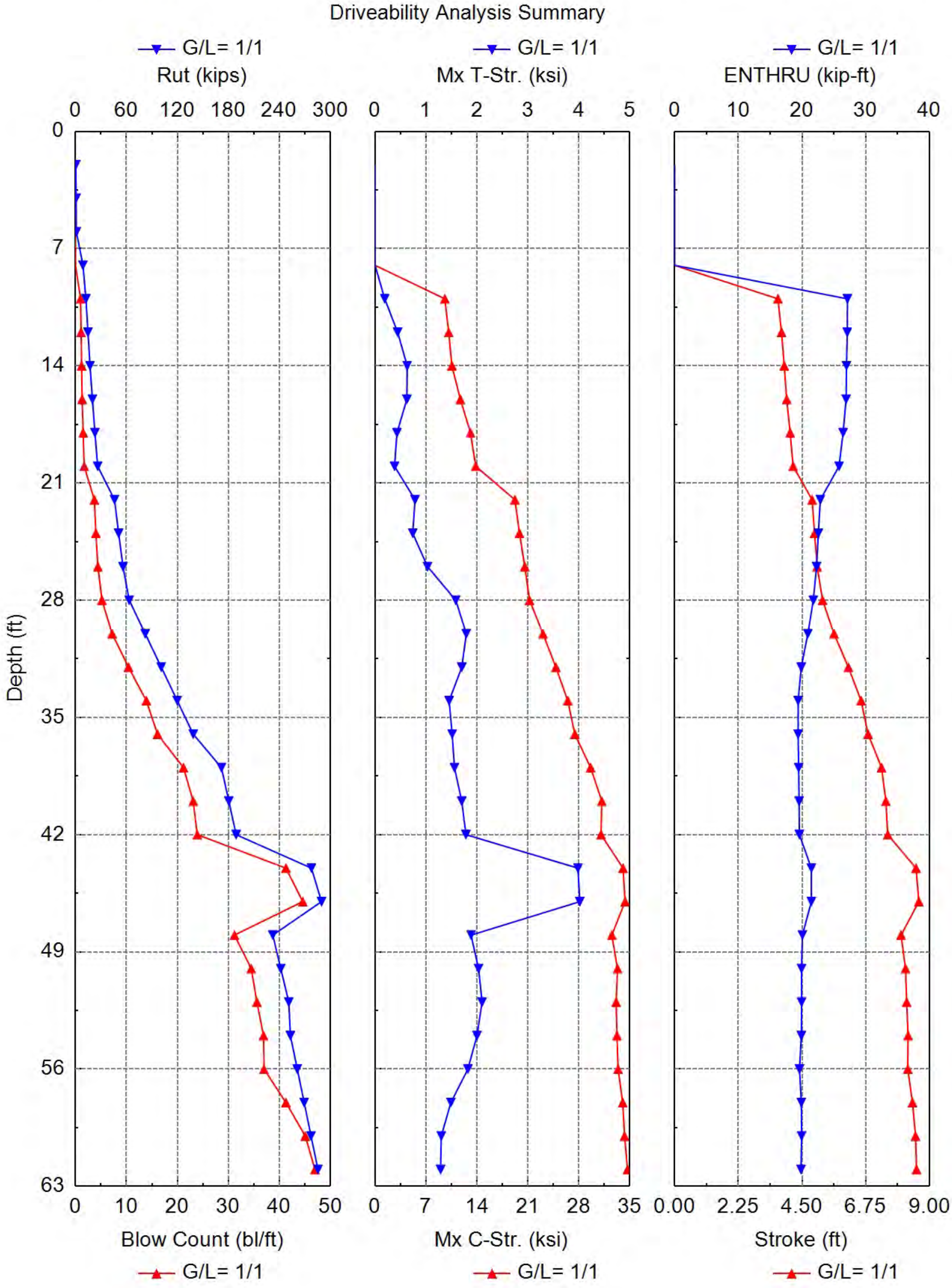


Extrema Results of Gain/Loss at Shaft/Toe = 0.667/1.000 and Depth = 10.00 ft



Driveability Analysis Summary




Driveability Analysis Summary
G/L= 1/1
Rut (kips)
0 60 120 180 240 300
G/L= 1/1
Mx T-Str. (ksi)
0 1 2 3 4 5
G/L= 1/1
ENTHRU (kip-ft)
0 10 20 30 40
Depth (ft)
0 7 14 21 28 35 42 49 56 63
0 10 20 30 40 50
Blow Count (bl/ft)
G/L= 1/1
0 7 14 21 28 35
Mx C-Str. (ksi)
G/L= 1/1
0.00 2.25 4.50 6.75 9.00
Stroke (ft)
G/L= 1/1

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

Depth ft	Rut kips	Rshaft kips	Rtoe kips	Blow Ct bl/ft	Mx C-Str. ksi	Mx T-Str. ksi	Stroke ft	ENTHRU kip-ft	Hammer -
2.0	0.3	0.0	0.3	0.3	0.000	0.000	10.81	0.0	D 19-42
4.0	0.7	0.0	0.7	0.3	0.000	0.000	10.81	0.0	D 19-42
6.0	1.0	0.0	1.0	0.3	0.000	0.000	10.81	0.0	D 19-42
8.0	8.7	0.7	8.0	0.0	0.000	0.000	0.00	0.0	D 19-42
10.0	11.9	2.0	9.9	1.0	9.422	0.061	3.63	27.0	D 19-42
12.0	14.0	3.5	10.5	1.1	9.859	0.282	3.73	27.0	D 19-42
14.0	16.0	5.6	10.5	1.2	10.277	0.535	3.82	26.9	D 19-42
16.0	18.3	7.9	10.5	1.3	10.702	0.816	3.90	26.8	D 19-42
18.0	20.8	10.4	10.5	1.4	12.294	0.718	3.99	26.6	D 19-42
20.0	23.5	13.0	10.5	1.5	13.340	0.544	4.08	26.3	D 19-42
22.0	42.6	16.6	26.0	3.4	18.892	0.491	4.78	22.9	D 19-42
24.0	46.7	20.7	26.0	3.7	19.438	0.814	4.85	22.7	D 19-42
26.0	51.0	25.0	26.0	4.0	20.035	0.732	4.93	22.4	D 19-42
28.0	54.7	33.5	21.2	4.4	20.270	1.078	5.03	22.1	D 19-42
30.0	67.3	46.1	21.2	5.6	21.815	1.368	5.31	21.4	D 19-42
32.0	79.8	58.6	21.2	7.8	23.342	1.976	5.74	20.3	D 19-42
34.0	92.4	71.2	21.2	10.0	24.753	1.466	6.08	19.6	D 19-42
36.0	105.0	83.8	21.2	11.4	25.453	1.333	6.27	19.4	D 19-42
38.0	133.6	93.0	40.6	16.0	27.654	1.293	6.81	19.1	D 19-42
40.0	139.4	98.7	40.6	17.3	28.563	1.308	6.94	18.9	D 19-42
42.0	145.2	104.5	40.6	17.8	28.689	1.253	6.98	18.9	D 19-42
44.0	231.4	112.2	119.2	31.4	31.602	2.592	7.98	19.9	D 19-42
46.0	241.3	122.1	119.2	33.1	31.928	2.512	8.04	20.0	D 19-42
48.0	178.5	134.4	44.2	23.0	29.840	0.846	7.40	18.8	D 19-42
50.0	184.8	140.6	44.2	24.6	30.625	0.987	7.51	18.7	D 19-42
52.0	191.1	146.9	44.2	25.1	30.394	0.978	7.54	18.7	D 19-42
54.0	190.3	152.3	38.0	25.5	30.276	0.853	7.58	18.5	D 19-42
56.0	195.7	157.7	38.0	25.2	30.512	0.835	7.56	18.4	D 19-42
58.0	201.1	163.2	38.0	27.5	30.677	0.609	7.69	18.4	D 19-42
60.0	206.6	168.6	38.0	29.1	31.182	0.410	7.77	18.4	D 19-42
62.0	212.0	174.0	38.0	29.7	31.098	0.368	7.80	18.3	D 19-42

Summary_Total driving time: 17 minutes; Total Number of Blows: 738 (starting at penetration 2.0 ft)

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

Depth ft	Rut kips	Rshaft kips	Rtoe kips	Blow Ct bl/ft	Mx C-Str. ksi	Mx T-Str. ksi	Stroke ft	ENTHRU kip-ft	Hammer -
2.0	0.3	0.0	0.3	0.3	0.000	0.000	10.81	0.0	D 19-42
4.0	0.7	0.0	0.7	0.3	0.000	0.000	10.81	0.0	D 19-42
6.0	1.0	0.0	1.0	0.3	0.000	0.000	10.81	0.0	D 19-42
8.0	8.8	0.8	8.0	0.0	0.000	0.000	0.00	0.0	D 19-42
10.0	12.3	2.4	9.9	1.0	9.584	0.190	3.65	27.1	D 19-42
12.0	14.7	4.2	10.5	1.1	10.117	0.444	3.78	27.1	D 19-42
14.0	17.1	6.7	10.5	1.2	10.558	0.630	3.87	27.0	D 19-42
16.0	19.9	9.4	10.5	1.3	11.721	0.625	3.96	26.9	D 19-42
18.0	22.9	12.4	10.5	1.5	13.110	0.430	4.08	26.5	D 19-42

20.0	26.1	15.6	10.5	1.7	13.836	0.382	4.19	25.8	D 19-42
22.0	45.9	20.0	26.0	3.7	19.212	0.785	4.86	22.9	D 19-42
24.0	50.8	24.8	26.0	4.0	19.847	0.740	4.94	22.6	D 19-42
26.0	56.0	30.0	26.0	4.4	20.572	1.030	5.04	22.3	D 19-42
28.0	63.3	42.1	21.2	5.2	21.229	1.584	5.23	21.8	D 19-42
30.0	82.1	60.9	21.2	7.2	23.070	1.791	5.63	20.9	D 19-42
32.0	101.0	79.8	21.2	10.4	24.847	1.703	6.14	19.9	D 19-42
34.0	119.8	98.6	21.2	13.9	26.475	1.454	6.59	19.4	D 19-42
36.0	138.7	117.5	21.2	16.1	27.450	1.513	6.84	19.4	D 19-42
38.0	171.9	131.2	40.6	21.2	29.615	1.559	7.31	19.5	D 19-42
40.0	180.5	139.9	40.6	23.1	31.155	1.701	7.46	19.5	D 19-42
42.0	189.2	148.6	40.6	23.9	31.049	1.784	7.53	19.6	D 19-42
44.0	277.8	158.7	119.2	41.3	34.072	3.982	8.53	21.5	D 19-42
46.0	289.7	170.6	119.2	44.6	34.359	4.019	8.63	21.5	D 19-42
48.0	232.3	188.1	44.2	31.2	32.523	1.884	8.00	20.1	D 19-42
50.0	241.7	197.6	44.2	34.5	33.316	2.031	8.16	19.9	D 19-42
52.0	251.2	207.0	44.2	35.6	33.121	2.101	8.20	19.9	D 19-42
54.0	253.1	215.1	38.0	36.9	33.239	2.000	8.25	19.9	D 19-42
56.0	261.2	223.2	38.0	37.0	33.392	1.823	8.24	19.6	D 19-42
58.0	269.3	231.3	38.0	41.3	34.021	1.488	8.40	19.9	D 19-42
60.0	277.4	239.4	38.0	45.1	34.285	1.300	8.51	19.9	D 19-42
62.0	285.5	247.5	38.0	47.0	34.682	1.286	8.55	19.8	D 19-42

Summary_Total driving time: 24 minutes; Total Number of Blows: 1025 (starting at penetration 2.0 ft)

FRA-00070-23.920 - P1 (B-069-0-19) + 12" CIP - 0.375" Wall Thick 12/3/2022
RESOURCE INTERNATIONAL INC GRLWEAP 14.1.15.0

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

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

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

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

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

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

SOIL PROFILE

Depth ft	Soil Type -	Spec. Wt lb/ft³	Su ksf	Phi °	Unit Rs ksf	Unit Rt ksf
0.0	Sand	125.0	0.0	0.0	0.00	0.00
5.5	Sand	125.0	0.0	0.0	0.00	1.22
5.5	Sand	120.0	0.0	0.0	0.00	1.22
6.7	Sand	120.0	0.0	0.0	0.00	1.48
6.7	Sand	120.0	0.0	27.0	0.18	8.55
12.5	Sand	120.0	0.0	27.0	0.34	13.32
12.5	Sand	125.0	0.0	29.0	0.39	13.32
20.5	Sand	125.0	0.0	29.0	0.54	13.32
20.5	Sand	125.0	0.0	32.0	0.72	33.09
27.0	Sand	125.0	0.0	32.0	0.86	33.09
27.0	Clay	130.5	3.0	0.0	3.00	27.00
37.0	Clay	130.5	3.0	0.0	3.00	27.00
37.0	Clay	120.0	5.7	0.0	1.38	51.75
43.0	Clay	120.0	5.7	0.0	1.38	51.75
43.0	Sand	135.0	0.0	36.0	1.82	151.75
46.5	Sand	135.0	0.0	36.0	1.95	151.75
46.5	Clay	130.0	6.2	0.0	6.25	56.25
47.0	Clay	130.0	6.2	0.0	6.25	56.25
47.0	Clay	130.0	6.2	0.0	1.50	56.25
52.0	Clay	130.0	6.2	0.0	1.50	56.25
52.0	Clay	130.0	5.4	0.0	1.29	48.37
67.0	Clay	130.0	5.4	0.0	1.29	48.37
67.0	Clay	120.0	2.6	0.0	1.04	23.62
75.0	Clay	120.0	2.6	0.0	1.04	23.62

PILE INPUT

Uniform Pile		Pile Type:	Pipe
Pile Length: (ft)	65.000	Pile Penetration: (ft)	62.000
Pile Size: (ft)	1.00	Toe Area: (in²)	113.10

Pile Profile

Lb Top ft	X-Area in²	E-Modulus ksi	Spec. Wt lb/ft³	Perim. ft	Crit. Index -
0.0	13.7	30,000.0	492.0	3.1	0
65.0	13.7	30,000.0	492.0	3.1	0

HAMMER INPUT

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

Hammer Data

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

DRIVE SYSTEM FOR DELMAG D 19-42-OED

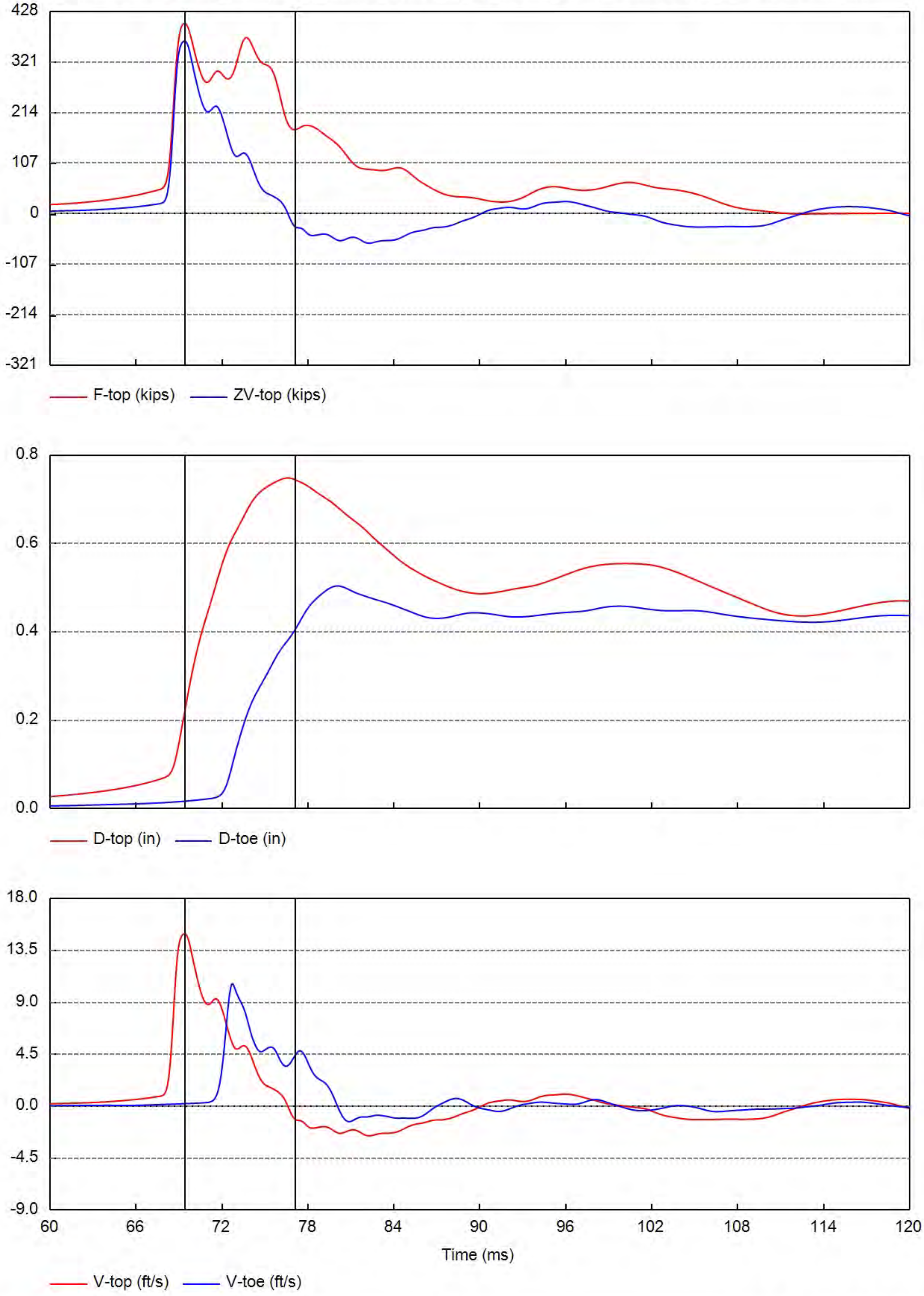
Type	X-Area	E-Modulus	Thickness	COR	Round-out	Stiffness
-	in²	ksi	in	-	in	kips/in
Hammer C.	227.000	530.000	2.000	0.800	0.120	60155.550
Helmet Wt.	1.900	kips				

SOIL RESISTANCE DISTRIBUTION

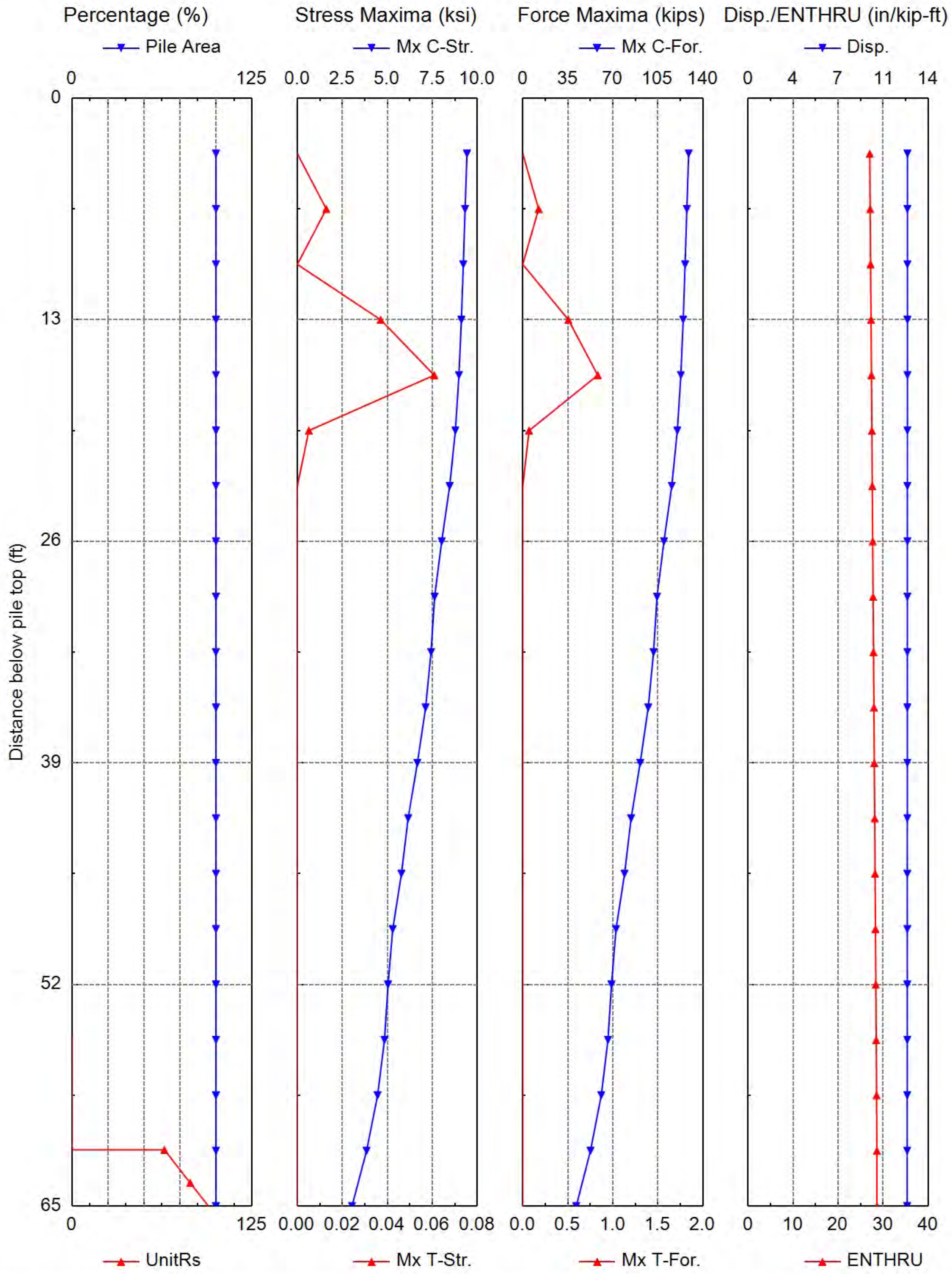
Depth	Unit Rs	Unit Rt	Qs	Qt	Js	Jt	Set. F.	Limit D.	Set. T.	EB Area
ft	ksf	ksf	in	in	s/ft	s/ft	-	ft	Hours	in²
0.0	0.0	0.0	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
1.8	0.0	0.4	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
3.7	0.0	0.8	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
5.5	0.0	1.2	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
5.5	0.0	1.2	0.10	0.20	0.10	0.15	1.2	6.6	1.0	113.1
6.7	0.0	1.5	0.10	0.20	0.10	0.15	1.2	6.6	1.0	113.1
6.7	0.2	8.5	0.10	0.20	0.10	0.15	1.2	6.6	1.0	113.1
8.6	0.2	10.9	0.10	0.20	0.10	0.15	1.2	6.6	1.0	113.1
10.6	0.3	13.3	0.10	0.20	0.10	0.15	1.2	6.6	1.0	113.1
12.5	0.3	13.3	0.10	0.20	0.10	0.15	1.2	6.6	1.0	113.1
12.5	0.4	13.3	0.10	0.20	0.05	0.15	1.2	6.6	1.0	113.1
14.5	0.4	13.3	0.10	0.20	0.05	0.15	1.2	6.6	1.0	113.1
16.5	0.5	13.3	0.10	0.20	0.05	0.15	1.2	6.6	1.0	113.1
18.5	0.5	13.3	0.10	0.20	0.05	0.15	1.2	6.6	1.0	113.1
20.5	0.5	13.3	0.10	0.20	0.05	0.15	1.2	6.6	1.0	113.1
20.5	0.7	33.1	0.10	0.10	0.05	0.15	1.2	6.6	1.0	113.1
22.7	0.8	33.1	0.10	0.10	0.05	0.15	1.2	6.6	1.0	113.1
24.8	0.8	33.1	0.10	0.10	0.05	0.15	1.2	6.6	1.0	113.1
27.0	0.9	33.1	0.10	0.10	0.05	0.15	1.2	6.6	1.0	113.1
27.0	3.0	27.0	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
28.7	3.0	27.0	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
30.3	3.0	27.0	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
32.0	3.0	27.0	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
33.7	3.0	27.0	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
35.3	3.0	27.0	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
37.0	3.0	27.0	0.10	0.15	0.20	0.15	1.5	6.6	168.0	113.1
37.0	1.4	51.7	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
39.0	1.4	51.7	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
41.0	1.4	51.7	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
43.0	1.4	51.7	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
43.0	1.8	151.8	0.10	0.10	0.05	0.15	1.2	6.6	1.0	113.1
44.7	1.9	151.8	0.10	0.10	0.05	0.15	1.2	6.6	1.0	113.1
46.5	1.9	151.8	0.10	0.10	0.05	0.15	1.2	6.6	1.0	113.1
46.5	6.2	56.2	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
47.0	6.2	56.2	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
47.0	1.5	56.2	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
48.7	1.5	56.2	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
50.3	1.5	56.2	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
52.0	1.5	56.2	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
52.0	1.3	48.4	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
53.7	1.3	48.4	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1

