Resource International, Inc.

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CAR-GRANT STREET
BRIDGE REPLACEMENT
PID 120055
CARROLL COUNTY, OHIO

STRUCTURE FOUNDATION EXPLORATION REPORT

Prepared For:
Village of Minerva
209 North Market Street
Minerva, Ohio 44657

Prepared By:
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Rii Project No. W-23-185

October 2025

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April 18, 2024 (Revised October 2, 2025)

Mr. James T. Williams
Service Director
Village of Minerva
209 North Market Street
Minerva, Ohio 44657

Re: Structure Foundation Exploration Report
CAR-Grant Street Bridge Replacement
PID 120055
Minerva, Carroll County, Ohio
Rii Project No. W-23-185

Mr. Williams:

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 replacement of the existing bridge carrying Grant Street over Sandy Creek in the Village of Minerva, Carroll County, Ohio. This revised report supersedes our previous submittals.

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

Sincerely,

RESOURCE INTERNATIONAL, INC.

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

Jonathan P. Sterenberg, P.E.
Vice President – Geotechnical Services

Enclosure: Revised Structure Foundation Exploration Report

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EXECUTIVE SUMMARY

Resource International, Inc. (Rii) has completed a structure foundation exploration performed for the design and construction of the proposed replacement of the existing bridge (CAR GRANT 00860, SFN 1032321) carrying Grant Street over Sandy Creek in the Village of Minerva, Carroll County, Ohio.

Rii understands the existing structure is a single-span galvanized steel pony truss on concrete wall type abutments, with steel decking and an asphalt concrete wearing surface. The length of the existing bridge is 90 feet with a total bridge width of approximately 20 feet from one face of rail to the other. The proposed bridge replacement will consist of a single span structure on prestressed concrete box beams with a reinforced concrete deck and cast-in-place semi-integral abutments on driven piles. The length of the proposed bridge is 95 feet with a total width of 31 feet form one face of rail to the other.

Exploration and Findings

On January 30 and 31, 2024, a total of two (2) borings, designated as B-001-0-24 and B-002-024, were performed for this project. The borings were performed for the proposed bridge replacement and were advanced to depths of 90.0 feet each below the existing grade.

Borings B-001-0-24 and B-002-0-24 were drilled through the existing roadway surface of Grant Street and encountered asphalt pavement with thicknesses of 17.0 and 10.0 inches, respectively. No aggregate base material was encountered below the asphalt pavement. Below the surficial materials, the soil borings encountered existing fill to depths of 3.0 and 8.3 feet below the existing ground surface in borings B-001-0-24 and B-002-0-24, respectively. Underlying the fill, natural granular soils described as gravel, gravel with sand, gravel with sand and silt, coarse and fine sand, and fine sand (ODOT A-1-a, A-1-b, A-2-4, A-3a, A-3) were encountered.

During drilling groundwater was encountered in borings B-001-0-24 and B-002-0-24 at depths of 10.0 and 11.0 feet below the existing ground surface, respectively. Groundwater was not able to be measured due to the introduction of water or drilling mud during the drilling process.

Analyses and Recommendations

Given the subsurface conditions encountered, Rii recommends that steel CIP pipe piles (ODOT Item 507.06) driven to the depth of the ultimate bearing value (UBV) be employed for foundation support.

Given the proximity of the construction to the nearby existing residential structures, there is a risk of inducing total and/or differential settlement of these structures due to vibrations from the pile driving operations. Therefore, it is recommended to pre-bore the piles at the rear abutment to a minimum elevation of 1014 feet.

Driven Pile Recommendations

Given the subsurface conditions encountered, Rii recommends that steel CIP pipe piles (ODOT Item 507.06) driven to the depth of the ultimate bearing value (UBV) be employed for foundation support. The geotechnical/structural resistance recommendations for CIP pipe piles are provided in the following table.

Substructure Reference	Bottom of Footing [1] (feet)	Pile Size / Type	Min. Req. Pile Wall Thickness (inch)	Pile Elevation (feet)		Est. Pile Length [3] (feet)	Scour Friction (kips)	UBV [4] (kips/pile)	φ_{dyn} [5]
				Top [2]	Tip				
Rear Abutment (B-001-0-24)	1032.5	12" CIP (ASTM A252, Grade 3 Steel)	0.25 (1/4)	1033.5	955.0	80.0	16.6	330.0	0.7
Forward Abutment (B-002-0-24)	1031.5		0.25 (1/4)	1032.5	961.0	75.0	11.3	263.7	

1. *Bottom of footing elevation determined from design plans provided by Carpenter Marty Transportation.*
2. *The top of pile elevation corresponds to the pile cutoff elevation, which is considered to be 1.0-foot above the bottom of footing elevation.*
3. *Per Section 305.3.5.2 of the 2023 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. Order (furnished) length for each pile should be calculated by adding 5 feet on estimated pile length.*
4. *UBV is the required resistance that an individual pile is expected to provide based on the structural loading and accounting for the applicable geotechnical resistance factor. Values are determined based on the design maximum factored structural loads and scour elevations provided by Carpenter Marty Transportation, as per Section 606.2 of the ODOT BDM, as well as the estimated pre-bore elevation at the rear abutment.*
5. *The resistance factor listed assumes dynamic testing of the pile elements per Section 305.7.1 of the 2023 ODOT BDM.*

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

1.0 INTRODUCTION

This report is a presentation of the structure foundation exploration performed for the design and construction of the proposed replacement of the existing bridge (CAR GRANT 00860, SFN 1032321) carrying Grant Street over Sandy Creek in the Village of Minerva, Carroll County, Ohio.

Rii understands the existing structure is a single-span galvanized steel pony truss on concrete wall type abutments, with steel decking and an asphalt concrete wearing surface. The length of the existing bridge is 90 feet with a total bridge width of approximately 20 feet from one face of rail to the other. The proposed bridge replacement will consist of a single span structure on prestressed concrete box beams with a reinforced concrete deck and cast-in-place semi-integral abutments on driven piles. The length of the proposed bridge is 95 feet with a total width of 31 feet form one face of rail to the other.

2.0 GEOLOGY AND OBSERVATIONS OF THE PROJECT

2.1 Site Geology

The site is located within the Muskingum-Pittsburgh Plateau Region of the Allegheny Plateau Section. The region is within the unglaciated area of Ohio and is characterized generally by a moderately high to high relief dissected plateau having broad river valleys that contain outwash terraces, and tributaries with lacustrine terraces. Surficial deposits include silt-loam colluvium derived from local bedrock, including weathered material, landslides, and bedrock outcrop, as well as alluvium in valleys.

Based on the Ohio Department of Natural Resources (ODNR) bedrock maps, the overburden soils are underlain by Pennsylvanian-aged Allegheny and Pottsville bedrock formations. The Allegheny and Pottsville formations consist of undifferentiated shale, siltstone, sandstone, and conglomerate, underclay, coal and flint.

Based on the Ohio Department of Natural Resources (ODNR) bedrock topography maps, the bedrock surface elevations in the vicinity of this project site ranges from approximately 850 to 840 feet which is approximately 190 to 200 feet below the existing roadway grade.

2.2 Existing Conditions

The site of the proposed structure replacement is located on Grant Street in the southern area of the Village of Minerva, approximately 750 feet southeast of the intersection of Grant Street and Valley Street (SR 183). The existing structure is a 90-foot long single-span galvanized steel pony truss on concrete wall type abutments, with steel decking and an asphalt concrete wearing surface. In the vicinity of the project area, the existing roadway is a two-lane, bidirectional, asphalt surfaced roadway with an

approximate width of 20.0 feet that is aligned northwest to southeast. Within the project limits, the roadway traverses primarily along residential properties. Overhead electric lines aligned northwest to southeast were observed along the north side of Grant Street.

3.0 EXPLORATION

On January 30 and 31, 2024, a total of two (2) borings, designated as B-001-0-24 and B-002-024, were performed for this project. The borings were performed for the proposed bridge replacement and were advanced to depths of 90.0 feet each below the existing grade.

The soil borings were performed at the locations shown on the boring plan provided in Appendix I of this report. A summary of soil borings information is provided in Table 1.

Table 1. Test Boring Summary

Boring Number	Station [1]	Offset [1]	Latitude	Longitude	Ground Elevation [1] (feet)	Boring Depth (feet)
B-001-0-24	6+54	5' RT	40.723280°	-81.104480°	1042.9	90.0
B-002-0-24	7+88	8' LT	40.723108°	-81.104053°	1043.8	90.0

1. Station, offset and ground surface elevations were provided by Carpenter Marty Transportation.

The boring locations were determined and located in the field by Rii personnel. Rii utilized a handheld GPS unit to obtain geographic latitude and longitude coordinates of the boring locations. The borings were later surveyed by Carpenter Marty Transportation. Ground surface elevations, stations, offsets, and coordinates were provided by Carpenter Marty Transportation. Elevations reference the North American Vertical Datum of 1988 (NAVD 88).

The borings were drilled using a CME 550X truck mounted rotary drilling machine, utilizing 3.25-inch inside diameter hollow-stem augers to advance the holes. Standard penetration testing (SPT) and split spoon sampling were performed at 2.5-foot intervals to a depth of 35.0 feet below the existing ground surface, followed by 5-foot intervals to the boring termination depths. In addition, continuous (1.5-foot) SPT sampling was performed beginning where the existing stream channel meets the existing abutment, to 6 feet below in both borings to obtain soil samples for scour considerations.

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. A calibrated automatic drop hammer was utilized to generate consistent energy transfer to the sampler. Driving resistance is recorded on the boring logs in terms of blows per 6.0-inch interval of the driving distance. The second and third intervals are added to obtain the number of blows per foot (N). Standard penetration blow counts aid in determining soil properties applicable in

foundation design. Measured blow count (N) values are corrected to an equivalent (60%) energy ratio, N_{60}, by the following equation. Both values are represented on boring logs in Appendix III.

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

Where:

N = measured N value

ER = drill rod energy ratio, expressed as a percent, for the system used

The hammer for the CME 550X drill rig was calibrated on April 28, 2023, and had a drill rod energy ratio of 85.0 percent.

At the completion of drilling in borings, the boreholes were allowed to naturally collapse, and the remainder of the open boreholes were backfilled with a mixture of soil cuttings and bentonite chips. The pavement was patched with an equivalent thickness of cold patch asphalt.

In general, for instances of no recovery from standard split spoon sampling, a 3.0-inch outside diameter split spoon sampler was driven the full length of the standard split spoon interval plus an additional 6.0 inches to obtain a representative sample. These samples are designated with a “3S” preceding the sample number on the boring logs. Only the final 6.0 inches of sample were retained for classification.

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

Table 2. Laboratory Test Schedule

Laboratory Test	Test Designation	Number of Tests Performed
Natural Moisture Content	ASTM D 2216	51
Plastic and Liquid Limits	AASHTO T89, T90	0
Gradation – Sieve/Hydrometer	AASHTO T88	15
Gradation – Sieve Only	AASHTO T88	1

The tests performed are necessary to classify the existing soil according to the Ohio Department of Transportation (ODOT) classification system and to estimate engineering properties of importance for foundation design and construction recommendations. Results of the laboratory testing are presented on the boring logs in Appendix III.

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 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. A description of the soil terms used throughout this report is presented in Appendix II.

4.1 Surface Materials

Borings B-001-0-24 and B-002-0-24 were drilled through the existing roadway surface of Grant Street and encountered asphalt pavement with thicknesses of 17.0 and 10.0 inches, respectively. No aggregate base material was encountered below the asphalt pavement.

4.2 Subsurface Soils

Below the surficial materials, the soil borings encountered existing fill to depths of 3.0 and 8.3 feet below the existing ground surface in borings B-001-0-24 and B-002-0-24, respectively. The fill was described as gravel and coarse and fine sand (ODOT A-1-a, A-3a) and contained brick, coal, asphalt and concrete fragments.

Underlying the fill, natural granular soils described as gravel, gravel with sand, gravel with sand and silt, coarse and fine sand, and fine sand (ODOT A-1-a, A-1-b, A-2-4, A-3a, A-3) were encountered. The relative density of granular soils is primarily derived from SPT blow counts (N_{60}). Based on the SPT blow counts obtained, the relative density of the granular soils encountered ranged from very loose ($N_{60} \leq 5$ blows per foot [bpf]) to very dense ($N_{60} > 50$ bpf). The majority of the soils were medium dense in relative density. SPT blow counts (N_{60}) of the granular and cohesionless soils deposits ranged from 3 bpf to 58 bpf.

Natural moisture contents of the soil samples tested ranged from 12 to 30 percent.

4.3 Bedrock

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

4.4 Groundwater

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

Table 3. Groundwater Levels

Boring Number	Ground Elevation (feet)	During Drilling		Upon Completion [1]	
		Depth (feet)	Elevation (feet)	Depth (feet)	Elevation (feet)
B-001-0-24	1042.9	10.0	1032.9	N/A	N/A
B-002-0-24	1043.8	11.0	1032.8	N/A	N/A

1. *Groundwater at completion was not able to be measured due to the introduction of water as a circulating fluid during rock coring.*

During drilling groundwater was encountered in borings B-001-0-24 and B-002-0-24 at depths of 10.0 and 11.0 feet below the existing ground surface, respectively. Groundwater was not able to be measured due to the introduction of water or drilling mud during the drilling process.

Please note that short-term water level readings are not necessarily an accurate indication of the actual groundwater level. In addition, groundwater levels or the presence of groundwater are considered to be dependent on seasonal fluctuations in precipitation.

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

5.0 ANALYSES AND RECOMMENDATIONS

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

Design details of the proposed structure were provided by Carpenter Marty Transportation. Based on the information provided, the proposed bridge replacement will consist of a single span structure on prestressed concrete box beams with a reinforced concrete deck and cast-in-place semi-integral abutments on driven piles. The length of the proposed bridge is 95 feet with a total width of 31 feet form one face of rail to the other.

Based on the available plans, the proposed roadway grade in the vicinity of the proposed bridge will approximately match existing grades. Further, it is understood that rear

abutment service and strength axial pile loads of 97 and 133 kips, receptively, are anticipated, and rear abutment service and strength axial pile loads of 99 and 135 kips, respectively, are anticipated. Further, it is understood that the scour design flood elevations at the rear and forward abutments are 1030.09 and 1028.91 feet, respectively.

Table 4. Bridge Design Elevations and Loads

Substructure Unit (Boring)	Structure Component	Elevation (feet)	Design Maximum Factored Load (kips)
Rear Abutment (B-001-0-24)	Bottom of Footing	1032.5	133
Forward Abutment (B-002-0-24)	Bottom of Footing	1031.5	135

If the design details of the proposed structure and/or proposed site grading differs from what is described in this report, Rii should be provided the information for our report revised or amended, as necessary.

5.1 Driven Pile Recommendations

Given the subsurface conditions encountered, Rii recommends that steel CIP pipe piles (ODOT Item 507.06) driven to the depth of the ultimate bearing value (UBV) be employed for foundation support. The geotechnical/structural resistance recommendations for CIP pipe piles are provided in Table 5. If higher loading per pile is anticipated for the proposed foundation then Rii should be provided the information for our analyses and our recommendations should be revised.

Given the proximity of the construction to the nearby existing residential structures, there is a risk of inducing total and/or differential settlement of these structures due to vibrations from the pile driving operations. Therefore, it is recommended to pre-bore the piles at the rear abutment to a minimum elevation of 1014 feet. A vibration impact assessment has been performed in accordance with Section 305.3.6 of the 2020 ODOT BDM, and is presented in Section 5.1.4 and Appendix VI.

Per Section 305.3.1.2 of the 2020 ODOT BDM, refusal is met during driving when the pile penetration is an inch or less after receiving at least 20 blows from the pile hammer. Table 5 shows the recommended pile lengths and the corresponding ultimate bearing value (UBV) of the steel CIP pipe piles.

Table 5. Driven Pile Recommendations

Substructure Reference	Bottom of Footing [1] (feet)	Pile Size / Type	Min. Req. Pile Wall Thickness (inch)	Pile Elevation (feet)		Est. Pile Length [3] (feet)	Scour Friction (kips)	UBV [4] (kips/pile)	φ_{dyn} [5]
				Top [2]	Tip				
Rear Abutment (B-001-0-24)	1032.5	12" CIP (ASTM A252, Grade 3 Steel)	0.25 (1/4)	1033.5	955.0	80.0	16.6	330.0	0.7
Forward Abutment (B-002-0-24)	1031.5		0.25 (1/4)	1032.5	961.0	75.0	11.3	263.7	

1. *Bottom of footing elevation determined from design plans provided by Carpenter Marty Transportation.*
2. *The top of pile elevation corresponds to the pile cutoff elevation, which is considered to be 1.0-foot above the bottom of footing elevation.*
3. *Per Section 305.3.5.2 of the 2023 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. Order (furnished) length for each pile should be calculated by adding 5 feet on estimated pile length.*
4. *UBV is the required resistance that an individual pile is expected to provide based on the structural loading and accounting for the applicable geotechnical resistance factor. Values are determined based on the design maximum factored structural loads and scour elevations provided by Carpenter Marty Transportation, as per Section 606.2 of the ODOT BDM, as well as the estimated pre-bore elevation at the rear abutment.*
5. *The resistance factor listed assumes dynamic testing of the pile elements per Section 305.7.1 of the 2023 ODOT BDM.*

The factored structural axial resistances listed in Table 5 consider an axially loaded pile with negligible moment, no appreciable loss of section due to deterioration throughout the life of the structure, no capacity reduction due to scour, Grade 3 steel with a yield strength of 45 ksi, and piles fully braced along their length.

The piles were analyzed using the DrivenPiles 1.4.0 software program and the results are provided in Appendix V. The ultimate bearing values listed in Table 5 were calculated in accordance with Section 305.3.2 and 305.3.4 of the ODOT BDM and Section 1304.1 of the ODOT GDM. IN addition, UBV and resulting piles lengths in Table 5 consider the capacity reduction due to scour within Sandy Creek.

The ultimate bearing values listed in Table 5 represent the calculated nominal values at the end of service life. The CIP pipe piles will be driven into predominantly granular soils (ODOT A-1-a, A-1-b, A-2-4, A-3a, A-3) that are present below the proposed abutments. Therefore, soil-pile setup is not anticipated to be required to achieve the required bearing resistance, and a wait period or restrike of the piles should not be required. However, the capacity at the EOID should be verified through the use of dynamic testing. Dynamic testing at the rear and forward abutments at the EOID should achieve minimum axial capacities of 348.0 and 275.0 kips, respectively.

The estimated friction loss due to pre-boring the piles at the rear abutment is 9.4 kips.

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 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 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 D4945. Further installation considerations are presented in Section 5.1.2.

5.1.1 Drivability

Drivability analyses were performed in accordance with Section 10.7.8 of the 2020 AASHTO LRFD BDS using the GRLWEAP software program, and the results are provided in Appendix IV. 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. Based on the results of this analysis, driving stresses induced on the CIP-piles **would not exceed** 90 percent of the yield stress of the steel (f_y = 45 ksi, 0.9f_y = 40.5 ksi) if driven to the elevations provided in Table 5. Care should be taken during pile driving operations to ensure that the driving stresses induced on the pile elements do not exceed the maximum allowable value of 90 percent of the yield stress of the steel, subsequently damaging the pile elements. Pile driving should be terminated upon achieving the required 20 blows from the pile hammer with an inch or less of penetration to reduce the possibility of damaging the pile element.

5.1.2 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. It is essential that installation be considered during the design stage to ensure that piles shown on the plans can be installed. 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 their pile 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 ODOT BDM.

5.1.3 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 V. In order to evaluate the lateral capacity, it is recommended that a derivation of COM624, such as LPILE, be utilized to determine the proper embedment depth required to resist the lateral load for a given end condition and deflection. Table 6 lists the eleven different soil types internal to the LPILE program. These strata were utilized to define the soil strata in the soil profile for each boring provided in Appendix V.

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)

5.1.4 Vibration Evaluation and Design Considerations

Several existing structures are located in the vicinity of the proposed bridge replacement. The nearest proposed structure appears to be residential in nature and is estimated to be approximately 40 feet from the location of proposed pile driving activities.

