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GEOTECHNICAL DESIGN REPORT
St. George River Bridge No. 5893
Route 17 over St. George River
MAINE DOT WIN 27158.00
Union, Maine

August 2026
09.0026237.01

Prepared for:
Stantec
Portland, Maine

Prepared by:
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VIA EMAIL

August 12, 2026
File No. 09.0026237.01

Sarah Williams, P.E.
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Re: Geotechnical Design Report (Revision 1)
Replacement of St. George River Bridge No. 5893
Route 17 over St. George River
MaineDOT WIN 27158.00
Union, Maine

Dear Sarah:

We are pleased to provide Revision 1 of this Geotechnical Design Report, which includes geotechnical design recommendations for the replacement of St. George River Bridge No. 5893, Route 17 over St. George River in Union, Maine.

Our work was completed in accordance with GZA GeoEnvironmental, Inc.'s Project Contract for the above referenced project dated October 20, 2025, our September 9, 2025, proposal, and the attached Limitations contained in **Appendix A** of this report.

It has been a pleasure serving Stantec on this phase of the project, and we look forward to our continued work with you through project completion. If you have any questions regarding the report, or if we can provide further assistance, please do not hesitate to contact the undersigned.

Very truly yours,

GZA GEOENVIRONMENTAL, INC.


Jason L. Keohane, P.E.^{MA}
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Attachment: Geotechnical Design Report



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1.0 INTRODUCTION

This report presents the results of the geotechnical evaluation by GZA GeoEnvironmental, Inc. (GZA) for the subject project. Our services were completed in accordance with GZA's Project Contract for the above referenced project dated October 20, 2025, our September 9, 2025, proposal, and the attached Limitations contained in **Appendix A** of this report.

1.1 BACKGROUND

The project includes replacement of the St. George River Bridge No. 5893 carrying Route 17 over St. George River in Union, Maine, the location of which is shown on **Figure 1**. The existing bridge is a 175-foot-long, three-span, continuous bridge with steel beams and a reinforced concrete deck. The bridge is 33 feet wide and is supported by concrete piers and concrete stub abutments. The 1959 plans indicate that each stub abutment is supported by twelve (12) 10 BP 42 driven piles that are either plumb or battered at 2.5 horizontal to 12 vertical (2.5H:12V), depending on the location. The maximum pile design load is 37 tons. Abutments 1 and 2 estimated pile lengths are 40 to 50 feet and 35 to 40 feet, respectively. The concrete piers are each comprised of three cast-in-place concrete columns, each supported by 17, 10 BP 42 driven piles that are either plumb or battered at 2H:12V, depending on the location.

It is GZA's understanding that the proposed bridge replacement will consist of a 168-foot-long, single-span, pile-supported integral abutment bridge. Each abutment will be supported by five (5) HP14x117 H-piles oriented for weak axis bending. The replacement bridge is proposed on the existing alignment, as shown on **Figure 2**. A temporary bridge is planned to allow full closure of the bridge during construction.

Elevations referenced in this report are in feet and refer to the North American Vertical Datum of 1988 (NAVD88).

1.2 OBJECTIVES AND SCOPE OF SERVICES

The objectives of our work were to evaluate subsurface conditions and to provide geotechnical engineering recommendations for the proposed bridge. To meet these objectives, GZA completed the following Scope of Services:

- Conducted a site visit to observe surficial conditions and reviewed existing data such as historical test borings and mapped surficial and bedrock geology of the site;
- Coordinated and observed subsurface exploration programs, consisting of four preliminary and three final design test borings, to evaluate subsurface conditions;
- Conducted laboratory testing programs to evaluate engineering and index properties of the site soils;
- Conducted geotechnical engineering analyses for soil and bedrock properties; stability, settlement, and frost susceptibility of approach embankments; AASHTO LRFD load resistance factors associated with geotechnical design elements; and pile design considerations, including axial resistance, drivability, and lateral resistance, as appropriate;



- Developed geotechnical engineering recommendations including foundation design recommendations for driven piles, lateral earth pressures, and seismic design parameters;
- Developed geotechnical construction considerations; and
- Prepared this geotechnical design report summarizing our findings and design recommendations.

2.0 SUBSURFACE EXPLORATIONS

2.1 HISTORIC (1959) BORINGS

In 1959, Maine Department of Transportation (MaineDOT) conducted eight test borings, designated Borings 1 through 8, to explore subsurface conditions for the existing bridge. The boring location plan, interpretive subsurface profile, and boring log sheets from the 1959 geotechnical report entitled “Soils Report s-0205(11) St. George River Bridge,” are included in **Appendix B**. Elevations referenced from the 1959 report were converted from National Geodetic Vertical Datum of 1929 to NAVD88 using a datum shift of -0.7 feet as provided by Stantec. The approximate boring locations were estimated by GZA by overlaying the boring location plan included in **Appendix B** on a current bridge layout drawing showing the existing bridge footprint. This method should be considered approximate to the degree implied by the method used.

2.2 GZA TEST BORINGS

GZA completed a preliminary subsurface exploration program between May 28 and June 4, 2024, consisting of four test borings, designated as BB-USGR-101 through BB-USGR-103, and BB-USGR-101A. New England Boring Contractors of Hermon, Maine (NEBC) provided drilling services, coordinated utility clearance, and provided traffic control for the project. The preliminary borings were completed using a Mobile B-53 drill carried on a CME track-mounted rig. GZA completed a supplemental exploration program between December 16, 2025, and January 14, 2026, consisting of three test borings, designated as BB-USGR-201, -201A, and BB-USGR-202. Seaboard Drilling, LLC of Bangor, Maine (Seaboard) provided drilling services, coordinated utility clearance, and provided traffic control for the project. The supplemental borings were completed using a Diedrich D-50 ATV-mounted drill rig.

Test borings were drilled to termination depths of approximately 28 to 75 feet below ground surface (bgs) after obtaining 5 to 10 feet of rock core, except for borings that were terminated due to obstructions and/or casing issues (BB-USGR-101 and -201). GZA personnel monitored the drilling work, classified soil and bedrock samples collected in accordance with MaineDOT procedures, and prepared logs of each boring, included in **Appendix C**. Wet and dry photographs of the collected rock core are presented in **Appendix D**.

Borings were drilled using 3- and 4-inch casing and drive- or spin-and-wash drilling techniques, as noted on the boring logs. Standard penetration testing (SPT) and split-spoon sampling were performed continuously or at standard 5-foot intervals using a 24-inch-long, 1-3/8-inch inside diameter sampler. SPTs were conducted using automatic hammer NEBC No. 23 for the -100 series borings which had a rated hammer energy transfer ratio at the time of drilling of 0.76. SPTs were conducted using automatic hammer Seaboard SN#362 for the -200 series borings with a rated hammer energy transfer ratio at the time of drilling of 1.011. Bedrock cores were obtained using NX coring equipment.



The borings were generally backfilled with ¾-inch crushed stone and/or soil cuttings. The holes cut through the bridge deck were filled with concrete flush to the deck surface. GZA personnel monitored the drilling work and prepared the logs of each boring, which are included in **Appendix B**. The as-drilled boring locations and ground surface elevations were surveyed by MaineDOT and provided to GZA and are shown on the boring logs and on **Figure 2**.

3.0 LABORATORY TESTING

GZA retained Thielsch Engineering (Thielsch) of Cranston, Rhode Island to complete laboratory testing programs to assess the gradation and index properties of soil samples from the preliminary and supplemental exploration programs. The testing program included:

COMPLETED LABORATORY TESTS		
Laboratory Test	ASTM Standard	Number of Tests
Grain Size Analysis	D6913	17
Hydrometer	D7928	5
Atterberg Limits	D4318	5
Moisture Content	D2216	22
Organic Content	D2974	3

Results of the testing are included in **Appendix E**.

4.0 SUBSURFACE CONDITIONS

4.1 SURFICIAL AND BEDROCK GEOLOGY

Based on available geologic mapping¹, the surficial units in the vicinity of the site consist of Stream Alluvium deposits, the Presumpscot Formation (glaciomarine deposit), and Glacial Till. Stream Alluvium is described as sand, gravel, and silt deposited on flood plains and may contain wetland deposits. The Presumpscot Formation consists of silt, clay, and sand. Glacial Till is described as a loose to compact mixture of sand, silt, and gravel-sized rock debris, with boulders commonly scattered throughout.

Based on available bedrock geologic mapping², the site is mapped as the Penobscot Formation undifferentiated (O€pu) and is described as several metamorphic rock types including rusty-weathering schist, greenish gray calc-silicate rocks, hornblende amphibolite, felsic gneiss, and sulfidic quartzite.

¹ Woodrow B, Thomspen. Surficial Geologic Map of Union Quadrangle Maine: Maine Geological Survey, Open-file No. 14-25 2014, scale 1:24,000.

² Norton, Stephen A., Berry, Henry N., IV, and West, David P., Jr., 2021, Bedrock geology of the Union quadrangle, Maine: Maine Geological Survey, Open-File Map 21-1, scale 1:24,000. Maine Geological Survey Maps. 2138. https://digitalmaine.com/mgs_maps/2138



4.2 SUBSURFACE PROFILE

Four soil units were encountered in the recent test borings beneath approximately 12 inches of asphalt pavement and above bedrock at the site: Fill, Alluvial Sand/Silt, Marine Clay, and Glacial Till. The approximate thicknesses and generalized descriptions of the subsurface units are presented in the following table, in descending order from existing ground surface. Detailed descriptions of the materials encountered at specific locations are provided in the boring logs in **Appendix C**. The thickness and elevation of each stratum is summarized on the attached **Table 1** and an interpretive subsurface profile based on the explorations is presented as **Figure 3**.



Soil Unit	Approximate Encountered Thickness (ft)	Generalized Description
Fill	22 to 26	Variable <u>from</u>: Grey, dense to very dense, Sandy GRAVEL, trace to some silt; <u>to</u>: brown, medium dense, fine to coarse SAND, little to some gravel, little silt. Probable cobbles and boulders encountered in BB-USGR-101 only. Typical MaineDOT Frost Classification = 0 to III Results from 7 Grain Size and Moisture Content Analyses • AASHTO Classification: A-1-b, A-2-4(0) • USCS Classification: SM • Moisture Content: 3.4 to 13.5% <i>Encountered in all approach embankment borings.</i>
Alluvium	7 to 10	Variable <u>from</u>: Brown/grey, medium dense, Silty fine SAND, trace gravel; <u>to</u>: olive/dark brown, loose to medium dense, fine to coarse SAND, some gravel, little silt. Occasional organics and gravel seams. Typical MaineDOT Frost Classification = III to IV Results from 6 Grain Size and Moisture Content Analyses: • AASHTO Classification: A-4(0), A-1-a, A-2-4(0) • USCS Classification: ML, SM, SP-SM, GW • Moisture Content: 9.9 to 46.9% <i>Encountered in all borings except BB-USGR-103 and -202</i>
Marine Clay	3 to 14	Grey, medium stiff, Silty CLAY to Clayey SILT, trace to some sand, trace gravel, trace organics. MaineDOT Frost Classification = III to IV Results of 2 Grain Size Analyses, 4 Atterberg Limits, 9 Moisture Content Analyses, and 1 Organic Content Analysis • AASTHO Classification: A-4(0) • USCS Classification: ML, CL • Liquid Limit: 26 to 44 • Plastic Limit: 15 to 19 • Plastic Index: 11 to 25 • Moisture Content: 19.2 to 36.0% • Organic Content: 0.7% <i>Encountered in all borings except BB-USGR-103.</i>
Glacial Till	5 to 21	Dark grey to grey, loose to very dense, fine to coarse SAND, trace silt to Silty, trace to some gravel. Probable cobbles and boulders throughout; see Section 4.2.2 below. MaineDOT Frost Classification = I to IV Results from 2 Grain Size and Moisture Content Analyses • AASHTO Classification: A-2-4(0) • USCS Classification: SM • Moisture Content: 10.0 to 29.0% <i>Encountered in all borings which penetrated through bottom of marine clay.</i>
Top of Bedrock Elevation	Abutment 1: Approx. El. 6.3 to 8.0 (63 feet bgs) Abutment 2: Approx. El. 30.1 to 45.4 (32 feet bgs)	



4.2.1 Boulders/Cobbles

Borings BB-USGR-101, -101A, -103, and -202 encountered significant boulders and/or cobbles during drilling. The table below summarizes the approximate depths, elevations, and stratum in which the boulders/cobbles were encountered. Approximate locations of the encountered boulders/cobbles are shown on **Figure 3**.

APPROXIMATE LOCATION OF ENCOUNTERED COBBLES/BOULDERS			
Boring ID	Depth BGS (ft)	Elevation (ft NAVD88)	Stratum
BB-USGR-101	9.3 to 11.5	59.5 to 57.3	Fill
BB-USGR-101A	57.5 to 61.3	10.9 to 7.1	Glacial Till
BB-USGR-103	27.3 to 32.3	50.3 to 45.3	
BB-USGR-202	24.7 to 28.5	42.2 to 38.4	

4.2.2 Bedrock

Bedrock was cored in borings BB-USGR-101A, -102, -103, -201A and -202. The bedrock was identified as either Gneiss, Granite, or Schist. Gneiss was encountered in all borings and was described as hard, fresh, fine-grained, and grey. The joints are described as very close to moderately spaced, low angle to moderately dipping, rough to smooth, planar to undulating, discolored to fresh, tight to open, with occasional silt and infilling. Granite was encountered in boring BB-USGR-102 below the Gneiss and was described as hard, fresh, medium to coarse grained, and white. No joints were observed in the approximate 7-foot-long core of granite. Schist was encountered in boring BB-USGR-201A below the Gneiss and was described as hard, fresh, fine grained, and grey. The joints are described as moderately spaced, moderately dipping, stepped, rough, fresh, tight to open, with occasional sand infilling.

4.2.3 Groundwater

Groundwater depth was measured in all borings. Groundwater depths for borings drilled outside of the river ranged from 10.2 to 26.5 feet bgs, corresponding to approximately El. 58.0 to 42.5. Groundwater levels in the borings were measured during or immediately after drilling and were likely affected by casing in the hole and drilling procedures, which included introduction of water for drilling purposes.

The groundwater observations were made at the times and under the conditions stated in the boring logs. Fluctuations in groundwater level occur due to variations in season, precipitation, river levels, and construction activities in the area. Consequently, water levels during construction are likely to vary from those encountered at the time the observations were made.

5.0 ENGINEERING EVALUATIONS

5.1 GENERAL EVALUATIONS

GZA conducted geotechnical engineering evaluations in accordance with *2024 AASHTO LRFD Bridge Design Specifications, 10th Edition* (herein designated as AASHTO) and the *MaineDOT Bridge Design Guide, 2003 Edition*, with 2018 updates (MaineDOT BDG). The sections that follow describe the evaluations and geotechnical basis for each element.



5.2 APPROACH EMBANKMENTS

Abutment 1 was evaluated as the critical section for global stability because it contains the thickest clay stratum. GZA completed a global stability analysis to assess the factor of safety against rotational instability of the approach embankment at Sta. 40+50 along the left (northern) embankment side slope. An undrained shear strength of 500 psf was assumed in the marine clay based on the available in-situ data. We used the computer analytical software Slope/W 2025.1, developed by GeoSlope International, with the Morgenstern-Price method.

A grid and radius technique was used to identify the slip surface with the lowest calculated factor of safety. The results indicate that the factor of safety was 1.4 for the proposed cross section, which meets AASHTO LRFD criteria. The global stability analysis, including assumed soil properties, is included in **Appendix F**.

Raise in grade of the roadway is approximately 1 to 1.5 feet behind the abutments, which will require a similar general fill thickness over the approach embankments. At Abutment 1, the grade will be cut below existing grade in front of the abutment, resulting in a net decrease in effective stress in the marine clay stratum. Therefore, settlement will be negligible. The Abutment 2 approach will require fill placement between the existing and new abutments, which will result in an average fill thickness of about 7 feet extending about 10 feet behind the proposed abutment, along with similar thickness fills over the approach embankment in this limited area. The marine clay encountered in these borings appears over consolidated, indicating that settlement will be limited and will occur immediately during construction. Therefore, post-construction settlement is anticipated to be minimal.

5.3 SCOUR CONSIDERATIONS

Available laboratory data for the soil at and near riverbed elevations were evaluated to estimate D50 values, as summarized in the table below.

Boring & Sample ID	Depth (feet)	Approximate Elevation (ft NAVD 88)	Water Content (%)	D ₅₀ (mm)	Classification	
					USCS	AASHTO
BB-USGR-101, 7D-1	26-28	42.8-40.8	22.3	0.06	ML	A-4(0)
BB-USGR-101A, 1D	29-31	39.4-37.4	46.9	0.10	SM	A-4(0)
BB-USGR-101A, 2D	31-33	37.4-35.4	11.3	2.01	SP-SM	A-1-a
BB-USGR-102, 1D	4-6	32.9-30.9	9.9	0.33	SM	A-2-4(0)
BB-USGR-201, 5D	15-17	54.0-52.0	6.8	0.17	SM	A-2-4(0)
BB-USGR-202, 5D	21-23	45.9-23.9	23.8	0.02	ML	A-4(0)

Gradation curves for these samples are included in **Appendix E**.



5.4 EVALUATION OF FOUNDATIONS

5.4.1 Foundation Type Assessment

The proposed integral abutment configurations would place the bottom of the backwall approximately 13 feet below the proposed pavement elevation, corresponding to approximately El. 57 for Abutment 1 and El. 64 for Abutment 2.

H-piles driven to refusal on bedrock are the preferred foundation type for the proposed integral abutments.

5.5 LOAD AND RESISTANCE FACTORS

In GZA's experience, piles gaining a significant portion of their geotechnical resistance in very dense soils or on bedrock typically have the drivability resistance control their geotechnical resistance. For this condition, the piles will be driven to a nominal resistance calculated by dividing the maximum factored pile load (Strength load case) by a resistance factor of 0.65, per AASHTO LRFD Table 10.5.5.2.3-1.

Structural resistance of piles should be checked at the strength limit state considering a resistance factor of $\phi_c=0.50$, per AASHTO LRFD Article 10.7.3.2.3 for hard driving conditions. Since the abutment piles will be subject to lateral loading, the piles should also be checked for resistance to combined axial compression and flexure per AASHTO LRFD Articles 6.9.2.2 and 6.15.2. Per LRFD Article 6.5.4.2, the axial resistance factor $\phi_{cc}=0.75$ and the flexural resistance factor $\phi_f=1.0$ should be applied to the combined axial and flexural resistance of the pile interaction equation (AASHTO LRFD Eq. 6.9.2.2-1).

AASHTO LRFD load factors should be applied to horizontal earth pressure (EH), vertical earth pressure (EV), live load surcharge (LS) and components and attachments (DC) loads using the load factors provided in AASHTO LRFD Table 3.4.1-2 for all load combination limit states.

5.6 PILE DESIGN CONSIDERATIONS

5.6.1 Pile Type and Loading

The abutments are planned to be supported on ASTM A572, Grade 50 ($f_y=50$ ksi) HP14x117 steel H-Piles. A single row of five plumb piles is planned to support each abutment. Stantec provided a maximum axial load of 400 kips per pile for the Strength load case for the abutments. Therefore, piles should be installed to a nominal axial resistance of 616 kips, calculated by dividing the maximum factored axial load by a geotechnical resistance factor of 0.65. The resistance factor assumes dynamic pile testing with signal matching analysis will be conducted during construction to assess nominal geotechnical pile resistance in accordance with AASTHO requirements.

The skin friction resistance was evaluated for use as an input in drivability analyses. Based on our experience, we anticipate friction will be limited during driving in the marine clay and overlying granular soils, with increased friction resistance in the glacial till. Therefore, we estimated skin friction as a percent of nominal resistance to be 25 percent for Abutment 1 and 5 percent for Abutment 2 for drivability analyses.



By utilizing steel H-piles driven to bedrock for support of the abutments, total and differential settlement will be limited to elastic compression of the piles and should be less than ½ inch.

Post-construction settlement is anticipated to be negligible surrounding the piles. Therefore, downdrag loading was not considered.

The piles will be fully embedded after installation. Therefore, corrosion was not considered in the design. Axial tensile geotechnical (uplift) resistance was not evaluated because the structural loads provided by Stantec do not include uplift loading on the piles.

5.6.2 Lateral Pile Analysis

GZA developed a soil profile for lateral pile evaluations for Abutments 1 and 2. The elevations of the base of the approach slab and the bottom of the abutment backwall were modeled as the ground surface for the expansion and contraction cases, respectively. Input parameters for pile lengths and design profiles are presented in the following tables.

Abutment 1, Pile length = 50' (Depth from Bottom of Abutment to Bedrock)					
Stratum	Soil Model	Top of Layer Elevation (NAVD88 ft)	k (pci) / ϵ_{50}	ϕ' (deg)/ c_u (psf)	γ_e (pcf)
New Fill Above Pile (Expansion only)	Reese Sand	68.0	83	32	125
Existing Fill	Reese Sand	57.0	164	36	125
Existing Fill*	Reese Sand	48.0	97	36	62.6
Alluvium	Reese Sand	46.0	55	32	57.6
Marine Clay	Soft Clay	38.0	0.01	500	47.6
Glacial Till	Reese Sand	24.0	120	38	67.6

Abutment 2, Pile length = 32' (Depth from Bottom of Abutment to Bedrock)					
Stratum	Soil Model	Top of Layer Elevation (NAVD88 ft)	k (pci) / ϵ_{50}	ϕ' (deg)/ c_u (psf)	γ_e (pcf)
New Fill Above Pile (Expansion only)	Reese Sand	73.8	83	32	125
Existing Fill	Reese Sand	63.8	164	36	125
Marine Clay	Stiff Clay	48.8	0.007	800	110
Marine Clay*	Stiff Clay	46.8	0.007	800	47.6
Glacial Till	Reese Sand	41.8	120	38	67.6

Note: * indicates the top of layer is the approximate ground water elevation based on the boring logs.

GZA's lateral pile analysis for the integral abutments was conducted in accordance with Section 5.4.2.4 of the MaineDOT BDG and the recommendations included in the "Integral Abutment Bridge Design Guidelines" by the Vermont Department of Transportation (VTrans). Lateral pile analysis used the Ensoft, Inc. LPile version 2022.12.11 software.



For initial analysis, the structural resistance was checked to determine if the moment calculated in LPile for a fixed-head condition exceeds the plastic moment, resulting in a plastic hinge, for the specified displacement and factored axial load. The pile head boundary conditions and results of the initial analysis are summarized in the table below.

LATERAL PILE RESULTS – INITIAL ANALYSIS					
ABUTMENT 1					
Condition	Axial Load (kips)	Lateral Thermal Deflection (in)	LPile Moment at Pile Head (in-kips)	Total Stress at Pile Head (ksi)	Interaction Equation Ratio
Expansion	400	0.39	4,086	79.8	1.12
Contraction	400	0.72	4,152	80.9	1.14
ABUTMENT 2					
Condition	Axial Load (kips)	Lateral Thermal Deflection (in)	LPile Moment at Pile Head (in-kips)	Total Stress at Pile Head (ksi)	Interaction Equation Ratio
Expansion	400	0.39	4,083	79.8	1.12
Contraction	400	0.72	4,218	82.1	1.15

The results indicate that the piles are expected to form a plastic hinge at the base of pile cap for the proposed configuration. The hinge is assumed to transform the pile head to a pinned condition and allow the pile head to rotate and maintain a maximum moment equal to the plastic moment. In the VTrans design methodology, this transformation results in a reduction of the axial buckling resistance of the upper segment of the pile (Segment 1) where the plastic hinge forms and a check is required on the structural demand ratio of Segments 1 and 2 located below the hinge. The results of the analysis are summarized below.

LATERAL PILE RESULTS – PLASTIC HINGE					
ABUTMENT 1					
Condition	Axial Load (kips)	Lateral Thermal Deflection (in)	Plastic Hinge Moment at Pile Head (in-kips)	Axial Resistance Ratio, Segment 1	Combined Bending Demand Ratio, Segment 2
Expansion	400	0.39	3,469	0.33	0.61
Contraction	400	0.72	3,431	0.35	0.61
ABUTMENT 2					
Condition	Axial Load (kips)	Lateral Thermal Deflection (in)	Plastic Hinge Moment at Pile Head (in-kips)	Axial Resistance Ratio, Segment 1	Combined Bending Demand Ratio, Segment 2
Expansion	400	0.39	3,467	0.33	0.60
Contraction	400	0.72	3,429	0.35	0.61



The results indicate that the axial resistance and combined bending demand ratios are less than 1, indicating the proposed pile detail is acceptable. Lateral pile analysis calculations are included in **Appendix F**. It is noted that our calculation and the tables above are based on a factored axial load of 386 kips. The load subsequently increased to 400 kips, but the calculations were not updated because it is clear by inspection that the change would not affect our conclusions. The structural engineer should perform a final check of the pile's structural resistance.

5.6.3 Preliminary Wave Equation Analysis

GZA completed preliminary wave equation analyses to assess the drivability of HP 14x117 piles with a nominal geotechnical resistance of 616 kips at both abutments. The preliminary analyses used a Pileco D30-32 diesel hammer with a ram weight of 6,610 pounds and a maximum rated energy of 69,895 foot-pounds. The geotechnical side resistance described in the previous section was used to estimate the percent side friction for the analysis.

We modeled a pile length of 60 feet for Abutment 1 driven through 50 feet of overburden materials and 10 feet of stick up. For this length, we anticipate the pile will derive approximately 25 percent of its resistance inside friction. We used a toe quake of 0.1 which is considered appropriate to assess drivability of a pile driven if a less abrupt refusal is encountered along with higher skin friction, both of which tend to reduce the resistance shown by dynamic methods.

We modeled a pile length of 40 feet for Abutment 2 driven through 30 feet of overburden materials and 10 feet of stick up. We anticipate 5 percent side friction due to the short length. We used a toe quake of 0.04 which is considered appropriate to assess drivability of a relatively short pile driven to more immediate take-up in bedrock.

The above properties were input into the software GRLWEAP 14.2.2.0 and the results are summarized in the table below.

SUMMARY OF WEAP ANALYSES					
Pile Analysis and Type	Embedded Pile Length	Driving System	Stroke Length (ft)	Max Driving Stress (ksi)	Final Penetration Resistance (blows per inch)
Abutment 1 HP 14x117	50 feet	Pileco D30-32 (Fuel setting 3, 90% of max)	8.6	37	7
Abutment 2 HP 14x117	30 feet	Pileco D30-32 (Fuel setting 3, 90% of max)	8.7	45	6

Since the driving stresses do not exceed the limiting driving stress of 45 ksi for ASTM A572 steel (50 ksi yield stress), and the calculated penetration resistance for the pier piles is within the MaineDOT preferred range of 3 to 15 blows per inch, the analyzed hammer system is judged acceptable to install the pier piles to the required nominal resistance of 616 kips. It is noted that the fuel setting could be reduced if necessary for the shortest piles to further reduce the driving stress. Results of the preliminary wave equation analyses are provided in **Appendix F**.



5.7 LATERAL EARTH PRESSURE

5.7.1 Soil Backfill

Thermal expansion of the bridge will cause the backwalls and wingwalls of the integral abutment to move toward the backfill, which will result in earth pressures ranging from at-rest to passive earth pressure. The material properties will be controlled by the backfill material, which is proposed to consist of BDG Type 4 soil.

MaineDOT provided a thermal expansion for use in abutment design of 0.39 inches. The abutment height is approximately 13 feet resulting in a calculated abutment rotation of 0.003 feet/foot. Based on the MassDOT methodology, we recommend a passive earth pressure coefficient of 2.88 for design of backwalls and wingwalls. Passive earth coefficient calculations are included in **Appendix F**.

AASHTO LRFD Commentary C3.10.9.1 specifies that bridges in Seismic Zone 1 are not required to include acceleration-augmented (earthquake-induced) soil pressures for design.

5.8 FROST PENETRATION

Fill soils are anticipated to be present at the abutments and embankments, either as existing fill or imported backfill. Based on MaineDOT BDG, Section 5.2.1, the Freezing index for the site is 1,360, and with a low-moisture content (<10 percent) of soil, the estimated depth of frost penetration is approximately 6.5 feet. However, BDG Section 5.2.1 allows for the embedment of pile-supported integral abutments to be reduced to 4 feet for frost protection. Frost calculations are provided in **Appendix F**.

6.0 RECOMMENDATIONS

6.1 EMBANKMENT DESIGN CONSIDERATIONS

Embankment side slopes should be designed with MaineDOT-typical slope angles of 2H:1V or flatter, except in front of abutments where the 1.75H:1V slope angle will be used with an appropriate riprap surface treatment. Earth slopes should be provided with loam and seed for permanent erosion protection. Riprap should also be provided for scour protection where the embankment side slope angle will be 2H:1V and the slopes will be near or below high water levels in the St. George River.

6.2 SEISMIC DESIGN CONSIDERATIONS

The AASHTO LRFD 10th Edition uses the average shear wave velocity in the upper 100 feet of soil and bedrock (V_{s-BAR}) to determine the site class. When measured shear wave velocities are not available, empirical correlations are specified to calculate the shear wave velocity (V_s) for the available data. If V_{s-BAR} is developed using empirical correlations, it is required to consider uncertainty of ± 30 percent to assess the possible range in site class.



Correlations for granular and cohesive soils given in PEER (2012)³ were used to calculate shear wave velocities for each N-value in soil in test borings BB-USGR-101 through -103, and BB-USGR-201 through -202. A V_s value of 3,900 feet per second (fps) was used for bedrock, which is at the Soft Rock (B/C) to Medium Rock (B) boundary and is considered suitable for the bedrock at this site. At the approaches, the velocities of the existing soil were considered. The addition of about 2 feet of new fill over existing is considered to have negligible impact on the site class and was not considered. The site class evaluation results are summarized in the table below.

SITE CLASS EVALUATION				
Boring ID	V_{s-BAR} (ft/sec)	$1.3 \cdot V_{s-BAR}$ (ft/sec)	$V_{s-BAR}/1.3$ (ft/sec)	Site Class(es)
BB-USGR-101/A	868	1128	668	C, C/D, D, D/E
BB-USGR-102	1391	1809	1070	
BB-USGR-103	1339	1741	1030	
BB-USGR-201/A	779	1013	779	
BB-USGR-202	1148	1493	883	

Spectral design accelerations were developed for each site class using the AASHTO-USGS Seismic Design Ground Motion Database (2023). In accordance with AASHTO Section 3.10.3.1, the maximum spectral values of the range in site classes were selected for evaluation of Seismic Zone and (if necessary) for seismic analysis.

The Seismic Zone for the bridge was evaluated in accordance with AASHTO 3.10.6. Based on the calculated S_{D1} for each site class, the controlling value of S_{D1} was calculated to be 0.09. Based on AASHTO Table 3.10.6-1, the bridge should be assigned to Seismic Zone 1. Therefore, based on AASHTO 4.7.4, seismic analysis is not required. Minimum horizontal design connection forces should be determined in accordance with AASHTO 3.10.9. Seismic calculations are included in **Appendix F**.

6.3 ABUTMENT AND WINGWALL DESIGN

- Backfill between new abutments and wingwalls and a 1.5H:1V plane extending up from the bottom of the abutment to the pavement subgrade should consist of MaineDOT 703.19 Granular Borrow for Underwater Backfill, MaineDOT BDG Type 4 soil. Recommended soil properties for Type 4 soils are as follows:
 - Internal Friction Angle of Soil = 32°
 - Soil Total Unit Weight = 125 pcf
 - Coefficient of Passive Earth Pressure, K_p = 2.88 (use for design of backwalls and wingwalls).
- Live load surcharge should be applied as a uniform lateral surcharge pressure using the equivalent fill height (H_{eq}) values developed in accordance with LRFD Section 3.11.6.4, based on the

³ Wair, B. R., DeJong, J. T., & Shantz, T. (2012). Guidelines for Estimation of Shear Wave Velocity, PEER Report 2012-08. Pacific Earthquake Engineering Research Center, University of California, Berkeley, CA.



abutment/wingwall height and distance from the wall backface to the edge of traffic. A minimum H_{eq} of 2 feet is recommended.

- Foundation drainage should be provided in accordance with Section 5.4.1.9 of the MaineDOT BDG. We recommend the use of French drains on the uphill side of abutments and wing walls to prevent buildup of differential hydrostatic pressure. The drains should be sloped to drain by gravity and should either outlet through a series of 4-inch-diameter weep holes, spaced approximately 10 feet center-to-center, or the French drain material should extend below the bottom of the structure elevation and daylight in front of the foundations. Alternatively, prefabricated drainage geocomposite material can be placed against the uphill side of abutments, after holes have been created through the backing material at the weep hole locations.

6.4 RECOMMENDATIONS FOR FOUNDATIONS

6.4.1 Pile Design

- The proposed abutments may be supported on HP14x117 ASTM A572, Grade 50 steel (50 ksi yield stress) H-piles, oriented for weak axis bending, driven to the required nominal resistance, anticipated to be developed through a combination of skin friction and end-bearing on bedrock.
- To limit pile damage during driving, cast steel pile points should be provided in accordance with MaineDOT Standard Specification Section 501.10 – Pile Tips.
- Pile installation should be controlled using wave equation analysis and field logging of the pile installation with final penetration resistance based on dynamic pile testing with signal matching analysis.
- The abutment piles should be driven to a nominal resistance of 616 kips, calculated by dividing the maximum factored axial load of 400 kips by a resistance factor of 0.65, and they should be oriented in the weak axis.
- Preliminary wave equation analyses indicate that the piles could be driven to the required nominal resistance using a diesel hammer with a maximum rated energy of about 69,895 foot-pounds for the anticipated 30- to 50-foot long ASTM A572 Grade 50 HP14x117 piles without exceeding the allowable driving stress of 45 ksi (0.9F_y for 50 ksi steel), and with a final penetration resistance of approximately 5 to 6 blows per inch.
- We recommend that the pile tip elevations consider the lowest interpreted bedrock elevation shown on **Figure 2** at each abutment (approximately El. 5 at Abutment 1, and approximately El. 28 at Abutment 2). Assuming 5 feet of embedment into bedrock, estimated pile lengths are 60 feet at Abutment 1 and 45 feet at Abutment 2.
- We recommend that one pile at each abutment be dynamically tested at the end of initial drive to assess driving stress and establish the penetration resistance criteria to achieve the required nominal resistance for the production piles. The plans should also require a restrrike test on each test pile. An additional 5 feet of pile length should be provided for connection of the dynamic pile driving equipment to the piles.
- Piles shall be spliced in accordance with MaineDOT Section 501.047.
- Integral abutment piles should be checked for resistance to combined axial compression and flexure per AASHTO LRFD Articles 6.9.2.2 and 6.15.2. Per AASHTO LRFD Article 6.5.4.2, the axial resistance



factor $\phi_{cc}=0.7$ and the flexural resistance factor $\phi_f=1.0$ should be applied to the combined axial and flexural resistance of the pile in the interaction equation (AASHTO LRFD Eq. 6.9.2.2-1).

- Approach slabs should be constructed at each abutment to smooth the transition from the approach embankment to the bridge.

7.0 CONSTRUCTION CONSIDERATIONS

This section provides guidance regarding quality control during pile installation, excavation, dewatering, and foundation subgrade preparation and protection. These items are discussed in the paragraphs that follow.

7.1 PILE INSTALLATION CONTROL

We recommend that the H-pile installation be controlled using wave equation analysis of the contractor's proposed driving system, field logging of the pile installation, and determination of final penetration resistance based on dynamic pile testing with signal matching analysis. As previously noted, the piles should be driven to a nominal resistance calculated by dividing the maximum factored pile load by a resistance factor of 0.65, per AASHTO Table 10.5.5.2.3-1.

AASHTO Table 10.5.5.2.3-1 requires that at least one load test with signal matching be performed per substructure in conjunction with the resistance factor of 0.65. We recommend that one PDA test with Signal Matching be completed at each abutment, including a restrike test for each tested pile.

It should be noted that cobbles and boulders were encountered in the fill and glacial till. These materials may also exist elsewhere at the Site and could represent obstructions to pile advancement. Pre-drilling obstructions or spudding may be required.

7.2 EXCAVATION, TEMPORARY LATERAL SUPPORT, AND DEWATERING

Excavations for abutment foundations are anticipated to be up to 12 feet below the existing ground surface at Abutment 1 and up to 14 feet below existing ground surface at Abutment 2. It is our understanding that a temporary bridge will be constructed and Route 17 traffic will be re-routed to the temporary bridge during construction. In areas where sufficient space is available and water conditions permit, the excavation slopes may consist of sloped, open cuts. Cofferdams or alternative underwater demolition methods may be required to partially remove existing substructures as required for the design. In all cases, temporary excavations should comply with OSHA excavation safety requirements.

We anticipate that the inflow of groundwater or surface water to abutment excavations can be handled by open pumping from sumps installed at the bottoms of excavations. The contractor should be responsible for controlling groundwater, surface runoff, infiltration, and water from all other sources by methods which preserve the undisturbed condition of the subgrade and permit foundation construction in-the-dry. Discharge of pumped groundwater and river water should comply with all local, State, and federal regulations.



