Sycamore Creek Bridge Replacement

Geotechnical Engineering Report

July 3, 2024 | Terracon Project No. N1235414

Prepared for:

Woolpert Inc.
4454 Idea Center Boulevard
Dayton, Ohio 45430

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611 Lunken Park Drive
Cincinnati, Ohio 45226
P (513) 321-5816
Terracon.com

July 3, 2024

Woolpert Inc.
4454 Idea Center Boulevard
Dayton, Ohio 45430

Attn: Mr. Patrick Plews, P.E.
P: (937) 531-1392
E: Pat.plews@woolpert.com

Re: Geotechnical Engineering Report
Sycamore Creek Bridge Replacement
Great Miami Recreational Trail over Sycamore Creek
Miamisburg, Ohio 45342
Terracon Project No. N1235414

Dear Mr. Plews:

We have completed the scope of Geotechnical Engineering services for the above-referenced project in general accordance with Terracon Proposal No. PN1235414 dated November 20, 2023, and authorized on June 11, 2024. This report presents the findings of the subsurface borings performed by Bowser Morner and provides geotechnical recommendations concerning earthwork and foundations for the proposed bridge replacement project.

We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report or if we may be of further service, please contact us.

Sincerely,

Terracon

STATE OF OHIO
DAVID W. WESTENDORF
74346
REGISTERED
PROFESSIONAL ENGINEER

Munal Pandey, E.I.
Senior Staff Engineer

David W. Westendorf, P.E.
Principal/Group Manager

Table of Contents

Note: This report was originally delivered in a web-based format. **Blue Bold** text in the report indicates a referenced section heading. The PDF version also includes hyperlinks that direct the reader to that section and clicking on the Terracon logo will bring you back to this page. For more interactive features, please view your project online at **client.terracon.com**.

Refer to each individual Attachment for a listing of contents.

Executive Summary

- The geotechnical recommendations provided in this report are primarily based on the 2 borings drilled by Bowser Morner in 2017 at the anticipated foundation location up to a depth of 30 feet below existing site grades on this project. During construction, the actual conditions should be observed for consistency with the information shown in the boring logs and Terracon informed if any discrepancies occur so that we can adjust our recommendations.
- Based on the 2017 borings, the subsurface profile at the site consists of loose to medium-dense granular soil up to 8.5 feet below existing site grades followed by very-soft cohesive soil up to 11 feet below the existing site grades. The subsurface profile underneath consists primarily of dense to very dense granular soil with occasional layers of hard cohesive soils up to the maximum exploration depth of 30 feet.
- Based on the anticipated ultimate load of approximately 213 kips and the anticipated subsurface profile, we recommend the proposed deep foundations (12-inch diameter driven piles) be extended to the dense to very dense granular soil at a depth of approximately 22 feet below the existing site grades at both abutments. This embedment depth must be revised if the bridge loads are different from the assumed value shown above.
- Preliminary driveability analyses for the proposed piles were performed considering the Delmag D 12-42 hammer. Prior to construction, the contractor shall perform a drivability analysis using the actual pile hammer-cushion combination that will be used during construction. These preliminary analyses were performed using GRLWEAP and considered 45 ksi ASTM A252 Grade 3 steel pipe piles. The initial analyses indicated that the piles using 1/4-inch wall thickness would be acceptable.
- Terracon recommends all earthwork, pavement subgrade, and bridge construction be performed per the ODOT Construction and Materials Specifications (ODOT CMS).

Introduction

The project includes the replacement of an existing two-span box beam bridge carrying the Great Miami Recreational Trail over Sycamore Creek with a new single-span composite prestressed concrete box beam. The bridge is anticipated to be 62 feet long and 15 feet wide and will be primarily subjected to pedestrian live load (90 psf) or H-15 vehicles. Based on the information provided to us by Woolpert, the bridge abutments are anticipated to be supported on cast-in-place (CIP) driven piles.

The purpose of this geotechnical study was to provide information and geotechnical engineering recommendations relative to:

- Subsurface soil conditions
- Short-term groundwater conditions
- Site preparation and earthwork
- Foundation recommendations

The geotechnical engineering Scope of Services for this project included the review of historical test borings, engineering analysis, and preparation of this report. Drawings showing the site and boring locations are shown on the **Site Location** and **Exploration Plan**, respectively. The provided boring logs and the laboratory test results along with the analysis outputs are provided in the **Attachments** section.

Geology and Observations

Based on the Physiographic Region of Ohio map from the Ohio Geologic Survey, the project is located in Southern Ohio Loamy Till Plain which is generally characterized by the surface of loamy till with stream valleys filled with outwash and alternates between broad floodplains and narrows. Due to the proximity of the site to the existing Great Miami River and Sycamore Creek, this site appears to be in a region with surficial outwash soils with glacial till underneath.

Based on USDA Soil Survey Maps, the surficial soils at the site are classified as Ross Silt Loam which consists of very deep, well-drained soils that are formed in loamy alluvium on flood plains and low terraces.

Based on USGS, the overburden soils are underlain by the Ordovician Age bedrock belonging to the Undivided Grant Lake and Fairview Formations consisting of interbedded shale (~50%-90%) and limestone (~10%-50%) layers. Bedrock topographic mapping indicated bedrock elevations at about El. 550 to 600 feet MSL in the project area which is approximately 100 to 150 feet below existing site grades.

Terracon did not perform site reconnaissance as part of this study. Based on the publicly available aerial imagery of the site, the project is located to the east of the Great Miami River and west of the Sycamore Creek bridge over North Main Street. The site is generally wooded around the proposed bridge location. To the east of the project site, the surrounding area is generally residential with some commercial buildings.

Historical Subsurface Exploration

The information provided by Woolpert during the request for proposal indicated a total of two (2) borings that were performed by Bower Morner on August 23, 2017, near the two proposed abutment locations. The test borings were performed using an ATV-mounted drill rig. The drill rig utilized continuous-flight hollow augers to permit split-spoon sampling in overburden soils. Groundwater levels were observed during drilling and immediately upon the completion at each test boring location. Any information on the hammer energy transfer ratio (ETR) used for drilling has not been provided in the report, hence our analysis is based on the raw SPT N-values provided in the boring logs. The laboratory test program included 11 moisture contents, 3 grain-size analyses, and 1 Atterberg Limit.

In addition, Terracon also reviewed the two (2) archive borings available in ODOT TIMS performed by Engineering and Environmental Services between November 20, 1973, and November 30, 1973, for the existing Sycamore Creek bridge along North Main Street located southeast of the site.

Historical Exploration Findings

Subsurface Profile

Based on the historical borings, the subsurface profile at the site consists of loose to medium-dense granular soil up to 8.5 feet below existing site grades followed by very-soft cohesive soil up to 11 feet below the existing site grades. The subsurface profile underneath consists primarily of dense to very dense granular soil with occasional layers of hard cohesive soils. An undocumented fill consisting mainly of loose sand and gravel was encountered at the top 4 feet at the south abutment location.

Conditions encountered at each boring location are indicated in the provided boring logs shown in the **Attachments** section. It should be noted that the stratification boundaries on the boring logs represent the approximate location of changes in native soil types; in situ, the transition between materials may be gradual.

Groundwater Conditions

The historical boreholes were observed while drilling and after completion for the presence and level of groundwater. The table below summarizes the depth of groundwater at each test boring.

Boring No.	Groundwater Depth[1,2]	
	While Drilling	At Completion
1	8.5	6.0
2	10.0	10.0

1. Below existing site grades.
2. The average water level at the Great Miami River is about Elevation 680 feet MSL in the Miamisburg area. The depth at which groundwater was encountered at the borings roughly corresponds to the average water level along the Great Miami River.

The groundwater summary in the table above does not indicate a stable groundwater level at these boring locations. Long-term piezometers or observation wells sealed with the influence of surface water are often required to define groundwater levels. In addition, perched groundwater is often encountered in glacial till profile soils.

Groundwater level fluctuations occur due to seasonal variations in the amount of rainfall, runoff along the Sycamore Creek, level of water in Great Miami River, and other factors not evident at the time the borings were performed. Groundwater levels during construction and at other times in the life of the bridge may be higher or lower than the levels indicated on the boring logs. The possibility of groundwater level fluctuations or perched water should be considered when developing the design and construction plans for the project.

Analysis and Recommendations

Earthwork Recommendations

Prior to placing new fill, all vegetation, topsoil, existing pavement, and any otherwise unsuitable material should be removed from the construction areas. Wet or dry material should either be removed, or moisture conditioned and recompacted. After stripping and grubbing, the subgrade should be proof-rolled where possible to aid in locating loose or soft areas. Soft, dry, and low-density soil should be removed or compacted in place prior to placing new fill in accordance with ODOT specifications.

We recommend all earthwork and engineered fill placement be performed per the ODOT Construction and Materials Specifications (ODOT CMS). Based on the review of the historical borings, the on-site soils appear suitable for re-use as engineered fill following proper moisture conditioning. Unsuitable soils were not encountered at the site, but some culling of unsuitable soils should be anticipated.

Foundation Recommendations

The proposed bridge is anticipated to consist of a single-span composite prestressed concrete box beam. The bridge is anticipated to be 62 feet long and 15 feet wide and will be primarily subjected to pedestrian live load (90 psf) or H-15 vehicles. Based on the information provided to us by Woolpert, the bridge abutments are anticipated to be supported on 12-inch diameter, cast-in-place (CIP), closed-end, driven piles. In addition, the design scour depth for the abutments is 2.16 feet based on the information provided.

Driven Pile Recommendations

Driven pile analyses were performed using APILE (version 2019.9.11) and in accordance with ODOT BDM requirements. The analyses considered 12-inch diameter cast-in-place (CIP), closed-end driven piles. The analysis was performed for each of the two borings drilled for this bridge, due to slight variations in the encountered soil profiles. The analyses showed some variability in resistance and drivability across each of the borings. Driven piles should be spaced at least three pile diameters apart (center-to-center) when side friction is used for compressive loads. Results and calculations for each of the analysis cases are included as **Attachments** to this report.

Based on the information provided by Woolpert, the APILE analyses have been performed to get an anticipated ultimate bearing value (UBV) of at least 213 kips. The table below summarizes the APILE analysis results.

Structure	Pile Length (ft)	Approx. Tip Elevation (ft)	Side Resistance (kips)	End Bearing (kips)	UBV (kips)
South Abutment (Per Boring No. 1)	22.0	668	46.4	172.2	**218.5**
North Abutment (Per Boring No. 2)	22.0	668	48.9	172.5	**221.4**
Pile Type/Size= 12-inch closed end pipe; Steel Grade= 45 ksi;					

Preliminary driveability analyses for the proposed piles were performed considering the Delmag D 19-42 hammer. Prior to construction, the contractor shall perform a drivability analysis using the pile hammer-cushion combination that will be used. These preliminary analyses were performed using GRLWEAP and considered 45 ksi ASTM A252 Grade 3 steel pipe piles. The initial analyses indicated that the piles using 1/4-inch wall thickness would be acceptable.

Pile driving conditions, hammer efficiency, and stress on the pile during driving could be better evaluated during installation using a Pile Driving Analyzer (PDA) performed by a qualified pile testing contractor. Driving criteria for the driven CIP piles should be recommended by the pile testing contractor, based on the PDA results. During driving, a maximum of 100 blows per foot is recommended to reduce the potential of damage to the piles. Each pile should be observed and checked for buckling, crimping, and alignment in addition to recording penetration resistance, depth of embedment, and general pile driving operations.

The pile driving process should be performed under the direction of the Geotechnical Engineer or their representative. They should document the pile installation process including hammer blow counts and groundwater conditions encountered, consistency with expected conditions, and details of the installed pile.

Seismic Considerations

The seismic design requirements for buildings and other structures are based on the Seismic Design Category. Site Classification is required to determine the Seismic Design Category for a structure. The Site Classification is based on the upper 100 feet of the site profile defined by a weighted average value of either shear wave velocity, standard penetration resistance, or undrained shear strength in accordance with AASHTO LRFD Bridge Design Specifications Section 3.10.3.1. Based on the soil properties per the historical logs, it is our opinion that the **Seismic Site Classification is D**. Subsurface explorations at this site were extended to a maximum depth of about 40 feet. The site properties below the boring depth to 100 feet were estimated based on our experience and knowledge of the geologic conditions of the general area. Additional deeper borings or geophysical testing may be performed to confirm the conditions below the current boring depth.

General Comments

Our analysis and opinions are based on our understanding of the project, the geotechnical conditions in the area, and the data obtained from the historical subsurface exploration. Variations will occur between exploration point locations or due to the modifying effects of construction or weather. The nature and extent of such variations may not become evident until during or after construction. If variations appear, we can provide further evaluation and supplemental recommendations. If variations are noted in the absence of our observation and testing services on-site, we should be immediately notified so that we can provide evaluation and supplemental recommendations.

Our Scope of Services does not include either specifically or by implication any environmental or biological (e.g., mold, fungi, bacteria) assessment of the site or identification or prevention of pollutants, hazardous materials, or conditions. If the owner is concerned about the potential for such contamination or pollution, other studies should be undertaken.

Our services and any correspondence are intended for the sole benefit and exclusive use of our client for specific application to the project discussed and are accomplished under generally accepted geotechnical engineering practices with no third-party beneficiaries intended. Any third-party access to services or correspondence is solely for information purposes to support the services provided by Terracon to our client. Reliance upon the services and any work product is limited to our client and is not intended for third parties. Any use or reliance of the provided information by third parties is done solely at their own risk. No warranties, either express or implied, are intended or made.

Site characteristics as provided are for design purposes and not to estimate excavation cost. Any use of our report in that regard is done at the sole risk of the excavating cost estimator as there may be variations on the site that are not apparent in the data that could significantly affect excavation cost. Any parties charged with estimating excavation costs should seek their site characterization for specific purposes to obtain the specific level of detail necessary for costing. Site safety and cost estimating including excavation support and dewatering requirements/design are the responsibility of others. If changes in the nature, design, or location of the project are planned, our conclusions and recommendations shall not be considered valid unless we review the changes and either verify or modify our conclusions in writing.

Attachments

Contents:

Site Location

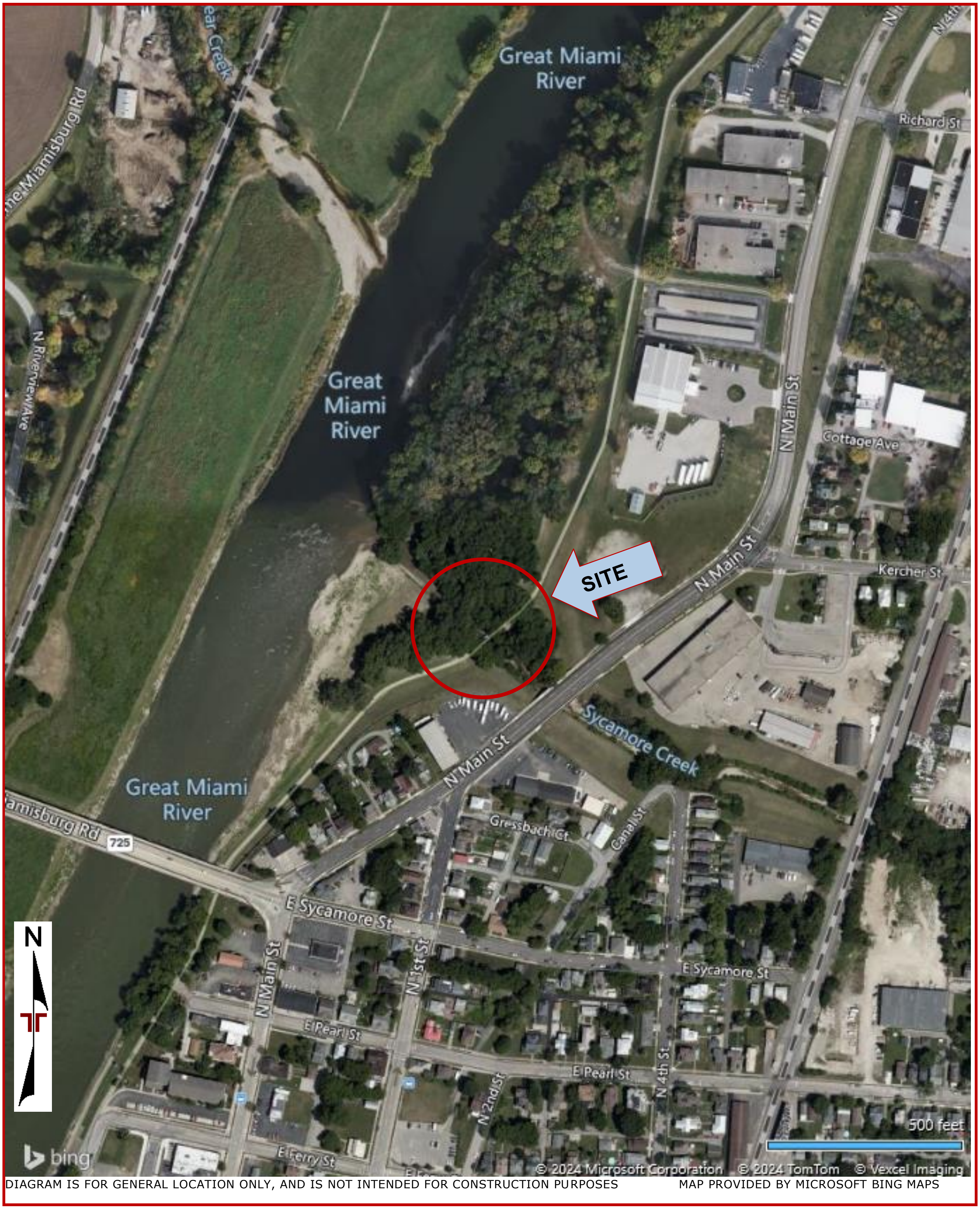


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

MAP PROVIDED BY MICROSOFT BING MAPS

Historical Exploration Plan

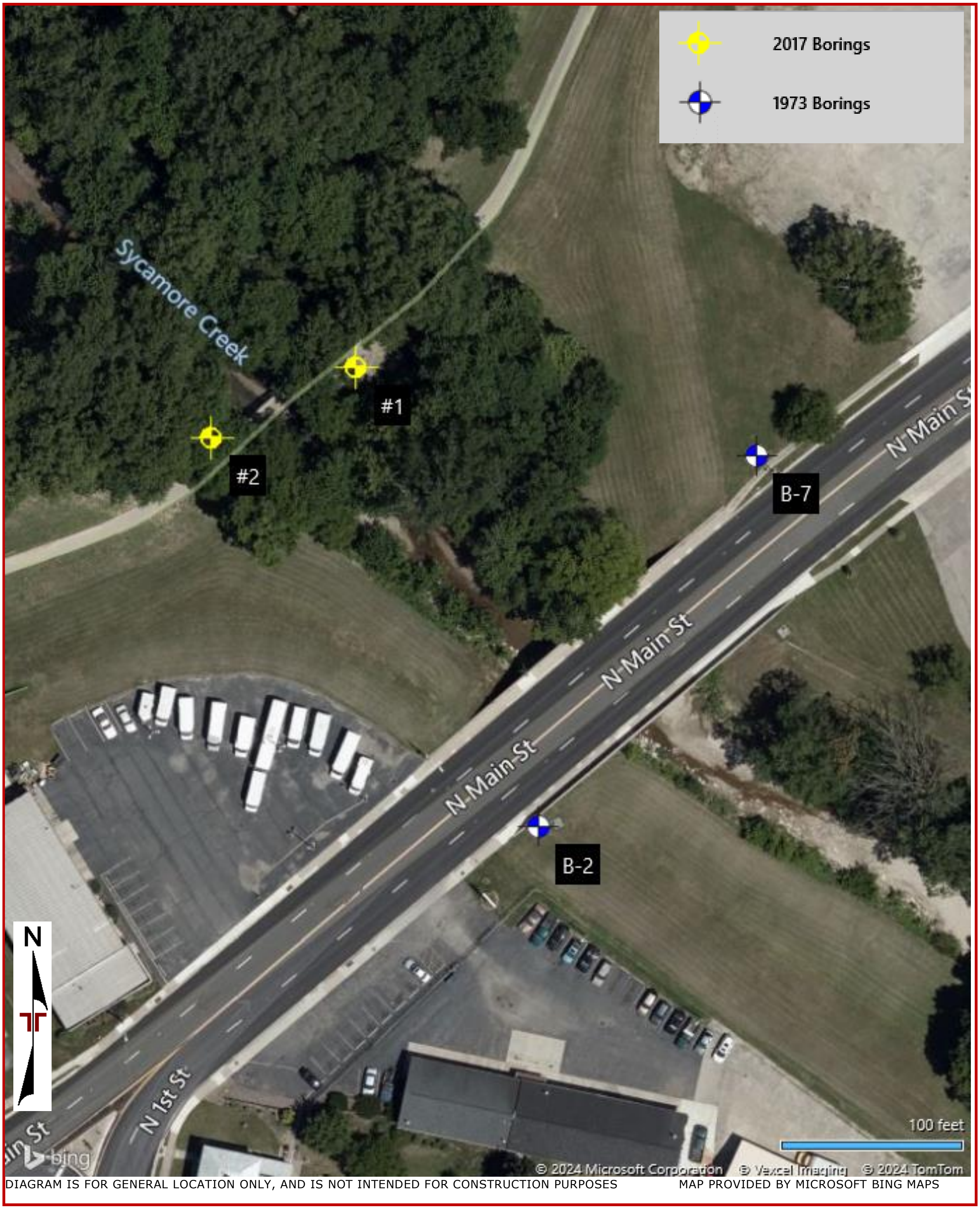


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES MAP PROVIDED BY MICROSOFT BING MAPS

Historical Boring Logs and Laboratory Results

CLIENT
Pennoni

PROJECT
Soil Study for Proposed Trail Bridge over Sycamore Creek, Near North Main Street, Miamisburg, Ohio

JOB NO. **180573**

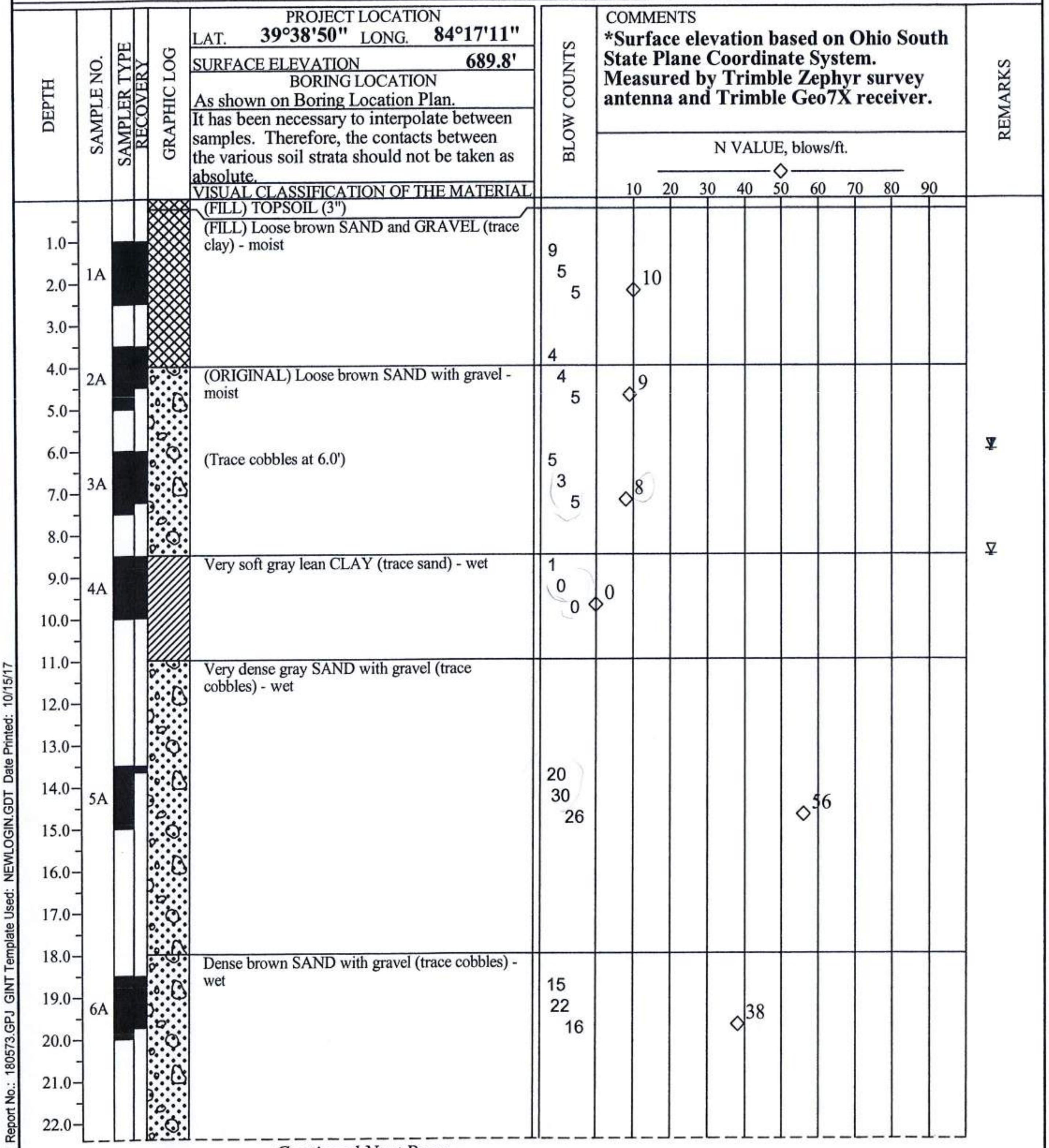
BORING STARTED **8/23/17**
BORING COMPLETED **8/23/17**
DRILLER **TB, DC**
METHOD **3 1/4" HSA**
TYPED BY **crr**

1
Boring No.
Sheet 1 of 2

PROJECT LOCATION
LAT. **39°38'50"** LONG. **84°17'11"**
SURFACE ELEVATION **689.8'**

BORING LOCATION
As shown on Boring Location Plan.
It has been necessary to interpolate between samples. Therefore, the contacts between the various soil strata should not be taken as absolute.

COMMENTS
***Surface elevation based on Ohio South State Plane Coordinate System. Measured by Trimble Zephyr survey antenna and Trimble Geo7X receiver.**



DEPTH	SAMPLE NO.	VISUAL CLASSIFICATION OF THE MATERIAL	BLOW COUNTS	N VALUE, blows/ft.	REMARKS
0.0		(FILL) TOPSOIL (3")			
0.25		(FILL) Loose brown SAND and GRAVEL (trace clay) - moist			
1.0–2.5	1A		9 5 5	10	
3.5–5.0	2A	(ORIGINAL) Loose brown SAND with gravel - moist (from 4.0)	4 4 5	9	
6.0		(Trace cobbles at 6.0')			▼
6.0–7.5	3A		5 3 5	8	
8.5		Very soft gray lean CLAY (trace sand) - wet			∇
8.5–10.0	4A		1 0 0	0	
11.0		Very dense gray SAND with gravel (trace cobbles) - wet			
13.5–15.0	5A		20 30 26	56	
18.0		Dense brown SAND with gravel (trace cobbles) - wet			
18.5–20.0	6A		15 22 16	38	

Continued Next Page

WATER LEVEL MEASUREMENTS

	DEPTH		DATE
INITIAL	8.5	∇	8/23/2017
AT COMPLETION	6.0	▼	8/23/2017
OTHER	N/A	▼	N/A

■	A—SPLIT SPOON
◨	B—ROCK CORE
☒	C—SHELBY TUBE
▩	D—SOIL PROBE
◧	E—AUGER CUTTINGS
░	F—SONIC

Bowser-Morner, Inc.

Telephone:
Fax:

BOWSER MORNER.

GINT Report Used: NEWLOGIN Report No.: 180573.GPJ GINT Template Used: NEWLOGIN.GDT Date Printed: 10/15/17

CLIENT
Pennoni

PROJECT
Soil Study for Proposed Trail Bridge over Sycamore Creek, Near North Main Street, Miamisburg, Ohio

JOB NO. **180573**
BORING STARTED **8/23/17**
BORING COMPLETED **8/23/17**
DRILLER **TB, DC**
METHOD **3 1/4" HSA**
TYPED BY **crr**

1
Boring No.
Sheet 2 of 2

PROJECT LOCATION
LAT. **39°38'50"** LONG. **84°17'11"**
SURFACE ELEVATION **689.8'**

BORING LOCATION
As shown on Boring Location Plan.

It has been necessary to interpolate between samples. Therefore, the contacts between the various soil strata should not be taken as absolute.

COMMENTS
***Surface elevation based on Ohio South State Plane Coordinate System. Measured by Trimble Zephyr survey antenna and Trimble Geo7X receiver.**

DEPTH	SAMPLE NO.	VISUAL CLASSIFICATION OF THE MATERIAL	BLOW COUNTS	N VALUE, blows/ft.	REMARKS
23.0		Dense brown SAND with gravel (trace cobbles) - wet			
24.0 25.0 26.0 27.0	7A	Hard gray sandy lean CLAY (trace gravel) - moist	13 18 18	36	
28.0 29.0	8A	Dense gray SAND with gravel (trace cobbles) - wet	15 15 16	31	
30.0		Bottom of boring at 30.0 feet			
31.0 32.0 33.0 34.0 35.0 36.0 37.0 38.0 39.0 40.0 41.0 42.0 43.0 44.0 45.0 46.0 47.0 48.0					

CLIENT
Pennoni

JOB NO.
180573

BORING STARTED **8/23/17**
BORING COMPLETED **8/23/17**
DRILLER **TB, DC**
METHOD **3 1/4" HSA**
TYPED BY **crr**

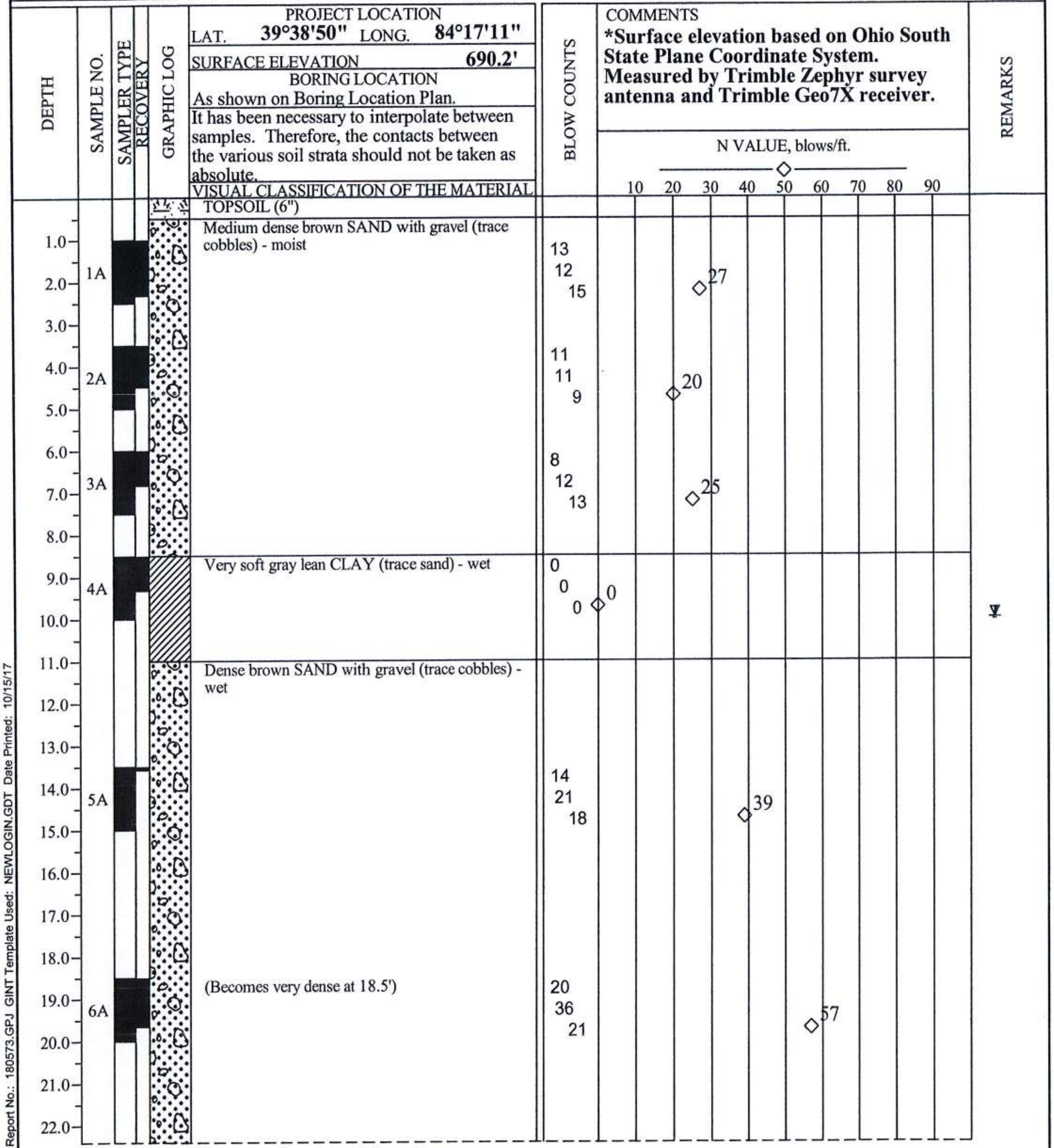
2
Boring No.
Sheet 1 of 2

PROJECT
Soil Study for Proposed Trail Bridge over Sycamore Creek, Near North Main Street, Miamisburg, Ohio

PROJECT LOCATION
LAT. **39°38'50"** LONG. **84°17'11"**
SURFACE ELEVATION **690.2'**

BORING LOCATION
As shown on Boring Location Plan.
It has been necessary to interpolate between samples. Therefore, the contacts between the various soil strata should not be taken as absolute.

COMMENTS
***Surface elevation based on Ohio South State Plane Coordinate System. Measured by Trimble Zephyr survey antenna and Trimble Geo7X receiver.**



SAMPLE NO.	BLOW COUNTS	N VALUE	VISUAL CLASSIFICATION OF THE MATERIAL	REMARKS
			TOPSOIL (6")	
1A	13 12 15	27	Medium dense brown SAND with gravel (trace cobbles) - moist	
2A	11 11 9	20		
3A	8 12 13	25		
4A	0 0 0	0	Very soft gray lean CLAY (trace sand) - wet	▼
5A	14 21 18	39	Dense brown SAND with gravel (trace cobbles) - wet	
6A	20 36 21	57	(Becomes very dense at 18.5')	

Continued Next Page

WATER LEVEL MEASUREMENTS

	DEPTH		DATE
INITIAL	10.0	▽	8/23/2017
AT COMPLETION	10.0	▼	8/23/2017
OTHER	N/A	▼	N/A

- ■ A—SPLIT SPOON
- B—ROCK CORE
- ☒ C—SHELBY TUBE
- ▨ D—SOIL PROBE
- E—AUGER CUTTINGS
- F—SONIC

Bowser-Morner, Inc.