An analysis has been performed to estimate the induced vibration within the ground as a function of the distance from the pile and size of the impact hammer using the analysis procedure outlined in Section 7.1.1 of the California Department of Transportation (CalTrans) Transportation and Construction Vibration Guidance Manual. The following equation was used to estimate the peak particle velocity of the specified impact hammer at a specified distance from the pile.

$$PPV_{Impact\ Pile\ Driver} = PPV_{Ref}(25/D)^n \times \left(E_{equip}/R_{Ref}\right)^{0.5} \quad \text{(in/sec)}$$

Where:

PPV_{Ref} = 0.65 in/sec for a reference pile driver at 25 ft

D = distance from pile driver to the receiver (ft)

n = value related to the vibration attenuation rate through ground per Table 17 of the CalTrans Transportation and Construction Vibration Guidance Manual

E_{Ref} = 36,000 ft-lb (rated energy of reference pile driver)

E_{equip} = rated energy of impact pile driver in ft-lbs

Per Section 5.1.1, a Delmag D 19-42 hammer with a rated energy of approximately 44,000 ft-lbs was considered for installation of the piles. Based on a review of Table 17 of the CalTrans Transportation and Construction Vibration Guidance Manual, an n-value of 1.3 was selected based on the soil conditions encountered. The horizontal distance of the nearest existing structure to the rear abutment is approximately 40 feet. A minimum total distance to restrict peak particle velocities below the threshold value of 0.3 inches/second for damage to older residential structures is 50 feet. Therefore, the required vertical distance from pile driving operations to existing structures is 30 feet. The proposed rear abutment footing will bear 11 feet below existing grade, consequently the prebore length should extend 19 feet below the proposed bottom of rear abutment footing, corresponding to an elevation of 1014 feet.

The analysis performed and results provided above are valid for a hammer with a rated energy at or below 44,000 ft-lbs. If a hammer with a higher rated energy is utilized to install the piles, then larger peak particle velocities will be generated during the pile driving operations.

5.2 Scour Data

Soil borings performed for the proposed bridge replacement encountered granular soils consisting of gravel with sand, gravel with sand and silt, coarse and fine sand, and fine sand (ODOT A-1-b, A-2-4, A-3a, A-3) at or near the existing creek bed elevations. Classification tests were performed on the soil samples recovered from near the creek bed elevations for the scour considerations. A summary of soil parameters for scour analysis are tabulated in Table 7.

Table 7. Parameters for Scour Analysis

Boring Number	Sample	Elevation, (feet)	Soil Type	D_{50} (mm)	Critical Shear Stress τ_c, (psf)	$D_{50, equv.}$ (mm)	Erosion Category (EC)
B-001-0-24	SS-3	1036.9-1035.4	A-1-b	0.3500	0.0073	0.3500	1.653
	SS-4	1034.4-1032.9	A-3a	0.6800	0.0142	0.6800	1.999
	SS-6	1030.4-1028.9	A-1-b	0.9730	0.0203	0.9730	2.186
	SS-7	1028.9-1027.4	A-1-b	0.8440	0.0176	0.8440	2.112
	SS-8	1027.4-1025.9	A-1-b	0.7920	0.0165	0.7920	2.078
B-002-0-24	SS-4	1035.3-1033.8	A-1-b	0.6800	0.0142	0.680	1.999
	SS-5	1032.8-1031.3	A-2-4	1.0030	0.0209	1.003	2.202
	SS-7	1029.8-1028.3	A-3	0.4110	0.0086	0.411	1.737
	SS-8	1028.3-1026.8	A-3	0.3300	0.0069	0.330	1.622

5.3 Lateral Earth Pressure

For the soil types encountered in the borings, the "in-situ" unit weight (γ), cohesion (c), effective angle of friction (φ'), and lateral earth pressure coefficients for at-rest conditions (k_o), active conditions (k_a), and passive conditions (k_p) have been estimated and are provided in Table 8 and Table 9.

Table 8. Estimated Undrained (Short-term) Soil Parameters for Design

Soil Type	γ (pcf) [1]	c (psf)	φ	k_a	k_o	k_p
Very Loose to Loose Granular Soil	120	0	28°	0.36	0.53	2.77
Medium Dense to Very Dense Granular Soil	125	0	32°	0.31	0.47	3.25
Compacted Cohesive Engineered Fill	120	2,000	0°	N/A	N/A	N/A
Compacted Granular Engineered Fill	130	0	32°	0.31	0.47	3.25

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

Table 9. Estimated Drained (Long-term) Soil Parameters for Design

Soil Type	γ (pcf) [1]	c' (psf)	φ'	k_a	k_o	k_p
Very Loose to Loose Granular Soil	120	0	28°	0.36	0.53	2.77
Medium Dense to Very Dense Granular Soil	125	0	32°	0.31	0.47	3.25
Compacted Cohesive Engineered Fill	120	0	28°	0.36	0.53	2.77
Compacted Granular Engineered Fill	130	0	32°	0.31	0.47	3.25

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

These parameters are considered appropriate for the design of 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.

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.

Where necessary, temporary retaining structures, such as sheet pile system, should be designed using the undrained soil parameters provided in Table 8, and the design should follow all applicable guidelines for the type of retaining structure utilized. Permanent retaining and subsurface structures should be designed using the drained soil parameters provided in Table 9. 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.

5.4 Construction Considerations

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

5.4.1 Excavation Considerations

All excavations should be shored / braced or laid back at a safe angle in accordance with 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. Actual excavation back slopes must be field verified by qualified personnel at the time of excavation in strict accordance with OSHA guidelines.

5.4.2 Groundwater Considerations

Groundwater should be anticipated at or near the elevation as indicated in Table 3. Groundwater should be anticipated within the upper granular soils at the creek elevation when the creek level is above the normal pool elevation. Additionally, groundwater conditions affecting construction may be encountered within the trapped/perched zones. These trapped/perched zones are generally the layer(s) of granular soils that are isolated within the fine-grained soil layers and may not be identified in boring logs. If excavation encounter such layers, temporary dewatering may be accomplished by placing localized sumps and pumps within and beyond the excavation. Seepage rates from these layers are difficult to predict and flow rate could be significant.

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

6.0 LIMITATIONS OF STUDY

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

The recommendations for this project were developed utilizing soil and bedrock information obtained from the test borings that were made at the proposed site for the current investigation. Resource International is not responsible for the data, conclusions, opinions or recommendations made by others during previous investigations at this site. At this time we would like to point out that soil borings only depict the soil and bedrock conditions at the specific locations and time at which they were made. The conditions at other locations on the site may differ from those occurring at the boring locations.

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

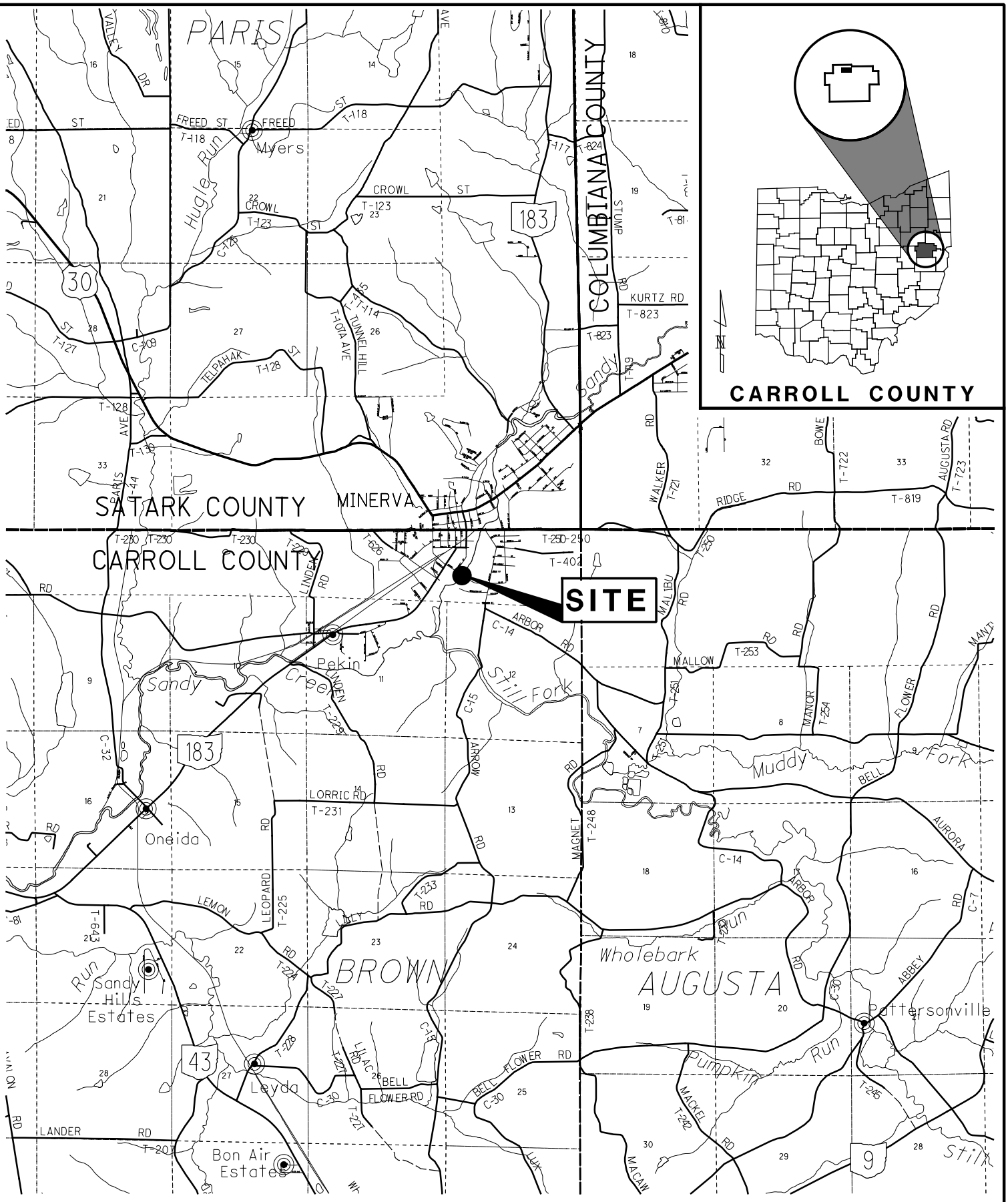
The scope of our services does not include any environmental assessment or investigation for the presence or absence of hazardous or toxic materials in the soil,

groundwater or surface water within or beyond the site studied. Any statements in this report or on the test boring logs regarding odors, staining of soils or other unusual conditions observed are strictly for the information of our client.

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

APPENDIX I

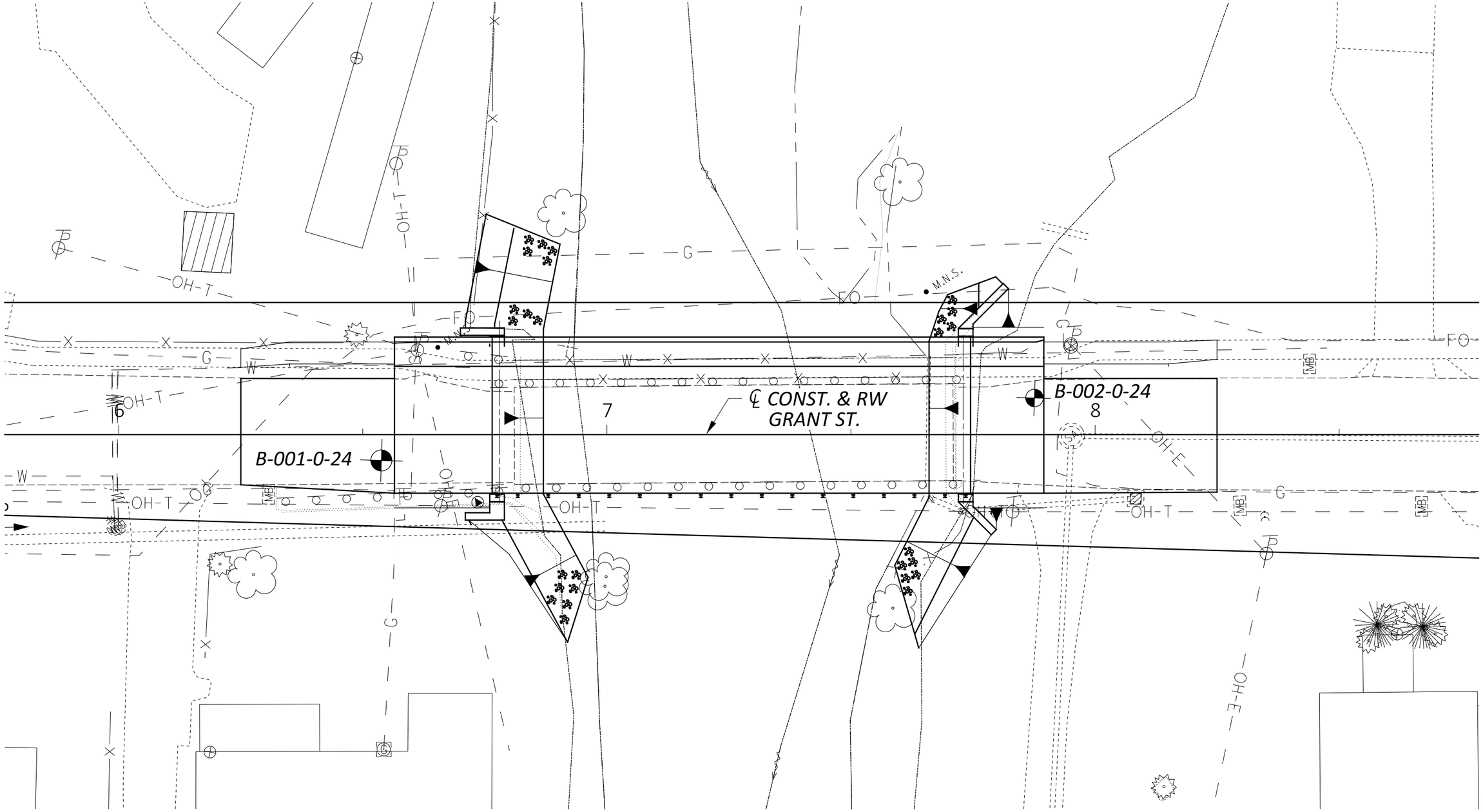
VICINITY MAP AND BORING PLAN



VICINITY MAP
CAR-GRANT STREET BRIDGE REPLACEMENT
CARROLL COUNTY, OHIO

RII PROJECT NO. W-23-185	DRAWN JAS
SCALE: 1"=5000' (0, 2500, 5000)	REVIEWED DEK
	DATE 4/5/2024

RESOURCE INTERNATIONAL



BORING PLAN
CAR-GRANT STREET BRIDGE REPLACEMENT
CARROLL COUNTY, OHIO

RII PROJECT NO. W-23-185		DRAWN JAS
SCALE: 1"=20' 0 10 20	N	REVIEWED DEK
		DATE 4/5/2024

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APPENDIX II

DESCRIPTION OF SOIL TERMS

DESCRIPTION OF SOIL TERMS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

CLASSIFICATION OF SOILS

Ohio Department of Transportation

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

SYMBOL	DESCRIPTION	Classifcation		LL_O/LL x 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	
	Fine Sand	A-3			51 Min.	10 Max.	NON-PLASTIC		0	
	Coarse and Fine Sand	--	A-3a			35 Max.		6 Max.	0	Min. of 50% combined coarse and fine sand sizes
	Gravel and/or Stone Fragments with Sand and Silt	A-2-4				35 Max.	40 Max.	10 Max.	0	
		A-2-5					41 Min.			
	Gravel and/or Stone Fragments with Sand, Silt and Clay	A-2-6				35 Max.	40 Max.	11 Min.	4	
		A-2-7					41 Min.			
	Sandy Silt	A-4	A-4a	76 Min.		36 Min.	40 Max.	10 Max.	8	Less than 50% silt sizes
	Silt	A-4	A-4b	76 Min.		50 Min.	40 Max.	10 Max.	8	50% or more silt sizes
	Elastic Silt and Clay	A-5		76 Min.		36 Min.	41 Min.	10 Max.	12	
	Silt and Clay	A-6	A-6a	76 Min.		36 Min.	40 Max.	11 - 15	10	
	Silty Clay	A-6	A-6b	76 Min.		36 Min.	40 Max.	16 Min.	16	
	Elastic Clay	A-7-5		76 Min.		36 Min.	41 Min.	$\leq$LL-30	20	
	Clay	A-7-6		76 Min.		36 Min.	41 Min.	>LL-30	20	
	Organic Silt	A-8	A-8a	75 Max.		36 Min.				W/o organics would classify as A-4a or A-4b
	Organic Clay	A-8	A-8b	75 Max.		36 Min.				W/o organics would classify as A-5, A-6a, A-6b, A-7-5 or A-7-6

MATERIAL CLASSIFIED BY VISUAL INSPECTION

 Sod and Topsoil

 Pavement or Base

 Uncontrolled Fill (Describe)

 Bouldery Zone

Peat

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

APPENDIX III

BORING LOGS:

B-001-0-24 & B-002-0-24

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: CAR-GRANT STREET BRIDGE	DRILLING FIRM / OPERATOR: ADC / TF	DRILL RIG: CME 550X (347863)	STATION / OFFSET: 6+54 / 5' RT	**EXPLORATION ID B-001-0-24**
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / ET	HAMMER: AUTOMATIC	ALIGNMENT: CL S GRAND BLVD	
PID: 120055 SFN: NA	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 4/28/23	ELEVATION: 1042.9 (MSL) EOB: 90.0 ft.	PAGE 1 OF 3
START: 1/30/24 END: 1/30/24	SAMPLING METHOD: SPT	ENERGY RATIO (%): 85	LAT / LONG: 40.723280, -81.104480	

MATERIAL DESCRIPTION AND NOTES	ELEV. 1042.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
1.4' - ASPHALT (17.0")	1041.5	1																
FILL: MEDIUM DENSE, BLACK TO BROWN **COARSE AND FINE SAND**, SOME FINE GRAVEL, TRACE SILT, MOIST. -TRACE COAL, BRICK AND ASPHALT FRAGMENTS	1039.7	2	5 5 3	11	89	SS-1	-	22	25	25	20	8	NP	NP	NP	13	A-3a (0)	
MEDIUM DENSE, BROWN **COARSE AND FINE SAND**, SOME FINE GRAVEL, TRACE SILT, MOIST.	1037.4	3																
		4	4 6 4	14	72	SS-2	-	-	-	-	-	-	-	-	-	13	A-3a (V)	
LOOSE, BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST.	1034.9	5																
		6	2 2 2	6	33	SS-3	-	32	26	24	11	7	NP	NP	NP	18	A-1-b (0)	
VERY LOOSE, BROWN **COARSE AND FINE SAND**, LITTLE SILT, TARCE FINE GRAVEL, TRACE CLAY, WET.	1032.4	7																
		8																
		9	1 1 1	3	67	SS-4	-	6	15	56	15	8	NP	NP	NP	17	A-3a (0)	
		W 1032.9 10																
VERY LOOSE TO MEDIUM DENSE, BROWN **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, WET.	1024.9	11																
		12	1 1 3	6	33	SS-5	-	-	-	-	-	-	-	-	-	20	A-1-b (V)	
		13	3 5 4	13	67	SS-6	-	34	34	24	5	3	NP	NP	NP	15	A-1-b (0)	
		14																
		15	3 1 1	3	61	SS-7	-	31	35	25	6	3	NP	NP	NP	19	A-1-b (0)	
		16	1 4 3	10	100	SS-8	-	19	52	22	4	3	NP	NP	NP	17	A-1-b (0)	
		17																
		18																
MEDIUM DENSE TO DENSE, BROWN **FINE SAND**, SOME COARSE SAND, SOME FINE GRAVEL, TRACE CLAY, WET.		19	1 3 6	13	100	SS-9	-	-	-	-	-	-	-	-	-	30	A-3 (V)	
		20																
		21																
		22	8 17 14	44	100	SS-10	-	-	-	-	-	-	-	-	-	12	A-3 (V)	
		23																
		24	7 9 9	26	100	SS-11	-	-	-	-	-	-	-	-	-	13	A-3 (V)	
		25																
		26																
		27	7 9 9	26	83	SS-12	-	26	22	45	4	3	NP	NP	NP	16	A-3 (0)	
		28																
		29	6 5 4	13	61	SS-13	-	-	-	-	-	-	-	-	-	18	A-3 (V)	

F S

RESOURCE INTERNATIONAL, INC.