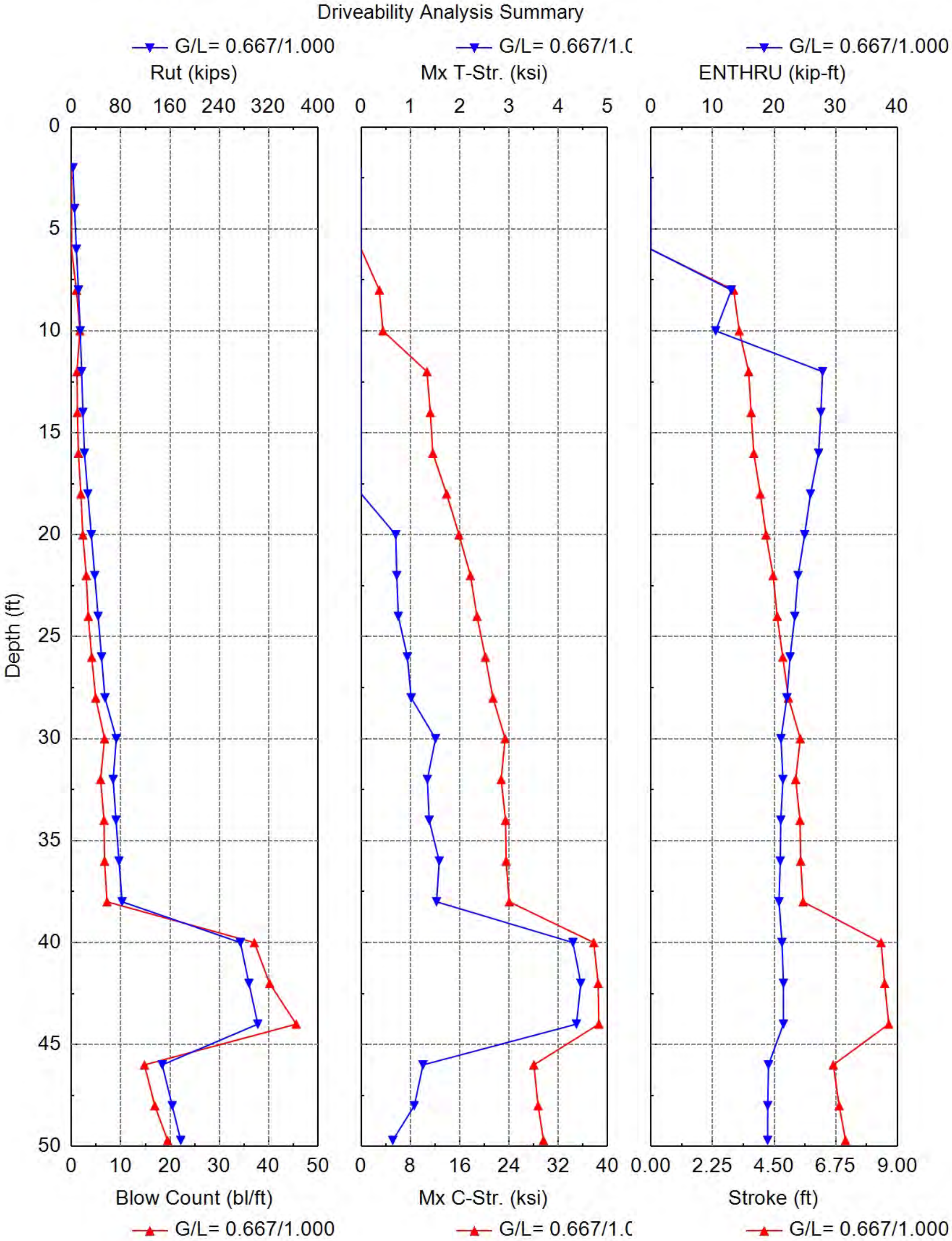
55.3	1.3	48.4	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
57.0	1.3	48.4	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
58.7	1.3	48.4	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
60.3	1.3	48.4	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1
62.0	1.3	48.4	0.10	0.10	0.20	0.15	1.5	6.6	168.0	113.1

Variable Time Hisotry with DELMAG D 19-42; Depth = 62.00ft; Shaft/Toe G/L = 0.667/1.000

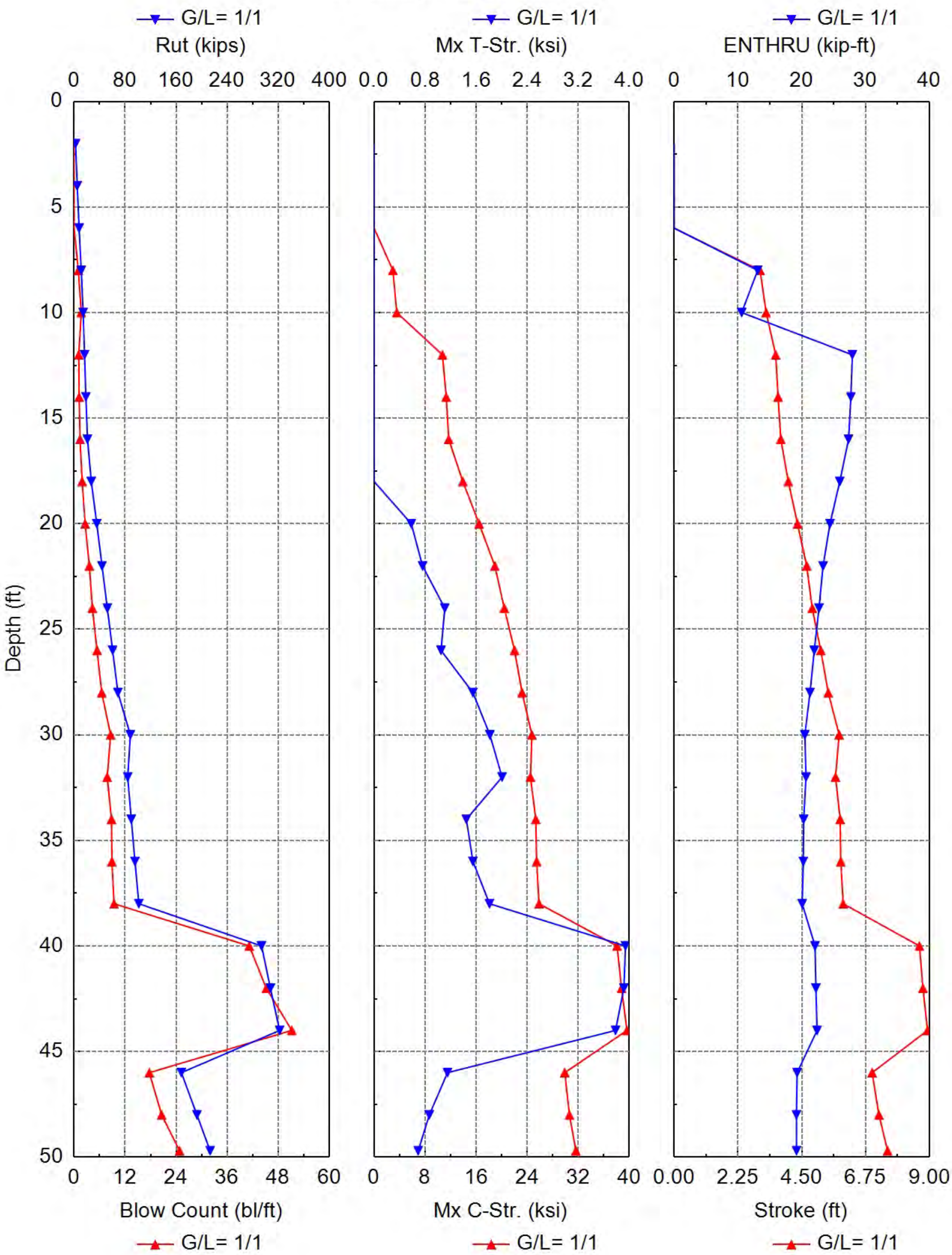


Extrema Results of Gain/Loss at Shaft/Toe = 0.667/1.000 and Depth = 10.00 ft




Driveability Analysis Summary
G/L= 0.667/1.000
G/L= 0.667/1.(
G/L= 0.667/1.000
Rut (kips)
Mx T-Str. (ksi)
ENTHRU (kip-ft)
0 80 160 240 320 400
0 1 2 3 4 5
0 10 20 30 40
Depth (ft)
0 5 10 15 20 25 30 35 40 45 50
0 10 20 30 40 50
0 8 16 24 32 40
0.00 2.25 4.50 6.75 9.00
Blow Count (bl/ft)
Mx C-Str. (ksi)
Stroke (ft)
G/L= 0.667/1.000
G/L= 0.667/1.(
G/L= 0.667/1.000

Driveability Analysis Summary



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

Depth ft	Rut kips	Rshaft kips	Rtoe kips	Blow Ct bl/ft	Mx C-Str. ksi	Mx T-Str. ksi	Stroke ft	ENTHRU kip-ft	Hammer -
2.0	2.3	0.2	2.1	0.3	0.000	0.000	10.81	0.0	D 19-42
4.0	4.9	0.7	4.3	0.0	0.000	0.000	0.00	0.0	D 19-42
6.0	7.9	1.5	6.4	0.0	0.000	0.000	0.00	0.0	D 19-42
8.0	11.2	2.7	8.5	1.0	2.933	0.000	3.02	13.1	D 19-42
10.0	14.2	4.1	10.1	1.7	3.526	0.000	3.22	10.5	D 19-42
12.0	16.4	6.0	10.5	1.1	10.672	0.000	3.57	27.9	D 19-42
14.0	18.6	8.1	10.5	1.2	11.217	0.000	3.66	27.6	D 19-42
16.0	21.1	10.6	10.5	1.4	11.622	0.000	3.76	27.2	D 19-42
18.0	26.4	14.1	12.4	1.9	13.855	0.000	4.00	25.9	D 19-42
20.0	32.2	19.8	12.4	2.3	15.879	0.700	4.20	25.0	D 19-42
22.0	37.7	25.3	12.4	3.0	17.729	0.721	4.46	23.9	D 19-42
24.0	43.2	30.8	12.4	3.4	18.794	0.753	4.61	23.4	D 19-42
26.0	48.7	36.4	12.4	4.1	20.149	0.936	4.81	22.6	D 19-42
28.0	54.3	41.9	12.4	4.9	21.387	1.013	5.02	22.1	D 19-42
30.0	72.7	46.7	26.0	6.7	23.360	1.507	5.46	21.1	D 19-42
32.0	67.6	51.3	16.3	5.9	22.714	1.342	5.29	21.4	D 19-42
34.0	72.2	56.0	16.3	6.6	23.427	1.379	5.44	21.1	D 19-42
36.0	77.1	60.8	16.3	6.7	23.517	1.583	5.47	21.0	D 19-42
38.0	82.1	65.9	16.3	7.2	24.023	1.528	5.56	20.8	D 19-42
40.0	274.2	76.4	197.8	37.1	37.751	4.296	8.41	21.3	D 19-42
42.0	288.0	90.2	197.8	40.2	38.466	4.455	8.53	21.5	D 19-42
44.0	302.5	104.7	197.8	45.6	38.576	4.367	8.69	21.5	D 19-42
46.0	147.3	119.9	27.4	14.8	28.018	1.253	6.66	19.1	D 19-42
48.0	163.5	136.1	27.4	16.9	28.709	1.077	6.87	19.0	D 19-42
49.7	177.3	149.9	27.4	19.5	29.598	0.639	7.11	18.9	D 19-42

Summary_Total driving time: 10 minutes; Total Number of Blows: 442 (starting at penetration 2.0 ft)

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

Depth ft	Rut kips	Rshaft kips	Rtoe kips	Blow Ct bl/ft	Mx C-Str. ksi	Mx T-Str. ksi	Stroke ft	ENTHRU kip-ft	Hammer -
2.0	2.3	0.2	2.1	0.3	0.000	0.000	10.81	0.0	D 19-42
4.0	4.9	0.7	4.3	0.0	0.000	0.000	0.00	0.0	D 19-42
6.0	7.9	1.5	6.4	0.0	0.000	0.000	0.00	0.0	D 19-42
8.0	11.2	2.7	8.5	1.0	2.945	0.000	3.03	13.1	D 19-42
10.0	14.2	4.1	10.1	1.7	3.552	0.000	3.24	10.6	D 19-42
12.0	16.4	6.0	10.5	1.1	10.710	0.000	3.58	27.9	D 19-42
14.0	18.6	8.1	10.5	1.2	11.310	0.000	3.67	27.7	D 19-42
16.0	21.1	10.6	10.5	1.4	11.700	0.000	3.76	27.3	D 19-42
18.0	27.0	14.6	12.4	1.9	13.907	0.000	4.03	26.0	D 19-42
20.0	35.6	23.2	12.4	2.6	16.454	0.582	4.35	24.4	D 19-42
22.0	43.8	31.5	12.4	3.6	18.930	0.759	4.68	23.3	D 19-42
24.0	52.1	39.8	12.4	4.3	20.412	1.109	4.87	22.7	D 19-42
26.0	60.4	48.1	12.4	5.4	22.014	1.049	5.17	22.0	D 19-42
28.0	68.7	56.4	12.4	6.5	23.195	1.549	5.44	21.3	D 19-42
30.0	88.3	62.3	26.0	8.6	24.739	1.814	5.82	20.5	D 19-42

32.0	84.1	67.8	16.3	7.8	24.509	2.006	5.69	20.7	D 19-42
34.0	89.7	73.4	16.3	8.8	25.343	1.446	5.86	20.3	D 19-42
36.0	95.5	79.2	16.3	8.9	25.480	1.549	5.88	20.2	D 19-42
38.0	101.5	85.3	16.3	9.4	25.853	1.809	5.96	20.1	D 19-42
40.0	293.9	96.1	197.8	41.2	38.082	3.941	8.65	22.1	D 19-42
42.0	307.8	110.0	197.8	45.2	38.786	3.915	8.78	22.2	D 19-42
44.0	322.2	124.5	197.8	51.2	39.637	3.784	8.94	22.4	D 19-42
46.0	168.2	140.9	27.4	17.7	29.882	1.150	6.98	19.3	D 19-42
48.0	192.6	165.2	27.4	20.6	30.622	0.866	7.22	19.2	D 19-42
49.7	213.3	185.9	27.4	24.8	31.639	0.691	7.53	19.2	D 19-42

Summary_Total driving time: 12 minutes; Total Number of Blows: 518 (starting at penetration 2.0 ft)

GRLWEAP: Wave Equation Analysis of Pile Foundations

FRA-00070-23.920 - FA (B-070-0-19) + 0.3125" Wall Thick 11/30/2022
RESOURCE INTERNATIONAL INC GRLWEAP 14.1.15.0

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

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

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

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

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

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

SOIL PROFILE

Depth ft	Soil Type -	Spec. Wt lb/ft³	Su ksf	Phi °	Unit Rs ksf	Unit Rt ksf
0.0	Sand	125.0	0.0	28.0	0.00	0.00
17.7	Sand	125.0	0.0	28.0	0.47	13.32
17.7	Clay	120.0	1.7	0.0	1.75	15.75
18.2	Clay	120.0	1.7	0.0	1.75	15.75
18.2	Clay	120.0	1.7	0.0	1.32	15.75
28.2	Clay	120.0	1.7	0.0	1.32	15.75
28.2	Sand	125.0	0.0	32.0	0.88	33.09
30.7	Sand	125.0	0.0	32.0	0.93	33.09
30.7	Sand	125.0	0.0	31.0	0.84	20.71
38.7	Sand	125.0	0.0	31.0	1.00	20.71
38.7	Sand	135.0	0.0	38.0	2.10	251.83
45.7	Sand	135.0	0.0	38.0	2.43	251.83
45.7	Clay	125.0	3.9	0.0	3.87	34.87
64.7	Clay	125.0	3.9	0.0	3.87	34.87
64.7	Clay	125.0	4.1	0.0	0.99	37.12
84.7	Clay	125.0	4.1	0.0	0.99	37.12
84.7	Clay	125.0	3.4	0.0	0.85	30.37
92.7	Clay	125.0	3.4	0.0	0.85	30.37

PILE INPUT

Uniform Pile		Pile Type:	Pipe
Pile Length: (ft)	55.000	Pile Penetration: (ft)	49.700
Pile Size: (ft)	1.00	Toe Area: (in²)	113.10

Pile Profile

Lb Top ft	X-Area in²	E-Modulus ksi	Spec. Wt lb/ft³	Perim. ft	Crit. Index -
0.0	11.5	30,000.0	492.0	3.1	0
55.0	11.5	30,000.0	492.0	3.1	0

HAMMER INPUT

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

Hammer Data

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

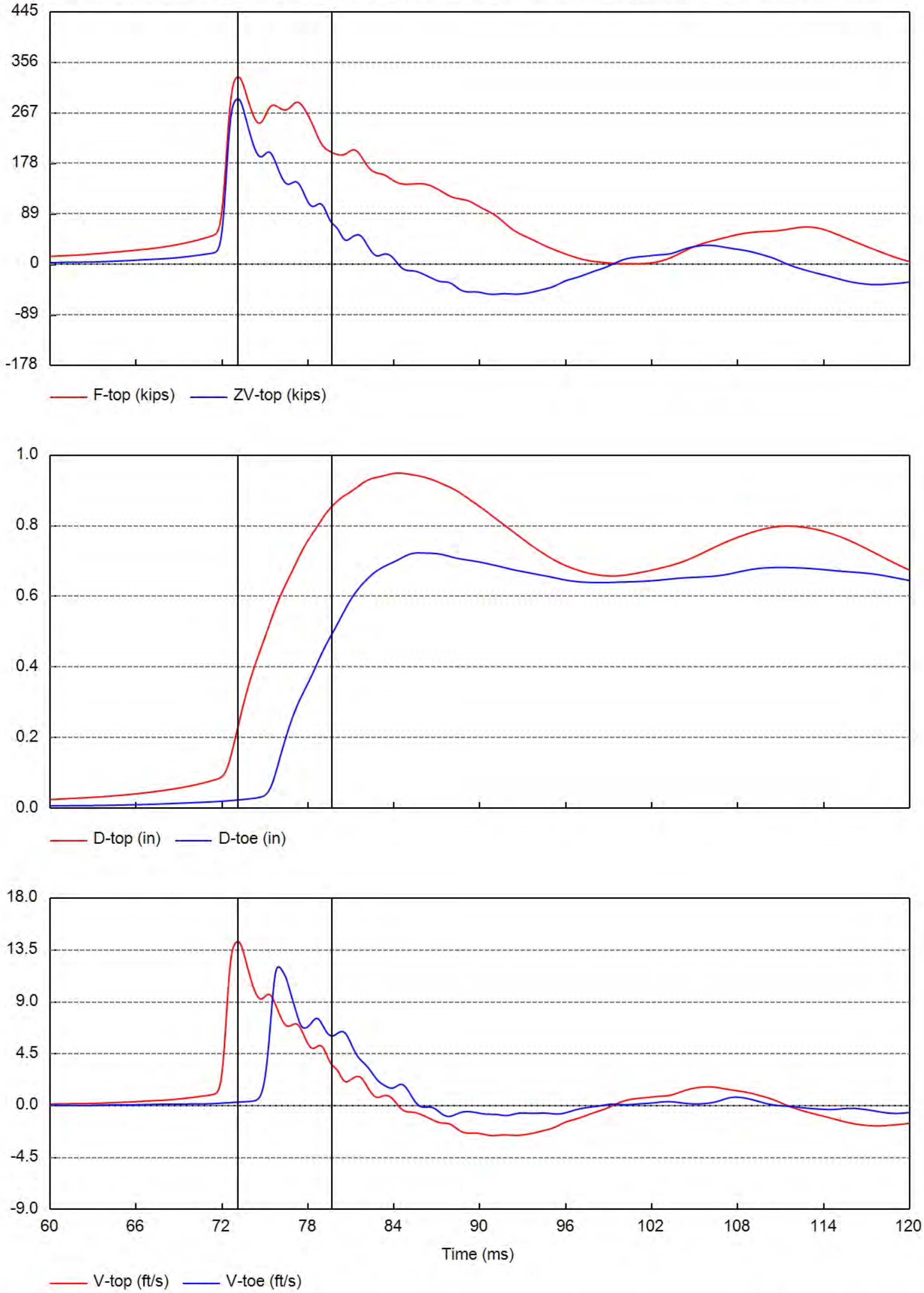
DRIVE SYSTEM FOR DELMAG D 19-42-OED

Type -	X-Area in²	E-Modulus ksi	Thickness in	COR -	Round-out in	Stiffness kips/in
Hammer C.	227.000	530.000	2.000	0.800	0.120	60155.550
Helmet Wt.	1.900	kips				

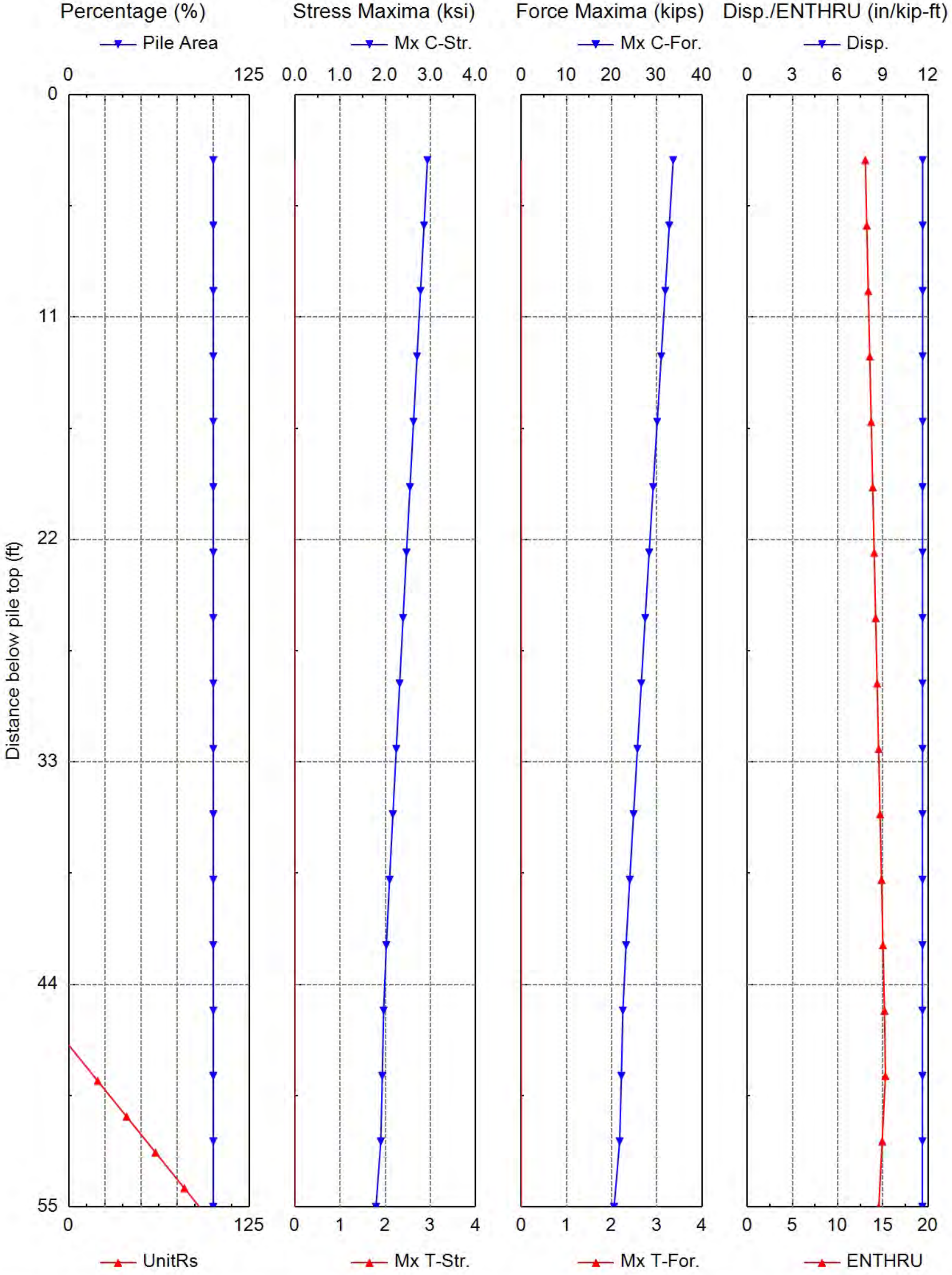
SOIL RESISTANCE DISTRIBUTION

Depth ft	Unit Rs ksf	Unit Rt ksf	Qs in	Qt in	Js s/ft	Jt s/ft	Set. F. -	Limit D. ft	Set. T. Hours	EB Area in²
0.0	0.0	0.0	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
1.8	0.0	2.4	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
3.5	0.1	4.8	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
5.3	0.1	7.2	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
7.1	0.2	9.6	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
8.9	0.2	12.0	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
10.6	0.3	13.3	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
12.4	0.3	13.3	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
14.2	0.4	13.3	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
15.9	0.4	13.3	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
17.7	0.5	13.3	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
17.7	1.7	15.7	0.10	0.20	0.15	0.15	1.5	6.6	168.0	113.1
18.2	1.7	15.7	0.10	0.20	0.15	0.15	1.5	6.6	168.0	113.1
18.2	1.3	15.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
19.9	1.3	15.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
21.5	1.3	15.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
23.2	1.3	15.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
24.9	1.3	15.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
26.5	1.3	15.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
28.2	1.3	15.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
28.2	0.9	33.1	0.10	0.15	0.05	0.15	1.2	6.6	1.0	113.1
29.5	0.9	33.1	0.10	0.15	0.05	0.15	1.2	6.6	1.0	113.1
30.7	0.9	33.1	0.10	0.15	0.05	0.15	1.2	6.6	1.0	113.1
30.7	0.8	20.7	0.10	0.15	0.05	0.15	1.2	6.6	1.0	113.1
32.7	0.9	20.7	0.10	0.15	0.05	0.15	1.2	6.6	1.0	113.1
34.7	0.9	20.7	0.10	0.15	0.05	0.15	1.2	6.6	1.0	113.1
36.7	1.0	20.7	0.10	0.15	0.05	0.15	1.2	6.6	1.0	113.1
38.7	1.0	20.7	0.10	0.15	0.05	0.15	1.2	6.6	1.0	113.1
38.7	2.1	251.8	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
40.5	2.2	251.8	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
42.2	2.3	251.8	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
44.0	2.3	251.8	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
45.7	2.4	251.8	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
45.7	3.9	34.9	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
47.4	3.9	34.9	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
49.2	3.9	34.9	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
50.9	3.9	34.9	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1