August 12, 2026

GEOTECHNICAL DESIGN REPORT
ST. GEORGE RIVER BRIDGE NO. 5893 - UNION
09.0026237.01

TABLE



TABLE 1
Summary of Subsurface Explorations
St. George River Bridge No. 5893
Union, Maine
GZA File No. 09.0026237.01

Boring ID	Northing	Easting	Ground Surface El. (ft)	Top of Stratum Elevation						Stratum Thickness					Depth to Bedrock (ft)	Bottom of Boring Depth (ft)	Bottom of Boring El. (ft)	Groundwater	
				Asphalt	Fill	Alluvium	Marine Clay	Glacial Till	Bedrock	Asphalt	Fill	Alluvium	Marine Clay	Glacial Till				El. (ft)	Depth (ft)
GZA TEST BORINGS																			
BB-USGR-101	261368.8	1600142.5	68.8	68.8	67.7	44.8	37.8	NE	NE	1.1	22.9	7.0	≥ 1	NE	NE	32.0	36.8	58.0	10.8
BB-USGR-101A	261369.9	1600136.1	68.4	NM	NM	NM	34.4	26.7	7.1	NM	NM	NM	7.7	19.6	61.3	68.3	0.1	49.4	19
BB-USGR-102	261355.6	1600242.6	36.9	NE	NE	36.9	27.9	24.9	18.9	NE	NE	9.0	3.0	6.0	18.0	27.8	9.1	--	--
BB-USGR-103	261322.8	1600365.6	77.6	77.6	76.6	NE	NE	50.3	45.4	1.0	26.3	NE	NE	4.9	32.2	42.6	35.0	58.8	18.8
BB-USGR-201	261350.3	1600156.6	69.0	69.0	68.0	47.0	38.7	NE	NE	1.0	21.0	8.3	≥ 9.7	NE	NE	40.0	29.0	42.5	26.5
BB-USGR-201A	261351.0	1600158.5	69.1	NM	NM	NM	NM	24.6	6.3	NM	NM	NM	≥ 9.5	18.3	62.8	75.0	-6.0	42.6	26.5
BB-USGR-202	261326.6	1600330.4	66.9	NE	66.9	NE	50.6	42.2	33.0	NE	16.3	NE	8.4	9.2	33.9	44.5	22.4	56.7	10.2
HISTORIC (1959) TEST BORINGS																			
Boring 1			47.3						<17.5										
Boring 2			46.3						8.0										
Boring 3			48.4						9.7										
Boring 4			48.8						10.1										
Boring 5			41.7						20.8										
Boring 6			40.2						26.5										
Boring 7			43.9						30.1										
Boring 8			47.2						37.7										

El. = Elevation, NE = Not Encountered, NM = Not Measured, NP = Not Penetrated, ≥ Boring Began in or was Terminated in Stratum

Notes:

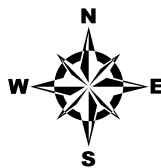
- 1. Refer to the boring logs in Appendix B for additional information.
- 2. Project elevation datum is North American Vertical Datum (NAVD 88), unless noted otherwise.
- 3. As-drilled locations and elevations were surveyed by MaineDOT and provided to GZA.
- 4. Stratum depths, thickness and elevations are rounded to the nearest 0.1 foot as interpreted on the boring logs, but this does not represent the precision of the data.
- 5. Marine Clay stratum depths for BB-USGR-201A considers top of clay elevation from -201, respectively, as the alternate boring was not sampled above the clay.
- 5. Ground surface elevations for the historic (1959) borings were taken from the logs in the 1959 soils report entitled "Soils Report s-0205(11) St. George River Bridge". Elevations were in NGVD 1929 and converted to NAVD 88 based on a value of -0.7, as provided by Stantec. These elevations were prior to construction of existing embankments and are significantly different than current grades at the locations.
- 6. Northings and Eastings are not shown for the historic (1959) borings. The approximate boring locations were estimated by overlaying the circa-1959 boring location plan on the current bridge drawing. The locations should considered approximate to the degree implied by the method used.



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GEOTECHNICAL DESIGN REPORT
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09.0026237.01

FIGURES



USGS
QUADRANGLE
LOCATION

SOURCE : THIS MAP CONTAINS THE ESRI ARCGIS ONLINE USA TOPOGRAPHIC MAP SERVICE, PUBLISHED DECEMBER 12, 2009 BY ESRI ARCS SERVICES AND UPDATED AS NEEDED. THIS SERVICE USES UNIFORM NATIONALLY RECOGNIZED DATUM AND CARTOGRAPHY STANDARDS AND A VARIETY OF AVAILABLE SOURCES FROM SEVERAL DATA PROVIDERS. THIS MAP ALSO CONTAINS THE ESRI ARCGIS ONLINE USA COUNTIES WHICH PROVIDES DETAILED BOUNDARIES THAT ARE CONSISTENT WITH THE TRACT, BLOCK GROUP, AND STATE DATA SETS AND ARE EFFECTIVE AT REGIONAL AND STATE LEVELS.

0 1,000 2,000 4,000 6,000

SCALE IN FEET

Data Supplied by :



PROJ. MGR.: BMC
DESIGNED BY: EAF
REVIEWED BY: BMC
OPERATOR: EAF

DATE: AUGUST 2026

LOCUS PLAN

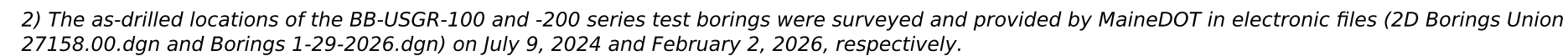
REPLACEMENT OF ST. GEORGE RIVER BRIDGE NO. 5893
ROUTE 17 OVER ST. GEORGE RIVER
UNION, MAINE

JOB NO.
09.0026237.01

FIGURE NO.
1

● *MDOT NO. 1*

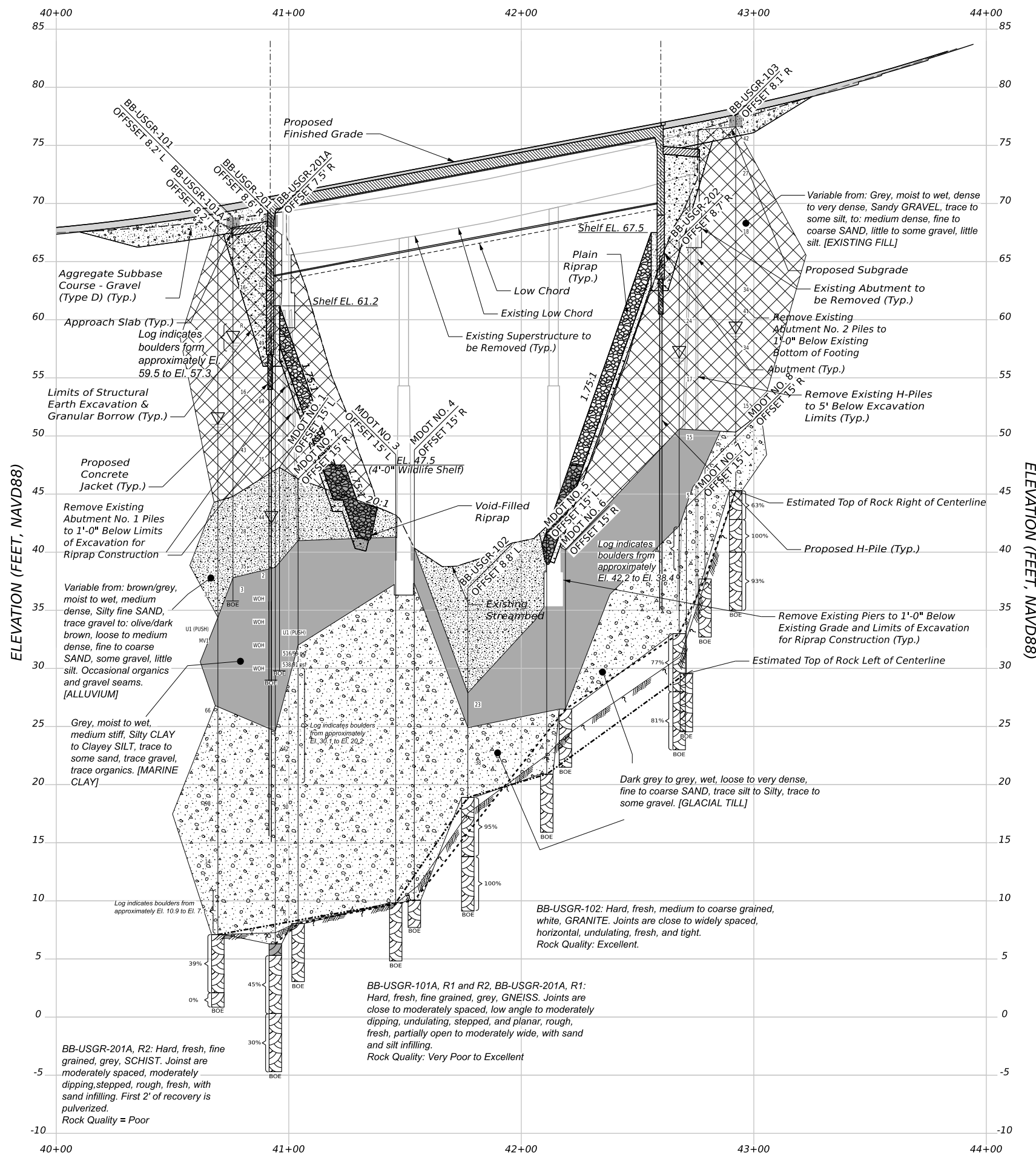
Location and designation of historic borings performed and observed by MaineDOT in September of 1959.



A scale bar labeled "Scale of Feet" with markings at 25, 0, 25, and 50. The segment from 0 to 25 is divided into five equal black and white squares.

2

BORING LOCATION PLAN



NOTES

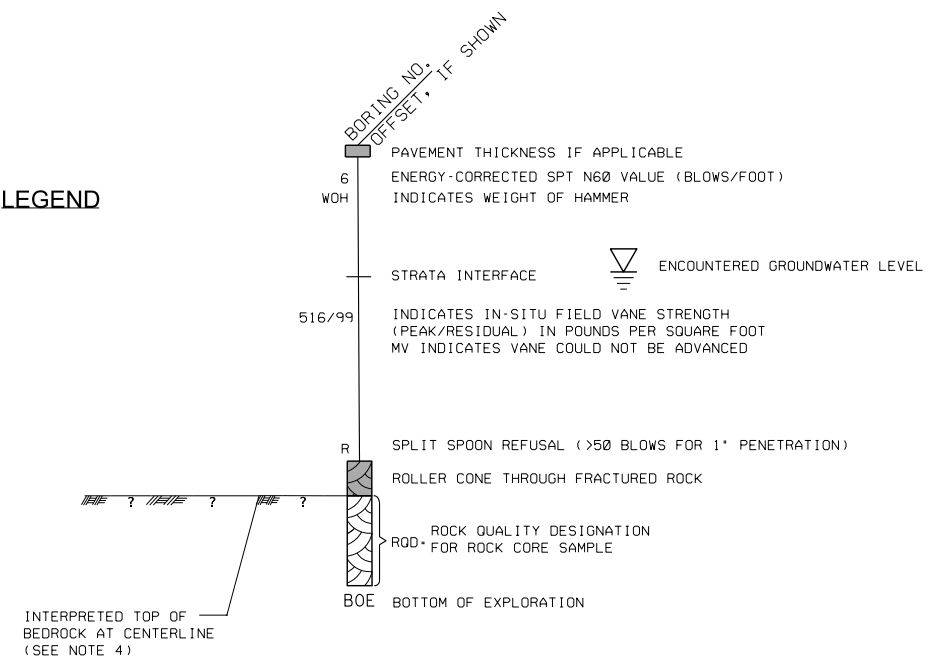
1) Profile developed from electronic files provided by Stantec on February 2, 2026 and updated on June 11, 2026.

2) The as-drilled boring locations were surveyed by a MaineDOT survey crew and provided to GZA in an electronic file (BORINGS 1-29-2026) on February 2, 2026.

3) BB-USGR-100 series bridge borings were performed by MaineDOT of Augusta, Maine and observed by GZA personnel between May 29 and May 31, 2024. BB-USGR-200 series bridge borings were performed by Seaboard Drilling, LLC of Bangor, Maine and observed by GZA personnel between December 16, 2025 and January 14, 2026. Historic soil borings were performed and observed by MaineDOT in September of 1959.

4) This generalized interpretive soil and rock profile is intended to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized, and have been developed by interpretations of widely spaced explorations and samples. Actual soil transitions may vary and are probably more erratic. Boring data are shown for borings drilled off alignment. Estimated top of rock is also shown using borings left and right of centerline. Soil and rock descriptions are based on BB-USGR-100 and -200 series borings. For more specific information refer to the exploration logs.

LEGEND



DEPARTMENT OF TRANSPORTATION STATE OF MAINE Federal Project No. 2715800 WIN 27158.00

PROJECT NUMBER	JNB	ST. JEROME/NO. 1	DATE
DESIGN-DETAILED	JNB	JNB	JUNE 2026
CHECKED-REVIEWED	ALK	A88	JUNE 2026
DESIGN-DETAILED2			SIGNATURE
DESIGN-DETAILED3			
REVISIONS 1			P.E. NUMBER
REVISIONS 2			
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			DATE

GEORGE RIVER BRIDGE NO. 5893
CROSSING ST. GEORGE RIVER
UNION
INTERPRETIVE SUBSURFACE
PROFILE

ST. GEORGE RIVER BRIDGE #5893
MAINEDOT WIN 27158.00
UNION, MAINE

INTERPRETIVE SUBSURFACE PROFILE

PREPARED BY:  **GZA** GeoEnvironmental, Inc.
Engineers and Scientists
www.qza.com

PREPARED FOR:

STANTEC

PROJ MGR: JLK	REVIEWED BY: ARB
DESIGNED BY: JNB	DRAWN BY: JNB
DATE: AUGUST 2026	PROJECT NO. 09 0026237 01

CHECKED BY: JLK	FIGURE 3
SCALE: AS SHOWN	
REVISION NO. 1	

SHEET NO: 3 OF 3

PRELIMINARY
NOT FOR CONSTRUCTION



August 12, 2026

GEOTECHNICAL DESIGN REPORT

ST. GEORGE RIVER BRIDGE NO. 5893 - UNION

09.0026237.01

APPENDIX A – LIMITATIONS



GEOTECHNICAL LIMITATIONS

Use of Report

1. GZA GeoEnvironmental, Inc. (GZA) prepared this report on behalf of, and for the exclusive use of our Client for the stated purpose(s) and location(s) identified in the Proposal for Services and/or Report. Use of this report, in whole or in part, at other locations, or for other purposes, may lead to inappropriate conclusions; and we do not accept any responsibility for the consequences of such use(s). Further, reliance by any party not expressly identified in the contract documents, for any use, without our prior written permission, shall be at that party's sole risk, and without any liability to GZA.

Standard of Care

2. GZA's findings and conclusions are based on the work conducted as part of the Scope of Services set forth in Proposal for Services and/or Report, and reflect our professional judgment. These findings and conclusions must be considered not as scientific or engineering certainties, but rather as our professional opinions concerning the limited data gathered during the course of our work. If conditions other than those described in this report are found at the subject location(s), or the design has been altered in any way, GZA shall be so notified and afforded the opportunity to revise the report, as appropriate, to reflect the unanticipated changed conditions .
3. GZA's services were performed using the degree of skill and care ordinarily exercised by qualified professionals performing the same type of services, at the same time, under similar conditions, at the same or a similar property. No warranty, expressed or implied, is made.
4. In conducting our work, GZA relied upon certain information made available by public agencies, Client and/or others. GZA did not attempt to independently verify the accuracy or completeness of that information. Inconsistencies in this information which we have noted, if any, are discussed in the Report.

Subsurface Conditions

5. The generalized soil profile(s) provided in our Report are based on widely-spaced subsurface explorations and are intended only to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized, and were based on our assessment of subsurface conditions. The composition of strata, and the transitions between strata, may be more variable and more complex than indicated. For more specific information on soil conditions at a specific location refer to the exploration logs. The nature and extent of variations between these explorations may not become evident until further exploration or construction. If variations or other latent conditions then become evident, it will be necessary to reevaluate the conclusions and recommendations of this report.
6. In preparing this report, GZA relied on certain information provided by the Client, state and local officials, and other parties referenced therein which were made available to GZA at the time of our evaluation. GZA did not attempt to independently verify the accuracy or completeness of all information reviewed or received during the course of this evaluation.



7. Water level readings have been made in test holes (as described in this Report) and monitoring wells at the specified times and under the stated conditions. These data have been reviewed and interpretations have been made in this Report. Fluctuations in the level of the groundwater however occur due to temporal or spatial variations in areal recharge rates, soil heterogeneities, the presence of subsurface utilities, and/or natural or artificially induced perturbations. The water table encountered in the course of the work may differ from that indicated in the Report.
8. GZA's services did not include an assessment of the presence of oil or hazardous materials at the property. Consequently, we did not consider the potential impacts (if any) that contaminants in soil or groundwater may have on construction activities, or the use of structures on the property.
9. Recommendations for foundation drainage, waterproofing, and moisture control address the conventional geotechnical engineering aspects of seepage control. These recommendations may not preclude an environment that allows the infestation of mold or other biological pollutants.

Compliance with Codes and Regulations

10. We used reasonable care in identifying and interpreting applicable codes and regulations. These codes and regulations are subject to various, and possibly contradictory, interpretations. Compliance with codes and regulations by other parties is beyond our control.

Cost Estimates

11. Unless otherwise stated, our cost estimates are only for comparative and general planning purposes. These estimates may involve approximate quantity evaluations. Note that these quantity estimates are not intended to be sufficiently accurate to develop construction bids, or to predict the actual cost of work addressed in this Report. Further, since we have no control over either when the work will take place or the labor and material costs required to plan and execute the anticipated work, our cost estimates were made by relying on our experience, the experience of others, and other sources of readily available information. Actual costs may vary over time and could be significantly more, or less, than stated in the Report.

Additional Services

12. GZA recommends that we be retained to provide services during any future: site observations, design, implementation activities, construction and/or property development/redevelopment. This will allow us the opportunity to: i) observe conditions and compliance with our design concepts and opinions; ii) allow for changes in the event that conditions are other than anticipated; iii) provide modifications to our design; and iv) assess the consequences of changes in technologies and/or regulations.



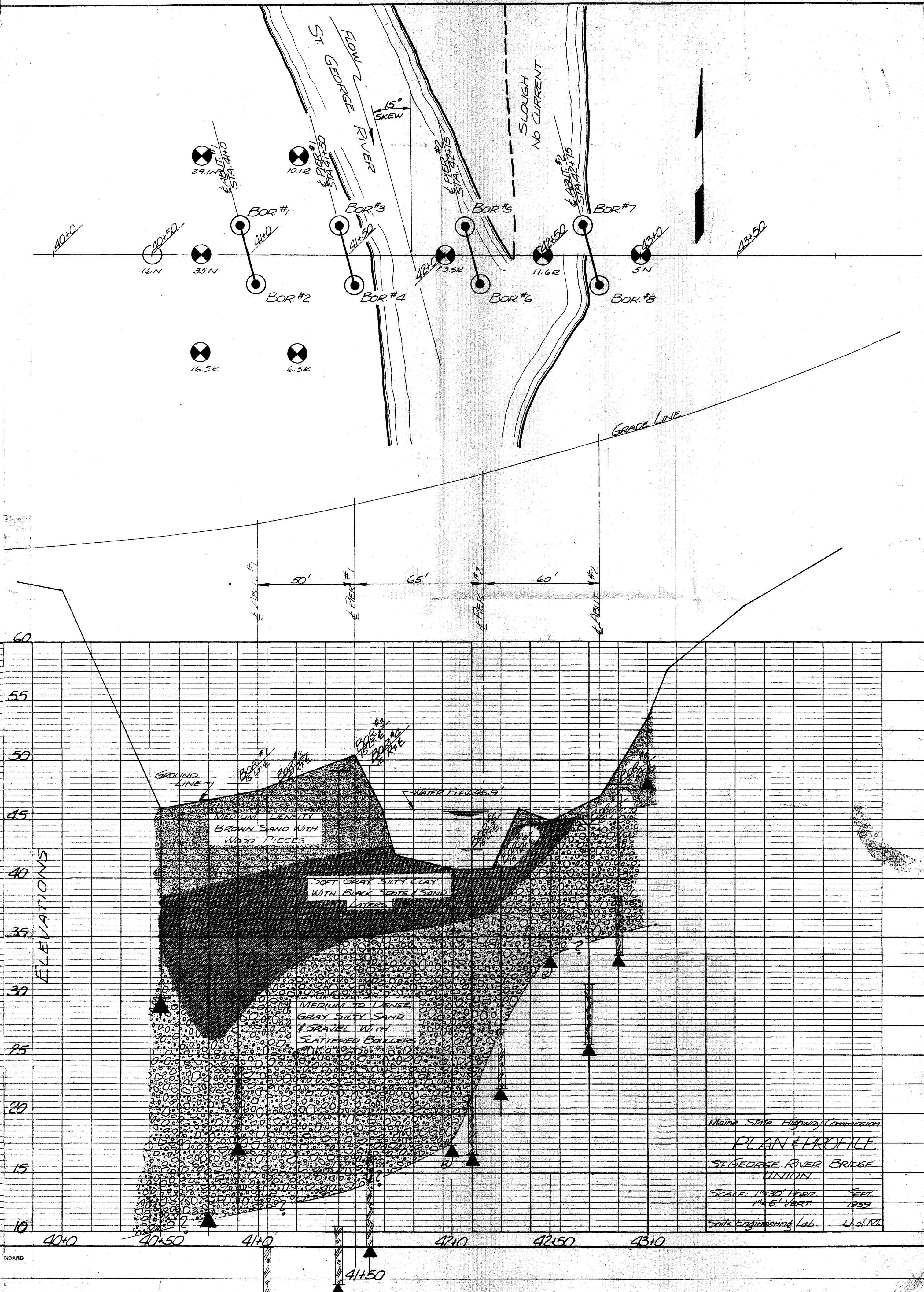
August 12, 2026

GEOTECHNICAL DESIGN REPORT

ST. GEORGE RIVER BRIDGE NO. 5893 - UNION

09.0026237.01

APPENDIX B – HISTORIC (1959) TEST BORING LOGS



Maine State Highway Commission
PLAN & PROFILE
 ST. GEORGE RIVER BRIDGE
 UNION
 SCALE: 1"=30' HORIZ. 1"=5' VERT.
 SOILS ENGINEERING LAB. LI OF NH
 SEPT. 1959

SHEAR AND WATER CONTENT NOTES

Shear Notes:

1. Field vane shear strengths indicated thus: ●
2. Laboratory vane shear strengths indicated thus: x
3. One half unconfined compressive strengths indicated thus: ○
4. Strengths beyond range of plot indicated at right edge of plot by numerical values and symbols thus: 1.62 ●
5. Field vane shear strengths in excess of capacity of equipment indicated thus: —●→
6. Laboratory vane shear strengths in excess of capacity of equipment (1.0 T/sf) indicated thus: —x→
7. Field vane shear strengths in excess of capacity of equipment and beyond range of plot indicated at right edge of plot thus: 1.50 (+) ●
8. Laboratory vane shear strength in excess of capacity of equipment (1.0 T/sf) and beyond range of plot indicated at right edge of plot thus: 1.00 (+) x

Water Content Notes:

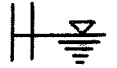
1. Natural water contents, given as percent of dry weight, are indicated thus: ○
2. Plastic and liquid limits are indicated thus: ⊗ — — — x
3. Ignition losses are given as percent of dry weight.

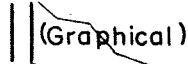
BORING NOTES

LOG SHEETS

DETAIL SHEETS

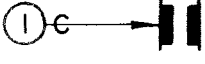
1. All samples and vanes are made ahead of casing.
2. Scales and casing size as noted on drawings.
3. Ground water table indicated thus:



4. Number of blows of 275# hammer falling 18 inches required to drive extra heavy casing one foot thus:



5. Location and designation of "dry" samples taken in S&H sampler #1290s indicated thus:



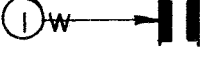
6. Location and designation of "dry" samples taken in 2" O.D. 16 ga. seamless tubing indicated thus:



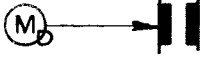
7. Location and designation of "dry" samples taken in 3 1/2" O.D. 16 ga. seamless tubing indicated thus:



8. Location and designation of wash samples indicated thus:



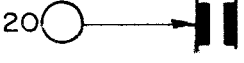
9. Unsuccessful attempts to secure dry sample indicated thus, followed by type of sampler:



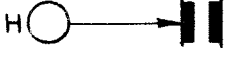
10. Location of field vane test indicated thus:



11. Number of blows of 275# hammer falling 15" required to drive spoon or tubing one foot indicated thus:



12. Sampling spoon or seamless tubing driven by static weight of drill rods and 275# hammer indicated thus:



13. 3 1/2" O.D. "dry" samples taken with piston sampler.



14. Natural water contents, given as percent of dry weight are indicated thus:



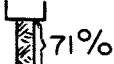
15. Bottom of boring indicated thus:

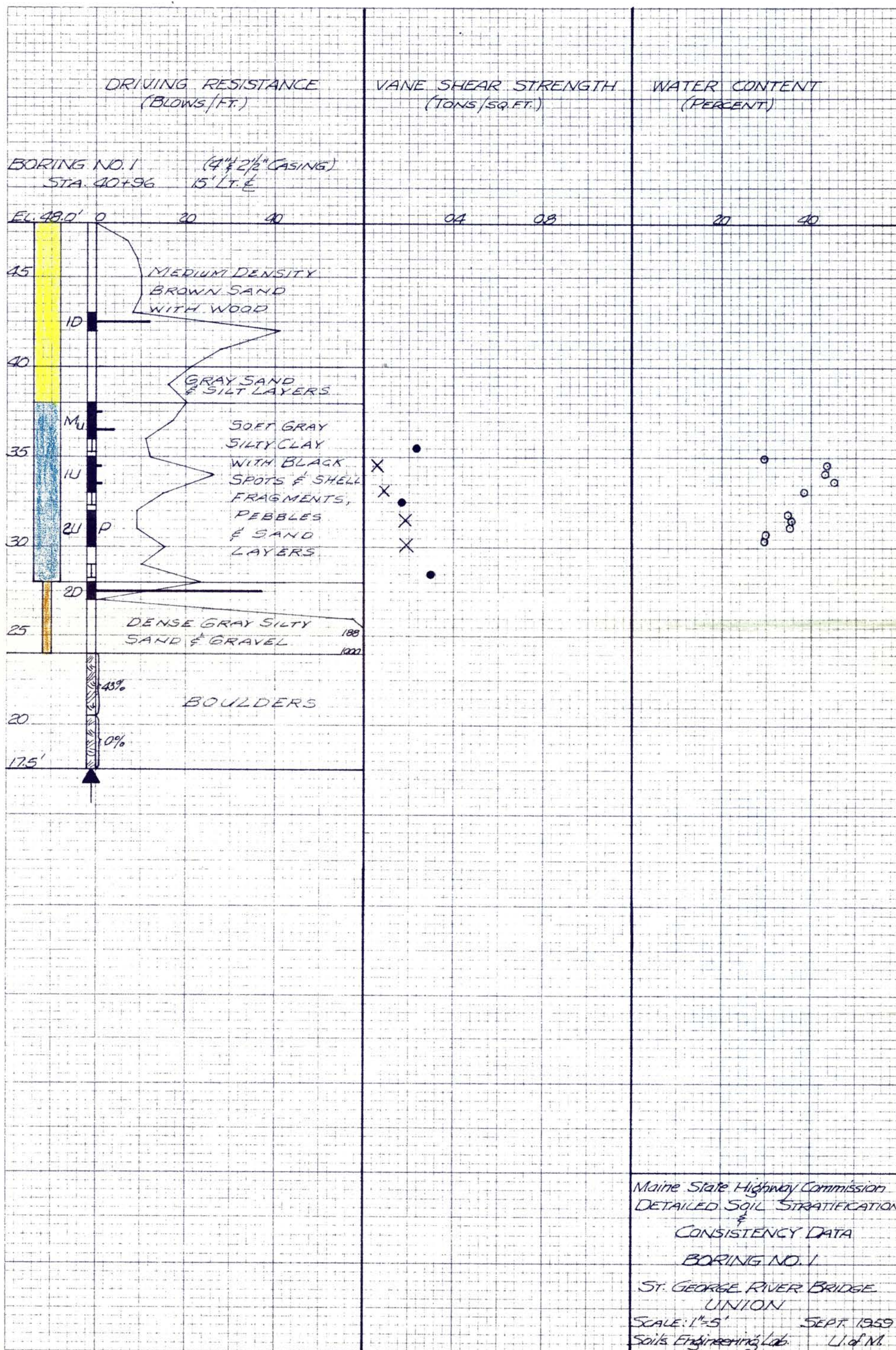


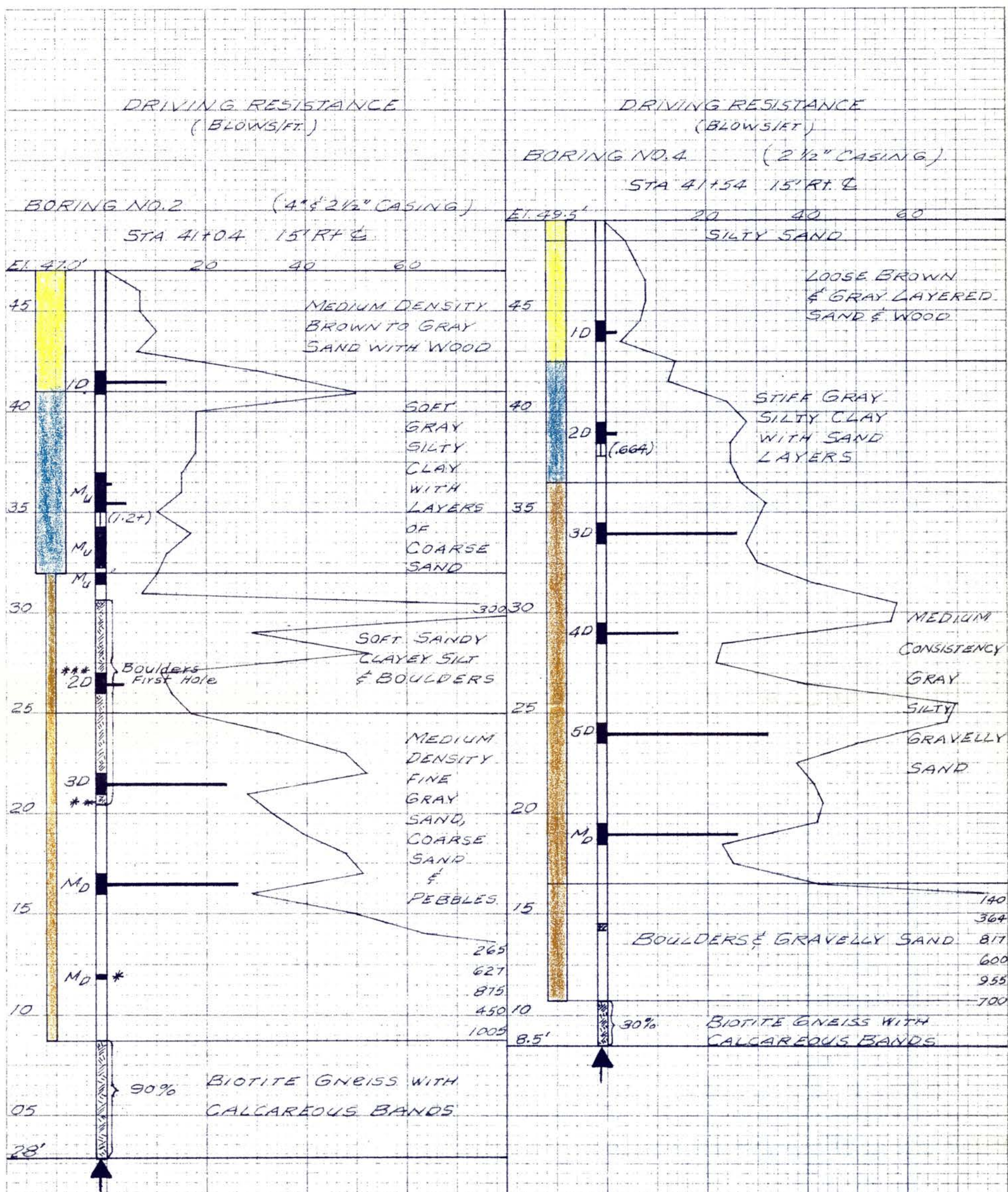
16. Refusal of drill rods or casing indicated thus:



17. Percent recovery of rock core by diamond bit thus:

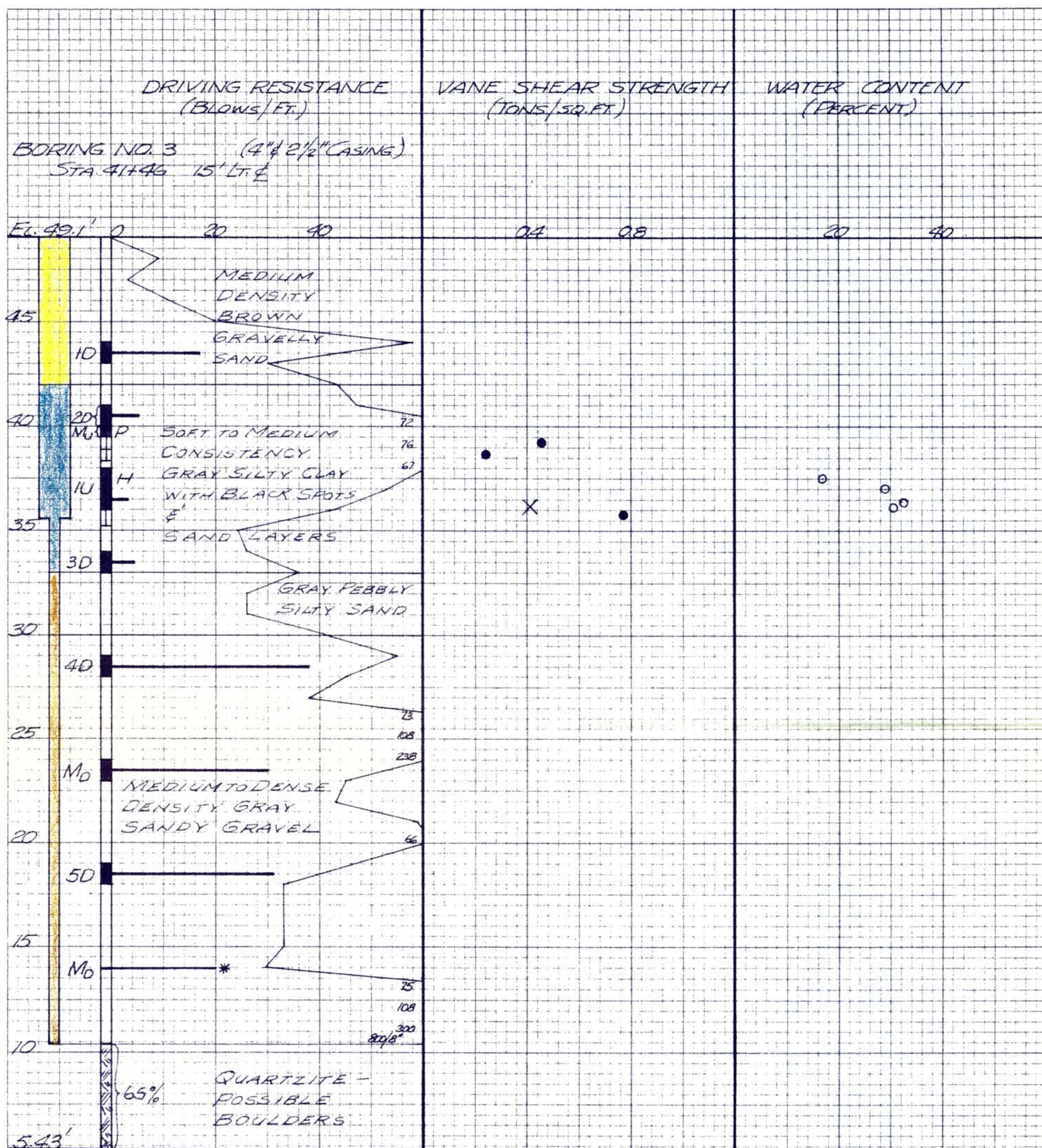




* NO PENETRATION
** BOTTOM OF FIRST HOLE
*** TOP OF SECOND HOLE

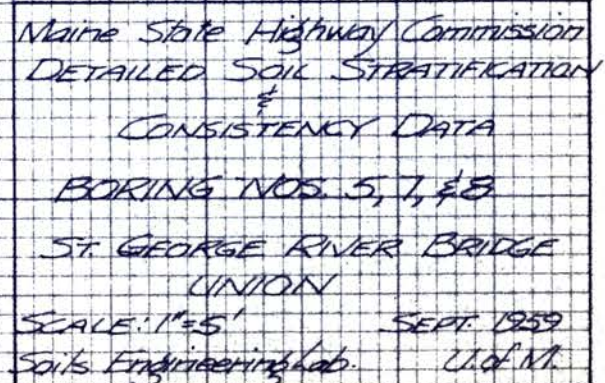
Maine State Highway Commission
DETAILED SOIL STRATIFICATION
&
CONSISTENCY DATA
BORING NOS. 2 & 4
ST. GEORGE RIVER BRIDGE
UNION
SCALE: 1"=5' SEPT. 1939
Soils Engineering Lab. U. of M.