PROJECT: CAR-GRANT STREET BRIDGE	DRILLING FIRM / OPERATOR: ADC / TF	DRILL RIG: CME 550X (347863)	STATION / OFFSET: 6+54 / 5' RT.	**EXPLORATION ID**	
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / ET	HAMMER: AUTOMATIC	ALIGNMENT: CL S GRAND BLVD	**B-001-0-24**	
PID: 120055 SFN: 106000	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 4/28/23	ELEVATION: 1042.9 (MSL) EOB: 90.0 ft.	PAGE	
START: 1/30/24 END: 1/30/24	SAMPLING METHOD: SPT	ENERGY RATIO (%): 85	LAT / LONG: 40.723280, -81.104480	1 OF 3	

MATERIAL DESCRIPTION AND NOTES	ELEV. 1042.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
1.4' - ASPHALT (17.0")	1041.5	1																
FILL: MEDIUM DENSE, BLACK TO BROWN **COARSE AND FINE SAND**, SOME FINE GRAVEL, TRACE SILT, MOIST. -TRACE COAL, BRICK AND ASPHALT FRAGMENTS	1039.7	2	5 5 3	11	89	SS-1	-	22	25	25	20	8	NP	NP	NP	13	A-3a (0)	
MEDIUM DENSE, BROWN **COARSE AND FINE SAND**, SOME FINE GRAVEL, TRACE SILT, MOIST.	1037.4	3																
		4	4 6 4	14	72	SS-2	-	-	-	-	-	-	-	-	-	13	A-3a (V)	
LOOSE, BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST.	1034.9	5																
		6	2 2 2	6	33	SS-3	-	32	26	24	11	7	NP	NP	NP	18	A-1-b (0)	
VERY LOOSE, BROWN **COARSE AND FINE SAND**, LITTLE SILT, TARCE FINE GRAVEL, TRACE CLAY, WET.	1032.4	7																
		8																
		9	1 1 1	3	67	SS-4	-	6	15	56	15	8	NP	NP	NP	17	A-3a (0)	
		W 1032.9 10																
VERY LOOSE TO MEDIUM DENSE, BROWN **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, WET.		11																
		12	1 1 3	6	33	SS-5	-	-	-	-	-	-	-	-	-	20	A-1-b (V)	
		13	3 5 4	13	67	SS-6	-	34	34	24	5	3	NP	NP	NP	15	A-1-b (0)	
		14																
		15	3 1 1	3	61	SS-7	-	31	35	25	6	3	NP	NP	NP	19	A-1-b (0)	
		16	1 4 3	10	100	SS-8	-	19	52	22	4	3	NP	NP	NP	17	A-1-b (0)	
	1024.9	17																
MEDIUM DENSE TO DENSE, BROWN **FINE SAND**, SOME COARSE SAND, SOME FINE GRAVEL, TRACE CLAY, WET.		18																
		19	1 3 6	13	100	SS-9	-	-	-	-	-	-	-	-	-	30	A-3 (V)	
		20																
		21																
		22	8 17 14	44	100	SS-10	-	-	-	-	-	-	-	-	-	12	A-3 (V)	
		23																
		24	7 9 9	26	100	SS-11	-	-	-	-	-	-	-	-	-	13	A-3 (V)	
		25																
		26																
		27	7 9 9	26	83	SS-12	-	26	22	45	4	3	NP	NP	NP	16	A-3 (0)	
		28																
		29	6 5 4	13	61	SS-13	-	-	-	-	-	-	-	-	-	18	A-3 (V)	

F S

000-23 RII STA ODOT BORING LOG (8.5X11) - OH DOT.GDT - 12/3/24 09:38 - U:\GI8\PROJECTS\2023\W-23-185.GPJ

PID: 120055	SFN: NA	PROJECT: CAR-GRANT STREET BRIDGE	STATION / OFFSET: 654, 5' RT.	START: 1/30/24	END: 1/30/24	PG 2 OF 3	B-001-0-24

MATERIAL DESCRIPTION AND NOTES	ELEV.	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
MEDIUM DENSE TO DENSE, BROWN **FINE SAND**, SOME COARSE SAND, SOME FINE GRAVEL, TRACE CLAY, WET. *(continued)* -WATER ADDED TO AUGERS	1012.9	31	6 12 9	30	100	SS-14	-	-	-	-	-	-	-	-	-	20	A-3 (V)	
		32																
		33																
		34	4 8 19	38	100	SS-15	-	-	-	-	-	-	-	-	-	21	A-3 (V)	
-7.0' OF HEAVING SANDS @31.0' AND 38.5'		35																
		36																
		37																
-7.0' OF HEAVING SANDS @ 38.5'		38																
		39	8 9 8	24	100	SS-16	-	-	-	-	-	-	-	-	-	24	A-3 (V)	
		40																
		41																
		42																
	F.S.	43																
-MUD ADDED TO AUGERS @ 43.5'		44	11 7 12	27	100	SS-17	-	3	41	53	1	2	NP	NP	NP	19	A-3 (0)	
		45																
		46																
		47																
		48																
		49	20 9 7	23	100	SS-18	-	-	-	-	-	-	-	-	-	23	A-3 (V)	
		50																
		51																
		52																
		53																
		54	7 5 7	17	0	SS-19	-	-	-	-	-	-	-	-	-	-		
	987.9	55	11	-	100	3S-19A	-	-	-	-	-	-	-	-	-	19	A-1-b (V)	
MEDIUM DENSE, BROWN **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, WET.		56																
		57																
		58																
		59	9 10 12	31	72	SS-20	-	-	-	-	-	-	-	-	-	17	A-1-b (V)	
		60																
		61																

PID: 120055	SFN: NA	PROJECT: CAR-GRANT STREET BRIDGE	STATION / OFFSET: 654, 5' RT.	START: 1/30/24	END: 1/30/24	PG 3 OF 3	B-001-0-24

MATERIAL DESCRIPTION AND NOTES	ELEV.	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
MEDIUM DENSE, BROWN **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, WET. *(continued)*	980.8	63																
		64	8 8 9	24	56	SS-21	-	-	-	-	-	-	-	-	-	21	A-1-b (V)	
		65																
		66																
		67																
		68																
		69	13 13 15	40	100	SS-22	-	-	-	-	-	-	-	-	-	13	A-1-b (V)	
		70																
		71																
		72																
		73																
		74	14 10 8	26	50	SS-23	-	30	29	36	3	2	NP	NP	NP	24	A-1-b (0)	
		75																
		76																
		77																
		78																
		79	9 10 11	30	61	SS-24	-	-	-	-	-	-	-	-	-	15	A-1-b (V)	
		80																
		81																
		82																
		83																
		84	7 4 3	10	0	SS-25	-	-	-	-	-	-	-	-	-	-		
		85	7	-	0	3S-25A	-	-	-	-	-	-	-	-	-	-		
		86																
		87																
		88																
		89	20 23 18	58	44	SS-26	-	-	-	-	-	-	-	-	-	20	A-1-b (V)	
	952.9	EOB 90																

NOTES: GROUNDWATER ENCOUNTERED @11.0'; WATER LEVEL @10.0' BEFORE WATER ADDED TO AUGERS @31.0'; CAVE-IN DEPTH @8.0'.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: BACKFILLED WITH 12.5 LBS. BENTONITE CHIPS AND SOIL CUTTINGS. PAVEMENT PATCHED WITH COLD PATCH ASPHALT .

RESOURCE INTERNATIONAL, INC.

PROJECT: CAR-GRANT STREET BRIDGE	DRILLING FIRM / OPERATOR: ADC / TF	DRILL RIG: CME 550X (347863)	STATION / OFFSET: 7+88 / 8' LT.	**EXPLORATION ID B-002-0-24**
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / ET	HAMMER: AUTOMATIC	ALIGNMENT: CL S GRAND BLVD	
PID: 120055 SFN: 106000	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 4/28/23	ELEVATION: 1043.8 (MSL) EOB: 90.0 ft.	PAGE 1 OF 3
START: 1/31/24 END: 1/31/24	SAMPLING METHOD: SPT	ENERGY RATIO (%): 85	LAT / LONG: 40.723108, -81.104053	

MATERIAL DESCRIPTION AND NOTES	ELEV. 1043.8	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.8' - ASPHALT (10.0")	1043.0																	
FILL: MEDIUM DENSE, BROWNISH BLACK **GRAVEL**, SOME SAND, TRACE SILT, TRACE CLAY, WET. -TRACE BRICK AND COAL FRAGMENTS	1040.6		6 3 5	11	33	SS-1	-	71	14	8	7	-	-	-	-	11	A-1-a (V)	
FILL: MEDIUM DENSE, BROWNISH BLACK **GRAVEL**, SOME SAND, TRACE SILT, TRACE CLAY, WET. -TRACE BRICK/CONCRETE FRAGMENTS @ 7.5' -WATER ADDED TO AUGERS @8.0'	1035.5		3 5 8	18	33	SS-2	-	-	-	-	-	-	-	-	-	9	A-1-a (V)	
			6 5 3	11	0	SS-3	-	-	-	-	-	-	-	-	-	-		
			6	-	33	3S-3A	-	-	-	-	-	-	-	-	-	10	A-1-a (V)	
MEDIUM DENSE, BROWN **GRAVEL WITH SAND**, TRACE SILT, WET.	1033.3		2 2 2	6	44	SS-4	-	36	21	18	14	11	NP	NP	NP	12	A-1-b (0)	
LOOSE TO MEDIUM DENSE, BROWN **GRAVEL WITH SAND AND SILT**, TRACE CLAY, WET.	1029.8	W 1032.8	1 2 3	7	39	SS-5	-	40	22	16	12	10	25	18	7	18	A-2-4 (0)	
			4 5 3	11	11	SS-6	-	-	-	-	-	-	-	-	-	18	A-2-4 (V)	
VERY LOOSE TO MEDIUM DENSE, BROWN TO GRAY **FINE SAND**, LITTLE GRAVEL, TRACE SILT AND CLAY, WET. -MUD ADDED TO AUGERS	1018.3		1 1 1	3	67	SS-7	-	11	38	41	5	5	NP	NP	NP	19	A-3 (0)	
			1 1 2	4	50	SS-8	-	13	30	49	4	4	NP	NP	NP	21	A-3 (0)	
			1 3 5	11	56	SS-9	-	24	36	29	4	7	NP	NP	NP	18	A-3 (V)	
			6 4 5	13	83	SS-10	-	-	-	-	-	-	-	-	-	18	A-3 (V)	
			1 3 5	11	44	SS-11	-	-	-	-	-	-	-	-	-	14	A-3 (V)	
MEDIUM DENSE, GRAY TO BROWNISH GRAY **GRAVEL**, "AND" COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, WET.			7 7 5	17	44	SS-12	-	-	-	-	-	-	-	-	-	12	A-1-a (V)	
			2 4 5	13	33	SS-13	-	54	28	13	2	3	NP	NP	NP	14	A-1-a (0)	

PID: 120055	SFN: NA	PROJECT: CAR-GRANT STREET BRIDGE	STATION / OFFSET: 788, 8' LT.	START: 1/31/24	END: 1/31/24	PG 2 OF 3	B-002-0-24

MATERIAL DESCRIPTION AND NOTES	ELEV. 1013.8	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
MEDIUM DENSE, GRAY TO BROWNISH GRAY **GRAVEL**, "AND" COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, WET. *(continued)*		31																
		32	4 6 7	18	56	SS-14	-	-	-	-	-	-	-	-	-	16	A-1-a (V)	
	1010.8	33																
MEDIUM DENSE TO DENSE, GRAY TO BROWN **FINE SAND**, LITTLE COARSE SAND, TRACE FINE GRAVEL, TRACE SILT, TRACE CLAY, WET.		34	3 7 8	21	61	SS-15	-	-	-	-	-	-	-	-	-	14	A-3 (V)	
		35																
		36																
		37																
		38																
		39	14 7 9	23	61	SS-16	-	-	-	-	-	-	-	-	-	16	A-3 (V)	
		40																
		41																
		42																
		43																
		44	4 6 11	24	83	SS-17	-	-	-	-	-	-	-	-	-	23	A-3 (V)	
		45																
		46																
		47																
		48																
-10.0' OF HEAVING SANDS @48.5'		49	4 6 9	21	100	SS-18	-	1	17	76	2	4	NP	NP	NP	21	A-3 (0)	
		50																
		51																
		52																
		53																
		54	15 16 14	43	83	SS-19	-	-	-	-	-	-	-	-	-	12	A-3 (V)	
		55																
		56																
		57																
		58																
		59	6 6 8	20	61	SS-20	-	-	-	-	-	-	-	-	-	17	A-3 (V)	
		60																
		61																

PID: 120055	SFN: NA	PROJECT: CAR-GRANT STREET BRIDGE	STATION / OFFSET: 788, 8' LT.	START: 1/31/24	END: 1/31/24	PG 3 OF 3	B-002-0-24

MATERIAL DESCRIPTION AND NOTES	ELEV.	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
MEDIUM DENSE TO DENSE, GRAY TO BROWN **FINE SAND**, LITTLE COARSE SAND, TRACE FINE GRAVEL, TRACE SILT, TRACE CLAY, WET. *(continued)*	981.7	63																
		64	10 14 13	38	72	SS-21	-	-	-	-	-	-	-	-	-	17	A-3 (V)	
		65																
		66																
		67																
		68																
		69	11 9 9	26	56	SS-22	-	-	-	-	-	-	-	-	-	13	A-3 (V)	
		70																
		71																
	972.1	72																
MEDIUM DENSE TO DENSE, BROWNISH GRAY **GRAVEL**, SOME COARSE AND FINE SAND, TRACE SILT, TRACE CLAY, WET.		73																
		74	4 10 10	28	50	SS-23	-	-	-	-	-	-	-	-	-	12	A-1-a (V)	
		75																
		76																
		77																
		78																
		79	1 5 10	21	44	SS-24	-	66	22	9	1	2	NP	NP	NP	16	A-1-a (0)	
		80																
		81																
		82																
		83																
		84	12 12 17	41	56	SS-25	-	-	-	-	-	-	-	-	-	15	A-1-a (V)	
		85																
		86																
		87																
		88																
		89	9 10 12	31	56	SS-26	-	-	-	-	-	-	-	-	-	17	A-1-a (V)	
	953.8	EOB 90																

NOTES: GROUNDWATER ENCOUNTERED @11.0'; WATER LEVEL @8.0' BEFORE MUD ADDED TO AUGERS @15.5'; CAVE-IN DEPTH @13.0'.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: BACKFILLED WITH 12.5 LBS. BENTONITE CHIPS AND SOIL CUTTINGS. PAVEMENT PATCHED WITH COLD PATCH ASPHALT .

APPENDIX IV

DRIVENPILES OUTPUTS

GRLWEAP DRIVABILITY ANALYSIS OUTPUTS

Rear Abutment
B-001-0-24

DrivenPiles - Report

General Project Information

Filename: C:\Users\Legacy\Documents\W-23-185\B-001-0-24\B-001-0-24.dvn
Project Name: CAR-Grant Street Bridge Replacement B-001-0-24
Project Client: CM Transportation
Prepared By: Rii
Project Manager: DEK

Pile Information

Pile Type: Pipe Pile - Closed End
Top of Pile: 19.00 ft
Diameter of Pile: 12.00 in

Nominal Considerations

Water Table Depth At Time Of:

Drilling:	0.00 ft
Driving/Restrike:	0.00 ft
Nominal:	0.00 ft

Nominal Considations:

Local Scour:	0.00 ft
Long Term Scour:	4.92 ft
Soft Soil:	0.00 ft

Nominal Profile

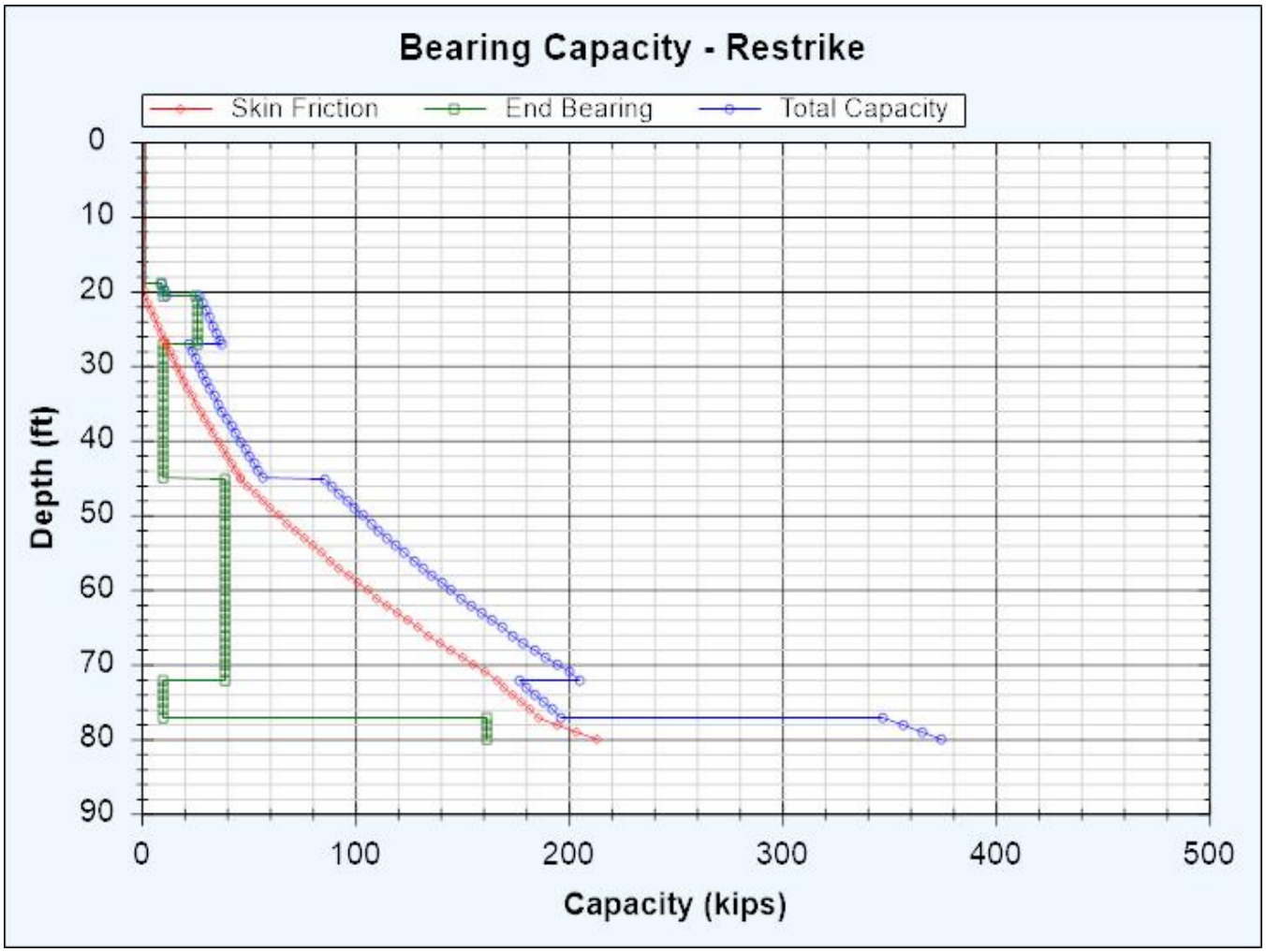
Layer	Soil Type	Thickness	Setup Factor	Unit Weight	Strength	Nominal Curve
1	Cohesionless	0.60 ft	1.000	115.00 pcf	26.0/26.0	Nordlund
2	Cohesionless	7.50 ft	1.000	120.00 pcf	28.0/28.0	Nordlund
3	Cohesionless	2.50 ft	1.200	125.00 pcf	27.0/27.0	Nordlund
4	Cohesionless	2.50 ft	1.200	130.00 pcf	34.0/34.0	Nordlund
5	Cohesionless	5.00 ft	1.200	130.00 pcf	30.0/30.0	Nordlund
6	Cohesionless	2.50 ft	1.200	125.00 pcf	27.0/27.0	Nordlund
7	Cohesionless	6.50 ft	1.200	130.00 pcf	32.0/32.0	Nordlund
8	Cohesionless	15.00 ft	1.200	125.00 pcf	30.0/30.0	Nordlund
9	Cohesionless	3.00 ft	1.200	125.00 pcf	28.0/28.0	Nordlund
10	Cohesionless	27.00 ft	1.000	130.00 pcf	33.0/33.0	Nordlund
11	Cohesionless	5.00 ft	1.000	120.00 pcf	29.0/29.0	Nordlund
12	Cohesionless	3.00 ft	1.000	135.00 pcf	37.0/37.0	Nordlund