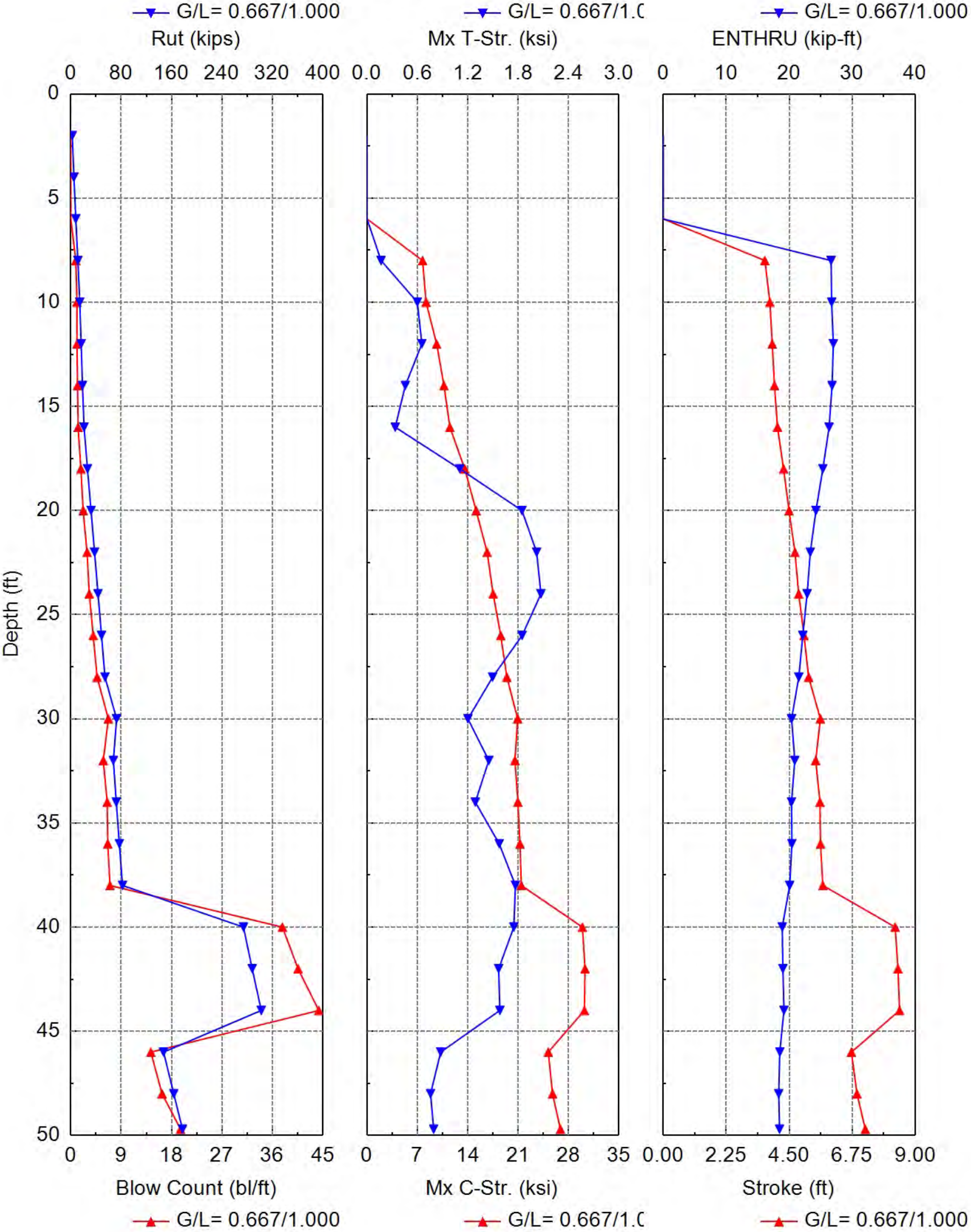
Variable Time Hisotry with DELMAG D 19-42; Depth = 49.70ft; Shaft/Toe G/L = 0.667/1.000



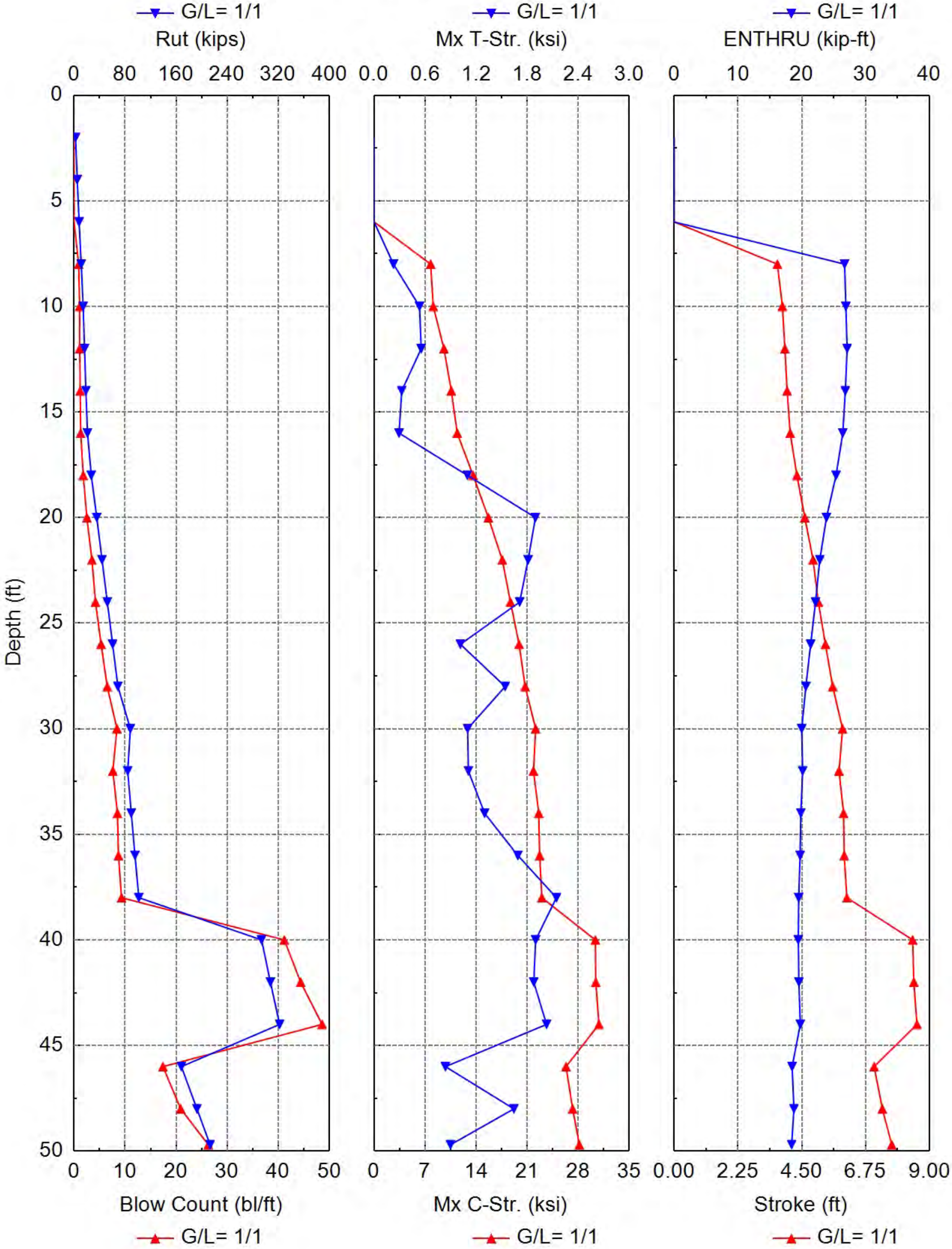
Extrema Results of Gain/Loss at Shaft/Toe = 0.667/1.000 and Depth = 8.00 ft



Driveability Analysis Summary



Driveability Analysis Summary



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

Depth ft	Rut kips	Rshaft kips	Rtoe kips	Blow Ct bl/ft	Mx C-Str. ksi	Mx T-Str. ksi	Stroke ft	ENTHRU kip-ft	Hammer -
2.0	2.3	0.2	2.1	0.3	0.000	0.000	10.81	0.0	D 19-42
4.0	4.9	0.7	4.3	0.3	0.000	0.000	10.81	0.0	D 19-42
6.0	7.9	1.5	6.4	0.0	0.000	0.000	0.00	0.0	D 19-42
8.0	11.2	2.7	8.5	0.9	7.717	0.168	3.63	26.7	D 19-42
10.0	14.2	4.1	10.1	1.1	8.204	0.599	3.81	26.7	D 19-42
12.0	16.4	6.0	10.5	1.1	9.674	0.653	3.90	27.0	D 19-42
14.0	18.6	8.1	10.5	1.2	10.693	0.456	3.98	26.8	D 19-42
16.0	21.1	10.6	10.5	1.3	11.516	0.336	4.08	26.3	D 19-42
18.0	26.4	14.1	12.4	1.8	13.578	1.105	4.30	25.3	D 19-42
20.0	32.2	19.8	12.4	2.2	15.161	1.845	4.49	24.3	D 19-42
22.0	37.7	25.3	12.4	2.9	16.689	2.020	4.71	23.4	D 19-42
24.0	43.2	30.8	12.4	3.3	17.521	2.072	4.84	22.9	D 19-42
26.0	48.7	36.4	12.4	4.0	18.583	1.847	5.03	22.2	D 19-42
28.0	54.3	41.9	12.4	4.7	19.431	1.496	5.20	21.5	D 19-42
30.0	72.7	46.7	26.0	6.7	20.935	1.202	5.62	20.4	D 19-42
32.0	67.6	51.3	16.3	5.8	20.552	1.450	5.45	20.9	D 19-42
34.0	72.2	56.0	16.3	6.5	20.965	1.290	5.60	20.4	D 19-42
36.0	77.1	60.8	16.3	6.6	21.255	1.574	5.62	20.4	D 19-42
38.0	82.1	65.9	16.3	7.0	21.437	1.767	5.70	20.1	D 19-42
40.0	274.2	76.4	197.8	37.8	29.932	1.748	8.29	18.9	D 19-42
42.0	288.0	90.2	197.8	40.6	30.295	1.567	8.39	19.0	D 19-42
44.0	302.5	104.7	197.8	44.3	30.199	1.582	8.44	19.2	D 19-42
46.0	147.3	119.9	27.4	14.3	25.185	0.878	6.72	18.5	D 19-42
48.0	163.5	136.1	27.4	16.3	25.773	0.757	6.92	18.3	D 19-42
49.7	177.3	149.9	27.4	19.6	26.878	0.794	7.22	18.5	D 19-42

Summary_Total driving time: 10 minutes; Total Number of Blows: 436 (starting at penetration 2.0 ft)

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

Depth ft	Rut kips	Rshaft kips	Rtoe kips	Blow Ct bl/ft	Mx C-Str. ksi	Mx T-Str. ksi	Stroke ft	ENTHRU kip-ft	Hammer -
2.0	2.3	0.2	2.1	0.3	0.000	0.000	10.81	0.0	D 19-42
4.0	4.9	0.7	4.3	0.3	0.000	0.000	10.81	0.0	D 19-42
6.0	7.9	1.5	6.4	0.0	0.000	0.000	0.00	0.0	D 19-42
8.0	11.2	2.7	8.5	0.9	7.755	0.228	3.64	26.7	D 19-42
10.0	14.2	4.1	10.1	1.1	8.113	0.534	3.82	26.9	D 19-42
12.0	16.4	6.0	10.5	1.1	9.578	0.553	3.91	27.1	D 19-42
14.0	18.6	8.1	10.5	1.2	10.591	0.325	3.99	26.8	D 19-42
16.0	21.1	10.6	10.5	1.3	11.401	0.293	4.09	26.4	D 19-42
18.0	27.0	14.6	12.4	1.8	13.578	1.097	4.33	25.4	D 19-42
20.0	35.6	23.2	12.4	2.5	15.669	1.896	4.61	23.9	D 19-42
22.0	43.8	31.5	12.4	3.5	17.581	1.811	4.90	22.8	D 19-42
24.0	52.1	39.8	12.4	4.2	18.700	1.712	5.08	22.2	D 19-42
26.0	60.4	48.1	12.4	5.3	19.887	1.015	5.34	21.4	D 19-42
28.0	68.7	56.4	12.4	6.5	20.719	1.541	5.59	20.6	D 19-42
30.0	88.3	62.3	26.0	8.4	22.160	1.100	5.94	20.0	D 19-42

32.0	84.1	67.8	16.3	7.6	21.865	1.108	5.82	20.1	D 19-42
34.0	89.7	73.4	16.3	8.5	22.586	1.299	5.98	19.9	D 19-42
36.0	95.5	79.2	16.3	8.7	22.705	1.690	6.00	19.7	D 19-42
38.0	101.5	85.3	16.3	9.3	23.007	2.143	6.09	19.5	D 19-42
40.0	293.9	96.1	197.8	41.2	30.341	1.899	8.41	19.5	D 19-42
42.0	307.8	110.0	197.8	44.4	30.409	1.877	8.45	19.6	D 19-42
44.0	322.2	124.5	197.8	48.6	30.839	2.028	8.56	19.8	D 19-42
46.0	168.2	140.9	27.4	17.4	26.321	0.839	7.05	18.5	D 19-42
48.0	192.6	165.2	27.4	20.9	27.235	1.644	7.34	18.8	D 19-42
49.7	213.3	185.9	27.4	26.3	28.160	0.898	7.68	18.4	D 19-42

Summary_Total driving time: 12 minutes; Total Number of Blows: 509 (starting at penetration 2.0 ft)

GRLWEAP: Wave Equation Analysis of Pile Foundations

FRA-00070-23.920 - FA (B-070-0-19) + 0.50" Wall Thick 12/3/2022
RESOURCE INTERNATIONAL INC GRLWEAP 14.1.15.0

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

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

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

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

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

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

SOIL PROFILE

Depth ft	Soil Type -	Spec. Wt lb/ft³	Su ksf	Phi °	Unit Rs ksf	Unit Rt ksf
0.0	Sand	125.0	0.0	28.0	0.00	0.00
17.7	Sand	125.0	0.0	28.0	0.47	13.32
17.7	Clay	120.0	1.7	0.0	1.75	15.75
18.2	Clay	120.0	1.7	0.0	1.75	15.75
18.2	Clay	120.0	1.7	0.0	1.32	15.75
28.2	Clay	120.0	1.7	0.0	1.32	15.75
28.2	Sand	125.0	0.0	32.0	0.88	33.09
30.7	Sand	125.0	0.0	32.0	0.93	33.09
30.7	Sand	125.0	0.0	31.0	0.84	20.71
38.7	Sand	125.0	0.0	31.0	1.00	20.71
38.7	Sand	135.0	0.0	38.0	2.10	251.83
45.7	Sand	135.0	0.0	38.0	2.43	251.83
45.7	Clay	125.0	3.9	0.0	3.87	34.87
64.7	Clay	125.0	3.9	0.0	3.87	34.87
64.7	Clay	125.0	4.1	0.0	0.99	37.12
84.7	Clay	125.0	4.1	0.0	0.99	37.12
84.7	Clay	125.0	3.4	0.0	0.85	30.37
92.7	Clay	125.0	3.4	0.0	0.85	30.37

PILE INPUT

Uniform Pile		Pile Type:	Pipe
Pile Length: (ft)	55.000	Pile Penetration: (ft)	49.700
Pile Size: (ft)	1.00	Toe Area: (in²)	113.10

Pile Profile

Lb Top ft	X-Area in²	E-Modulus ksi	Spec. Wt lb/ft³	Perim. ft	Crit. Index -
0.0	18.1	30,000.0	492.0	3.1	0
55.0	18.1	30,000.0	492.0	3.1	0

HAMMER INPUT

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

Hammer Data

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

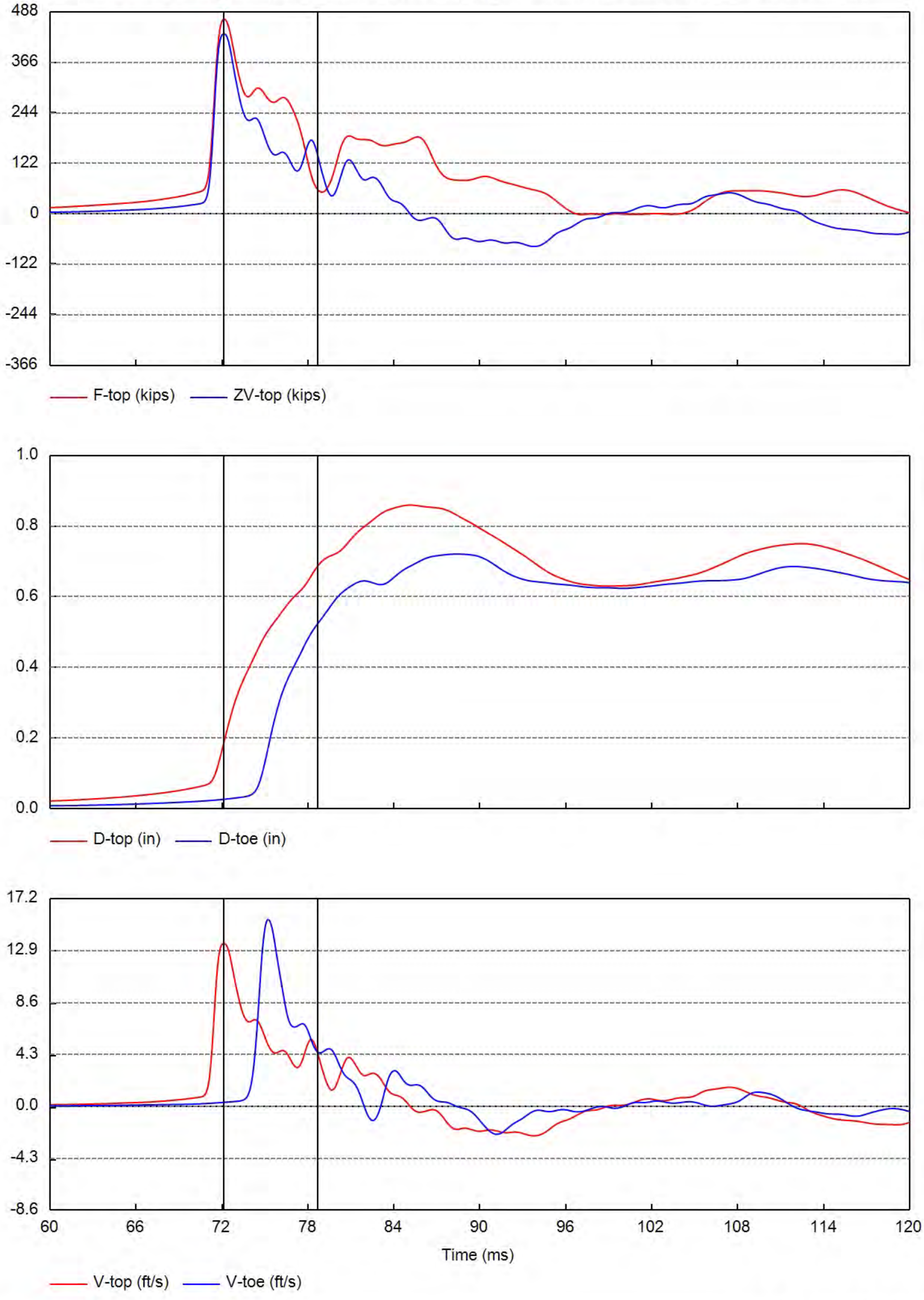
DRIVE SYSTEM FOR DELMAG D 19-42-OED

Type -	X-Area in²	E-Modulus ksi	Thickness in	COR -	Round-out in	Stiffness kips/in
Hammer C.	227.000	530.000	2.000	0.800	0.120	60155.550
Helmet Wt.	1.900	kips				

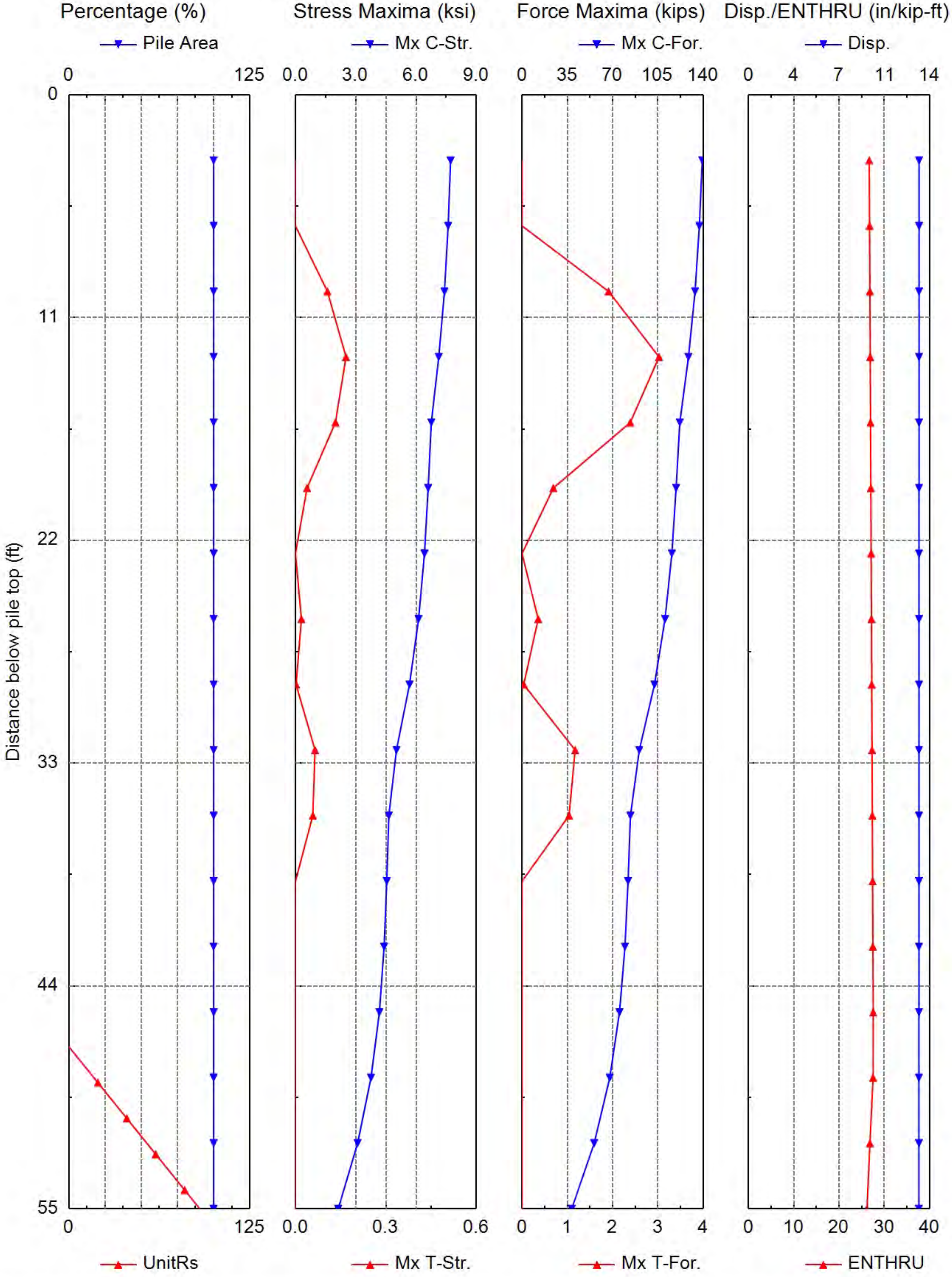
SOIL RESISTANCE DISTRIBUTION

Depth ft	Unit Rs ksf	Unit Rt ksf	Qs in	Qt in	Js s/ft	Jt s/ft	Set. F. -	Limit D. ft	Set. T. Hours	EB Area in²
0.0	0.0	0.0	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
1.8	0.0	2.4	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
3.5	0.1	4.8	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
5.3	0.1	7.2	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
7.1	0.2	9.6	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
8.9	0.2	12.0	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
10.6	0.3	13.3	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
12.4	0.3	13.3	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
14.2	0.4	13.3	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
15.9	0.4	13.3	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
17.7	0.5	13.3	0.10	0.20	0.05	0.15	1.0	6.6	1.0	113.1
17.7	1.7	15.7	0.10	0.20	0.15	0.15	1.5	6.6	168.0	113.1
18.2	1.7	15.7	0.10	0.20	0.15	0.15	1.5	6.6	168.0	113.1
18.2	1.3	15.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
19.9	1.3	15.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
21.5	1.3	15.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
23.2	1.3	15.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
24.9	1.3	15.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
26.5	1.3	15.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
28.2	1.3	15.7	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
28.2	0.9	33.1	0.10	0.15	0.05	0.15	1.2	6.6	1.0	113.1
29.5	0.9	33.1	0.10	0.15	0.05	0.15	1.2	6.6	1.0	113.1
30.7	0.9	33.1	0.10	0.15	0.05	0.15	1.2	6.6	1.0	113.1
30.7	0.8	20.7	0.10	0.15	0.05	0.15	1.2	6.6	1.0	113.1
32.7	0.9	20.7	0.10	0.15	0.05	0.15	1.2	6.6	1.0	113.1
34.7	0.9	20.7	0.10	0.15	0.05	0.15	1.2	6.6	1.0	113.1
36.7	1.0	20.7	0.10	0.15	0.05	0.15	1.2	6.6	1.0	113.1
38.7	1.0	20.7	0.10	0.15	0.05	0.15	1.2	6.6	1.0	113.1
38.7	2.1	251.8	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
40.5	2.2	251.8	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
42.2	2.3	251.8	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
44.0	2.3	251.8	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
45.7	2.4	251.8	0.10	0.10	0.05	0.15	1.0	6.6	1.0	113.1
45.7	3.9	34.9	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
47.4	3.9	34.9	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
49.2	3.9	34.9	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1
50.9	3.9	34.9	0.10	0.15	0.15	0.15	1.5	6.6	168.0	113.1

Variable Time Hisotry with DELMAG D 19-42; Depth = 49.70ft; Shaft/Toe G/L = 0.667/1.000



Extrema Results of Gain/Loss at Shaft/Toe = 0.667/1.000 and Depth = 8.00 ft



APPENDIX VIII

DESIGN SOIL PARAMETERS

FRA-70-22.85
FRA-00070-23.920 Brice Road Bridge over IR 70
Design Soil Parameters