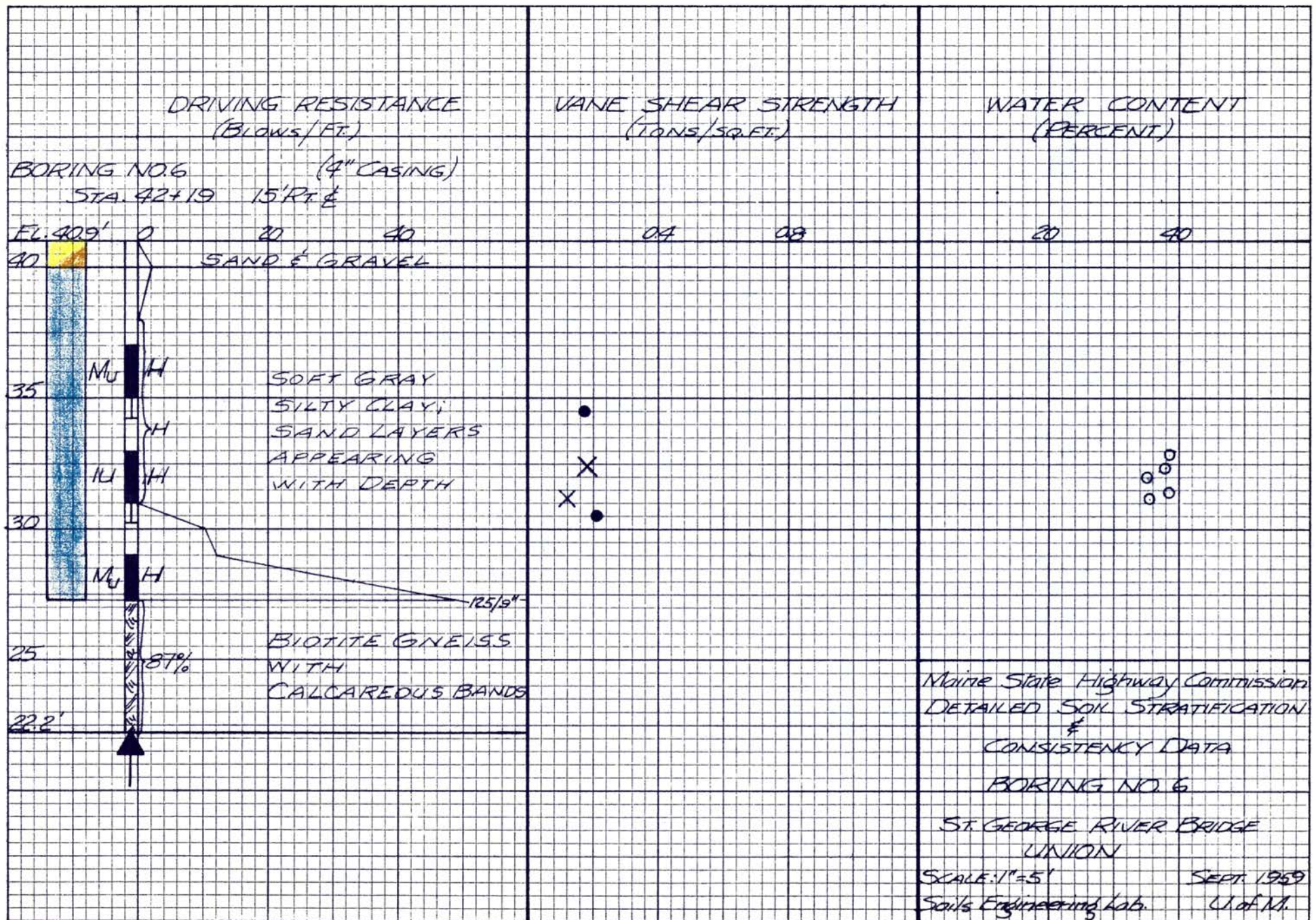


- * NO PENETRATION

Maine State Highway Commission
DETAILED SOIL STRATIFICATION
&
CONSISTENCY DATA
BORING NO. 3
ST. GEORGE RIVER BRIDGE
UNION
SCALE: 1"=5' SEPT. 1959
Soils Engineering Lab. U. of M.

SHEET #6







August 12, 2026

GEOTECHNICAL DESIGN REPORT
ST. GEORGE RIVER BRIDGE NO. 5893 - UNION
09.0026237.01

APPENDIX C – GZA TEST BORING LOGS

UNIFIED SOIL CLASSIFICATION SYSTEM					MODIFIED BURMISTER SYSTEM																																																							
MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES																																																								
COARSE-GRAINED SOILS (more than half of material is larger than No. 200 sieve size)	GRAVELS (more than half of coarse fraction is larger than No. 4 sieve size)	CLEAN GRAVELS	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.		Descriptive Term																																																						
		(little or no fines)	GP	Poorly-graded gravels, gravel sand mixtures, little or no fines.		Portion of Total (%)																																																						
		GRAVEL WITH FINES (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixtures.		trace																																																						
			GC	Clayey gravels, gravel-sand-clay mixtures.		little																																																						
	SANDS (more than half of coarse fraction is smaller than No. 4 sieve size)	CLEAN SANDS	SW	Well-graded sands, Gravelly sands, little or no fines		some																																																						
		(little or no fines)	SP	Poorly-graded sands, Gravelly sand, little or no fines.		adjective (e.g. Sandy, Clayey)																																																						
SANDS WITH FINES (Appreciable amount of fines)		SM	Silty sands, sand-silt mixtures																																																									
		SC	Clayey sands, sand-clay mixtures.																																																									
FINE-GRAINED SOILS (more than half of material is smaller than No. 200 sieve size)	SILTS AND CLAYS (liquid limit less than 50)	ML	Inorganic silts and very fine sands, rock flour, Silty or Clayey fine sands, or Clayey silts with slight plasticity.																																																									
		CL	Inorganic clays of low to medium plasticity, Gravelly clays, Sandy clays, Silty clays, lean clays.																																																									
		OL	Organic silts and organic Silty clays of low plasticity.																																																									
	SILTS AND CLAYS (liquid limit greater than 50)	MH	Inorganic silts, micaceous or diatomaceous fine Sandy or Silty soils, elastic silts.																																																									
		CH	Inorganic clays of high plasticity, fat clays.																																																									
		OH	Organic clays of medium to high plasticity, organic silts.																																																									
	HIGHLY ORGANIC SOILS	Pt	Peat and other highly organic soils.																																																									
Desired Soil Observations (in this order, if applicable): Color (Munsell color chart) Moisture (dry, damp, moist, wet) Density/Consistency (from above right hand side) Texture (fine, medium, coarse, etc.) Name (Sand, Silty Sand, Clay, etc., including portions - trace, little, etc.) Gradation (well-graded, poorly-graded, uniform, etc.) Plasticity (non-plastic, slightly plastic, moderately plastic, highly plastic) Structure (layering, fractures, cracks, etc.) Bonding (well, moderately, loosely, etc.,) Cementation (weak, moderate, or strong) Geologic Origin (till, marine clay, alluvium, etc.) Groundwater level					TERMS DESCRIBING DENSITY/CONSISTENCY Coarse-grained soils (more than half of material is larger than No. 200 sieve): Includes (1) clean gravels; (2) Silty or Clayey gravels; and (3) Silty, Clayey or Gravelly sands. Density is rated according to standard penetration resistance (N-value). <table><thead><tr><th>Density of Cohesionless Soils</th><th>Standard Penetration Resistance N₆₀-Value (blows per foot)</th></tr></thead><tbody><tr><td>Very loose</td><td>0 - 4</td></tr><tr><td>Loose</td><td>5 - 10</td></tr><tr><td>Medium Dense</td><td>11 - 30</td></tr><tr><td>Dense</td><td>31 - 50</td></tr><tr><td>Very Dense</td><td>> 50</td></tr></tbody></table> Fine-grained soils (more than half of material is smaller than No. 200 sieve): Includes (1) inorganic and organic silts and clays; (2) Gravelly, Sandy or Silty clays; and (3) Clayey silts. Consistency is rated according to undrained shear strength as indicated. <table><thead><tr><th>Consistency of Cohesive soils</th><th>SPT N₆₀-Value (blows per foot)</th><th>Approximate Undrained Shear Strength (psf)</th><th>Field Guidelines</th></tr></thead><tbody><tr><td>Very Soft</td><td>WOH, WOR, WOP, <2</td><td>0 - 250</td><td>Fist easily penetrates</td></tr><tr><td>Soft</td><td>2 - 4</td><td>250 - 500</td><td>Thumb easily penetrates</td></tr><tr><td>Medium Stiff</td><td>5 - 8</td><td>500 - 1000</td><td>Thumb penetrates with moderate effort</td></tr><tr><td>Stiff</td><td>9 - 15</td><td>1000 - 2000</td><td>Indented by thumb with great effort</td></tr><tr><td>Very Stiff</td><td>16 - 30</td><td>2000 - 4000</td><td>Indented by thumbnail</td></tr><tr><td>Hard</td><td>>30</td><td>over 4000</td><td>Indented by thumbnail with difficulty</td></tr></tbody></table> Rock Quality Designation (RQD): RQD (%) = $\frac{\text{sum of the lengths of intact pieces of core}^* > 4 \text{ inches}}{\text{length of core advance}}$ *Minimum NQ rock core (1.88 in. OD of core) Rock Quality Based on RQD <table><thead><tr><th>Rock Quality</th><th>RQD (%)</th></tr></thead><tbody><tr><td>Very Poor</td><td>≤25</td></tr><tr><td>Poor</td><td>26 - 50</td></tr><tr><td>Fair</td><td>51 - 75</td></tr><tr><td>Good</td><td>76 - 90</td></tr><tr><td>Excellent</td><td>91 - 100</td></tr></tbody></table> Desired Rock Observations (in this order, if applicable): Color (Munsell color chart) Texture (aphanitic, fine-grained, etc.) Rock Type (granite, schist, sandstone, etc.) Hardness (very hard, hard, mod. hard, etc.) Weathering (fresh, very slight, slight, moderate, mod. severe, severe, etc.) Geologic discontinuities/jointing: -dip (horiz - 0-5 deg., low angle - 5-35 deg., mod. dipping - 35-55 deg., steep - 55-85 deg., vertical - 85-90 deg.) -spacing (very close - <2 inch, close - 2-12 inch, mod. close - 1-3 feet, wide - 3-10 feet, very wide >10 feet) -tightness (tight, open, or healed) -infilling (grain size, color, etc.) Formation (Waterville, Ellsworth, Cape Elizabeth, etc.) RQD and correlation to rock quality (very poor, poor, etc.) ref: ASTM D6032 and FHWA NHI-16-072 GEC 5 - Geotechnical Site Characterization, Table 4-12 Recovery (inch/inch and percentage) Rock Core Rate (X.X ft - Y.Y ft (min:sec))				Density of Cohesionless Soils	Standard Penetration Resistance N ₆₀ -Value (blows per foot)	Very loose	0 - 4	Loose	5 - 10	Medium Dense	11 - 30	Dense	31 - 50	Very Dense	> 50	Consistency of Cohesive soils	SPT N ₆₀ -Value (blows per foot)	Approximate Undrained Shear Strength (psf)	Field Guidelines	Very Soft	WOH, WOR, WOP, <2	0 - 250	Fist easily penetrates	Soft	2 - 4	250 - 500	Thumb easily penetrates	Medium Stiff	5 - 8	500 - 1000	Thumb penetrates with moderate effort	Stiff	9 - 15	1000 - 2000	Indented by thumb with great effort	Very Stiff	16 - 30	2000 - 4000	Indented by thumbnail	Hard	>30	over 4000	Indented by thumbnail with difficulty	Rock Quality	RQD (%)	Very Poor	≤25	Poor	26 - 50	Fair	51 - 75	Good	76 - 90	Excellent	91 - 100
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Maine Department of Transportation Geotechnical Section Key to Soil and Rock Descriptions and Terms Field Identification Information					Sample Container Labeling Requirements: WIN Blow Counts Bridge Name / Town Sample Recovery Boring Number Date Sample Number Personnel Initials Sample Depth																																																							

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: St. George River Bridge No. 5893 Location: Union, Maine				Boring No.: BB-USGR-101 WIN: 27158.00									
Driller: New England Boring Contractors				Elevation (ft.) 68.8				Auger ID/OD:									
Operator: B. Gromm				Datum: NAVD88				Sampler: Standard Splitspoon									
Logged By: J. Cozens				Rig Type: Track-Mounted Mobile B-53				Hammer Wt./Fall: 140#/30"									
Date Start/Finish: 5-28-24 / 5-28-24				Drilling Method: SSA / Drive & Wash				Core Barrel: NQ									
Boring Location: Sta. 40+69.6, 8.2' LT				Casing ID/OD: 4.0/4.5"				Water Level*: 10.8'									
Hammer Efficiency Factor: 0.76				Hammer Type: Automatic ☒ Hydraulic ☐ Rope & Cathead ☐													
Definitions: D = Split Spoon Sample MD = Unsuccessful Split Spoon Sample Attempt U = Thin Wall Tube Sample MU = Unsuccessful Thin Wall Tube Sample Attempt V = Field Vane Shear Test, PP = Pocket Penetrometer MV = Unsuccessful Field Vane Shear Test Attempt				R = Rock Core Sample SSA = Solid Stem Auger HSA = Hollow Stem Auger RC = Roller Cone WOH = Weight of 140lb. Hammer WOR/C = Weight of Rods or Casing WO1P = Weight of One Person				Su = Peak/Remolded Field Vane Undrained Shear Strength (psf) Su(lab) = Lab Vane Undrained Shear Strength (psf) qp = Unconfined Compressive Strength (ksf) N-uncorrected = Raw Field SPT N-value Hammer Efficiency Factor = Rig Specific Annual Calibration Value N60 = SPT N-uncorrected Corrected for Hammer Efficiency N60 = (Hammer Efficiency Factor/60%)*N-uncorrected									
T _v = Pocket Torvane Shear Strength (psf) WC = Water Content, percent LL = Liquid Limit PL = Plastic Limit PI = Plasticity Index G = Grain Size Analysis C = Consolidation Test																	
Sample Information												Graphic Log		Visual Description and Remarks		Laboratory Testing Results/ AASHTO and Unified Class.	
Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing Blows	Elevation (ft.)									
0							SPIN	67.7		0'-1.0': Asphalt							
	1D	24/3	1.0 - 3.0	18-24-16-19	40	51	30			1D (Top 1"): Asphalt							
							65			1D (Bottom 2"): Brown, moist, very dense, fine to coarse SAND, some gravel, trace silt, (Fill).							
							85										
							65										
5	2D	24/8	5.0 - 7.0	7-7-6-12	13	16	18			Brown, moist, medium dense, fine to coarse SAND, some gravel, little silt, (Fill).							
							28										
							58										
							99										
10	3D	3/0	9.0 - 9.3	50/3"	R		128		59.8	Spoon refusal at 9.3'. Cuttings in wash return indicate probable boulder from 9.3'-11.5'.							
							81										
							78		57.3								
							89										
							114										
15	4D	24/7	14.0 - 16.0	12-8-5-6	13	16	66			Brown, medium dense, moist, fine to coarse SAND, some silt, some gravel, (Fill).		G#24-S-2593 A-2-4(0), SM WC=11.6%					
							41										
							47										
							47										
							76										
20	5D	24/2	19.0 - 21.0	11-16-18-18	34	43	44			Grey, moist, dense, GRAVEL, some sand, little silt, (Fill).							
							73										
							84										
							235										
							99										
25	6D	24/17	24.0 - 26.0	3-1-2-3	3	4	37		44.8	6D (Top 10"): Brown-black, wet, loose, Silty fine SAND, with roots							
Remarks:																	
1. Automatic hammer NEBC #23 with an energy transfer ratio = 0.76. 2. Water level measured at completion of drilling within casing, after 10 feet of casing was removed and water level was given 15 minutes to stabilize. 3. 4" casing refusal at 9.5', telescoped with 3" casing to 29.0'. 4. As-drilled boring locations were surveyed by MaineDOT in the field (261368.8N, 1600142.5E) and provided in an electronic file (2D Borings Union 27158.00.dgn) on July 9, 2024.																	
Stratification lines represent approximate boundaries between soil types; transitions may be gradual. * Water level readings have been made at times and under conditions stated. Groundwater fluctuations may occur due to conditions other than those present at the time measurements were made.												Page 1 of 2					
												Boring No.: BB-USGR-101					

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: St. George River Bridge No. 5893 Location: Union, Maine				Boring No.: BB-USGR-101 WIN: 27158.00							
Driller: New England Boring Contractors				Elevation (ft.): 68.8				Auger ID/OD:							
Operator: B. Gromm				Datum: NAVD88				Sampler: Standard Splitspoon							
Logged By: J. Cozens				Rig Type: Track-Mounted Mobile B-53				Hammer Wt./Fall: 140#/30"							
Date Start/Finish: 5-28-24 / 5-28-24				Drilling Method: SSA / Drive & Wash				Core Barrel: NQ							
Boring Location: Sta. 40+69.6, 8.2' LT				Casing ID/OD: 4.0/4.5"				Water Level*: 10.8'							
Hammer Efficiency Factor: 0.76				Hammer Type: Automatic ☒ Hydraulic ☐ Rope & Cathead ☐											
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Sample Information										Graphic Log		Visual Description and Remarks		Laboratory Testing Results/ AASHTO and Unified Class.	
Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing Blows	Elevation (ft.)							
25							43				and rootlets, (Alluvial Sand/Silt). 6D (Bottom 7"): Grey, wet, Sandy SILT, (Alluvial Sand/Silt). PP = 0.5 tsf 7D (Top 7"): Grey, wet, SILT, some sand, trace gravel, (Alluvial Sand/Silt). 7D (Bottom 4"): Grey, wet, Sandy GRAVEL, little silt, (Alluvial Sand/Silt).	G#24-S-2594 A-4(0), ML WC=22.3%			
	7D	24/11	26.0 - 28.0	3-9-13-12	22	28	60								
								99							
								178							
30	8D	24/11	29.0 - 31.0	18-17-11-17	28	35	RC				Dark grey, wet, dense, Sandy GRAVEL, trace silt, clay in tip of spoon. (Alluvial Sand/Silt).				
	9D	24/14	31.0 - 33.0	2-1-1-2	2	3			37.8		Dark grey/blue, wet, soft, Silty CLAY, with sand and gravel seam, (Marine Clay). PP = 0.0, 0.15, 0.10, tsf 3" casing broke, not able to advance past 32.0'. Bottom of Exploration at 33.0 feet below ground surface.	G#24-S-2595 WC=25.8%			
35															
40															
45															
50															
Remarks: 1. Automatic hammer NEBC #23 with an energy transfer ratio = 0.76. 2. Water level measured at completion of drilling within casing, after 10 feet of casing was removed and water level was given 15 minutes to stabilize. 3. 4" casing refusal at 9.5', telescoped with 3" casing to 29.0'. 4. As-drilled boring locations were surveyed by MaineDOT in the field (261368.8N, 1600142.5E) and provided in an electronic file (2D Borings Union 27158.00.dgn) on July 9, 2024.															
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[illegible]

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS						Project: St. George River Bridge No. 5893 Location: Union, Maine							Boring No.: BB-USGR-102 WIN: 27158.00																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
Driller: New England Boring Contractors						Elevation (ft.): 36.9							Auger ID/OD:																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
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Remarks: 1. Automatic hammer NEBC #23 with an energy transfer ratio = 0.76. 2. Bridge deck cored and 4" casing lowered to the mudline which was measured to be 35' below top of deck. 3. GZA measured 29' from top of deck to water line of river. 4. As-drilled boring locations were surveyed by MainesDOT in the field (261355.6N, 1600242.6E) and provided in an electronic file (2D Borings Union 27158.00.dgn) on July 9, 2024.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: St. George River Bridge No. 5893 Location: Union, Maine		Boring No.: BB-USGR-103 WIN: 27158.00						
Driller: New England Boring Contractors			Elevation (ft.) 77.6			Auger ID/OD:						
Operator: B. Gromm			Datum: NAVD88			Sampler: Standard Splitspoon						
Logged By: R. Franklin			Rig Type: Track-Mounted Mobile B-53			Hammer Wt./Fall: 140#/30"						
Date Start/Finish: 5-31-24 / 5-31-24			Drilling Method: Drive & Wash			Core Barrel: NQ						
Boring Location: Sta. 42+92.2, 8.1' RT			Casing ID/OD: 4.0/4.5"			Water Level*: 18.8'						
Hammer Efficiency Factor: 0.76			Hammer Type: Automatic ☒ Hydraulic ☐ Rope & Cathead ☐									
Definitions: D = Split Spoon Sample MD = Unsuccessful Split Spoon Sample Attempt U = Thin Wall Tube Sample MU = Unsuccessful Thin Wall Tube Sample Attempt V = Field Vane Shear Test, PP = Pocket Penetrometer MV = Unsuccessful Field Vane Shear Test Attempt R = Rock Core Sample SSA = Solid Stem Auger HSA = Hollow Stem Auger RC = Roller Cone WOH = Weight of 140lb. Hammer WOR/C = Weight of Rods or Casing WO1P = Weight of One Person S_u = Peak/Remolded Field Vane Undrained Shear Strength (psf) S_{u(lab)} = Lab Vane Undrained Shear Strength (psf) q_p = Unconfined Compressive Strength (ksf) N_{uncorrected} = Raw Field SPT N-value Hammer Efficiency Factor = Rig Specific Annual Calibration Value N₆₀ = SPT N-uncorrected Corrected for Hammer Efficiency N₆₀ = (Hammer Efficiency Factor/60%)*N_{uncorrected} T_y = Pocket Torvane Shear Strength (psf) WC = Water Content, percent LL = Liquid Limit PL = Plastic Limit PI = Plasticity Index G = Grain Size Analysis C = Consolidation Test												
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0							SSA	76.6		Top 12": Asphalt.		
5	1D	24/15	1.0 - 3.0	10-17-16-32	33	42				Brown, moist, dense, fine to coarse SAND, trace silt, trace gravel, (Fill).	G#24-S-2603A-1-b, SM WC=3.4%	
								59				
	2D	24/8	4.0 - 6.0	17-10-11-12	21	27	68					Brown, moist, medium dense, fine to coarse SAND, some gravel, little silt, (Fill).
							75					
							182					Grey, moist, medium dense, GRAVEL, some sand, (Fill).
							76					
							60					
	3D	24/3	9.0 - 11.0	7-10-4-3	14	18	20					
10							31			Grey/brown, moist, dense, Gravelly fine to coarse SAND, little silt, (Fill).	G#24-S-2604A-1-b, SM WC=9.2%	
							77					
							78					
							106					
	4D	24/8	14.0 - 16.0	12-13-14-23	27	34	55					Brown, moist, dense, fine to coarse SAND, little gravel, little silt, (Fill).
							185					
	5D	20/7	16.0 - 17.7	79-12-20-19	32	41	366					
							132					
20							104			Brown, wet, dense, fine to coarse SAND, some silt, little gravel, (Fill).	G#24-S-2605A-2-4(0), SM WC=6.3%	
	6D	24/13	19.0 - 21.0	18-18-9-9	27	34	46					
							82					
							153					
							97					
							77					
	7D	24/4	24.0 - 26.0	10-5-7-14	12	15	60					7D (Top 2"): Grey, medium dense, SAND, trace silt, (Fill). 7D (Bottom 2"): Brown/grey, wet, Silty CLAY, little sand, with wood
Remarks: 1. Automatic hammer NEBC #23 with an energy transfer ratio = 0.76. 2. Water level measured within casing at completion of drilling, before removal of casing. 3. As-drilled boring locations were surveyed by MaineDOT in the field (261322.8N, 1600365.6E) and provided in an electronic file (2D Borings Union 27158.00.dgn) on July 9, 2024.												
Stratification lines represent approximate boundaries between soil types; transitions may be gradual. * Water level readings have been made at times and under conditions stated. Groundwater fluctuations may occur due to conditions other than those present at the time measurements were made.										Page 1 of 2 Boring No.: BB-USGR-103		

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Advanced roller bit to 32.3' and set up to core at 32.3'. 32.2' R2: Hard, fresh, fine grained, grey, GNEISS. Joints are close to moderately spaced, horizontal to low angle, undulating, rough, discolored, open, with silt and sand infilling. -PENOBSCOT FORMATION- Rock Quality = Fair Recovery = 100% Rock Core Times (min:sec): 32.3-33.3' (1:50), 33.3-34.3' (1:48), 34.3-34.8' (1:43) R3: Hard, fresh, fine grained, grey, GNEISS. Joints are close to moderately spaced, low angle to moderately dipping, rough, planar, tight, with no infilling. -PENOBSCOT FORMATION- Rock Quality = Excellent Recovery = 100% Rock Core Times (min:sec): 34.8-35.8' (1:01), 35.8-36.8' (2:10), 36.8-37.6' (2:17) R4: Hard, fresh, fine grained, grey, GNEISS. 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Remarks: 1. Automatic hammer NEBC #23 with an energy transfer ratio = 0.76. 2. Water level measured within casing at completion of drilling, before removal of casing. 3. As-drilled boring locations were surveyed by MaineDOT in the field (261322.8N, 1600365.6E) and provided in an electronic file (2D Borings Union 27158.00.dgn) on July 9, 2024.																																																																																																																																																																																																																																																										
Stratification lines represent approximate boundaries between soil types; transitions may be gradual. * Water level readings have been made at times and under conditions stated. Groundwater fluctuations may occur due to conditions other than those present at the time measurements were made. Page 2 of 2 Boring No.: BB-USGR-103																																																																																																																																																																																																																																																										

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS					Project: St. George River Bridge #5893 Location: Union, Maine					Boring No.: BB-USGR-201 WIN: 27158.00				
Driller: Seaboard Drilling			Elevation (ft.) 69.0			Auger ID/OD: 4" OD								
Operator: R. Hackett			Datum: NAVD88			Sampler: Splitspoon								
Logged By: S. Miller			Rig Type: Diedrich D-50 ATV			Hammer Wt./Fall: 140/30								
Date Start/Finish: 12/16/2025-12/17/2025			Drilling Method: Drive & Wash			Core Barrel:								
Boring Location: Sta. 40+92.5, 8.6' RT			Casing ID/OD: 4"/4.5"			Water Level*: 26.5'								
Hammer Efficiency Factor: 1.011			Hammer Type: Automatic ☒ Hydraulic ☐ Rope & Cathead ☐											
Definitions: D = Split Spoon Sample MD = Unsuccessful Split Spoon Sample Attempt U = Thin Wall Tube Sample MU = Unsuccessful Thin Wall Tube Sample Attempt V = Field Vane Shear Test, PP = Pocket Penetrometer MV = Unsuccessful Field Vane Shear Test Attempt			R = Rock Core Sample SSA = Solid Stem Auger HSA = Hollow Stem Auger RC = Roller Cone WOH = Weight of 140 lb. Hammer WOR/C = Weight of Rods or Casing WO1P = Weight of One Person			S _u = Peak/Remolded Field Vane Undrained Shear Strength (psf) S _u (lab) = Lab Vane Undrained Shear Strength (psf) q _p = Unconfined Compressive Strength (ksf) N-uncorrected = Raw Field SPT N-value Hammer Efficiency Factor = Rig Specific Annual Calibration Value N ₆₀ = SPT N-uncorrected Corrected for Hammer Efficiency N ₆₀ = (Hammer Efficiency Factor/60%)*N-uncorrected			T _v = Pocket Torvane Shear Strength (psf) WC = Water Content, percent LL = Liquid Limit PL = Plastic Limit PI = Plasticity Index G = Grain Size Analysis C = Consolidation Test					
Depth (ft.)	Sample Information								Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.			
	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing Blows	Elevation (ft.)						
30	8D	24/17	30.0 - 32.0	7-1-WOH-1	1	2		38.7		8D: (Top 4") Brown, wet, fine to coarse SAND, some gravel, some silt. (Alluvial Sand/Silt)	CL LL=45 PL=19 PI=26 WC=31.3%			
										8D: (Bottom 13") Grey, moist, Silty CLAY, little sand. (Marine Clay)				
	9D	24/22	32.0 - 34.0	WOH/24"	WOH					Grey, moist, soft to medium stiff, Silty CLAY, trace sand, trace wood. (Marine Clay)				
										PP = 0.0				
35	10D	24/24	34.0 - 36.0	WOH/24"	WOH					Grey, wet, soft to medium stiff, Silty CLAY, trace sand. (Marine Clay)				
	11D	24/13	36.0 - 38.0	WOH/24"	WOH					Grey, wet, soft to medium stiff, Silty CLAY, trace sand. (Marine Clay)				
											CL LL=44 PL=18 PI=26 WC=36.0%			
	12D	24/18	38.0 - 40.0	WOR/24"	WOR				Grey, wet, soft to medium stiff, Silty CLAY, trace sand, trace gravel. (Marine Clay)					
40								29.0	Bottom of Exploration at 40.0 feet below ground surface.					
45														
50														
55														
60														
Remarks: 1. Fine grained soil descriptions on this log are based on plasticity estimated using visual classification techniques or laboratory Atterberg Limit Test if available, rather than the MaineDOT standard based percentages passing specific grain sizes. 2. Automatic hammer Seaboard SN#362 Energy Transfer Ratio = 1.011. 3. Water level measured inside casing (casing at 30', borehole 40' deep) on the morning of 12/17 before drilling resumed. 4. Boring terminated after casing broke at 40' depth. Offset 2' west, see boring log BB-USGR-201A. 5. The as-drilled boring location was surveyed by MaineDOT in the field (261350.3N, 1600156.6E) and provided in an electronic file (Borings 1-29-2026) on February 2, 2026.														
Stratification lines represent approximate boundaries between soil types; transitions may be gradual. * Water level readings have been made at times and under conditions stated. Groundwater fluctuations may occur due to conditions other than those present at the time measurements were made.										Page 2 of 2 Boring No.: BB-USGR-201				

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: St. George River Bridge #5893 Location: Union, Maine				Boring No.: BB-USGR-201A WIN: 27158.00				
Driller: Seaboard Drilling				Elevation (ft.) 69.1				Auger ID/OD: 4" OD				
Operator: R. Hackett				Datum: NAVD88				Sampler: Splitspoon				
Logged By: S. Miller				Rig Type: Diedrich D-50 ATV				Hammer Wt./Fall: 140/30				
Date Start/Finish: 1/12/2026-1/13/2026				Drilling Method: SSA/Drive & Wash				Core Barrel: NQ				
Boring Location: Sta. 40+94.3, 7.5' RT				Casing ID/OD: 4"/4.5", 3"/3.5"				Water Level*: 26.5'				
Hammer Efficiency Factor: 1.011				Hammer Type: Automatic ☒ Hydraulic ☐ Rope & Cathead ☐								
Definitions: D = Split Spoon Sample MD = Unsuccessful Split Spoon Sample Attempt U = Thin Wall Tube Sample MU = Unsuccessful Thin Wall Tube Sample Attempt V = Field Vane Shear Test, PP = Pocket Penetrometer MV = Unsuccessful Field Vane Shear Test Attempt R = Rock Core Sample SSA = Solid Stem Auger HSA = Hollow Stem Auger RC = Roller Cone WOH = Weight of 140lb. Hammer WOR/C = Weight of Rods or Casing WO1P = Weight of One Person S_u = Peak/Remolded Field Vane Undrained Shear Strength (psf) S_{u(lab)} = Lab Vane Undrained Shear Strength (psf) q_p = Unconfined Compressive Strength (ksf) N_{uncorrected} = Raw Field SPT N-value Hammer Efficiency Factor = Rig Specific Annual Calibration Value N₆₀ = SPT N-uncorrected Corrected for Hammer Efficiency N₆₀ = (Hammer Efficiency Factor/60%)*N_{uncorrected} T_y = Pocket Torvane Shear Strength (psf) WC = Water Content, percent LL = Liquid Limit PL = Plastic Limit PI = Plasticity Index G = Grain Size Analysis C = Consolidation Test												
Depth (ft.)	Sample Information									Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing Blows	Elevation (ft.)				
0							SSA		See boring log BB-USGR-201 for soil stratum and descriptions from 0-40 feet. Decrease in resistance of rollercone at 27'.			
5							RC					
10												
15												
20												
25												
30												
Remarks: 1. Fine grained soil descriptions on this log are based on plasticity estimated using visual classification techniques or laboratory Atterberg Limit Test if available, rather than the MaineDOT standard based percentages passing specific grain sizes. 2. Automatic hammer Seaboard SN#362 Energy Transfer Ratio = 1.011. 3. Water level measured after removal of casing. 4. The as-drilled boring location was surveyed by MaineDOT in the field (261351.0N, 1600158.5E) and provided in an electronic file (Borings 1-29-2026) on February 2, 2026.												
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Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS					Project: St. George River Bridge #5893 Location: Union, Maine					Boring No.: BB-USGR-202 WIN: 27158.00																																																																																																																																																																																																																																																																
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Hammer Efficiency Factor: 1.011					Hammer Type: Automatic ☒ Hydraulic ☐ Rope & Cathead ☐																																																																																																																																																																																																																																																																					
Definitions: D = Split Spoon Sample MD = Unsuccessful Split Spoon Sample Attempt U = Thin Wall Tube Sample MU = Unsuccessful Thin Wall Tube Sample Attempt V = Field Vane Shear Test, PP = Pocket Penetrometer MV = Unsuccessful Field Vane Shear Test Attempt R = Rock Core Sample SSA = Solid Stem Auger HSA = Hollow Stem Auger RC = Roller Cone WOH = Weight of 140lb. Hammer WOR/C = Weight of Rods or Casing WO1P = Weight of One Person S _u = Peak/Remolded Field Vane Undrained Shear Strength (psf) S _{u(lab)} = Lab Vane Undrained Shear Strength (psf) q _p = Unconfined Compressive Strength (ksf) N _{uncorrected} = Raw Field SPT N-value Hammer Efficiency Factor = Rig Specific Annual Calibration Value N ₆₀ = SPT N-uncorrected Corrected for Hammer Efficiency N ₆₀ = (Hammer Efficiency Factor/60%)*N _{uncorrected} T _y = Pocket Torvane Shear Strength (psf) WC = Water Content, percent LL = Liquid Limit PL = Plastic Limit PI = Plasticity Index G = Grain Size Analysis C = Consolidation Test																																																																																																																																																																																																																																																																										
<table><tr><th rowspan="2">Depth (ft.)</th><th colspan="8">Sample Information</th><th rowspan="2">Graphic Log</th><th rowspan="2">Visual Description and Remarks</th><th rowspan="2">Laboratory Testing Results/ AASHTO and Unified Class.</th></tr><tr><th>Sample No.</th><th>Pen./Rec. (in.)</th><th>Sample Depth (ft.)</th><th>Blows (6 in.) Shear Strength (psf) or RQD (%)</th><th>N-uncorrected</th><th>N₆₀</th><th>Casing Blows</th><th>Elevation (ft.)</th></tr><tr><td rowspan="5">0</td><td>1D</td><td>24/3</td><td>0.0 - 2.0</td><td>1-2-1-2</td><td>3</td><td>5</td><td>32</td><td rowspan="20"> 50.6 42.2 </td><td rowspan="20"></td><td rowspan="20">Brown, wet, loose, fine to coarse SAND, little gravel, little silt. (Fill)</td><td rowspan="20">G#26-S-280 A-2-4(0), SM WC=13.5%</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>15</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>18</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>39</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>35</td></tr><tr><td rowspan="5">5</td><td></td><td></td><td></td><td></td><td></td><td></td><td>37</td></tr><tr><td>2D</td><td>24/5</td><td>6.0 - 8.0</td><td>7-7-7-7</td><td>14</td><td>24</td><td>26</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>47</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>52</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>67</td></tr><tr><td rowspan="5">10</td><td></td><td></td><td></td><td></td><td></td><td></td><td>49</td></tr><tr><td>3D</td><td>24/11</td><td>11.0 - 13.0</td><td>8-5-5-3</td><td>10</td><td>17</td><td>37</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>30</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>47</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>68</td></tr><tr><td rowspan="5">15</td><td></td><td></td><td></td><td></td><td></td><td></td><td>72</td></tr><tr><td>4D</td><td>24/12</td><td>16.0 - 18.0</td><td>16-5-4-5</td><td>9</td><td>15</td><td>52</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>39</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>57</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>42</td></tr><tr><td rowspan="5">20</td><td></td><td></td><td></td><td></td><td></td><td></td><td>34</td></tr><tr><td>5D</td><td>24/19</td><td>21.0 - 23.0</td><td>1-2-1-2</td><td>3</td><td>5</td><td>30</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>32</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>48</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>200/8"</td></tr><tr><td rowspan="5">25</td><td></td><td></td><td></td><td></td><td></td><td></td><td>RC</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>30</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr></table>															Depth (ft.)	Sample Information								Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing Blows	Elevation (ft.)	0	1D	24/3	0.0 - 2.0	1-2-1-2	3	5	32	50.6 42.2		Brown, wet, loose, fine to coarse SAND, little gravel, little silt. (Fill)	G#26-S-280 A-2-4(0), SM WC=13.5%							15							18							39							35	5							37	2D	24/5	6.0 - 8.0	7-7-7-7	14	24	26							47							52							67	10							49	3D	24/11	11.0 - 13.0	8-5-5-3	10	17	37							30							47							68	15							72	4D	24/12	16.0 - 18.0	16-5-4-5	9	15	52							39							57							42	20							34	5D	24/19	21.0 - 23.0	1-2-1-2	3	5	30							32							48							200/8"	25							RC																													30											
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Remarks: 1. Fine grained soil descriptions on this log are based on plasticity estimated using visual classification techniques or laboratory Atterberg Limit Test if available, rather than the MaineDOT standard based percentages passing specific grain sizes. 2. Automatic hammer Seaboard SN#362 Energy Transfer Ratio = 1.011. 3. Water level measured inside casing upon completion of boring, depth is from top of ground below the bridge. 4. Bridge deck cored and 4" casing lowered to ground which was measured to be 9' below top of deck. Boring elevation equal to top of ground. 5. The as-drilled boring location was surveyed by MainesDOT in the field (261326.6N, 1600330.4E) and provided in an electronic file (Borings 1-29-2026) on February 2, 2026.																																																																																																																																																																																																																																																																										
Stratification lines represent approximate boundaries between soil types; transitions may be gradual. * Water level readings have been made at times and under conditions stated. Groundwater fluctuations may occur due to conditions other than those present at the time measurements were made.										Page 1 of 2 Boring No.: BB-USGR-202																																																																																																																																																																																																																																																																