Restrike - Summary of Capacities

Depth	Skin Friction	End Bearing	Total Capacity
0.01 ft	0.00 kips	0.00 kips	0.00 kips
0.59 ft	0.00 kips	0.00 kips	0.00 kips
0.61 ft	0.00 kips	0.00 kips	0.00 kips
1.60 ft	0.00 kips	0.00 kips	0.00 kips
2.60 ft	0.00 kips	0.00 kips	0.00 kips
3.60 ft	0.00 kips	0.00 kips	0.00 kips
4.60 ft	0.00 kips	0.00 kips	0.00 kips
4.91 ft	0.00 kips	0.00 kips	0.00 kips
4.93 ft	0.00 kips	0.00 kips	0.00 kips
5.92 ft	0.00 kips	0.00 kips	0.00 kips
6.92 ft	0.00 kips	0.00 kips	0.00 kips
7.92 ft	0.00 kips	0.00 kips	0.00 kips
8.09 ft	0.00 kips	0.00 kips	0.00 kips
8.11 ft	0.00 kips	0.00 kips	0.00 kips
9.10 ft	0.00 kips	0.00 kips	0.00 kips
10.10 ft	0.00 kips	0.00 kips	0.00 kips
10.59 ft	0.00 kips	0.00 kips	0.00 kips
10.61 ft	0.00 kips	0.00 kips	0.00 kips
11.60 ft	0.00 kips	0.00 kips	0.00 kips
12.60 ft	0.00 kips	0.00 kips	0.00 kips
13.09 ft	0.00 kips	0.00 kips	0.00 kips
13.11 ft	0.00 kips	0.00 kips	0.00 kips
14.10 ft	0.00 kips	0.00 kips	0.00 kips
15.10 ft	0.00 kips	0.00 kips	0.00 kips
16.10 ft	0.00 kips	0.00 kips	0.00 kips
17.10 ft	0.00 kips	0.00 kips	0.00 kips
18.09 ft	0.00 kips	0.00 kips	0.00 kips
18.11 ft	0.00 kips	0.00 kips	0.00 kips
18.99 ft	0.00 kips	0.00 kips	0.00 kips
19.01 ft	0.01 kips	9.46 kips	9.47 kips
20.00 ft	0.83 kips	9.96 kips	10.79 kips
20.59 ft	1.33 kips	10.17 kips	11.51 kips
20.61 ft	1.36 kips	25.40 kips	26.76 kips
21.60 ft	2.76 kips	25.92 kips	28.68 kips
22.60 ft	4.24 kips	25.92 kips	30.16 kips
23.60 ft	5.80 kips	25.92 kips	31.72 kips
24.60 ft	7.43 kips	25.92 kips	33.35 kips
25.60 ft	9.14 kips	25.92 kips	35.06 kips
26.60 ft	10.92 kips	25.92 kips	36.83 kips
27.09 ft	11.81 kips	25.92 kips	37.73 kips
27.11 ft	11.85 kips	10.46 kips	22.31 kips
28.10 ft	13.35 kips	10.46 kips	23.81 kips

Depth	Skin Friction	End Bearing	Total Capacity
29.10 ft	14.92 kips	10.46 kips	25.38 kips
30.10 ft	16.55 kips	10.46 kips	27.01 kips
31.10 ft	18.22 kips	10.46 kips	28.69 kips
32.10 ft	19.96 kips	10.46 kips	30.42 kips
33.10 ft	21.75 kips	10.46 kips	32.21 kips
34.10 ft	23.59 kips	10.46 kips	34.05 kips
35.10 ft	25.49 kips	10.46 kips	35.95 kips
36.10 ft	27.44 kips	10.46 kips	37.90 kips
37.10 ft	29.44 kips	10.46 kips	39.90 kips
38.10 ft	31.50 kips	10.46 kips	41.96 kips
39.10 ft	33.61 kips	10.46 kips	44.07 kips
40.10 ft	35.78 kips	10.46 kips	46.24 kips
41.10 ft	38.00 kips	10.46 kips	48.46 kips
42.09 ft	40.25 kips	10.46 kips	50.71 kips
42.11 ft	40.30 kips	10.46 kips	50.76 kips
43.10 ft	42.27 kips	10.46 kips	52.73 kips
44.10 ft	44.31 kips	10.46 kips	54.77 kips
45.09 ft	46.38 kips	10.46 kips	56.84 kips
45.11 ft	46.43 kips	39.27 kips	85.70 kips
46.10 ft	49.80 kips	39.27 kips	89.07 kips
47.10 ft	53.28 kips	39.27 kips	92.55 kips
48.10 ft	56.84 kips	39.27 kips	96.11 kips
49.10 ft	60.48 kips	39.27 kips	99.75 kips
50.10 ft	64.20 kips	39.27 kips	103.47 kips
51.10 ft	68.01 kips	39.27 kips	107.28 kips
52.10 ft	71.89 kips	39.27 kips	111.16 kips
53.10 ft	75.85 kips	39.27 kips	115.11 kips
54.10 ft	79.88 kips	39.27 kips	119.15 kips
55.10 ft	84.00 kips	39.27 kips	123.27 kips
56.10 ft	88.20 kips	39.27 kips	127.47 kips
57.10 ft	92.48 kips	39.27 kips	131.75 kips
58.10 ft	96.84 kips	39.27 kips	136.11 kips
59.10 ft	101.28 kips	39.27 kips	140.55 kips
60.10 ft	105.80 kips	39.27 kips	145.07 kips
61.10 ft	110.39 kips	39.27 kips	149.66 kips
62.10 ft	115.07 kips	39.27 kips	154.34 kips
63.10 ft	119.83 kips	39.27 kips	159.10 kips
64.10 ft	124.67 kips	39.27 kips	163.94 kips
65.10 ft	129.58 kips	39.27 kips	168.85 kips
66.10 ft	134.58 kips	39.27 kips	173.85 kips
67.10 ft	139.66 kips	39.27 kips	178.93 kips
68.10 ft	144.81 kips	39.27 kips	184.08 kips

Depth	Skin Friction	End Bearing	Total Capacity
69.10 ft	150.05 kips	39.27 kips	189.32 kips
70.10 ft	155.36 kips	39.27 kips	194.63 kips
71.10 ft	160.76 kips	39.27 kips	200.03 kips
72.09 ft	166.18 kips	39.27 kips	205.45 kips
72.11 ft	166.27 kips	10.46 kips	176.73 kips
73.10 ft	170.01 kips	10.46 kips	180.47 kips
74.10 ft	173.82 kips	10.46 kips	184.29 kips
75.10 ft	177.69 kips	10.46 kips	188.15 kips
76.10 ft	181.60 kips	10.46 kips	192.06 kips
77.09 ft	185.52 kips	10.46 kips	195.98 kips
77.11 ft	185.65 kips	161.82 kips	347.47 kips
78.10 ft	194.64 kips	161.82 kips	356.47 kips
79.10 ft	203.86 kips	161.82 kips	365.68 kips
80.09 ft	213.11 kips	161.82 kips	374.94 kips

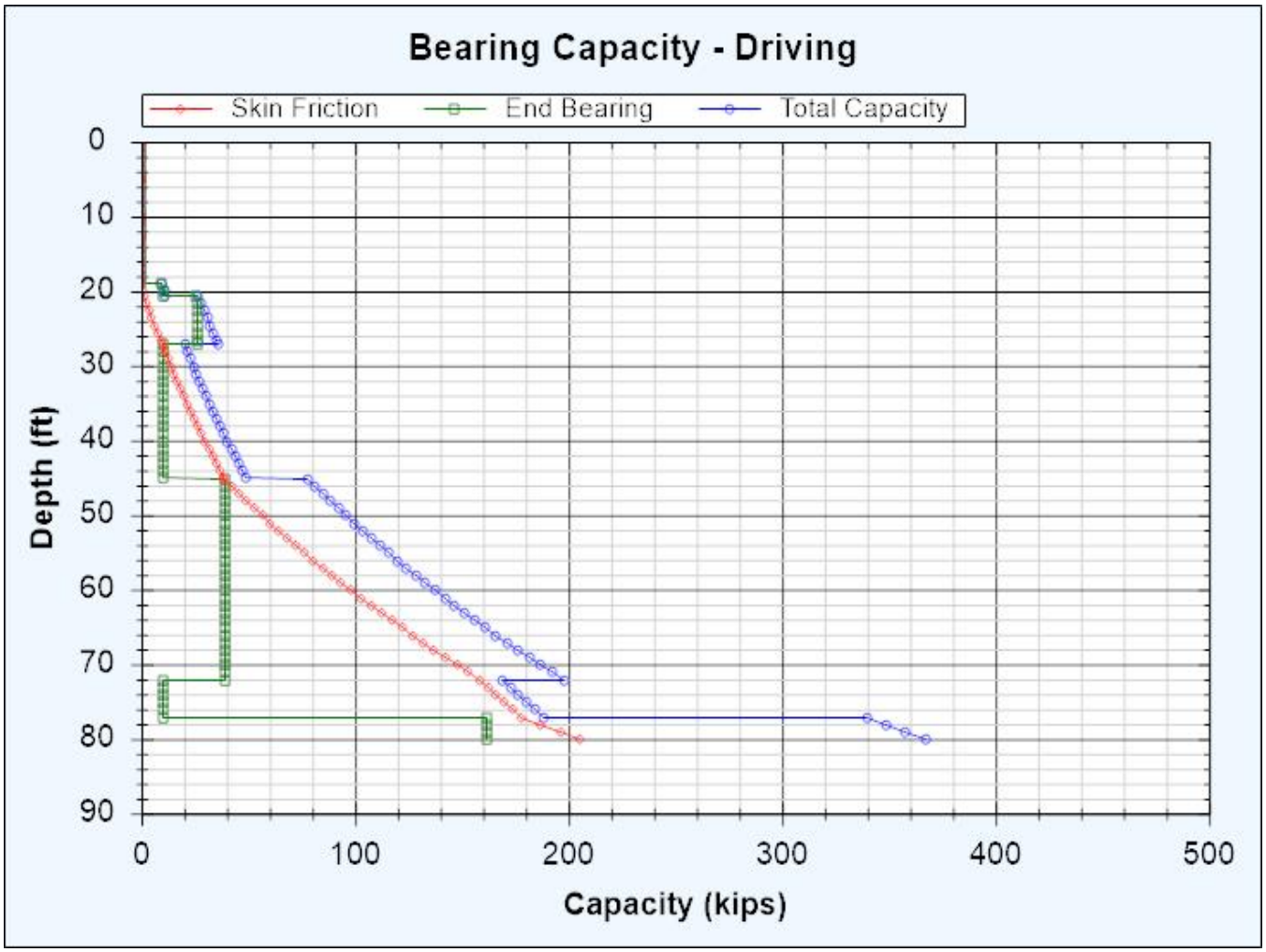

Bearing Capacity - Restrike
Skin Friction
End Bearing
Total Capacity
Depth (ft)
0
10
20
30
40
50
60
70
80
90
0
100
200
300
400
500
Capacity (kips)

Driving - Summary of Capacities

Depth	Skin Friction	End Bearing	Total Capacity
0.01 ft	0.00 kips	0.00 kips	0.00 kips
0.59 ft	0.00 kips	0.00 kips	0.00 kips
0.61 ft	0.00 kips	0.00 kips	0.00 kips
1.60 ft	0.00 kips	0.00 kips	0.00 kips
2.60 ft	0.00 kips	0.00 kips	0.00 kips
3.60 ft	0.00 kips	0.00 kips	0.00 kips
4.60 ft	0.00 kips	0.00 kips	0.00 kips
4.91 ft	0.00 kips	0.00 kips	0.00 kips
4.93 ft	0.00 kips	0.00 kips	0.00 kips
5.92 ft	0.00 kips	0.00 kips	0.00 kips
6.92 ft	0.00 kips	0.00 kips	0.00 kips
7.92 ft	0.00 kips	0.00 kips	0.00 kips
8.09 ft	0.00 kips	0.00 kips	0.00 kips
8.11 ft	0.00 kips	0.00 kips	0.00 kips
9.10 ft	0.00 kips	0.00 kips	0.00 kips
10.10 ft	0.00 kips	0.00 kips	0.00 kips
10.59 ft	0.00 kips	0.00 kips	0.00 kips
10.61 ft	0.00 kips	0.00 kips	0.00 kips
11.60 ft	0.00 kips	0.00 kips	0.00 kips
12.60 ft	0.00 kips	0.00 kips	0.00 kips
13.09 ft	0.00 kips	0.00 kips	0.00 kips
13.11 ft	0.00 kips	0.00 kips	0.00 kips
14.10 ft	0.00 kips	0.00 kips	0.00 kips
15.10 ft	0.00 kips	0.00 kips	0.00 kips
16.10 ft	0.00 kips	0.00 kips	0.00 kips
17.10 ft	0.00 kips	0.00 kips	0.00 kips
18.09 ft	0.00 kips	0.00 kips	0.00 kips
18.11 ft	0.00 kips	0.00 kips	0.00 kips
18.99 ft	0.00 kips	0.00 kips	0.00 kips
19.01 ft	0.01 kips	9.46 kips	9.47 kips
20.00 ft	0.69 kips	9.96 kips	10.65 kips
20.59 ft	1.11 kips	10.17 kips	11.29 kips
20.61 ft	1.13 kips	25.40 kips	26.53 kips
21.60 ft	2.30 kips	25.92 kips	28.22 kips
22.60 ft	3.54 kips	25.92 kips	29.45 kips
23.60 ft	4.84 kips	25.92 kips	30.75 kips
24.60 ft	6.20 kips	25.92 kips	32.11 kips
25.60 ft	7.62 kips	25.92 kips	33.53 kips
26.60 ft	9.10 kips	25.92 kips	35.01 kips
27.09 ft	9.84 kips	25.92 kips	35.76 kips
27.11 ft	9.87 kips	10.46 kips	20.33 kips
28.10 ft	11.12 kips	10.46 kips	21.58 kips

Depth	Skin Friction	End Bearing	Total Capacity
29.10 ft	12.43 kips	10.46 kips	22.89 kips
30.10 ft	13.79 kips	10.46 kips	24.25 kips
31.10 ft	15.19 kips	10.46 kips	25.65 kips
32.10 ft	16.63 kips	10.46 kips	27.09 kips
33.10 ft	18.12 kips	10.46 kips	28.58 kips
34.10 ft	19.66 kips	10.46 kips	30.12 kips
35.10 ft	21.24 kips	10.46 kips	31.70 kips
36.10 ft	22.86 kips	10.46 kips	33.32 kips
37.10 ft	24.53 kips	10.46 kips	34.99 kips
38.10 ft	26.25 kips	10.46 kips	36.71 kips
39.10 ft	28.01 kips	10.46 kips	38.47 kips
40.10 ft	29.82 kips	10.46 kips	40.28 kips
41.10 ft	31.67 kips	10.46 kips	42.13 kips
42.09 ft	33.54 kips	10.46 kips	44.00 kips
42.11 ft	33.58 kips	10.46 kips	44.04 kips
43.10 ft	35.22 kips	10.46 kips	45.69 kips
44.10 ft	36.93 kips	10.46 kips	47.39 kips
45.09 ft	38.65 kips	10.46 kips	49.11 kips
45.11 ft	38.70 kips	39.27 kips	77.97 kips
46.10 ft	42.07 kips	39.27 kips	81.34 kips
47.10 ft	45.55 kips	39.27 kips	84.82 kips
48.10 ft	49.11 kips	39.27 kips	88.38 kips
49.10 ft	52.75 kips	39.27 kips	92.02 kips
50.10 ft	56.47 kips	39.27 kips	95.74 kips
51.10 ft	60.27 kips	39.27 kips	99.54 kips
52.10 ft	64.15 kips	39.27 kips	103.42 kips
53.10 ft	68.11 kips	39.27 kips	107.38 kips
54.10 ft	72.15 kips	39.27 kips	111.42 kips
55.10 ft	76.27 kips	39.27 kips	115.54 kips
56.10 ft	80.47 kips	39.27 kips	119.74 kips
57.10 ft	84.75 kips	39.27 kips	124.02 kips
58.10 ft	89.11 kips	39.27 kips	128.38 kips
59.10 ft	93.54 kips	39.27 kips	132.81 kips
60.10 ft	98.06 kips	39.27 kips	137.33 kips
61.10 ft	102.66 kips	39.27 kips	141.93 kips
62.10 ft	107.34 kips	39.27 kips	146.61 kips
63.10 ft	112.09 kips	39.27 kips	151.36 kips
64.10 ft	116.93 kips	39.27 kips	156.20 kips
65.10 ft	121.85 kips	39.27 kips	161.12 kips
66.10 ft	126.84 kips	39.27 kips	166.11 kips
67.10 ft	131.92 kips	39.27 kips	171.19 kips
68.10 ft	137.08 kips	39.27 kips	176.35 kips

Depth	Skin Friction	End Bearing	Total Capacity
69.10 ft	142.31 kips	39.27 kips	181.58 kips
70.10 ft	147.63 kips	39.27 kips	186.90 kips
71.10 ft	153.02 kips	39.27 kips	192.29 kips
72.09 ft	158.44 kips	39.27 kips	197.71 kips
72.11 ft	158.54 kips	10.46 kips	169.00 kips
73.10 ft	162.27 kips	10.46 kips	172.73 kips
74.10 ft	166.09 kips	10.46 kips	176.55 kips
75.10 ft	169.95 kips	10.46 kips	180.42 kips
76.10 ft	173.87 kips	10.46 kips	184.33 kips
77.09 ft	177.78 kips	10.46 kips	188.25 kips
77.11 ft	177.91 kips	161.82 kips	339.74 kips
78.10 ft	186.91 kips	161.82 kips	348.73 kips
79.10 ft	196.12 kips	161.82 kips	357.95 kips
80.09 ft	205.38 kips	161.82 kips	367.20 kips

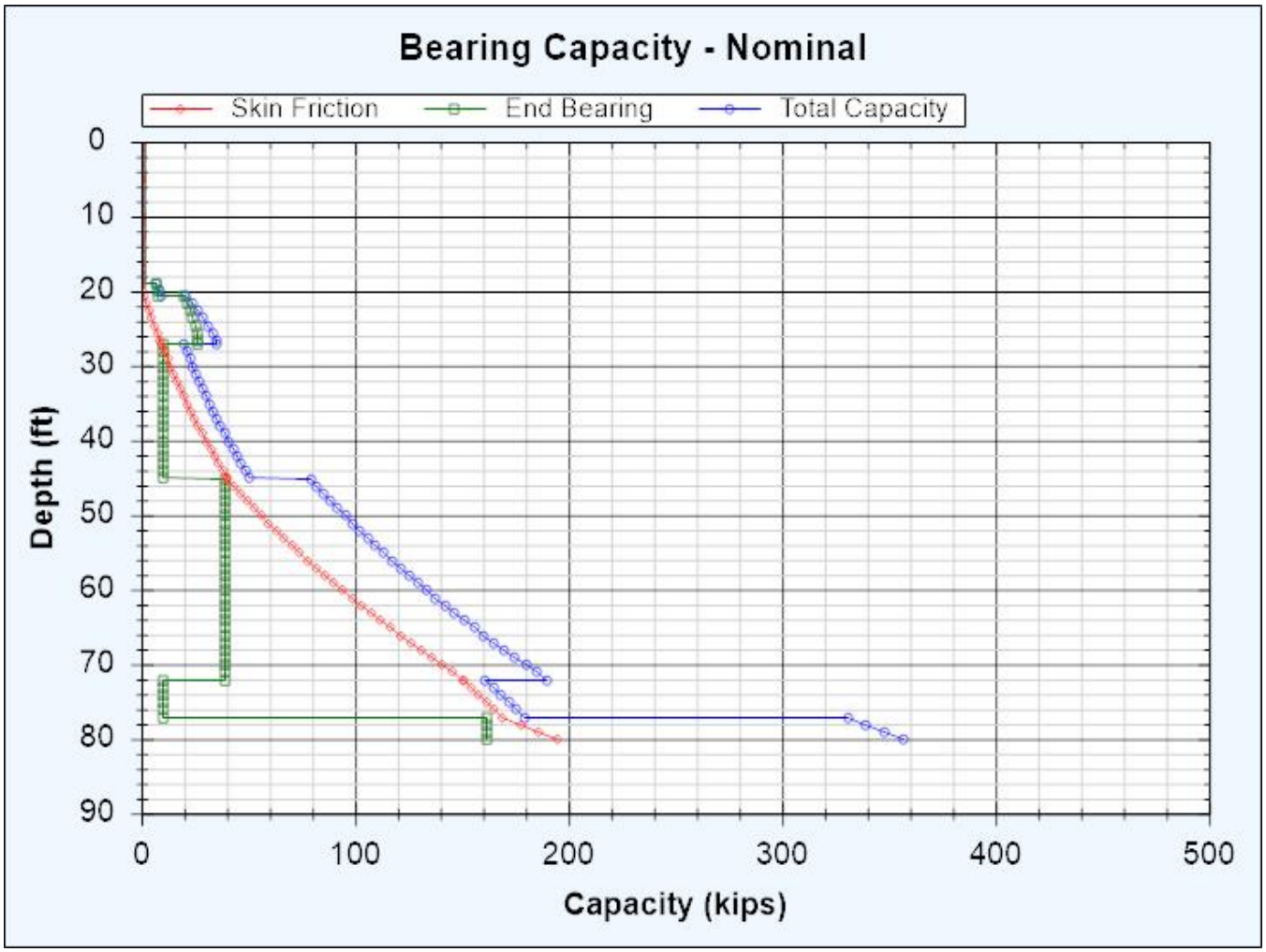

Bearing Capacity - Driving
Skin Friction
End Bearing
Total Capacity
Depth (ft)
0
10
20
30
40
50
60
70
80
90
0
100
200
300
400
500
Capacity (kips)