Boring	Ground Elevation (ft msl)	D_w (ft)	Layer #	Soil Class.	Material Type	Stratum Depth, z (ft)	Stratum Thickness (ft)	Bottom Elevation (ft msl)	γ (pcf)	σ_v' (Midpoint) (psf)	σ_v (Bottom) (psf)	N_{60} (bpf)	S_u (psf)	φ' (deg)	K (pci)	ε_{50}	Q_u (psi)	E_i (psi)	k_{rm}	RQD
B-065-0-19	820.8	40.0	1	A-6b	C	5.0	5.0	815.8	120	300	600	13	1,625	26	540	0.0068				
			2	A-6b	C	8.0	3.0	812.8	120	780	960	19	2,375	26	790	0.0058				
			3	A-6a	C	10.5	2.5	810.3	120	1,110	1,260	21	2,625	27	875	0.0055				
			4	A-6b	C	15.5	5.0	805.3	120	1,560	1,860	15	1,875	26	625	0.0065				
			5	A-6a	C	27.0	11.5	793.8	120	2,550	3,240	22	2,750	27	915	0.0053				
			6	A-6b	C	32.0	5.0	788.8	130	3,565	3,890	47	5,875	27	1,960	0.0040				
			7	A-6b	C	42.0	10.0	778.8	130	4,540	5,190	47	5,875	27	1,960	0.0040				
			8	A-1-b	G	47.0	5.0	773.8	130	5,234	5,840	44		36	105					
			9	A-1-b	G	52.0	5.0	768.8	130	5,572	6,490	37		34	75					
			10	A-1-b	G	57.0	5.0	763.8	135	5,923	7,165	50		37	125					
			11	A-6a	C	67.0	10.0	753.8	125	6,417	8,415	33	4,125	28	1,375	0.0046				
			12	A-6a	C	72.0	5.0	748.8	130	6,899	9,065	53	6,625	28	2,210	0.0038				
			13	A-6a	C	75.0	3.0	745.8	125	7,162	9,440	34	4,250	28	1,415	0.0046				
B-066-0-19	801.6	15.3	1	A-4a	C	3.0	3.0	798.6	115	173	345	7	875	28	165	0.0095				
			2	A-6a	C	8.0	5.0	793.6	115	633	920	10	1,250	27	365	0.0080				
			3	A-4a	C	13.0	5.0	788.6	110	1,195	1,470	5	625	28	85	0.0125				
			4	A-3a	G	15.5	2.5	786.1	125	1,626	1,783	15		29	35					
			5	A-1-b	G	20.5	5.0	781.1	130	1,939	2,433	36		34	75					
			6	A-3a	G	23.0	2.5	778.6	125	2,186	2,745	25		31	50					
			7	A-1-b	G	27.0	4.0	774.6	135	2,410	3,285	50		37	125					
			8	A-1-b	G	32.0	5.0	769.6	125	2,711	3,910	23		32	50					
			9	A-4a	C	37.0	5.0	764.6	125	3,024	4,535	30	3,750	30	1,250	0.0048				
			10	A-4a	C	40.0	3.0	761.6	130	3,282	4,925	66	8,000	30	2,665	0.0033				
			11	A-6a	C	57.0	17.0	744.6	125	3,916	7,050	39	4,875	28	1,625	0.0044				
			12	A-6a	C	70.0	13.0	731.6	130	4,887	8,740	50	6,250	28	2,085	0.0039				
B-067-0-19	796.0	13.5	1	A-6b	C	9.5	9.5	786.5	115	546	1,093	6	750	25	100	0.0100				
			2	A-2-4	G	18.0	8.5	778.0	125	1,608	2,155	25		32	50					
			3	A-2-4	G	23.0	5.0	773.0	135	2,056	2,830	46		36	105					
			4	A-1-a	G	27.0	4.0	769.0	135	2,382	3,370	100		38	125					
			5	A-2-4	G	32.0	5.0	764.0	135	2,709	4,045	46		36	105					
			6	A-4a	C	57.0	25.0	739.0	130	3,736	7,295	50	6,250	30	2,085	0.0039				
			7	A-6a	C	67.0	10.0	729.0	130	4,919	8,595	45	5,625	28	1,875	0.0041				
			8	A-6b	C	75.0	8.0	721.0	120	5,487	9,555	22	2,750	26	915	0.0053				
B-068-0-19	796.9	12.5	1	A-6a	C	5.0	5.0	791.9	120	300	600	13	1,625	27	540	0.0068				
			2	A-6a	C	8.0	3.0	788.9	120	780	960	23	2,875	27	960	0.0052				
			3	A-7-6	C	10.5	2.5	786.4	115	1,104	1,248	12	1,500	25	500	0.0070				
			4	A-2-4	G	13.0	2.5	783.9	125	1,404	1,560	24		32	65					
			5	A-2-4	G	18.0	5.0	778.9	135	1,710	2,235	50		37	125					
			6	A-2-4	G	20.5	2.5	776.4	130	1,976	2,560	35		34	75					
			7	A-3a	G	23.0	2.5	773.9	135	2,152	2,898	72		36	125					
			8	A-2-4	G	27.0	4.0	769.9	135	2,388	3,438	56		37	125					
			9	A-4a	C	30.0	3.0	766.9	130	2,634	3,828	47	5,875	30	1,960	0.0040				
			10	A-4a	C	37.0	7.0	759.9	130	2,972	4,738	66	8,000	30	2,665	0.0033				
			11	A-4a	C	44.0	7.0	752.9	130	3,445	5,648	44	5,500	30	1,835	0.0042				
			12	A-4a	C	50.0	6.0	746.9	130	3,885	6,428	60	7,500	30	2,500	0.0035				
			13	A-6a	C	57.0	7.0	739.9	130	4,324	7,338	50	6,250	28	2,085	0.0039				
			14	A-6a	C	62.0	5.0	734.9	120	4,705	7,938	21	2,625	27	875	0.0055				
			15	A-6a	C	67.0	5.0	729.9	125	5,005	8,563	35	4,375	28	1,460	0.0045				
			16	A-6a	C	75.0	8.0	721.9	120	5,392	9,523	24	3,000	28	1,000	0.0050				

FRA-70-22.85
FRA-00070-23.920 Brice Road Bridge over IR 70
Design Soil Parameters

Boring	Ground Elevation (ft msl)	D_w (ft)	Layer #	Soil Class.	Material Type	Stratum Depth, z (ft)	Stratum Thickness (ft)	Bottom Elevation (ft msl)	γ (pcf)	σ_v' (Midpoint) (psf)	σ_v (Bottom) (psf)	N_{60} (bpf)	S_u (psf)	φ' (deg)	K (pci)	ε_{50}	Q_u (psi)	E_i (psi)	k_{rm}	RQD
B-069-0-19	797.8	13.5	1	A-1-b	G	5.5	5.5	792.3	120	330	660	9		29	25					
			2	A-4a	G	12.5	7.0	785.3	120	1,080	1,500	9		27	25					
			3	A-2-4	G	15.0	2.5	782.8	120	1,634	1,800	8		28	15					
			4	A-1-b	G	20.5	5.5	777.3	125	1,879	2,488	13		29	20					
			5	A-2-6	G	27.0	6.5	770.8	130	2,270	3,333	31		32	60					
			6	A-6a	C	37.0	10.0	760.8	120	2,778	4,533	24	3,000	28	1,000	0.0050				
			7	A-6a	C	43.0	6.0	754.8	130	3,269	5,313	46	5,750	28	1,915	0.0041				
			8	A-2-6	G	46.5	3.5	751.3	135	3,599	5,785	50		36	125					
			9	A-6a	C	52.0	5.5	745.8	130	3,912	6,500	50	6,250	28	2,085	0.0039				
			10	A-6a	C	67.0	15.0	730.8	130	4,605	8,450	43	5,375	28	1,790	0.0042				
			11	A-7-6	C	75.0	8.0	722.8	120	5,342	9,410	21	2,625	25	875	0.0055				
B-070-0-19	796.6	13.5	1	A-4a	C	10.5	10.5	786.1	120	630	1,260	14	1,750	29	585	0.0067				
			2	A-2-4	G	13.0	2.5	783.6	125	1,416	1,573	24		32	65					
			3	A-2-6	G	21.0	8.0	775.6	125	1,854	2,573	24		31	50					
			4	A-3a	G	23.0	2.0	773.6	125	2,167	2,823	24		31	50					
			5	A-1-a	G	28.0	5.0	768.6	135	2,411	3,498	50		38	125					
			6	A-4a	C	47.0	19.0	749.6	125	3,187	5,873	31	3,875	30	1,290	0.0047				
			7	A-4a	C	62.0	15.0	734.6	130	4,289	7,823	95	8,000	30	2,665	0.0033				
			8	A-4a	C	67.0	5.0	729.6	125	4,953	8,448	33	4,125	30	1,375	0.0046				
			9	A-6b	C	75.0	8.0	721.6	125	5,360	9,448	27	3,375	27	1,125	0.0049				
B-071-0-19	820.7	34.0	1	A-6b	C	8.0	8.0	812.7	120	480	960	19	2,375	26	790	0.0058				
			2	A-6b	C	10.5	2.5	810.2	125	1,116	1,273	32	4,000	27	1,335	0.0047				
			3	A-6b	C	18.0	7.5	802.7	120	1,723	2,173	23	2,875	26	960	0.0052				
			4	A-6b	C	23.5	5.5	797.2	130	2,530	2,888	45	5,625	27	1,875	0.0041				
			5	A-6a	C	27.0	3.5	793.7	130	3,115	3,343	51	6,375	28	2,125	0.0039				
			6	A-6a	C	32.0	5.0	788.7	125	3,655	3,968	29	3,625	28	1,210	0.0048				
			7	A-6a	C	37.0	5.0	783.7	125	4,249	4,593	34	4,250	28	1,415	0.0046				
			8	A-2-4	G	52.0	15.0	768.7	130	4,912	6,543	36		34	75					
			9	A-6b	C	62.0	10.0	758.7	120	5,707	7,743	22	2,750	26	915	0.0053				
			10	A-6b	C	75.0	13.0	745.7	130	6,435	9,433	45	5,625	27	1,875	0.0041				
B-072-0-19	820.8	38.7	1	A-6a	C	5.5	5.5	815.3	125	344	688	26	3,250	28	1,085	0.0049				
			2	A-6a	C	20.5	15.0	800.3	120	1,588	2,488	20	2,500	27	835	0.0057				
			3	A-6a	C	23.0	2.5	797.8	130	2,650	2,813	62	7,750	28	2,585	0.0034				
			4	A-6a	C	27.5	4.5	793.3	125	3,094	3,375	29	3,625	28	1,210	0.0048				
			5	A-6a	C	31.5	4.0	789.3	125	3,625	3,875	27	3,375	28	1,125	0.0049				
			6	A-2-4	G	37.0	5.5	783.8	125	4,219	4,563	17		30	35					
			7	A-1-b	G	47.0	10.0	773.8	130	5,007	5,863	31		33	60					
			8	A-2-4	G	52.0	5.0	768.8	135	5,526	6,538	67		37	125					
			9	A-6a	C	57.0	5.0	763.8	130	5,877	7,188	45	5,625	28	1,875	0.0041				
			10	A-4a	C	62.0	5.0	758.8	120	6,190	7,788	24	3,000	30	1,000	0.0050				
			11	A-2-4	G	75.0	13.0	745.8	135	6,805	9,543	100		37	125					

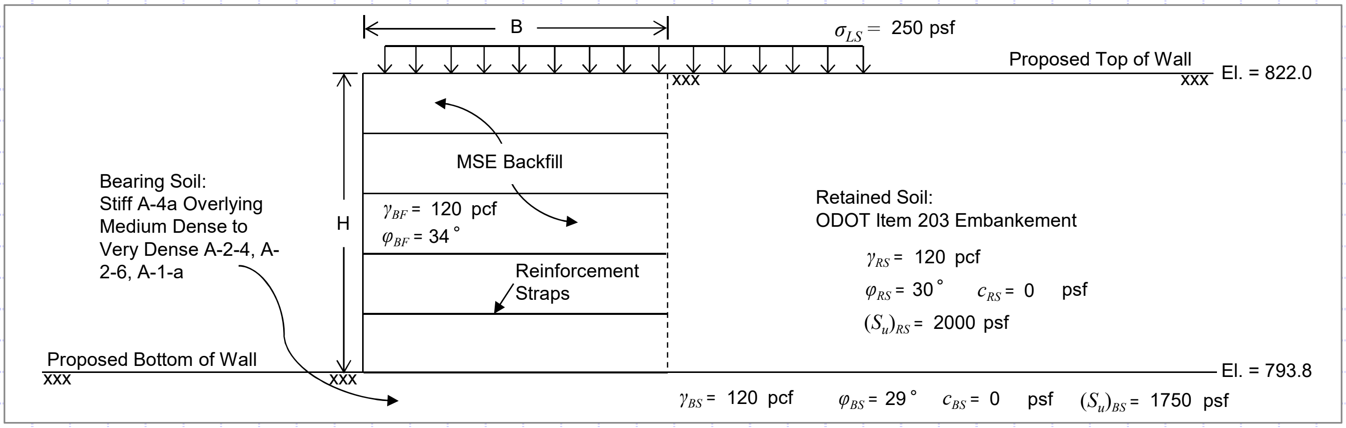
FRA-70-22.85
FRA-00070-23.920 Brice Road Bridge over IR 70
Design Soil Parameters

Boring	Ground Elevation (ft msl)	D_w (ft)	Layer #	Soil Class.	Material Type	Stratum Depth, z (ft)	Stratum Thickness (ft)	Bottom Elevation (ft msl)	γ (pcf)	σ_v' (Midpoint) (psf)	σ_v (Bottom) (psf)	N_{60} (bpf)	S_u (psf)	φ' (deg)	K (pci)	ε_{50}	Q_u (psi)	E_i (psi)	k_{rm}	RQD
B-003-0-65	790.8	8.3	1	A-2-4	G	11.5	11.5	779.3	125	719	1,438	25		32	65					
			2	A-1-a	G	19.5	8.0	771.3	135	1,528	2,518	60		38	125					
			3	A-4a	C	28.0	8.5	762.8	120	2,063	3,538	24	3,000	30	1,000	0.0050				
			4	A-6a	C	33.0	5.0	757.8	125	2,465	4,163	34	4,250	28	1,415	0.0046				
			5	A-4a	C	43.0	10.0	747.8	125	2,934	5,413	35	4,375	30	1,460	0.0045				
			6	A-6a	C	48.0	5.0	742.8	125	3,404	6,038	31	3,875	28	1,290	0.0047				
			7	A-6b	C	53.0	5.0	737.8	125	3,717	6,663	35	4,375	27	1,460	0.0045				
			8	A-4b	G	58.0	5.0	732.8	130	4,042	7,313	31		30	60					
			9	A-6a	C	61.0	3.0	729.8	125	4,305	7,688	38	4,750	28	1,585	0.0044				
B-007-0-65	793.4	10.3	1	A-2-4	G	6.5	6.5	786.9	130	423	845	43		36	185					
			2	A-1-a	G	9.0	2.5	784.4	130	1,008	1,170	31		34	90					
			3	A-1-a	G	19.0	10.0	774.4	135	1,614	2,520	71		38	125					
			4	A-6b	C	24.5	5.5	768.9	125	2,149	3,208	35	4,375	27	1,460	0.0045				
			5	A-4a	C	28.0	3.5	765.4	125	2,431	3,645	33	4,125	30	1,375	0.0046				
			6	A-4a	C	38.0	10.0	755.4	130	2,879	4,945	54	6,750	30	2,250	0.0038				
			7	A-4a	C	41.0	3.0	752.4	125	3,310	5,320	39	4,875	30	1,625	0.0044				

APPENDIX IX

MSE WALL CALCULATIONS

Retaining Wall 5B - Sta. 15+85 to 17+96 (BL Wall 5B) - FRA-BRICE-04342 Fwd. Abut. - B-070-0-19 and B-007-0-65 - Level Backfill - 28.2 ft. Wall Height



MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	28.2	ft
MSE Wall Width (Reinforcement Length), (B) =	24.0	ft
MSE Wall Length, (L) =	211	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion [1], (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties [1]:

	Bearing	Sliding	
Bearing Soil Unit Weight, (γ_{BS}) =	120	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	29	29	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	0	psf
Bearing Soil Undrained Shear Strength, $[(S_u)_{BS}]$ =	1750	1750	psf
Embedment Depth, (D_f) =	3.0 ft		
Depth to Grounwater (Below Bot. of Wall), (D_W) =	10.0 ft		

LRFD Load Factors

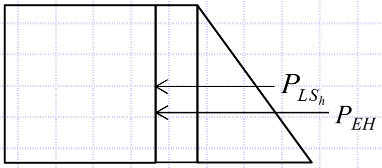
	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

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

1. Soil properties for bearing resistance based on critical soil type w/i 1.5B below the bottom of wall. Soil properties for sliding resistance based on soil type w/i 3.0 ft. below the bottom of wall.

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

Sliding Force: $P_H = P_{EH} + P_{LS_h}$



Sliding Force at Bottom of Wall (Top of Foundation Preparation):

$P_{EH} = \frac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH}$ = ½(120 pcf)(28.2 ft)²(0.297)(1.5) = 21.26 kip/ft

$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS}$ = (250 psf)(28.2 ft)(0.297)(1.75) = 3.66 kip/ft

P_H = 21.26 kip/ft + 3.66 kip/ft = 24.92 kip/ft

Sliding Force at Bottom of Foundation Preparation:

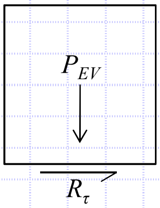
$P_{EH} = \frac{1}{2}\gamma_{RS}(H+1)^2(K_a)(\gamma_{EH})$ = ½(120 pcf)(28.2 ft + 1 ft)²(0.297)(1.5) = 22.79 kip/ft

$P_{LS_h} = \sigma_{LS}(H+1)(K_a)(\gamma_{LS})$ = (250 psf)(28.2 ft + 1 ft)(0.297)(1.75) = 3.79 kip/ft

P_H = 22.79 kip/ft + 3.79 kip/ft = 26.58 kip/ft

Check Sliding Resistance - Drained Condition (At Bottom of Foundation Preparation, 1.0-foot Below Bottom of Wall)

Nominal Sliding Resistance: $R_\tau = P_{EV} \cdot \tan\delta$



$P_E = \gamma_{BF}(H+1)(B)(\gamma_{EV})$ = (120 pcf)(28.2 ft + 1 ft)(24.0 ft)(1.00) = 84.1 kip/ft

$\tan\delta = (\tan\varphi_{BS} \leq \tan\varphi_{BF})$ ⟶ tan(29) ≤ tan(34) ⟶ 0.55 ≤ 0.67 = 0.55

R_τ = (84.1 kip/ft)(0.55) = 46.26 kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Drained Condition (Bottom of Foundation Preparation)

$P_H \leq R_\tau \cdot \phi_\tau$ ⟶ 26.58 kip/ft ≤ (46.26 kip/ft)(1.0) = 46.26 kip/ft ⟶ 26.58 kip/ft ≤ 46.26 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) =	28.2	ft
MSE Wall Width (Reinforcement Length), (B) =	24.0	ft
MSE Wall Length, (L) =	211	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties [1]:

	Bearing	Sliding	
Bearing Soil Unit Weight, (γ_{BS}) =	120	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	29	29	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	1750	1750	psf
Embedment Depth, (D_f) =	3.0 ft		
Depth to Grounwater (Below Bot. of Wall), (D_W) =	10.0 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)

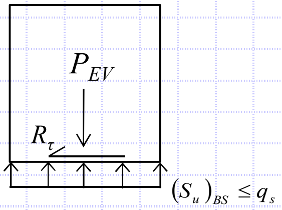
[1] Soil properties for bearing resistance based on critical soil type w/i 1.5B below the bottom of wall. Soil properties for sliding resistance based on soil type w/i 3.0 ft. below the bottom of wall.

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

Check Sliding Resistance - Undrained Condition (At Bottom of Foundation Preparation, 1.0-foot Below Bottom of Wall)

Nominal Sliding Resisting:

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



$(S_u)_{BS} =$ 1.75 ksf

$q_s = \sigma_v / 2$ = (3.50 ksf) / 2 = 1.75 ksf

$\sigma_v = P_{EV} / B$ = (84.1 kip/ft) / (24 ft) = 3.50 ksf

R_τ = (1.75 ksf ≤ 1.75 ksf)(24.0 ft) = 42.00 kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition (Bottom of Foundation Preparation)

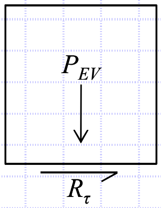
$P_H \le R_\tau \cdot \phi_\tau$ ⟶ 26.58 kip/ft ≤ (42.00 kip/ft)(1.0) = 42.00 kip/ft ⟶ 26.58 kip/ft ≤ 42.00 kip/ft **OK**

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

Check Sliding Resistance - Drained Condition (At Bottom of Wall, Top of Foundation Preparation)

Nominal Sliding Resistance:

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



$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(28.2 ft)(24.0 ft)(1.00) = 81.22 kip/ft

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

$\tan\delta =$ tan(34) ≤ tan(34) ⟶ 0.67 ≤ 0.67 ⟶ $\tan\delta =$ 0.67

R_τ = (81.22 kip/ft)(0.67) = 54.42 kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Drained Condition (Bottom of Wall)

$P_H \le R_\tau \cdot \phi_\tau$ ⟶ 24.92 kip/ft ≤ (54.42 kip/ft)(1.0) = 54.42 kip/ft ⟶ 24.92 kip/ft ≤ 54.42 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) =	28.2	ft
MSE Wall Width (Reinforcement Length), (B) =	24.0	ft
MSE Wall Length, (L) =	211	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties [1]:

	Bearing	Sliding	
Bearing Soil Unit Weight, (γ_{BS}) =	120	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	29	29	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	1750	1750	psf
Embedment Depth, (D_f) =	3.0 ft		
Depth to Groundwater (Below Bot. of Wall), (D_W) =	10.0 ft		

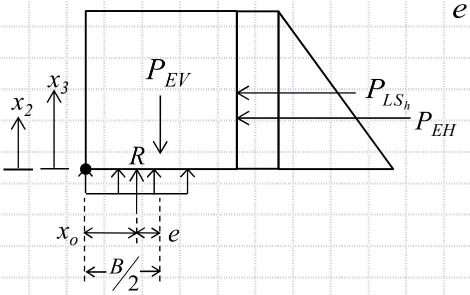
LRFD Load Factors

	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)

1. Soil properties for bearing resistance based on critical soil type w/i 1.5B below the bottom of wall. Soil properties for sliding resistance based on soil type w/i 3.0 ft. below the bottom of wall.

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



$$e = {}^{B}\!/_{2} - x_o$$

$$x_o = \frac{M_{EV} - M_H}{P_{EV}} = \text{(974.64 kip·ft/ft - 251.45 kip·ft/ft) / (81.22 kip/ft)} = 8.90 \text{ ft}$$

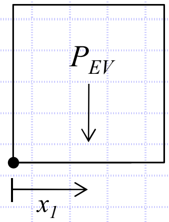
M_{EV} = 974.64 kip·ft/ft
M_H = 251.45 kip·ft/ft
P_{EV} = 81.22 kip/ft

Defined below

$$e = \text{(24 ft)/2 - 8.9 ft} = 3.10 \text{ ft}$$

Resisting Moment, M_{EV}:

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



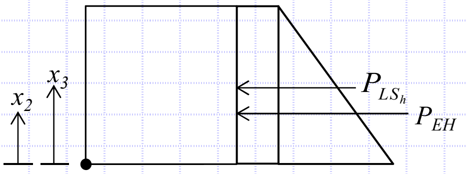
$$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} = \text{(120 pcf)(28.2 ft)(24.0 ft)(1.00)} = 81.22 \text{ kip/ft}$$

$$x_1 = {}^{B}\!/_{2} = \text{(24.0 ft) / 2} = 12.00 \text{ ft}$$

$$M_{EV} = \text{(81.22 kip/ft)(12.00 ft)} = 974.64 \text{ kip·ft/ft}$$

Overturning Moment, M_H:

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



$$P_{EH} = \tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH} = \text{½(120 pcf)(28.2 ft)²(0.297)(1.5)} = 21.26 \text{ kip/ft}$$

$$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS} = \text{(250 psf)(28.2 ft)(0.297)(1.75)} = 3.66 \text{ kip/ft}$$

$$x_2 = {}^{H}\!/_{3} = \text{(28.2 ft) / 3} = 9.40 \text{ ft}$$

$$x_3 = {}^{H}\!/_{2} = \text{(28.2 ft) / 2} = 14.10 \text{ ft}$$

$$M_H = \text{(21.26 kip/ft)(9.4 ft) + (3.66 kip/ft)(14.10 ft)} = 251.45 \text{ kip·ft/ft}$$

Check Eccentricity

$e < e_{\max} \longrightarrow$ 3.10 ft < 8.00 ft **OK**

Limiting Eccentricity: $e_{\max} = {}^{B}\!/_{3} \longrightarrow e_{\max} =$ (24.0 ft) / 3 = 8.00 ft

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	28.2	ft
MSE Wall Width (Reinforcement Length), (B) =	24.0	ft
MSE Wall Length, (L) =	211	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties [1]:

	Bearing	Sliding	
Bearing Soil Unit Weight, (γ_{BS}) =	120	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	29	29	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	1750	1750	psf
Embedment Depth, (D_f) =	3.0 ft		
Depth to Grounwater (Below Bot. of Wall), (D_W) =	10.0 ft		

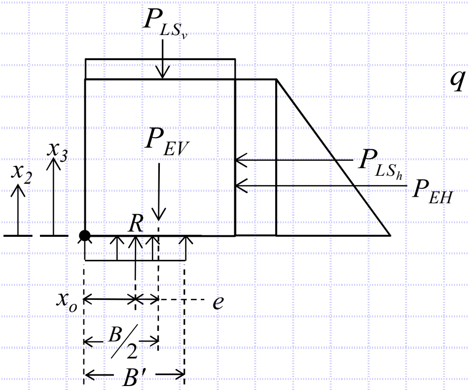
LRFD Load Factors

	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)

1. Soil properties for bearing resistance based on critical soil type w/i 1.5B below the bottom of wall. Soil properties for sliding resistance based on soil type w/i 3.0 ft. below the bottom of wall.