Telephone:
Fax:

BOWSER MORNER.

CLIENT
Pennoni

PROJECT
Soil Study for Proposed Trail Bridge over Sycamore Creek, Near North Main Street, Miamisburg, Ohio

JOB NO. **180573**

BORING STARTED **8/23/17**

BORING COMPLETED **8/23/17**

DRILLER **TB, DC**

METHOD **3 1/4" HSA**

TYPED BY **crr**

2
Boring No.

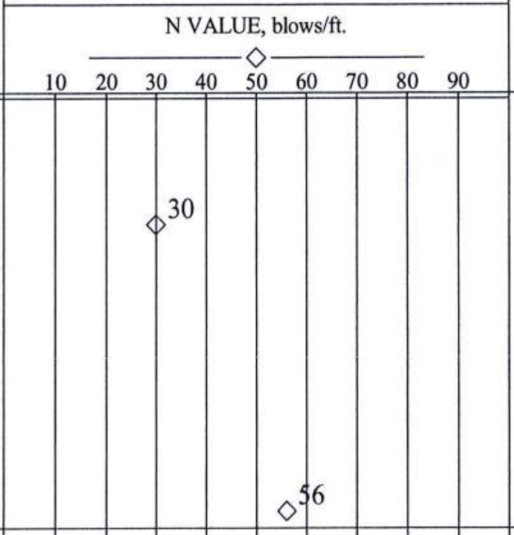
Sheet 2 of 2

PROJECT LOCATION
LAT. **39°38'50"** LONG. **84°17'11"**
SURFACE ELEVATION **690.2'**

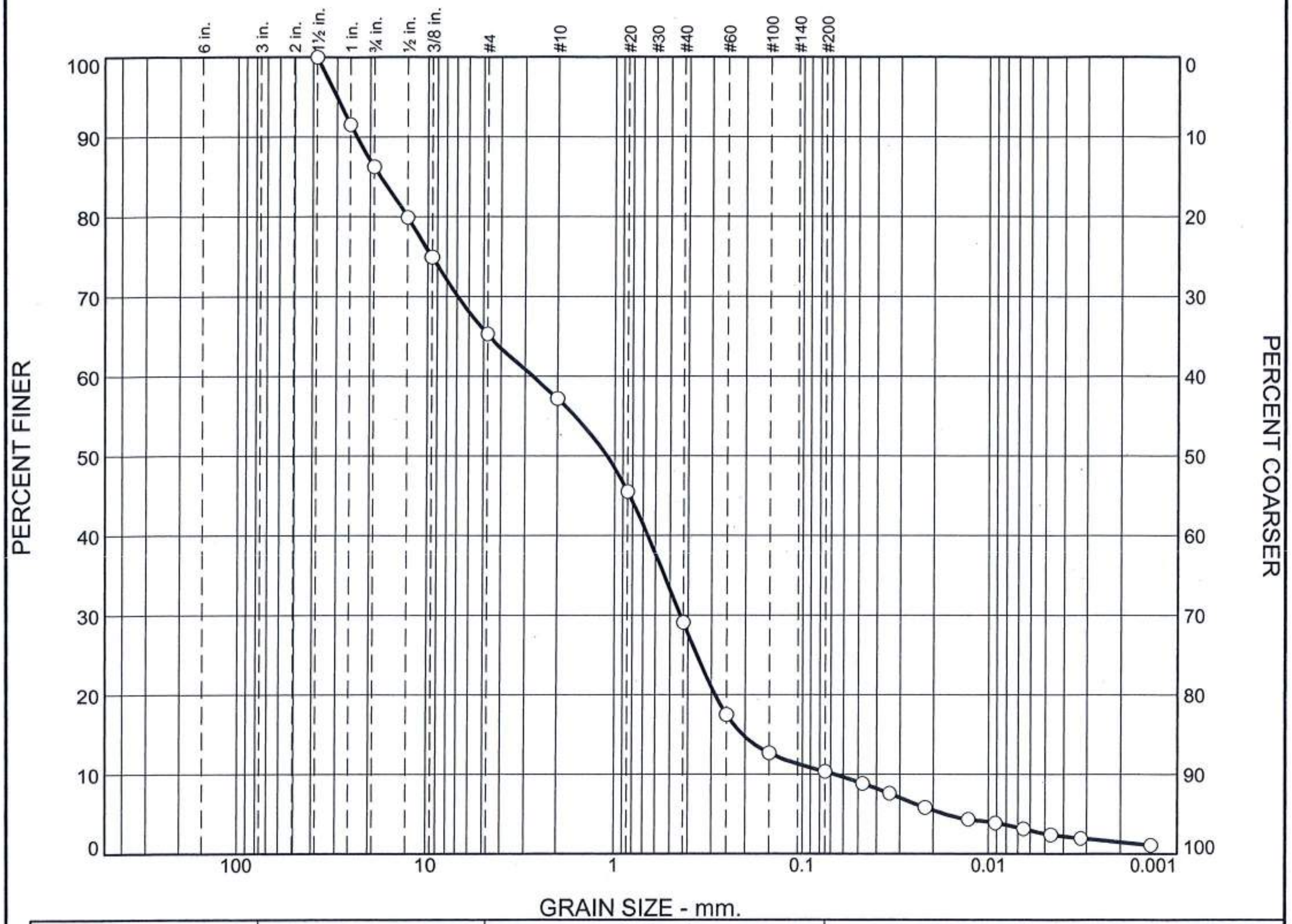
BORING LOCATION
As shown on Boring Location Plan.
It has been necessary to interpolate between samples. Therefore, the contacts between the various soil strata should not be taken as absolute.

COMMENTS
***Surface elevation based on Ohio South State Plane Coordinate System. Measured by Trimble Zephyr survey antenna and Trimble Geo7X receiver.**

DEPTH	SAMPLE NO.	VISUAL CLASSIFICATION OF THE MATERIAL	BLOW COUNTS	N VALUE, blows/ft.	REMARKS
23.0		Very dense brown SAND with gravel (trace cobbles) - wet			
24.0	7A	(Becomes medium dense at 23.5')	11 12 18	30	
25.0					
26.0					
27.0					
28.0					
29.0	8A	(Becomes very dense at 28.5')	23 26 30	56	
30.0		Bottom of boring at 30.0 feet			
31.0					
32.0					
33.0					
34.0					
35.0					
36.0					
37.0					
38.0					
39.0					
40.0					
41.0					
42.0					
43.0					
44.0					
45.0					
46.0					
47.0					
48.0					



GRAIN SIZE DISTRIBUTION REPORT



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	13.7	21.0	8.1	28.1	18.7	8.9	1.5

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	NV	NP	17.6001	2.7201	1.1001	0.4409	0.2056	0.0665	1.07	40.89

Material Description	USCS	AASHTO
○ brown well-graded sand with silt and gravel	SW-SM	A-1-b

Project No. 180573 **Client:** Pennoni

Project: Proposed Bridge

○ **Source of Sample:** B-1 **Depth:** 6.0' - 7.5' **Sample Number:** 3A

Remarks:

○As Received

Moisture Content: 7.6%

BOWSER-MORNER, INC.

Dayton, Ohio

GRAIN SIZE DISTRIBUTION TEST DATA

9/27/2017

Client: Pennoni
Project: Proposed Bridge
Project Number: 180573
Location: B-1
Depth: 6.0' - 7.5'
Sample Number: 3A
Material Description: brown well-graded sand with silt and gravel
Liquid Limit: NV
Plastic Limit: NP
USCS Classification: SW-SM
AASHTO Classification: A-1-b
Testing Remarks: As Received
Moisture Content: 7.6%

Sieve Test Data

Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer	Percent Retained
637.00	114.59	0.00	1.5	0.00	100.0	0.0
			1	44.17	91.5	8.5
			.75	71.71	86.3	13.7
			.5	104.76	79.9	20.1
			.375	130.93	74.9	25.1
			#4	181.28	65.3	34.7
			#10	223.64	57.2	42.8
115.14	0.00	0.00	#20	23.54	45.5	54.5
			#40	56.61	29.1	70.9
			#60	79.88	17.5	82.5
			#100	89.58	12.7	87.3
			#200	94.29	10.4	89.6

Hydrometer Test Data

Hydrometer test uses material passing #10
Percent passing #10 based upon complete sample = 57.2
Weight of hydrometer sample =115.26
Hygroscopic moisture correction:
Moist weight and tare = 51.92
Dry weight and tare = 51.72
Tare weight = 31.66
Hygroscopic moisture = 1.0%
Automatic temperature correction
Composite correction (fluid density and meniscus height) at 20 deg. C = -6.5
Meniscus correction only = 0.0
Specific gravity of solids = 2.65
Hydrometer type = 152H
Hydrometer effective depth equation: L = 16.294964 - 0.164 - 0.164 **x Rm**

Elapsed Time (min.)	Temp. (deg. C.)	Actual Reading	Corrected Reading	K	Rm	Eff. Depth	Diameter (mm.)	Percent Finer	Percent Retained
1.00	21.0	24.0	17.7	0.0135	24.0	12.4	0.0474	8.9	91.1
2.00	21.0	21.5	15.2	0.0135	21.5	12.8	0.0341	7.6	92.4
5.00	21.0	18.0	11.7	0.0135	18.0	13.3	0.0220	5.9	94.1
15.00	21.0	15.0	8.7	0.0135	15.0	13.8	0.0129	4.3	95.7
30.00	21.5	14.0	7.8	0.0134	14.0	14.0	0.0092	3.9	96.1
60.00	21.5	12.5	6.3	0.0134	12.5	14.2	0.0065	3.2	96.8
120.00	21.5	11.0	4.8	0.0134	11.0	14.5	0.0047	2.4	97.6
250.00	22.0	10.0	3.9	0.0133	10.0	14.7	0.0032	2.0	98.0
1440.00	21.0	8.5	2.2	0.0135	8.5	14.9	0.0014	1.1	98.9

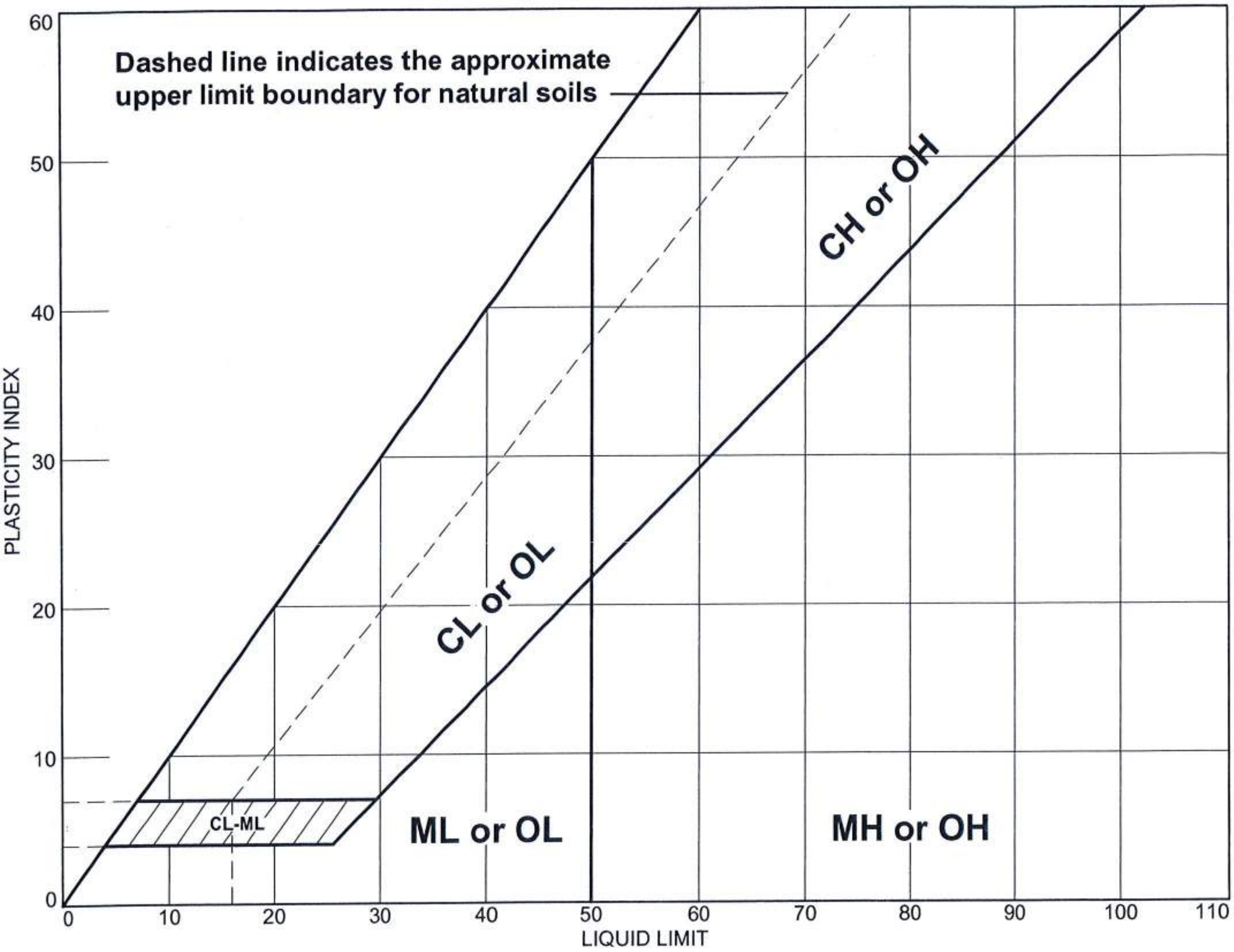
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	13.7	21.0	34.7	8.1	28.1	18.7	54.9	8.9	1.5	10.4

D_5	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
0.0171	0.0665	0.2056	0.2874	0.4409	0.6600	1.1001	2.7201	12.7410	17.6001	23.4589	30.0985

Fineness Modulus	C_u	C_c
3.92	40.89	1.07

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	brown well-graded sand with silt and gravel	NV	NP	NP	29.1	10.4	SW-SM

Project No. 180573 **Client:** Pennoni

Project: Proposed Bridge

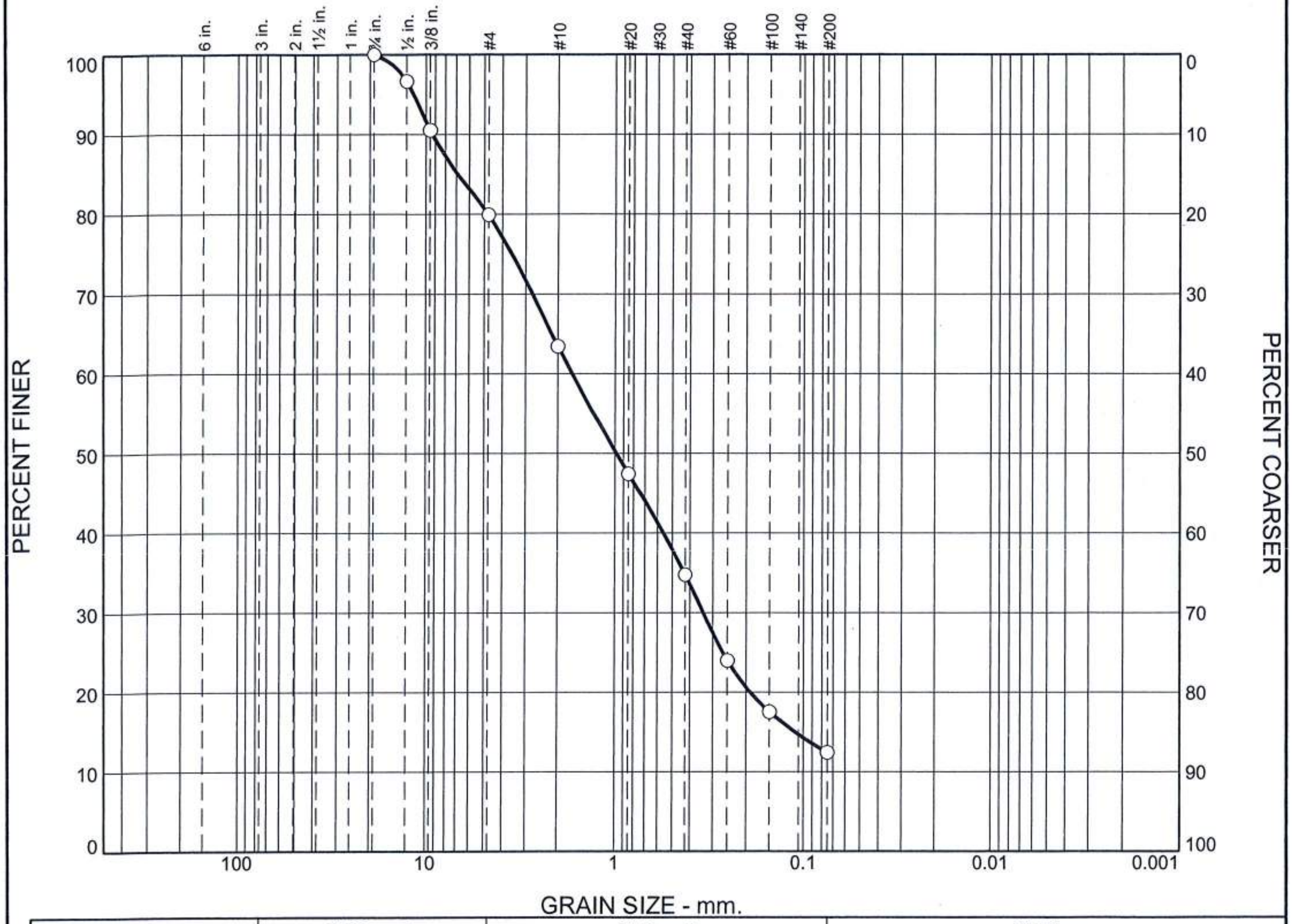
● **Source of Sample:** B-1 **Depth:** 6.0' - 7.5' **Sample Number:** 3A

Remarks:

BOWSER-MORNER, INC.