Nominal - Summary of Capacities

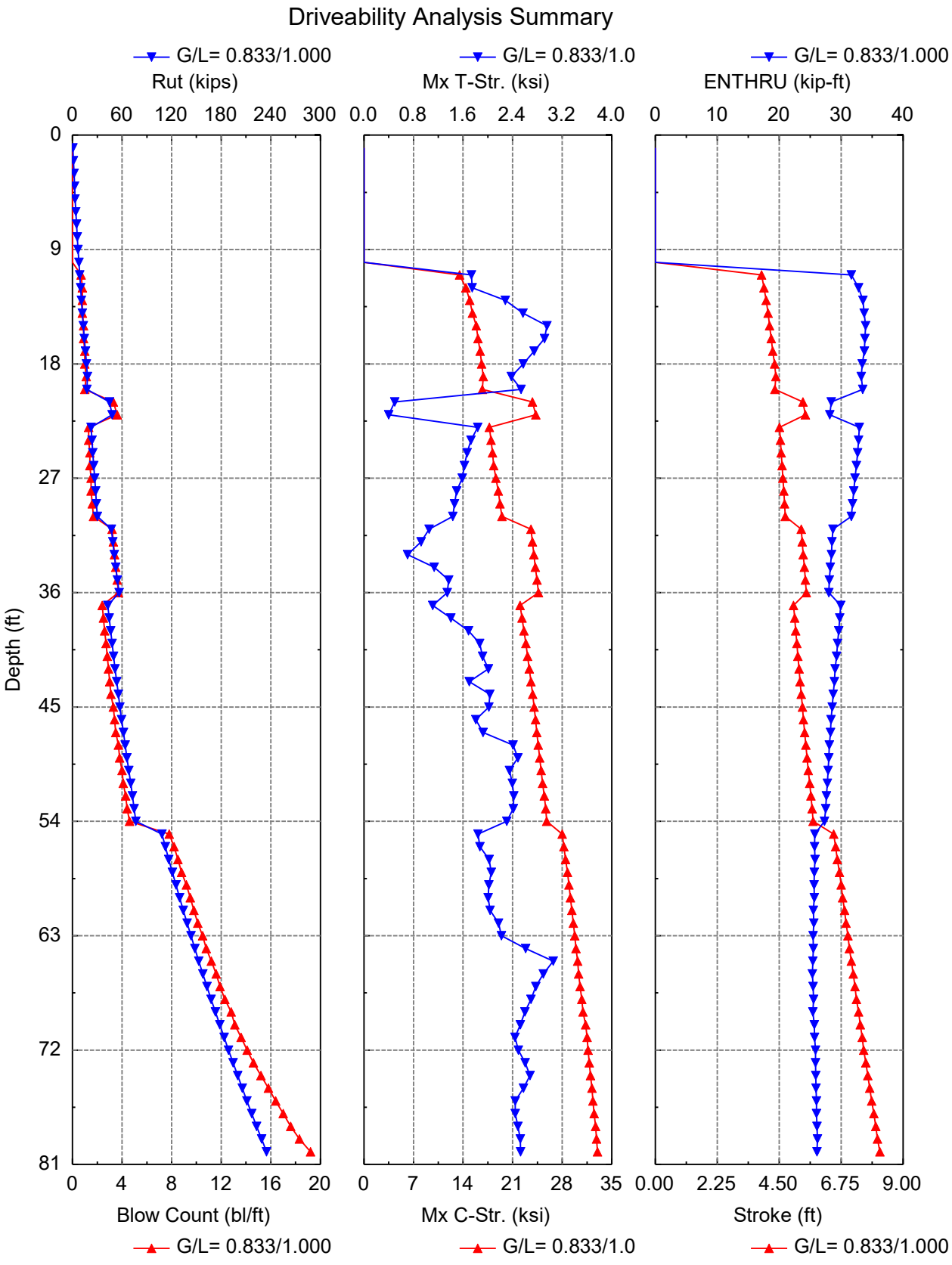
Depth	Skin Friction	End Bearing	Total Capacity
0.01 ft	0.00 kips	0.00 kips	0.00 kips
0.59 ft	0.00 kips	0.00 kips	0.00 kips
0.61 ft	0.00 kips	0.00 kips	0.00 kips
1.60 ft	0.00 kips	0.00 kips	0.00 kips
2.60 ft	0.00 kips	0.00 kips	0.00 kips
3.60 ft	0.00 kips	0.00 kips	0.00 kips
4.60 ft	0.00 kips	0.00 kips	0.00 kips
4.91 ft	0.00 kips	0.00 kips	0.00 kips
4.93 ft	0.00 kips	0.00 kips	0.00 kips
5.92 ft	0.00 kips	0.00 kips	0.00 kips
6.92 ft	0.00 kips	0.00 kips	0.00 kips
7.92 ft	0.00 kips	0.00 kips	0.00 kips
8.09 ft	0.00 kips	0.00 kips	0.00 kips
8.11 ft	0.00 kips	0.00 kips	0.00 kips
9.10 ft	0.00 kips	0.00 kips	0.00 kips
10.10 ft	0.00 kips	0.00 kips	0.00 kips
10.59 ft	0.00 kips	0.00 kips	0.00 kips
10.61 ft	0.00 kips	0.00 kips	0.00 kips
11.60 ft	0.00 kips	0.00 kips	0.00 kips
12.60 ft	0.00 kips	0.00 kips	0.00 kips
13.09 ft	0.00 kips	0.00 kips	0.00 kips
13.11 ft	0.00 kips	0.00 kips	0.00 kips
14.10 ft	0.00 kips	0.00 kips	0.00 kips
15.10 ft	0.00 kips	0.00 kips	0.00 kips
16.10 ft	0.00 kips	0.00 kips	0.00 kips
17.10 ft	0.00 kips	0.00 kips	0.00 kips
18.09 ft	0.00 kips	0.00 kips	0.00 kips
18.11 ft	0.00 kips	0.00 kips	0.00 kips
18.99 ft	0.00 kips	0.00 kips	0.00 kips
19.01 ft	0.01 kips	7.22 kips	7.23 kips
20.00 ft	0.64 kips	7.72 kips	8.35 kips
20.59 ft	1.03 kips	8.01 kips	9.04 kips
20.61 ft	1.05 kips	19.93 kips	20.98 kips
21.60 ft	2.15 kips	21.26 kips	23.41 kips
22.60 ft	3.34 kips	22.60 kips	25.93 kips
23.60 ft	4.59 kips	23.94 kips	28.53 kips
24.60 ft	5.93 kips	25.28 kips	31.21 kips
25.60 ft	7.33 kips	25.92 kips	33.25 kips
26.60 ft	8.80 kips	25.92 kips	34.72 kips
27.09 ft	9.55 kips	25.92 kips	35.47 kips
27.11 ft	9.58 kips	10.46 kips	20.04 kips
28.10 ft	10.84 kips	10.46 kips	21.31 kips

Depth	Skin Friction	End Bearing	Total Capacity
29.10 ft	12.17 kips	10.46 kips	22.63 kips
30.10 ft	13.56 kips	10.46 kips	24.02 kips
31.10 ft	14.99 kips	10.46 kips	25.45 kips
32.10 ft	16.48 kips	10.46 kips	26.95 kips
33.10 ft	18.03 kips	10.46 kips	28.49 kips
34.10 ft	19.63 kips	10.46 kips	30.09 kips
35.10 ft	21.28 kips	10.46 kips	31.75 kips
36.10 ft	22.99 kips	10.46 kips	33.45 kips
37.10 ft	24.75 kips	10.46 kips	35.22 kips
38.10 ft	26.57 kips	10.46 kips	37.03 kips
39.10 ft	28.44 kips	10.46 kips	38.90 kips
40.10 ft	30.37 kips	10.46 kips	40.83 kips
41.10 ft	32.34 kips	10.46 kips	42.81 kips
42.09 ft	34.36 kips	10.46 kips	44.82 kips
42.11 ft	34.39 kips	10.46 kips	44.86 kips
43.10 ft	36.16 kips	10.46 kips	46.63 kips
44.10 ft	38.00 kips	10.46 kips	48.46 kips
45.09 ft	39.86 kips	10.46 kips	50.32 kips
45.11 ft	39.91 kips	39.27 kips	79.18 kips
46.10 ft	42.95 kips	39.27 kips	82.22 kips
47.10 ft	46.10 kips	39.27 kips	85.37 kips
48.10 ft	49.33 kips	39.27 kips	88.60 kips
49.10 ft	52.64 kips	39.27 kips	91.91 kips
50.10 ft	56.03 kips	39.27 kips	95.30 kips
51.10 ft	59.50 kips	39.27 kips	98.77 kips
52.10 ft	63.05 kips	39.27 kips	102.32 kips
53.10 ft	66.68 kips	39.27 kips	105.95 kips
54.10 ft	70.39 kips	39.27 kips	109.66 kips
55.10 ft	74.17 kips	39.27 kips	113.44 kips
56.10 ft	78.04 kips	39.27 kips	117.31 kips
57.10 ft	81.99 kips	39.27 kips	121.26 kips
58.10 ft	86.02 kips	39.27 kips	125.29 kips
59.10 ft	90.13 kips	39.27 kips	129.40 kips
60.10 ft	94.31 kips	39.27 kips	133.58 kips
61.10 ft	98.58 kips	39.27 kips	137.85 kips
62.10 ft	102.93 kips	39.27 kips	142.20 kips
63.10 ft	107.35 kips	39.27 kips	146.62 kips
64.10 ft	111.86 kips	39.27 kips	151.13 kips
65.10 ft	116.44 kips	39.27 kips	155.71 kips
66.10 ft	121.11 kips	39.27 kips	160.38 kips
67.10 ft	125.86 kips	39.27 kips	165.13 kips
68.10 ft	130.68 kips	39.27 kips	169.95 kips

Depth	Skin Friction	End Bearing	Total Capacity
69.10 ft	135.59 kips	39.27 kips	174.86 kips
70.10 ft	140.57 kips	39.27 kips	179.84 kips
71.10 ft	145.64 kips	39.27 kips	184.91 kips
72.09 ft	150.73 kips	39.27 kips	190.00 kips
72.11 ft	150.81 kips	10.46 kips	161.28 kips
73.10 ft	154.33 kips	10.46 kips	164.79 kips
74.10 ft	157.92 kips	10.46 kips	168.38 kips
75.10 ft	161.56 kips	10.46 kips	172.02 kips
76.10 ft	165.25 kips	10.46 kips	175.71 kips
77.09 ft	168.94 kips	10.46 kips	179.40 kips
77.11 ft	169.07 kips	161.82 kips	330.89 kips
78.10 ft	177.56 kips	161.82 kips	339.38 kips
79.10 ft	186.26 kips	161.82 kips	348.09 kips
80.09 ft	195.01 kips	161.82 kips	356.84 kips


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

Rear Abutment
B-001-0-24



Gain/Loss Factor at Shaft/Toe = 0.833/1.000

Depth	Rut	Rshaft	Rtoe	Blow Ct	Mx C-Str	Mx T-Str.	Stroke	ENTHRU	Hammer
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft	-
1.0	0.6	0.0	0.5	0.3	0.000	0.000	10.81	0.0	D 19-42
2.0	1.2	0.1	1.1	0.3	0.000	0.000	10.81	0.0	D 19-42
3.0	1.8	0.2	1.6	0.3	0.000	0.000	10.81	0.0	D 19-42
4.0	2.5	0.3	2.2	0.3	0.000	0.000	10.81	0.0	D 19-42
5.0	3.3	0.5	2.8	0.3	0.000	0.000	10.81	0.0	D 19-42
6.0	4.1	0.8	3.3	0.3	0.000	0.000	10.81	0.0	D 19-42
7.0	4.9	1.0	3.9	0.3	0.000	0.000	10.81	0.0	D 19-42
8.0	5.8	1.4	4.4	0.0	0.000	0.000	0.00	0.0	D 19-42
9.0	6.7	1.7	5.0	0.0	0.000	0.000	0.00	0.0	D 19-42
10.0	7.7	2.1	5.6	0.0	0.000	0.000	0.00	0.0	D 19-42
11.0	8.7	2.6	6.1	0.7	13.520	1.734	3.85	31.6	D 19-42
12.0	9.8	3.1	6.7	0.8	14.404	1.748	3.95	32.8	D 19-42
13.0	10.9	3.6	7.2	0.8	14.935	2.282	4.02	33.5	D 19-42
14.0	12.0	4.2	7.8	0.8	15.332	2.568	4.09	33.7	D 19-42
15.0	13.2	4.8	8.3	0.9	15.875	2.954	4.15	33.9	D 19-42
16.0	14.4	5.5	8.9	0.9	16.116	2.916	4.21	33.8	D 19-42
17.0	15.7	6.2	9.5	1.0	16.408	2.747	4.26	33.7	D 19-42
18.0	17.0	7.0	10.0	1.0	16.626	2.571	4.33	33.4	D 19-42
19.0	18.2	7.7	10.5	1.1	16.866	2.381	4.38	33.2	D 19-42
20.0	17.6	8.4	9.2	1.0	16.716	2.536	4.34	33.4	D 19-42
21.0	44.7	9.5	35.2	3.3	23.783	0.495	5.36	28.4	D 19-42
22.0	47.9	10.8	37.1	3.6	24.278	0.401	5.44	28.1	D 19-42
23.0	22.6	12.1	10.5	1.3	17.698	1.837	4.51	32.9	D 19-42
24.0	23.6	13.1	10.5	1.3	17.959	1.726	4.54	32.8	D 19-42
25.0	24.7	14.2	10.5	1.4	18.143	1.664	4.57	32.6	D 19-42
26.0	25.8	15.3	10.5	1.4	18.338	1.623	4.60	32.4	D 19-42
27.0	26.9	16.5	10.5	1.5	18.647	1.587	4.63	32.2	D 19-42
28.0	28.1	17.6	10.5	1.5	18.977	1.498	4.66	32.0	D 19-42
29.0	29.0	18.6	10.5	1.6	19.225	1.463	4.69	31.8	D 19-42
30.0	30.1	19.6	10.5	1.7	19.479	1.434	4.72	31.6	D 19-42
31.0	47.1	21.1	26.0	3.2	23.588	1.051	5.30	28.7	D 19-42
32.0	48.8	22.9	26.0	3.3	23.786	0.922	5.34	28.5	D 19-42
33.0	50.6	24.6	26.0	3.4	24.007	0.704	5.37	28.4	D 19-42
34.0	52.5	26.5	26.0	3.5	24.214	1.132	5.41	28.2	D 19-42
35.0	54.4	28.4	26.0	3.6	24.429	1.368	5.45	28.1	D 19-42
36.0	56.3	30.4	26.0	3.7	24.644	1.343	5.48	28.0	D 19-42
37.0	42.7	32.3	10.5	2.4	22.047	1.112	5.02	29.9	D 19-42
38.0	44.4	34.0	10.5	2.5	22.325	1.403	5.06	29.7	D 19-42

39.0	46.2	35.7	10.5	2.6	22.591	1.689	5.10	29.6	D 19-42
40.0	47.9	37.5	10.5	2.7	22.859	1.867	5.14	29.4	D 19-42
41.0	49.7	39.3	10.5	2.8	23.104	1.914	5.18	29.3	D 19-42
42.0	51.6	41.1	10.5	2.9	23.351	2.010	5.22	29.0	D 19-42
43.0	53.5	43.1	10.5	3.0	23.584	1.700	5.26	28.9	D 19-42
44.0	55.5	45.0	10.5	3.1	23.811	2.032	5.30	28.7	D 19-42
45.0	57.5	47.0	10.5	3.3	24.033	2.017	5.34	28.5	D 19-42
46.0	59.5	49.1	10.5	3.4	24.221	1.804	5.38	28.4	D 19-42
47.0	61.6	51.1	10.5	3.5	24.413	1.924	5.42	28.3	D 19-42
48.0	63.7	53.3	10.5	3.7	24.617	2.407	5.47	28.1	D 19-42
49.0	65.9	55.5	10.5	3.8	24.822	2.487	5.51	28.0	D 19-42
50.0	68.2	57.7	10.5	4.0	25.030	2.348	5.56	27.9	D 19-42
51.0	70.4	60.0	10.5	4.1	25.238	2.395	5.60	27.7	D 19-42
52.0	72.7	62.2	10.5	4.3	25.466	2.417	5.65	27.6	D 19-42
53.0	74.7	64.2	10.5	4.4	25.666	2.410	5.69	27.5	D 19-42
54.0	76.8	66.3	10.5	4.6	25.821	2.304	5.73	27.3	D 19-42
55.0	108.3	68.9	39.4	7.8	27.977	1.839	6.47	25.7	D 19-42
56.0	112.4	73.0	39.4	8.2	28.229	1.873	6.55	25.7	D 19-42
57.0	116.5	77.2	39.4	8.5	28.474	2.020	6.61	25.8	D 19-42
58.0	120.8	81.4	39.4	8.8	28.733	2.057	6.68	25.6	D 19-42
59.0	125.1	85.8	39.4	9.2	28.959	2.017	6.75	25.6	D 19-42
60.0	129.6	90.2	39.4	9.5	29.169	2.005	6.80	25.7	D 19-42
61.0	134.1	94.7	39.4	9.8	29.362	2.034	6.87	25.5	D 19-42
62.0	138.6	99.3	39.4	10.1	29.550	2.171	6.92	25.6	D 19-42
63.0	143.3	103.9	39.4	10.5	29.763	2.220	6.99	25.5	D 19-42
64.0	148.0	108.7	39.4	10.8	29.952	2.608	7.05	25.5	D 19-42
65.0	152.9	113.5	39.4	11.2	30.180	3.055	7.12	25.4	D 19-42
66.0	157.8	118.4	39.4	11.6	30.331	2.893	7.19	25.3	D 19-42
67.0	162.7	123.4	39.4	11.9	30.539	2.775	7.25	25.4	D 19-42
68.0	167.8	128.4	39.4	12.3	30.750	2.696	7.30	25.5	D 19-42
69.0	172.9	133.6	39.4	12.8	30.926	2.598	7.38	25.4	D 19-42
70.0	178.2	138.8	39.4	13.1	31.320	2.522	7.44	25.7	D 19-42
71.0	183.5	144.1	39.4	13.6	31.514	2.436	7.51	25.7	D 19-42
72.0	188.9	149.5	39.4	14.1	31.663	2.493	7.57	25.8	D 19-42
73.0	194.3	155.0	39.4	14.6	31.813	2.602	7.64	25.8	D 19-42
74.0	199.9	160.5	39.4	15.2	31.997	2.680	7.71	25.9	D 19-42
75.0	205.5	166.1	39.4	15.8	32.209	2.576	7.79	25.9	D 19-42
76.0	211.2	171.8	39.4	16.4	32.347	2.443	7.86	26.0	D 19-42
77.0	217.0	177.6	39.4	17.0	32.492	2.443	7.93	26.0	D 19-42
78.0	222.9	183.5	39.4	17.6	32.700	2.484	8.00	26.1	D 19-42
79.0	228.8	189.4	39.4	18.3	32.859	2.525	8.06	26.2	D 19-42

80.0	234.8	195.5	39.4	19.2	32.998	2.527	8.15	26.1	D 19-42

Total driving time: 10 minutes; Total Number of Blows: 429 (starting at penetration 1.0 ft)

GRLWEAP: Wave Equation Analysis of Pile Foundations

CAR-Grant Street Bridge Replacement B-001-0-24 + 12" CIP 8/7/2025
RESOURCE INTERNATIONAL INC GRLWEAP 14.1.20.1