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



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

$$B' = B - 2e \quad = \quad \text{24.0 ft - 2(2.09 ft)} \quad = \quad 19.82 \quad \text{ft}$$

$$e = B/2 - x_o \quad = \quad \text{(24.0 ft) / 2 - 9.91 ft} \quad = \quad 2.09 \quad \text{ft}$$

$$x_o = \frac{M_V - M_H}{P_V} \quad = \quad \text{(1441.70 kip·ft/ft - 251.48 kip·ft/ft) / 120.14 kip/ft} \quad = \quad 9.91 \quad \text{ft}$$

$$q_{eq} = \quad \text{(120.14 kip/ft) / (19.82 ft)} \quad = \quad 6.06 \quad \text{ksf}$$

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

$$M_V = \quad \text{[(120 pcf)(28.2 ft)(24.0 ft)(1.35)](12 ft) + [(250 psf)(24.0 ft)(1.75)](12 ft)} \quad = \quad 1441.70 \quad \text{kip·ft/ft}$$

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

$$M_H = \quad \text{[½(120 pcf)(28.2 ft)²(0.297)(1.5)](9.4 ft) + [(250 psf)(28.2 ft)(0.297)(1.75)](14.1 ft)} \quad = \quad 251.48 \quad \text{kip·ft/ft}$$

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

$$P_V = \quad \text{(120 pcf)(28.2 ft)(24.0 ft)(1.35) + (250 psf)(24.0 ft)(1.75)} \quad = \quad 120.14 \quad \text{kip/ft}$$

Check Bearing Resistance - Drained Condition

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

$N_{cm} = N_c s_c i_c$ = 29.39

N_c = 27.86
s_c = 1+(19.82 ft/211 ft)(16.44/27.86)
= 1.055
i_c = 1.000 (Assumed)

$N_{qm} = N_q s_q d_q i_q$ = 17.16

N_q = 16.44
s_q = 1.000
d_q = 1+2tan(29°)[1-sin(29°)]²tan⁻¹(3.0 ft/19.82 ft)
1.044
i_q = 1.000 (Assumed)
C_{wq} = 10.0 ft > 3.0 ft = 1.000

$N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 18.61

N_γ = 19.34
s_γ = 0.962
i_γ = 1.000 (Assumed)
$C_{w\gamma}$ = 10.0 ft < 1.5(19.82 ft) + 3.0 ft = 0.668

$$q_n = \quad \text{(0 psf)(29.392) + (120 pcf)(3.0 ft)(17.163)(1.000) + ½(120 pcf)(19.8 ft)(18.605)(0.668)} \quad = \quad 20.96 \quad \text{ksf}$$

Verify Equivalent Pressure Less Than Factored Bearing Resistance

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

$q_{eq} \leq q_n \cdot \phi_b \longrightarrow$ 6.06 ksf ≤ (20.96 ksf)(0.65) = 13.62 ksf $\longrightarrow$ 6.06 ksf ≤ 13.62 ksf **OK**

JOB	FRA-70-22.85 FEF	NO.	W-17-140
SHEET NO.	5	OF	6
CALCULATED BY	PPM	DATE	1/21/2022
CHECKED BY	BRT	DATE	3/23/2022

Retaining Wall 5B - Sta. 15+85 to 17+96 (BL Wall 5B)

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	28.2	ft
MSE Wall Width (Reinforcement Length), (B) =	24.0	ft
MSE Wall Length, (L) =	211	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties [1]:

	Bearing	Sliding	
Bearing Soil Unit Weight, (γ_{BS}) =	120	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	29	29	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	1750	1750	psf
Embedment Depth, (D_f) =	3.0 ft		
Depth to Grounwater (Below Bot. of Wall), (D_W) =	10.0 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)

1. Soil properties for bearing resistance based on critical soil type w/i 1.5B below the bottom of wall. Soil properties for sliding resistance based on soil type w/i 3.0 ft. below the bottom of wall.

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

Check Bearing Resistance - Undrained Condition

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

$N_{cm} = N_c s_c i_c$ = 5.230

N_c = 5.140

s_c = 1+(19.82 ft/[(5)(211 ft)]) = 1.018

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/19.82 ft)

1.000

i_q = 1.000 (Assumed)

C_{wq} = 10.0 ft > 3.0 ft = 1.000

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

N_γ = 0.000

s_γ = 1.000

i_γ = 1.000 (Assumed)

$C_{w\gamma}$ = 10.0 ft < 1.5(19.82 ft) + 3.0 ft = 0.668

$q_n =$ (1750 psf)(5.230) + (120 pcf)(3.0 ft)(1.000)(1.000) + ½(120 pcf)(19.8 ft)(0.000)(0.668) = 9.51 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

$q_{eq} \leq q_n \cdot \phi_b$ ⟶ 6.06 ksf ≤ (9.51 ksf)(0.65) = 6.18 ksf ⟶ 6.06 ksf ≤ 6.18 ksf **OK**

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

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JOB FRA-70-22.85 FEF NO. W-17-140
SHEET NO. 6 OF 6
CALCULATED BY PPM DATE 1/21/2022
CHECKED BY BRT DATE 3/23/2022
Retaining Wall 5B - Sta. 15+85 to 17+96 (BL Wall 5B)

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	28.2	ft
MSE Wall Width (Reinforcement Length), (B) =	24.0	ft
MSE Wall Length, (L) =	211	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties [1]:

	Bearing	Sliding	
Bearing Soil Unit Weight, (γ_{BS}) =	120	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	29	29	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	1750	1750	psf
Embedment Depth, (D_f) =	3.0 ft		
Depth to Grounwater (Below Bot. of Wall), (D_W) =	10.0 ft		

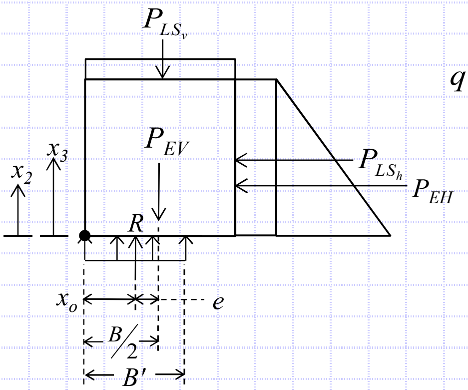
LRFD Load Factors

	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)

1. Soil properties for bearing resistance based on critical soil type w/i 1.5B below the bottom of wall. Soil properties for sliding resistance based on soil type w/i 3.0 ft. below the bottom of wall.

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



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

$B' = B - 2e$ = 24.0 ft - 2(1.87 ft) = 20.26 ft

$e = B \big/ 2 - x_o$ = (24.0 ft) / 2 - 10.13 ft = 1.87 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (1046.59 kip·ft/ft - 162.73 kip·ft/ft) / 87.22 kip/ft = 10.13 ft

$q_{eq} =$ (87.22 kip/ft) / (20.26 ft) = 4.31 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)(28.2 ft)(24.0 ft)(1.00)](12.0 ft) + [(250 psf)(24.0 ft)(1.00)](12.0 ft) = 1046.59 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(120 pcf)(28.2 ft)²(0.297)(1.00)](9.4 ft) + [(250 psf)(28.2 ft)(0.297)(1.00)](14.1 ft) = 162.73 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)(28.2 ft)(24.0 ft)(1.00) + (250 psf)(24.0 ft)(1.00) = 87.22 kip/ft

Settlement, Time Rate of Consolidation and Differential Settlement:

Boring	Station Along Wall 5B	Total Settlement at Center of Reinforced Soil Mass	Total Settlement at Wall Facing	Time for 90% Consolidation	Distance Along Wall Facing	Differential Settlement Along Wall Facing
B-070-0-19	17+70	2.567 in	1.763 in	155 days		
B-007-0-65	16+30	1.148 in	0.879 in	85 days	140 ft	1 in / 160 ft

FRA-70-20.85 FEF - Retaining Wall 5B - Sta. 15+85 to 17+96 (BL Wall 5B) - FRA-BRICE-04342 Forward Abutment
MSE Wall Settlement

Calculated By: PPM Date: 1/21/2022
Checked By: BRT Date: 11/23/2022

Boring B-070-0-19

H =	28.2	ft	Wall height
B =	24.0	ft	Width of wall
D_w =	10.0	ft	Depth below bottom of wall
γ_{BF} =	120	pcf	Unit weight of backfill
q =	3,384	psf	Bearing pressure at bottom of wall

																					Total Settlement at Center of Reinforced Soil Mass					Total Settlement at Facing of Wall				
Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Elevation (ft. msl)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' (1) (psf)	LL	C_c (2)	C_r (3)	e_o (4)	N_{60}	$(N1)_{60}$ (5)	C' (6)	Z_f/B	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	S_c (9,10) (ft)	S_c (in)	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	S_c (9,10) (ft)	S_c (in)
1	A-4a	C	0.0	3.7	793.8	790.1	3.7	1.9	120	444	222	222	3,222	25	0.135	0.014	0.467				0.08	0.998	3,379	3,601	0.056	0.672	0.500	1,692	1,914	0.032	0.382
	A-4a	C	3.7	7.7	790.1	786.1	4.0	5.7	120	924	684	684	3,684	25	0.135	0.014	0.467				0.24	0.964	3,264	3,948	0.038	0.455	0.497	1,683	2,367	0.020	0.238
2	A-2-4	G	7.7	10.2	786.1	783.6	2.5	9.0	125	1,237	1,080	1,080	4,080					24	29	96	0.37	0.897	3,036	4,116	0.015	0.181	0.491	1,660	2,740	0.011	0.126
3	A-2-6	G	10.2	14.2	783.6	779.6	4.0	12.2	125	1,737	1,487	1,349	4,349					24	27	91	0.51	0.813	2,751	4,100	0.021	0.254	0.479	1,621	2,970	0.015	0.180
	A-2-6	G	14.2	18.2	779.6	775.6	4.0	16.2	125	2,237	1,987	1,600	4,600					24	26	88	0.68	0.710	2,404	4,004	0.018	0.218	0.459	1,552	3,152	0.013	0.161
4	A-3a	G	18.2	20.2	775.6	773.6	2.0	19.2	125	2,487	2,362	1,787	4,787					24	25	76	0.80	0.642	2,172	3,959	0.009	0.109	0.440	1,491	3,278	0.007	0.083
5	A-1-a	G	20.2	25.2	773.6	768.6	5.0	22.7	135	3,162	2,824	2,032	5,032					50	50	169	0.95	0.573	1,938	3,969	0.009	0.104	0.418	1,414	3,445	0.007	0.082
6	A-4a	C	25.2	34.2	768.6	759.6	9.0	29.7	125	4,287	3,724	2,495	5,495	22	0.108	0.011	0.444				1.24	0.466	1,576	4,070	0.014	0.172	0.372	1,259	3,753	0.012	0.143
	A-4a	C	34.2	44.2	759.6	749.6	10.0	39.2	125	5,537	4,912	3,089	6,089	22	0.108	0.011	0.444				1.63	0.367	1,243	4,332	0.011	0.132	0.317	1,071	4,161	0.010	0.116
7	A-4a	C	44.2	51.7	749.6	742.1	7.5	48.0	130	6,512	6,024	3,656	6,656	23	0.117	0.012	0.452				2.00	0.306	1,036	4,692	0.007	0.079	0.275	931	4,587	0.006	0.071
	A-4a	C	51.7	59.2	742.1	734.6	7.5	55.5	130	7,487	6,999	4,163	7,163	23	0.117	0.012	0.452				2.31	0.267	905	5,067	0.005	0.062	0.246	833	4,996	0.005	0.057
8	A-4a	C	59.2	64.2	734.6	729.6	5.0	61.7	125	8,112	7,799	4,573	7,573	24	0.126	0.013	0.460				2.57	0.242	818	5,390	0.003	0.037	0.226	764	5,336	0.003	0.035
9	A-6b	C	64.2	72.2	729.6	721.6	8.0	68.2	125	9,112	8,612	4,980	7,980	38	0.252	0.025	0.569				2.84	0.220	743	5,723	0.008	0.093	0.207	702	5,682	0.007	0.088
																							Total Settlement:			2.567 in		Total Settlement:			1.763 in

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

FRA-70-20.85 FEF - Retaining Wall 5B - Sta. 15+85 to 17+96 (BL Wall 5B) - FRA-BRICE-04342 Forward Abutment
MSE Wall Settlement

Calculated By: PPM Date: 1/21/2022
Checked By: BRT Date: 11/23/2022

Boring B-070-0-19

H = 28.2 ft Wall height
B = 24.0 ft Width of wall
D_w = 10.0 ft Depth below bottom of wall
γ_{BF} = 120 Unit weight of backfill
q = 3,384 psf Bearing pressure at bottom of wall

t = 0 days Time following completion of construction

																									Total Settlement at Facing of Wall			Settlement Complete at 36% of Primary Consolidation					
Layer	Soil Class.	Soil Type	Layer Depth (ft)		Elevation (ft msl)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	$\sigma_p'^{(1)}$ (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)	c_v (ft^2/yr)	H_{dr} (ft)	T_v	U (%)	$(S_c)_t^{(11)}$ (in)	Layer Settlement (in)
1	A-4a	C	0.0	3.7	793.8	790.1	3.7	1.9	120	444	222	222	3,222	25	0.135	0.014	0.467				0.08	0.500	1,692	1,914	0.032	0.382	0.620	400	3.7	0.000	0	0.000	0.000
	A-4a	C	3.7	7.7	790.1	786.1	4.0	5.7	120	924	684	684	3,684	25	0.135	0.014	0.467				0.24	0.497	1,683	2,367	0.020	0.238		400	3.9	0.000	0	0.000	
2	A-2-4	G	7.7	10.2	786.1	783.6	2.5	9.0	125	1,237	1,080	1,080	4,080					24	29	96	0.37	0.491	1,660	2,740	0.011	0.126	0.126				100	0.126	0.126
3	A-2-6	G	10.2	14.2	783.6	779.6	4.0	12.2	125	1,737	1,487	1,349	4,349					24	27	91	0.51	0.479	1,621	2,970	0.015	0.180	0.341				100	0.180	0.341
	A-2-6	G	14.2	18.2	779.6	775.6	4.0	16.2	125	2,237	1,987	1,600	4,600					24	26	88	0.68	0.459	1,552	3,152	0.013	0.161					100	0.161	
4	A-3a	G	18.2	20.2	775.6	773.6	2.0	19.2	125	2,487	2,362	1,787	4,787					24	25	76	0.80	0.440	1,491	3,278	0.007	0.083	0.083				100	0.083	0.083
5	A-1-a	G	20.2	25.2	773.6	768.6	5.0	22.7	135	3,162	2,824	2,032	5,032					50	50	169	0.95	0.418	1,414	3,445	0.007	0.082	0.082				100	0.082	0.082
6	A-4a	C	25.2	34.2	768.6	759.6	9.0	29.7	125	4,287	3,724	2,495	5,495	22	0.108	0.011	0.444				1.24	0.372	1,259	3,753	0.012	0.143	0.259	400	9.0	0.000	0	0.000	0.000
	A-4a	C	34.2	44.2	759.6	749.6	10.0	39.2	125	5,537	4,912	3,089	6,089	22	0.108	0.011	0.444				1.63	0.317	1,071	4,161	0.010	0.116		400	19.0	0.000	0	0.000	
7	A-4a	C	44.2	51.7	749.6	742.1	7.5	48.0	130	6,512	6,024	3,656	6,656	23	0.117	0.012	0.452				2.00	0.275	931	4,587	0.006	0.071	0.129	400	26.5	0.000	0	0.000	0.000
	A-4a	C	51.7	59.2	742.1	734.6	7.5	55.5	130	7,487	6,999	4,163	7,163	23	0.117	0.012	0.452				2.31	0.246	833	4,996	0.005	0.057		400	34.0	0.000	0	0.000	
8	A-4a	C	59.2	64.2	734.6	729.6	5.0	61.7	125	8,112	7,799	4,573	7,573	24	0.126	0.013	0.460				2.57	0.226	764	5,336	0.003	0.035	0.035	400	39.0	0.000	0	0.000	0.000
9	A-6b	C	64.2	72.2	729.6	721.6	8.0	68.2	125	9,112	8,612	4,980	7,980	38	0.252	0.025	0.569				2.84	0.207	702	5,682	0.007	0.088	0.088	200	47.0	0.000	0	0.000	0.000

$(S_c)_t$ = 0.632 in

Settlement Remaining After Hold Period: 1.132 in

1. $\sigma_p' = \sigma_{vo}'+\sigma_{m;}$ Estimate σ_m of 3,000 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. $C_r = 0.10(C_c)$; Ref. Chapter 8.11, Holtz and Kovacs 1981
4. $e_o = (C_c/0.54)+0.35$; Ref. Table 6-11, FHWA GEC 5
5. $(N1)_{60} = C_nN_{60}$, 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; $I = [\beta+\sin(\beta)\cos(\beta+2\delta)]/\pi$, where $\beta = \tan^{-1}[(x+B/2)/Z_f]-\delta$, $\delta = \tan^{-1}[(x-B/2)/Z_f]$ and x = horizontal distance from center of footing; Ref. Figure 6.13 and Equation 6.24, Das 2005
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesive soil layers)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
11. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0

FRA-70-20.85 FEF - Retaining Wall 5B - Sta. 15+85 to 17+96 (BL Wall 5B) - FRA-BRICE-04342 Forward Abutment
MSE Wall Settlement

Calculated By: PPM Date: 1/21/2022
Checked By: BRT Date: 11/23/2022

Boring B-070-0-19

H = 28.2 ft Wall height
B = 24.0 ft Width of wall
D_w = 10.0 ft Depth below bottom of wall
γ_{BF} = 120 Unit weight of backfill
q = 3,384 psf Bearing pressure at bottom of wall

t = 30 days Time following completion of construction

																									Total Settlement at Facing of Wall			Settlement Complete at 81% of Primary Consolidation					
Layer	Soil Class.	Soil Type	Layer Depth (ft)		Elevation (ft msl)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' (1) (psf)	LL	C_c (2)	C_r (3)	e_o (4)	N_{60}	$(N1)_{60}$ (5)	C' (6)	Z_f/B	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	S_c (9,10) (ft)	S_c (in)	Layer Settlement (in)	c_v (ft^2/yr)	H_{dr} (ft)	T_v	U (%)	$(S_c)_t$ (11) (in)	Layer Settlement (in)
1	A-4a	C	0.0	3.7	793.8	790.1	3.7	1.9	120	444	222	222	3,222	25	0.135	0.014	0.467				0.08	0.500	1,692	1,914	0.032	0.382	0.620	400	3.7	2.402	100	0.382	0.620
	A-4a	C	3.7	7.7	790.1	786.1	4.0	5.7	120	924	684	684	3,684	25	0.135	0.014	0.467				0.24	0.497	1,683	2,367	0.020	0.238		400	3.9	2.218	100	0.238	
2	A-2-4	G	7.7	10.2	786.1	783.6	2.5	9.0	125	1,237	1,080	1,080	4,080					24	29	96	0.37	0.491	1,660	2,740	0.011	0.126	0.126				100	0.126	0.126
3	A-2-6	G	10.2	14.2	783.6	779.6	4.0	12.2	125	1,737	1,487	1,349	4,349					24	27	91	0.51	0.479	1,621	2,970	0.015	0.180	0.341				100	0.180	0.341
	A-2-6	G	14.2	18.2	779.6	775.6	4.0	16.2	125	2,237	1,987	1,600	4,600					24	26	88	0.68	0.459	1,552	3,152	0.013	0.161					100	0.161	
4	A-3a	G	18.2	20.2	775.6	773.6	2.0	19.2	125	2,487	2,362	1,787	4,787					24	25	76	0.80	0.440	1,491	3,278	0.007	0.083	0.083				100	0.083	0.083
5	A-1-a	G	20.2	25.2	773.6	768.6	5.0	22.7	135	3,162	2,824	2,032	5,032					50	50	169	0.95	0.418	1,414	3,445	0.007	0.082	0.082				100	0.082	0.082
6	A-4a	C	25.2	34.2	768.6	759.6	9.0	29.7	125	4,287	3,724	2,495	5,495	22	0.108	0.011	0.444				1.24	0.372	1,259	3,753	0.012	0.143	0.259	400	9.0	0.406	70	0.100	0.140
	A-4a	C	34.2	44.2	759.6	749.6	10.0	39.2	125	5,537	4,912	3,089	6,089	22	0.108	0.011	0.444				1.63	0.317	1,071	4,161	0.010	0.116		400	19.0	0.091	34	0.039	
7	A-4a	C	44.2	51.7	749.6	742.1	7.5	48.0	130	6,512	6,024	3,656	6,656	23	0.117	0.012	0.452				2.00	0.275	931	4,587	0.006	0.071	0.129	400	26.5	0.047	24	0.017	0.028
	A-4a	C	51.7	59.2	742.1	734.6	7.5	55.5	130	7,487	6,999	4,163	7,163	23	0.117	0.012	0.452				2.31	0.246	833	4,996	0.005	0.057		400	34.0	0.028	19	0.011	
8	A-4a	C	59.2	64.2	734.6	729.6	5.0	61.7	125	8,112	7,799	4,573	7,573	24	0.126	0.013	0.460				2.57	0.226	764	5,336	0.003	0.035	0.035	400	39.0	0.022	17	0.006	0.006
9	A-6b	C	64.2	72.2	729.6	721.6	8.0	68.2	125	9,112	8,612	4,980	7,980	38	0.252	0.025	0.569				2.84	0.207	702	5,682	0.007	0.088	0.088	200	47.0	0.007	10	0.009	0.009

$(S_c)_t$ = 1.435 in

Settlement Remaining After Hold Period: 0.329 in

1. $\sigma_p' = \sigma_{vo}'+\sigma_{m;}$ Estimate σ_m of 3,000 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. $C_r = 0.10(C_c)$; Ref. Chapter 8.11, Holtz and Kovacs 1981
4. $e_o = (C_c/0.54)+0.35$; Ref. Table 6-11, FHWA GEC 5
5. $(N1)_{60} = C_nN_{60}$, 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; $I = [\beta+\sin(\beta)\cos(\beta+2\delta)]/\pi$, where $\beta = \tan^{-1}[(x+B/2)/Z_f]-\delta$, $\delta = \tan^{-1}[(x-B/2)/Z_f]$ and x = horizontal distance from center of footing; Ref. Figure 6.13 and Equation 6.24, Das 2005
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesive soil layers)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
11. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0

FRA-70-20.85 FEF - Retaining Wall 5B - Sta. 15+85 to 17+96 (BL Wall 5B) - FRA-BRICE-04342 Forward Abutment

MSE Wall Settlement

Calculated By: PPM Date: 1/21/2022

Checked By: BRT Date: 11/23/2022

Boring B-070-0-19

H = 28.2 ft Wall height

B = 24.0 ft Width of wall

D_w = 10.0 ft Depth below bottom of wall

γ_{BF} = 120 Unit weight of backfill

q = 3,384 psf Bearing pressure at bottom of wall

t = 155 days Time following completion of construction

																								Total Settlement at Facing of Wall			Settlement Complete at 90% of Primary Consolidation					
Layer	**Soil Class.**	**Soil Type**	**Layer Depth (ft)**		**Elevation (ft msl)**		**Layer Thickness H (ft)**	**Depth to Midpoint (ft)**	**γ (pcf)**	**σ_{vo} Bottom (psf)**	**σ_{vo} Midpoint (psf)**	**σ_{vo}' Midpoint (psf)**	**σ_p' (1) (psf)**	**LL**	**C_c (2)**	**C_r (3)**	**e_o (4)**	**N_{60}**	**$(N1)_{60}$ (5)**	**C' (6)**	**Z_f/B**	**I (7)**	**$\Delta\sigma_v$ (8) (psf)**	**σ_{vf}' Midpoint (psf)**	**S_c (9,10) (ft)**	**S_c (in)**	**Layer Settlement (in)**	**c_v (ft^2/yr)**	**H_{dr} (ft)**	**T_v**	**U (%)**	**$(S_c)_t$ (11) (in)**	**Layer Settlement (in)**
1	A-4a	C	0.0	3.7	793.8	790.1	3.7	1.9	120	444	222	222	3,222	25	0.135	0.014	0.467				0.08	0.500	1,692	1,914	0.032	0.382	0.620	400	3.7	12.408	100	0.382	0.620
	A-4a	C	3.7	7.7	790.1	786.1	4.0	5.7	120	924	684	684	3,684	25	0.135	0.014	0.467				0.24	0.497	1,683	2,367	0.020	0.238		400	3.9	11.460	100	0.238	
2	A-2-4	G	7.7	10.2	786.1	783.6	2.5	9.0	125	1,237	1,080	1,080	4,080					24	29	96	0.37	0.491	1,660	2,740	0.011	0.126	0.126				100	0.126	0.126
3	A-2-6	G	10.2	14.2	783.6	779.6	4.0	12.2	125	1,737	1,487	1,349	4,349					24	27	91	0.51	0.479	1,621	2,970	0.015	0.180	0.341				100	0.180	0.341
	A-2-6	G	14.2	18.2	779.6	775.6	4.0	16.2	125	2,237	1,987	1,600	4,600					24	26	88	0.68	0.459	1,552	3,152	0.013	0.161					100	0.161	
4	A-3a	G	18.2	20.2	775.6	773.6	2.0	19.2	125	2,487	2,362	1,787	4,787					24	25	76	0.80	0.440	1,491	3,278	0.007	0.083	0.083				100	0.083	0.083
5	A-1-a	G	20.2	25.2	773.6	768.6	5.0	22.7	135	3,162	2,824	2,032	5,032					50	50	169	0.95	0.418	1,414	3,445	0.007	0.082	0.082				100	0.082	0.082
6	A-4a	C	25.2	34.2	768.6	759.6	9.0	29.7	125	4,287	3,724	2,495	5,495	22	0.108	0.011	0.444				1.24	0.372	1,259	3,753	0.012	0.143	0.259	400	9.0	2.097	100	0.143	0.230
	A-4a	C	34.2	44.2	759.6	749.6	10.0	39.2	125	5,537	4,912	3,089	6,089	22	0.108	0.011	0.444				1.63	0.317	1,071	4,161	0.010	0.116		400	19.0	0.471	75	0.087	
7	A-4a	C	44.2	51.7	749.6	742.1	7.5	48.0	130	6,512	6,024	3,656	6,656	23	0.117	0.012	0.452				2.00	0.275	931	4,587	0.006	0.071	0.129	400	26.5	0.242	55	0.039	0.064
	A-4a	C	51.7	59.2	742.1	734.6	7.5	55.5	130	7,487	6,999	4,163	7,163	23	0.117	0.012	0.452				2.31	0.246	833	4,996	0.005	0.057		400	34.0	0.147	43	0.025	
8	A-4a	C	59.2	64.2	734.6	729.6	5.0	61.7	125	8,112	7,799	4,573	7,573	24	0.126	0.013	0.460				2.57	0.226	764	5,336	0.003	0.035	0.035	400	39.0	0.112	38	0.013	0.013
9	A-6b	C	64.2	72.2	729.6	721.6	8.0	68.2	125	9,112	8,612	4,980	7,980	38	0.252	0.025	0.569				2.84	0.207	702	5,682	0.007	0.088	0.088	200	47.0	0.038	22	0.019	0.019

$(S_c)_t$ = 1.579 in

Settlement Remaining After Hold Period: 0.184 in

1. $\sigma_p' = \sigma_{vo}'+\sigma_{m;}$ Estimate σ_m of 3,000 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. $C_r = 0.10(C_c)$; Ref. Chapter 8.11, Holtz and Kovacs 1981
4. $e_o = (C_c/0.54)+0.35$; Ref. Table 6-11, FHWA GEC 5
5. $(N1)_{60} = C_nN_{60}$, 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; $I = [\beta+\sin(\beta)\cos(\beta+2\delta)]/\pi$, where $\beta = \tan^{-1}[(x+B/2)/Z_f]-\delta$, $\delta = \tan^{-1}[(x-B/2)/Z_f]$ and x = horizontal distance from center of footing; Ref. Figure 6.13 and Equation 6.24, Das 2005
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesive soil layers)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
11. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0