Dayton, Ohio

GRAIN SIZE DISTRIBUTION REPORT



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	20.1	16.5	28.6	22.4	12.4	

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			6.8706	1.6810	0.9818	0.3392	0.1102			

Material Description	USCS	AASHTO
○ B-1, 2A		

Project No. 180573 **Client:** Pennoni

Project: Proposed Bridge

○ **Source of Sample:** B-1 **Depth:** 3.5' - 5.0' **Sample Number:** 2A

Remarks:

○As Received

Moisture Content: 6.8%

BOWSER-MORNER, INC.

Dayton, Ohio

GRAIN SIZE DISTRIBUTION TEST DATA

9/27/2017

Client: Pennoni
Project: Proposed Bridge
Project Number: 180573
Location: B-1
Depth: 3.5' - 5.0'

Sample Number: 2A

Material Description: B-1, 2A
Testing Remarks: As Received
Moisture Content: 6.8%

Sieve Test Data

Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer	Percent Retained
629.50	220.48	0.00	.75	0.00	100.0	0.0
			.5	13.71	96.6	3.4
			.375	38.73	90.5	9.5
			#4	82.10	79.9	20.1
			#10	149.53	63.4	36.6
			#20	214.93	47.5	52.5
			#40	266.78	34.8	65.2
			#60	310.97	24.0	76.0
			#100	337.34	17.5	82.5
			#200	358.25	12.4	87.6

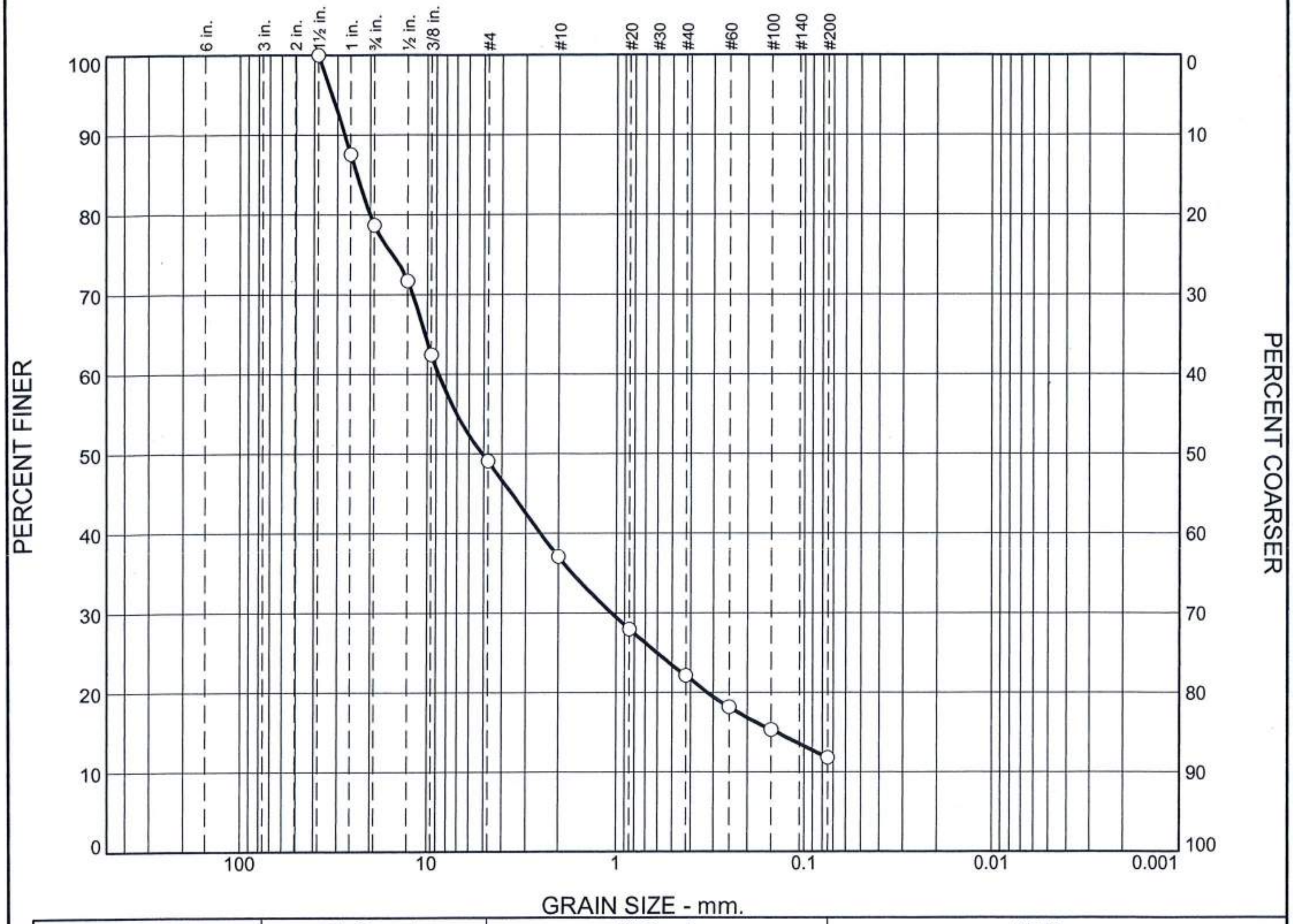
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.0	20.1	20.1	16.5	28.6	22.4	67.5			12.4

D_5	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
		0.1102	0.1899	0.3392	0.5571	0.9818	1.6810	4.7729	6.8706	9.2836	11.6506

Fineness Modulus
3.23

GRAIN SIZE DISTRIBUTION REPORT



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	21.3	29.6	12.0	15.0	10.3	11.8	

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			23.5387	8.7636	5.0774	1.0580	0.1408			

Material Description	USCS	AASHTO
○ B-2, 3A		

Project No. 180573 **Client:** Pennoni

Project: Proposed Bridge

○ **Source of Sample:** B-2 **Depth:** 6.0' - 7.5' **Sample Number:** 3A

BOWSER-MORNER, INC.

Dayton, Ohio

Remarks:

○As Received

Moisture Content: 4.6%

GRAIN SIZE DISTRIBUTION TEST DATA

9/27/2017

Client: Pennoni
Project: Proposed Bridge
Project Number: 180573
Location: B-2
Depth: 6.0' - 7.5'

Sample Number: 3A

Material Description: B-2, 3A
Testing Remarks: As Received
Moisture Content: 4.6%

Sieve Test Data

Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer	Percent Retained
648.70	234.72	0.00	1.5	0.00	100.0	0.0
			1	51.48	87.6	12.4
			.75	88.12	78.7	21.3
			.5	117.08	71.7	28.3
			.375	155.41	62.5	37.5
			#4	210.73	49.1	50.9
			#10	260.53	37.1	62.9
			#20	298.28	27.9	72.1
			#40	322.37	22.1	77.9
			#60	338.69	18.2	81.8
			#100	350.54	15.3	84.7
			#200	365.03	11.8	88.2

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	21.3	29.6	50.9	12.0	15.0	10.3	37.3			11.8

D_{5}	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
		0.1408	0.3234	1.0580	2.4928	5.0774	8.7636	20.0547	23.5387	27.3677	32.1731

Fineness Modulus
4.80

Moisture Content of Soil

ASTM (D-2216)

BOWSER MORNER.

Client: Pennoni
Project: Proposed Bridge

Work Order No.: 180573
Date: 09/27/17

Boring Number	Sample Number	Depth, (ft)	Depth, (m)	Moisture Content, (%)
B-1	1 A	1.0 - 2.5	0.3 - 0.8	8.9
	2 A	3.5 - 5.0	1.1 - 1.5	6.8
	3 A	6.0 - 7.5	1.8 - 2.3	7.6
	4 A	8.5 - 10.0	2.6 - 3.0	31.1
	5 A	13.5 - 15.0	4.1 - 4.6	Not Tested
	6 A	18.5 - 20.0	5.6 - 6.1	16.1
	7 A	23.5 - 25.0	7.2 - 7.6	Not Tested
	8 A	28.5 - 30.0	8.7 - 9.1	11.1
B-2	1 A	1.0 - 2.5	0.3 - 0.8	Not Tested
	2 A	3.5 - 5.0	1.1 - 1.5	5.0
	3 A	6.0 - 7.5	1.8 - 2.3	4.6
	4 A	8.5 - 10.0	2.6 - 3.0	17.8
	5 A	13.5 - 15.0	4.1 - 4.6	Not Tested
	6 A	18.5 - 20.0	5.6 - 6.1	7.1
	7 A	23.5 - 25.0	7.2 - 7.6	Not Tested
	8 A	28.5 - 30.0	8.7 - 9.1	7.3

LOG OF BORING

Date Started 11-20-73
Date Completed 11-26-73
Boring No. B-2
Sampler Type SS Dia 1 3/8"
Casing: Length ______ Dia. ______
Station & Offset 103+76, 35 RT (RETAINING WING WALL)
Water Elev. 681.5'
Surface Elev. 700.0'

Elev.	Depth	Std. Pen. (N)	Rec. ft.	Loss ft.	Description	Sample No.	Physical Characteristics % Agg.	% C.S.	% F.S.	% Silt	% Clay	L.L.	P.I.	W.C.	SHTL Class.
700.0	0														
	2														
	4				BROWN SAND & GRAVEL (DRILLER'S DESCRIPTION)		V		I	S		U	A		L
695.0	6	12/8/12			BROWN SILTY SANDY GRAVEL WITH COBBLES	1	61	15	9	9	6	20	5	7	A-1-b
	8														
690.0	10														
	12	9/10/15			BROWN GRAVELLY SANDY CLAY	2	21	8	15	34	22	29	11	14	A-6a
	14														
685.0	16														
	18	20/39/47			GRAY SANDY GRAVEL	3	73	15	5	4	3	NP	NP	6	A-1-a
680.0	20														
	22	13/21/27			BROWN SANDY GRAVEL	4	58	26	6	5	5	21	6	13	A-1-a
	24														
675.0	26	70/50			BROWN SILTY SANDY GRAVEL	5	65	17	6	3	4	NP	NP	10	A-1-a
	28														
670.0	30	33/17													
669.2		(0.8)			GRAY SILTY SANDY GRAVEL	6	35	16	14	19	16	19	6	11	A-2-4

BOTTOM OF BORING

L 7
not in wall

LOG OF BORING

Date Started 11-20-73
Date Completed 11-20-73
Boring No. B-7

Sampler Type SS Dia 1 3/8"
Casing Length ____ Dia. ____
Station & Offset 105+95, 40' LT (RETAINING WALL)

Water Elev. 682.2
Surface Elev. 702.6

Elev.	Depth	Std. Pen. (N)	Rec. ft.	Loss ft.	Description	Sample No.	Physical Characteristics								SHTL Class.
							% Agg	% C.S.	% F.S.	% Silt	% Clay	L.L.	P.I.	W.C.	
702.6	0														
702.4					SOD & TOPSOIL										
	2				BROWN SAND & GRAVEL (DRILLER'S DESCRIPTION)		V		I	S		U	A		L
	4														
697.6															
	6	5/8/7			BROWN SILTY SANDY GRAVEL	1	52	17	13	12	6	NP	NP	6	A-1-b
	8														
692.6	10														
	12	3/3/13			BROWN GRAVELLY CLAY	2	22	14	4	38	32	39	15	33	A-6a
	14														
687.6	16	16/18/	12		GRAY SILTY GRAVEL	3	77	7	5	8	3	NP	NP	5	A-1-a
	18														
682.6	20														
	22	33/36/	38		GRAY SILTY SANDY GRAVEL	4	69	15	6	6	4	NP	NP	14	A-1-a
	24														
677.6	26	14/21/	41		BROWN SILTY GRAVELLY SAND	5	36	29	21	10	4	NP	NP	15	A-1-b
	28														
672.6	30														
	32	21/50			GRAY GRAVELLY SANDY SILT	6	19	9	14	29	29	22	9	10	A-4a
	34														
667.6	36	17/21/	24		GRAY SANDY GRAVELLY SILT	7	33	13	14	21	19	19	7	11	A-4a
	38														
662.6	40														
	42	22/37/	43		GRAY SANDY GRAVEL	8	61	27	6	-6-	-	NP	NP	14	A-1-a
	44														
657.6	46	10/18/	35		BROWN GRAVELLY SAND	9	43	35	14	-8-	-	NP	NP	11	A-1-b
	48														
652.6	50	35/50 (0.8')			GRAY GRAVELLY SAND	10	37	41	16	-6-	-	NP	NP	8	A-1-b
651.8															

BOTTOM OF BORING

Driven Pile Calculation Results (APILE and WEAP)

Driven Friction Pile Calculations

Project: Sycamore Creek Bridge Replacement
Proj#: N1235302
Case: South Abutment (Boring No. 1)

Calculated By: MP **Reviewed By: DWW**

References:

ODOT SGE 7-21-23, ODOT BDM 2020 7-21-23, ODOT C&MS, FHWA-NHI-16-064 (FHWA GEC 012)

Bridge Geometry

Substructure: Abutment- South side

Elevation of Ground Surface, $EG := 690\ ft$ (approx.)

Approx. Top of Pile/Bottom of Pile Cap Elevation, $ETP := 690\ ft$ (Pile above this will be sleeved)

Scour Depth, $D_{Scour} := 2.16\ ft$

Depth to Water Below Top of Pile, $Depth_{GW} := 10\ ft$ Use normal creek/river level if adjacent

Soil Layers

Layer	Soil Type	Bot. Depth from Surface	TopElev	BotElev	Bot. Depth Below Top of Pile	γ	ϕ'	S_u	APILE Setup Factor, f_{su}
		ft	ft	ft	ft	pcf	deg	psf	
1	Loose granular	8.5	690.0	681.5	8.5	122	31	-	1.00
2	Very soft cohesive	11.0	681.5	679.0	11.0	100	-	250	1.00
3	Dense to V. Dense granular	23.5	679.0	666.5	23.5	132	38	-	1.00
4	Hard cohesive	28.0	666.5	662.0	28.0	130	-	4,000	1.00
5	Dense granular	30.0	662.0	660.0	30.0	128	36	-	1.00

Driven Pile Capacity using APile 2019 (FHWA Method)

Driven Pile Capacity Summary *(enter results from APile)*

Pile Type/Size	Pile Driven Length (ft.)	Approx. Tip Elevation (ft.)	Side Resistance (kips)	End Bearing (kips)	UBV (kips)
12	22	668	46.4	172.2	218.5

Setup

The affected soil layers have APILE setup factors equal to 1. Thus the result is similar to the capacity with no setup considered.