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

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

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

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

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

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

SOIL PROFILE

Depth	Soil Type	Spec. Wt	Su	Phi	Unit Rs	Unit Rt
ft	-	lb/ft³	ksf	°	ksf	ksf
0.0	Sand	115.0	0.0	28.0	0.00	0.00
0.5	Sand	115.0	0.0	28.0	0.01	0.32
0.5	Sand	120.0	0.0	28.0	0.01	0.32
18.5	Sand	120.0	0.0	28.0	0.25	13.11
18.5	Sand	120.0	0.0	28.0	0.25	13.11
19.0	Sand	120.0	0.0	28.0	0.26	13.32
19.0	Sand	120.0	0.0	27.0	0.24	11.21
20.3	Sand	120.0	0.0	27.0	0.26	11.91
20.2	Sand	130.0	0.0	34.0	0.48	43.05
22.7	Sand	130.0	0.0	34.0	0.55	48.96
22.7	Sand	130.0	0.0	30.0	0.37	13.32
27.7	Sand	130.0	0.0	30.0	0.46	13.32
27.7	Sand	125.0	0.0	27.0	0.37	13.32
30.2	Sand	125.0	0.0	27.0	0.40	13.32
30.2	Sand	130.0	0.0	32.0	0.63	33.09
36.7	Sand	130.0	0.0	32.0	0.78	33.09
36.7	Sand	125.0	0.0	30.0	0.63	13.32
51.7	Sand	125.0	0.0	30.0	0.89	13.32
51.7	Sand	125.0	0.0	28.0	0.77	13.32
54.7	Sand	125.0	0.0	28.0	0.81	13.32
54.7	Sand	130.0	0.0	33.0	1.29	50.11
81.7	Sand	130.0	0.0	33.0	1.98	50.11
81.7	Sand	120.0	0.0	29.0	1.35	13.32
86.7	Sand	120.0	0.0	29.0	1.42	13.32
86.7	Sand	135.0	0.0	37.0	3.21	203.27
89.7	Sand	135.0	0.0	37.0	3.34	203.27

PILE INPUT

Uniform Pile		Pile Type:	Closed-End Pipe
Pile Length: (ft)	90.000	Pile Penetration: (ft)	80.000
Pile Size: (ft)	1.00	Toe Area: (in²)	113.10

Pile Profile

Lb Top	X-Area	E-Modulus	Spec. Wt	Perim.	Crit. Index
ft	in²	ksi	lb/ft³	ft	-
0.0	9.2	30,000.0	493.4	3.1	0
90.0	9.2	30,000.0	493.4	3.1	0

HAMMER INPUT

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

Hammer Data

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

DRIVE SYSTEM FOR DELMAG D 19-42-OED

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

SOIL RESISTANCE DISTRIBUTION

Depth	Unit Rs	Unit Rt	Qs	Qt	Js	Jt	Set. F.	Limit D.	Set. T.	EB Area
ft	ksf	ksf	in	in	s/ft	s/ft	-	ft	Hours	in²
0.0	0.0	0.0	0.10	0.06	0.05	0.15	1.0	6.0	1.0	113.1
0.5	0.0	0.3	0.10	0.06	0.05	0.15	1.0	6.0	1.0	113.1
0.5	0.0	0.3	0.10	0.04	0.05	0.15	1.0	6.0	1.0	113.1
2.3	0.0	1.6	0.10	0.04	0.05	0.15	1.0	6.0	1.0	113.1
4.1	0.1	2.9	0.10	0.04	0.05	0.15	1.0	6.0	1.0	113.1
5.9	0.1	4.2	0.10	0.04	0.05	0.15	1.0	6.0	1.0	113.1
7.7	0.1	5.4	0.10	0.04	0.05	0.15	1.0	6.0	1.0	113.1
9.5	0.1	6.7	0.10	0.04	0.05	0.15	1.0	6.0	1.0	113.1
11.3	0.2	8.0	0.10	0.04	0.05	0.15	1.0	6.0	1.0	113.1
13.1	0.2	9.3	0.10	0.04	0.05	0.15	1.0	6.0	1.0	113.1
14.9	0.2	10.6	0.10	0.04	0.05	0.15	1.0	6.0	1.0	113.1
16.7	0.2	11.8	0.10	0.04	0.05	0.15	1.0	6.0	1.0	113.1
18.5	0.3	13.1	0.10	0.04	0.05	0.15	1.0	6.0	1.0	113.1
18.5	0.3	13.1	0.10	0.04	0.05	0.15	1.2	6.0	1.0	113.1
19.0	0.3	13.3	0.10	0.04	0.05	0.15	1.2	6.0	1.0	113.1
19.0	0.2	11.2	0.10	0.04	0.05	0.15	1.2	6.0	1.0	113.1
20.3	0.3	11.9	0.10	0.04	0.05	0.15	1.2	6.0	1.0	113.1
20.2	0.5	43.0	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
21.5	0.5	46.0	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
22.7	0.6	49.0	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
22.7	0.4	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
24.4	0.4	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
26.1	0.4	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1

27.7	0.5	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
27.7	0.4	13.3	0.10	0.04	0.05	0.15	1.2	6.0	1.0	113.1
29.0	0.4	13.3	0.10	0.04	0.05	0.15	1.2	6.0	1.0	113.1
30.2	0.4	13.3	0.10	0.04	0.05	0.15	1.2	6.0	1.0	113.1
30.2	0.6	33.1	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
32.4	0.7	33.1	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
34.6	0.7	33.1	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
36.7	0.8	33.1	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
36.7	0.6	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
38.4	0.7	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
40.1	0.7	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
41.7	0.7	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
43.4	0.7	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
45.1	0.8	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
46.7	0.8	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
48.4	0.8	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
50.1	0.9	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
51.7	0.9	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
51.7	0.8	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
53.2	0.8	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
54.7	0.8	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
54.7	1.3	50.1	0.10	0.20	0.05	0.15	1.0	6.0	1.0	113.1
56.4	1.3	50.1	0.10	0.20	0.05	0.15	1.0	6.0	1.0	113.1
58.1	1.4	50.1	0.10	0.20	0.05	0.15	1.0	6.0	1.0	113.1
59.8	1.4	50.1	0.10	0.20	0.05	0.15	1.0	6.0	1.0	113.1
61.5	1.5	50.1	0.10	0.20	0.05	0.15	1.0	6.0	1.0	113.1
63.2	1.5	50.1	0.10	0.20	0.05	0.15	1.0	6.0	1.0	113.1
64.9	1.5	50.1	0.10	0.20	0.05	0.15	1.0	6.0	1.0	113.1
66.6	1.6	50.1	0.10	0.20	0.05	0.15	1.0	6.0	1.0	113.1
68.2	1.6	50.1	0.10	0.20	0.05	0.15	1.0	6.0	1.0	113.1
69.9	1.7	50.1	0.10	0.20	0.05	0.15	1.0	6.0	1.0	113.1
71.6	1.7	50.1	0.10	0.20	0.05	0.15	1.0	6.0	1.0	113.1
73.3	1.8	50.1	0.10	0.20	0.05	0.15	1.0	6.0	1.0	113.1
75.0	1.8	50.1	0.10	0.20	0.05	0.15	1.0	6.0	1.0	113.1
76.7	1.8	50.1	0.10	0.20	0.05	0.15	1.0	6.0	1.0	113.1
78.4	1.9	50.1	0.10	0.20	0.05	0.15	1.0	6.0	1.0	113.1
80.0	1.9	50.1	0.10	0.20	0.05	0.15	1.0	6.0	1.0	113.1

Fwd Abutment
B-002-0-24

DrivenPiles - Report

General Project Information

Filename: C:\Users\Legacy\Documents\W-23-185\B-002-0-24\B-002-0-24.dvn
Project Name: CAR-Grant Street Bridge Replacement B-002-0-24
Project Client: CM Transportation
Prepared By: Rii
Project Manager: DEK

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:	0.00 ft
Driving/Restrike:	0.00 ft
Nominal:	0.00 ft

Nominal Considations:

Local Scour:	0.00 ft
Long Term Scour:	3.10 ft
Soft Soil:	0.00 ft

Nominal Profile

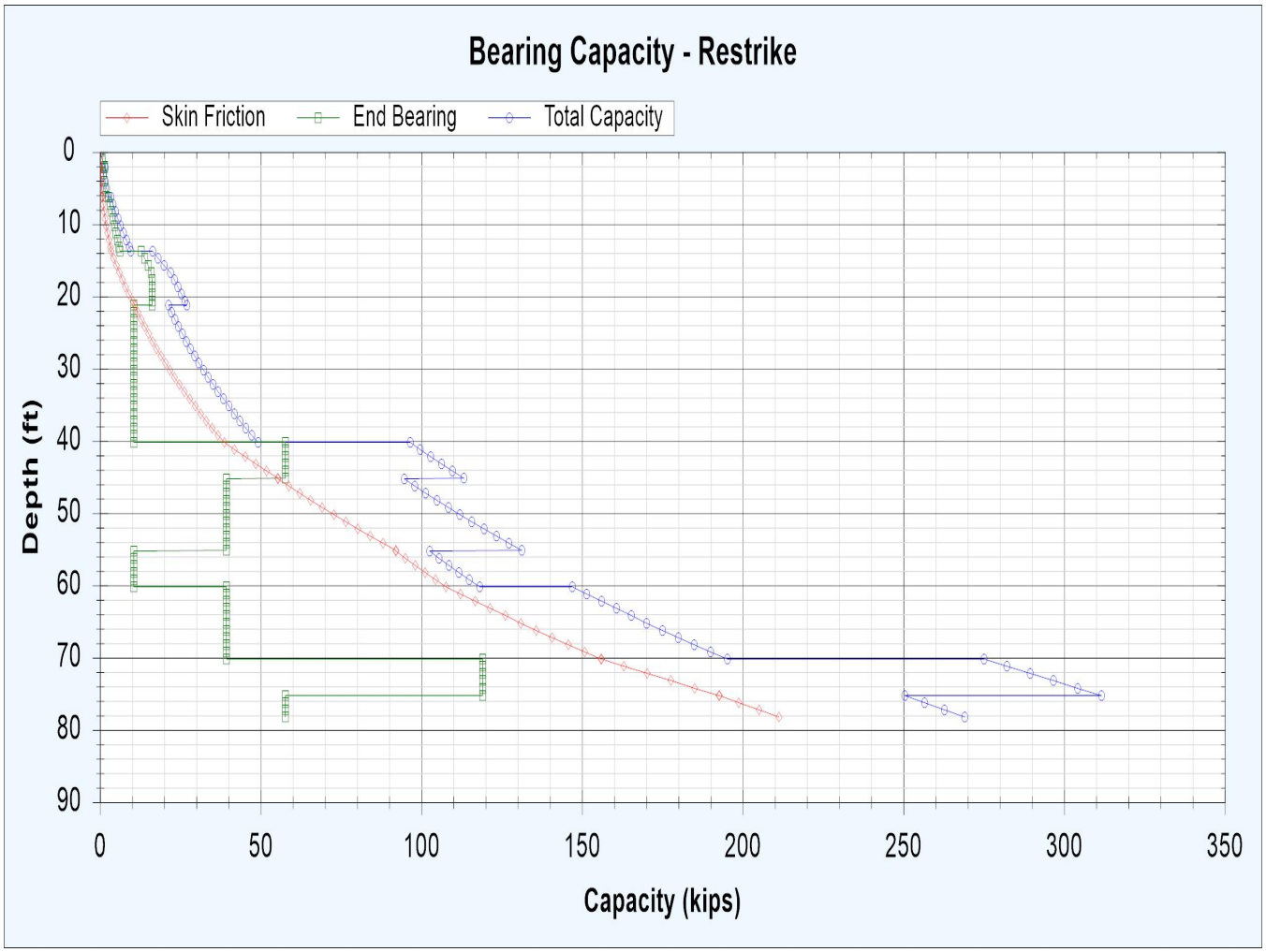
Layer	Soil Type	Thickness	Setup Factor	Unit Weight	Strength	Nominal Curve
1	Cohesionless	2.20 ft	1.200	120.00 pcf	29.0/29.0	Nordlund
2	Cohesionless	4.00 ft	1.200	115.00 pcf	25.0/25.0	Nordlund
3	Cohesionless	7.50 ft	1.200	120.00 pcf	27.0/27.0	Nordlund
4	Cohesionless	7.50 ft	1.000	125.00 pcf	31.0/31.0	Nordlund
5	Cohesionless	19.00 ft	1.200	125.00 pcf	29.0/29.0	Nordlund
6	Cohesionless	5.00 ft	1.200	130.00 pcf	34.0/34.0	Nordlund
7	Cohesionless	10.00 ft	1.200	130.00 pcf	33.0/33.0	Nordlund
8	Cohesionless	5.00 ft	1.200	130.00 pcf	30.0/30.0	Nordlund
9	Cohesionless	10.00 ft	1.000	125.00 pcf	33.0/33.0	Nordlund
10	Cohesionless	5.00 ft	1.000	130.00 pcf	36.0/36.0	Nordlund
11	Cohesionless	3.00 ft	1.000	130.00 pcf	34.0/34.0	Nordlund

Restrike - Summary of Capacities

Depth	Skin Friction	End Bearing	Total Capacity
0.01 ft	0.00 kips	0.01 kips	0.01 kips
1.00 ft	0.02 kips	0.67 kips	0.69 kips
2.00 ft	0.09 kips	1.33 kips	1.43 kips
2.19 ft	0.11 kips	1.46 kips	1.57 kips
2.21 ft	0.11 kips	0.70 kips	0.82 kips
3.09 ft	0.19 kips	0.96 kips	1.15 kips
3.11 ft	0.19 kips	0.97 kips	1.16 kips
4.10 ft	0.30 kips	1.26 kips	1.56 kips
5.10 ft	0.45 kips	1.55 kips	1.99 kips
6.10 ft	0.62 kips	1.84 kips	2.46 kips
6.19 ft	0.64 kips	1.86 kips	2.50 kips
6.21 ft	0.64 kips	2.70 kips	3.34 kips
7.20 ft	0.89 kips	3.16 kips	4.04 kips
8.20 ft	1.18 kips	3.62 kips	4.79 kips
9.20 ft	1.50 kips	4.08 kips	5.58 kips
10.20 ft	1.87 kips	4.54 kips	6.41 kips
11.20 ft	2.28 kips	5.00 kips	7.27 kips
12.20 ft	2.72 kips	5.46 kips	8.18 kips
13.20 ft	3.21 kips	5.92 kips	9.12 kips
13.69 ft	3.46 kips	6.14 kips	9.60 kips
13.71 ft	3.47 kips	12.83 kips	16.30 kips
14.70 ft	4.24 kips	13.86 kips	18.10 kips
15.70 ft	5.07 kips	14.90 kips	19.98 kips
16.70 ft	5.97 kips	15.95 kips	21.92 kips
17.70 ft	6.93 kips	16.23 kips	23.16 kips
18.70 ft	7.94 kips	16.23 kips	24.17 kips
19.70 ft	9.02 kips	16.23 kips	25.25 kips
20.70 ft	10.16 kips	16.23 kips	26.39 kips
21.19 ft	10.74 kips	16.23 kips	26.97 kips
21.21 ft	10.76 kips	10.46 kips	21.22 kips
22.20 ft	11.77 kips	10.46 kips	22.23 kips
23.20 ft	12.84 kips	10.46 kips	23.30 kips
24.20 ft	13.96 kips	10.46 kips	24.42 kips
25.20 ft	15.13 kips	10.46 kips	25.59 kips
26.20 ft	16.35 kips	10.46 kips	26.81 kips
27.20 ft	17.62 kips	10.46 kips	28.08 kips
28.20 ft	18.94 kips	10.46 kips	29.40 kips
29.20 ft	20.31 kips	10.46 kips	30.77 kips
30.20 ft	21.73 kips	10.46 kips	32.19 kips
31.20 ft	23.20 kips	10.46 kips	33.66 kips
32.20 ft	24.72 kips	10.46 kips	35.18 kips
33.20 ft	26.29 kips	10.46 kips	36.75 kips

Depth	Skin Friction	End Bearing	Total Capacity
34.20 ft	27.91 kips	10.46 kips	38.37 kips
35.20 ft	29.58 kips	10.46 kips	40.04 kips
36.20 ft	31.30 kips	10.46 kips	41.76 kips
37.20 ft	33.08 kips	10.46 kips	43.54 kips
38.20 ft	34.90 kips	10.46 kips	45.36 kips
39.20 ft	36.77 kips	10.46 kips	47.23 kips
40.19 ft	38.67 kips	10.46 kips	49.13 kips
40.21 ft	38.72 kips	57.74 kips	96.47 kips
41.20 ft	41.86 kips	57.74 kips	99.60 kips
42.20 ft	45.12 kips	57.74 kips	102.86 kips
43.20 ft	48.46 kips	57.74 kips	106.20 kips
44.20 ft	51.89 kips	57.74 kips	109.63 kips
45.19 ft	55.37 kips	57.74 kips	113.11 kips
45.21 ft	55.44 kips	39.27 kips	94.71 kips
46.20 ft	58.71 kips	39.27 kips	97.98 kips
47.20 ft	62.09 kips	39.27 kips	101.36 kips
48.20 ft	65.55 kips	39.27 kips	104.82 kips
49.20 ft	69.09 kips	39.27 kips	108.36 kips
50.20 ft	72.72 kips	39.27 kips	111.99 kips
51.20 ft	76.42 kips	39.27 kips	115.69 kips
52.20 ft	80.20 kips	39.27 kips	119.47 kips
53.20 ft	84.06 kips	39.27 kips	123.33 kips
54.20 ft	88.00 kips	39.27 kips	127.27 kips
55.19 ft	91.98 kips	39.27 kips	131.25 kips
55.21 ft	92.05 kips	10.46 kips	102.51 kips
56.20 ft	95.03 kips	10.46 kips	105.49 kips
57.20 ft	98.09 kips	10.46 kips	108.55 kips
58.20 ft	101.22 kips	10.46 kips	111.68 kips
59.20 ft	104.40 kips	10.46 kips	114.86 kips
60.19 ft	107.61 kips	10.46 kips	118.07 kips
60.21 ft	107.68 kips	39.27 kips	146.95 kips
61.20 ft	112.13 kips	39.27 kips	151.40 kips
62.20 ft	116.70 kips	39.27 kips	155.97 kips
63.20 ft	121.35 kips	39.27 kips	160.62 kips
64.20 ft	126.07 kips	39.27 kips	165.34 kips
65.20 ft	130.86 kips	39.27 kips	170.13 kips
66.20 ft	135.72 kips	39.27 kips	174.99 kips
67.20 ft	140.66 kips	39.27 kips	179.93 kips
68.20 ft	145.67 kips	39.27 kips	184.94 kips
69.20 ft	150.76 kips	39.27 kips	190.03 kips
70.19 ft	155.87 kips	39.27 kips	195.14 kips
70.21 ft	155.99 kips	119.07 kips	275.06 kips

Depth	Skin Friction	End Bearing	Total Capacity
71.20 ft	163.05 kips	119.07 kips	282.11 kips
72.20 ft	170.28 kips	119.07 kips	289.35 kips
73.20 ft	177.63 kips	119.07 kips	296.69 kips
74.20 ft	185.08 kips	119.07 kips	304.15 kips
75.19 ft	192.57 kips	119.07 kips	311.63 kips
75.21 ft	192.70 kips	57.74 kips	250.44 kips
76.20 ft	198.79 kips	57.74 kips	256.53 kips
77.20 ft	205.03 kips	57.74 kips	262.77 kips
78.19 ft	211.29 kips	57.74 kips	269.03 kips