FRA-70-20.85 FEF - Retaining Wall 5B - Sta. 15+85 to 17+96 (BL Wall 5B) - FRA-BRICE-04342 Forward Abutment
MSE Wall Settlement

Calculated By: PPM Date: 1/21/2022
Checked By: BRT Date: 11/23/2022

Boring B-007-0-65

H = 28.2 ft Wall height
B = 24.0 ft Width of wall
D_w = 10.0 ft Depth below bottom of wall
γ_{BF} = 120 pcf Unit weight of backfill
q = 3,384 psf Bearing pressure at bottom of wall

																						Total Settlement at Center of Reinforced Soil Mass					Total Settlement at Facing of Wall				
Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Elevation (ft. msl)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' (1) (psf)	LL	C_c (2)	C_r (3)	e_o (4)	N_{60}	$(N1)_{60}$ (5)	C' (6)	Z_f/B	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	S_c (9,10) (ft)	S_c (in)	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	S_c (9,10) (ft)	S_c (in)
1	A-2-4	G	0.0	3.4	793.8	790.4	3.4	1.7	130	442	221	221	3,221					43	75	295	0.07	0.999	3,380	3,601	0.014	0.167	0.500	1,692	1,913	0.011	0.129
	A-2-4	G	3.4	6.9	790.4	786.9	3.5	5.2	130	897	670	670	3,670					43	59	209	0.21	0.973	3,291	3,961	0.013	0.155	0.498	1,685	2,355	0.009	0.110
2	A-1-a	G	6.9	9.4	786.9	784.4	2.5	8.2	130	1,222	1,060	1,060	4,060					31	38	122	0.34	0.916	3,100	4,160	0.012	0.145	0.493	1,667	2,727	0.008	0.101
3	A-1-a	G	9.4	14.4	784.4	779.4	5.0	11.9	135	1,897	1,560	1,441	4,441					71	79	300	0.50	0.821	2,778	4,219	0.008	0.093	0.480	1,625	3,066	0.005	0.066
	A-1-a	G	14.4	19.4	779.4	774.4	5.0	16.9	135	2,572	2,235	1,804	4,804					71	74	288	0.70	0.694	2,347	4,151	0.006	0.075	0.455	1,538	3,342	0.005	0.056
4	A-6b	C	19.4	24.9	774.4	768.9	5.5	22.2	125	3,260	2,916	2,158	5,158	32	0.198	0.020	0.522				0.92	0.583	1,972	4,129	0.020	0.242	0.421	1,426	3,584	0.016	0.189
5	A-4a	C	24.9	28.4	768.9	765.4	3.5	26.7	125	3,697	3,478	2,439	5,439	22	0.108	0.011	0.444				1.11	0.508	1,718	4,157	0.006	0.073	0.392	1,325	3,765	0.005	0.059
6	A-4a	C	28.4	33.4	765.4	760.4	5.0	30.9	130	4,347	4,022	2,718	5,718	22	0.108	0.011	0.444				1.29	0.451	1,525	4,243	0.007	0.087	0.364	1,233	3,951	0.006	0.073
	A-4a	C	33.4	38.4	760.4	755.4	5.0	35.9	130	4,997	4,672	3,056	6,056	22	0.108	0.011	0.444				1.50	0.397	1,343	4,399	0.006	0.071	0.335	1,132	4,188	0.005	0.061
7	A-4a	C	38.4	41.4	755.4	752.4	3.0	39.9	125	5,372	5,185	3,319	6,319	23	0.117	0.012	0.452				1.66	0.362	1,224	4,542	0.003	0.040	0.313	1,059	4,378	0.003	0.035
																						Total Settlement:			1.148 in		Total Settlement:			0.879 in	

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

FRA-70-20.85 FEF - Retaining Wall 5B - Sta. 15+85 to 17+96 (BL Wall 5B) - FRA-BRICE-04342 Forward Abutment
MSE Wall Settlement

Calculated By: PPM Date: 1/21/2022
Checked By: BRT Date: 11/23/2022

Boring B-007-0-65

H =	28.2	ft	Wall height
B =	24.0	ft	Width of wall
D_w =	10.0	ft	Depth below bottom of wall
γ_{BF} =	120		Unit weight of backfill
q =	3,384	psf	Bearing pressure at bottom of wall

t = 0 days Time following completion of construction

																							Total Settlement at Facing of Wall			Settlement Complete at 52% of Primary Consolidation					
Layer	Soil Class.	Soil Type	Layer Depth (ft)		Elevation (ft msl)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' (1) (psf)	LL	C_c (2)	C_r (3)	e_o (4)	N_{60}	$(N1)_{60}$ (5)	C' (6)	Z_f/B	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	S_c (9,10) (ft)	S_c (in)	Layer Settlement (in)	c_v (ft^2/yr)	H_{dr} (ft)	T_v	U (%)	$(S_c)_t$ (11) (in)	Layer Settlement (in)
1	A-2-4	G	0.0	3.4	793.8	790.4	3.4	1.7	130	442	221	221	3,221					43	75	295	0.07	0.500	1,692	1,913	0.011	0.129	0.239				100	0.129	0.239
	A-2-4	G	3.4	6.9	790.4	786.9	3.5	5.2	130	897	670	670	3,670					43	59	209	0.21	0.498	1,685	2,355	0.009	0.110					100	0.110	
2	A-1-a	G	6.9	9.4	786.9	784.4	2.5	8.2	130	1,222	1,060	1,060	4,060					31	38	122	0.34	0.493	1,667	2,727	0.008	0.101	0.101				100	0.101	0.101
3	A-1-a	G	9.4	14.4	784.4	779.4	5.0	11.9	135	1,897	1,560	1,441	4,441					71	79	300	0.50	0.480	1,625	3,066	0.005	0.066	0.121				100	0.066	0.121
	A-1-a	G	14.4	19.4	779.4	774.4	5.0	16.9	135	2,572	2,235	1,804	4,804					71	74	288	0.70	0.455	1,538	3,342	0.005	0.056					100	0.056	
4	A-6b	C	19.4	24.9	774.4	768.9	5.5	22.2	125	3,260	2,916	2,158	5,158	32	0.198	0.020	0.522				0.92	0.421	1,426	3,584	0.016	0.189	0.189	100	5.5	0.000	0	0.000	0.000
5	A-4a	C	24.9	28.4	768.9	765.4	3.5	26.7	125	3,697	3,478	2,439	5,439	22	0.108	0.011	0.444				1.11	0.392	1,325	3,765	0.005	0.059	0.059	400	9.0	0.000	0	0.000	0.000
6	A-4a	C	28.4	33.4	765.4	760.4	5.0	30.9	130	4,347	4,022	2,718	5,718	22	0.108	0.011	0.444				1.29	0.364	1,233	3,951	0.006	0.073	0.134	400	14.0	0.000	0	0.000	0.000
	A-4a	C	33.4	38.4	760.4	755.4	5.0	35.9	130	4,997	4,672	3,056	6,056	22	0.108	0.011	0.444				1.50	0.335	1,132	4,188	0.005	0.061		400	19.0	0.000	0	0.000	
7	A-4a	C	38.4	41.4	755.4	752.4	3.0	39.9	125	5,372	5,185	3,319	6,319	23	0.117	0.012	0.452				1.66	0.313	1,059	4,378	0.003	0.035	0.035	400	22.0	0.000	0	0.000	0.000

$(S_c)_t$ = 0.461 in

Settlement Remaining After Hold Period: 0.418 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. Chapter 8.11, Holtz and Kovacs 1981
4. $e_o = (C_c/0.54)+0.35$; Ref. Table 6-11, FHWA GEC 5
5. $(N1)_{60} = C_nN_{60}$, 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; $I = [\beta+\sin(\beta)\cos(\beta+2\delta)]/\pi$, where $\beta = \tan^{-1}[(x+B/2)/Z_f]-\delta$, $\delta = \tan^{-1}[(x-B/2)/Z_f]$ and x = horizontal distance from center of footing; Ref. Figure 6.13 and Equation 6.24, Das 2005
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesive soil layers)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
11. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0

FRA-70-20.85 FEF - Retaining Wall 5B - Sta. 15+85 to 17+96 (BL Wall 5B) - FRA-BRICE-04342 Forward Abutment
MSE Wall Settlement

Calculated By: PPM Date: 1/21/2022
Checked By: BRT Date: 11/23/2022

Boring B-007-0-65

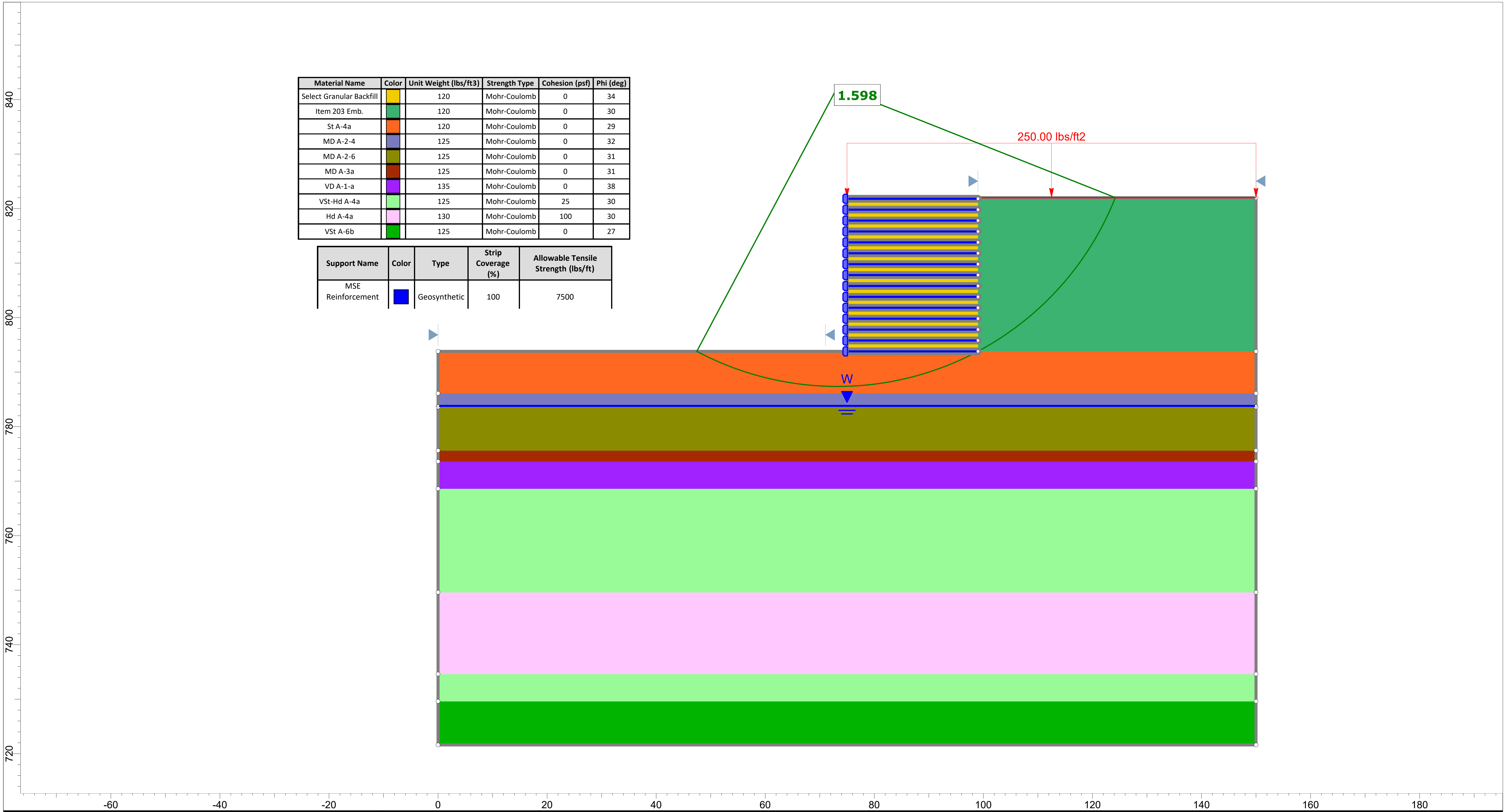
H =	28.2	ft	Wall height
B =	24.0	ft	Width of wall
D_w =	10.0	ft	Depth below bottom of wall
γ_{BF} =	120		Unit weight of backfill
q =	3,384	psf	Bearing pressure at bottom of wall
t =	85	days	Time following completion of construction

																									Total Settlement at Facing of Wall			Settlement Complete at 90% of Primary Consolidation					
Layer	Soil Class.	Soil Type	Layer Depth (ft)		Elevation (ft msl)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' (1) (psf)	LL	C_c (2)	C_r (3)	e_o (4)	N_{60}	$(N1)_{60}$ (5)	C' (6)	Z_f/B	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	S_c (9,10) (ft)	S_c (in)	Layer Settlement (in)	c_v (ft^2/yr)	H_{dr} (ft)	T_v	U (%)	$(S_c)_t$ (11) (in)	Layer Settlement (in)
1	A-2-4	G	0.0	3.4	793.8	790.4	3.4	1.7	130	442	221	221	3,221					43	75	295	0.07	0.500	1,692	1,913	0.011	0.129	0.239				100	0.129	0.239
	A-2-4	G	3.4	6.9	790.4	786.9	3.5	5.2	130	897	670	670	3,670					43	59	209	0.21	0.498	1,685	2,355	0.009	0.110					100	0.110	
2	A-1-a	G	6.9	9.4	786.9	784.4	2.5	8.2	130	1,222	1,060	1,060	4,060					31	38	122	0.34	0.493	1,667	2,727	0.008	0.101	0.101				100	0.101	0.101
3	A-1-a	G	9.4	14.4	784.4	779.4	5.0	11.9	135	1,897	1,560	1,441	4,441					71	79	300	0.50	0.480	1,625	3,066	0.005	0.066	0.121				100	0.066	0.121
	A-1-a	G	14.4	19.4	779.4	774.4	5.0	16.9	135	2,572	2,235	1,804	4,804					71	74	288	0.70	0.455	1,538	3,342	0.005	0.056					100	0.056	
4	A-6b	C	19.4	24.9	774.4	768.9	5.5	22.2	125	3,260	2,916	2,158	5,158	32	0.198	0.020	0.522				0.92	0.421	1,426	3,584	0.016	0.189	0.189	100	5.5	0.770	88	0.166	0.166
5	A-4a	C	24.9	28.4	768.9	765.4	3.5	26.7	125	3,697	3,478	2,439	5,439	22	0.108	0.011	0.444				1.11	0.392	1,325	3,765	0.005	0.059	0.059	400	9.0	1.150	95	0.056	0.056
6	A-4a	C	28.4	33.4	765.4	760.4	5.0	30.9	130	4,347	4,022	2,718	5,718	22	0.108	0.011	0.444				1.29	0.364	1,233	3,951	0.006	0.073	0.134	400	14.0	0.475	75	0.055	0.090
	A-4a	C	33.4	38.4	760.4	755.4	5.0	35.9	130	4,997	4,672	3,056	6,056	22	0.108	0.011	0.444				1.50	0.335	1,132	4,188	0.005	0.061		400	19.0	0.258	57	0.035	
7	A-4a	C	38.4	41.4	755.4	752.4	3.0	39.9	125	5,372	5,185	3,319	6,319	23	0.117	0.012	0.452				1.66	0.313	1,059	4,378	0.003	0.035	0.035	400	22.0	0.192	50	0.017	0.017

$(S_c)_t$ = 0.791 in

Settlement Remaining After Hold Period: 0.088 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. Chapter 8.11, Holtz and Kovacs 1981
4. $e_o = (C_c/0.54)+0.35$; Ref. Table 6-11, FHWA GEC 5
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; $I = [\beta+\sin(\beta)\cos(\beta+2\delta)]/\pi$, where $\beta = \tan^{-1}[(x+B/2)/Z_f]-\delta$, $\delta = \tan^{-1}[(x-B/2)/Z_f]$ and x = horizontal distance from center of footing; Ref. Figure 6.13 and Equation 6.24, Das 2005
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesive soil layers)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
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 Backfill	🟨	120	Mohr-Coulomb	0	34
Item 203 Emb.	🟩	120	Mohr-Coulomb	0	30
St A-4a	🟧	120	Mohr-Coulomb	0	29
MD A-2-4	🟦	125	Mohr-Coulomb	0	32
MD A-2-6	🟫	125	Mohr-Coulomb	0	31
MD A-3a	🟥	125	Mohr-Coulomb	0	31
VD A-1-a	🟪	135	Mohr-Coulomb	0	38
VSt-Hd A-4a	🟩	125	Mohr-Coulomb	25	30
Hd A-4a	🟪	130	Mohr-Coulomb	100	30
VSt A-6b	🟩	125	Mohr-Coulomb	0	27

Support Name	Color	Type	Strip Coverage (%)	Allowable Tensile Strength (lbs/ft)
MSE Reinforcement	🟦	Geosynthetic	100	7500

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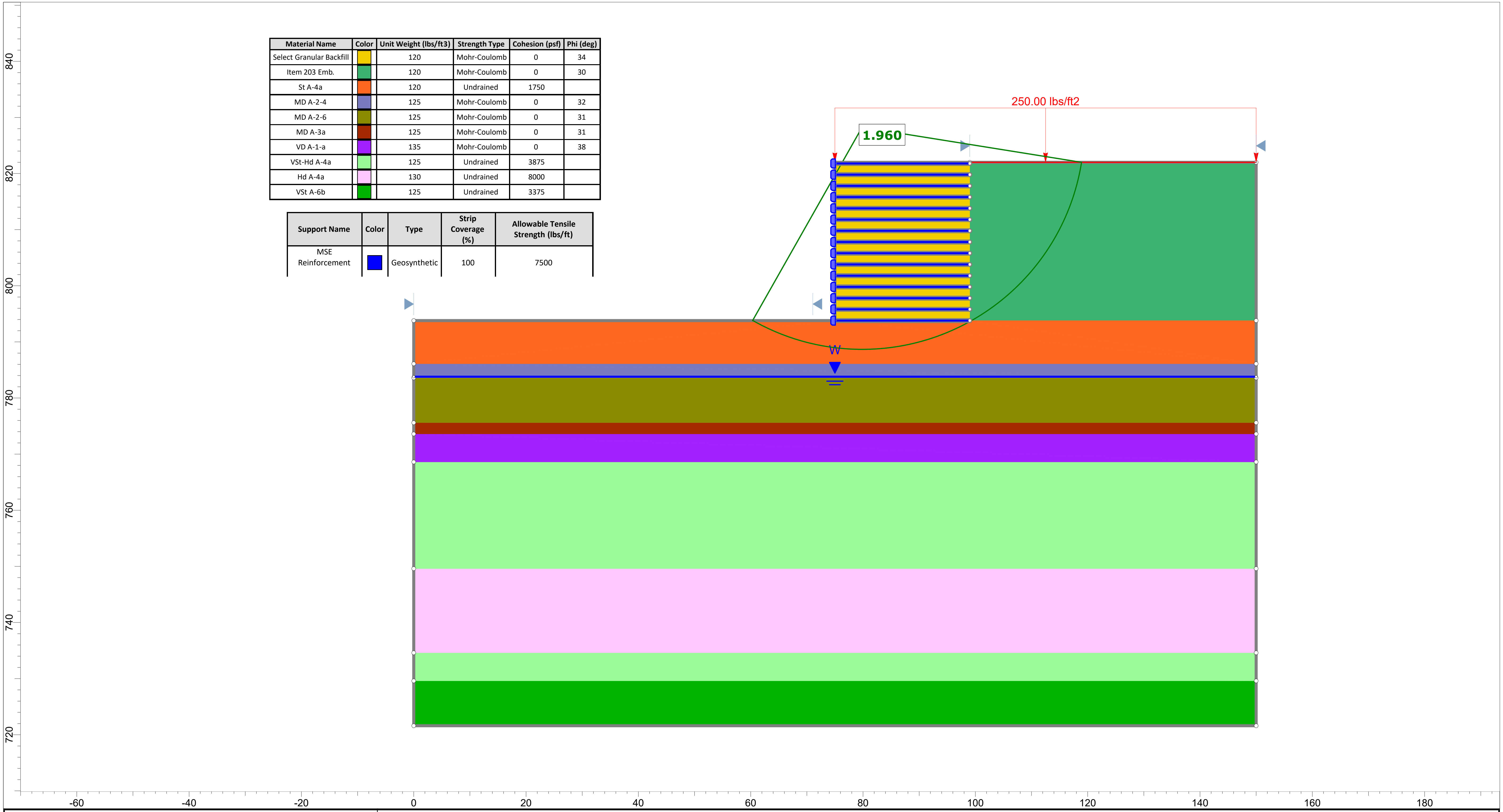
SLIDEINTERPRET 9.019

Project	FRA-70-22.85 FEF - Retaining Wall 5B - FRA-BRICE-04342 Forward Abutment
Analysis Description	Global Stability - Sta. 15+85 to 17+96 (BL Wall 5B) - B-070-0-19 and B-007-0-65 - Level Backfill - 28.2 ft. Wall Height - Drained - Circular
Drawn By	BRT
Scale	1:200
Company	Resource International, Inc.
Date	3/24/2022, 7:04:26 PM
File Name	Wall 5B - Bridge Section - Global Stability.slmd



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Select Granular Backfill	🟨	120	Mohr-Coulomb	0	34
Item 203 Emb.	🟩	120	Mohr-Coulomb	0	30
St A-4a	🟧	120	Undrained	1750	
MD A-2-4	🟪	125	Mohr-Coulomb	0	32
MD A-2-6	🟫	125	Mohr-Coulomb	0	31
MD A-3a	🟥	125	Mohr-Coulomb	0	31
VD A-1-a	🟪	135	Mohr-Coulomb	0	38
VSt-Hd A-4a	🟩	125	Undrained	3875	
Hd A-4a	🟪	130	Undrained	8000	
VSt A-6b	🟩	125	Undrained	3375	

Support Name	Color	Type	Strip Coverage (%)	Allowable Tensile Strength (lbs/ft)
MSE Reinforcement	🟦	Geosynthetic	100	7500

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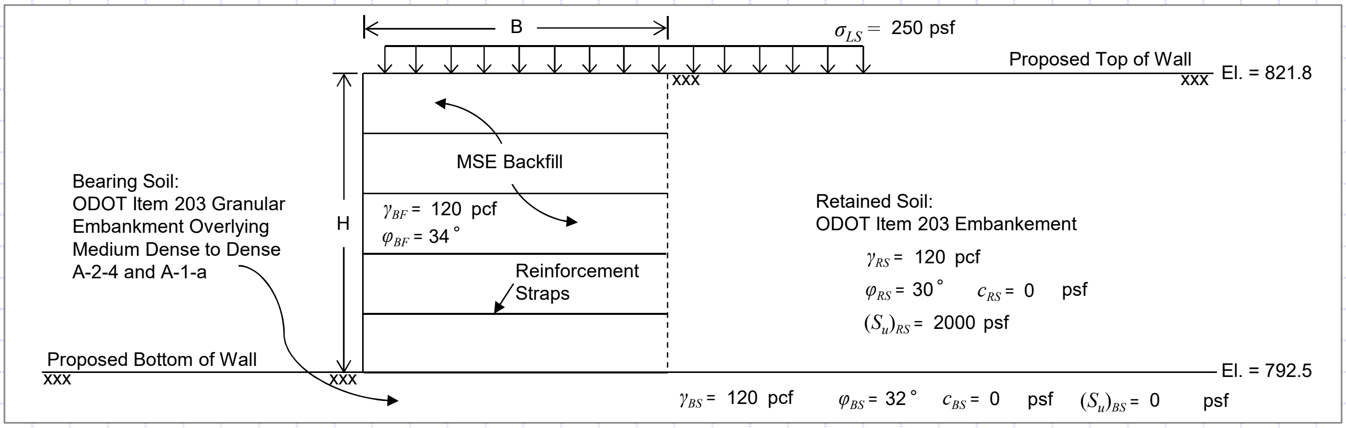
SLIDEINTERPRET 9.019

Project	FRA-70-22.85 FEF - Retaining Wall 5B - FRA-BRICE-04342 Forward Abutment		
Analysis Description	Global Stability - Sta. 15+85 to 17+96 (BL Wall 5B) - B-070-0-19 and B-007-0-65 - Level Backfill - 28.2 ft. Wall Height - Undrained - Circular		
Drawn By	BRT	*Scale*	1:194
Company	Resource International, Inc.		
Date	3/24/2022, 7:04:26 PM	*File Name*	Wall 5B - Bridge Section - Global Stability.slmd

JOB	FRA-70-22.85 FEF	NO.	W-17-140
SHEET NO.	1	OF	6
CALCULATED BY	PPM	DATE	1/21/2022
CHECKED BY	BRT	DATE	11/23/2022

Retaining Wall 6 - Sta. 10+00 to 12+55 (BL Wall 6)

Retaining Wall 6 - Sta. 10+00 to 12+55 (BL Wall 6) - FRA-BRICE-04342 Re. Abut. - B-067-1-19 and B-003-0-65 - Level Backfill - 29.3 ft. Wall Height



MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	29.3	ft
MSE Wall Width (Reinforcement Length), (B) =	20.5	ft
MSE Wall Length, (L) =	255	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion [1], (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties [1]:

	Bearing	Sliding	
Bearing Soil Unit Weight, (γ_{BS}) =	120	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	32	32	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	0	psf
Bearing Soil Undrained Shear Strength, [$(S_u)_{BS}$] =	0	0	psf
Embedment Depth, (D_f) =	3.0 ft		
Depth to Grounwater (Below Bot. of Wall), (D_W) =	18.5 ft		

LRFD Load Factors

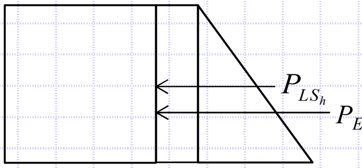
	EV	EH	LS	
Strength Ia	1.00	1.50	1.75	*(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)*
Strength Ib	1.35	1.50	1.75	
Service I	1.00	1.00	1.00	

1. Soil properties for bearing resistance based on critical soil type w/i 1.5B below the bottom of wall. Soil properties for sliding resistance based on soil type w/i 3.0 ft. below the bottom of wall.