See attached APILE Results

```
     =========================================================================

                      APILE for Windows, Version 2023.10.3

                       Serial Number :  506768014

                       A Program for Analyzing the Axial Capacity
                       and Short-term Settlement of Driven Piles
                                 under Axial Loading.
                     (c) Copyright ENSOFT, Inc., 1987-2023
                           All Rights Reserved

     =========================================================================


     This program is licensed to :

     Terracon, Inc.
     APILE Global, Global License

     Path to file locations      : E:\Projects\2023\N1235414\Working
Files\Calculations-Analyses\Driven piles\APILE\B-1\
     Name of input data file     : B-1- 12 inches A Pile.ap10d
     Name of output file         : B-1- 12 inches A Pile.ap10o
     Name of plot output file    : B-1- 12 inches A Pile.ap10p

     -------------------------------------------------------------------------
                          Time and Date of Analysis
     -------------------------------------------------------------------------

               Date:  June 11, 2024     Time:  13:53:16



1
          *********************
          * INPUT INFORMATION *
          *********************

          PROJECT DESCRIPTION   :
          Boring No. 1
          DESIGNER   : MP
          JOB NUMBER : N1235414

          METHOD FOR UNIT LOAD TRANSFERS :
          - FHWA (Federal Highway Administration)
            Unfactored Unit Side Friction and Unit Side Resistance are used.

          COMPUTATION METHOD(S) FOR PILE CAPACITY :
          - FHWA (Federal Highway Administration)
```

```
TYPE OF LOADING :
- COMPRESSION

PILE TYPE :
Steel pipe pile or non-tapered portion of monotube pile
- Close-Ended Pile

 AVERAGE DEPTH TO ESTIMATE TIP RESISTANCE:
- USE 1.5 DIAMETERS ABOVE AND BELOW TIP

DATA FOR AXIAL STIFFNESS :
- MODULUS OF ELASTICITY     = 0.290E+08 PSI
- CROSS SECTION AREA        =      9.23 IN2

CIRCULAR PILE PROPERTIES :
- OUTSIDE DIAMETER, OD      =     12.00 IN.
- INTERNAL DIAMETER, ID     =     11.50 IN.
- TOTAL PILE LENGTH, TL     =     28.00 FT.
- BATTER ANGLE              =      0.00 DEG
- PILE STICKUP LENGTH, PSL  =      0.00 FT.
- ZERO FRICTION LENGTH, ZFL =      2.95 FT.
- INCREMENT OF PILE LENGTH
  USED IN COMPUTATION       =      1.00 FT.
- PRINTING INCREMENT        =         1
- LENGTH OF ENHANCED
  END SECTION               =     28.00 FT.
- INTERNAL DIAMETER OF
  ENHANCED END SECTION      =     11.50 IN.

PLUGGED/UNPLUGGED CONDITIONS :
Internal Pile Plug Calculated by Program


SOIL INFORMATIONS :

                  LATERAL    EFFECTIVE    FRICTION      Nq
          SOIL    EARTH      UNIT         ANGLE       FACTOR
 DEPTH    TYPE    PRESSURE   WEIGHT       DEGREES      FHWA
  FT.                        LB/FT^3
   0.00    SAND   1500.00      122.00        31.00      35.20**
   8.50    SAND   1500.00      122.00        31.00      35.20**
   8.50    CLAY      0.80*     100.00         0.00       4.80**
  11.00    CLAY      0.80*     100.00         0.00       4.80**
  11.00    SAND   1500.00      132.00        38.00     110.40**
  23.50    SAND   1500.00      132.00        38.00     110.40**
  23.50    CLAY      0.80*     130.00         0.00       4.80**
  28.00    CLAY      0.80*     130.00         0.00       4.80**
  28.00    SAND   4500.00      128.00        36.00      77.60**
  30.00    SAND   4500.00      128.00        36.00      77.60**
```

```
*  VALUE ASSUMED BY THE PROGRAM
** VALUE ESTIMATED BY THE PROGRAM BASED ON FRICTION ANGLE


MAXIMUM   MAXIMUM   UNDISTURB  REMOLDED
UNIT      UNIT      SHEAR      SHEAR     BLOW   UNIT SKIN  UNIT END
FRICTION  BEARING   STRENGTH   STRENGTH  COUNT  FRICTION   BEARING
  KSF       KSF        KSF       KSF               KSF       KSF
0.10E+08* 0.10E+08*       0.00      0.00   0.00       0.00      0.00
0.10E+08* 0.10E+08*       0.00      0.00   0.00       0.00      0.00
0.10E+08* 0.10E+08*       0.05      0.00   0.00       0.00      0.00
0.10E+08* 0.10E+08*       0.05      0.00   0.00       0.00      0.00
0.10E+08* 0.10E+08*       0.00      0.00   0.00       0.00      0.00
0.10E+08* 0.10E+08*       0.00      0.00   0.00       0.00      0.00
0.10E+08* 0.10E+08*       4.00      0.00   0.00       0.00      0.00
0.10E+08* 0.10E+08*       4.00      0.00   0.00       0.00      0.00
0.10E+08* 0.10E+08*       0.00      0.00   0.00       0.00      0.00
0.10E+08* 0.10E+08*       0.00      0.00   0.00       0.00      0.00

* MAXIMUM UNIT FRICTION AND/OR MAXIMUM UNIT BEARING
  WERE SET TO LARGE VALUES INDICATING THAT APILE
  USES THE LIMITS SPECIFIED BY EACH SELECTED
  CRITERIA (IF ANY).


         LRFD FACTOR  LRFD FACTOR
          ON UNIT      ON UNIT
 DEPTH    FRICTION     BEARING
  FT.
   0.00    1.000       1.000
   8.50    1.000       1.000
   8.50    1.000       1.000
  11.00    1.000       1.000
  11.00    1.000       1.000
  23.50    1.000       1.000
  23.50    1.000       1.000
  28.00    1.000       1.000
  28.00    1.000       1.000
  30.00    1.000       1.000




 DEPTH     Z PEAK      T RESIDUAL
    FT.      IN.
   0.00     0.120 *       0.00
   8.50     0.120 *       0.00
   8.50     0.120 *       0.90 **
  11.00     0.120 *       0.90 **
```

```
            11.00     0.120 *       0.00
            23.50     0.120 *       0.00
            23.50     0.120 *       0.90 **
            28.00     0.120 *       0.90 **
            28.00     0.120 *       0.00
            30.00     0.120 *       0.00

          * DEFAULT VALUE = 0.01 D
          ** DEFAULT VALUE = 0.9



1
          *********************
          * COMPUTATION RESULT *
          *********************



                            *********************
                            *  FED. HWY. METHOD  *
                            *********************


               PILE LENGTH         SKIN             END          ULTIMATE
               BELOW GND.        FRICTION         BEARING        CAPACITY
                   FT.              KIP             KIP             KIP
                  0.00              0.0             0.8             0.8
                  1.00              0.0             2.1             2.1
                  2.00              0.0             4.1             4.1
                  3.00              0.2             6.1             6.3
                  4.00              0.6             8.1             8.7
                  5.00              1.1            10.2            11.2
                  6.00              1.7            12.2            13.9
                  7.00              2.4            14.1            16.6
                  8.00              3.3            12.8            16.1
                  9.00              4.3             8.2            12.5
                 10.00              4.8            16.8            21.7
                 11.00              5.0            43.9            48.9
                 12.00              6.4            76.4            82.8
                 13.00              9.3            97.8           107.1
                 14.00             12.4           106.0           118.5
                 15.00             15.8           114.3           130.1
                 16.00             19.4           122.6           142.0
                 17.00             23.3           130.8           154.1
                 18.00             27.4           139.1           166.5
                 19.00             31.8           147.4           179.1
                 20.00             36.4           155.6           192.0
                 21.00             41.3           163.9           205.2
```

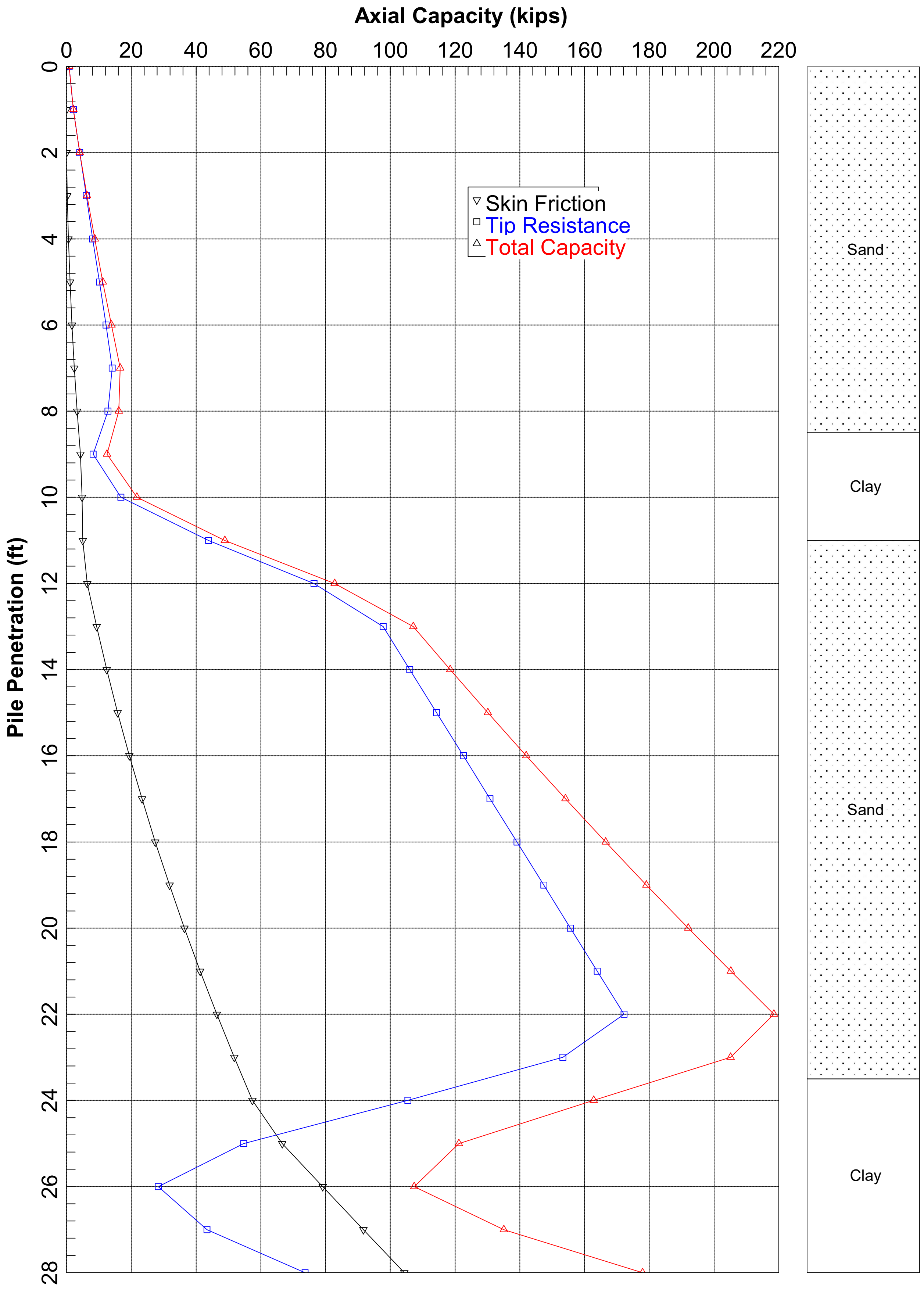
```
         22.00             46.4           172.2           218.5
         23.00             51.8           153.3           205.1
         24.00             57.4           105.4           162.8
         25.00             66.6            54.7           121.2
         26.00             79.1            28.3           107.4
         27.00             91.7            43.4           135.1
         28.00            104.3            73.7           177.9


    NOTES:
    - AN ASTERISK IS PLACED IN THE END-BEARING COLUMN
      IF THE TIP RESISTANCE IS CONTROLLED BY THE FRICTION
      OF SOIL PLUG INSIDE AN OPEN-ENDED PIPE PILE.



        *************************************************
        * COMPUTE LOAD-DISTRIBUTION AND LOAD-SETTLEMENT *
        * CURVES FOR AXIAL LOADING                      *
        *************************************************


T-Z CURVE   NO. OF   DEPTH TO CURVE   LOAD TRANSFER   PILE MOVEMENT
   NO.      POINTS        FT.              PSI             IN.

    1         10      0.4167E-01
                                       0.0000E+00      0.0000E+00
                                       0.0000E+00      0.1920E-01
                                       0.0000E+00      0.3720E-01
                                       0.0000E+00      0.6840E-01
                                       0.0000E+00      0.9600E-01
                                       0.0000E+00      0.1200E+00
                                       0.0000E+00      0.2400E+00
                                       0.0000E+00      0.3600E+00
                                       0.0000E+00      0.6000E+00
                                       0.0000E+00      0.2400E+01
    2         10      0.4250E+01
                                       0.0000E+00      0.0000E+00
                                       0.3194E+00      0.1920E-01
                                       0.5324E+00      0.3720E-01
                                       0.7985E+00      0.6840E-01
                                       0.9583E+00      0.9600E-01
                                       0.1065E+01      0.1200E+00
                                       0.1065E+01      0.2400E+00
                                       0.1065E+01      0.3600E+00
                                       0.1065E+01      0.6000E+00
                                       0.1065E+01      0.2400E+01
    3         10      0.8458E+01
                                       0.0000E+00      0.0000E+00
                                       0.6357E+00      0.1920E-01
```

```
                                   0.1060E+01      0.3720E-01
                                   0.1589E+01      0.6840E-01
                                   0.1907E+01      0.9600E-01
                                   0.2119E+01      0.1200E+00
                                   0.2119E+01      0.2400E+00
                                   0.2119E+01      0.3600E+00
                                   0.2119E+01      0.6000E+00
                                   0.2119E+01      0.2400E+01
4         10      0.8542E+01
                                   0.0000E+00      0.0000E+00
                                   0.6420E+00      0.1920E-01
                                   0.1070E+01      0.3720E-01
                                   0.1605E+01      0.6840E-01
                                   0.1926E+01      0.9600E-01
                                   0.2140E+01      0.1200E+00
                                   0.1926E+01      0.2400E+00
                                   0.1926E+01      0.3600E+00
                                   0.1926E+01      0.6000E+00
                                   0.1926E+01      0.2400E+01
5         10      0.9750E+01
                                   0.0000E+00      0.0000E+00
                                   0.2472E+00      0.1920E-01
                                   0.4120E+00      0.3720E-01
                                   0.6181E+00      0.6840E-01
                                   0.7417E+00      0.9600E-01
                                   0.8241E+00      0.1200E+00
                                   0.7417E+00      0.2400E+00
                                   0.7417E+00      0.3600E+00
                                   0.7417E+00      0.6000E+00
                                   0.7417E+00      0.2400E+01
6         10      0.1096E+02
                                   0.0000E+00      0.0000E+00
                                   0.1042E+00      0.1920E-01
                                   0.1736E+00      0.3720E-01
                                   0.2604E+00      0.6840E-01
                                   0.3125E+00      0.9600E-01
                                   0.3472E+00      0.1200E+00
                                   0.3125E+00      0.2400E+00
                                   0.3125E+00      0.3600E+00
                                   0.3125E+00      0.6000E+00
                                   0.3125E+00      0.2400E+01
7         10      0.1104E+02
                                   0.0000E+00      0.0000E+00
                                   0.1754E+00      0.1920E-01
                                   0.2923E+00      0.3720E-01
                                   0.4384E+00      0.6840E-01
                                   0.5261E+00      0.9600E-01
                                   0.5845E+00      0.1200E+00
                                   0.5845E+00      0.2400E+00
                                   0.5845E+00      0.3600E+00
```

```
                                    0.5845E+00       0.6000E+00
                                    0.5845E+00       0.2400E+01
  8          10       0.1725E+02
                                    0.0000E+00       0.0000E+00
                                    0.2691E+01       0.1920E-01
                                    0.4485E+01       0.3720E-01
                                    0.6728E+01       0.6840E-01
                                    0.8073E+01       0.9600E-01
                                    0.8970E+01       0.1200E+00
                                    0.8970E+01       0.2400E+00
                                    0.8970E+01       0.3600E+00
                                    0.8970E+01       0.6000E+00
                                    0.8970E+01       0.2400E+01
  9          10       0.2346E+02
                                    0.0000E+00       0.0000E+00
                                    0.3730E+01       0.1920E-01
                                    0.6217E+01       0.3720E-01
                                    0.9325E+01       0.6840E-01
                                    0.1119E+02       0.9600E-01
                                    0.1243E+02       0.1200E+00
                                    0.1243E+02       0.2400E+00
                                    0.1243E+02       0.3600E+00
                                    0.1243E+02       0.6000E+00
                                    0.1243E+02       0.2400E+01
 10          10       0.2354E+02
                                    0.0000E+00       0.0000E+00
                                    0.3744E+01       0.1920E-01
                                    0.6240E+01       0.3720E-01
                                    0.9360E+01       0.6840E-01
                                    0.1123E+02       0.9600E-01
                                    0.1248E+02       0.1200E+00
                                    0.1123E+02       0.2400E+00
                                    0.1123E+02       0.3600E+00
                                    0.1123E+02       0.6000E+00
                                    0.1123E+02       0.2400E+01
 11          10       0.2575E+02
                                    0.0000E+00       0.0000E+00
                                    0.8333E+01       0.1920E-01
                                    0.1389E+02       0.3720E-01
                                    0.2083E+02       0.6840E-01
                                    0.2500E+02       0.9600E-01
                                    0.2778E+02       0.1200E+00
                                    0.2500E+02       0.2400E+00
                                    0.2500E+02       0.3600E+00
                                    0.2500E+02       0.6000E+00
                                    0.2500E+02       0.2400E+01
 12          10       0.2796E+02
                                    0.0000E+00       0.0000E+00
                                    0.8333E+01       0.1920E-01
                                    0.1389E+02       0.3720E-01
```

```
                                            0.2083E+02       0.6840E-01
                                            0.2500E+02       0.9600E-01
                                            0.2778E+02       0.1200E+00
                                            0.2500E+02       0.2400E+00
                                            0.2500E+02       0.3600E+00
                                            0.2500E+02       0.6000E+00
                                            0.2500E+02       0.2400E+01
    13          10       0.2804E+02
                                            0.0000E+00       0.0000E+00
                                            0.8333E+01       0.1920E-01
                                            0.1389E+02       0.3720E-01
                                            0.2083E+02       0.6840E-01
                                            0.2500E+02       0.9600E-01
                                            0.2778E+02       0.1200E+00
                                            0.2778E+02       0.2400E+00
                                            0.2778E+02       0.3600E+00
                                            0.2778E+02       0.6000E+00
                                            0.2778E+02       0.2400E+01
    14          10       0.2900E+02
                                            0.0000E+00       0.0000E+00
                                            0.8333E+01       0.1920E-01
                                            0.1389E+02       0.3720E-01
                                            0.2083E+02       0.6840E-01
                                            0.2500E+02       0.9600E-01
                                            0.2778E+02       0.1200E+00
                                            0.2778E+02       0.2400E+00
                                            0.2778E+02       0.3600E+00
                                            0.2778E+02       0.6000E+00
                                            0.2778E+02       0.2400E+01
    15          10       0.2996E+02
                                            0.0000E+00       0.0000E+00
                                            0.8333E+01       0.1920E-01
                                            0.1389E+02       0.3720E-01
                                            0.2083E+02       0.6840E-01
                                            0.2500E+02       0.9600E-01
                                            0.2778E+02       0.1200E+00
                                            0.2778E+02       0.2400E+00
                                            0.2778E+02       0.3600E+00
                                            0.2778E+02       0.6000E+00
                                            0.2778E+02       0.2400E+01


 TIP   LOAD        TIP MOVEMENT
     KIP               IN.

 0.0000E+00         0.0000E+00
 0.4604E+01         0.6000E-02
 0.9209E+01         0.1200E-01
 0.1842E+02         0.2400E-01
```

```
 0.3684E+02         0.1560E+00
 0.5525E+02         0.5040E+00
 0.6630E+02         0.8760E+00
 0.7367E+02         0.1200E+01
 0.7367E+02         0.1800E+01
 0.7367E+02         0.2400E+01


               LOAD VERSUS SETTLEMENT CURVE
               ****************************



 TOP  LOAD     TOP MOVEMENT       TIP  LOAD      TIP MOVEMENT
    KIP             IN.              KIP              IN.
0.3122E+00      0.4017E-03      0.7674E-01      0.1000E-03
0.3122E+01      0.4017E-02      0.7674E+00      0.1000E-02
0.1593E+02      0.2035E-01      0.3837E+01      0.5000E-02
0.3149E+02      0.4058E-01      0.7674E+01      0.1000E-01
0.5791E+02      0.7751E-01      0.1535E+02      0.2000E-01
0.9619E+02      0.1461E+00      0.2205E+02      0.5000E-01
0.1194E+03      0.2006E+00      0.2623E+02      0.8000E-01
0.1295E+03      0.2321E+00      0.2902E+02      0.1000E+00
0.1396E+03      0.3449E+00      0.3916E+02      0.2000E+00
0.1541E+03      0.6631E+00      0.5504E+02      0.5000E+00
0.1631E+03      0.9744E+00      0.6405E+02      0.8000E+00
0.1681E+03      0.1181E+01      0.6912E+02      0.1000E+01
0.1727E+03      0.2187E+01      0.7367E+02      0.2000E+01
```


Axial Capacity (kips)
0
20
40
60
80
100
120
140
160
180
200
220
Pile Penetration (ft)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
Skin Friction
Tip Resistance
Total Capacity
Sand
Clay
Sand
Clay

Drivability Analysis (GRL WEAP 14)

100 blows per foot (bpf) considered to be practical refusal for friction pile. For piles to rock 20 blows per inch (240 bpf) or greater is practical refusal.