August 12, 2026

GEOTECHNICAL DESIGN REPORT

ST. GEORGE RIVER BRIDGE NO. 5893 - UNION

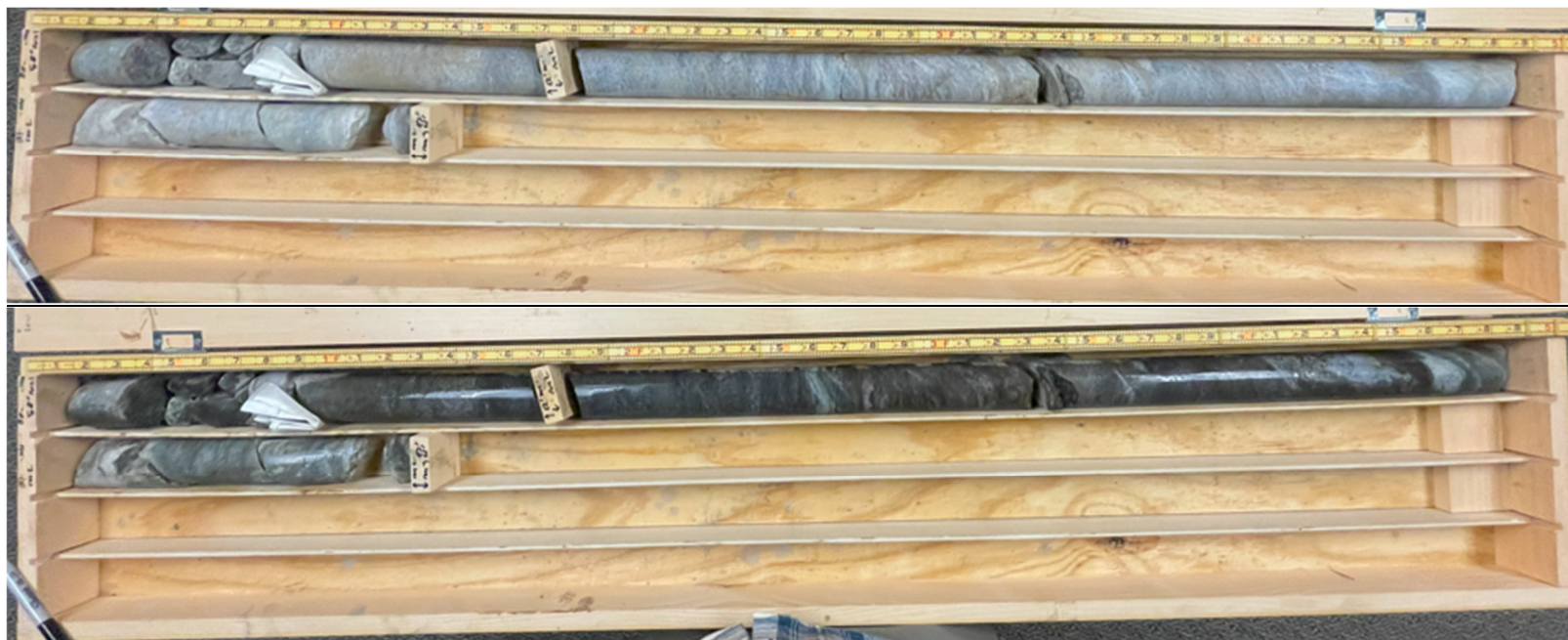
09.0026237.01

APPENDIX D – ROCK CORE PHOTOGRAPHIC LOG



MaineDOT Bridge No. 5893
Route 17 over St. George River
Union, ME
WIN 27158.00
Rock Core Photographs

Boring No.	Run	Depth (ft)		Recovery (in)	Recovery (%)	RQD (in)	RQD (%)	Rock Type	Box Row
BB-USGR-101A	R1	58.0	- 62.0	20	42	9	19	GNEISS	1
BB-USGR-101A	R2	62.0	- 66.0	47	97	39	82	GNEISS	1&2

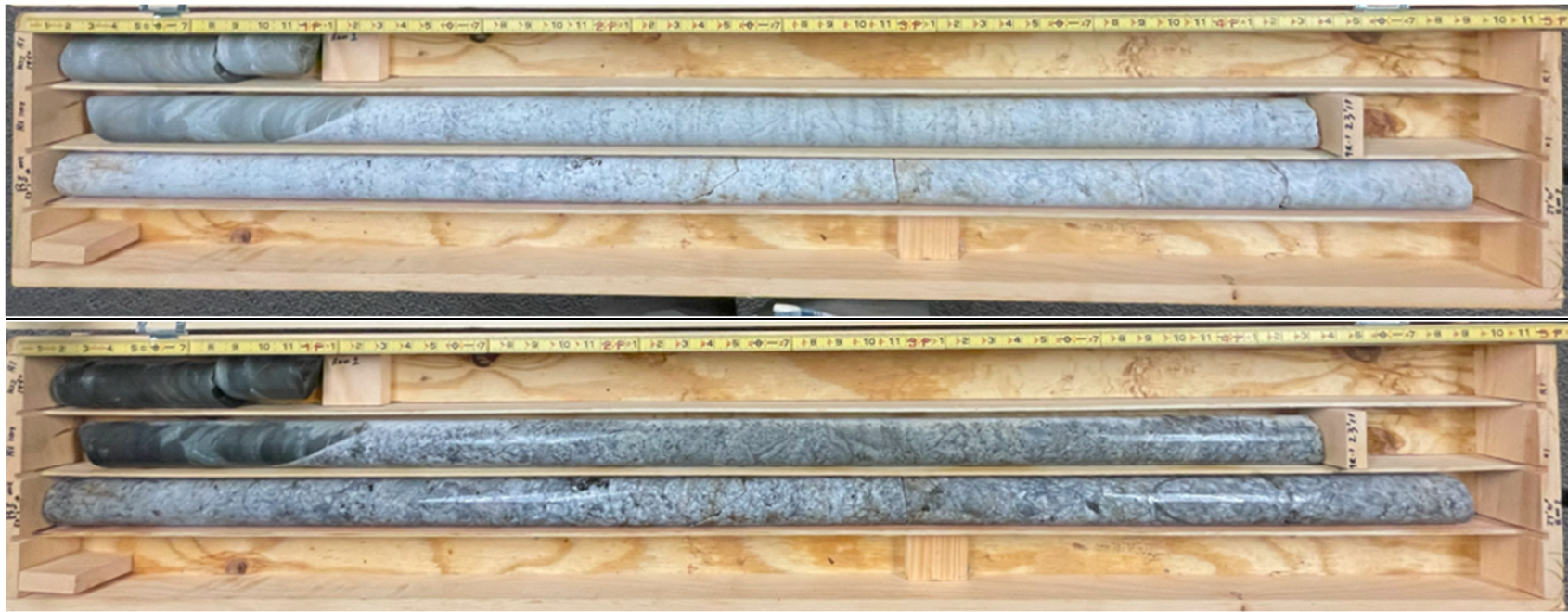


- Notes:
1. Box row corresponds to the core box section in which the rock core sample is contained; Row 1=Top, Row 4=Bottom.
 2. Top photo is dry, bottom photo is wet.



MaineDOT Bridge No. 5893
Route 17 over St. George River
Union, ME
WIN 27158.00
Rock Core Photographs

Boring No.	Run	Depth (ft)		Recovery (in)	Recovery (%)	RQD (in)	RQD (%)	Rock Type	Box Row
BB-USGR -102	R1	18.0	- 23.1	61	100	58	95	GNEISS/GRANITE	1&2
BB-USGR-102	R2	23.1	- 27.1	56	100	57	100	GRANITE	3



- Notes:**
1. Box row corresponds to the core box section in which the rock core sample is contained; Row 1=Top, Row 4=Bottom.
 2. Top photo is dry, bottom photo is wet.



MaineDOT Bridge No. 5893
Route 17 over St. George River
Union, ME
WIN 27158.00
Rock Core Photographs

Boring No.	Run	Depth (ft)	Recovery (in)	Recovery (%)	RQD (in)	RQD (%)	Rock Type	Box Row
BB- USGR-103	R1	27.3 - 32.3	8	13	0	0	COBBLES/BOULDERS	1 (L)
BB-USGR-103	R2	32.3 - 34.8	30	100	19	63	GNEISS	1 (R)
BB-USGR -103	R3	34.8 - 37.6	33	100	33	100	GNEISS	2
BB-USGR-103	R4	37.6 - 42.6	56	93	56	93	GNEISS	3



- Notes:**
1. Box row corresponds to the core box section in which the rock core sample is contained; Row 1=Top, Row 4=Bottom.
 2. Top photo is dry, bottom photo is wet.



MaineDOT Bridge No. 5893
Route 17 over St. George River
Union, ME
WIN 27158.00
Rock Core Photographs

Boring No.	Run	Depth (ft)	Recovery (in)	Recovery (%)	RQD (in)	RQD (%)	Rock Type	Box Row
BB- USGR-201A	R1	63.8 - 68.8	39	65	27	45	GNEISS	1
BB-USGR-201A	R2	70.0 - 75.0	50	83	18	30	SCHIST	2
BB-USGR-202	R1	34.9 - 39.9	54	90	41	68	GNEISS	3
BB-USGR-202	R2	39.9 - 44.5	59	100	48	81	GNEISS	4



- Notes:**
1. Box row corresponds to the core box section in which the rock core sample is contained; Row 1=Top, Row 4=Bottom.
 2. Top photo is dry, bottom photo is wet.



August 12, 2026

GEOTECHNICAL DESIGN REPORT
ST. GEORGE RIVER BRIDGE NO. 5893 - UNION
09.0026237.01

APPENDIX E – LABORATORY TEST RESULTS

	195 Frances Avenue Cranston RI, 02910 Phone: (401)-467-6454 Fax: (401)-467-2398 cts.thielsch.com <i>Let's Build a Solid Foundation</i>	Client Information:	Project Information:
		GZA GeoEnvironmental South Portland, ME Project Manager: John Cozens Assigned By: John Cozens Collected By: GZA	St. George River Bridge No. 5893 Route 17 over St. George River, Union ME Project Number: 09.0026237.00 Summary Page: 1 of 1 Report Date: 7/11/2024

LABORATORY TESTING DATA SHEET, Report No.: 7424-G-124

Boring No.	Sample ID	Depth (ft)	Laboratory No.	Identification Tests										Proctor / CBR / Permeability Tests									Laboratory Log and Soil Description
				As Rcvd Moisture Content %	LL %	PL %	OD LL	Gravel %	Sand %	Fines %	Org. %	pH	$\frac{g_d}{W_{opt}}$ <u>MAX (pcf)</u> (%)	$\frac{g_d}{W_{opt}}$ <u>MAX (pcf)</u> (Corr.)	Dry unit wt. (pcf)	Test Moisture Content %	Target Test Setup as % of Proctor	CBR @ 0.1"	CBR @ 0.2"	Permeability cm/sec			
				D2216	D4318			D6913			D2974	D4792	D1557										
BB-USGR-101	4D	14-16	24-S-2593	11.6				26.3	40.4	33.3											Brown f-c SAND, some Silt, some f-c Gravel		
BB-USGR-101	7D-A	26-28	24-S-2594	22.3				8.1	25.2	66.7											Brown SILTY CLAY, some f-m Sand, trace fine Gravel		
BB-USGR-101	9D	31-33	24-S-2595	25.8	39	18															Grey SILTY CLAY		
BB-USGR-101A	1D	29-31	24-S-2596	46.9				0.0	62.4	37.6											Dark Brown Organic f-m Silty Sand		
BB-USGR-101A	2D	31-33	24-S-2597	11.3				32.3	56.8	10.9											Dark Brown f-c SAND, some f-c Gravel, little Silt		
BB-USGR-101A	3D-A	41-43	24-S-2598	25.4	27	16															Grey CLAYEY SILT		
BB-USGR-101A	5D	49-51	24-S-2599	10.0				22.0	47.4	30.6											Dark Brown f-c SAND, some Silt, some f-c Gravel		
BB-USGR-102	1D	4-6	24-S-2600	9.9				21.1	47.2	31.7											Dark Brown f-c SAND, some Silt, some fine Gravel		
BB-USGR-102	2D-A	9-11	24-S-2601	19.2				1.0	20.1	78.9											Grey CLAYEY SILT, some f-m Sand, trace fine Gravel		
BB-USGR-102	2D-B	9-11	24-S-2602	19.4				13.1	24.5	62.4											Grey CLAYEY SILT, some f-m Sand, little f-c Gravel		
BB-USGR-103	2D	4-6	24-S-2603	3.4				32.5	53.0	14.5											Brown f-c SAND, some f-c Gravel, little Silt		
BB-USGR-103	4D	14-16	24-S-2604	9.2				39.6	49.8	10.6											Brown gravelly f-c SAND, little Silt		
BB-USGR-103	6D-A	19-21	24-S-2605	6.3				11.4	55.5	33.1											Brown f-c SAND, some Silt, little fine Gravel		

Date Received: 7/5/2024

Reviewed By: 

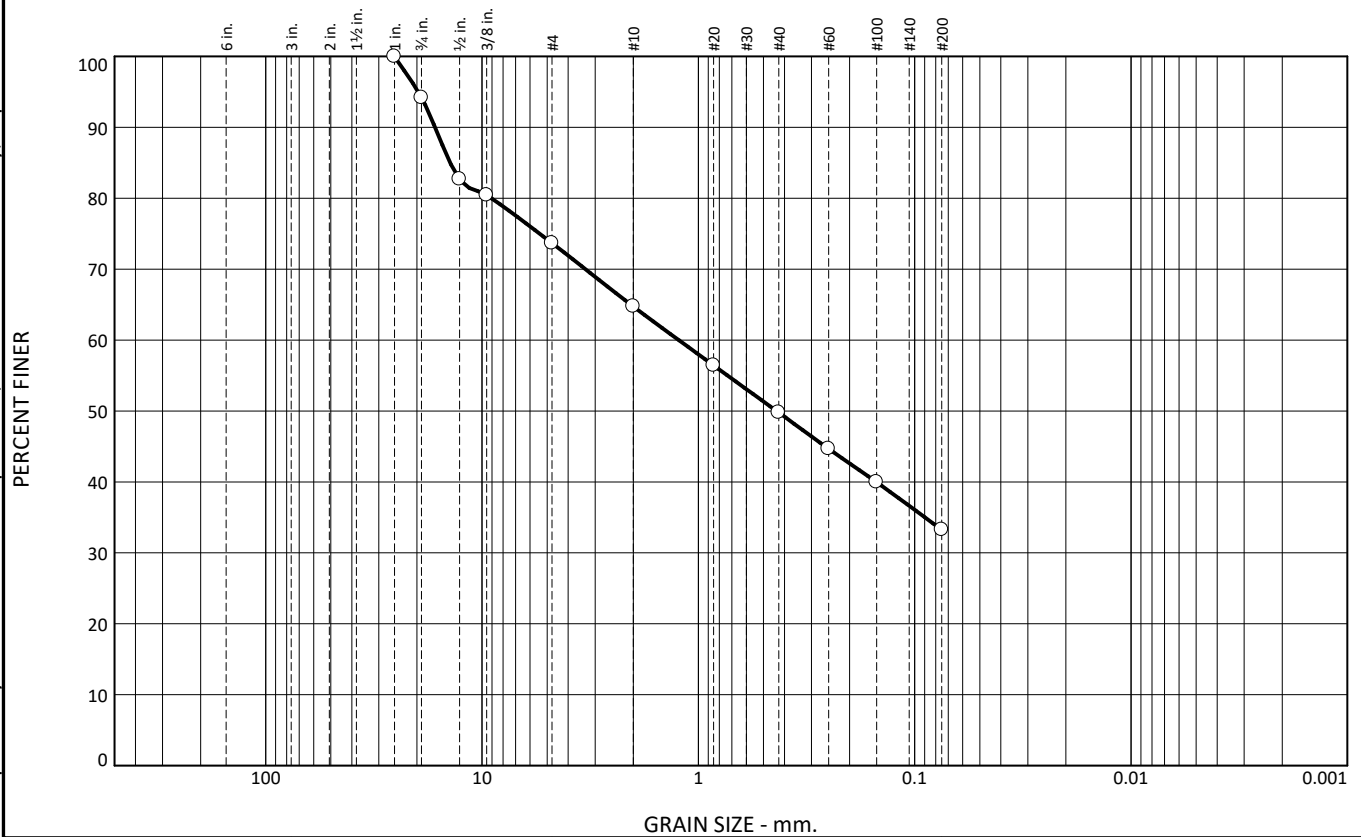
Date Reviewed: 7/11/2024

This report only relates to items inspect and/or tested. No warranty, expressed or implied, is made.

This report shall not be reproduced, except in full, without prior written approval from the Agency, as defined in ASTM E329.

These results are for the exclusive use of the client for whom they were obtained. This report only relates to items inspected and/or tested. No warranty, expressed or implied, is made.

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	5.8	20.5	9.0	14.9	16.5	33.3	

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1"	100.0		
3/4"	94.2		
1/2"	82.7		
3/8"	80.4		
#4	73.7		
#10	64.7		
#20	56.4		
#40	49.8		
#60	44.7		
#100	40.0		
#200	33.3		

* (no specification provided)

Soil Description
Brown f-c SAND, some Silt, some f-c Gravel

PL= NP Atterberg Limits LL= NV PI= NP
Coefficients
D₉₀= 16.4955 D₈₅= 14.0317 D₆₀= 1.2327
D₅₀= 0.4348 D₃₀= D₁₅=
D₁₀= C_u= C_c=

Classification
USCS= SM AASHTO= A-2-4(0)

Remarks
Sample visually classified as non-plastic.

Source of Sample: BB-USGR-101
Sample Number: 4D

Depth: 14-16'

Date: 7.10.24

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental
Project: St. George River Bridge No. 5893
Rte 17 over St. George River, Union ME

Project No: 09.0026237.00

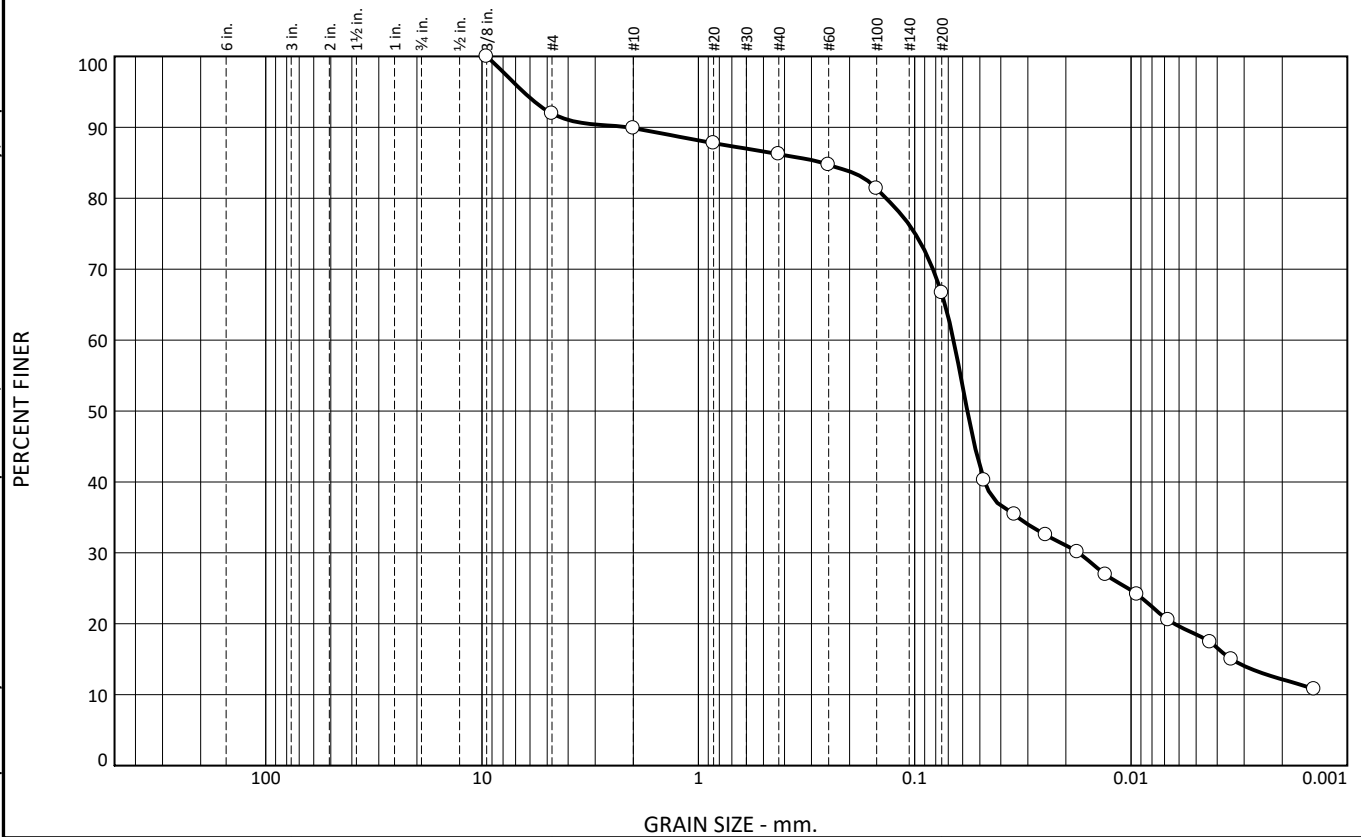
Fig. 24-S-2593

Tested By: MCS

Checked By: Kris Roland

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Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	8.1	2.0	3.7	19.5	54.5	12.2

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8"	100.0		
#4	91.9		
#10	89.9		
#20	87.8		
#40	86.2		
#60	84.7		
#100	81.4		
#200	66.7		
0.0478 mm.	40.2		
0.0346 mm.	35.4		
0.0248 mm.	32.5		
0.0177 mm.	30.1		
0.0131 mm.	26.9		
0.0094 mm.	24.1		
0.0067 mm.	20.5		
0.0043 mm.	17.4		
0.0034 mm.	15.0		
0.0014 mm.	10.8		

* (no specification provided)

Soil Description
Brown SILT & CLAY, some f-m Sand, trace fine Gravel

PL= **Atterberg Limits** LL= PI=

Coefficients
D₉₀= 2.1094 D₈₅= 0.2673 D₆₀= 0.0662
D₅₀= 0.0571 D₃₀= 0.0175 D₁₅= 0.0034
D₁₀= C_u= C_c=

Classification
USCS= ML AASHTO= A-4(0)

Remarks
Sample visually classified as plastic. Sample rolled to 1/8".

Source of Sample: BB-USGR-101
Sample Number: 7D-A

Depth: 26-28'

Date: 7.11.24

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental
Project: St. George River Bridge No. 5893
Rte 17 over St. George River, Union ME

Project No: 09.0026237.00

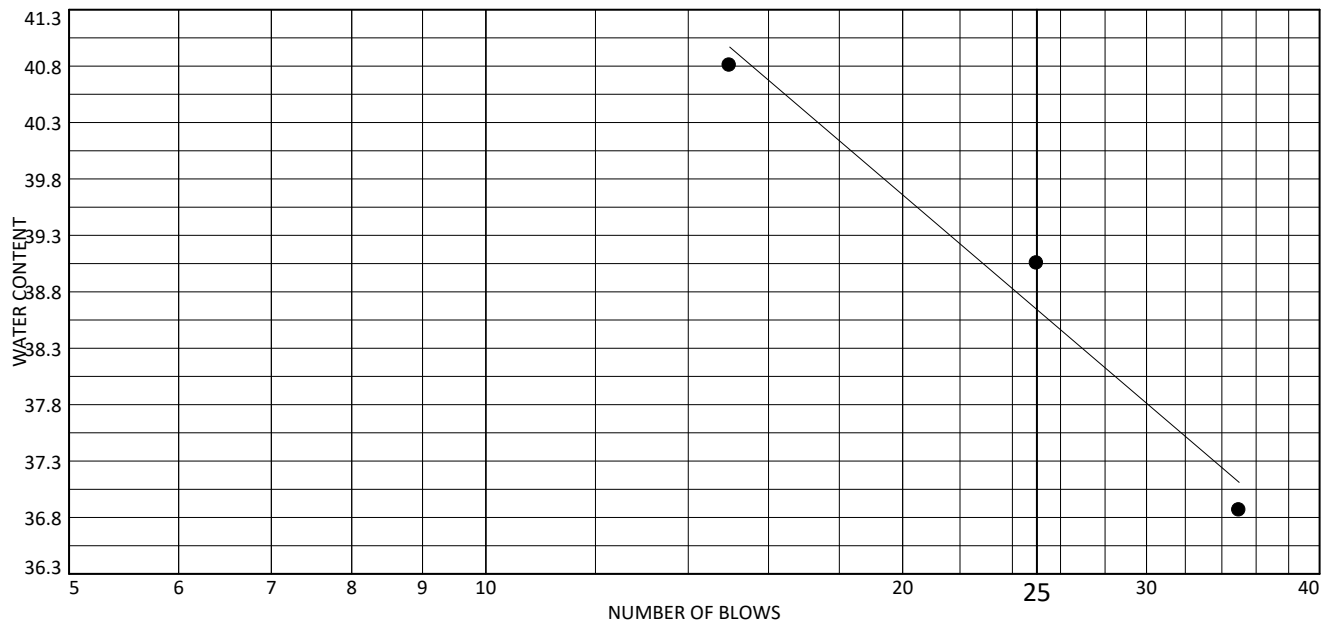
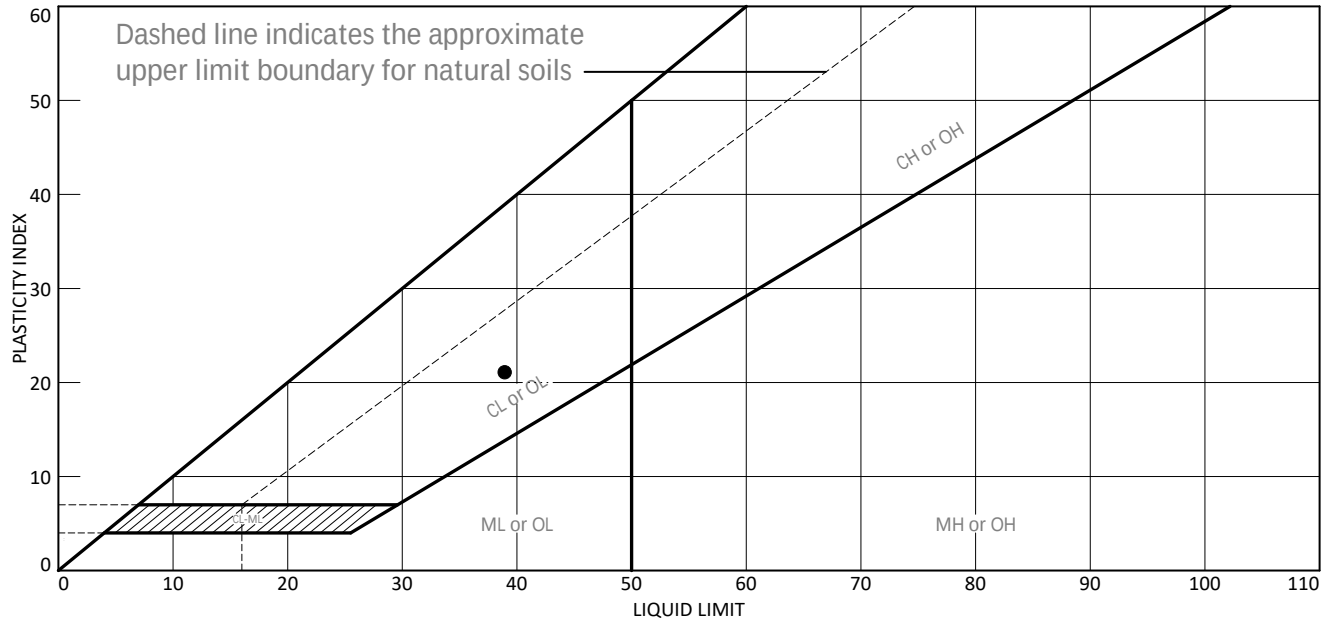
Fig. 24-S-2594

Tested By: RB/MCS

Checked By: Kris Roland

These results are for the exclusive use of the client for whom they were obtained. This report only relates to items inspect and/or tested. No warranty, expressed or implied, is made.

LIQUID AND PLASTIC LIMITS TEST REPORT



MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
● Grey SILTY CLAY	39	18	21			

Project No. 09.0026237.00 Client: GZA GeoEnvironmental
Project: St. George River Bridge No. 5893
Rte 17 over St. George River, Union ME
Source of Sample: BB-USGR-101 Depth: 31-33'
Sample Number: 9D

Thielsch Engineering Inc.

Cranston, RI

Remarks:

Fig. 24-L-2595

Tested By: RB

Checked By: Kris Roland

These results are for the exclusive use of the client for whom they were obtained. This report only relates to items inspected and/or tested. No warranty, expressed or implied, is made.

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	1.0	14.7	46.7	37.6	

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	99.0		
#20	89.8		
#40	84.3		
#60	79.2		
#100	65.3		
#200	37.6		

* (no specification provided)

Soil Description
Dark Brown Organic f-m SAND and SILT

Atterberg Limits
PL= LL= PI=

Coefficients
D₉₀= 0.8650 D₈₅= 0.4614 D₆₀= 0.1295
D₅₀= 0.1011 D₃₀= D₁₅=
D₁₀= C_u= C_c=

Classification
USCS= SM AASHTO= A-4(0)

Remarks
Sample contains fine-grained organic material.

Source of Sample: BB-USGR-101A
Sample Number: 1D

Depth: 29-31'

Date: 7.10.24

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental
Project: St. George River Bridge No. 5893
Rte 17 over St. George River, Union ME

Project No: 09.0026237.00

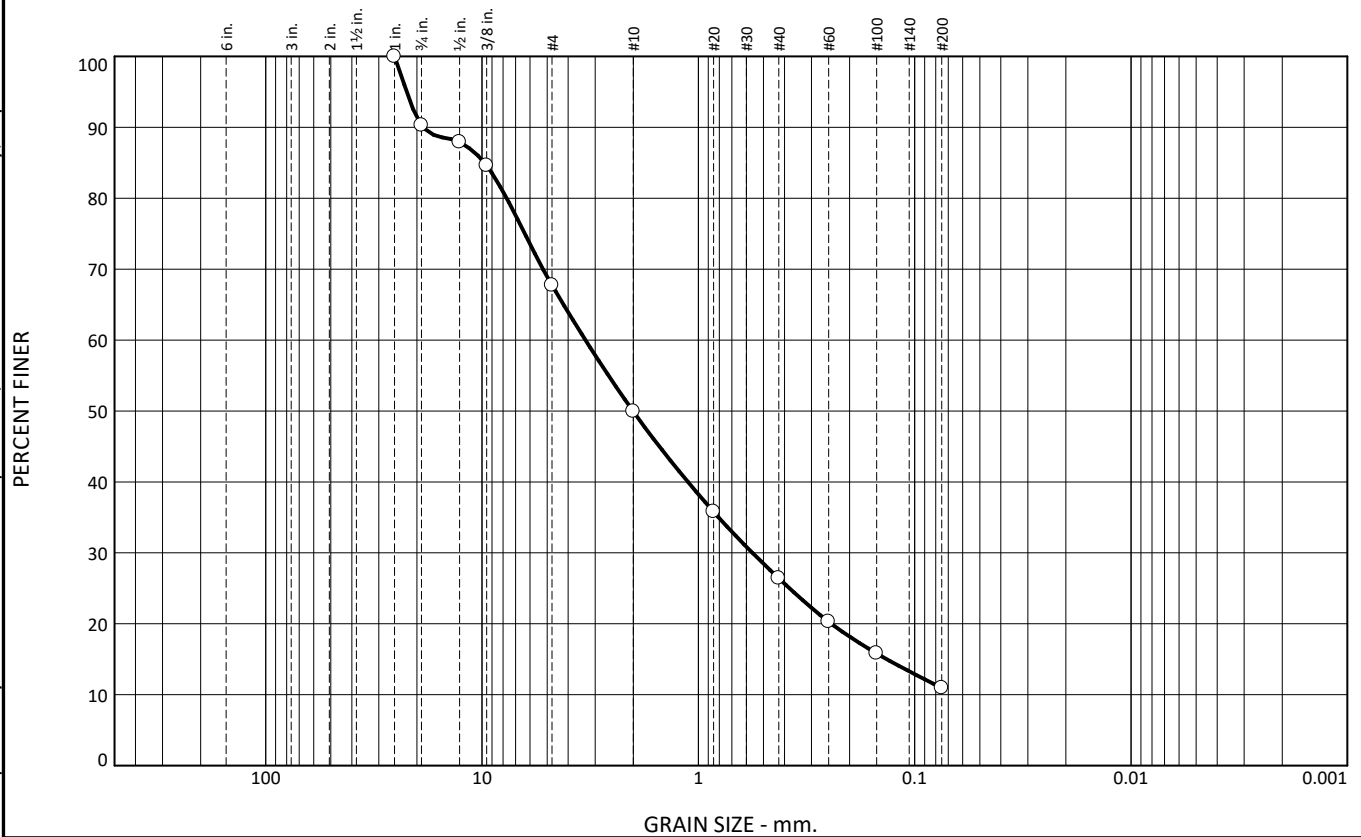
Fig. 24-S-2596

Tested By: MCS

Checked By: Kris Roland

These results are for the exclusive use of the client for whom they were obtained. This report only relates to items inspected and/or tested. No warranty, expressed or implied, is made.

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	9.7	22.6	17.8	23.5	15.5	10.9	

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1"	100.0		
3/4"	90.3		
1/2"	87.9		
3/8"	84.6		
#4	67.7		
#10	49.9		
#20	35.8		
#40	26.4		
#60	20.3		
#100	15.8		
#200	10.9		

* (no specification provided)

Soil Description
Dark Brown f-c SAND, some f-c Gravel, little Silt

PL= NP Atterberg Limits LL= NV PI= NP
Coefficients
D₉₀= 18.7021 D₈₅= 9.7446 D₆₀= 3.3251
D₅₀= 2.0058 D₃₀= 0.5623 D₁₅= 0.1349
D₁₀= C_u= C_c=

Classification
USCS= SP-SM AASHTO= A-1-a
Remarks

Source of Sample: BB-USGR-101A
Sample Number: 2D

Depth: 31-33'

Date: 7.10.24

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental
Project: St. George River Bridge No. 5893
Rte 17 over St. George River, Union ME

Project No: 09.0026237.00

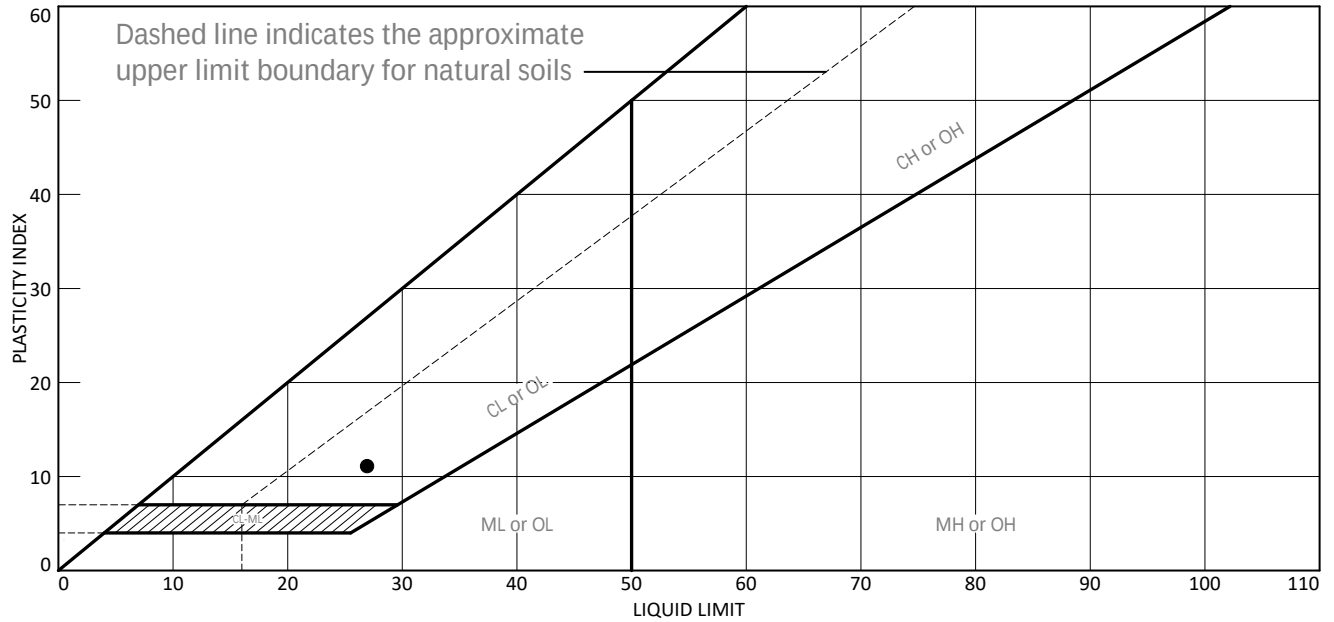
Fig. 24-S-2597

Tested By: MCS

Checked By: Kris Roland

These results are for the exclusive use of the client for whom they were obtained. This report only relates to items inspect and/or tested. No warranty, expressed or implied, is made.