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

Sliding Force: $P_H = P_{EH} + P_{LS_h}$

Sliding Force at Bottom of Wall (Top of Foundation Preparation):



$P_{EH} = ½\gamma_{RS} H^2 K_a \gamma_{EH}$ = ½(120 pcf)(29.3 ft)²(0.297)(1.5) = 22.95 kip/ft

$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS}$ = (250 psf)(29.3 ft)(0.297)(1.75) = 3.81 kip/ft

P_H = 22.95 kip/ft + 3.81 kip/ft = 26.76 kip/ft

Sliding Force at Bottom of Foundation Preparation:

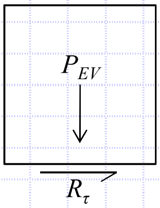
$P_{EH} = ½\gamma_{RS}(H+1)^2(K_a)(\gamma_{EH})$ = ½(120 pcf)(29.3 ft + 1 ft)²(0.297)(1.5) = 24.54 kip/ft

$P_{LS_h} = \sigma_{LS}(H+1)(K_a)(\gamma_{LS})$ = (250 psf)(29.3 ft + 1 ft)(0.297)(1.75) = 3.94 kip/ft

P_H = 24.54 kip/ft + 3.94 kip/ft = 28.48 kip/ft

Check Sliding Resistance - Drained Condition (At Bottom of Foundation Preparation, 1.0-foot Below Bottom of Wall)

Nominal Sliding Resistance: $R_\tau = P_{EV} \cdot \tan\delta$



$P_E = \gamma_{BF}(H+1)(B)(\gamma_{EV})$ = (120 pcf)(29.3 ft + 1 ft)(20.5 ft)(1.00) = 74.54 kip/ft

$\tan\delta = (\tan\varphi_{BS} \le \tan\varphi_{BF})$ ⟶ tan(32) ≤ tan(34) ⟶ 0.62 ≤ 0.67 = 0.62

R_τ = (74.54 kip/ft)(0.62) = 46.21 kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Drained Condition (Bottom of Foundation Preparation)

$P_H \le R_\tau \cdot \phi_\tau$ ⟶ 28.48 kip/ft ≤ (46.21 kip/ft)(1.0) = 46.21 kip/ft ⟶ 28.48 kip/ft ≤ 46.21 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) =	29.3	ft
MSE Wall Width (Reinforcement Length), (B) =	20.5	ft
MSE Wall Length, (L) =	255	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties [1]:

	Bearing	Sliding	
Bearing Soil Unit Weight, (γ_{BS}) =	120	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	32	32	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	0	0	psf
Embedment Depth, (D_f) =	3.0 ft		
Depth to Grounwater (Below Bot. of Wall), (D_W) =	18.5 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)

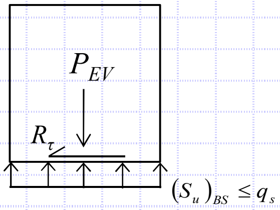
1. Soil properties for bearing resistance based on critical soil type w/i 1.5B below the bottom of wall. Soil properties for sliding resistance based on soil type w/i 3.0 ft. below the bottom of wall.

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

Check Sliding Resistance - Undrained Condition (At Bottom of Foundation Preparation, 1.0-foot Below Bottom of Wall)

Nominal Sliding Resisting:

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



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

$q_s = \sigma_v / 2$ = (3.64 ksf) / 2 = 1.82 ksf

$\sigma_v = P_{EV} / B$ = (74.54 kip/ft) / (20.5 ft) = 3.64 ksf

R_τ = (N/A ksf ≤ 1.82 ksf)(20.5 ft) = N/A kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition (Bottom of Foundation Preparation)

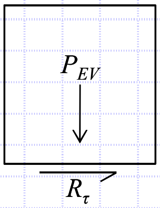
$P_H \le R_\tau \cdot \phi_\tau$ ⟶ N/A ⟶ N/A

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

Check Sliding Resistance - Drained Condition (At Bottom of Wall, Top of Foundation Preparation)

Nominal Sliding Resistance:

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



$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(29.3 ft)(20.5 ft)(1.00) = 72.08 kip/ft

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

$\tan\delta =$ tan(34) ≤ tan(34) ⟶ 0.67 ≤ 0.67 ⟶ $\tan\delta =$ 0.67

R_τ = (72.08 kip/ft)(0.67) = 48.29 kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Drained Condition (Bottom of Wall)

$P_H \le R_\tau \cdot \phi_\tau$ ⟶ 26.76 kip/ft ≤ (48.29 kip/ft)(1.0) = 48.29 kip/ft ⟶ 26.76 kip/ft ≤ 48.29 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) =	29.3	ft
MSE Wall Width (Reinforcement Length), (B) =	20.5	ft
MSE Wall Length, (L) =	255	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties [1]:

	Bearing	Sliding	
Bearing Soil Unit Weight, (γ_{BS}) =	120	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	32	32	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	0	0	psf
Embedment Depth, (D_f) =	3.0 ft		
Depth to Groundwater (Below Bot. of Wall), (D_W) =	18.5 ft		

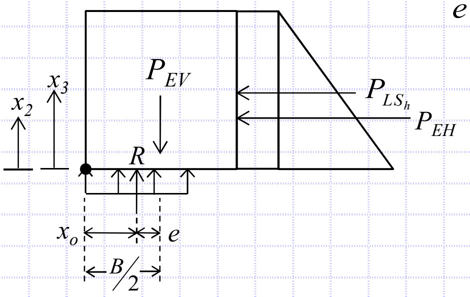
LRFD Load Factors

	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)

1. Soil properties for bearing resistance based on critical soil type w/i 1.5B below the bottom of wall. Soil properties for sliding resistance based on soil type w/i 3.0 ft. below the bottom of wall.

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



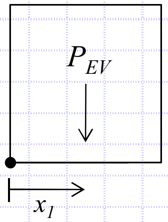
$$e = {}^{B}\!/_{2} - x_o$$

$$x_o = \frac{M_{EV} - M_H}{P_{EV}}$$ = (738.82 kip·ft/ft - 280.04 kip·ft/ft) / (72.08 kip/ft) = 6.36 ft

M_{EV} = 738.82 kip·ft/ft
M_H = 280.04 kip·ft/ft
P_{EV} = 72.08 kip/ft
Defined below

$e =$ (20.5 ft)/2 - 6.36 ft = 3.89 ft

Resisting Moment, M_{EV}:



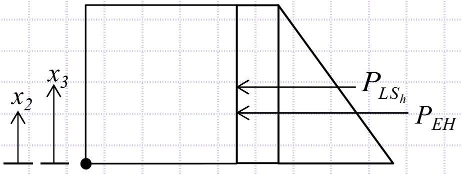
$$M_{EV} = P_{EV}(x_1)$$

$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(29.3 ft)(20.5 ft)(1.00) = 72.08 kip/ft

$x_1 = {}^{B}\!/_{2}$ = (20.5 ft) / 2 = 10.25 ft

$M_{EV} =$ (72.08 kip/ft)(10.25 ft) = 738.82 kip·ft/ft

Overturning Moment, M_H:



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

$P_{EH} = {}^{1}\!/_{2}\,\gamma_{RS} H^2 K_a \gamma_{EH}$ = ½(120 pcf)(29.3 ft)²(0.297)(1.5) = 22.95 kip/ft

$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS}$ = (250 psf)(29.3 ft)(0.297)(1.75) = 3.81 kip/ft

$x_2 = {}^{H}\!/_{3}$ = (29.3 ft) / 3 = 9.77 ft

$x_3 = {}^{H}\!/_{2}$ = (29.3 ft) / 2 = 14.65 ft

$M_H =$ (22.95 kip/ft)(9.77 ft) + (3.81 kip/ft)(14.65 ft) = 280.04 kip·ft/ft

Check Eccentricity

$e < e_{\max} \longrightarrow$ 3.89 ft < 6.83 ft **OK**

Limiting Eccentricity: $e_{\max} = {}^{B}\!/_{3} \longrightarrow e_{\max} =$ (20.5 ft) / 3 = 6.83 ft

JOB	FRA-70-22.85 FEF	NO.	W-17-140
SHEET NO.	4	OF	6
CALCULATED BY	PPM	DATE	1/21/2022
CHECKED BY	BRT	DATE	11/23/2022

Retaining Wall 6 - Sta. 10+00 to 12+55 (BL Wall 6)

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	29.3	ft
MSE Wall Width (Reinforcement Length), (B) =	20.5	ft
MSE Wall Length, (L) =	255	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties [1]:

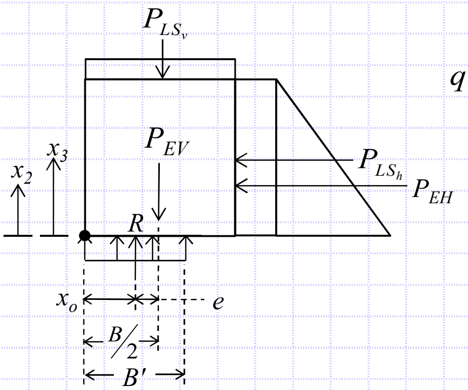
	Bearing	Sliding	
Bearing Soil Unit Weight, (γ_{BS}) =	120	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	32	32	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	0	0	psf
Embedment Depth, (D_f) =	3.0 ft		
Depth to Groundwater (Below Bot. of Wall), (D_W) =	18.5 ft		

LRFD Load Factors

	EV	EH	LS	
Strength Ia	1.00	1.50	1.75	(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)
Strength Ib	1.35	1.50	1.75	
Service I	1.00	1.00	1.00	

1. Soil properties for bearing resistance based on critical soil type w/i 1.5B below the bottom of wall. Soil properties for sliding resistance based on soil type w/i 3.0 ft. below the bottom of wall.

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



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

$B' = B - 2e$ = 20.5 ft - 2(2.63 ft) = 15.24 ft

$e = B/2 - x_o$ = (20.5 ft) / 2 - 7.62 ft = 2.63 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (1089.31 kip·ft/ft - 279.97 kip·ft/ft) / 106.27 kip/ft = 7.62 ft

q_{eq} = (106.27 kip/ft) / (15.24 ft) = 6.97 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)(29.3 ft)(20.5 ft)(1.35)](10.25 ft) + [(250 psf)(20.5 ft)(1.75)](10.25 ft) = 1089.31 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(120 pcf)(29.3 ft)²(0.297)(1.5)](9.77 ft) + [(250 psf)(29.3 ft)(0.297)(1.75)](14.65 ft) = 279.97 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)(29.3 ft)(20.5 ft)(1.35) + (250 psf)(20.5 ft)(1.75) = 106.27 kip/ft

Check Bearing Resistance - Drained Condition

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

$N_{cm} = N_c s_c i_c$ = 36.87

N_c = 35.49

s_c = 1+(15.24 ft/255 ft)(23.18/35.49)

= 1.039

i_c = 1.000 (Assumed)

$N_{qm} = N_q s_q d_q i_q$ = 24.43

N_q = 23.18

s_q = 1.000

d_q = 1+2tan(32°)[1-sin(32°)]²tan⁻¹(3.0 ft/15.24 ft)

1.054

i_q = 1.000 (Assumed)

C_{wq} = 18.5 ft > 3.0 ft = 1.000

$N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 29.48

N_γ = 30.21

s_γ = 0.976

i_γ = 1.000 (Assumed)

$C_{w\gamma}$ = 18.5 ft < 1.5(15.24 ft) + 3.0 ft = 0.905

q_n = (0 psf)(36.874) + (120 pcf)(3.0 ft)(24.432)(1.000) + ½(120 pcf)(15.2 ft)(29.485)(0.905) = 33.2 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

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

$q_{eq} \le q_n \cdot \phi_b$ ⟶ 6.97 ksf ≤ (33.20 ksf)(0.65) = 21.58 ksf ⟶ 6.97 ksf ≤ 21.58 ksf **OK**

JOB	FRA-70-22.85 FEF	NO.	W-17-140
SHEET NO.	5	OF	6
CALCULATED BY	PPM	DATE	1/21/2022
CHECKED BY	BRT	DATE	11/23/2022

Retaining Wall 6 - Sta. 10+00 to 12+55 (BL Wall 6)

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	29.3	ft
MSE Wall Width (Reinforcement Length), (B) =	20.5	ft
MSE Wall Length, (L) =	255	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties ^{1}:

	Bearing	Sliding	
Bearing Soil Unit Weight, (γ_{BS}) =	120	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	32	32	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	0	0	psf
Embedment Depth, (D_f) =	3.0 ft		
Depth to Grounwater (Below Bot. of Wall), (D_W) =	18.5 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)

1. Soil properties for bearing resistance based on critical soil type w/i 1.5B below the bottom of wall. Soil properties for sliding resistance based on soil type w/i 3.0 ft. below the bottom of wall.

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

Check Bearing Resistance - Undrained Condition

Nominal Bearing Resistance: $$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + ½\,\gamma B N_{\gamma m} C_{w\gamma}$$

$N_{cm} = N_c s_c i_c$ = 5.220

N_c = 5.140

s_c = 1+(15.24 ft/[(5)(255 ft)]) = 1.015

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/15.24 ft)

1.000

i_q = 1.000 (Assumed)

C_{wq} = 18.5 ft > 3.0 ft = 1.000

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

N_γ = 0.000

s_γ = 1.000

i_γ = 1.000 (Assumed)

$C_{w\gamma}$ = 18.5 ft < 1.5(15.24 ft) + 3.0 ft = 0.905

$q_n =$ (0 psf)(5.220) + (120 pcf)(3.0 ft)(1.000)(1.000) + ½(120 pcf)(15.2 ft)(0.000)(0.905) = N/A ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

$q_{eq} \leq q_n \cdot \phi_b \longrightarrow$ 6.97 ksf ≤ (N/A ksf)(0.65) = N/A ksf $\longrightarrow$ N/A

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

JOB FRA-70-22.85 FEF NO. W-17-140
SHEET NO. 6 OF 6
CALCULATED BY PPM DATE 1/21/2022
CHECKED BY BRT DATE 11/23/2022
Retaining Wall 6 - Sta. 10+00 to 12+55 (BL Wall 6)

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	29.3	ft
MSE Wall Width (Reinforcement Length), (B) =	20.5	ft
MSE Wall Length, (L) =	255	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties [1]:

	Bearing	Sliding	
Bearing Soil Unit Weight, (γ_{BS}) =	120	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	32	32	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	0	0	psf
Embedment Depth, (D_f) =	3.0 ft		
Depth to Grounwater (Below Bot. of Wall), (D_W) =	18.5 ft		

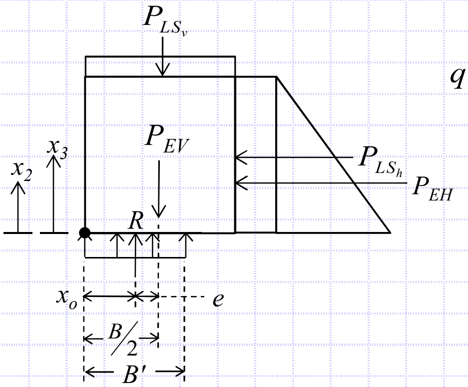
LRFD Load Factors

	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)

1. Soil properties for bearing resistance based on critical soil type w/i 1.5B below the bottom of wall. Soil properties for sliding resistance based on soil type w/i 3.0 ft. below the bottom of wall.

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



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

$$B' = B - 2e \quad = \quad 20.5\text{ ft} - 2(2.35\text{ ft}) \quad = \quad 15.80 \quad \text{ft}$$

$$e = B/2 - x_o \quad = \quad (20.5\text{ ft}) / 2 - 7.9\text{ ft} \quad = \quad 2.35 \quad \text{ft}$$

$$x_o = \frac{M_V - M_H}{P_V} \quad = \quad (791.33\text{ kip·ft/ft} - 181.34\text{ kip·ft/ft}) / 77.2\text{ kip/ft} \quad = \quad 7.9 \quad \text{ft}$$

$$q_{eq} = \quad (77.2\text{ kip/ft}) / (15.8\text{ ft}) \quad = \quad 4.89 \quad \text{ksf}$$

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

$$M_V = \quad [(120\text{ pcf})(29.3\text{ ft})(20.5\text{ ft})(1.00)](10.3\text{ ft}) + [(250\text{ psf})(20.5\text{ ft})(1.00)](10.3\text{ ft}) \quad = \quad 791.33 \quad \text{kip·ft/ft}$$

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

$$M_H = \quad [\tfrac{1}{2}(120\text{ pcf})(29.3\text{ ft})^2(0.297)(1.00)](9.77\text{ ft}) + [(250\text{ psf})(29.3\text{ ft})(0.297)(1.00)](14.65\text{ ft}) \quad = \quad 181.34 \quad \text{kip·ft/ft}$$

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

$$P_V = \quad (120\text{ pcf})(29.3\text{ ft})(20.5\text{ ft})(1.00) + (250\text{ psf})(20.5\text{ ft})(1.00) \quad = \quad 77.2 \quad \text{kip/ft}$$

Settlement, Time Rate of Consolidation and Differential Settlement:

Boring	Station Along Wall 6	Total Settlement at Center of Reinforced Soil Mass	Total Settlement at Wall Facing	Time for 90% Consolidation	Distance Along Wall Facing	Differential Settlement Along Wall Facing
B-067-1-19	11+80	1.206 in	0.919 in	150 days		
B-003-0-65	10+60	1.200 in	0.920 in	250 days	120 ft	1 in / 120,000 ft

FRA-70-22.85 FEF - Retaining Wall 6 - Sta. 10+00 to 12+55 (BL Wall 6) - FRA-BRICE-04342 Rear Abutment
MSE Wall Settlement

Calculated By: PPM Date: 1/19/2022
Checked By: BRT Date: 11/23/2022

Boring B-067-1-19

H =	29.3	ft	Wall height
B =	20.5	ft	Width of wall
D_w =	18.5	ft	Depth below bottom of wall
γ_{BF} =	120	pcf	Unit weight of backfill
q =	3,516	psf	Bearing pressure at bottom of wall
q_{net} =	2,016	psf	Considers net pressure from MSE wall mass minus the pressure from the existing spillthru slope (El. 800 ft msl at wall face, El. 810 ft msl at back of wall, Use avg. El. of 805 ft msl)

																					Total Settlement at Center of Reinforced Soil Mass					Total Settlement at Facing of Wall				
Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Elevation (ft. msl)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' (1) (psf)	LL	C_c (2)	C_r (3)	e_o (4)	N_{60}	$(N1)_{60}$ (5)	C' (6)	Z_f/B	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	S_c (9,10) (ft)	S_c (in)	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	2.0	792.5	790.5	2.0	1.0	120	240	120	120	3,120					30	58	207	0.05	1.000	2,015	2,135	0.012	0.145	0.500	1,008	1,128	0.009	0.113
	A-1-b	G	2.0	4.0	790.5	788.5	2.0	3.0	120	480	360	360	3,360					30	47	158	0.15	0.990	1,997	2,357	0.010	0.124	0.499	1,007	1,367	0.007	0.088
	A-1-b	G	4.0	6.0	788.5	786.5	2.0	5.0	120	720	600	600	3,600					30	42	138	0.24	0.962	1,939	2,539	0.009	0.109	0.497	1,002	1,602	0.006	0.074
2	A-2-4	G	6.0	10.0	786.5	782.5	4.0	8.0	125	1,220	970	970	3,970					25	31	102	0.39	0.887	1,788	2,758	0.018	0.213	0.489	987	1,957	0.012	0.143
	A-2-4	G	10.0	14.5	782.5	778.0	4.5	12.3	125	1,783	1,501	1,501	4,501					25	27	92	0.60	0.757	1,526	3,027	0.015	0.179	0.469	945	2,446	0.010	0.125
3	A-2-4	G	14.5	19.5	778.0	773.0	5.0	17.0	135	2,458	2,120	2,120	5,120					46	45	150	0.83	0.627	1,264	3,384	0.007	0.081	0.436	879	2,999	0.005	0.060
4	A-1-b	G	19.5	23.5	773.0	769.0	4.0	21.5	135	2,998	2,728	2,540	5,540					100	92	300	1.05	0.531	1,070	3,610	0.002	0.024	0.401	809	3,350	0.002	0.019
5	A-2-4	G	23.5	28.5	769.0	764.0	5.0	26.0	135	3,673	3,335	2,867	5,867					46	41	133	1.27	0.456	920	3,787	0.005	0.055	0.367	740	3,607	0.004	0.045
6	A-4a	C	28.5	33.5	764.0	759.0	5.0	31.0	130	4,323	3,998	3,218	6,218	25	0.135	0.014	0.467				1.51	0.393	792	4,010	0.004	0.053	0.332	670	3,888	0.004	0.045
	A-4a	C	33.5	43.5	759.0	749.0	10.0	38.5	130	5,623	4,973	3,725	6,725	25	0.135	0.014	0.467				1.88	0.324	653	4,378	0.006	0.077	0.288	580	4,305	0.006	0.069
	A-4a	C	43.5	53.5	749.0	739.0	10.0	48.5	130	6,923	6,273	4,401	7,401	22	0.108	0.011	0.444				2.37	0.261	527	4,927	0.004	0.044	0.241	487	4,887	0.003	0.041
7	A-6a	C	53.5	63.5	739.0	729.0	10.0	58.5	130	8,223	7,573	5,077	8,077	32	0.198	0.020	0.522				2.85	0.219	441	5,517	0.005	0.056	0.207	417	5,493	0.004	0.053
8	A-6b	C	63.5	71.5	729.0	721.0	8.0	67.5	120	9,183	8,703	5,645	8,645	38	0.252	0.025	0.569				3.29	0.190	384	6,029	0.004	0.044	0.182	368	6,013	0.004	0.042
																					Total Settlement:			1.206 in		Total Settlement:			0.919 in	

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

FRA-70-22.85 FEF - Retaining Wall 6 - Sta. 10+00 to 12+55 (BL Wall 6) - FRA-BRICE-04342 Rear Abutment
MSE Wall Settlement

Calculated By: PPM Date: 1/19/2022
Checked By: BRT Date: 11/23/2022

Boring B-067-1-19

H =	29.3	ft	Wall height
B =	20.5	ft	Width of wall
D_w =	18.5	ft	Depth below bottom of wall
γ_{BF} =	120		Unit weight of backfill
q =	3,516	psf	Bearing pressure at bottom of wall
q_{net} =	2,016	psf	Considers net pressure from MSE wall mass minus the pressure from the existing spillthru slope (El. 800 ft msl at wall face, El. 810 ft msl at back of wall, Use avg. El. of 805 ft msl)

t =	0	days	Time following completion of construction

																									Total Settlement at Facing of Wall			Settlement Complete at 73% of Primary Consolidation					
Layer	Soil Class.	Soil Type	Layer Depth (ft)		Elevation (ft msl)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' (1) (psf)	LL	C_c (2)	C_r (3)	e_o (4)	N_{60}	$(N1)_{60}$ (5)	C' (6)	Z_f/B	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	S_c (9,10) (ft)	S_c (in)	Layer Settlement (in)	c_v (ft^2/yr)	H_{dr} (ft)	T_v	U (%)	$(S_c)_t$ (11) (in)	Layer Settlement (in)
1	A-1-b	G	0.0	2.0	792.5	790.5	2.0	1.0	120	240	120	120	3,120					30	58	207	0.05	0.500	1,008	1,128	0.009	0.113	0.275				100	0.113	0.275
	A-1-b	G	2.0	4.0	790.5	788.5	2.0	3.0	120	480	360	360	3,360					30	47	158	0.15	0.499	1,007	1,367	0.007	0.088					100	0.088	
	A-1-b	G	4.0	6.0	788.5	786.5	2.0	5.0	120	720	600	600	3,600					30	42	138	0.24	0.497	1,002	1,602	0.006	0.074					100	0.074	
2	A-2-4	G	6.0	10.0	786.5	782.5	4.0	8.0	125	1,220	970	970	3,970					25	31	102	0.39	0.489	987	1,957	0.012	0.143	0.268				100	0.143	0.268
	A-2-4	G	10.0	14.5	782.5	778.0	4.5	12.3	125	1,783	1,501	1,501	4,501					25	27	92	0.60	0.469	945	2,446	0.010	0.125					100	0.125	
3	A-2-4	G	14.5	19.5	778.0	773.0	5.0	17.0	135	2,458	2,120	2,120	5,120					46	45	150	0.83	0.436	879	2,999	0.005	0.060	0.060				100	0.060	0.060
4	A-1-b	G	19.5	23.5	773.0	769.0	4.0	21.5	135	2,998	2,728	2,540	5,540					100	92	300	1.05	0.401	809	3,350	0.002	0.019	0.019				100	0.019	0.019
5	A-2-4	G	23.5	28.5	769.0	764.0	5.0	26.0	135	3,673	3,335	2,867	5,867					46	41	133	1.27	0.367	740	3,607	0.004	0.045	0.045				100	0.045	0.045
6	A-4a	C	28.5	33.5	764.0	759.0	5.0	31.0	130	4,323	3,998	3,218	6,218	25	0.135	0.014	0.467				1.51	0.332	670	3,888	0.004	0.045	0.156	400	5.0	0.000	0	0.000	0.000
	A-4a	C	33.5	43.5	759.0	749.0	10.0	38.5	130	5,623	4,973	3,725	6,725	25	0.135	0.014	0.467				1.88	0.288	580	4,305	0.006	0.069		400	15.0	0.000	0	0.000	
	A-4a	C	43.5	53.5	749.0	739.0	10.0	48.5	130	6,923	6,273	4,401	7,401	22	0.108	0.011	0.444				2.37	0.241	487	4,887	0.003	0.041		400	25.0	0.000	0	0.000	
7	A-6a	C	53.5	63.5	739.0	729.0	10.0	58.5	130	8,223	7,573	5,077	8,077	32	0.198	0.020	0.522				2.85	0.207	417	5,493	0.004	0.053	0.053	300	35.0	0.000	0	0.000	0.000
8	A-6b	C	63.5	71.5	729.0	721.0	8.0	67.5	120	9,183	8,703	5,645	8,645	38	0.252	0.025	0.569				3.29	0.182	368	6,013	0.004	0.042	0.042	200	43.0	0.000	0	0.000	0.000