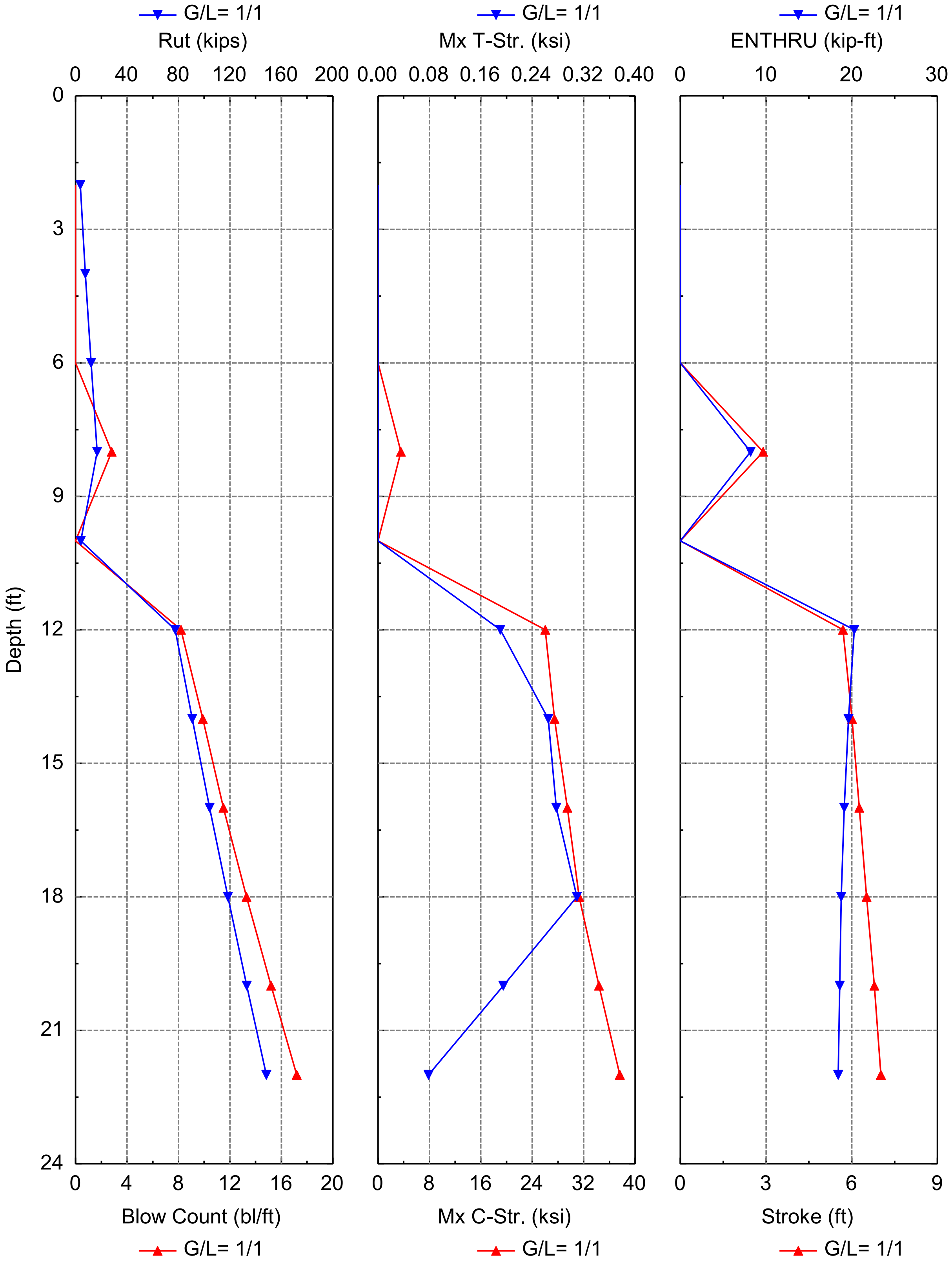
Allowable Stress during Driving for Steel = 0.9 φda fy = 0.9*1.0*45ksi (for 45 ksi pipe piles)

Summary of Driveability Analysis

Pile Type/ Size	Hammer	Wall Thickness (in)	Results
12	D19-42	0.25	Compressive Stress and Blow Count (OK)

See attached results of GRL Weap analyses

Driveability Analysis Summary



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

Depth ft	Rut kips	Rshaft kips	Rtoe kips	Blow Ct bl/ft	Mx C-Str ksi	Mx T-Str. ksi	Stroke ft	ENTHRU kip-ft	Hammer -
2.0	3.6	0.2	3.4	0.0	0.000	0.000	0.00	0.0	D 19-42
4.0	7.6	0.8	6.8	0.0	0.000	0.000	0.00	0.0	D 19-42
6.0	12.0	1.8	10.2	0.0	0.000	0.000	0.00	0.0	D 19-42
8.0	16.8	3.2	13.7	2.8	3.577	0.000	2.90	8.2	D 19-42
10.0	4.1	3.8	0.4	0.0	0.000	0.000	0.00	0.0	D 19-42
12.0	77.5	6.2	71.4	8.2	26.028	0.190	5.69	20.3	D 19-42
14.0	90.6	11.1	79.6	9.9	27.452	0.265	6.01	19.6	D 19-42
16.0	104.3	16.5	87.8	11.5	29.455	0.278	6.26	19.1	D 19-42
18.0	118.4	22.5	96.0	13.3	31.302	0.309	6.52	18.8	D 19-42
20.0	133.1	29.0	104.1	15.2	34.370	0.195	6.79	18.6	D 19-42
22.0	148.3	36.0	112.3	17.2	37.612	0.078	7.02	18.4	D 19-42
22.0	148.3	36.0	112.3	17.2	37.612	0.078	7.02	18.4	D 19-42

Summary_Total driving time: 3 minutes; Total Number of Blows: 139 (starting at penetration 2.0 ft)

GRLWEAP: Wave Equation Analysis of Pile Foundations

Sycamore Creek Bridge Replacement + B-1 7/3/2024
TSVC GRLWEAP 14.1.15.0

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

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

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

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

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

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

SOIL PROFILE

Depth ft	Soil Type -	Spec. Wt lb/ft³	Su ksf	Phi °	Unit Rs ksf	Unit Rt ksf
0.0	Sand	101.9	1.5	31.0	0.00	0.00
8.5	Sand	101.9	1.5	31.0	0.27	18.47
8.5	Clay	105.0	0.0	0.0	0.04	0.45
11.0	Clay	105.0	0.0	0.0	0.04	0.45
11.0	Sand	127.3	0.0	38.0	0.70	85.68
23.5	Sand	127.3	0.0	38.0	1.23	150.86
23.5	Clay	130.5	4.0	0.0	4.00	36.00
28.0	Clay	130.5	4.0	0.0	4.00	36.00
28.0	Sand	127.3	4.5	36.0	1.13	117.42
30.0	Sand	127.3	4.5	36.0	1.19	124.28

PILE INPUT

Uniform Pile		Pile Type:	Pipe
Pile Length: (ft)	22.000	Pile Penetration: (ft)	22.000
Pile Size: (ft)	1.00	Toe Area: (in²)	113.10

Pile Profile

Lb Top ft	X-Area in²	E-Modulus ksi	Spec. Wt lb/ft³	Perim. ft	Crit. Index -
0.0	9.2	30,000.0	492.0	3.1	0
22.0	9.2	30,000.0	492.0	3.1	0

HAMMER INPUT

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

Hammer Data

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

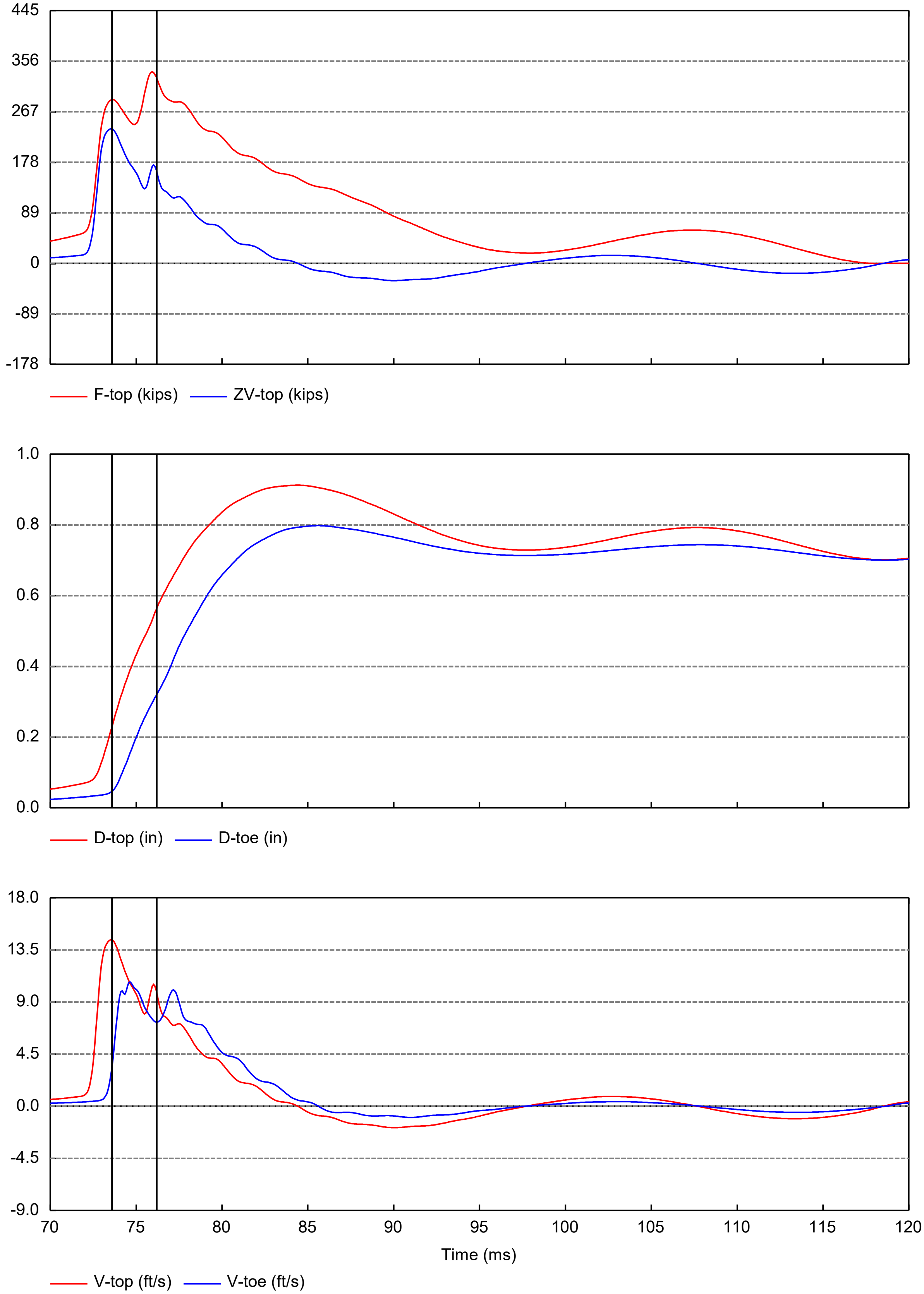
DRIVE SYSTEM FOR DELMAG D 19-42-OED

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

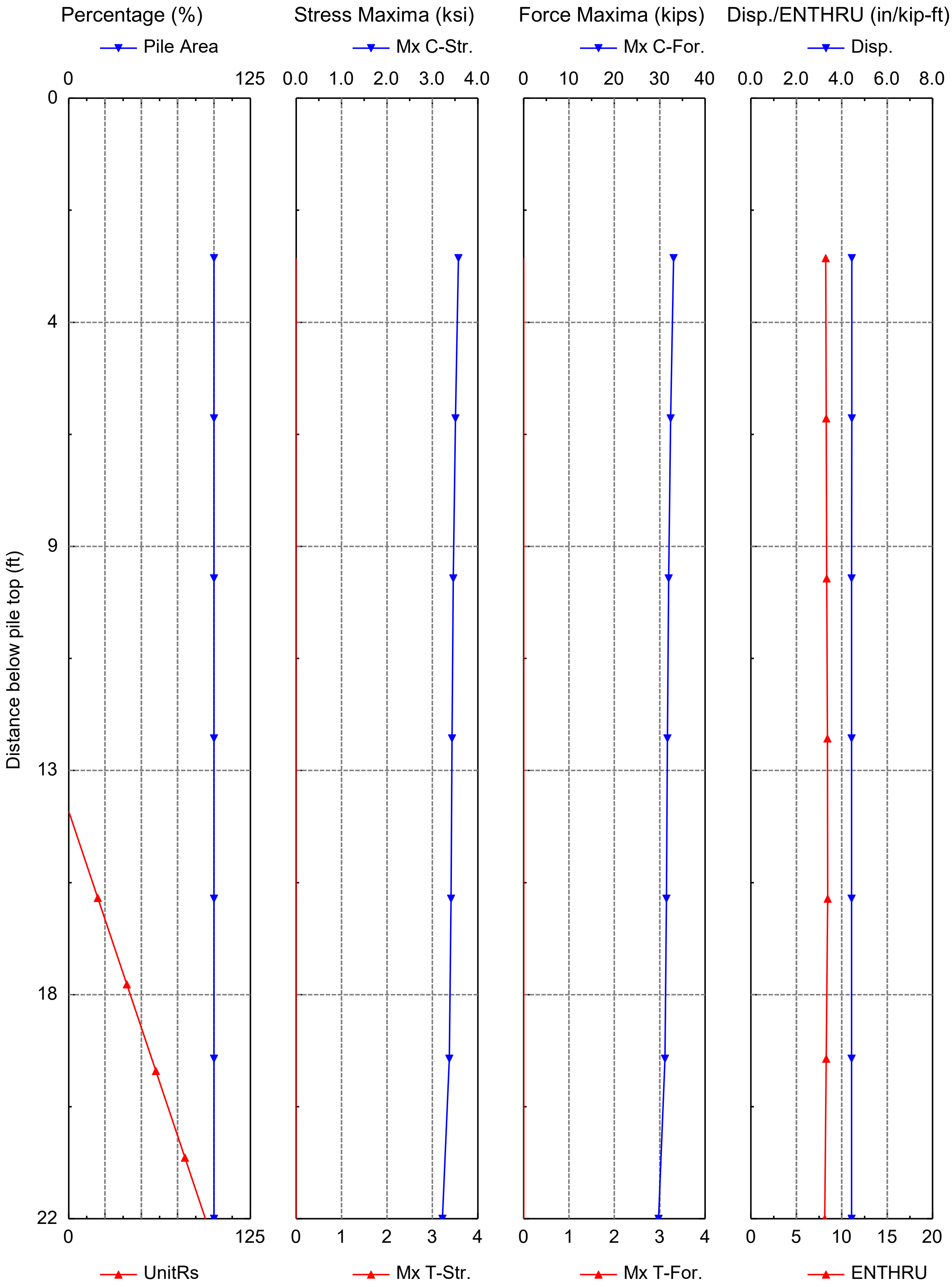
SOIL RESISTANCE DISTRIBUTION

Depth ft	Unit Rs ksf	Unit Rt ksf	Qs in	Qt in	Js s/ft	Jt s/ft	Set. F. -	Limit D. ft	Set. T. Hours	EB Area in²
0.0	0.0	0.0	0.10	0.20	0.05	0.15	1.0	6.6	24.0	113.1
1.7	0.1	3.7	0.10	0.20	0.05	0.15	1.0	6.6	24.0	113.1
3.4	0.1	7.4	0.10	0.20	0.05	0.15	1.0	6.6	24.0	113.1
5.1	0.2	11.1	0.10	0.20	0.05	0.15	1.0	6.6	24.0	113.1
6.8	0.2	14.8	0.10	0.20	0.05	0.15	1.0	6.6	24.0	113.1
8.5	0.3	18.5	0.10	0.20	0.05	0.15	1.0	6.6	24.0	113.1
8.5	0.0	0.4	0.10	0.20	0.20	0.15	1.8	6.6	720.0	113.1
9.7	0.0	0.4	0.10	0.20	0.20	0.15	1.8	6.6	720.0	113.1
11.0	0.0	0.4	0.10	0.20	0.20	0.15	1.8	6.6	720.0	113.1
11.0	0.7	85.7	0.10	0.10	0.05	0.15	1.0	6.6	24.0	113.1
12.8	0.8	95.0	0.10	0.10	0.05	0.15	1.0	6.6	24.0	113.1
14.6	0.8	104.3	0.10	0.10	0.05	0.15	1.0	6.6	24.0	113.1
16.4	0.9	113.6	0.10	0.10	0.05	0.15	1.0	6.6	24.0	113.1
18.1	1.0	122.9	0.10	0.10	0.05	0.15	1.0	6.6	24.0	113.1
19.9	1.1	132.2	0.10	0.10	0.05	0.15	1.0	6.6	24.0	113.1
21.7	1.1	141.5	0.10	0.10	0.05	0.15	1.0	6.6	24.0	113.1
23.5	1.2	150.9	0.10	0.10	0.05	0.15	1.0	6.6	24.0	113.1