LIQUID AND PLASTIC LIMITS TEST REPORT



MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
● Grey CLAY & SILT	27	16	11			

Project No. 09.0026237.00 Client: GZA GeoEnvironmental
Project: St. George River Bridge No. 5893
Rte 17 over St. George River, Union ME
Source of Sample: BB-USGR-101A Depth: 41-43'
Sample Number: 3D-A

Thielsch Engineering Inc.

Cranston, RI

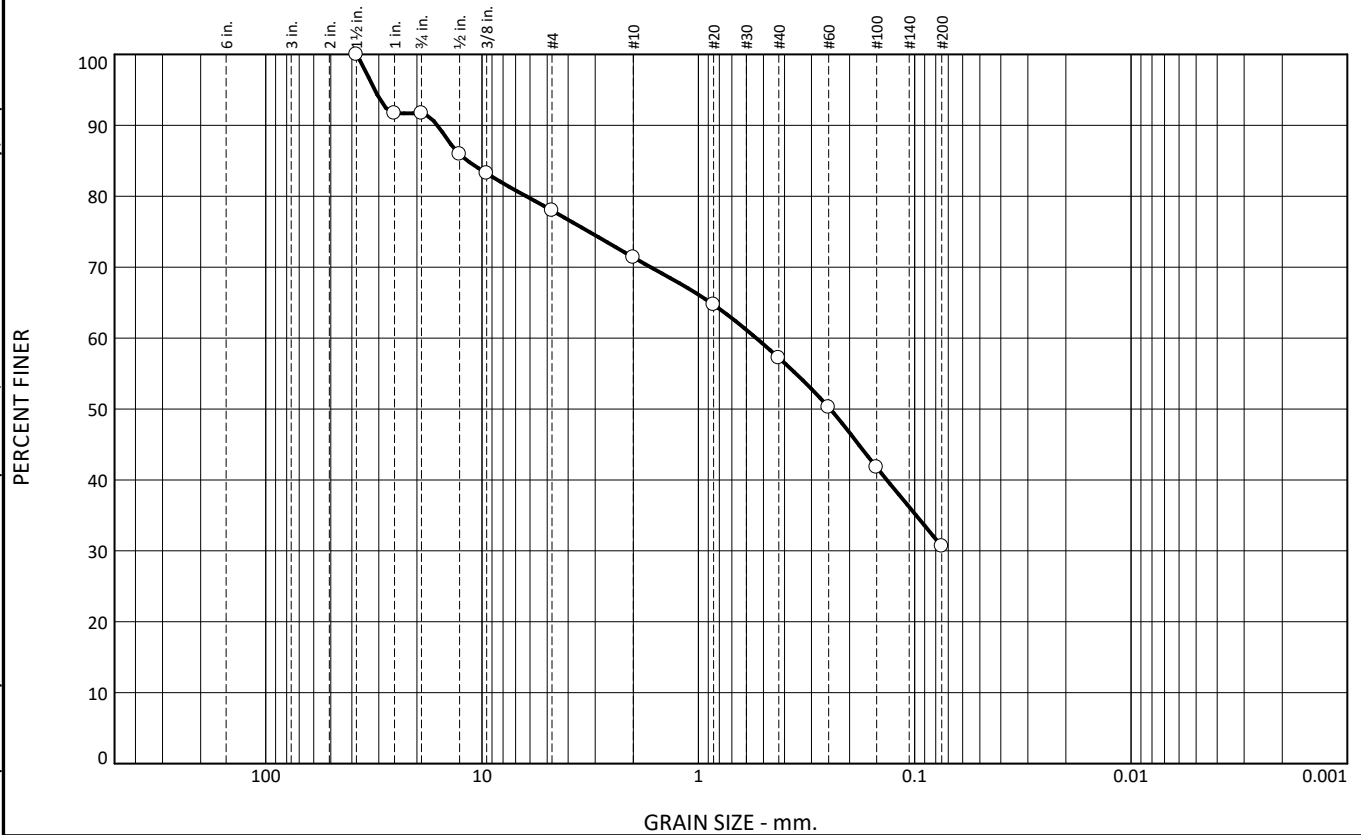
Remarks:

Fig. 24-L-2598

Tested By: RB Checked By: Kris Roland

These results are for the exclusive use of the client for whom they were obtained. This report only relates to items inspected and/or tested. No warranty, expressed or implied, is made.

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	8.3	13.7	6.6	14.2	26.6	30.6	

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1 1/2"	100.0		
1"	91.7		
3/4"	91.7		
1/2"	85.9		
3/8"	83.2		
#4	78.0		
#10	71.4		
#20	64.7		
#40	57.2		
#60	50.2		
#100	41.8		
#200	30.6		

* (no specification provided)

Soil Description
Dark Brown f-c SAND, some Silt, some f-c Gravel

PL= NP Atterberg Limits LL= NV PI= NP
Coefficients
D₉₀= 16.0817 D₈₅= 11.6619 D₆₀= 0.5400
D₅₀= 0.2459 D₃₀= D₁₅=
D₁₀= C_u= C_c=

Classification
USCS= SM AASHTO= A-2-4(0)

Remarks
Sample visually classified as non-plastic.

Source of Sample: BB-USGR-101A
Sample Number: 5D

Depth: 49-51'

Date: 7.10.24

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental
Project: St. George River Bridge No. 5893
Rte 17 over St. George River, Union ME

Project No: 09.0026237.00

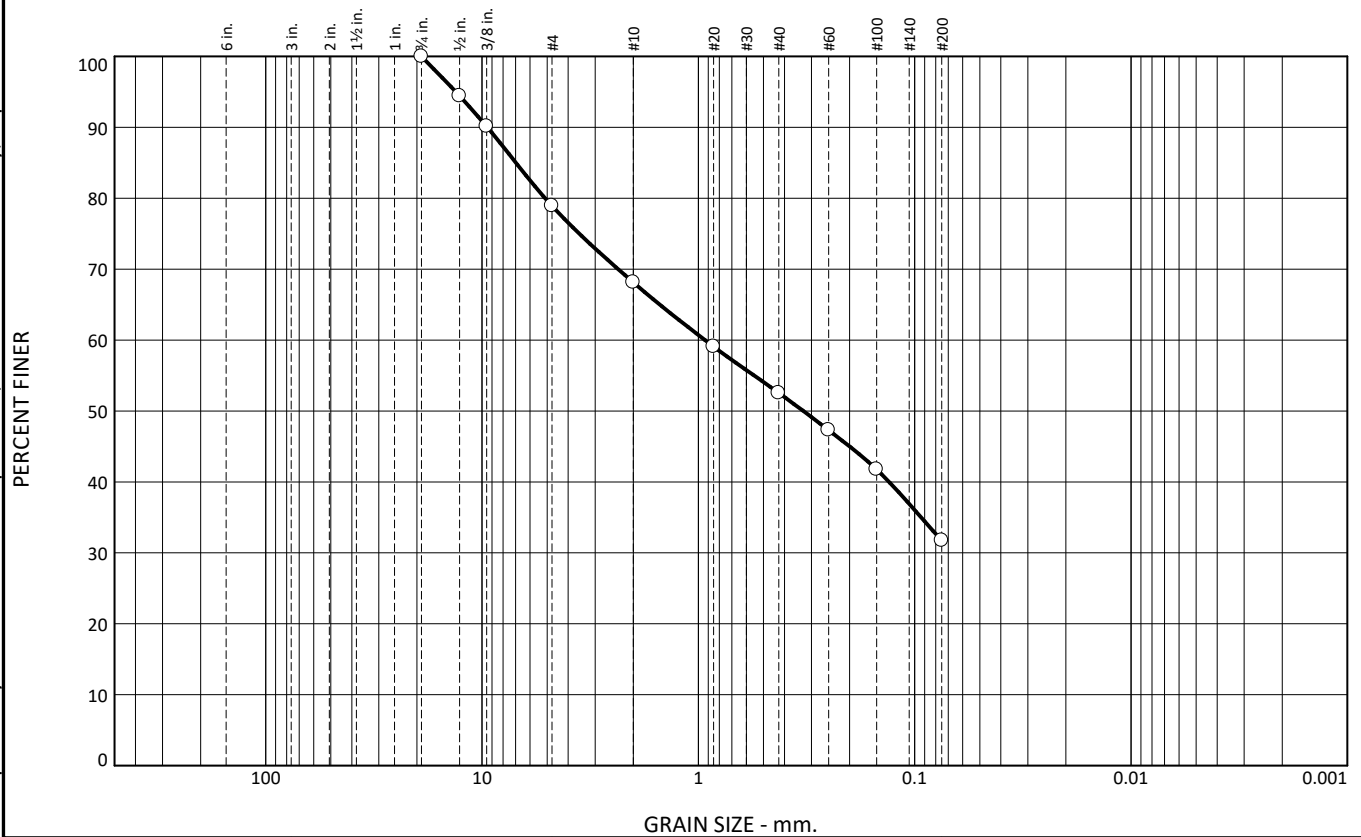
Fig. 24-S-2599

Tested By: MCS

Checked By: Kris Roland

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Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	21.1	10.8	15.6	20.8	31.7	

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4"	100.0		
1/2"	94.4		
3/8"	90.1		
#4	78.9		
#10	68.1		
#20	59.1		
#40	52.5		
#60	47.3		
#100	41.8		
#200	31.7		

* (no specification provided)

Soil Description
Dark Brown f-c SAND, some Silt, some fine Gravel

Atterberg Limits
PL= NP LL= NV PI= NP
Coefficients
D₉₀= 9.4498 D₈₅= 6.9668 D₆₀= 0.9312
D₅₀= 0.3271 D₃₀= D₁₅=
D₁₀= C_u= C_c=

Classification
USCS= SM AASHTO= A-2-4(0)

Remarks
Sample visually classified as non-plastic.

Source of Sample: BB-USGR-102
Sample Number: 1D

Depth: 4-6'

Date: 7.10.24

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental
Project: St. George River Bridge No. 5893
Rte 17 over St. George River, Union ME

Project No: 09.0026237.00

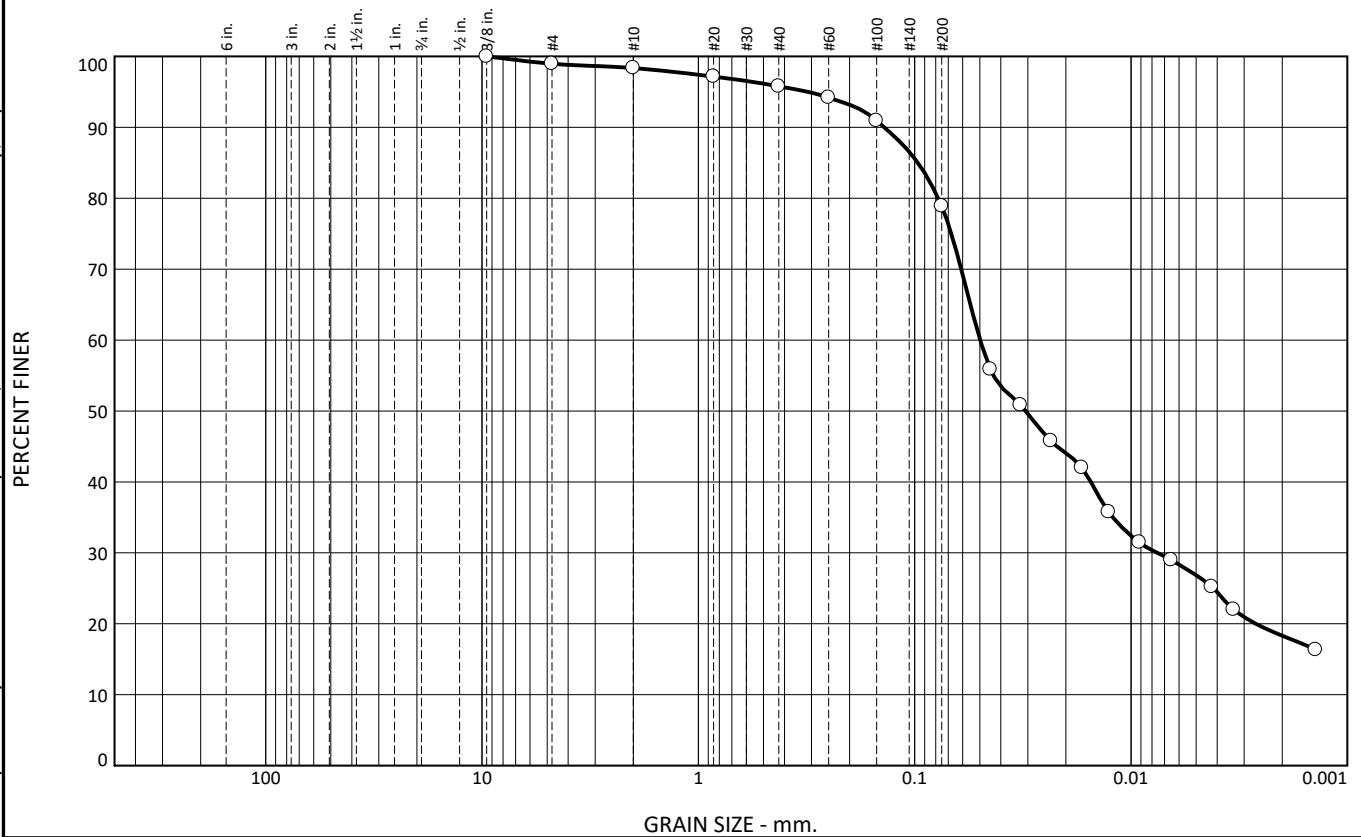
Fig. 24-S-2600

Tested By: MCS

Checked By: Kris Roland

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Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	1.0	0.6	2.6	16.9	60.6	18.3

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8"	100.0		
#4	99.0		
#10	98.4		
#20	97.2		
#40	95.8		
#60	94.2		
#100	90.9		
#200	78.9		
0.0447 mm.	55.9		
0.0324 mm.	50.8		
0.0235 mm.	45.8		
0.0169 mm.	42.0		
0.0127 mm.	35.8		
0.0091 mm.	31.5		
0.0065 mm.	29.0		
0.0042 mm.	25.2		
0.0034 mm.	22.0		
0.0014 mm.	16.3		

* (no specification provided)

Soil Description
Grey CLAYEY SILT, some f-m Sand, trace fine Gravel

PL= Atterberg Limits LL= PI=

Coefficients
D₉₀= 0.1384 D₈₅= 0.0966 D₆₀= 0.0498
D₅₀= 0.0308 D₃₀= 0.0076 D₁₅=
D₁₀= C_u= C_c=

Classification
USCS= ML AASHTO= A-4(0)

Remarks
Sample visually classified as plastic. Sample rolled to 1/4"

Source of Sample: BB-USGR-102
Sample Number: 2D-A

Depth: 9-11'

Date: 7.11.24

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental
Project: St. George River Bridge No. 5893
Rte 17 over St. George River, Union ME

Project No: 09.0026237.00

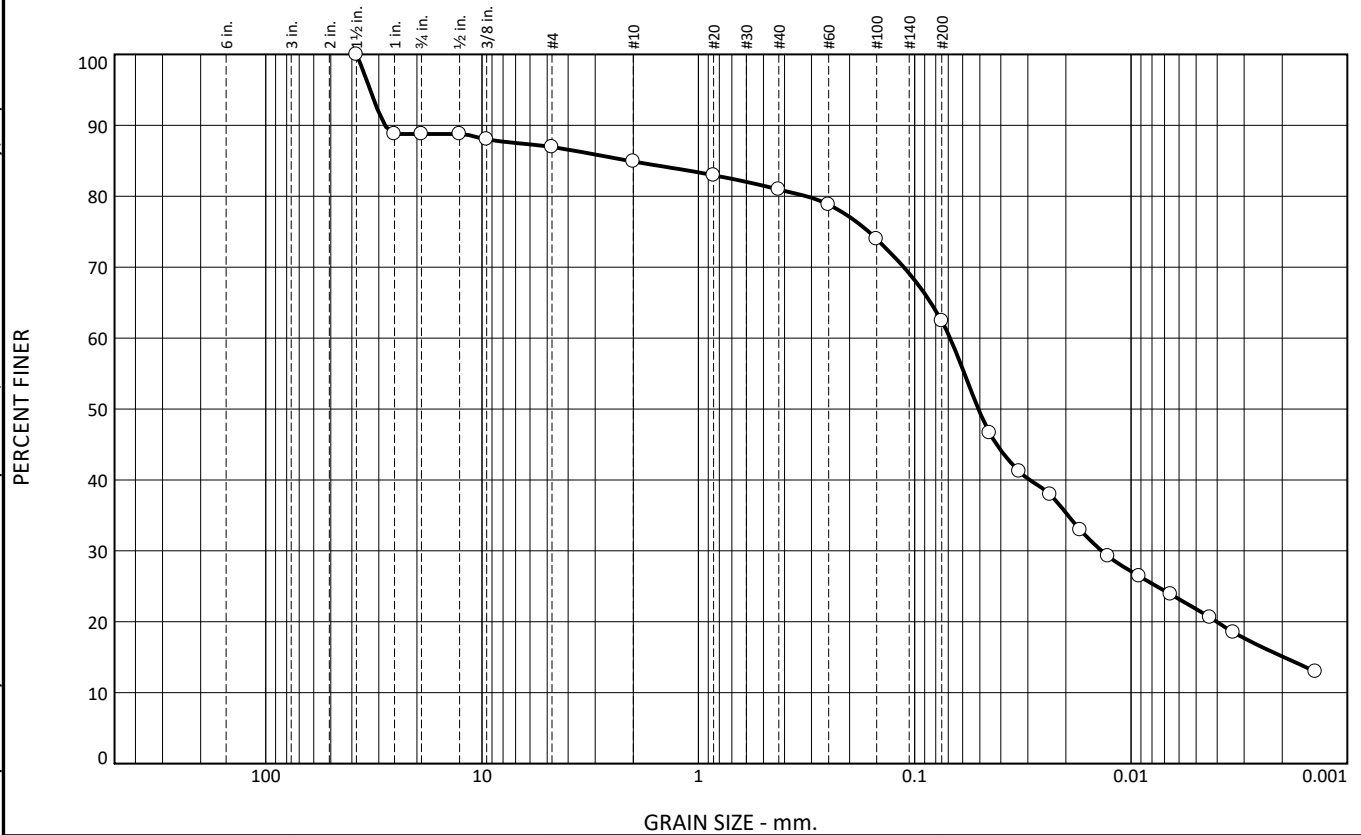
Fig. 24-S-2601

Tested By: RB/MCS

Checked By: Kris Roland

These results are for the exclusive use of the client for whom they were obtained. This report only relates to items inspected and/or tested. No warranty, expressed or implied, is made.

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	11.2	1.9	2.0	4.0	18.5	47.3	15.1

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1 1/2"	100.0		
1"	88.8		
3/4"	88.8		
1/2"	88.8		
3/8"	88.0		
#4	86.9		
#10	84.9		
#20	83.0		
#40	80.9		
#60	78.8		
#100	74.0		
#200	62.4		
0.0451 mm.	46.6		
0.0329 mm.	41.2		
0.0237 mm.	37.9		
0.0172 mm.	32.9		
0.0128 mm.	29.2		
0.0092 mm.	26.4		
0.0066 mm.	23.9		
0.0043 mm.	20.6		
0.0034 mm.	18.5		
0.0014 mm.	13.0		

* (no specification provided)

Soil Description
Grey CLAYEY SILT, some f-m Sand, little f-c Gravel

PL= Atterberg Limits LL= PI=

Coefficients

D₉₀= 28.0913 D₈₅= 2.0835 D₆₀= 0.0686
D₅₀= 0.0508 D₃₀= 0.0137 D₁₅= 0.0020
D₁₀= C_u= C_c=

Classification
USCS= ML AASHTO= A-4(0)

Remarks
Sample visually classified as plastic. Sample rolled to 1/4"

Source of Sample: BB-USGR-102
Sample Number: 2D-B

Depth: 9-11'

Date: 7.11.24

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental
Project: St. George River Bridge No. 5893
Rte 17 over St. George River, Union ME

Project No: 09.0026237.00

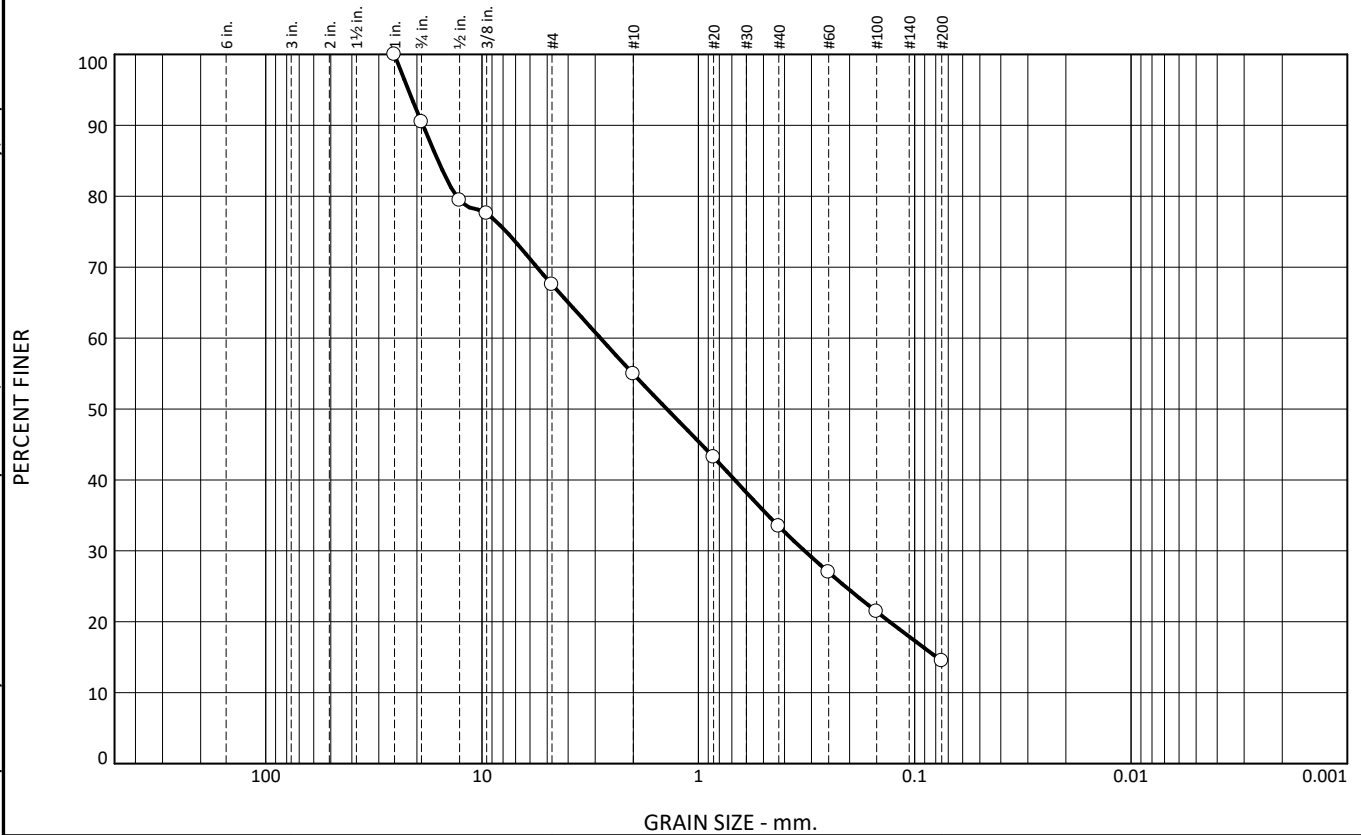
Fig. 24-S-2602

Tested By: RB/MCS

Checked By: Kris Roland

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Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	9.5	23.0	12.5	21.5	19.0	14.5	

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1"	100.0		
3/4"	90.5		
1/2"	79.4		
3/8"	77.6		
#4	67.5		
#10	55.0		
#20	43.2		
#40	33.5		
#60	27.0		
#100	21.4		
#200	14.5		

* (no specification provided)

Soil Description
Brown f-c SAND, some f-c Gravel, little Silt

PL= NP Atterberg Limits LL= NV PI= NP
Coefficients
D₉₀= 18.7478 D₈₅= 15.9567 D₆₀= 2.8373
D₅₀= 1.3985 D₃₀= 0.3229 D₁₅= 0.0792
D₁₀= C_u= C_c=

USCS= SM Classification AASHTO= A-1-b
Remarks

Source of Sample: BB-USGR-103
Sample Number: 2D

Depth: 4-6'

Date: 7.10.24

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental
Project: St. George River Bridge No. 5893
Rte 17 over St. George River, Union ME

Project No: 09.0026237.00

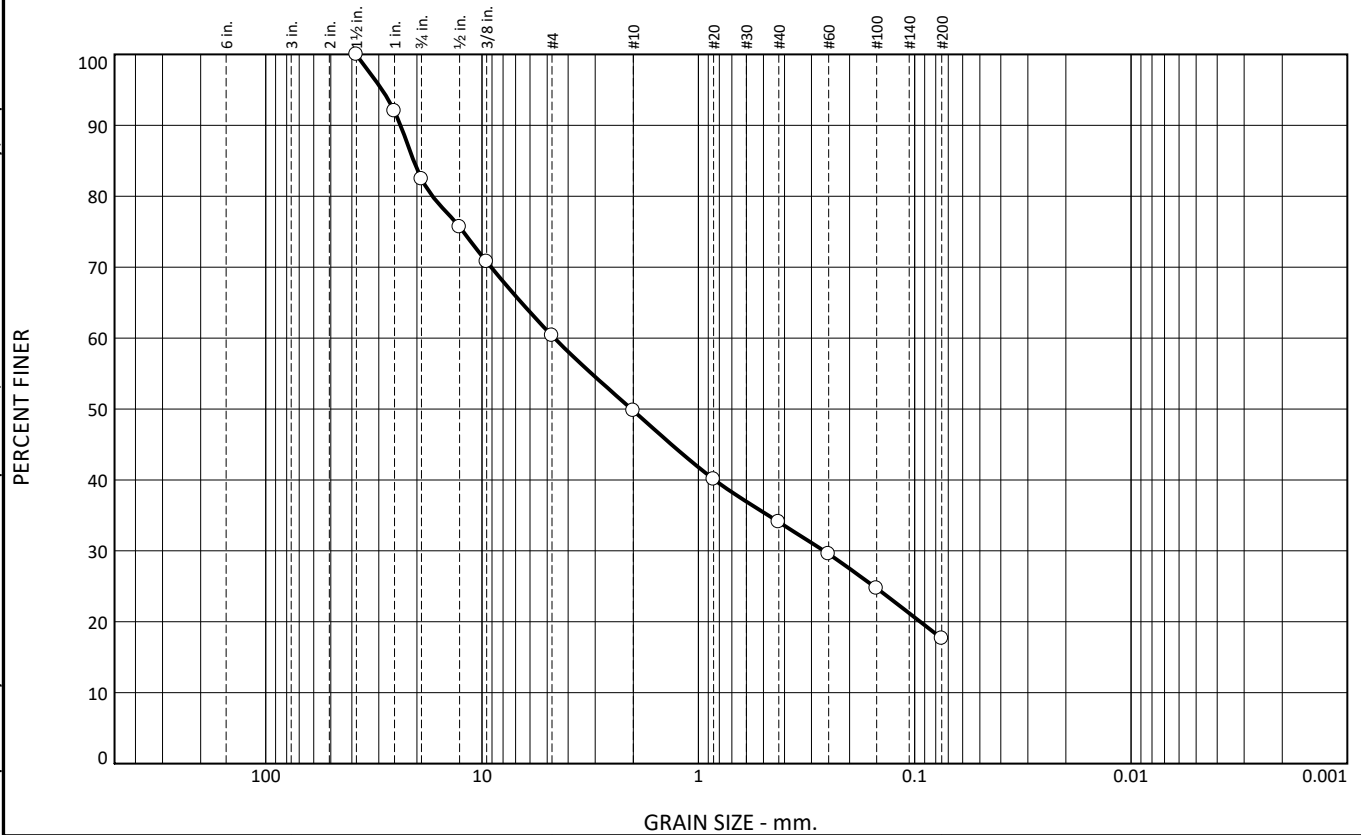
Fig. 24-S-2603

Tested By: MCS

Checked By: Kris Roland

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Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	17.6	22.0	10.6	15.7	16.5	17.6	

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1 1/2"	100.0		
1"	92.0		
3/4"	82.4		
1/2"	75.7		
3/8"	70.8		
#4	60.4		
#10	49.8		
#20	40.1		
#40	34.1		
#60	29.5		
#100	24.7		
#200	17.6		

* (no specification provided)

Soil Description
Brown f-c SAND and f-c GRAVEL, little Silt

PL= NP Atterberg Limits LL= NV PI= NP
Coefficients
D₉₀= 23.7822 D₈₅= 20.7176 D₆₀= 4.6265
D₅₀= 2.0397 D₃₀= 0.2631 D₁₅=
D₁₀= C_u= C_c=

Classification
USCS= SM AASHTO= A-1-b
Remarks

Source of Sample: BB-USGR-103
Sample Number: 4D

Depth: 14-16'

Date: 7.10.24

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental
Project: St. George River Bridge No. 5893
Rte 17 over St. George River, Union ME

Project No: 09.0026237.00

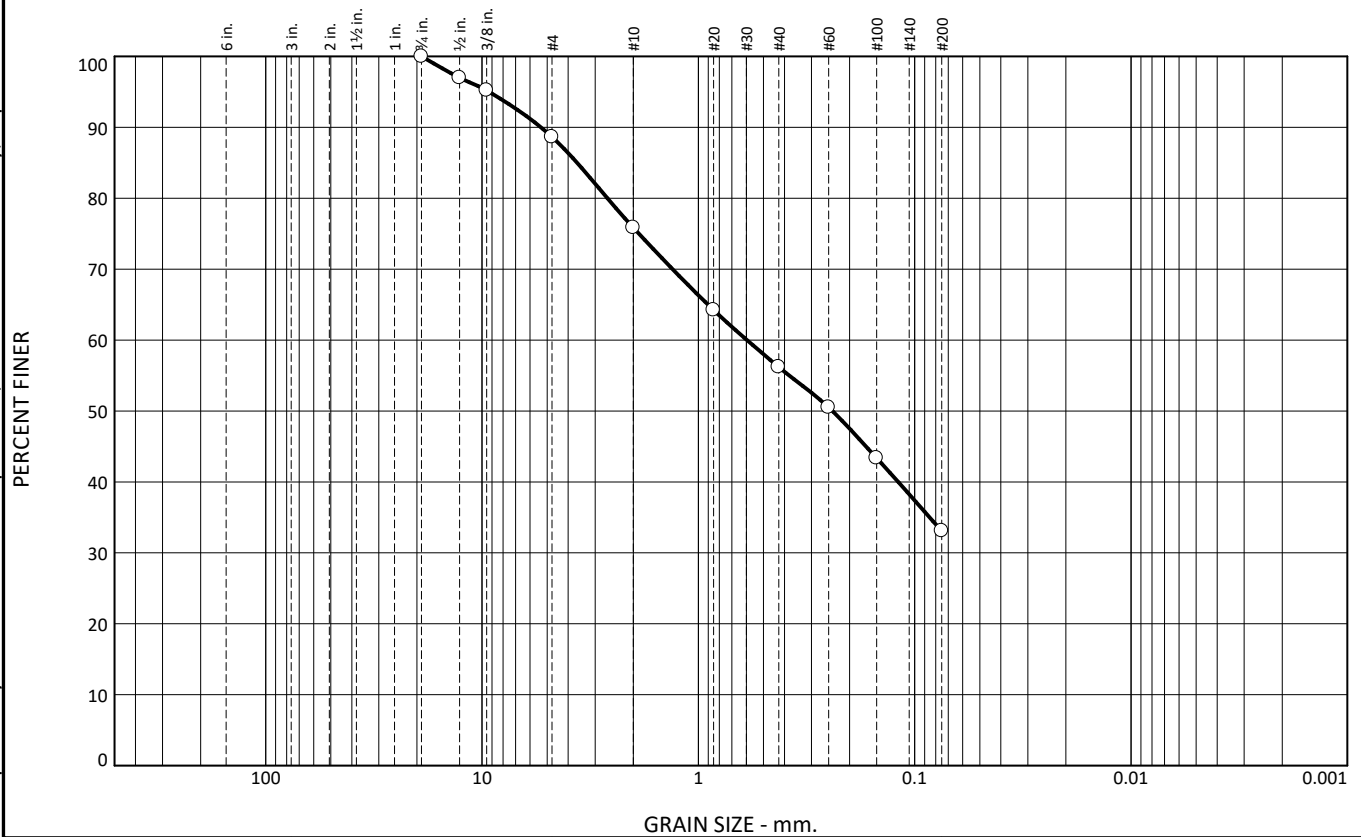
Fig. 24-S-2604

Tested By: MCS

Checked By: Kris Roland

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Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	11.4	12.7	19.7	23.1	33.1	

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4"	100.0		
1/2"	97.0		
3/8"	95.2		
#4	88.6		
#10	75.9		
#20	64.2		
#40	56.2		
#60	50.5		
#100	43.4		
#200	33.1		

* (no specification provided)

Soil Description
Brown f-c SAND, some Silt, little fine Gravel

Atterberg Limits
PL= NP LL= NV PI= NP

Coefficients
D₉₀= 5.3423 D₈₅= 3.6347 D₆₀= 0.5961
D₅₀= 0.2401 D₃₀= D₁₅=
D₁₀= C_u= C_c=

Classification
USCS= SM AASHTO= A-2-4(0)

Remarks
Sample visually classified as non-plastic.

Source of Sample: BB-USGR-103
Sample Number: 6D-A

Depth: 19-21'

Date: 7.10.24

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental
Project: St. George River Bridge No. 5893
Rte 17 over St. George River, Union ME

Project No: 09.0026237.00

Fig. 24-S-2605

Tested By: MCS

Checked By: Kris Roland

	195 Frances Avenue Cranston RI, 02910 Phone: (401)-467-6454 Fax: (401)-467-2398 cts.thielsch.com <i>Let's Build a Solid Foundation</i>	Client Information:	Project Information:
		GZA GeoEnvironmental, Inc. Portland, ME (207) 879-9190 Project Contact: Jason Keohane Collected By: S. Miller	St. George River Bridge #5893 Union, ME Project Number: 09.0026237.01 Task 3 Summary Page: 1 of 1 Report Date: 02.09.26

LABORATORY TESTING DATA SHEET, Report No.: 26B101

Boring No.	Sample ID	Depth (ft)	Laboratory No.	Identification Tests										Compaction / CBR / Permeability Tests								Laboratory Log and Soil Description
				As Rcvd Moisture Content %	LL %	PL %	OD LL	Gravel %	Sand %	Fines %	Org. %	pH	9 _d MAX (pcf) W _{opt} (%)	9 _d MAX (pcf) W _{opt} (%) (Corr.)	Dry unit wt. (pcf)	Test Moisture Content %	Target Test Setup as % of Proctor	CBR @ 0.1"	CBR @ 0.2"	Permeability cm/sec		
				D2216	D4318		D6913			D2974	D4792	D1557		D1883					D2434/D5084			
BB-USGR-201	4D	10-12	26-S-275	5.2				38.2	42.2	19.6											Brown f-c SAND and f-c GRAVEL little Silt	
BB-USGR-201	5D	15-17	26-S-276	6.8				0.0	66.3	33.7											Brown f-m SAND, some Silt	
BB-USGR-201	7D	25-27	26-S-277	7.8				55.7	41.4	2.9											Dark Grey f-c GRAVEL and f-c SAND, trace Silt	
BB-USGR-201	10D	34-36	26-L-278	31.3	45	19															Grey Silty CLAY	
BB-USGR-201	12D	38-40	26-L-279	36.0	44	18															Grey Silty CLAY	
BB-USGR-202	3D	11-13	26-S-280	13.5				3.7	58.5	37.8											Dark Brown f-c SAND and SILT, trace fine Gravel	
BB-USGR-202	4D (Bott. 8")	16.3-18	26-S-281	23.3	26	15					0.7										Grey CLAY & SILT	
BB-USGR-202	5D	21-23	26-S-282	23.8				0.0	32.1	67.9											Grey SILT & CLAY, some f-c Sand	
BB-USGR-202	6D	31-33	26-S-283	29.0				20.5	51.0	28.5											Dark Grey f-c SAND, some Silt, some f-c Gravel	
ASTM D2974 Organic Content performed by SF/AB 02-04-26.																						