$(S_c)_t$ = 0.668 in

Settlement Remaining After Hold Period: 0.251 in

1. $\sigma_p' = \sigma_{vo}'+\sigma_{m;}$ Estimate σ_m of 3,000 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. $C_r = 0.10(C_c)$; Ref. Chapter 8.11, Holtz and Kovacs 1981
4. $e_o = (C_c/0.54)+0.35$; Ref. Table 6-11, FHWA GEC 5
5. $(N1)_{60} = C_nN_{60}$, 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; $I = [\beta+\sin(\beta)\cos(\beta+2\delta)]/\pi$, where $\beta = \tan^{-1}[(x+B/2)/Z_f]-\delta$, $\delta = \tan^{-1}[(x-B/2)/Z_f]$ and x = horizontal distance from center of footing; Ref. Figure 6.13 and Equation 6.24, Das 2005
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesive soil layers)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
11. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0

FRA-70-22.85 FEF - Retaining Wall 6 - Sta. 10+00 to 12+55 (BL Wall 6) - FRA-BRICE-04342 Rear Abutment

MSE Wall Settlement

Calculated By: PPM Date: 1/19/2022

Checked By: BRT Date: 11/23/2022

Boring B-067-1-19

H =	29.3	ft	Wall height
B =	20.5	ft	Width of wall
D_w =	18.5	ft	Depth below bottom of wall
γ_{BF} =	120		Unit weight of backfill
q =	3,516	psf	Bearing pressure at bottom of wall
q_{net} =	2,016	psf	Considers net pressure from MSE wall mass minus the pressure from the existing spillthru slope (El. 800 ft msl at wall face, El. 810 ft msl at back of wall, Use avg. El. of 805 ft msl)
t =	150	days	Time following completion of construction

																								Total Settlement at Facing of Wall			Settlement Complete at 90% of Primary Consolidation					
Layer	Soil Class.	Soil Type	Layer Depth (ft)		Elevation (ft msl)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' (1) (psf)	LL	C_c (2)	C_r (3)	e_o (4)	N_{60}	$(N1)_{60}$ (5)	C' (6)	Z_f/B	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	S_c (9,10) (ft)	S_c (in)	Layer Settlement (in)	c_v (ft^2/yr)	H_{dr} (ft)	T_v	U (%)	$(S_c)_t$ (11) (in)	Layer Settlement (in)
1	A-1-b	G	0.0	2.0	792.5	790.5	2.0	1.0	120	240	120	120	3,120					30	58	207	0.05	0.500	1,008	1,128	0.009	0.113	0.275				100	0.113	0.275
	A-1-b	G	2.0	4.0	790.5	788.5	2.0	3.0	120	480	360	360	3,360					30	47	158	0.15	0.499	1,007	1,367	0.007	0.088					100	0.088	
	A-1-b	G	4.0	6.0	788.5	786.5	2.0	5.0	120	720	600	600	3,600					30	42	138	0.24	0.497	1,002	1,602	0.006	0.074					100	0.074	
2	A-2-4	G	6.0	10.0	786.5	782.5	4.0	8.0	125	1,220	970	970	3,970					25	31	102	0.39	0.489	987	1,957	0.012	0.143	0.268				100	0.143	0.268
	A-2-4	G	10.0	14.5	782.5	778.0	4.5	12.3	125	1,783	1,501	1,501	4,501					25	27	92	0.60	0.469	945	2,446	0.010	0.125					100	0.125	
3	A-2-4	G	14.5	19.5	778.0	773.0	5.0	17.0	135	2,458	2,120	2,120	5,120					46	45	150	0.83	0.436	879	2,999	0.005	0.060	0.060				100	0.060	0.060
4	A-1-b	G	19.5	23.5	773.0	769.0	4.0	21.5	135	2,998	2,728	2,540	5,540					100	92	300	1.05	0.401	809	3,350	0.002	0.019	0.019				100	0.019	0.019
5	A-2-4	G	23.5	28.5	769.0	764.0	5.0	26.0	135	3,673	3,335	2,867	5,867					46	41	133	1.27	0.367	740	3,607	0.004	0.045	0.045				100	0.045	0.045
6	A-4a	C	28.5	33.5	764.0	759.0	5.0	31.0	130	4,323	3,998	3,218	6,218	25	0.135	0.014	0.467				1.51	0.332	670	3,888	0.004	0.045	0.156	400	5.0	6.575	100	0.045	0.129
	A-4a	C	33.5	43.5	759.0	749.0	10.0	38.5	130	5,623	4,973	3,725	6,725	25	0.135	0.014	0.467				1.88	0.288	580	4,305	0.006	0.069		400	15.0	0.731	87	0.060	
	A-4a	C	43.5	53.5	749.0	739.0	10.0	48.5	130	6,923	6,273	4,401	7,401	22	0.108	0.011	0.444				2.37	0.241	487	4,887	0.003	0.041		400	25.0	0.263	58	0.024	
7	A-6a	C	53.5	63.5	739.0	729.0	10.0	58.5	130	8,223	7,573	5,077	8,077	32	0.198	0.020	0.522				2.85	0.207	417	5,493	0.004	0.053	0.053	300	35.0	0.101	36	0.019	0.019
8	A-6b	C	63.5	71.5	729.0	721.0	8.0	67.5	120	9,183	8,703	5,645	8,645	38	0.252	0.025	0.569				3.29	0.182	368	6,013	0.004	0.042	0.042	200	43.0	0.044	24	0.010	0.010

$(S_c)_t$ = 0.827 in

Settlement Remaining After Hold Period: 0.093 in

1. $\sigma_p' = \sigma_{vo}'+\sigma_{m;}$ Estimate σ_m of 3,000 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. $C_r = 0.10(C_c)$; Ref. Chapter 8.11, Holtz and Kovacs 1981
4. $e_o = (C_c/0.54)+0.35$; Ref. Table 6-11, FHWA GEC 5
5. $(N1)_{60} = C_N N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \le 2.0$ 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; $I = [\beta+\sin(\beta)\cos(\beta+2\delta)]/\pi$, where $\beta = \tan^{-1}[(x+B/2)/Z_f]-\delta$, $\delta = \tan^{-1}[(x-B/2)/Z_f]$ and x = horizontal distance from center of footing; Ref. Figure 6.13 and Equation 6.24, Das 2005
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$for $\sigma_p' \le \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \le \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesive soil layers)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
11. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0

FRA-70-22.85 FEF - Retaining Wall 6 - Sta. 10+00 to 12+55 (BL Wall 6) - FRA-BRICE-04342 Rear Abutment
MSE Wall Settlement

Calculated By: PPM Date: 1/19/2022
Checked By: BRT Date: 11/23/2022

Boring B-003-0-65

H = 29.3 ft Wall height
B = 20.5 ft Width of wall
D_w = 18.5 ft Depth below bottom of wall
γ_{BF} = 120 pcf Unit weight of backfill
q = 3,516 psf Bearing pressure at bottom of wall
q_{net} = 2,016 psf Considers net pressure from MSE wall mass minus the pressure from the existing spillthru slope (El. 800 ft msl at wall face, El. 810 ft msl at back of wall, Use avg. El. of 805 ft msl)

																				Total Settlement at Center of Reinforced Soil Mass					Total Settlement at Facing of Wall				
Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Elevation (ft. msl)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p'[1] (psf)	LL	C_c[2]	C_r[3]	e_o[4]	N_{60}	$(N1)_{60}$[5]	C'[6]	Z_f/B	I[7]	$\Delta\sigma_v$[8] (psf)	σ_{vf}' Midpoint (psf)	S_c[9,10] (ft)	S_c (in)	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	2.0	792.5	790.5	2.0	1.0	120	240	120	120	3,120					30	58	207	0.05	1.000	2,015	2,135	0.012	0.145	0.500	1,008	1,128	0.009	0.113
	A-1-b	G	2.0	4.0	790.5	788.5	2.0	3.0	120	480	360	360	3,360					30	47	158	0.15	0.990	1,997	2,357	0.010	0.124	0.499	1,007	1,367	0.007	0.088
	A-1-b	G	4.0	6.0	788.5	786.5	2.0	5.0	120	720	600	600	3,600					30	42	138	0.24	0.962	1,939	2,539	0.009	0.109	0.497	1,002	1,602	0.006	0.074
2	A-2-4	G	6.0	9.0	786.5	783.5	3.0	7.5	125	1,095	908	908	3,908					25	32	104	0.37	0.901	1,817	2,724	0.014	0.166	0.491	990	1,897	0.009	0.111
	A-2-4	G	9.0	13.2	783.5	779.3	4.2	11.1	125	1,620	1,358	1,358	4,358					25	28	94	0.54	0.792	1,597	2,954	0.015	0.181	0.475	958	2,316	0.010	0.124
3	A-1-a	G	13.2	21.2	779.3	771.3	8.0	17.2	135	2,700	2,160	2,160	5,160					60	59	208	0.84	0.622	1,254	3,414	0.008	0.092	0.435	876	3,036	0.006	0.068
4	A-4a	C	21.2	29.7	771.3	762.8	8.5	25.5	120	3,720	3,210	2,776	5,776	22	0.108	0.011	0.444				1.24	0.464	936	3,712	0.008	0.096	0.371	749	3,525	0.007	0.079
5	A-6a	C	29.7	34.7	762.8	757.8	5.0	32.2	125	4,345	4,033	3,178	6,178	29	0.171	0.017	0.499				1.57	0.380	766	3,944	0.005	0.064	0.325	655	3,832	0.005	0.056
6	A-4a	C	34.7	44.7	757.8	747.8	10.0	39.7	125	5,595	4,970	3,647	6,647	24	0.126	0.013	0.460				1.94	0.315	635	4,282	0.006	0.072	0.281	567	4,215	0.005	0.065
7	A-6a	C	44.7	49.7	747.8	742.8	5.0	47.2	125	6,220	5,908	4,117	7,117	30	0.180	0.018	0.507				2.30	0.268	541	4,657	0.003	0.038	0.247	497	4,614	0.003	0.036
8	A-6b	C	49.7	54.7	742.8	737.8	5.0	52.2	125	6,845	6,533	4,430	7,430	39	0.261	0.026	0.577				2.55	0.244	492	4,921	0.004	0.045	0.227	458	4,888	0.004	0.042
9	A-4b	G	54.7	59.7	737.8	732.8	5.0	57.2	130	7,495	7,170	4,755	7,755					31	22	43	2.79	0.223	450	5,206	0.005	0.055	0.211	425	5,180	0.004	0.052
10	A-6a	C	59.7	62.7	732.8	729.8	3.0	61.2	125	7,870	7,683	5,018	8,018	26	0.144	0.014	0.475				2.99	0.209	422	5,440	0.001	0.012	0.199	401	5,419	0.001	0.012
																						Total Settlement:			1.200 in		Total Settlement:			0.920 in

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

FRA-70-22.85 FEF - Retaining Wall 6 - Sta. 10+00 to 12+55 (BL Wall 6) - FRA-BRICE-04342 Rear Abutment
MSE Wall Settlement

Calculated By: PPM Date: 1/19/2022
Checked By: BRT Date: 11/23/2022

Boring B-003-0-65

H =	29.3	ft	Wall height
B =	20.5	ft	Width of wall
D_w =	18.5	ft	Depth below bottom of wall
γ_{BF} =	120		Unit weight of backfill
q =	3,516	psf	Bearing pressure at bottom of wall
q_{net} =	2,016	psf	Considers net pressure from MSE wall mass minus the pressure from the existing spillthru slope (El. 800 ft msl at wall face, El. 810 ft msl at back of wall, Use avg. El. of 805 ft msl)

t =	0	days	Time following completion of construction

																									Total Settlement at Facing of Wall			Settlement Complete at 63% of Primary Consolidation					
Layer	Soil Class.	Soil Type	Layer Depth (ft)		Elevation (ft msl)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' (1) (psf)	LL	C_c (2)	C_r (3)	e_o (4)	N_{60}	$(N1)_{60}$ (5)	C' (6)	Z_f/B	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	S_c (9,10) (ft)	S_c (in)	Layer Settlement (in)	c_v (ft^2/yr)	H_{dr} (ft)	T_v	U (%)	$(S_c)_t$ (11) (in)	Layer Settlement (in)
1	A-1-b	G	0.0	2.0	792.5	790.5	2.0	1.0	120	240	120	120	3,120					30	58	207	0.05	0.500	1,008	1,128	0.009	0.113	0.275				100	0.113	0.275
	A-1-b	G	2.0	4.0	790.5	788.5	2.0	3.0	120	480	360	360	3,360					30	47	158	0.15	0.499	1,007	1,367	0.007	0.088					100	0.088	
	A-1-b	G	4.0	6.0	788.5	786.5	2.0	5.0	120	720	600	600	3,600					30	42	138	0.24	0.497	1,002	1,602	0.006	0.074					100	0.074	
2	A-2-4	G	6.0	9.0	786.5	783.5	3.0	7.5	125	1,095	908	908	3,908					25	32	104	0.37	0.491	990	1,897	0.009	0.111	0.235				100	0.111	0.235
	A-2-4	G	9.0	13.2	783.5	779.3	4.2	11.1	125	1,620	1,358	1,358	4,358					25	28	94	0.54	0.475	958	2,316	0.010	0.124					100	0.124	
3	A-1-a	G	13.2	21.2	779.3	771.3	8.0	17.2	135	2,700	2,160	2,160	5,160					60	59	208	0.84	0.435	876	3,036	0.006	0.068	0.068				100	0.068	0.068
4	A-4a	C	21.2	29.7	771.3	762.8	8.5	25.5	120	3,720	3,210	2,776	5,776	22	0.108	0.011	0.444				1.24	0.371	749	3,525	0.007	0.079	0.079	400	8.5	0.000	0	0.000	0.000
5	A-6a	C	29.7	34.7	762.8	757.8	5.0	32.2	125	4,345	4,033	3,178	6,178	29	0.171	0.017	0.499				1.57	0.325	655	3,832	0.005	0.056	0.056	300	13.5	0.000	0	0.000	0.000
6	A-4a	C	34.7	44.7	757.8	747.8	10.0	39.7	125	5,595	4,970	3,647	6,647	24	0.126	0.013	0.460				1.94	0.281	567	4,215	0.005	0.065	0.065	400	23.5	0.000	0	0.000	0.000
7	A-6a	C	44.7	49.7	747.8	742.8	5.0	47.2	125	6,220	5,908	4,117	7,117	30	0.180	0.018	0.507				2.30	0.247	497	4,614	0.003	0.036	0.036	300	28.5	0.000	0	0.000	0.000
8	A-6b	C	49.7	54.7	742.8	737.8	5.0	52.2	125	6,845	6,533	4,430	7,430	39	0.261	0.026	0.577				2.55	0.227	458	4,888	0.004	0.042	0.042	200	33.5	0.000	0	0.000	0.000
9	A-4b	G	54.7	59.7	737.8	732.8	5.0	57.2	130	7,495	7,170	4,755	7,755					31	22	43	2.79	0.211	425	5,180	0.004	0.052	0.052	400	38.5	0.000	0	0.000	0.000
10	A-6a	C	59.7	62.7	732.8	729.8	3.0	61.2	125	7,870	7,683	5,018	8,018	26	0.144	0.014	0.475				2.99	0.199	401	5,419	0.001	0.012	0.012	300	41.5	0.000	0	0.000	0.000

$(S_c)_t$ = 0.579 in

Settlement Remaining After Hold Period: 0.342 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_{m;}$ Estimate σ_m of 3,000 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. $C_r = 0.10(C_c)$; Ref. Chapter 8.11, Holtz and Kovacs 1981
4. $e_o = (C_c/0.54)+0.35$; Ref. Table 6-11, FHWA GEC 5
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; $I = [\beta+\sin(\beta)\cos(\beta+2\delta)]/\pi$, where $\beta = \tan^{-1}[(x+B/2)/Z_f]-\delta$, $\delta = \tan^{-1}[(x-B/2)/Z_f]$ and x = horizontal distance from center of footing; Ref. Figure 6.13 and Equation 6.24, Das 2005
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesive soil layers)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
11. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0

FRA-70-22.85 FEF - Retaining Wall 6 - Sta. 10+00 to 12+55 (BL Wall 6) - FRA-BRICE-04342 Rear Abutment
MSE Wall Settlement

Calculated By: PPM Date: 1/19/2022
Checked By: BRT Date: 11/23/2022

Boring B-003-0-65

H = 29.3 ft Wall height
B = 20.5 ft Width of wall
D_w = 18.5 ft Depth below bottom of wall
γ_{BF} = 120 Unit weight of backfill
q = 3,516 psf Bearing pressure at bottom of wall
q_{net} = 2,016 psf Considers net pressure from MSE wall mass minus the pressure from the existing spillthru slope (El. 800 ft msl at wall face, El. 810 ft msl at back of wall, Use avg. El. of 805 ft msl)

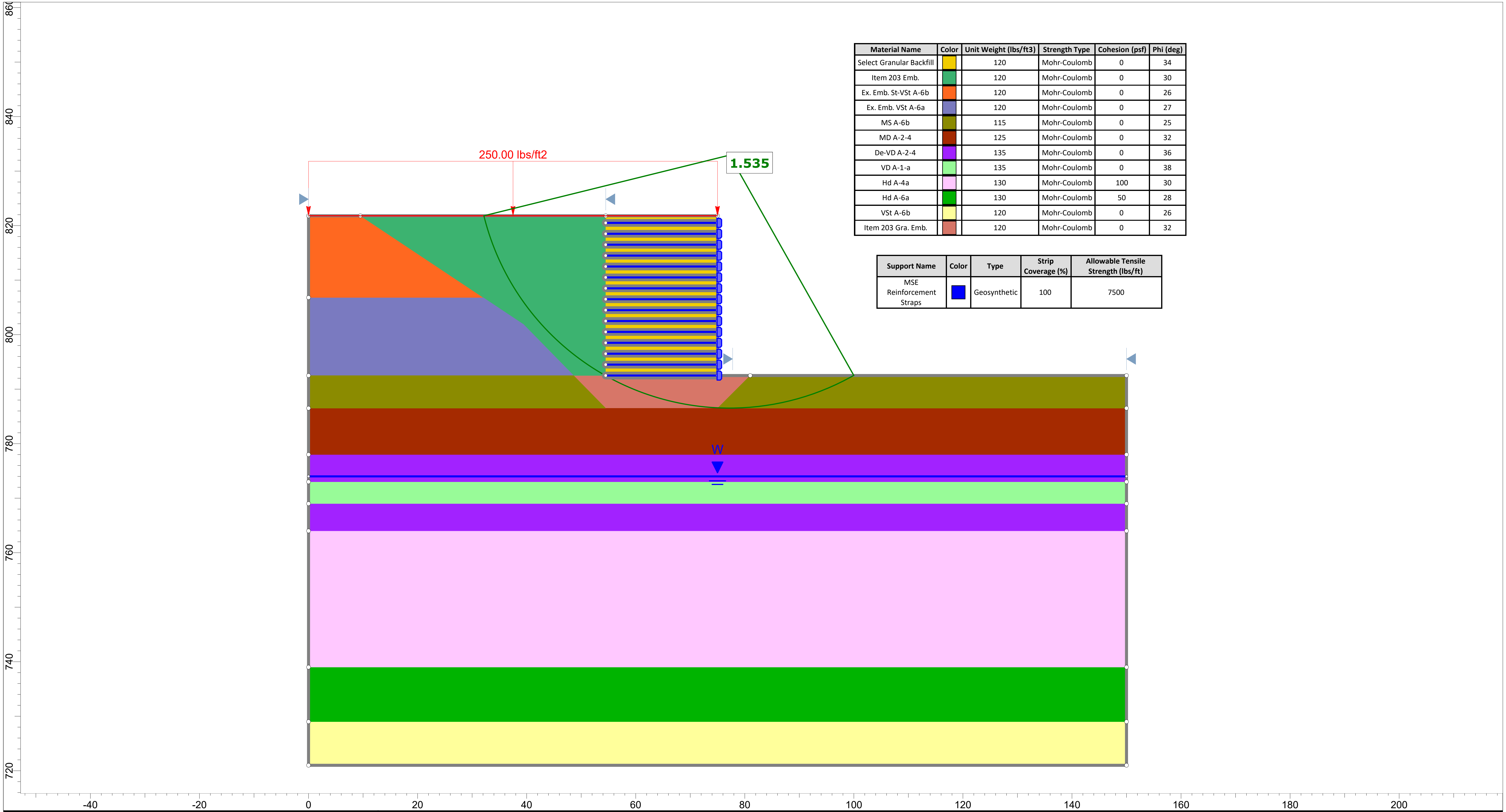
t = 250 days Time following completion of construction

																							Total Settlement at Facing of Wall			Settlement Complete at 90% of Primary Consolidation					
Layer	Soil Class.	Soil Type	Layer Depth (ft)		Elevation (ft msl)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' (1) (psf)	LL	C_c (2)	C_r (3)	e_o (4)	N_{60}	$(N1)_{60}$ (5)	C' (6)	Z_f/B	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	S_c (9,10) (ft)	S_c (in)	Layer Settlement (in)	c_v (ft^2/yr)	H_{dr} (ft)	T_v	U (%)	$(S_c)_t$ (11) (in)	Layer Settlement (in)
1	A-1-b	G	0.0	2.0	792.5	790.5	2.0	1.0	120	240	120	120	3,120					30	58	207	0.05	0.500	1,008	1,128	0.009	0.113	0.275				100	0.113	0.275
	A-1-b	G	2.0	4.0	790.5	788.5	2.0	3.0	120	480	360	360	3,360					30	47	158	0.15	0.499	1,007	1,367	0.007	0.088					100	0.088	
	A-1-b	G	4.0	6.0	788.5	786.5	2.0	5.0	120	720	600	600	3,600					30	42	138	0.24	0.497	1,002	1,602	0.006	0.074					100	0.074	
2	A-2-4	G	6.0	9.0	786.5	783.5	3.0	7.5	125	1,095	908	908	3,908					25	32	104	0.37	0.491	990	1,897	0.009	0.111	0.235				100	0.111	0.235
	A-2-4	G	9.0	13.2	783.5	779.3	4.2	11.1	125	1,620	1,358	1,358	4,358					25	28	94	0.54	0.475	958	2,316	0.010	0.124					100	0.124	
3	A-1-a	G	13.2	21.2	779.3	771.3	8.0	17.2	135	2,700	2,160	2,160	5,160					60	59	208	0.84	0.435	876	3,036	0.006	0.068	0.068				100	0.068	0.068
4	A-4a	C	21.2	29.7	771.3	762.8	8.5	25.5	120	3,720	3,210	2,776	5,776	22	0.108	0.011	0.444				1.24	0.371	749	3,525	0.007	0.079	0.079	400	8.5	3.792	100	0.079	0.079
5	A-6a	C	29.7	34.7	762.8	757.8	5.0	32.2	125	4,345	4,033	3,178	6,178	29	0.171	0.017	0.499				1.57	0.325	655	3,832	0.005	0.056	0.056	300	13.5	1.127	95	0.053	0.053
6	A-4a	C	34.7	44.7	757.8	747.8	10.0	39.7	125	5,595	4,970	3,647	6,647	24	0.126	0.013	0.460				1.94	0.281	567	4,215	0.005	0.065	0.065	400	23.5	0.496	76	0.049	0.049
7	A-6a	C	44.7	49.7	747.8	742.8	5.0	47.2	125	6,220	5,908	4,117	7,117	30	0.180	0.018	0.507				2.30	0.247	497	4,614	0.003	0.036	0.036	300	28.5	0.253	57	0.020	0.020
8	A-6b	C	49.7	54.7	742.8	737.8	5.0	52.2	125	6,845	6,533	4,430	7,430	39	0.261	0.026	0.577				2.55	0.227	458	4,888	0.004	0.042	0.042	200	33.5	0.122	39	0.017	0.017
9	A-4b	G	54.7	59.7	737.8	732.8	5.0	57.2	130	7,495	7,170	4,755	7,755					31	22	43	2.79	0.211	425	5,180	0.004	0.052	0.052	400	38.5	0.185	49	0.025	0.025
10	A-6a	C	59.7	62.7	732.8	729.8	3.0	61.2	125	7,870	7,683	5,018	8,018	26	0.144	0.014	0.475				2.99	0.199	401	5,419	0.001	0.012	0.012	300	41.5	0.119	39	0.005	0.005

1. $\sigma_p' = \sigma_{vo}'+\sigma_{m;}$ Estimate σ_m of 3,000 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. $C_r = 0.10(C_c)$; Ref. Chapter 8.11, Holtz and Kovacs 1981
4. $e_o = (C_c/0.54)+0.35$; Ref. Table 6-11, FHWA GEC 5
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; $I = [\beta+\sin(\beta)\cos(\beta+2\delta)]/\pi$, where $\beta = \tan^{-1}[(x+B/2)/Z_f]-\delta$, $\delta = \tan^{-1}[(x-B/2)/Z_f]$ and x = horizontal distance from center of footing; Ref. Figure 6.13 and Equation 6.24, Das 2005
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesive soil layers)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
11. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0

$(S_c)_t$ = 0.827 in

Settlement Remaining After Hold Period: 0.093 in



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Select Granular Backfill	🟨	120	Mohr-Coulomb	0	34
Item 203 Emb.	🟩	120	Mohr-Coulomb	0	30
Ex. Emb. St-VSt A-6b	🟧	120	Mohr-Coulomb	0	26
Ex. Emb. VSt A-6a	🟪	120	Mohr-Coulomb	0	27
MS A-6b	🟫	115	Mohr-Coulomb	0	25
MD A-2-4	🟥	125	Mohr-Coulomb	0	32
De-VD A-2-4	🟪	135	Mohr-Coulomb	0	36
VD A-1-a	🟩	135	Mohr-Coulomb	0	38
Hd A-4a	🟪	130	Mohr-Coulomb	100	30
Hd A-6a	🟩	130	Mohr-Coulomb	50	28
VSt A-6b	🟨	120	Mohr-Coulomb	0	26
Item 203 Gra. Emb.	🟥	120	Mohr-Coulomb	0	32

Support Name	Color	Type	Strip Coverage (%)	Allowable Tensile Strength (lbs/ft)
MSE Reinforcement Straps	🟦	Geosynthetic	100	7500

Resource International, Inc.
Planning | Engineering | Construction Management | Technology

SLIDEINTERPRET 9.019

Project	FRA-70-22.85 FEF - Retaining Wall 6 - FRA-BRICE-04342 Rear Abutment
Analysis Description	Global Stability - Sta. 10+00 to 12+55 (BL Wall 6) - B-067-0-19 and B-003-0-65 - Level Backfill - 29.3 ft. Wall Height - Drained - Circular
Drawn By	BRT
Scale	1:200
Company	Resource International, Inc.
Date	3/24/2022, 11:19:08 AM
File Name	Wall 6 - Global Stability.slmd