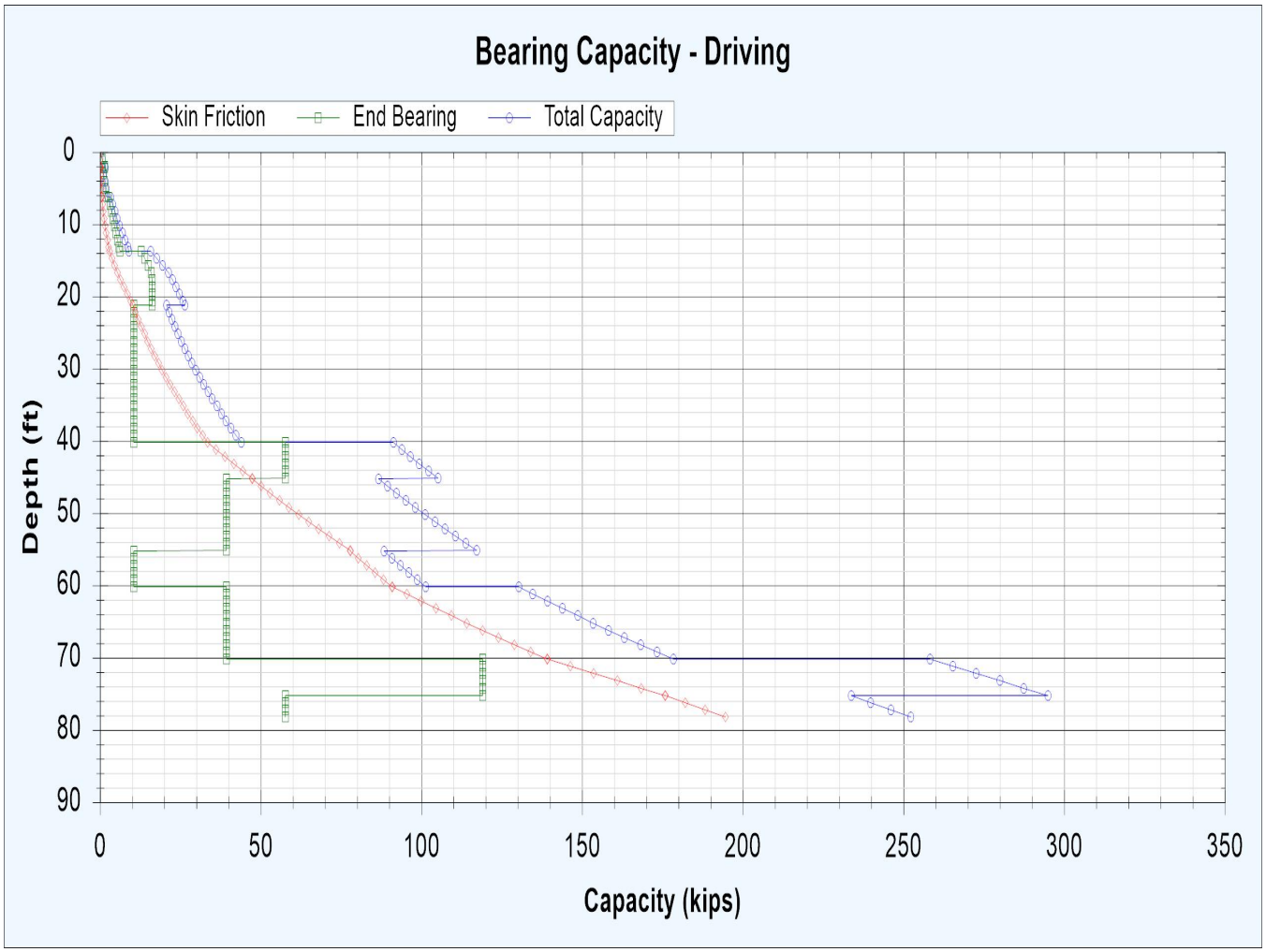

Bearing Capacity - Restrike
Skin Friction
End Bearing
Total Capacity
Depth (ft)
0
10
20
30
40
50
60
70
80
90
0
50
100
150
200
250
300
350
Capacity (kips)

Driving - Summary of Capacities

Depth	Skin Friction	End Bearing	Total Capacity
0.01 ft	0.00 kips	0.01 kips	0.01 kips
1.00 ft	0.02 kips	0.67 kips	0.69 kips
2.00 ft	0.08 kips	1.33 kips	1.41 kips
2.19 ft	0.09 kips	1.46 kips	1.55 kips
2.21 ft	0.09 kips	0.70 kips	0.80 kips
3.09 ft	0.16 kips	0.96 kips	1.12 kips
3.11 ft	0.16 kips	0.97 kips	1.12 kips
4.10 ft	0.25 kips	1.26 kips	1.51 kips
5.10 ft	0.37 kips	1.55 kips	1.92 kips
6.10 ft	0.52 kips	1.84 kips	2.35 kips
6.19 ft	0.53 kips	1.86 kips	2.39 kips
6.21 ft	0.53 kips	2.70 kips	3.23 kips
7.20 ft	0.74 kips	3.16 kips	3.89 kips
8.20 ft	0.98 kips	3.62 kips	4.60 kips
9.20 ft	1.25 kips	4.08 kips	5.33 kips
10.20 ft	1.56 kips	4.54 kips	6.09 kips
11.20 ft	1.90 kips	5.00 kips	6.89 kips
12.20 ft	2.27 kips	5.46 kips	7.72 kips
13.20 ft	2.67 kips	5.92 kips	8.59 kips
13.69 ft	2.88 kips	6.14 kips	9.02 kips
13.71 ft	2.89 kips	12.83 kips	15.72 kips
14.70 ft	3.66 kips	13.86 kips	17.52 kips
15.70 ft	4.50 kips	14.90 kips	19.40 kips
16.70 ft	5.39 kips	15.95 kips	21.34 kips
17.70 ft	6.35 kips	16.23 kips	22.58 kips
18.70 ft	7.37 kips	16.23 kips	23.60 kips
19.70 ft	8.44 kips	16.23 kips	24.67 kips
20.70 ft	9.58 kips	16.23 kips	25.81 kips
21.19 ft	10.16 kips	16.23 kips	26.39 kips
21.21 ft	10.18 kips	10.46 kips	20.65 kips
22.20 ft	11.02 kips	10.46 kips	21.49 kips
23.20 ft	11.92 kips	10.46 kips	22.38 kips
24.20 ft	12.85 kips	10.46 kips	23.31 kips
25.20 ft	13.82 kips	10.46 kips	24.28 kips
26.20 ft	14.84 kips	10.46 kips	25.30 kips
27.20 ft	15.90 kips	10.46 kips	26.36 kips
28.20 ft	17.00 kips	10.46 kips	27.46 kips
29.20 ft	18.14 kips	10.46 kips	28.60 kips
30.20 ft	19.32 kips	10.46 kips	29.78 kips
31.20 ft	20.55 kips	10.46 kips	31.01 kips
32.20 ft	21.81 kips	10.46 kips	32.27 kips
33.20 ft	23.12 kips	10.46 kips	33.58 kips

Depth	Skin Friction	End Bearing	Total Capacity
34.20 ft	24.47 kips	10.46 kips	34.93 kips
35.20 ft	25.87 kips	10.46 kips	36.33 kips
36.20 ft	27.30 kips	10.46 kips	37.76 kips
37.20 ft	28.78 kips	10.46 kips	39.24 kips
38.20 ft	30.30 kips	10.46 kips	40.76 kips
39.20 ft	31.86 kips	10.46 kips	42.32 kips
40.19 ft	33.44 kips	10.46 kips	43.90 kips
40.21 ft	33.48 kips	57.74 kips	91.23 kips
41.20 ft	36.10 kips	57.74 kips	93.84 kips
42.20 ft	38.81 kips	57.74 kips	96.55 kips
43.20 ft	41.60 kips	57.74 kips	99.34 kips
44.20 ft	44.45 kips	57.74 kips	102.20 kips
45.19 ft	47.35 kips	57.74 kips	105.10 kips
45.21 ft	47.41 kips	39.27 kips	86.68 kips
46.20 ft	50.14 kips	39.27 kips	89.41 kips
47.20 ft	52.96 kips	39.27 kips	92.23 kips
48.20 ft	55.84 kips	39.27 kips	95.11 kips
49.20 ft	58.79 kips	39.27 kips	98.06 kips
50.20 ft	61.81 kips	39.27 kips	101.08 kips
51.20 ft	64.89 kips	39.27 kips	104.16 kips
52.20 ft	68.05 kips	39.27 kips	107.32 kips
53.20 ft	71.26 kips	39.27 kips	110.53 kips
54.20 ft	74.55 kips	39.27 kips	113.82 kips
55.19 ft	77.86 kips	39.27 kips	117.13 kips
55.21 ft	77.92 kips	10.46 kips	88.38 kips
56.20 ft	80.40 kips	10.46 kips	90.86 kips
57.20 ft	82.96 kips	10.46 kips	93.42 kips
58.20 ft	85.56 kips	10.46 kips	96.02 kips
59.20 ft	88.21 kips	10.46 kips	98.67 kips
60.19 ft	90.88 kips	10.46 kips	101.34 kips
60.21 ft	90.95 kips	39.27 kips	130.22 kips
61.20 ft	95.41 kips	39.27 kips	134.68 kips
62.20 ft	99.98 kips	39.27 kips	139.25 kips
63.20 ft	104.62 kips	39.27 kips	143.89 kips
64.20 ft	109.34 kips	39.27 kips	148.61 kips
65.20 ft	114.13 kips	39.27 kips	153.40 kips
66.20 ft	118.99 kips	39.27 kips	158.26 kips
67.20 ft	123.93 kips	39.27 kips	163.20 kips
68.20 ft	128.95 kips	39.27 kips	168.22 kips
69.20 ft	134.03 kips	39.27 kips	173.30 kips
70.19 ft	139.14 kips	39.27 kips	178.41 kips
70.21 ft	139.26 kips	119.07 kips	258.33 kips

Depth	Skin Friction	End Bearing	Total Capacity
71.20 ft	146.32 kips	119.07 kips	265.39 kips
72.20 ft	153.56 kips	119.07 kips	272.62 kips
73.20 ft	160.90 kips	119.07 kips	279.97 kips
74.20 ft	168.35 kips	119.07 kips	287.42 kips
75.19 ft	175.84 kips	119.07 kips	294.90 kips
75.21 ft	175.97 kips	57.74 kips	233.72 kips
76.20 ft	182.06 kips	57.74 kips	239.81 kips
77.20 ft	188.30 kips	57.74 kips	246.04 kips
78.19 ft	194.56 kips	57.74 kips	252.30 kips

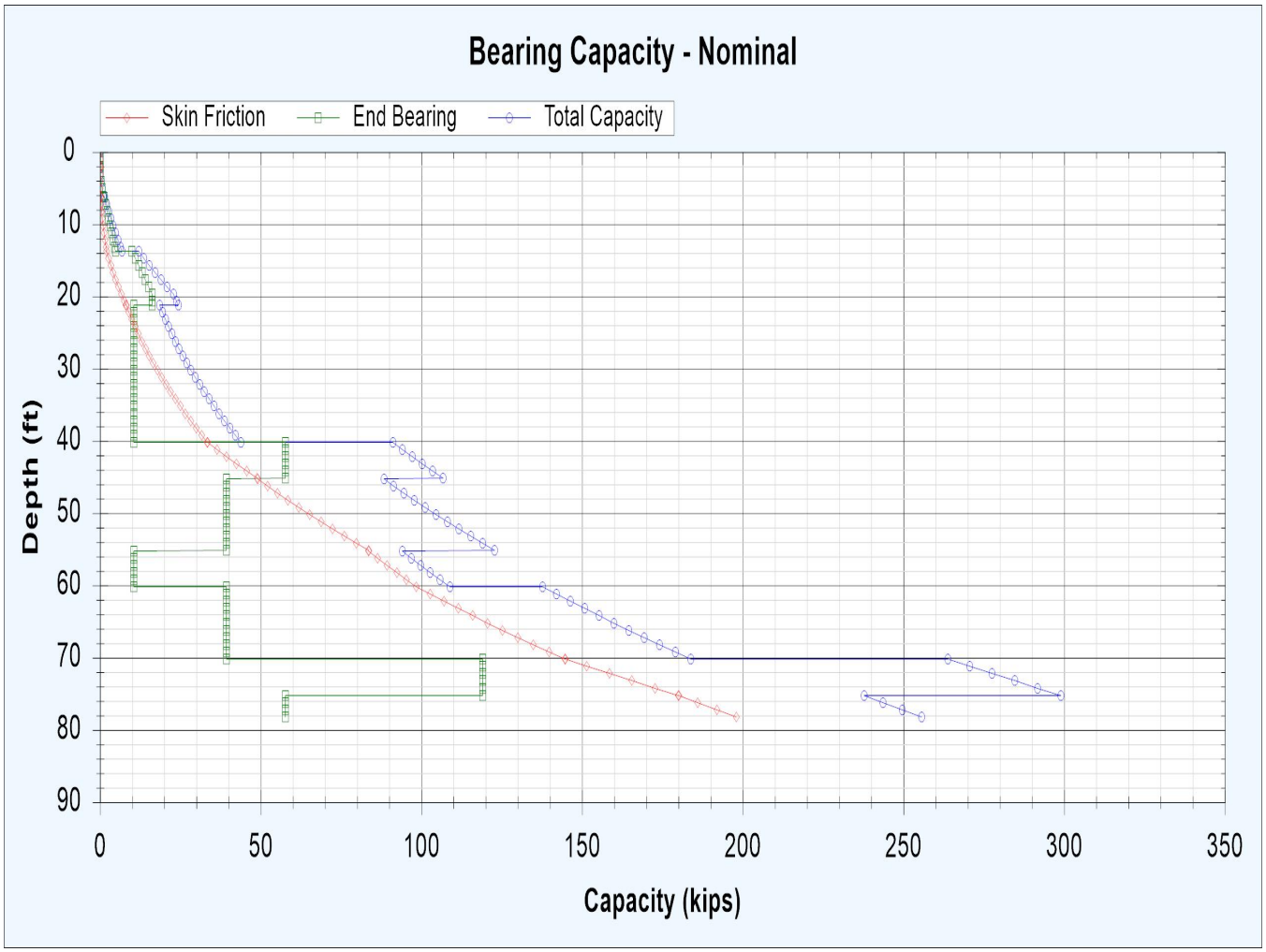

Bearing Capacity - Driving
Skin Friction
End Bearing
Total Capacity
Depth (ft)
0
10
20
30
40
50
60
70
80
90
0
50
100
150
200
250
300
350
Capacity (kips)

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
2.19 ft	0.00 kips	0.00 kips	0.00 kips
2.21 ft	0.00 kips	0.00 kips	0.00 kips
3.09 ft	0.00 kips	0.00 kips	0.00 kips
3.11 ft	0.00 kips	0.00 kips	0.00 kips
4.10 ft	0.01 kips	0.29 kips	0.31 kips
5.10 ft	0.06 kips	0.58 kips	0.64 kips
6.10 ft	0.13 kips	0.87 kips	1.01 kips
6.19 ft	0.14 kips	0.90 kips	1.04 kips
6.21 ft	0.14 kips	1.31 kips	1.45 kips
7.20 ft	0.27 kips	1.76 kips	2.04 kips
8.20 ft	0.44 kips	2.22 kips	2.67 kips
9.20 ft	0.65 kips	2.68 kips	3.34 kips
10.20 ft	0.90 kips	3.14 kips	4.05 kips
11.20 ft	1.19 kips	3.61 kips	4.79 kips
12.20 ft	1.52 kips	4.07 kips	5.58 kips
13.20 ft	1.88 kips	4.53 kips	6.41 kips
13.69 ft	2.07 kips	4.75 kips	6.83 kips
13.71 ft	2.08 kips	9.93 kips	12.01 kips
14.70 ft	2.69 kips	10.96 kips	13.65 kips
15.70 ft	3.35 kips	12.00 kips	15.36 kips
16.70 ft	4.08 kips	13.05 kips	17.13 kips
17.70 ft	4.87 kips	14.09 kips	18.96 kips
18.70 ft	5.72 kips	15.13 kips	20.85 kips
19.70 ft	6.63 kips	16.18 kips	22.80 kips
20.70 ft	7.60 kips	16.23 kips	23.83 kips
21.19 ft	8.09 kips	16.23 kips	24.32 kips
21.21 ft	8.11 kips	10.46 kips	18.58 kips
22.20 ft	8.98 kips	10.46 kips	19.45 kips
23.20 ft	9.91 kips	10.46 kips	20.37 kips
24.20 ft	10.89 kips	10.46 kips	21.35 kips
25.20 ft	11.92 kips	10.46 kips	22.38 kips
26.20 ft	13.00 kips	10.46 kips	23.46 kips
27.20 ft	14.13 kips	10.46 kips	24.59 kips
28.20 ft	15.31 kips	10.46 kips	25.77 kips
29.20 ft	16.54 kips	10.46 kips	27.00 kips
30.20 ft	17.82 kips	10.46 kips	28.28 kips
31.20 ft	19.15 kips	10.46 kips	29.62 kips
32.20 ft	20.54 kips	10.46 kips	31.00 kips
33.20 ft	21.97 kips	10.46 kips	32.43 kips

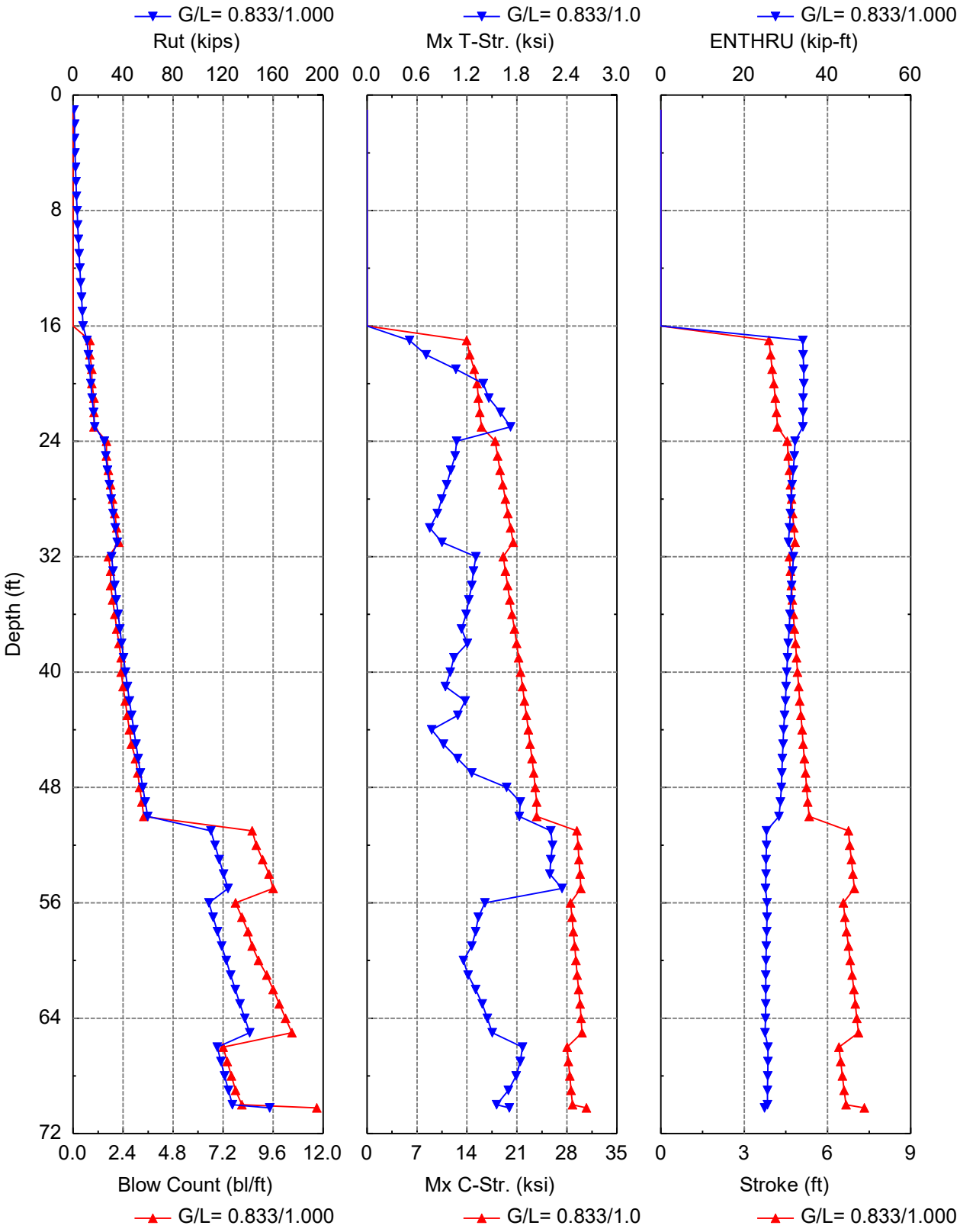
Depth	Skin Friction	End Bearing	Total Capacity
34.20 ft	23.45 kips	10.46 kips	33.91 kips
35.20 ft	24.98 kips	10.46 kips	35.44 kips
36.20 ft	26.56 kips	10.46 kips	37.02 kips
37.20 ft	28.19 kips	10.46 kips	38.66 kips
38.20 ft	29.88 kips	10.46 kips	40.34 kips
39.20 ft	31.61 kips	10.46 kips	42.07 kips
40.19 ft	33.37 kips	10.46 kips	43.83 kips
40.21 ft	33.42 kips	57.74 kips	91.16 kips
41.20 ft	36.34 kips	57.74 kips	94.08 kips
42.20 ft	39.37 kips	57.74 kips	97.11 kips
43.20 ft	42.49 kips	57.74 kips	100.23 kips
44.20 ft	45.69 kips	57.74 kips	103.43 kips
45.19 ft	48.95 kips	57.74 kips	106.69 kips
45.21 ft	49.02 kips	39.27 kips	88.29 kips
46.20 ft	52.08 kips	39.27 kips	91.35 kips
47.20 ft	55.26 kips	39.27 kips	94.53 kips
48.20 ft	58.52 kips	39.27 kips	97.79 kips
49.20 ft	61.85 kips	39.27 kips	101.12 kips
50.20 ft	65.27 kips	39.27 kips	104.54 kips
51.20 ft	68.77 kips	39.27 kips	108.04 kips
52.20 ft	72.34 kips	39.27 kips	111.61 kips
53.20 ft	76.00 kips	39.27 kips	115.27 kips
54.20 ft	79.73 kips	39.27 kips	119.00 kips
55.19 ft	83.51 kips	39.27 kips	122.78 kips
55.21 ft	83.58 kips	10.46 kips	94.04 kips
56.20 ft	86.40 kips	10.46 kips	96.87 kips
57.20 ft	89.32 kips	10.46 kips	99.78 kips
58.20 ft	92.29 kips	10.46 kips	102.75 kips
59.20 ft	95.32 kips	10.46 kips	105.78 kips
60.19 ft	98.38 kips	10.46 kips	108.84 kips
60.21 ft	98.45 kips	39.27 kips	137.72 kips
61.20 ft	102.70 kips	39.27 kips	141.97 kips
62.20 ft	107.07 kips	39.27 kips	146.34 kips
63.20 ft	111.51 kips	39.27 kips	150.78 kips
64.20 ft	116.02 kips	39.27 kips	155.29 kips
65.20 ft	120.60 kips	39.27 kips	159.87 kips
66.20 ft	125.26 kips	39.27 kips	164.53 kips
67.20 ft	130.00 kips	39.27 kips	169.27 kips
68.20 ft	134.80 kips	39.27 kips	174.07 kips
69.20 ft	139.69 kips	39.27 kips	178.96 kips
70.19 ft	144.59 kips	39.27 kips	183.86 kips
70.21 ft	144.71 kips	119.07 kips	263.78 kips