ASTM D2974 Organic Content performed by SF/AB 02-04-26.

Date Received: 01.30.26

Reviewed By: 

Date Reviewed: 02.09.26

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State of Maine - Department of Transportation

Laboratory Testing Summary Sheet

Project ID: St. George River Bridge
#5893

Thielsch Report ID: 26B101

Town(s): Union, ME

GZA Project Number: 09.0026237.01 Task 03

[illegible]

GSDC = Grain Size Distribution Curve as determined by AASHTO T 88-19 and/or ASTM D 7928-21e1 (Last Updated June 2021)

WC = water content as determined by AASHTO T 265-19 and/or ASTM D 2216-19

LL = Liquid limit as determined by AASHTO T 89-17 and/or ASTM D 4318-17E01

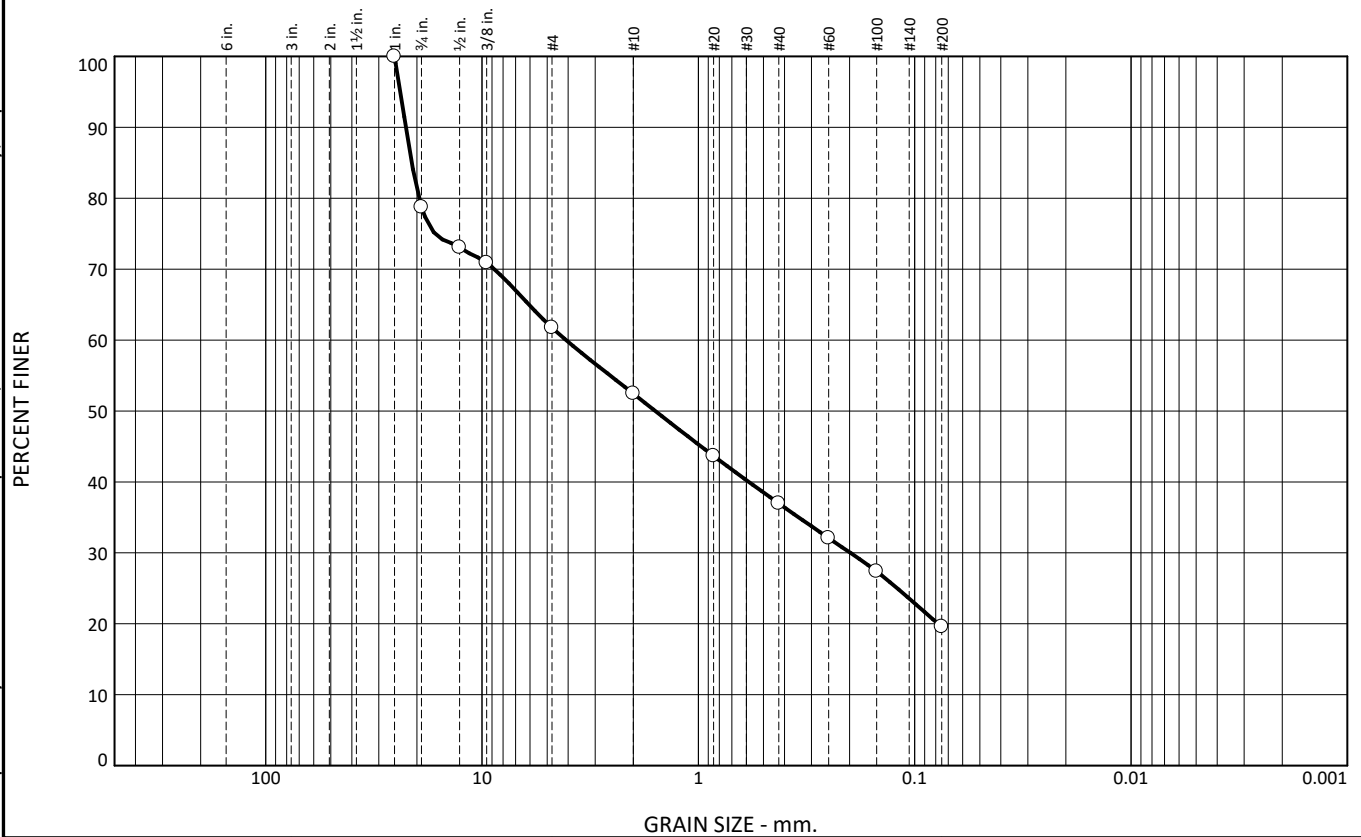
PI = Plasticity Index as determined by AASHTO 90-16 and/or ASTM D4318-17E01

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Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	21.3	16.9	9.3	15.5	17.4	19.6	

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1"	100.0		
3/4"	78.7		
1/2"	73.1		
3/8"	70.9		
#4	61.8		
#10	52.5		
#20	43.7		
#40	37.0		
#60	32.1		
#100	27.4		
#200	19.6		

* (no specification provided)

Soil Description
Brown f-c SAND and f-c Gravel, little Silt

Atterberg Limits
PL= NP LL= NV PI= NP

Coefficients
D₉₀= 22.4831 D₈₅= 21.1312 D₆₀= 4.0846
D₅₀= 1.5823 D₃₀= 0.1983 D₁₅=
D₁₀= C_u= C_c=

Classification
USCS= SM AASHTO= A-1-b

Remarks

Source of Sample: Test Boring Depth: 10-12
Sample Number: BB-USGR-201, 4D

Date: 2.6.2026

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental, Inc.
Project: St. George River BRidge #5893
Union, Maine

Project No: 09.0026237.01 Task 3

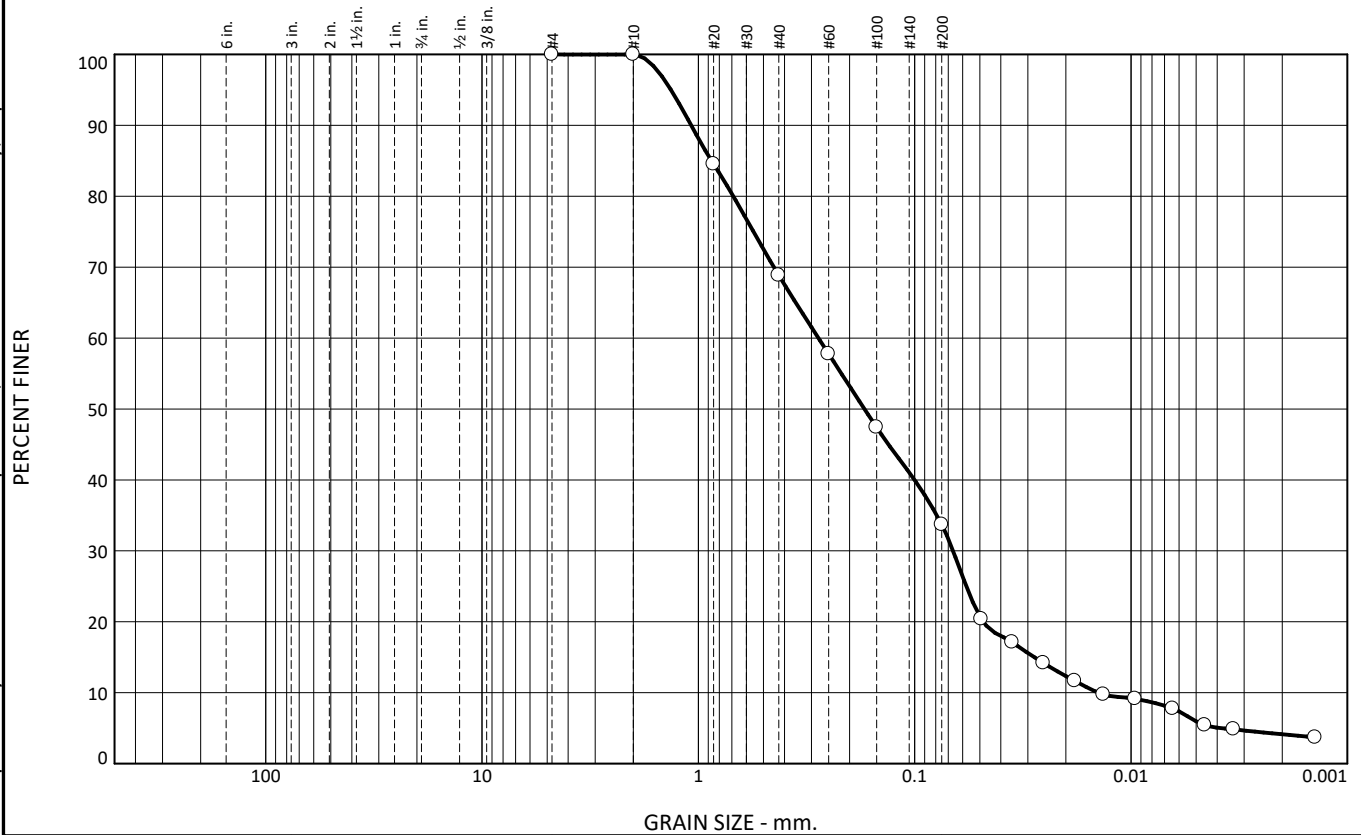
Figure 26-S-275

Tested By: AB

Checked By: Michael Collins

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Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	31.1	35.2	29.6	4.1

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	100.0		
#20	84.5		
#40	68.9		
#60	57.8		
#100	47.4		
#200	33.7		
0.0492 mm.	20.4		
0.0354 mm.	17.1		
0.0254 mm.	14.2		
0.0182 mm.	11.7		
0.0134 mm.	9.8		
0.0096 mm.	9.1		
0.0064 mm.	7.8		
0.0046 mm.	5.4		
0.0034 mm.	4.8		
0.0014 mm.	3.7		

* (no specification provided)

Soil Description
Brown f-m SAND, some Silt

Atterberg Limits
PL= NP LL= NV PI= NP
Coefficients
D₉₀= 1.0794 D₈₅= 0.8693 D₆₀= 0.2786
D₅₀= 0.1707 D₃₀= 0.0665 D₁₅= 0.0280
D₁₀= 0.0142 C_u= 19.68 C_c= 1.12

Classification
USCS= SM AASHTO= A-2-4(0)

Remarks
Sample visually classified as non-plastic. Sample could not be rolled to 1/4".

Source of Sample: Test Boring Depth: 15-17
Sample Number: BB-USGR-201, 5D

Date: 2.6.2026

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental, Inc.
Project: St. George River BRidge #5893
Union, Maine

Project No: 09.0026237.01 Task 3

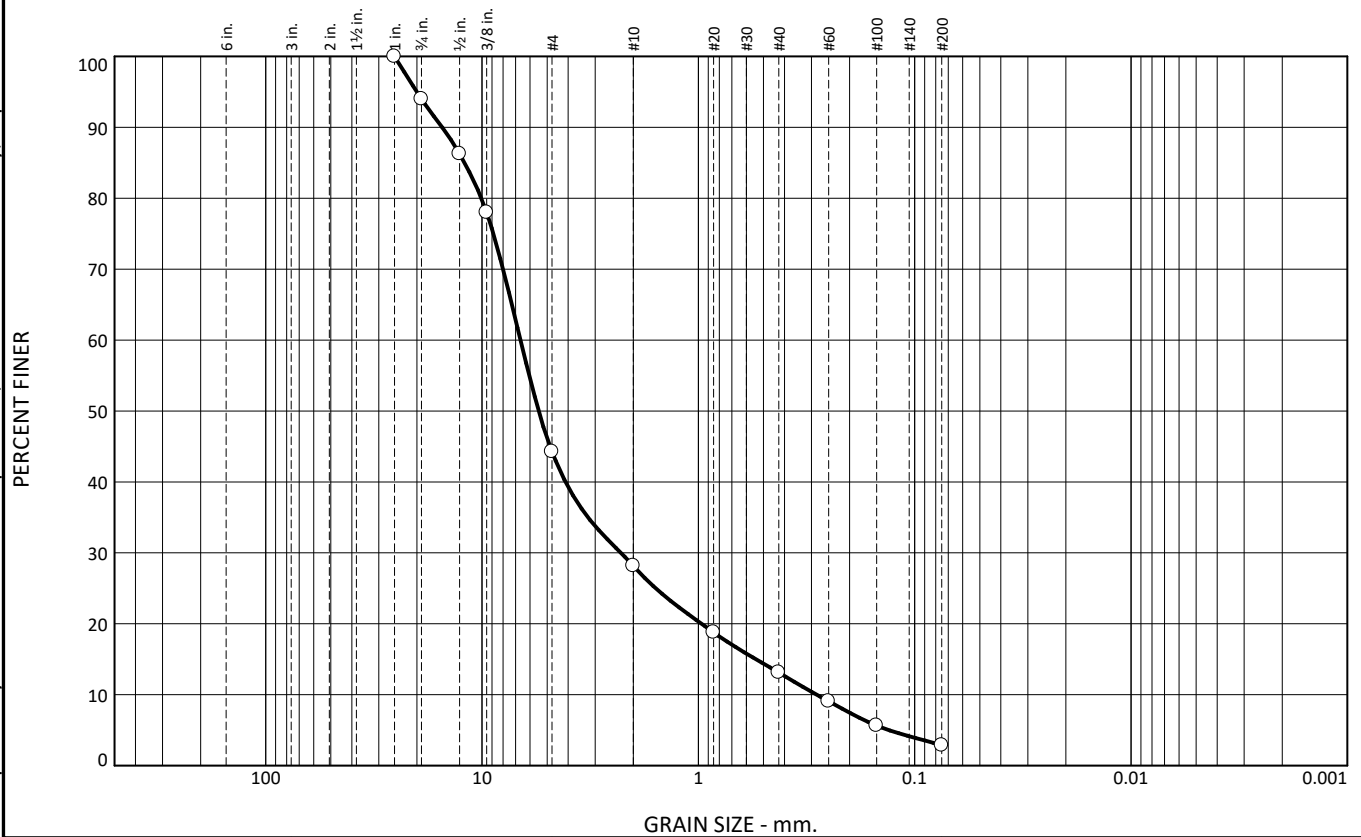
Figure 26-S-276

Tested By: BR

Checked By: Michael Collins

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Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	6.0	49.7	16.1	15.1	10.2	2.9	

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1"	100.0		
3/4"	94.0		
1/2"	86.3		
3/8"	78.0		
#4	44.3		
#10	28.2		
#20	18.8		
#40	13.1		
#60	9.1		
#100	5.6		
#200	2.9		

* (no specification provided)

Soil Description
Dark Grey f-c GRAVEL and f-c SAND, trace Silt

PL= NP Atterberg Limits LL= NV PI= NP
Coefficients
D₉₀= 15.2761 D₈₅= 12.0536 D₆₀= 6.6412
D₅₀= 5.4708 D₃₀= 2.2802 D₁₅= 0.5423
D₁₀= 0.2840 C_u= 23.38 C_c= 2.76

Classification
USCS= GW AASHTO= A-1-a
Remarks

Source of Sample: Test Boring Depth: 25-27
Sample Number: BB-USGR-201, 7D

Date: 2.6.2026

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental, Inc.
Project: St. George River BRidge #5893
Union, Maine

Project No: 09.0026237.01 Task 3

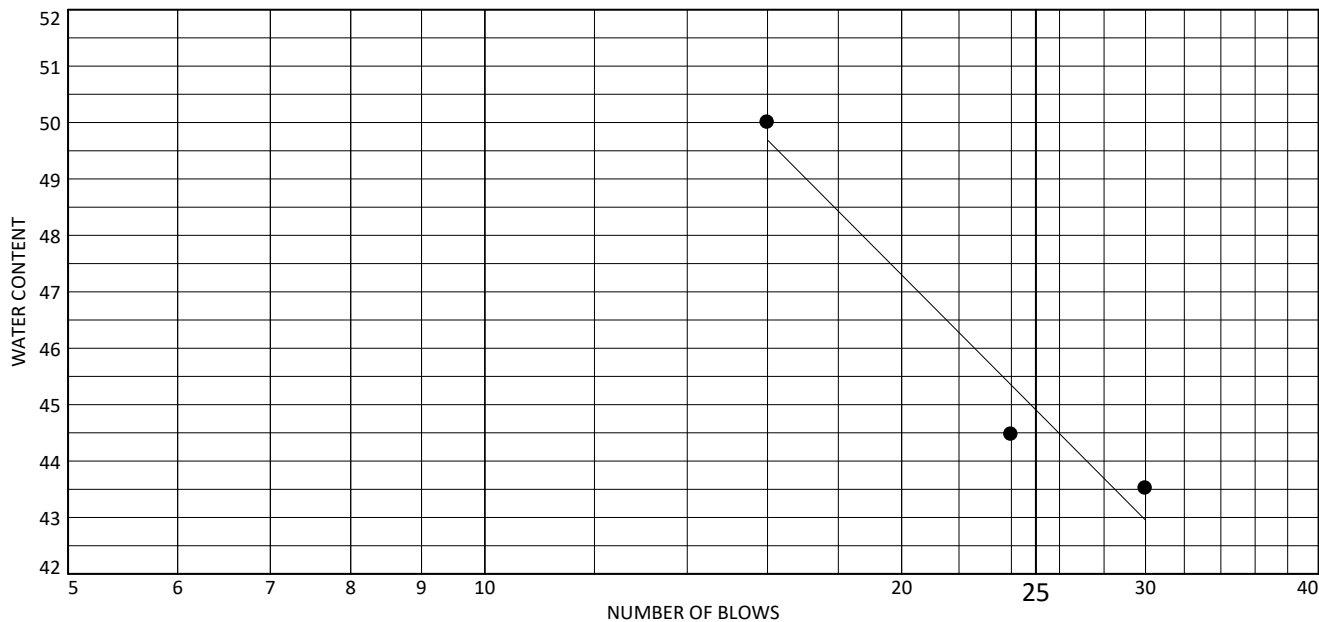
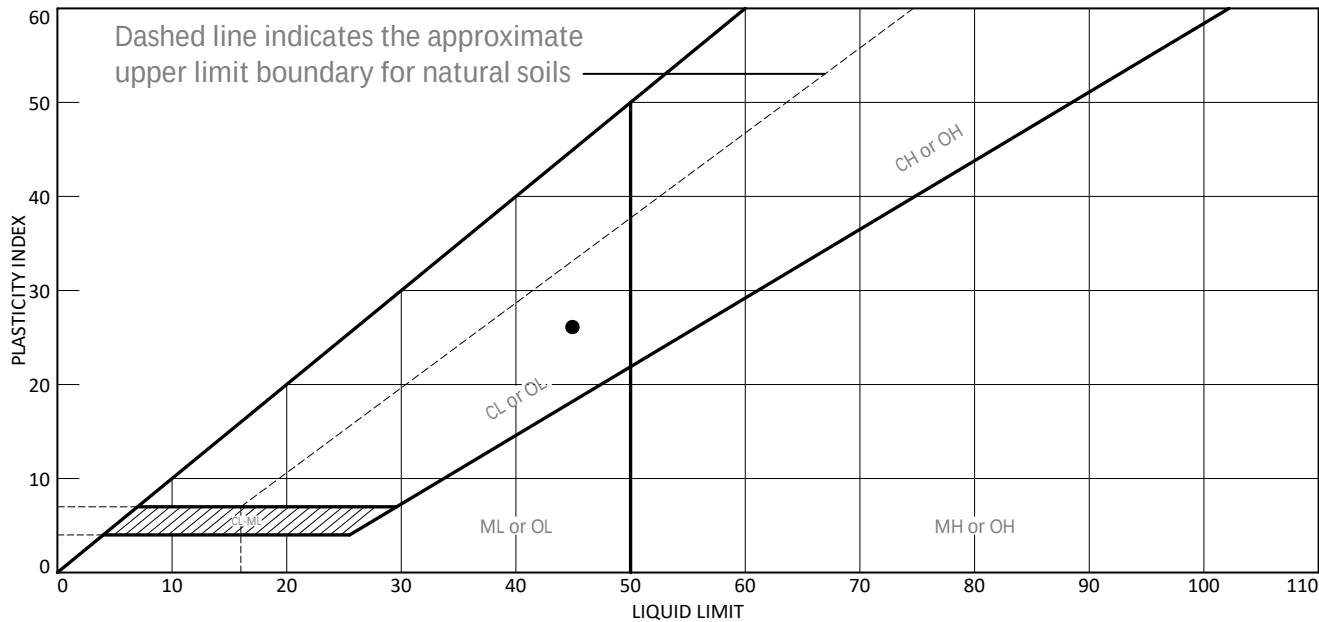
Figure 26-S-277

Tested By: DC

Checked By: Michael Collins

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LIQUID AND PLASTIC LIMITS TEST REPORT



MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
● Grey Silty CLAY	45	19	26			

Project No. 09.0026237.01 Task 3

Client: GZA GeoEnvironmental, Inc.

Project: St. George River BRidge #5893

Union, Maine

Source of Sample: Test Boring

Depth: 34-36

Sample Number: BB-USGR-201, 10D

Thielsch Engineering Inc.

Cranston, RI

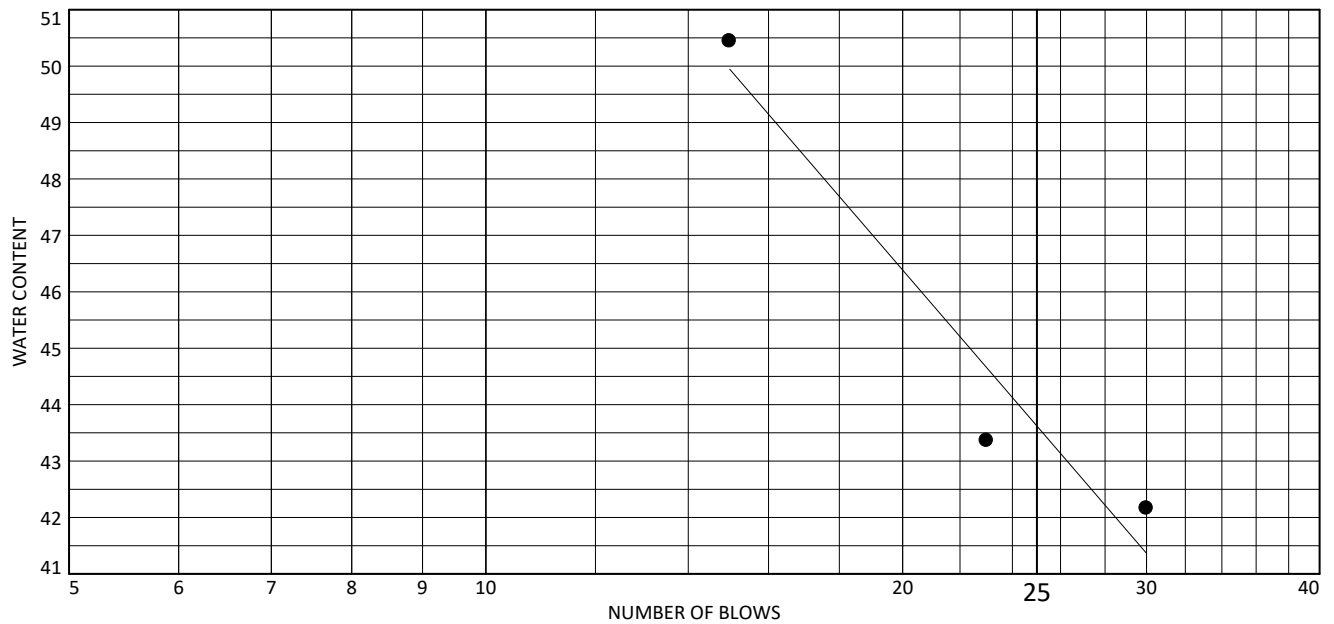
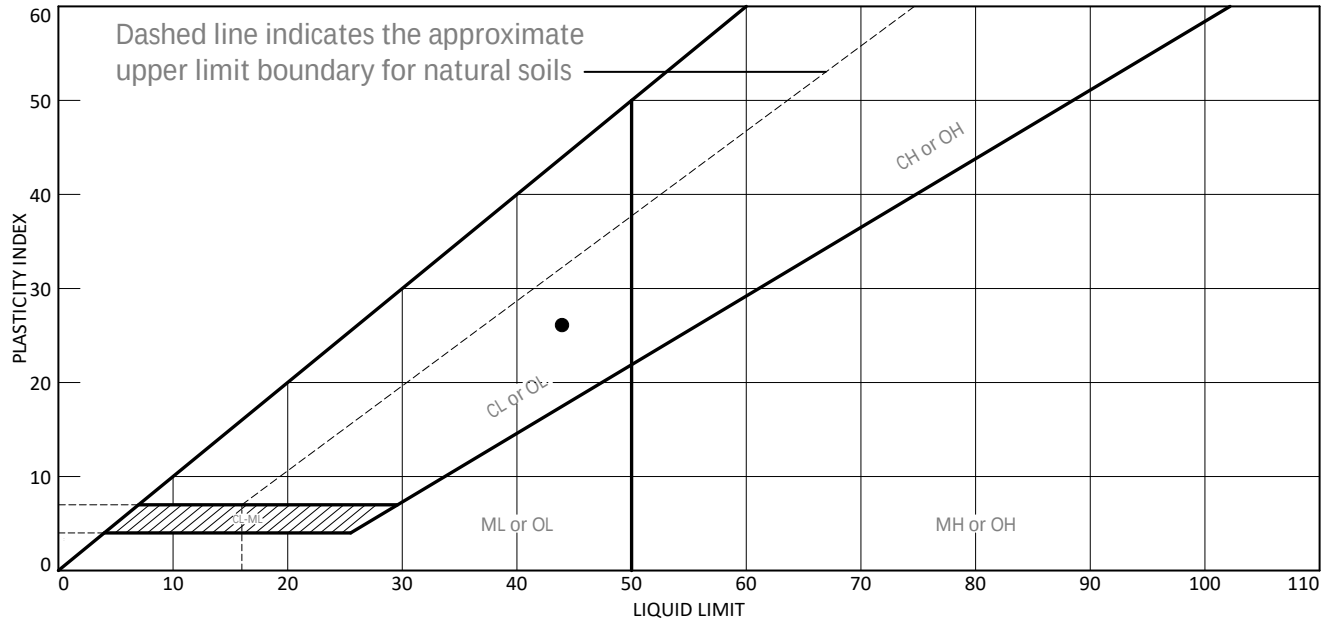
Remarks:

Figure 26-L-278

Tested By: SF Checked By: Michael Collins

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LIQUID AND PLASTIC LIMITS TEST REPORT



MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
● Grey Silty CLAY	44	18	26			

Project No. 09.0026237.01 Task 3 Client: GZA GeoEnvironmental, Inc.
Project: St. George River BRidge #5893
Union, Maine
Source of Sample: Test Boring Depth: 38-40
Sample Number: BB-USGR-201, 12D

Thielsch Engineering Inc.

Cranston, RI

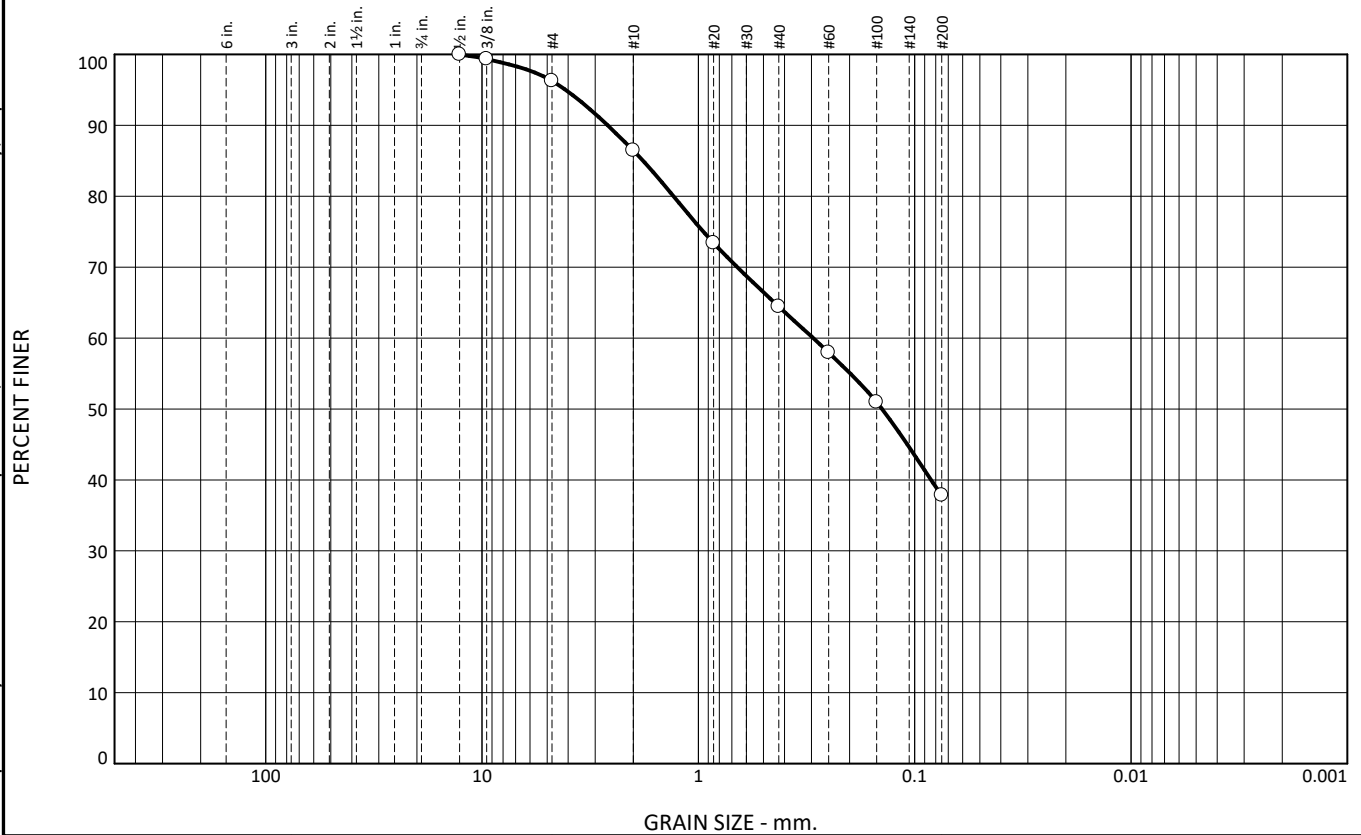
Remarks:

Figure 26-L279

Tested By: SF Checked By: Michael Collins

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Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	3.7	9.8	22.1	26.6	37.8	

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2"	100.0		
3/8"	99.4		
#4	96.3		
#10	86.5		
#20	73.4		
#40	64.4		
#60	58.0		
#100	51.0		
#200	37.8		

* (no specification provided)

Soil Description
Dark Brown f-c SAND and SILT trace fine Gravel

Atterberg Limits
PL= NP LL= NV PI= NP

Coefficients
D₉₀= 2.6260 D₈₅= 1.8002 D₆₀= 0.2944
D₅₀= 0.1416 D₃₀= C_u=
D₁₀= C_c=

Classification
USCS= SM AASHTO= A-4(0)

Remarks
Sample visually classified as non-plastic. Sample could not be rolled to 1/4".

Source of Sample: Test Boring Depth: 11-13
Sample Number: BB-USGR-202, 3D

Date: 2.6.2026

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental, Inc.
Project: St. George River Bridge #5893
Union, ME

Project No: 09.0026237.01 Task 3

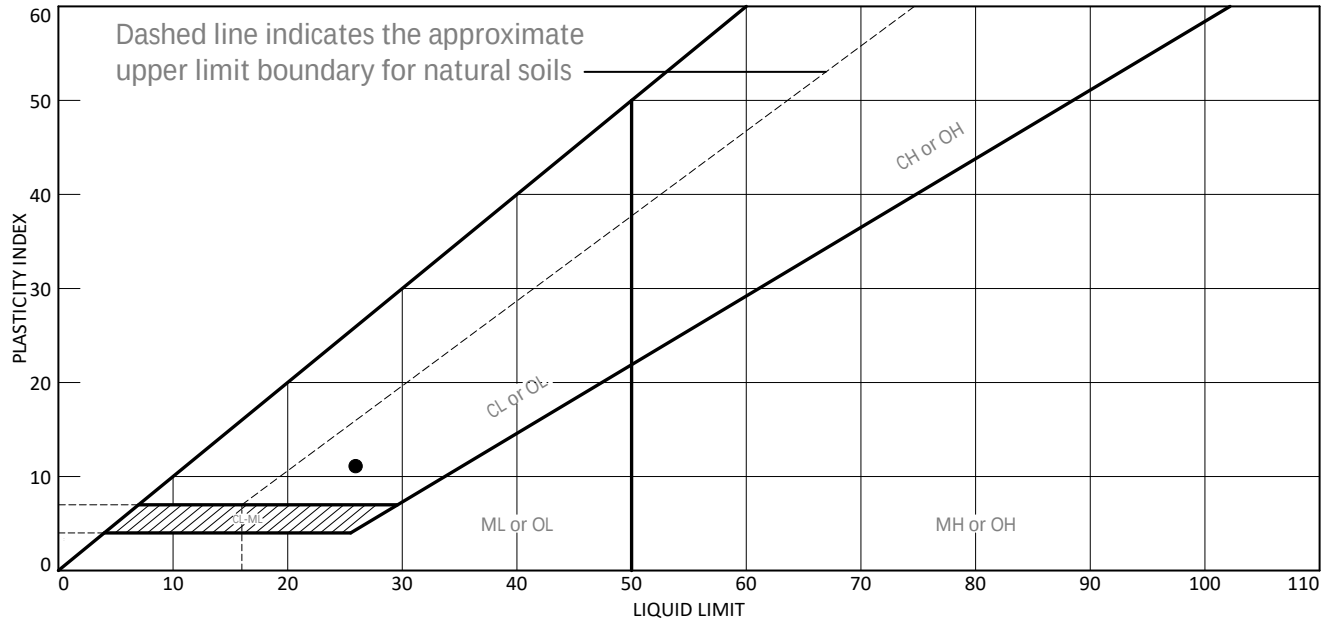
Figure 26-S-280

Tested By: AB

Checked By: Michael Collins

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LIQUID AND PLASTIC LIMITS TEST REPORT



MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
● Grey CLAY & SILT	26	15	11			

Project No. 09.0026237.01 Task 3 Client: GZA GeoEnvironmental, Inc.
Project: St. George River Bridge #5893
Union, ME
Source of Sample: Test Boring Depth: 16.3-18
Sample Number: BB-USGR-202,4D Bot8"

Thielsch Engineering Inc.

Cranston, RI

Remarks:

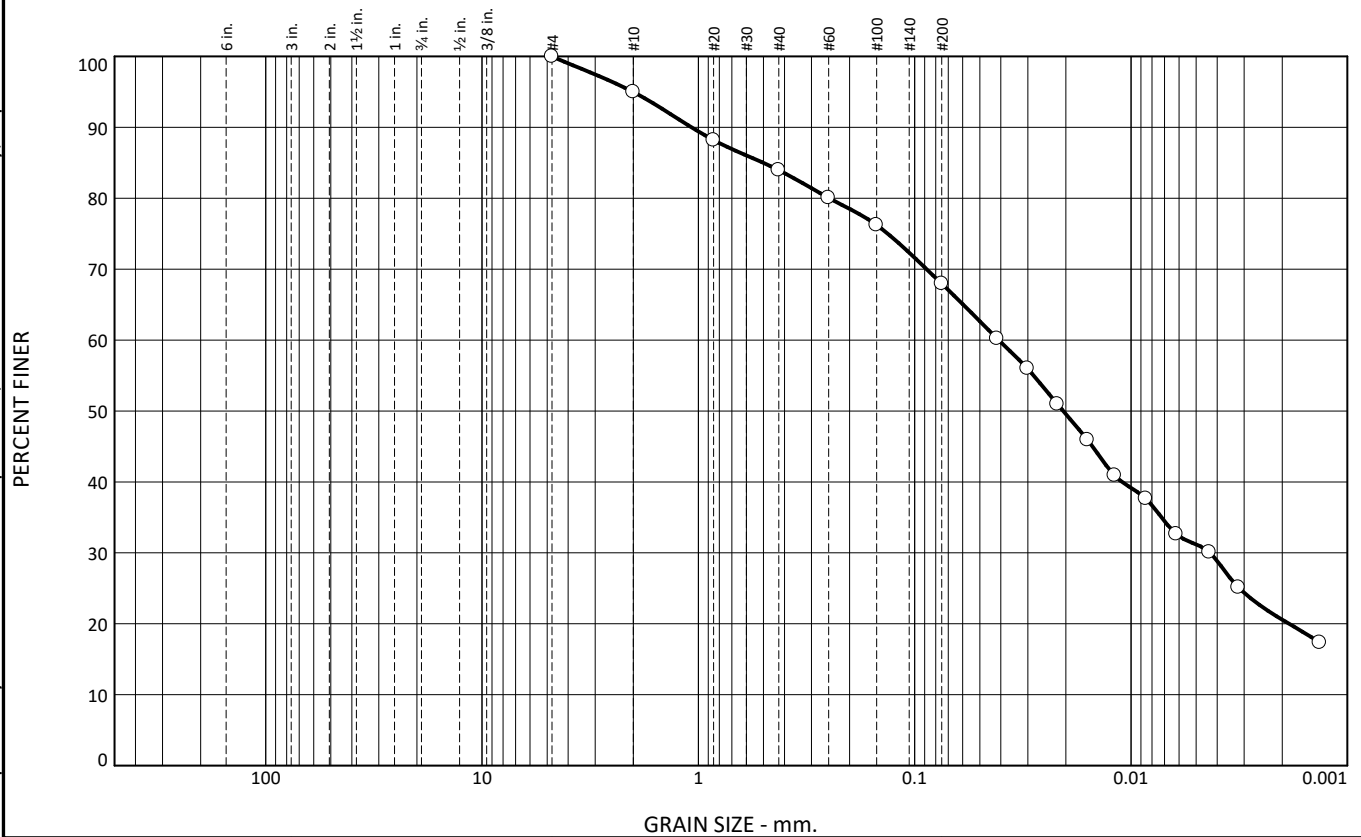
Figure 26-L-281

Tested By: SF

Checked By: Michael Collins

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Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	5.0	11.0	16.1	47.3	20.6

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	95.0		
#20	88.2		
#40	84.0		
#60	80.1		
#100	76.2		
#200	67.9		
0.0416 mm.	60.2		
0.0301 mm.	56.0		
0.0219 mm.	51.0		
0.0159 mm.	45.9		
0.0119 mm.	40.9		
0.0085 mm.	37.6		
0.0062 mm.	32.7		
0.0043 mm.	30.1		
0.0032 mm.	25.1		
0.0013 mm.	17.3		

* (no specification provided)

Soil Description
Grey SILT & CLAY, some f-c Sand

Atterberg Limits
PL= NP LL= NV PI= NP

Coefficients
D₉₀= 1.0749 D₈₅= 0.5013 D₆₀= 0.0409
D₅₀= 0.0206 D₃₀= 0.0043 D₁₅=
D₁₀= C_u= C_c=

Classification
USCS= ML AASHTO= A-4(0)

Remarks
Sample visually classified as plastic. Sample rolled to 1/8".