Variable Time Hisotry with DELMAG D 19-42; Depth = 22.00ft; Shaft/Toe G/L = 1.000/1.000



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



Driven Friction Pile Calculations

Project: Sycamore Creek Bridge Replacement
Proj#: N1235302
Case: North Abutment (Boring No. 2)

Calculated By: MP **Reviewed By: DWW**

References:
ODOT SGE 7-21-23, ODOT BDM 2020 7-21-23, ODOT C&MS, FHWA-NHI-16-064 (FHWA GEC 012)

Bridge Geometry

Substructure: Abutment- North Side
Elevation of Ground Surface, $EG := 690\ ft$ (approx.)
Approx. Top of Pile/Bottom of Pile Cap Elevation, $ETP := 690\ ft$ (Pile above this will be sleeved)
Scour Depth, $D_{Scour} := 2.16\ ft$
Depth to Water Below Top of Pile, $Depth_{GW} := 10\ ft$ Use normal creek/river level if adjacent

Soil Layers

Layer	Soil Type	Bot. Depth from Surface	TopElev	BotElev	Bot. Depth Below Top of Pile	γ	ϕ'	S_u	APILE Setup Factor, f_{su}
		ft	ft	ft	ft	pcf	deg	psf	
1	Med. Dense granular	8.5	690.0	681.5	8.5	125	35	-	1.00
2	Very soft cohesive	11.0	681.5	679.0	11.0	100	-	50	1.00
3	Dense to V. Dense granular	30.0	679.0	660.0	30.0	130	38	-	1.00

Driven Pile Capacity using APile 2019 (FHWA Method)

Driven Pile Capacity Summary *(enter results from APile)*

Pile Type/Size	Pile Driven Length (ft.)	Approx. Tip Elevation (ft.)	Side Resistance (kips)	End Bearing (kips)	UBV (kips)
12	22	668	48.9	172.5	221.4

Setup

The affected soil layers have APILE setup factors equal to 1. Thus the result is similar to the capacity with no setup considered.

See attached APILE Results

```
     =========================================================================

                      APILE for Windows, Version 2023.10.3

                       Serial Number :  506768014

                       A Program for Analyzing the Axial Capacity
                       and Short-term Settlement of Driven Piles
                                 under Axial Loading.
                     (c) Copyright ENSOFT, Inc., 1987-2023
                           All Rights Reserved

     =========================================================================


     This program is licensed to :

     Terracon, Inc.
     APILE Global, Global License

     Path to file locations      : E:\Projects\2023\N1235414\Working
Files\Calculations-Analyses\Driven piles\APILE\B-2\
     Name of input data file     : B-2- 12 inches A Pile.ap10d
     Name of output file         : B-2- 12 inches A Pile.ap10o
     Name of plot output file    : B-2- 12 inches A Pile.ap10p

     -------------------------------------------------------------------------
                          Time and Date of Analysis
     -------------------------------------------------------------------------

               Date:  June 11, 2024     Time:  13:55:12



1
          *********************
          * INPUT INFORMATION *
          *********************

          PROJECT DESCRIPTION   :
          Boring No. 2
          DESIGNER   : MP
          JOB NUMBER : N1235414

          METHOD FOR UNIT LOAD TRANSFERS :
          - FHWA (Federal Highway Administration)
            Unfactored Unit Side Friction and Unit Side Resistance are used.

          COMPUTATION METHOD(S) FOR PILE CAPACITY :
          - FHWA (Federal Highway Administration)
```

```
TYPE OF LOADING :
- COMPRESSION

PILE TYPE :
Steel pipe pile or non-tapered portion of monotube pile
- Close-Ended Pile

 AVERAGE DEPTH TO ESTIMATE TIP RESISTANCE:
- USE 1.5 DIAMETERS ABOVE AND BELOW TIP

DATA FOR AXIAL STIFFNESS :
- MODULUS OF ELASTICITY     = 0.290E+08 PSI
- CROSS SECTION AREA        =      9.23 IN2

CIRCULAR PILE PROPERTIES :
- OUTSIDE DIAMETER, OD      =     12.00 IN.
- INTERNAL DIAMETER, ID     =     11.50 IN.
- TOTAL PILE LENGTH, TL     =     28.00 FT.
- BATTER ANGLE              =      0.00 DEG
- PILE STICKUP LENGTH, PSL  =      0.00 FT.
- ZERO FRICTION LENGTH, ZFL =      2.95 FT.
- INCREMENT OF PILE LENGTH
  USED IN COMPUTATION       =      1.00 FT.
- PRINTING INCREMENT        =         1
- LENGTH OF ENHANCED
  END SECTION               =     28.00 FT.
- INTERNAL DIAMETER OF
  ENHANCED END SECTION      =     11.50 IN.

PLUGGED/UNPLUGGED CONDITIONS :
Internal Pile Plug Calculated by Program


SOIL INFORMATIONS :

                  LATERAL    EFFECTIVE    FRICTION      Nq
          SOIL    EARTH      UNIT         ANGLE        FACTOR
 DEPTH    TYPE    PRESSURE   WEIGHT       DEGREES       FHWA
  FT.                        LB/FT^3
   0.00   SAND   1500.00       125.00          35.00      64.00**
   8.50   SAND   1500.00       125.00          35.00      64.00**
   8.50   CLAY      0.80*      100.00           0.00       4.80**
  11.00   CLAY      0.80*      100.00           0.00       4.80**
  11.00   SAND   1500.00       130.00          38.00     110.40**
  30.00   SAND   1500.00       130.00          38.00     110.40**

*  VALUE ASSUMED BY THE PROGRAM
** VALUE ESTIMATED BY THE PROGRAM BASED ON FRICTION ANGLE
```

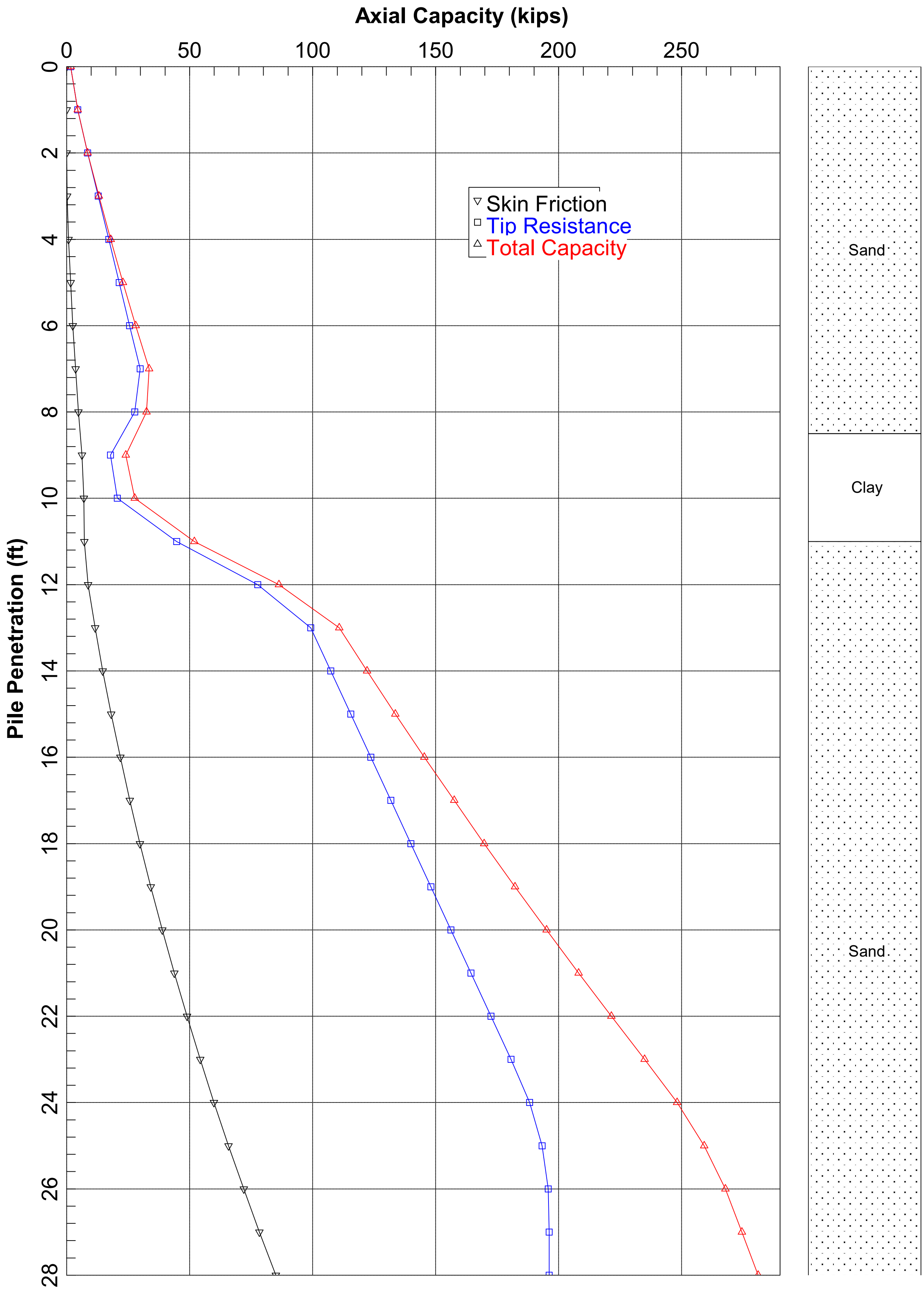
```
MAXIMUM   MAXIMUM   UNDISTURB  REMOLDED
UNIT      UNIT      SHEAR      SHEAR     BLOW   UNIT SKIN  UNIT END
FRICTION  BEARING   STRENGTH   STRENGTH  COUNT  FRICTION   BEARING
  KSF       KSF        KSF       KSF               KSF       KSF
0.10E+08* 0.10E+08*       0.00      0.00   0.00       0.00      0.00
0.10E+08* 0.10E+08*       0.00      0.00   0.00       0.00      0.00
0.10E+08* 0.10E+08*       0.05      0.00   0.00       0.00      0.00
0.10E+08* 0.10E+08*       0.05      0.00   0.00       0.00      0.00
0.10E+08* 0.10E+08*       0.00      0.00   0.00       0.00      0.00
0.10E+08* 0.10E+08*       0.00      0.00   0.00       0.00      0.00

* MAXIMUM UNIT FRICTION AND/OR MAXIMUM UNIT BEARING
  WERE SET TO LARGE VALUES INDICATING THAT APILE
  USES THE LIMITS SPECIFIED BY EACH SELECTED
  CRITERIA (IF ANY).


         LRFD FACTOR  LRFD FACTOR
          ON UNIT      ON UNIT
 DEPTH    FRICTION     BEARING
  FT.
   0.00    1.000       1.000
   8.50    1.000       1.000
   8.50    1.000       1.000
  11.00    1.000       1.000
  11.00    1.000       1.000
  30.00    1.000       1.000



 DEPTH     Z PEAK      T RESIDUAL
    FT.      IN.
   0.00     0.120 *       0.00
   8.50     0.120 *       0.00
   8.50     0.120 *       0.90 **
  11.00     0.120 *       0.90 **
  11.00     0.120 *       0.00
  30.00     0.120 *       0.00

* DEFAULT VALUE = 0.01 D
** DEFAULT VALUE = 0.9


1
          *********************
          * COMPUTATION RESULT *
          *********************
```

```
                **********************
                *  FED. HWY. METHOD  *
                **********************

   PILE LENGTH         SKIN             END        ULTIMATE
   BELOW GND.        FRICTION         BEARING      CAPACITY
       FT.              KIP             KIP             KIP
      0.00              0.0             1.6             1.6
      1.00              0.0             4.5             4.5
      2.00              0.0             8.5             8.5
      3.00              0.2            12.8            13.1
      4.00              0.8            17.1            17.9
      5.00              1.6            21.4            22.9
      6.00              2.5            25.6            28.1
      7.00              3.6            29.9            33.5
      8.00              4.8            27.7            32.5
      9.00              6.2            17.8            24.0
     10.00              7.0            20.6            27.7
     11.00              7.2            44.7            51.9
     12.00              8.7            77.7            86.3
     13.00             11.6            99.2           110.8
     14.00             14.7           107.4           122.1
     15.00             18.1           115.5           133.6
     16.00             21.8           123.6           145.4
     17.00             25.7           131.8           157.5
     18.00             29.8           139.9           169.7
     19.00             34.2           148.1           182.3
     20.00             38.9           156.2           195.1
     21.00             43.8           164.3           208.1
     22.00             48.9           172.5           221.4
     23.00             54.3           180.6           234.9
     24.00             59.9           188.2           248.1
     25.00             65.8           193.3           259.2
     26.00             72.0           195.8           267.8
     27.00             78.3           196.1           274.5
     28.00             85.0           196.1           281.1

NOTES:
- AN ASTERISK IS PLACED IN THE END-BEARING COLUMN
  IF THE TIP RESISTANCE IS CONTROLLED BY THE FRICTION
  OF SOIL PLUG INSIDE AN OPEN-ENDED PIPE PILE.
```

```
          *************************************************
          * COMPUTE LOAD-DISTRIBUTION AND LOAD-SETTLEMENT *
          * CURVES FOR AXIAL LOADING                      *
          *************************************************


  T-Z CURVE   NO. OF   DEPTH TO CURVE   LOAD TRANSFER   PILE MOVEMENT
     NO.      POINTS        FT.              PSI              IN.

      1         10      0.4167E-01
                                         0.0000E+00      0.0000E+00
                                         0.0000E+00      0.1920E-01
                                         0.0000E+00      0.3720E-01
                                         0.0000E+00      0.6840E-01
                                         0.0000E+00      0.9600E-01
                                         0.0000E+00      0.1200E+00
                                         0.0000E+00      0.2400E+00
                                         0.0000E+00      0.3600E+00
                                         0.0000E+00      0.6000E+00
                                         0.0000E+00      0.2400E+01
      2         10      0.4250E+01
                                         0.0000E+00      0.0000E+00
                                         0.4674E+00      0.1920E-01
                                         0.7790E+00      0.3720E-01
                                         0.1168E+01      0.6840E-01
                                         0.1402E+01      0.9600E-01
                                         0.1558E+01      0.1200E+00
                                         0.1558E+01      0.2400E+00
                                         0.1558E+01      0.3600E+00
                                         0.1558E+01      0.6000E+00
                                         0.1558E+01      0.2400E+01
      3         10      0.8458E+01
                                         0.0000E+00      0.0000E+00
                                         0.9302E+00      0.1920E-01
                                         0.1550E+01      0.3720E-01
                                         0.2325E+01      0.6840E-01
                                         0.2790E+01      0.9600E-01
                                         0.3101E+01      0.1200E+00
                                         0.3101E+01      0.2400E+00
                                         0.3101E+01      0.3600E+00
                                         0.3101E+01      0.6000E+00
                                         0.3101E+01      0.2400E+01
      4         10      0.8542E+01
                                         0.0000E+00      0.0000E+00
                                         0.9393E+00      0.1920E-01
                                         0.1566E+01      0.3720E-01
                                         0.2348E+01      0.6840E-01
                                         0.2818E+01      0.9600E-01
                                         0.3131E+01      0.1200E+00
                                         0.2818E+01      0.2400E+00
```

```
                                  0.2818E+01      0.3600E+00
                                  0.2818E+01      0.6000E+00
                                  0.2818E+01      0.2400E+01
5        10      0.9750E+01
                                  0.0000E+00      0.0000E+00
                                  0.3256E+00      0.1920E-01
                                  0.5426E+00      0.3720E-01
                                  0.8139E+00      0.6840E-01
                                  0.9767E+00      0.9600E-01
                                  0.1085E+01      0.1200E+00
                                  0.9767E+00      0.2400E+00
                                  0.9767E+00      0.3600E+00
                                  0.9767E+00      0.6000E+00
                                  0.9767E+00      0.2400E+01
6        10      0.1096E+02
                                  0.0000E+00      0.0000E+00
                                  0.1042E+00      0.1920E-01
                                  0.1736E+00      0.3720E-01
                                  0.2604E+00      0.6840E-01
                                  0.3125E+00      0.9600E-01
                                  0.3472E+00      0.1200E+00
                                  0.3125E+00      0.2400E+00
                                  0.3125E+00      0.3600E+00
                                  0.3125E+00      0.6000E+00
                                  0.3125E+00      0.2400E+01
7        10      0.1104E+02
                                  0.0000E+00      0.0000E+00
                                  0.1767E+00      0.1920E-01
                                  0.2945E+00      0.3720E-01
                                  0.4417E+00      0.6840E-01
                                  0.5300E+00      0.9600E-01
                                  0.5889E+00      0.1200E+00
                                  0.5889E+00      0.2400E+00
                                  0.5889E+00      0.3600E+00
                                  0.5889E+00      0.6000E+00
                                  0.5889E+00      0.2400E+01
8        10      0.2050E+02
                                  0.0000E+00      0.0000E+00
                                  0.3245E+01      0.1920E-01
                                  0.5408E+01      0.3720E-01
                                  0.8113E+01      0.6840E-01
                                  0.9735E+01      0.9600E-01
                                  0.1082E+02      0.1200E+00
                                  0.1082E+02      0.2400E+00
                                  0.1082E+02      0.3600E+00
                                  0.1082E+02      0.6000E+00
                                  0.1082E+02      0.2400E+01
9        10      0.2996E+02
                                  0.0000E+00      0.0000E+00
                                  0.4481E+01      0.1920E-01
```

```
                                        0.7468E+01      0.3720E-01
                                        0.1120E+02      0.6840E-01
                                        0.1344E+02      0.9600E-01
                                        0.1494E+02      0.1200E+00
                                        0.1494E+02      0.2400E+00
                                        0.1494E+02      0.3600E+00
                                        0.1494E+02      0.6000E+00
                                        0.1494E+02      0.2400E+01



 TIP   LOAD        TIP MOVEMENT
     KIP               IN.

 0.0000E+00         0.0000E+00
 0.1226E+02         0.6000E-02
 0.2452E+02         0.1200E-01
 0.4903E+02         0.2400E-01
 0.9806E+02         0.1560E+00
 0.1471E+03         0.5040E+00
 0.1765E+03         0.8760E+00
 0.1961E+03         0.1200E+01
 0.1961E+03         0.1800E+01
 0.1961E+03         0.2400E+01



               LOAD VERSUS SETTLEMENT CURVE
               ****************************



 TOP  LOAD     TOP MOVEMENT       TIP  LOAD      TIP MOVEMENT
    KIP             IN.              KIP            IN.
0.4644E+00      0.5569E-03      0.2043E+00      0.1000E-03
0.4644E+01      0.5569E-02      0.2043E+01      0.1000E-02
0.2366E+02      0.2823E-01      0.1021E+02      0.5000E-02
0.4576E+02      0.5570E-01      0.2043E+02      0.1000E-01
0.8368E+02      0.1060E+00      0.4086E+02      0.2000E-01
0.1256E+03      0.1803E+00      0.5869E+02      0.5000E-01
0.1491E+03      0.2366E+00      0.6983E+02      0.8000E-01
0.1605E+03      0.2704E+00      0.7726E+02      0.1000E+00
0.1887E+03      0.4058E+00      0.1043E+03      0.2000E+00
0.2310E+03      0.7589E+00      0.1465E+03      0.5000E+00
0.2550E+03      0.1089E+01      0.1705E+03      0.8000E+00
0.2685E+03      0.1306E+01      0.1840E+03      0.1000E+01
0.2806E+03      0.2321E+01      0.1961E+03      0.2000E+01
```