Depth	Skin Friction	End Bearing	Total Capacity
71.20 ft	151.49 kips	119.07 kips	270.56 kips
72.20 ft	158.45 kips	119.07 kips	277.51 kips
73.20 ft	165.51 kips	119.07 kips	284.58 kips
74.20 ft	172.68 kips	119.07 kips	291.75 kips
75.19 ft	179.89 kips	119.07 kips	298.96 kips
75.21 ft	180.02 kips	57.74 kips	237.77 kips
76.20 ft	185.89 kips	57.74 kips	243.63 kips
77.20 ft	191.90 kips	57.74 kips	249.65 kips
78.19 ft	197.94 kips	57.74 kips	255.68 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)

Fwd Abutment
B-002-0-24

Driveability Analysis Summary



Gain/Loss Factor at Shaft/Toe = 0.833/1.000

Depth	Rut	Rshaft	Rtoe	Blow Ct	Mx C-Str	Mx T-Str.	Stroke	ENTHRU	Hammer
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft	-
1.0	0.7	0.0	0.7	0.3	0.000	0.000	10.81	0.0	D 19-42
2.0	1.4	0.1	1.3	0.3	0.000	0.000	10.81	0.0	D 19-42
3.0	1.1	0.1	0.9	0.3	0.000	0.000	10.81	0.0	D 19-42
4.0	1.5	0.2	1.2	0.3	0.000	0.000	10.81	0.0	D 19-42
5.0	1.9	0.4	1.5	0.3	0.000	0.000	10.81	0.0	D 19-42
6.0	2.3	0.5	1.8	0.3	0.000	0.000	10.81	0.0	D 19-42
7.0	2.8	0.7	2.1	0.3	0.000	0.000	10.81	0.0	D 19-42
8.0	3.2	0.9	2.4	0.3	0.000	0.000	10.81	0.0	D 19-42
9.0	3.8	1.1	2.7	0.3	0.000	0.000	10.81	0.0	D 19-42
10.0	4.3	1.3	3.0	0.3	0.000	0.000	10.81	0.0	D 19-42
11.0	4.9	1.6	3.3	0.3	0.000	0.000	10.81	0.0	D 19-42
12.0	5.4	1.9	3.5	0.0	0.000	0.000	0.00	0.0	D 19-42
13.0	6.1	2.2	3.8	0.0	0.000	0.000	0.00	0.0	D 19-42
14.0	6.7	2.6	4.1	0.0	0.000	0.000	0.00	0.0	D 19-42
15.0	7.4	2.9	4.4	0.0	0.000	0.000	0.00	0.0	D 19-42
16.0	8.0	3.3	4.7	0.0	0.000	0.000	0.00	0.0	D 19-42
17.0	11.2	3.8	7.3	0.8	13.942	0.510	3.89	34.1	D 19-42
18.0	12.2	4.4	7.8	0.8	14.408	0.709	3.96	34.1	D 19-42
19.0	13.2	5.0	8.3	0.9	15.004	1.068	4.01	34.3	D 19-42
20.0	14.3	5.6	8.7	0.9	15.406	1.394	4.07	34.3	D 19-42
21.0	15.3	6.2	9.0	1.0	15.587	1.462	4.12	34.1	D 19-42
22.0	16.3	6.9	9.4	1.0	15.786	1.602	4.16	34.1	D 19-42
23.0	17.3	7.6	9.7	1.0	16.048	1.722	4.20	34.1	D 19-42
24.0	24.9	8.6	16.3	1.6	17.950	1.075	4.55	32.2	D 19-42
25.0	26.2	9.9	16.3	1.6	18.301	1.058	4.59	32.0	D 19-42
26.0	27.5	11.3	16.3	1.7	18.636	1.006	4.63	31.8	D 19-42
27.0	29.0	12.7	16.3	1.8	19.002	0.956	4.67	31.5	D 19-42
28.0	30.5	14.2	16.3	1.9	19.371	0.896	4.71	31.3	D 19-42
29.0	32.0	15.8	16.3	2.0	19.729	0.844	4.75	31.1	D 19-42
30.0	33.7	17.4	16.3	2.1	20.098	0.752	4.79	30.8	D 19-42
31.0	35.3	19.1	16.3	2.2	20.483	0.900	4.83	30.7	D 19-42
32.0	30.7	20.3	10.5	1.7	19.067	1.308	4.63	31.8	D 19-42
33.0	32.0	21.5	10.5	1.8	19.393	1.278	4.66	31.6	D 19-42
34.0	33.3	22.8	10.5	1.8	19.683	1.257	4.70	31.4	D 19-42
35.0	34.6	24.1	10.5	1.9	20.010	1.224	4.74	31.2	D 19-42
36.0	36.0	25.5	10.5	2.0	20.309	1.190	4.77	31.0	D 19-42
37.0	37.4	26.9	10.5	2.1	20.642	1.133	4.81	30.8	D 19-42
38.0	38.9	28.4	10.5	2.2	20.942	1.206	4.85	30.6	D 19-42

39.0	40.4	29.9	10.5	2.3	21.227	1.044	4.88	30.4	D 19-42
40.0	41.9	31.4	10.5	2.3	21.518	0.999	4.92	30.2	D 19-42
41.0	43.5	33.0	10.5	2.4	21.791	0.942	4.96	30.0	D 19-42
42.0	45.1	34.7	10.5	2.5	22.061	1.178	5.00	29.9	D 19-42
43.0	46.8	36.3	10.5	2.6	22.335	1.091	5.04	29.7	D 19-42
44.0	48.5	38.0	10.5	2.7	22.584	0.778	5.08	29.5	D 19-42
45.0	50.3	39.8	10.5	2.8	22.852	0.918	5.12	29.4	D 19-42
46.0	52.1	41.6	10.5	3.0	23.094	1.088	5.17	29.2	D 19-42
47.0	53.9	43.4	10.5	3.1	23.351	1.257	5.21	29.0	D 19-42
48.0	55.8	45.3	10.5	3.2	23.546	1.677	5.25	28.9	D 19-42
49.0	57.7	47.2	10.5	3.3	23.759	1.841	5.29	28.7	D 19-42
50.0	59.7	49.2	10.5	3.4	23.753	1.828	5.34	28.3	D 19-42
51.0	110.3	52.4	57.8	8.6	29.406	2.205	6.75	25.4	D 19-42
52.0	113.6	55.7	57.8	8.8	29.553	2.228	6.80	25.4	D 19-42
53.0	116.9	59.1	57.8	9.1	29.671	2.206	6.86	25.3	D 19-42
54.0	120.4	62.5	57.8	9.4	29.825	2.195	6.91	25.3	D 19-42
55.0	123.9	66.0	57.8	9.6	29.942	2.342	6.97	25.1	D 19-42
56.0	108.7	69.3	39.4	7.8	28.518	1.416	6.57	25.5	D 19-42
57.0	112.0	72.7	39.4	8.1	28.711	1.338	6.62	25.5	D 19-42
58.0	115.5	76.1	39.4	8.4	28.895	1.304	6.69	25.4	D 19-42
59.0	118.9	79.6	39.4	8.6	29.074	1.258	6.76	25.3	D 19-42
60.0	122.5	83.1	39.4	8.9	29.264	1.156	6.82	25.3	D 19-42
61.0	126.1	86.8	39.4	9.3	29.436	1.213	6.89	25.2	D 19-42
62.0	129.8	90.4	39.4	9.6	29.627	1.303	6.95	25.2	D 19-42
63.0	133.6	94.2	39.4	9.9	29.827	1.384	7.00	25.2	D 19-42
64.0	137.4	98.0	39.4	10.2	29.976	1.446	7.06	25.2	D 19-42
65.0	141.3	101.9	39.4	10.5	30.129	1.502	7.12	25.0	D 19-42
66.0	115.3	104.8	10.5	7.2	28.026	1.865	6.41	25.7	D 19-42
67.0	118.2	107.8	10.5	7.4	28.209	1.839	6.48	25.7	D 19-42
68.0	121.2	110.8	10.5	7.6	28.403	1.789	6.54	25.6	D 19-42
69.0	124.3	113.8	10.5	7.8	28.591	1.696	6.60	25.6	D 19-42
70.0	127.4	116.9	10.5	8.1	28.786	1.557	6.66	25.6	D 19-42
70.2	157.4	118.0	39.4	11.7	30.740	1.709	7.33	24.9	D 19-42

Total driving time: 5 minutes; Total Number of Blows: 244 (starting at penetration 1.0 ft)

GRLWEAP: Wave Equation Analysis of Pile Foundations

CAR-Grant Street Bridge Replacement B-002-0-24 + 12" CIP 8/7/2025
RESOURCE INTERNATIONAL INC GRLWEAP 14.1.20.1

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

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

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

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

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

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

SOIL PROFILE

Depth	Soil Type	Spec. Wt	Su	Phi	Unit Rs	Unit Rt
ft	-	lb/ft³	ksf	°	ksf	ksf
0.0	Sand	120.0	0.0	29.0	0.00	0.00
2.0	Sand	120.0	0.0	29.0	0.03	1.71
2.0	Sand	115.0	0.0	25.0	0.02	0.81
16.0	Sand	115.0	0.0	25.0	0.16	6.00
16.0	Sand	120.0	0.0	27.0	0.19	8.75
23.5	Sand	120.0	0.0	27.0	0.28	12.54
23.5	Sand	125.0	0.0	31.0	0.40	20.71
31.0	Sand	125.0	0.0	31.0	0.54	20.71
31.0	Sand	125.0	0.0	29.0	0.45	13.32
50.0	Sand	125.0	0.0	29.0	0.76	13.32
50.0	Sand	130.0	0.0	34.0	1.22	73.64
55.0	Sand	130.0	0.0	34.0	1.36	73.64
55.0	Sand	130.0	0.0	33.0	1.24	50.11
65.0	Sand	130.0	0.0	33.0	1.50	50.11
65.0	Sand	135.0	0.0	30.0	1.10	13.32
70.0	Sand	135.0	0.0	30.0	1.20	13.32
70.0	Sand	125.0	0.0	33.0	1.64	50.11
80.0	Sand	125.0	0.0	33.0	1.87	50.11
80.0	Sand	130.0	0.0	36.0	2.55	151.75
85.0	Sand	130.0	0.0	36.0	2.72	151.75
85.0	Sand	130.0	0.0	34.0	2.18	73.64
88.0	Sand	130.0	0.0	34.0	2.27	73.64

PILE INPUT

Uniform Pile		Pile Type:	Closed-End Pipe
Pile Length: (ft)	75.000	Pile Penetration: (ft)	70.210
Pile Size: (ft)	1.00	Toe Area: (in²)	113.10

Pile Profile

Lb Top	X-Area	E-Modulus	Spec. Wt	Perim.	Crit. Index
ft	in²	ksi	lb/ft³	ft	-
0.0	9.2	30,000.0	493.4	3.1	0
75.0	9.2	30,000.0	493.4	3.1	0

HAMMER INPUT

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

Hammer Data

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

DRIVE SYSTEM FOR DELMAG D 19-42-OED

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

SOIL RESISTANCE DISTRIBUTION

Depth	Unit Rs	Unit Rt	Qs	Qt	Js	Jt	Set. F.	Limit D.	Set. T.	EB Area
ft	ksf	ksf	in	in	s/ft	s/ft	-	ft	Hours	in²
0.0	0.0	0.0	0.10	0.04	0.10	0.15	1.2	6.0	24.0	113.1
1.0	0.0	0.9	0.10	0.04	0.10	0.15	1.2	6.0	24.0	113.1
2.0	0.0	1.7	0.10	0.04	0.10	0.15	1.2	6.0	24.0	113.1
2.0	0.0	0.8	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
3.8	0.0	1.5	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
5.5	0.1	2.1	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
7.3	0.1	2.8	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
9.0	0.1	3.4	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
10.8	0.1	4.1	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
12.5	0.1	4.7	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
14.3	0.1	5.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
16.0	0.2	6.0	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
16.0	0.2	8.7	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
17.9	0.2	9.9	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
19.8	0.2	11.0	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
21.6	0.3	11.8	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
23.5	0.3	12.5	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
23.5	0.4	20.7	0.10	0.03	0.05	0.15	1.0	6.0	1.0	113.1
25.4	0.4	20.7	0.10	0.03	0.05	0.15	1.0	6.0	1.0	113.1
27.3	0.5	20.7	0.10	0.03	0.05	0.15	1.0	6.0	1.0	113.1
29.1	0.5	20.7	0.10	0.03	0.05	0.15	1.0	6.0	1.0	113.1
31.0	0.5	20.7	0.10	0.03	0.05	0.15	1.0	6.0	1.0	113.1
31.0	0.5	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
32.7	0.5	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
34.5	0.5	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
36.2	0.5	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
37.9	0.6	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1

39.6	0.6	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
41.4	0.6	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
43.1	0.6	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
44.8	0.7	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
46.5	0.7	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
48.3	0.7	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
50.0	0.8	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
50.0	1.2	73.6	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
51.7	1.3	73.6	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
53.3	1.3	73.6	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
55.0	1.4	73.6	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
55.0	1.2	50.1	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
56.7	1.3	50.1	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
58.3	1.3	50.1	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
60.0	1.4	50.1	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
61.7	1.4	50.1	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
63.3	1.5	50.1	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
65.0	1.5	50.1	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
65.0	1.1	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
66.7	1.1	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
68.3	1.2	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
70.0	1.2	13.3	0.10	0.03	0.05	0.15	1.2	6.0	1.0	113.1
70.0	1.6	50.1	0.10	0.03	0.05	0.15	1.0	6.0	1.0	113.1
70.2	1.6	50.1	0.10	0.03	0.05	0.15	1.0	6.0	1.0	113.1

APPENDIX V

LATERAL DESIGN PARAMETERS

Lateral Design Parameters
W-23-185 CAR-Grant Street Bridge Replacement

Boring	Elevation (feet)	Soil Class.	Soil Type	Strata	N_{60}	γ (pcf)	γ' (pcf)	Strength Parameter	k (soil) k_{rm} (rock)	ε_{50} (soil) E_r (rock)	RQD (rock)
B-001-0-24	1042.9 to 1037.4	A-3a	G	4	12	125	125	φ = 28°	25 pci	-	-
	1037.4 to 1034.9	A-1-b	G	4	6	120	57.6	φ = 28°	20 pci	-	-
	1034.9 to 1032.4	A-3a	G	4	3	115	52.6	φ = 26°	20 pci	-	-
	1032.4 to 1024.9	A-1-b	G	4	8	120	57.6	φ = 28°	15 pci	-	-
	1024.9 to 1022.4	A-3	G	4	13	125	62.6	φ = 27°	20 pci	-	-
	1022.4 to 1019.9	A-3	G	4	44	130	67.6	φ = 34°	105 pci	-	-
	1019.9 to 1014.9	A-3	G	4	26	130	67.6	φ = 30°	50 pci	-	-
	1014.9 to 1012.4	A-3	G	4	13	125	62.6	φ = 27°	20 pci	-	-
	1012.4 to 1005.9	A-3	G	4	34	130	67.6	φ = 32°	75 pci	-	-
	1005.9 to 990.9	A-3	G	4	24	125	62.6	φ = 30°	50 pci	-	-
	990.9 to 987.9	A-3	G	4	17	125	62.6	φ = 28°	30 pci	-	-
	987.9 to 960.9	A-1-b	G	4	30	130	67.6	φ = 33°	60 pci	-	-
	960.9 to 955.9	A-1-b	G	4	10	120	57.6	φ = 29°	20 pci	-	-
	955.9 to 952.9	A-1-b	G	4	58	135	72.6	φ = 37°	125 pci	-	-
B-002-0-24	1043.8 to 1035.8	A-1-a	G	4	13	125	125	φ = 30°	25 pci	-	-
	1035.8 to 1033.3	A-1-b	G	4	6	120	57.6	φ = 28°	20 pci	-	-
	1033.3 to 1029.8	A-2-4	G	4	9	120	57.6	φ = 29°	20 pci	-	-
	1029.8 to 1025.8	A-3	G	4	3	115	52.6	φ = 25°	10 pci	-	-
	1025.8 to 1018.3	A-3	G	4	11	120	57.6	φ = 27°	20 pci	-	-
	1018.3 to 1010.8	A-1-a	G	4	16	125	62.6	φ = 31°	30 pci	-	-
	1010.8 to 991.8	A-3	G	4	22	125	62.6	φ = 29°	35 pci	-	-
	991.8 to 986.8	A-3	G	4	43	130	67.6	φ = 34°	105 pci	-	-
	986.8 to 976.8	A-3	G	4	38	130	67.6	φ = 33°	90 pci	-	-
	976.8 to 971.8	A-3	G	4	26	130	67.6	φ = 30°	50 pci	-	-
	971.8 to 961.8	A-1-a	G	4	24	125	62.6	φ = 33°	50 pci	-	-
	961.8 to 956.8	A-1-a	G	4	41	130	67.6	φ = 36°	90 pci	-	-
	956.8 to 953.8	A-1-a	G	4	31	130	67.6	φ = 34°	60 pci	-	-

APPENDIX VI

VIBRATION IMPACT ASSESSMENT CALCULATIONS

Vibration Impact Assessment
CAR-Grant Street Bridge Replacement
Rii Project No. W-23-185

Pile Driving - Impact

$PPV_{Impact\ Pile\ Driver}$	**0.29**	in/sec
PPV_{Ref}	0.65	in/sec
D	50	ft
n	1.3	dim
E_{equip}	44000	ft/lb
E_{Ref}	36000	ft/lb

Structure and Condition	Maximum PPV (in/sec) Transient Sources	Maximum PPV (in/sec) Continuous/Frequent Intermittent Sources
Extremely fragile historic building, ruins, and ancient monuments	0.12	0.08
Fragile buildings	0.2	0.1
Historic and some old buildings	0.5	0.25
Older residential structures	0.5	0.3
New residential structures	1.0	0.5
Modern industrial/commercial buildings	2.0	0.5

Human Response	Maximum PPV (in/sec) Transient Sources	Maximum PPV (in/sec) Continuous/Frequent Intermittent Sources
Barely perceptible	0.04	0.01
Distinctly perceptible	0.25	0.04
Strongly perceptible	0.9	0.1
Severe	2.0	0.4

Nearest bldg. horiz. distance (ft)	40
Req. total distance (ft)	50
Req. vert. distance (ft)	30
Footing Depth (ft)	11
Prebore Depth (ft)	19
Bottom of Prebore Elevation (ft)	**1014**