Source of Sample: Test Boring Depth: 21-23
Sample Number: BB-USGR-202, 5D

Date: 2.6.2026

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental, Inc.
Project: St. George River Bridge #5893
Union, ME

Project No: 09.0026237.01 Task 3

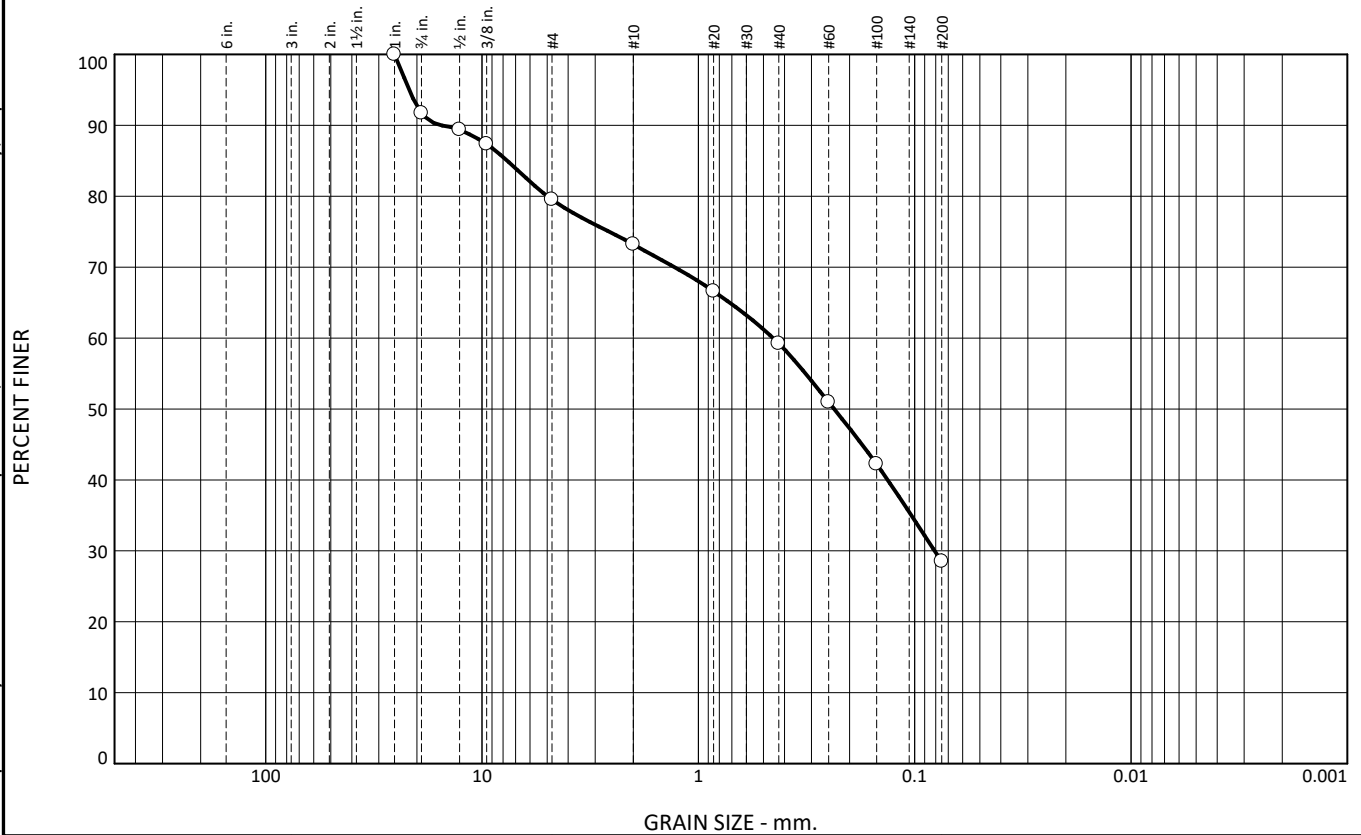
Figure 26-S-282

Tested By: BR

Checked By: Michael Collins

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Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	8.3	12.2	6.3	14.0	30.7	28.5	

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1"	100.0		
3/4"	91.7		
1/2"	89.4		
3/8"	87.4		
#4	79.5		
#10	73.2		
#20	66.6		
#40	59.2		
#60	51.0		
#100	42.2		
#200	28.5		

* (no specification provided)

Soil Description
Dark Grey f-c SAND, some Silt, some f-c Sand

PL= NP Atterberg Limits LL= NV PI= NP
D₉₀= 15.3963 D₈₅= 7.6375 D₆₀= 0.4516
D₅₀= 0.2358 D₃₀= 0.0809 D₁₅=
D₁₀= C_u= C_c=

USCS= SM Classification AASHTO= A-2-4(0)

Remarks

Source of Sample: Test Boring Depth: 31-33
Sample Number: BB-USGR-202, 6D

Date: 2.6.2026

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental, Inc.
Project: St. George River BRidge #5893
Union, Maine

Project No: 09.0026237.01 Task 3

Figure 26-S-283

Tested By: RB

Checked By: Michael Collins

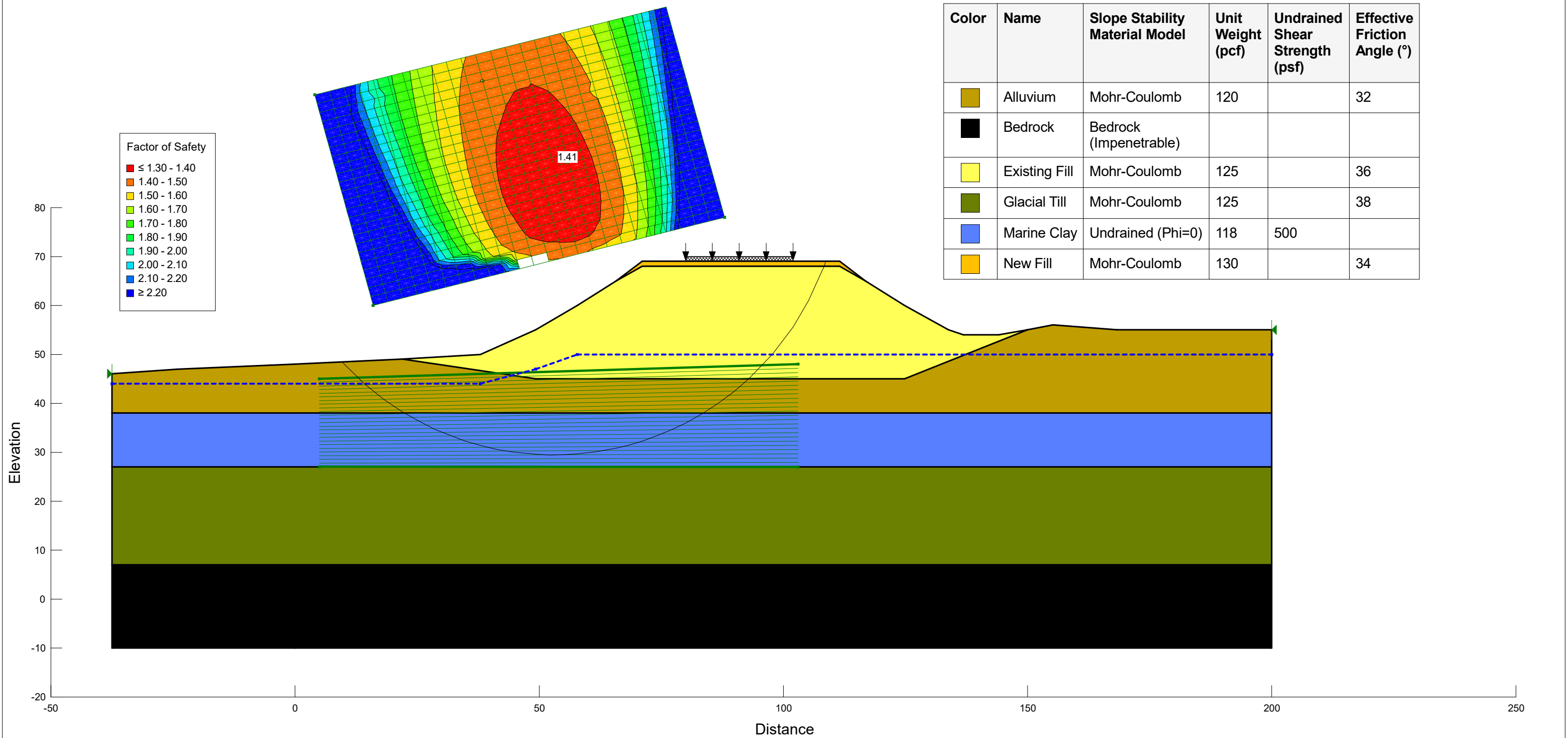


August 12, 2026

GEOTECHNICAL DESIGN REPORT
ST. GEORGE RIVER BRIDGE NO. 5893 - UNION
09.0026237.01

APPENDIX F – CALCULATIONS

Title: St George River Bridge
Date: 06/17/2026
File Name: Abutment 1 Section A-A.gsz
Name: Left Embankment,Kind: SLOPE/W,Analysis Type: Morgenstern-Price
Surcharge (Unit Weight): 250 pcf





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<http://www.gza.com>

*Engineers and
Scientists*

JOB: 09.0026237.01
SUBJECT: Pile Evaluation for Abut 1 Expansion
SHEET: 1 OF 9
CALCULATED BY J. Barnes 05/04/2026
CHECKED BY J. Keohane 05/05/2026

Integral Abutment LRFD Pile Design

Subject: Pile Design for the thermal expansion of the St. George River Bridge Replacement in Union, Maine at Abutment 1.

Reference:

- AASHTO LRFD Bridge Design Specifications, 10th Edition, 2024
- Maine BDG Chapter 5 - Substructures 2014
- VTRANS Integral Abutment Bridge Design Guidelines 2008

Design Steps - Maine BDG

Step 1 - Determine the foundation displacements and the load effects (P_u and M_u) from the superstructure and substructure designs.

$P_u := 386 \cdot \text{kip}$ Maximum Factored Axial Load from Stantec

Has increased to 400 kips, by inspection this will not change the conclusion of this calculation.

The limitations of the software require the plastic hinge evaluations be complete using a single deflection. Stantec provided a total deflection of 0.39 inches and no rotation.

Step 2 - If applicable, determine the magnitude of scour.

Analysis by others concludes that with additional detailing, scour is prevented.

Step 3 - Select preliminary pile size.

HP14 x 117 Weak Axis Properties

Steel yield strength	$F_y := 50 \text{ ksi}$
Modulus of elasticity for steel	$E := 29000 \text{ ksi}$
Cross sectional area of pile	$A_g := 34.4 \text{ in}^2$
Radius of gyration	$r_y := 3.59 \text{ in}$
Width of Flange	$b_f := 14.9 \text{ in}$
Thickness of Flange	$t_f := 0.805 \text{ in}$
Elastic Section Modulus	$S_y := 59.5 \text{ in}^3$
Plastic Section Modulus	$Z_y := 91.4 \text{ in}^3$

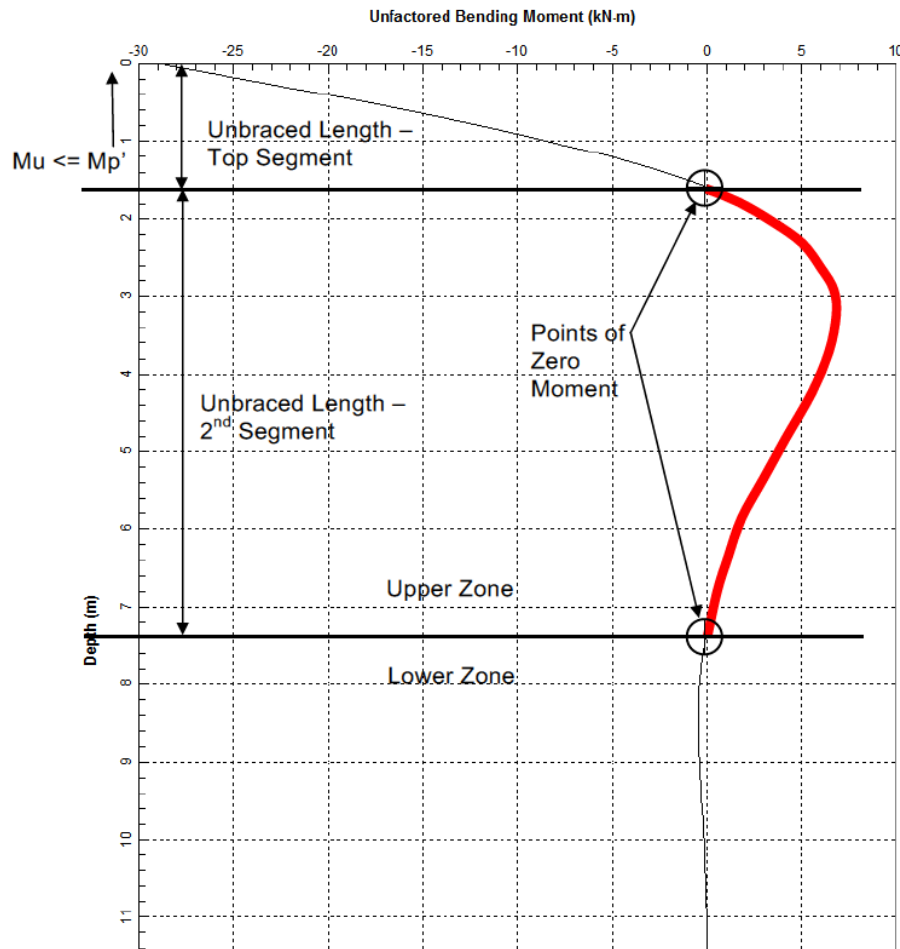
Step 4 - Determine the pile unbraced length and maximum moment at the top of the pile by running LPILE software for top translation = 0.39 inches and $P_u = 386 \text{ kip}$. No pile head rotation for Expansion case.



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SUBJECT: Pile Evaluation for Abut 1 Expansion
SHEET: 2 OF 9
CALCULATED BY J. Barnes 05/04/2026
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EXAMPLE FIGURE: NOT TAKEN FROM THIS ANALYSIS

Maximum moment from LPile output (page 40)

$$M_u := 4086 \text{ kip} \cdot \text{in} = 340.5 \cdot \text{kip} \cdot \text{ft}$$

Unbraced lengths from LPile output (pages 40-41)

Upper segment

$$L_1 := 2.6 \cdot \text{ft}$$

Lower segment

$$L_2 := 10.4 \cdot \text{ft}$$

Step 5 - Determine if the applied moment on the pile will cause pile head plastic deformation considering the interaction of combined axial and flexural load effects on a single pile (LRFD 6.9.2.2)

- Obtain the unbraced lengths of the top and lower segments of the pile and calculate the column slenderness factor (λ) for each segment.



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SHEET: 3 OF 9
CALCULATED BY J. Barnes 05/04/2026
CHECKED BY J. Keohane 05/05/2026

See previous page for unbraced lengths (critical lengths L_1 and L_2).

Upper segment slenderness factor

$$\lambda_1 := \frac{(L_1)}{r_y} = 8.7$$

Lower segment slenderness factor

$$\lambda_2 := \frac{(L_2)}{r_y} = 34.8$$

b. Determine K values for top and bottom of the pile per LRFD Table C4.6.2.5-1

	(a)	(b)	(c)	(d)	(e)	(f)
Buckled shape of column is shown by dashed line						
Theoretical K value	0.5	0.7	1.0	1.0	2.0	2.0
Design value of K when ideal conditions are approximated	0.65	0.80	1.0	1.2	2.1	2.0
End condition code						
		Rotation fixed	Rotation free	Translation fixed	Translation fixed	Translation fixed
		Rotation free	Rotation fixed	Translation free	Translation free	Translation free
		Rotation fixed	Rotation free	Translation fixed	Translation fixed	Translation fixed
		Rotation free	Rotation fixed	Translation free	Translation free	Translation free

Upper segment K value (Type d)

$$K_1 := 1.2$$

Lower segment K value (Type c)

$$K_2 := 1$$

c. Calculate the nominal and factored structural pile resistance P_n , per AASHTO LRFD 6.9.4.1 using the λ values



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 SHEET: 4 OF 9
 CALCULATED BY J. Barnes 05/04/2026
 CHECKED BY J. Keohane 05/05/2026

Elastic critical buckling resistance, P_e , based on flexural buckling (AASHTO LRFD Eq. 6.9.4.1.2-1)

$$\text{Upper } P_e \quad P_{e1} := \frac{(\pi^2 \cdot E) \cdot A_g}{(K_1 \cdot \lambda_1)^2} = 90526 \cdot \text{kip}$$

$$\text{Lower } P_e \quad P_{e2} := \frac{(\pi^2 \cdot E) \cdot A_g}{(K_2 \cdot \lambda_2)^2} = 8147 \cdot \text{kip}$$

$$\text{Nominal yield resistance, } P_o \quad P_o := F_{y50} \cdot A_g = 1720 \cdot \text{kip}$$

Check that the ratio of P_e to P_o is > 0.44

If $P_e/P_o > 0.44$ then use AASHTO LRFD Eq. 6.9.4.1.1-1

If $P_e/P_o < 0.44$ then use AASHTO LRFD Eq. 6.9.4.1.1-2

$$P_n = \left[0.658^{\left(\frac{P_o}{P_e} \right)} \right] P_o \quad (6.9.4.1.1-1)$$

$$P_n = 0.877 P_e \quad (6.9.4.1.1-2)$$

$$\frac{P_{e1}}{P_o} = 52.631 \quad \frac{P_{e2}}{P_o} = 4.737$$

Both ratios are greater than 0.44, therefore, use AASHTO LRFD Eq. 6.9.4.1.1-1: Nominal structural axial Pile resistance, P_n for both segments

$$P_{n1} := \left[0.658^{\left(\frac{P_o}{P_{e1}} \right)} \right] \cdot P_o = 1706 \cdot \text{kip}$$

$$P_{n2} := \left[0.658^{\left(\frac{P_o}{P_{e2}} \right)} \right] \cdot P_o = 1575 \cdot \text{kip}$$



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JOB: 09.0026237.01
 SUBJECT: Pile Evaluation for Abut 1 Expansion
 SHEET: 5 OF 9
 CALCULATED BY J. Barnes 05/04/2026
 CHECKED BY J. Keohane 05/05/2026

Factored structural axial Pile Resistance, $P_r = \phi_c (P_n)$

$$\phi_c := 0.7 \quad \text{for axial resistance according to AASHTO LRFD 6.5.4.2}$$

$$P_{r1} := \phi_c \cdot P_{n1} = 1194.5 \cdot \text{kip}$$

$$P_{r2} := \phi_c \cdot P_{n2} = 1.1 \times 10^3 \cdot \text{kip}$$

d. Compare the ratio of P_u , the maximum factored axial load, to P_r , the structural resistance in the specified portion of the pile - the pile size should be such that the ratio is not less than 0.20.

Check for both segments

$$\frac{P_u}{P_{r1}} = 0.323 > 0.20, \text{ OK} \quad \frac{P_u}{P_{r2}} = 0.35 > 0.20, \text{ OK}$$

e. Determine the nominal and factored flexural resistance about H-Pile weak axis, (AASHTO LRFD Eq. 6.12.2.2)

Check slenderness ratio for flange, limiting slenderness ratio for compact flange, and limiting slenderness ratio for a noncompact flange.

$$\lambda_f := \frac{b_f}{2 \cdot t_f} = 9.255 \quad \text{slenderness ratio for flange (AASHTO LRFD Eq. 6.12.2.2.1-3)}$$

$$\lambda_{pf} := 0.38 \cdot \left(\frac{E}{F_{y50}} \right)^{.5} = 9.152$$

$$\lambda_{rf} := 0.83 \cdot \left(\frac{E}{F_{y50}} \right)^{.5} = 19.989$$

If $\lambda_{pf} < \lambda_f < \lambda_{rf}$ Use AASHTO LRFD Eq. 6.12.2.2.1-2 to find the nominal flexural resistance

$$M_n := \left[1 - \left(1 - \frac{S_y}{Z_y} \right) \cdot \left[\frac{\lambda_f - \lambda_{pf}}{0.45 \cdot \left(\frac{E}{F_{y50}} \right)^{.5}} \right] \right] \cdot F_{y50} \cdot Z_y = 379.57 \cdot \text{ft} \cdot \text{kip}$$



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JOB: 09.0026237.01
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 SHEET: 6 OF 9
 CALCULATED BY J. Barnes 05/04/2026
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$\phi_f := 1.0$ for flexural resistance according to AASHTO LRFD 6.5.4.2

$$M_r := M_n \cdot \phi_f = 379.6 \cdot \text{ft} \cdot \text{kip}$$

$$M_u = 340.5 \cdot \text{ft} \cdot \text{kip}$$

$$\frac{P_u}{P_{r1}} + \frac{8}{9} \cdot \frac{M_u}{M_r} = 1.12$$

If less than 1, remains in elastic zone. Since it exceeds 1, yielding is expected at the base of the pile cap.

f. Calculate the moment that will cause a plastic hinge at the top of the pile, M_p' ,

Note: M_p' will be lower than M_n due to the inclusion of the axial load in the interaction equation for pile overstresses

$$\frac{P_u}{P_r} + \frac{8.0}{9.0} \left(\frac{M_{ux}}{M_{rx}} + \frac{M_{uy}}{M_{ry}} \right) \leq 1.0$$

AASHTO LRFD Eq. 6.9.2.2 Interaction equation

Use the interaction equation to find the moment that will cause a plastic hinge at the top of the pile. Assume M_{ux} and $M_{rx} = 0$ (out-of-plane), $M_{ry} = M_r$ and $M_u = M_p'$, solve for M_p'

$$M_p' := \left(\frac{9}{8} \right) \cdot \left[1 - \left(\frac{P_u}{P_{r1}} \right) \right] \cdot M_r = 289 \cdot \text{ft} \cdot \text{kip} \quad M_p = 3468.3 \cdot \text{in} \cdot \text{kip}$$

g. The calculated moment from LPILE Run 1 (shown in step 4) exceeds the moment that would cause a plastic hinge (above), therefore a plastic hinge forms, and the moment (M_p') represents the limiting moment reaction at the pile top for the subsequent analysis.

Step 6 - For fixed head piles, run a second LPILE analysis with end conditions 1) Top moment = M_p' , top translation = 0.39 in; and axial load equal to P_u . Recalculate unbraced lengths from the moment vs. depth curve.



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JOB: 09.0026237.01
 SUBJECT: Pile Evaluation for Abut 1 Expansion
 SHEET: 7 OF 9
 CALCULATED BY J. Barnes 05/04/2026
 CHECKED BY J. Keohane 05/05/2026

New unbraced lengths were determined from the second LPILE analysis

Upper segment $L_{1p} := 2.3 \cdot \text{ft}$

Lower segment $L_{2p} := 10.7 \cdot \text{ft}$

6a. Repeat steps 5a through 5d above.

6b- If the pile size is such that the ratio of P_u to structural resistance exceeds 0.2, check the upper segment of the pile with the interaction equation of AASHTO LRFD Eq. 6.9.2.2. If a plastic hinge forms at the top of the pile, the K value of the upper segment changes from 1.2, for a rotation fixed head condition, to 2.1, for a rotation free head condition. With the new K value and lengths repeat step 5.

5a.

Upper segment slenderness factor $\lambda_{1p} := \frac{(L_{1p})}{r_y} = 7.688$

Lower segment slenderness factor $\lambda_{2p} := \frac{(L_{2p})}{r_y} = 35.766$

5b.

Upper segment K value (Type e) $K_{1p} := 2.1$

Lower segment K value (Type c) $K_{2p} := 1$

5c. Elastic critical buckling resistance, P_e based on flexural buckling

Upper P_e $P_{ep1} := \frac{(\pi^2 \cdot E) \cdot A_g}{(K_{1p} \cdot \lambda_{1p})^2} = 37774 \cdot \text{kip}$

Lower P_e $P_{ep2} := \frac{(\pi^2 \cdot E) \cdot A_g}{(K_{2p} \cdot \lambda_{2p})^2} = 7697 \cdot \text{kip}$

Nominal yield resistance, P_o $P_o := F_{y50} \cdot A_g = 1720 \cdot \text{kip}$



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JOB: 09.0026237.01
 SUBJECT: Pile Evaluation for Abut 1 Expansion
 SHEET: 8 OF 9
 CALCULATED BY J. Barnes 05/04/2026
 CHECKED BY J. Keohane 05/05/2026

Check that the ratio of P_e to P_o is > 0.44

If $P_e/P_o > 0.44$ then use equation 6.9.4.1.1-1

If $P_e/P_o < 0.44$ then use equation 6.9.4.1.1-2

$$\frac{P_{ep1}}{P_o} = 21.961 \quad \frac{P_{ep2}}{P_o} = 4.475$$

Both ratios are greater than 0.44, therefore, use eq. 6.9.4.1.1-1: Nominal structural Pile resistance, P_n for both segments

$$P_{np1} := \left[0.658 \left(\frac{P_o}{P_{ep1}} \right) \right] \cdot P_o = 1688 \cdot \text{kip}$$

$$P_{np2} := \left[0.658 \left(\frac{P_o}{P_{ep2}} \right) \right] \cdot P_o = 1566 \cdot \text{kip}$$

Factored structural Pile Resistance, $P_r = \phi_c (P_n)$

$$P_{rp1} := \phi_c \cdot P_{np1} = 1181.3 \cdot \text{kip}$$

$$P_{rp2} := \phi_c \cdot P_{np2} = 1.1 \times 10^3 \cdot \text{kip}$$

5d. Compare the ratio of P_u to the structural resistance in the upper portion of the pile - the pile size should be such that the ratio is not less than 0.20.

Check for both segments

$$\frac{P_u}{P_{rp1}} = 0.327 \quad > 0.20, \text{ OK} \quad \frac{P_u}{P_{rp2}} = 0.352 \quad > 0.20, \text{ OK}$$

From VTrans Integral Abutment Design Section 4.5.2 - Check the axial capacity of the upper segment and the interaction equation for the second segment to assess suitability of pile section.

Upper Segment

Check that P_u/P_{rp1} is < 1

$$\frac{P_u}{P_{rp1}} = 0.327 \quad < 1, \text{ OK}$$



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JOB: 09.0026237.01
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SHEET: 9 OF 9
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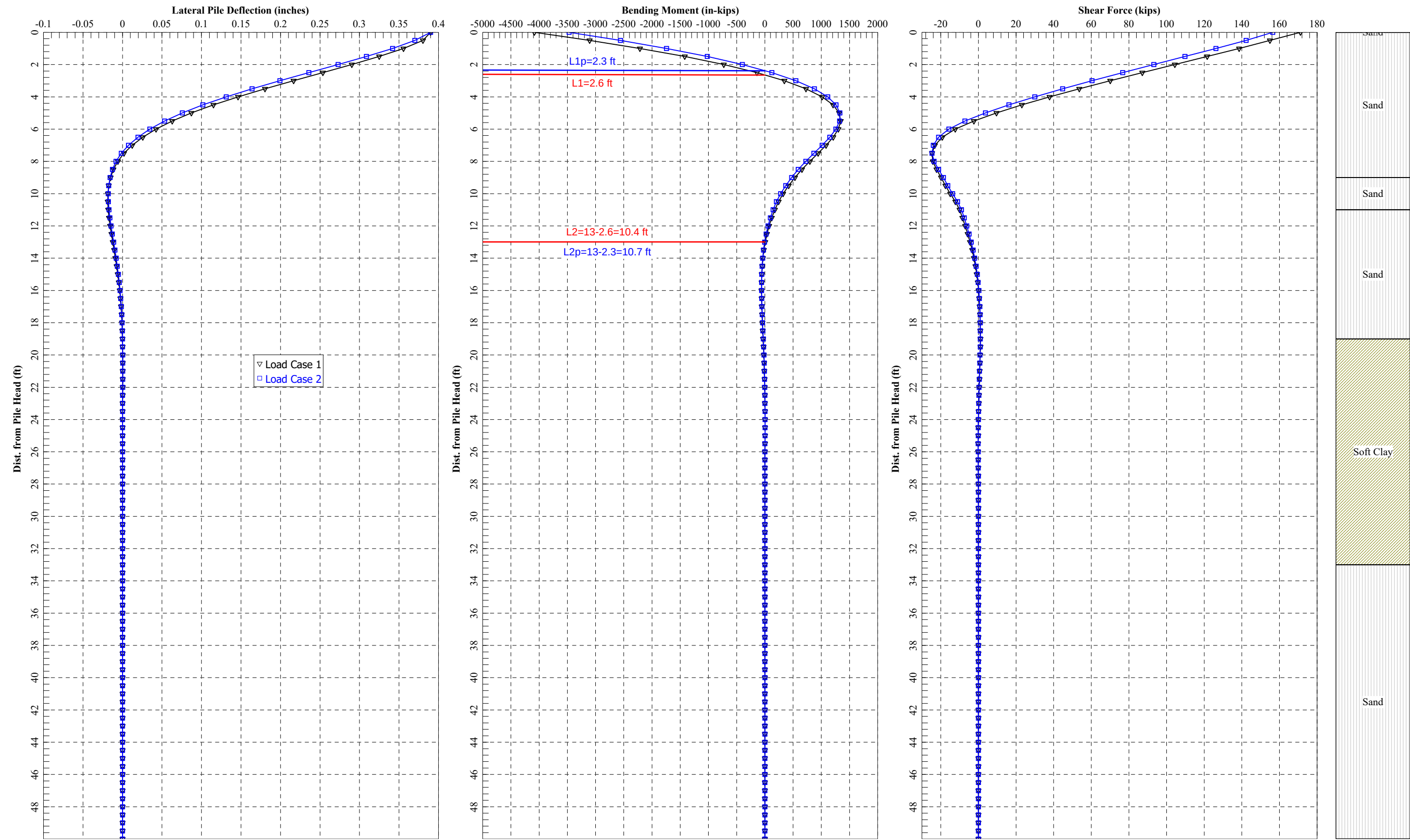
Lower Segment

Ultimate moment along the lower segment from LPile output

$$M_{\max p2} := 1330 \cdot \text{in} \cdot \text{kip}$$

$$\frac{P_u}{P_{rp2}} + \frac{8}{9} \cdot \frac{M_{\max p2}}{M_r} = 0.61 \quad < 1, \text{OK}$$

Abutment 1 - Expansion Case



=====

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Analysis of Individual Piles and Drilled Shafts
Subjected to Lateral Loading Using the p-y Method
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=====

This model was prepared by:
Alec.Stanley

Files Used for Analysis

Path to file locations:
\\09\09 Jobs\0026200s\09.0026237.00 - Stantec Union Bridge\01 - Final Design\Work\Calcs\Lpile\Abutment 1\Expansion\

Name of input data file:
Abutment 1 Expansion.lp12d

Name of output report file:
Abutment 1 Expansion.lp12o

Name of plot output file:
Abutment 1 Expansion.lp12p

Name of runtime message file:
Abutment 1 Expansion.lp12r

Date and Time of Analysis

Date: June 18, 2026 Time: 9:44:07

Problem Title

Project Name: St. George River Bridge, Union, Maine

Job Number: 09.0026237.01

Client: Stantec

Engineer: Jason Barnes

Description: Abutment 1 Expansion

Program Options and Settings

Computational Options:

- Conventional Analysis

Engineering Units Used for Data Input and Computations:

- US Customary System Units (pounds, feet, inches)

Analysis Control Options:

- | | | |
|--|---|---------------|
| - Maximum number of iterations allowed | = | 500 |
| - Deflection tolerance for convergence | = | 1.0000E-05 in |
| - Maximum allowable deflection | = | 100.0000 in |
| - Number of pile increments | = | 100 |

Loading Type and Number of Cycles of Loading:

- Static loading specified
- Use of p-y modification factors for p-y curves not selected
- Analysis uses layering correction (Method of Georgiadis)
- No distributed lateral loads are entered
- Loading by lateral soil movements acting on pile not selected
- Input of shear resistance at the pile tip not selected
- Input of moment resistance at the pile tip not selected
- Computation of pile-head foundation stiffness matrix not selected
- Push-over analysis of pile not selected
- Buckling analysis of pile not selected

Output Options:

- Output files use decimal points to denote decimal symbols.
- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (nodal spacing of output points) = 1
- No p-y curves to be computed and reported for user-specified depths
- Print using wide report formats

Pile Structural Properties and Geometry

- | | | |
|---------------------------------|---|-----------|
| Number of pile sections defined | = | 1 |
| Total length of pile | = | 50.000 ft |

Depth of ground surface below top of pile = -11.0000 ft

Pile diameters used for p-y curve computations are defined using 2 points.

p-y curves are computed using pile diameter values interpolated with depth over the length of the pile. A summary of values of pile diameter vs. depth follows.

Point No.	Depth Below Pile Head feet	Pile Diameter inches
-----	-----	-----
1	0.000	14.9000
2	50.000	14.9000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is a H weak axis steel pile
Length of section = 50.000000 ft
Pile width = 14.200000 in

Soil and Rock Layering Information

The soil profile is modelled using 6 layers

Layer 1 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = -11.00000 ft
Distance from top of pile to bottom of layer = 0.0000 ft
Effective unit weight at top of layer = 125.000000 pcf
Effective unit weight at bottom of layer = 125.000000 pcf
Friction angle at top of layer = 32.000000 deg.
Friction angle at bottom of layer = 32.000000 deg.
Subgrade k at top of layer = 83.000000 pci
Subgrade k at bottom of layer = 83.000000 pci

Layer 2 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 0.0000 ft
Distance from top of pile to bottom of layer = 9.000000 ft
Effective unit weight at top of layer = 125.000000 pcf
Effective unit weight at bottom of layer = 125.000000 pcf
Friction angle at top of layer = 36.000000 deg.
Friction angle at bottom of layer = 36.000000 deg.
Subgrade k at top of layer = 164.000000 pci
Subgrade k at bottom of layer = 164.000000 pci

Layer 3 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer	=	9.000000 ft
Distance from top of pile to bottom of layer	=	11.000000 ft
Effective unit weight at top of layer	=	62.600000 pcf
Effective unit weight at bottom of layer	=	62.600000 pcf
Friction angle at top of layer	=	36.000000 deg.
Friction angle at bottom of layer	=	36.000000 deg.
Subgrade k at top of layer	=	97.000000 pci
Subgrade k at bottom of layer	=	97.000000 pci

Layer 4 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer	=	11.000000 ft
Distance from top of pile to bottom of layer	=	19.000000 ft
Effective unit weight at top of layer	=	57.600000 pcf
Effective unit weight at bottom of layer	=	57.600000 pcf
Friction angle at top of layer	=	32.000000 deg.
Friction angle at bottom of layer	=	32.000000 deg.
Subgrade k at top of layer	=	55.000000 pci
Subgrade k at bottom of layer	=	55.000000 pci

Layer 5 is soft clay, p-y criteria by Matlock, 1970

Distance from top of pile to top of layer	=	19.000000	ft
Distance from top of pile to bottom of layer	=	33.000000	ft
Effective unit weight at top of layer	=	47.600000	pcf
Effective unit weight at bottom of layer	=	47.600000	pcf
Undrained cohesion at top of layer	=	500.000000	psf
Undrained cohesion at bottom of layer	=	500.000000	psf
Epsilon-50 at top of layer	=	0.010000	
Epsilon-50 at bottom of layer	=	0.010000	

Layer 6 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer	=	33.000000 ft
Distance from top of pile to bottom of layer	=	50.000000 ft
Effective unit weight at top of layer	=	67.600000 pcf
Effective unit weight at bottom of layer	=	67.600000 pcf
Friction angle at top of layer	=	38.000000 deg.
Friction angle at bottom of layer	=	38.000000 deg.
Subgrade k at top of layer	=	120.000000 pci
Subgrade k at bottom of layer	=	120.000000 pci

(Depth of the lowest soil layer extends 0.000 ft below the pile tip)

Summary of Input Soil Properties

[illegible]

1	Sand	-11.000	125.0000	--	32.0000	--	83.0000
	(Reese, et al.)	0.00	125.0000	--	32.0000	--	83.0000
2	Sand	0.00	125.0000	--	36.0000	--	164.0000
	(Reese, et al.)	9.0000	125.0000	--	36.0000	--	164.0000
3	Sand	9.0000	62.6000	--	36.0000	--	97.0000
	(Reese, et al.)	11.0000	62.6000	--	36.0000	--	97.0000
4	Sand	11.0000	57.6000	--	32.0000	--	55.0000
	(Reese, et al.)	19.0000	57.6000	--	32.0000	--	55.0000
5	Soft	19.0000	47.6000	500.0000	--	0.01000	--
	Clay	33.0000	47.6000	500.0000	--	0.01000	--
6	Sand	33.0000	67.6000	--	38.0000	--	120.0000
	(Reese, et al.)	50.0000	67.6000	--	38.0000	--	120.0000

Static Loading Type

Static loading criteria were used when computing p-y curves for all analyses.