Axial Capacity (kips)
0
50
100
150
200
250
Pile Penetration (ft)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
▽ Skin Friction
□ Tip Resistance
△ Total Capacity
Sand
Clay
Sand

Driven Friction Pile Calculations

Project: Sycamore Creek Bridge Replacement
Proj#: N1235302
Case: North Abutment (Boring No. 2)

Drivability Analysis (GRL WEAP 14)

100 blows per foot (bpf) considered to be practical refusal for friction pile. For piles to rock 20 blows per inch (240 bpf) or greater is practical refusal.

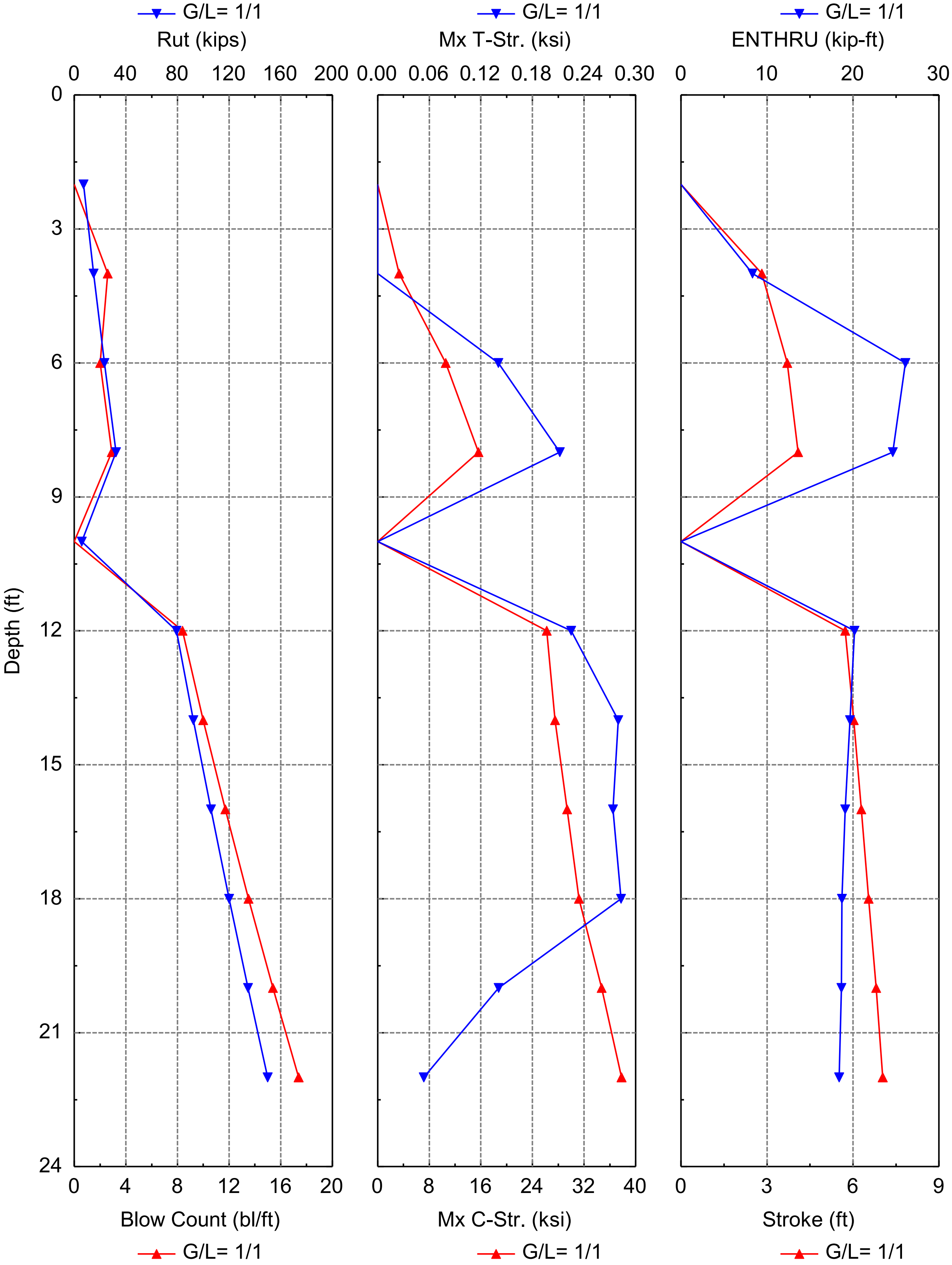
Allowable Stress during Driving for Steel = 0.9 φda fy = 0.9*1.0*45ksi (for 45 ksi pipe piles)

Summary of Driveability Analysis

Pile Type/ Size	Hammer	Wall Thickness (in)	Results
12	D19-42	0.25	Compressive Stress and Blow Count (OK)

See attached results of GRL Weap analyses

Driveability Analysis Summary



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

Depth ft	Rut kips	Rshaft kips	Rtoe kips	Blow Ct bl/ft	Mx C-Str ksi	Mx T-Str. ksi	Stroke ft	ENTHRU kip-ft	Hammer -
2.0	7.3	0.3	7.0	0.0	0.000	0.000	0.00	0.0	D 19-42
4.0	15.1	1.1	13.9	2.6	3.334	0.000	2.82	8.3	D 19-42
6.0	23.5	2.6	20.9	2.0	10.552	0.140	3.70	26.1	D 19-42
8.0	32.5	4.6	27.9	2.9	15.618	0.212	4.09	24.6	D 19-42
10.0	5.7	5.4	0.4	0.0	0.000	0.000	0.00	0.0	D 19-42
12.0	79.2	7.8	71.4	8.4	26.215	0.225	5.73	20.2	D 19-42
14.0	92.3	12.7	79.6	10.0	27.502	0.280	6.03	19.6	D 19-42
16.0	105.9	18.1	87.8	11.7	29.372	0.274	6.29	19.1	D 19-42
18.0	120.0	24.1	96.0	13.5	31.227	0.283	6.55	18.7	D 19-42
20.0	134.7	30.6	104.2	15.4	34.740	0.141	6.81	18.6	D 19-42
22.0	150.0	37.6	112.4	17.4	37.822	0.054	7.03	18.4	D 19-42
22.0	150.0	37.6	112.4	17.4	37.822	0.054	7.03	18.4	D 19-42

Summary_Total driving time: 3 minutes; Total Number of Blows: 150 (starting at penetration 2.0 ft)

GRLWEAP: Wave Equation Analysis of Pile Foundations

Sycamore Creek Bridge Replacement + B-2 7/3/2024
TSVC GRLWEAP 14.1.15.0

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

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

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

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

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

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

SOIL PROFILE

Depth ft	Soil Type -	Spec. Wt lb/ft³	Su ksf	Phi °	Unit Rs ksf	Unit Rt ksf
0.0	Sand	101.9	0.0	35.0	0.00	0.00
8.5	Sand	101.9	0.0	35.0	0.39	37.69
8.5	Clay	105.0	0.0	0.0	0.04	0.45
11.0	Clay	105.0	0.0	0.0	0.04	0.45
11.0	Sand	127.3	0.0	38.0	0.70	85.71
30.0	Sand	127.3	0.0	38.0	1.50	184.76

PILE INPUT

Uniform Pile		Pile Type:	Pipe
Pile Length: (ft)	22.000	Pile Penetration: (ft)	22.000
Pile Size: (ft)	1.00	Toe Area: (in²)	113.10

Pile Profile

Lb Top ft	X-Area in²	E-Modulus ksi	Spec. Wt lb/ft³	Perim. ft	Crit. Index -
0.0	9.2	30,000.0	492.0	3.1	0
22.0	9.2	30,000.0	492.0	3.1	0

HAMMER INPUT

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

Hammer Data

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

DRIVE SYSTEM FOR DELMAG D 19-42-OED

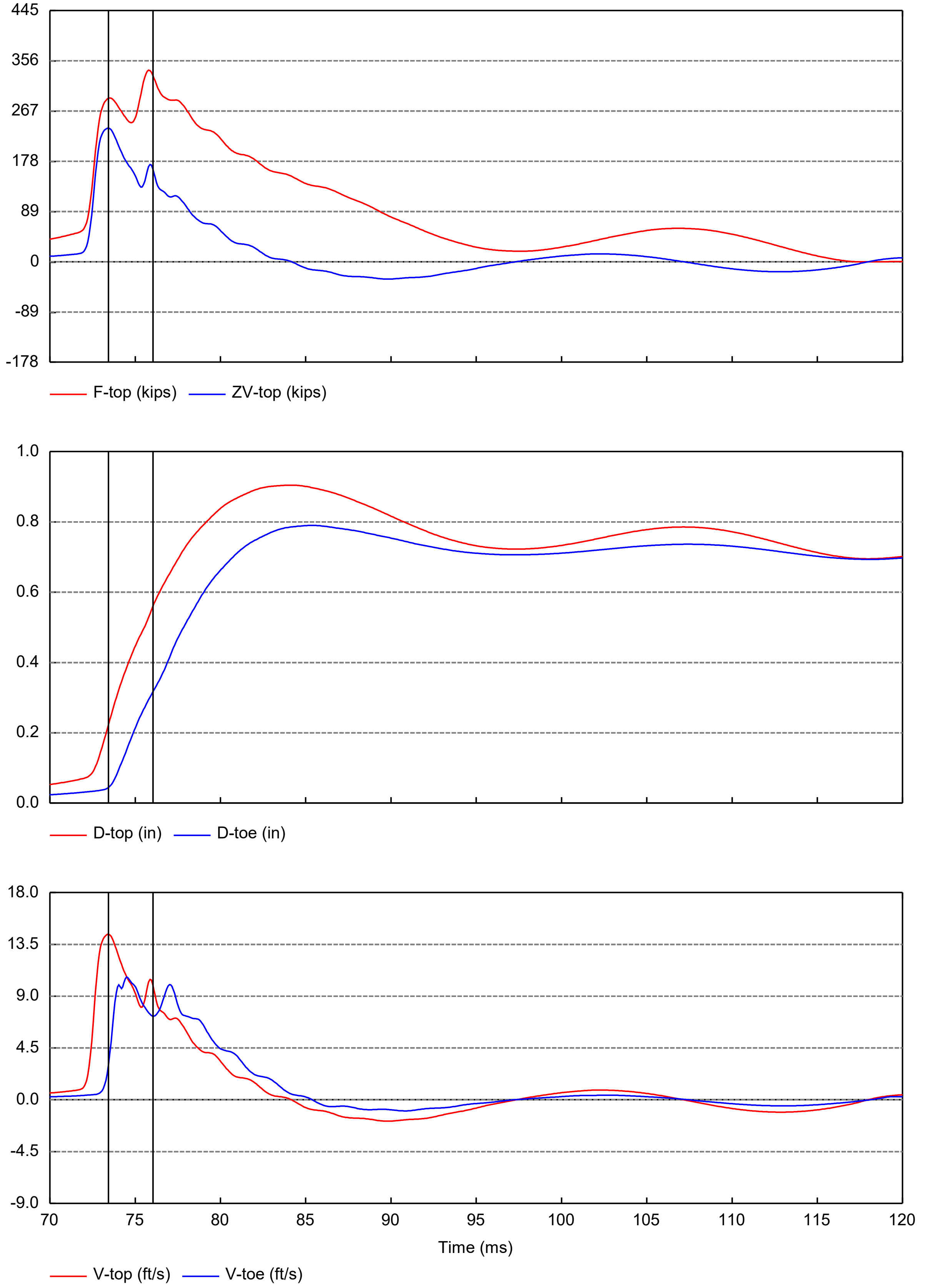
Type -	X-Area in²	E-Modulus ksi	Thickness in	COR -	Round-out in	Stiffness kips/in
Hammer C.	227.000	530.000	2.000	0.800	0.120	60155.555
Helmet Wt.	1.900	kips				

SOIL RESISTANCE DISTRIBUTION

Depth ft	Unit Rs ksf	Unit Rt ksf	Qs in	Qt in	Js s/ft	Jt s/ft	Set. F. -	Limit D. ft	Set. T. Hours	EB Area in²
0.0	0.0	0.0	0.10	0.13	0.05	0.15	1.0	6.6	24.0	113.1
1.7	0.1	7.5	0.10	0.13	0.05	0.15	1.0	6.6	24.0	113.1

3.4	0.2	15.1	0.10	0.13	0.05	0.15	1.0	6.6	24.0	113.1
5.1	0.2	22.6	0.10	0.13	0.05	0.15	1.0	6.6	24.0	113.1
6.8	0.3	30.2	0.10	0.13	0.05	0.15	1.0	6.6	24.0	113.1
8.5	0.4	37.7	0.10	0.13	0.05	0.15	1.0	6.6	24.0	113.1
8.5	0.0	0.4	0.10	0.20	0.20	0.15	1.8	6.6	720.0	113.1
9.7	0.0	0.4	0.10	0.20	0.20	0.15	1.8	6.6	720.0	113.1
11.0	0.0	0.4	0.10	0.20	0.20	0.15	1.8	6.6	720.0	113.1
11.0	0.7	85.7	0.10	0.10	0.05	0.15	1.0	6.6	24.0	113.1
12.7	0.8	94.7	0.10	0.10	0.05	0.15	1.0	6.6	24.0	113.1
14.5	0.8	103.7	0.10	0.10	0.05	0.15	1.0	6.6	24.0	113.1
16.2	0.9	112.7	0.10	0.10	0.05	0.15	1.0	6.6	24.0	113.1
17.9	1.0	121.7	0.10	0.10	0.05	0.15	1.0	6.6	24.0	113.1
19.6	1.1	130.7	0.10	0.10	0.05	0.15	1.0	6.6	24.0	113.1
21.4	1.1	139.7	0.10	0.10	0.05	0.15	1.0	6.6	24.0	113.1
23.1	1.2	148.7	0.10	0.10	0.05	0.15	1.0	6.6	24.0	113.1

Variable Time Hisotry with DELMAG D 19-42; Depth = 22.00ft; Shaft/Toe G/L = 1.000/1.000



Extrema Results of Gain/Loss at Shaft/Toe = 1.000/1.000 and Depth = 4.00 ft