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 2

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length	Run Analysis
1	5	y = 0.390000 in	S = 0.0000 in/in	386000.	N.A.	Yes
2	4	y = 0.390000 in	M = -3468300. in-lbs	386000.	N.A.	Yes

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Dimensions and Properties of Steel H Weak Axis:

Length of Section = 50.000000 ft
Flange Width = 14.900000 in
Section Depth = 14.200000 in
Flange Thickness = 0.805000 in
Web Thickness = 0.805000 in
Yield Stress of Pipe = 50.000000 ksi
Elastic Modulus = 29000. ksi
Cross-sectional Area = 34.123950 sq. in.
Moment of Inertia = 444.363799 in^4
Elastic Bending Stiffness = 12886550. kip-in^2
Plastic Modulus, Z = 91.398684in^3
Plastic Moment Capacity = Fy Z = 4570.in-kip

Axial Structural Capacities:

Nom. Axial Structural Capacity = Fy As = 1706.197 kips
Nominal Axial Tensile Capacity = -1706.197 kips

Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

Number	Axial Thrust Force kips
-----	-----
1	386.000

Definition of Run Messages:

Y = part of pipe section has yielded.

Axial Thrust Force = 386.000 kips

Bending Curvature rad/in.	Bending Moment in-kip	Bending Stiffness kip-in2	Depth to N Axis in	Max Total Stress ksi	Run Msg
-----	-----	-----	-----	-----	----
0.00000447	57.6462319	12886018.	94.6422382	12.2685485	
0.00000895	115.2924638	12886018.	51.0461191	13.2253936	
0.00001342	172.9386957	12886018.	36.5140794	14.1822388	
0.00001789	230.5849276	12886018.	29.2480595	15.1390839	
0.00002237	288.2311595	12886018.	24.8884476	16.0959290	
0.00002684	345.8773914	12886018.	21.9820397	17.0527742	
0.00003131	403.5236233	12886018.	19.9060340	18.0096193	
0.00003579	461.1698552	12886018.	18.3490298	18.9664645	
0.00004026	518.8160871	12886018.	17.1380265	19.9233096	
0.00004474	576.4623190	12886018.	16.1692238	20.8801547	
0.00004921	634.1085509	12886018.	15.3765671	21.8369998	
0.00005368	691.7547828	12886018.	14.7160198	22.7938450	
0.00005816	749.4010147	12886018.	14.1570952	23.7506902	
0.00006263	807.0472466	12886018.	13.6780170	24.7075353	
0.00006710	864.6934785	12886018.	13.2628159	25.6643804	
0.00007158	922.3397104	12886018.	12.8995149	26.6212255	
0.00007605	979.9859423	12886018.	12.5789552	27.5780707	

0.00008052	1038.	12886018.	12.2940132	28.5349159
0.00008500	1095.	12886018.	12.0390652	29.4917610
0.00008947	1153.	12886018.	11.8096119	30.4486061
0.00009394	1211.	12886018.	11.6020113	31.4054512
0.00009842	1268.	12886018.	11.4132836	32.3622964
0.0001029	1326.	12886018.	11.2409669	33.3191415
0.0001074	1384.	12886018.	11.0830099	34.2759867
0.0001118	1441.	12886018.	10.9376895	35.2328318
0.0001163	1499.	12886018.	10.8035476	36.1896769
0.0001208	1556.	12886018.	10.6793422	37.1465221
0.0001253	1614.	12886018.	10.5640085	38.1033672
0.0001297	1672.	12886018.	10.4566289	39.0602124
0.0001342	1729.	12886018.	10.3564079	40.0170575
0.0001387	1787.	12886018.	10.2626528	40.9739027
0.0001432	1845.	12886018.	10.1747574	41.9307478
0.0001476	1902.	12886018.	10.0921890	42.8875929
0.0001521	1960.	12886018.	10.0144776	43.8444381
0.0001566	2018.	12886018.	9.9412068	44.8012832
0.0001610	2075.	12886018.	9.8720066	45.7581283
0.0001655	2133.	12886018.	9.8065470	46.7149735
0.0001700	2191.	12886018.	9.7445326	47.6718186
0.0001745	2248.	12886018.	9.6856984	48.6286637
0.0001834	2363.	12880749.	9.5773618	50.0000000 Y
0.0001924	2470.	12840834.	9.4840016	50.0000000 Y
0.0002013	2570.	12768566.	9.4041633	50.0000000 Y
0.0002103	2665.	12673800.	9.3354859	50.0000000 Y
0.0002192	2754.	12562505.	9.2762732	50.0000000 Y
0.0002282	2838.	12438357.	9.2252878	50.0000000 Y
0.0002371	2918.	12306445.	9.1811140	50.0000000 Y
0.0002460	2994.	12169194.	9.1428293	50.0000000 Y
0.0002550	3067.	12028124.	9.1097379	50.0000000 Y
0.0002639	3137.	11885299.	9.0810754	50.0000000 Y
0.0002729	3204.	11742499.	9.0561571	50.0000000 Y
0.0002818	3269.	11599906.	9.0346493	50.0000000 Y
0.0002908	3332.	11458160.	9.0161572	50.0000000 Y
0.0002997	3391.	11315153.	8.9995889	50.0000000 Y
0.0003087	3446.	11165153.	8.9834339	50.0000000 Y
0.0003176	3497.	11010132.	8.9676295	50.0000000 Y
0.0003266	3544.	10851774.	8.9521181	50.0000000 Y
0.0003355	3587.	10691278.	8.9368150	50.0000000 Y
0.0003445	3627.	10529443.	8.9220161	50.0000000 Y
0.0003534	3664.	10367974.	8.9074630	50.0000000 Y
0.0003624	3699.	10207487.	8.8930399	50.0000000 Y
0.0003713	3731.	10048587.	8.8788483	50.0000000 Y
0.0003803	3761.	9891088.	8.8651582	50.0000000 Y
0.0003892	3789.	9736626.	8.8515813	50.0000000 Y
0.0003981	3816.	9584692.	8.8384468	50.0000000 Y
0.0004071	3841.	9435131.	8.8254390	50.0000000 Y
0.0004160	3864.	9288415.	8.8125282	50.0000000 Y
0.0004250	3886.	9144891.	8.8001206	50.0000000 Y
0.0004339	3907.	9004567.	8.7877958	50.0000000 Y
0.0004429	3927.	8866737.	8.7756499	50.0000000 Y
0.0004518	3946.	8732758.	8.7639374	50.0000000 Y
0.0004608	3963.	8601248.	8.7520754	50.0000000 Y
0.0004697	3980.	8472925.	8.7407916	50.0000000 Y
0.0004787	3996.	8347887.	8.7293769	50.0000000 Y
0.0004876	4011.	8225455.	8.7184233	50.0000000 Y
0.0004966	4025.	8106088.	8.7075862	50.0000000 Y

0.0005055	4039.	7989935.	8.6967283	50.0000000	Y
0.0005145	4052.	7875951.	8.6863676	50.0000000	Y
0.0005234	4064.	7765141.	8.6761208	50.0000000	Y
0.0005324	4076.	7656911.	8.6657339	50.0000000	Y
0.0005681	4119.	7249468.	8.6267508	50.0000000	Y
0.0006039	4155.	6879165.	8.5901242	50.0000000	Y
0.0006397	4185.	6542344.	8.5560686	50.0000000	Y
0.0006755	4211.	6234472.	8.5236973	50.0000000	Y
0.0007113	4234.	5953047.	8.4930774	50.0000000	Y
0.0007471	4255.	5694837.	8.4642335	50.0000000	Y
0.0007829	4272.	5457235.	8.4371145	50.0000000	Y
0.0008187	4288.	5238005.	8.4111949	50.0000000	Y
0.0008544	4302.	5034908.	8.3865498	50.0000000	Y
0.0008902	4315.	4846683.	8.3632788	50.0000000	Y
0.0009260	4327.	4672143.	8.3410937	50.0000000	Y
0.0009618	4337.	4508710.	8.3199547	50.0000000	Y
0.0009976	4346.	4356518.	8.2999221	50.0000000	Y

Summary of Results for Nominal Moment Capacity for Section 1

Load No.	Axial Thrust kips	Nominal Moment Capacity in-kips
----	-----	-----
1	386.0000000000	4346.

Note that the values in the above table are not factored by a strength reduction factor for LRFD.

The value of the strength reduction factor depends on the provisions of the LRFD code being followed.

The above values should be multiplied by the appropriate strength reduction factor to compute ultimate moment capacity according to the LRFD structural design standard being followed.

Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
----	-----	-----	-----	-----	-----	-----
1	-11.000	0.00	N.A.	No	0.00	140819.
2	0.00	9.7688	Yes	No	140819.	738325.
3	9.0000	18.7675	Yes	No	879145.	291114.
4	11.0000	24.2868	Yes	No	1170259.	919748.

5	19.0000	377.3376	No	No	2090006.	78225.
6	33.0000	27.5424	No	No	2168231.	N.A.

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays, non-liquefied sands, and cemented c-phi soil.

Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 1

Pile-head conditions are Displacement and Pile-head Rotation (Loading Type 5)
Displacement of pile head = 0.390000 inches
Rotation of pile head = 0.000E+00 radians
Axial load on pile head = 386000.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/inch	Soil Spr. Es*H lb/inch	Distrib. Lat. Load lb/inch
0.00	0.3900	-4085689.	171126.	0.00	79810.	7.56E+09	-2098.	16138.	0.00
0.5000	0.3803	-3104187.	154940.	-0.00285	63355.	7.56E+09	-2673.	42169.	0.00
1.0000	0.3557	-2213189.	138551.	-0.00460	48417.	1.29E+10	-2790.	47063.	0.00
1.5000	0.3250	-1420259.	121602.	-0.00545	35123.	1.29E+10	-2859.	52780.	0.00
2.0000	0.2904	-728730.	104377.	-0.00595	23529.	1.29E+10	-2882.	59559.	0.00
2.5000	0.2537	-140180.	87135.	-0.00615	13662.	1.29E+10	-2865.	67767.	0.00
3.0000	0.2166	345384.	70118.	-0.00610	17102.	1.29E+10	-2807.	77785.	0.00
3.5000	0.1804	729507.	53586.	-0.00585	23542.	1.29E+10	-2703.	89898.	0.00
4.0000	0.1463	1015526.	37814.	-0.00545	28338.	1.29E+10	-2554.	104727.	0.00
4.5000	0.1151	1208507.	23065.	-0.00493	31573.	1.29E+10	-2362.	123190.	0.00
5.0000	0.08718	1315139.	9583.	-0.00434	33361.	1.29E+10	-2132.	146705.	0.00
5.5000	0.06297	1343616.	-2404.	-0.00372	33838.	1.29E+10	-1864.	177640.	0.00
6.0000	0.04251	1303532.	-12263.	-0.00311	33166.	1.29E+10	-1422.	200736.	0.00
6.5000	0.02570	1210842.	-19185.	-0.00252	31612.	1.29E+10	-884.943	206640.	0.00
7.0000	0.01226	1084988.	-23143.	-0.00199	29502.	1.29E+10	-434.405	212544.	0.00
7.5000	0.00186	942326.	-24650.	-0.00151	27110.	1.29E+10	-67.792	218448.	0.00
8.0000	-0.00591	796207.	-24190.	-0.00111	24661.	1.29E+10	220.8530	224352.	0.00
8.5000	-0.01145	657180.	-22210.	-7.71E-04	22330.	1.29E+10	439.4229	230256.	0.00
9.0000	-0.01516	533264.	-19833.	-4.94E-04	20252.	1.29E+10	352.8903	139680.	0.00
9.5000	-0.01738	421477.	-17530.	-2.72E-04	18378.	1.29E+10	414.6448	143172.	0.00
10.0000	-0.01842	324163.	-14935.	-9.80E-05	16746.	1.29E+10	450.1987	146664.	0.00
10.5000	-0.01855	242706.	-12192.	3.40E-05	15381.	1.29E+10	464.3000	150156.	0.00
11.0000	-0.01801	177702.	-10015.	1.32E-04	14291.	1.29E+10	261.5023	87120.	0.00
11.5000	-0.01697	121920.	-8474.	2.02E-04	13356.	1.29E+10	252.0112	89100.	0.00
12.0000	-0.01559	75080.	-7008.	2.47E-04	12570.	1.29E+10	236.6635	91080.	0.00
12.5000	-0.01400	36678.	-5647.	2.73E-04	11927.	1.29E+10	217.1519	93060.	0.00
13.0000	-0.01231	6055.	-4410.	2.83E-04	11413.	1.29E+10	194.9679	95040.	0.00
13.5000	-0.01060	-17557.	-3311.	2.81E-04	11606.	1.29E+10	171.3935	97020.	0.00
14.0000	-0.00894	-34979.	-2354.	2.69E-04	11898.	1.29E+10	147.5005	99000.	0.00
14.5000	-0.00738	-47053.	-1539.	2.49E-04	12101.	1.29E+10	124.1564	100980.	0.00
15.0000	-0.00595	-54607.	-860.855	2.26E-04	12227.	1.29E+10	102.0370	102960.	0.00
15.5000	-0.00467	-58429.	-309.819	1.99E-04	12291.	1.29E+10	81.6414	104940.	0.00

16.0000	-0.00355	-59249.	125.0379	1.72E-04	12305.	1.29E+10	63.3110	106920.	0.00
16.5000	-0.00260	-57726.	456.7178	1.45E-04	12280.	1.29E+10	47.2489	108900.	0.00
17.0000	-0.00181	-54439.	699.0859	1.19E-04	12224.	1.29E+10	33.5404	110880.	0.00
17.5000	-0.00118	-49887.	866.2245	9.44E-05	12148.	1.29E+10	22.1724	112860.	0.00
18.0000	-6.82E-04	-44482.	971.8981	7.24E-05	12057.	1.29E+10	13.0521	114840.	0.00
18.5000	-3.09E-04	-38559.	1029.	5.31E-05	11958.	1.29E+10	6.0234	116820.	0.00
19.0000	-4.45E-05	-32379.	1081.	3.66E-05	11855.	1.29E+10	11.1741	1505599.	0.00
19.5000	1.30E-04	-25760.	1065.	2.31E-05	11744.	1.29E+10	-16.553	764854.	0.00
20.0000	2.32E-04	-19710.	954.8890	1.25E-05	11642.	1.29E+10	-20.011	516957.	0.00
20.5000	2.80E-04	-14360.	831.0411	4.55E-06	11552.	1.29E+10	-21.271	456449.	0.00
21.0000	2.87E-04	-9759.	702.8714	-1.07E-06	11475.	1.29E+10	-21.452	448729.	0.00
21.5000	2.67E-04	-5920.	575.6720	-4.72E-06	11411.	1.29E+10	-20.948	471080.	0.00
22.0000	2.30E-04	-2829.	452.9611	-6.75E-06	11359.	1.29E+10	-19.956	520066.	0.00
22.5000	1.86E-04	-453.299	337.3061	-7.52E-06	11319.	1.29E+10	-18.596	600654.	0.00
23.0000	1.40E-04	1253.	230.6793	-7.33E-06	11333.	1.29E+10	-16.947	726217.	0.00
23.5000	9.78E-05	2349.	134.6469	-6.49E-06	11351.	1.29E+10	-15.064	924460.	0.00
24.0000	6.21E-05	2899.	50.4928	-5.27E-06	11360.	1.29E+10	-12.987	1254950.	0.00
24.5000	3.45E-05	2979.	-20.665	-3.90E-06	11362.	1.29E+10	-10.732	1865785.	0.00
25.0000	1.53E-05	2669.	-77.672	-2.59E-06	11356.	1.29E+10	-8.270	3252209.	0.00
25.5000	3.46E-06	2059.	-107.137	-1.49E-06	11346.	1.29E+10	-1.552	2693043.	0.00
26.0000	-2.59E-06	1391.	-108.309	-6.84E-07	11335.	1.29E+10	1.1616	2693043.	0.00
26.5000	-4.75E-06	762.5311	-89.197	-1.83E-07	11324.	1.29E+10	5.2091	6581188.	0.00
27.0000	-4.78E-06	321.1224	-58.115	6.96E-08	11317.	1.29E+10	5.1516	6466676.	0.00
27.5000	-3.91E-06	64.8245	-28.675	1.59E-07	11313.	1.29E+10	4.6618	7147343.	0.00
28.0000	-2.87E-06	-23.718	-10.831	1.69E-07	11312.	1.29E+10	1.2864	2693043.	0.00
28.5000	-1.88E-06	-65.926	-4.434	1.48E-07	11313.	1.29E+10	0.8460	2693043.	0.00
29.0000	-1.09E-06	-77.607	-0.431	1.15E-07	11313.	1.29E+10	0.4882	2693043.	0.00
29.5000	-5.08E-07	-71.627	1.7174	8.00E-08	11313.	1.29E+10	0.2278	2693043.	0.00
30.0000	-1.28E-07	-57.368	2.5726	5.00E-08	11313.	1.29E+10	0.05723	2693043.	0.00
30.5000	9.23E-08	-40.987	2.6200	2.71E-08	11312.	1.29E+10	-0.04144	2693043.	0.00
31.0000	1.98E-07	-26.054	2.2296	1.15E-08	11312.	1.29E+10	-0.08871	2693043.	0.00
31.5000	2.30E-07	-14.286	1.6535	2.10E-09	11312.	1.29E+10	-0.103	2693043.	0.00
32.0000	2.23E-07	-6.221	1.0436	-2.68E-09	11312.	1.29E+10	-0.10000	2693043.	0.00
32.5000	1.98E-07	-1.750	0.4769	-4.53E-09	11312.	1.29E+10	-0.08889	2693043.	0.00
33.0000	1.68E-07	-0.477	0.1783	-5.05E-09	11312.	1.29E+10	-0.01067	380160.	0.00
33.5000	1.37E-07	0.4121	0.1198	-5.07E-09	11312.	1.29E+10	-0.00880	384480.	0.00
34.0000	1.08E-07	0.9842	0.07251	-4.74E-09	11312.	1.29E+10	-0.00697	388800.	0.00
34.5000	8.05E-08	1.3042	0.03578	-4.21E-09	11312.	1.29E+10	-0.00527	393120.	0.00
35.0000	5.70E-08	1.4330	0.00862	-3.57E-09	11312.	1.29E+10	-0.00378	397440.	0.00
35.5000	3.76E-08	1.4242	-0.01027	-2.91E-09	11312.	1.29E+10	-0.00252	401760.	0.00
36.0000	2.22E-08	1.3232	-0.02233	-2.27E-09	11312.	1.29E+10	-0.00150	406080.	0.00
36.5000	1.04E-08	1.1668	-0.02896	-1.69E-09	11312.	1.29E+10	-7.11E-04	410400.	0.00
37.0000	1.90E-09	0.9835	-0.03149	-1.19E-09	11312.	1.29E+10	-1.31E-04	414720.	0.00
37.5000	-3.85E-09	0.7945	-0.03107	-7.74E-10	11312.	1.29E+10	2.69E-04	419040.	0.00
38.0000	-7.39E-09	0.6143	-0.02870	-4.46E-10	11312.	1.29E+10	5.21E-04	423360.	0.00
38.5000	-9.20E-09	0.4521	-0.02517	-1.97E-10	11312.	1.29E+10	6.56E-04	427680.	0.00
39.0000	-9.76E-09	0.3132	-0.02109	-1.93E-11	11312.	1.29E+10	7.02E-04	432000.	0.00
39.5000	-9.43E-09	0.1991	-0.01693	1.00E-10	11312.	1.29E+10	6.86E-04	436320.	0.00
40.0000	-8.56E-09	0.1096	-0.01298	1.72E-10	11312.	1.29E+10	6.28E-04	440640.	0.00
40.5000	-7.37E-09	0.04251	-0.00946	2.07E-10	11312.	1.29E+10	5.47E-04	444960.	0.00
41.0000	-6.07E-09	-0.00490	-0.00645	2.16E-10	11312.	1.29E+10	4.55E-04	449280.	0.00
41.5000	-4.78E-09	-0.03594	-0.00401	2.06E-10	11312.	1.29E+10	3.61E-04	453600.	0.00
42.0000	-3.59E-09	-0.05392	-0.00210	1.86E-10	11312.	1.29E+10	2.74E-04	457920.	0.00
42.5000	-2.55E-09	-0.06198	-6.86E-04	1.59E-10	11312.	1.29E+10	1.97E-04	462240.	0.00
43.0000	-1.69E-09	-0.06289	2.99E-04	1.29E-10	11312.	1.29E+10	1.31E-04	466560.	0.00
43.5000	-1.00E-09	-0.05899	9.29E-04	1.01E-10	11312.	1.29E+10	7.86E-05	470880.	0.00
44.0000	-4.77E-10	-0.05221	0.00128	7.52E-11	11312.	1.29E+10	3.77E-05	475200.	0.00
44.5000	-9.81E-11	-0.04401	0.00141	5.28E-11	11312.	1.29E+10	7.84E-06	479520.	0.00

45.0000	1.57E-10	-0.03548	0.00140	3.43E-11	11312.	1.29E+10	-1.27E-05	483840.	0.00
45.5000	3.14E-10	-0.02737	0.00129	1.97E-11	11312.	1.29E+10	-2.55E-05	488160.	0.00
46.0000	3.94E-10	-0.02015	0.00111	8.63E-12	11312.	1.29E+10	-3.23E-05	492480.	0.00
46.5000	4.17E-10	-0.01407	9.11E-04	0.00	11312.	1.29E+10	-3.46E-05	496800.	0.00
47.0000	4.02E-10	-0.00922	7.07E-04	-4.75E-12	11312.	1.29E+10	-3.36E-05	501120.	0.00
47.5000	3.60E-10	-0.00556	5.15E-04	-8.19E-12	11312.	1.29E+10	-3.04E-05	505440.	0.00
48.0000	3.04E-10	-0.00300	3.46E-04	-1.02E-11	11312.	1.29E+10	-2.58E-05	509760.	0.00
48.5000	2.38E-10	-0.00136	2.08E-04	-1.12E-11	11312.	1.29E+10	-2.04E-05	514080.	0.00
49.0000	1.69E-10	-4.53E-04	1.03E-04	-1.16E-11	11312.	1.29E+10	-1.46E-05	518400.	0.00
49.5000	9.87E-11	-7.17E-05	3.32E-05	-1.17E-11	11312.	1.29E+10	-8.60E-06	522720.	0.00
50.0000	2.81E-11	0.00	0.00	-1.18E-11	11312.	1.29E+10	-2.47E-06	263520.	0.00

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 1:

Pile-head deflection = 0.39000000 inches
Computed slope at pile head = 0.000000 radians
Maximum bending moment = -4085689. inch-lbs
Maximum shear force = 171126. lbs
Depth of maximum bending moment = 0.000000 feet below pile head
Depth of maximum shear force = 0.000000 feet below pile head
Number of iterations = 9
Number of zero deflection points = 7

Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 2

Pile-head conditions are Displacement and Moment (Loading Type 4)
Displacement of pile head = 0.390000 inches
Moment at pile head = -3468300.0 in-lbs
Axial load at pile head = 386000.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/inch	Soil Spr. Es*H lb/inch	Distrib. Lat. Load lb/inch
0.00	0.3900	-3468300.	156410.	-0.00238	69460.	1.11E+10	-2098.	16138.	0.00
0.5000	0.3701	-2559919.	142249.	-0.00401	54230.	1.11E+10	-2622.	42512.	0.00
1.0000	0.3419	-1742736.	126236.	-0.00511	40530.	1.29E+10	-2715.	47655.	0.00
1.5000	0.3088	-1021430.	109799.	-0.00575	28437.	1.29E+10	-2764.	53695.	0.00
2.0000	0.2729	-398513.	93197.	-0.00608	17993.	1.29E+10	-2771.	60915.	0.00
2.5000	0.2358	125095.	76663.	-0.00614	13409.	1.29E+10	-2741.	69725.	0.00
3.0000	0.1992	549902.	60436.	-0.00599	20531.	1.29E+10	-2668.	80381.	0.00
3.5000	0.1640	878064.	44780.	-0.00565	26033.	1.29E+10	-2551.	93322.	0.00
4.0000	0.1313	1113450.	29954.	-0.00519	29979.	1.29E+10	-2391.	109268.	0.00
4.5000	0.1017	1261552.	16205.	-0.00464	32462.	1.29E+10	-2192.	129290.	0.00
5.0000	0.07564	1329393 Mmax2	3764.	-0.00403	33600.	1.29E+10	-1955.	155094.	0.00

5.5000	0.05329	1325408.	-7155.	-0.00342	33533.	1.29E+10	-1684.	189641.	0.00
6.0000	0.03464	1259357.	-15685.	-0.00282	32426.	1.29E+10	-1159.	200736.	0.00
6.5000	0.01951	1150224.	-21178.	-0.00225	30596.	1.29E+10	-671.949	206640.	0.00
7.0000	0.00759	1015661.	-24001.	-0.00175	28340.	1.29E+10	-268.968	212544.	0.00
7.5000	-0.00149	870319.	-24645.	-0.00131	25903.	1.29E+10	54.1614	218448.	0.00
8.0000	-0.00814	725989.	-23570.	-9.39E-04	23483.	1.29E+10	304.2448	224352.	0.00
8.5000	-0.01276	591829.	-21189.	-6.32E-04	21234.	1.29E+10	489.5787	230256.	0.00
9.0000	-0.01572	474655.	-18622.	-3.84E-04	19270.	1.29E+10	366.0733	139680.	0.00
9.5000	-0.01737	370148.	-16280.	-1.87E-04	17517.	1.29E+10	414.3905	143172.	0.00
10.0000	-0.01797	280160.	-13719.	-3.60E-05	16009.	1.29E+10	439.3408	146664.	0.00
10.5000	-0.01780	205686.	-11065.	7.71E-05	14760.	1.29E+10	445.4103	150156.	0.00
11.0000	-0.01705	147026.	-8986.	1.59E-04	13777.	1.29E+10	247.5342	87120.	0.00
11.5000	-0.01589	97117.	-7536.	2.16E-04	12940.	1.29E+10	235.9215	89100.	0.00
12.0000	-0.01445	55598.	-6170.	2.52E-04	12244.	1.29E+10	219.4241	91080.	0.00
12.5000	-0.01287	21917.	-4913.	2.70E-04	11679.	1.29E+10	199.5723	93060.	0.00
13.0000	-0.01122	-4602.	-3781.	2.74E-04	11389.	1.29E+10	177.7029	95040.	0.00
13.5000	-0.00958	-24720.	-2783.	2.67E-04	11726.	1.29E+10	154.9533	97020.	0.00
14.0000	-0.00802	-39232.	-1921.	2.52E-04	11969.	1.29E+10	132.2635	99000.	0.00
14.5000	-0.00656	-48940.	-1193.	2.31E-04	12132.	1.29E+10	110.3842	100980.	0.00
15.0000	-0.00524	-54622.	-592.353	2.07E-04	12227.	1.29E+10	89.8894	102960.	0.00
15.5000	-0.00407	-57009.	-109.109	1.81E-04	12267.	1.29E+10	71.1920	104940.	0.00
16.0000	-0.00306	-56771.	268.1534	1.55E-04	12264.	1.29E+10	54.5620	106920.	0.00
16.5000	-0.00221	-54508.	552.2740	1.29E-04	12226.	1.29E+10	40.1449	108900.	0.00
17.0000	-0.00151	-50742.	756.6519	1.04E-04	12162.	1.29E+10	27.9810	110880.	0.00
17.5000	-9.58E-04	-45913.	894.6644	8.20E-05	12081.	1.29E+10	18.0231	112860.	0.00
18.0000	-5.30E-04	-40385.	979.1938	6.19E-05	11989.	1.29E+10	10.1533	114840.	0.00
18.5000	-2.16E-04	-34449.	1022.	4.45E-05	11889.	1.29E+10	4.1980	116820.	0.00
19.0000	3.01E-06	-28324.	1031.	2.98E-05	11787.	1.29E+10	-1.353	2693043.	0.00
19.5000	1.43E-04	-22218.	975.6925	1.81E-05	11684.	1.29E+10	-17.011	716223.	0.00
20.0000	2.20E-04	-16700.	865.7526	9.02E-06	11592.	1.29E+10	-19.635	535674.	0.00
20.5000	2.51E-04	-11870.	745.2980	2.36E-06	11511.	1.29E+10	-20.516	491007.	0.00
21.0000	2.48E-04	-7767.	622.3506	-2.21E-06	11442.	1.29E+10	-20.466	494534.	0.00
21.5000	2.24E-04	-4392.	501.5352	-5.04E-06	11385.	1.29E+10	-19.805	529985.	0.00
22.0000	1.88E-04	-1725.	386.0114	-6.46E-06	11341.	1.29E+10	-18.702	597339.	0.00
22.5000	1.47E-04	270.0633	278.1185	-6.80E-06	11316.	1.29E+10	-17.262	706118.	0.00
23.0000	1.06E-04	1644.	179.6712	-6.36E-06	11339.	1.29E+10	-15.554	878343.	0.00
23.5000	7.04E-05	2456.	92.1261	-5.40E-06	11353.	1.29E+10	-13.628	1161210.	0.00
24.0000	4.14E-05	2774.	16.7029	-4.18E-06	11358.	1.29E+10	-11.513	1666985.	0.00
24.5000	2.02E-05	2675.	-45.478	-2.91E-06	11357.	1.29E+10	-9.214	2734555.	0.00
25.0000	6.47E-06	2242.	-93.134	-1.77E-06	11349.	1.29E+10	-6.672	6191264.	0.00
25.5000	-1.02E-06	1566.	-111.774	-8.83E-07	11338.	1.29E+10	0.4583	2693043.	0.00
26.0000	-4.13E-06	904.7669	-95.636	-3.08E-07	11327.	1.29E+10	4.9211	7144354.	0.00
26.5000	-4.72E-06	419.7577	-65.018	3.65E-10	11319.	1.29E+10	5.2849	6722334.	0.00
27.0000	-4.13E-06	124.5522	-33.823	1.27E-07	11314.	1.29E+10	5.1134	7431342.	0.00
27.5000	-3.19E-06	13.2938	-14.185	1.59E-07	11312.	1.29E+10	1.4327	2693043.	0.00
28.0000	-2.22E-06	-46.402	-6.900	1.51E-07	11312.	1.29E+10	0.9957	2693043.	0.00
28.5000	-1.37E-06	-70.203	-2.062	1.24E-07	11313.	1.29E+10	0.6169	2693043.	0.00
29.0000	-7.26E-07	-71.721	0.7669	9.13E-08	11313.	1.29E+10	0.3261	2693043.	0.00
29.5000	-2.79E-07	-61.423	2.1207	6.03E-08	11313.	1.29E+10	0.1252	2693043.	0.00
30.0000	-3.06E-09	-46.551	2.5005	3.51E-08	11312.	1.29E+10	0.00138	2693043.	0.00
30.5000	1.43E-07	-31.580	2.3124	1.70E-08	11312.	1.29E+10	-0.06409	2693043.	0.00
31.0000	2.00E-07	-18.881	1.8502	5.21E-09	11312.	1.29E+10	-0.08996	2693043.	0.00
31.5000	2.05E-07	-9.401	1.3039	-1.38E-09	11312.	1.29E+10	-0.09215	2693043.	0.00
32.0000	1.84E-07	-3.228	0.7798	-4.32E-09	11312.	1.29E+10	-0.08255	2693043.	0.00
32.5000	1.54E-07	-0.02363	0.3254	-5.07E-09	11312.	1.29E+10	-0.06891	2693043.	0.00
33.0000	1.23E-07	0.7004	0.09532	-4.91E-09	11312.	1.29E+10	-0.00780	380160.	0.00
33.5000	9.45E-08	1.1430	0.05375	-4.49E-09	11312.	1.29E+10	-0.00606	384480.	0.00
34.0000	6.92E-08	1.3662	0.02212	-3.90E-09	11312.	1.29E+10	-0.00449	388800.	0.00

34.5000	4.77E-08	1.4265	-7.16E-04	-3.25E-09	11312.	1.29E+10	-0.00313	393120.	0.00
35.0000	3.02E-08	1.3727	-0.01610	-2.60E-09	11312.	1.29E+10	-0.00200	397440.	0.00
35.5000	1.65E-08	1.2453	-0.02542	-1.99E-09	11312.	1.29E+10	-0.00111	401760.	0.00
36.0000	6.32E-09	1.0768	-0.03002	-1.45E-09	11312.	1.29E+10	-4.28E-04	406080.	0.00
36.5000	-8.70E-10	0.8918	-0.03113	-9.91E-10	11312.	1.29E+10	5.95E-05	410400.	0.00
37.0000	-5.57E-09	0.7079	-0.02980	-6.19E-10	11312.	1.29E+10	3.85E-04	414720.	0.00
37.5000	-8.30E-09	0.5371	-0.02690	-3.29E-10	11312.	1.29E+10	5.79E-04	419040.	0.00
38.0000	-9.52E-09	0.3865	-0.02315	-1.14E-10	11312.	1.29E+10	6.72E-04	423360.	0.00
38.5000	-9.67E-09	0.2598	-0.01907	3.64E-11	11312.	1.29E+10	6.89E-04	427680.	0.00
39.0000	-9.08E-09	0.1576	-0.01504	1.34E-10	11312.	1.29E+10	6.54E-04	432000.	0.00
39.5000	-8.06E-09	0.07872	-0.01132	1.89E-10	11312.	1.29E+10	5.86E-04	436320.	0.00
40.0000	-6.82E-09	0.02089	-0.00806	2.12E-10	11312.	1.29E+10	5.01E-04	440640.	0.00
40.5000	-5.52E-09	-0.01893	-0.00533	2.12E-10	11312.	1.29E+10	4.09E-04	444960.	0.00
41.0000	-4.27E-09	-0.04399	-0.00314	1.98E-10	11312.	1.29E+10	3.20E-04	449280.	0.00
41.5000	-3.15E-09	-0.05749	-0.00146	1.74E-10	11312.	1.29E+10	2.38E-04	453600.	0.00
42.0000	-2.19E-09	-0.06236	-2.49E-04	1.46E-10	11312.	1.29E+10	1.67E-04	457920.	0.00
42.5000	-1.40E-09	-0.06115	5.74E-04	1.17E-10	11312.	1.29E+10	1.08E-04	462240.	0.00
43.0000	-7.77E-10	-0.05601	0.00108	9.01E-11	11312.	1.29E+10	6.04E-05	466560.	0.00
43.5000	-3.15E-10	-0.04863	0.00133	6.57E-11	11312.	1.29E+10	2.47E-05	470880.	0.00
44.0000	1.10E-11	-0.04031	0.00141	4.50E-11	11312.	1.29E+10	-8.69E-07	475200.	0.00
44.5000	2.25E-10	-0.03197	0.00135	2.82E-11	11312.	1.29E+10	-1.79E-05	479520.	0.00
45.0000	3.49E-10	-0.02425	0.00121	1.51E-11	11312.	1.29E+10	-2.81E-05	483840.	0.00
45.5000	4.05E-10	-0.01751	0.00103	5.35E-12	11312.	1.29E+10	-3.30E-05	488160.	0.00
46.0000	4.13E-10	-0.01195	8.27E-04	-1.51E-12	11312.	1.29E+10	-3.39E-05	492480.	0.00
46.5000	3.87E-10	-0.00759	6.29E-04	-6.06E-12	11312.	1.29E+10	-3.21E-05	496800.	0.00
47.0000	3.40E-10	-0.00437	4.47E-04	-8.84E-12	11312.	1.29E+10	-2.84E-05	501120.	0.00
47.5000	2.81E-10	-0.00218	2.91E-04	-1.04E-11	11312.	1.29E+10	-2.37E-05	505440.	0.00
48.0000	2.16E-10	-8.32E-04	1.65E-04	-1.11E-11	11312.	1.29E+10	-1.83E-05	509760.	0.00
48.5000	1.48E-10	-1.46E-04	7.18E-05	-1.13E-11	11312.	1.29E+10	-1.27E-05	514080.	0.00
49.0000	8.03E-11	8.24E-05	1.29E-05	-1.13E-11	11312.	1.29E+10	-6.94E-06	518400.	0.00
49.5000	1.26E-11	6.09E-05	-1.12E-05	-1.13E-11	11312.	1.29E+10	-1.09E-06	522720.	0.00
50.0000	-5.50E-11	0.00	0.00	-1.13E-11	11312.	1.29E+10	4.83E-06	263520.	0.00

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 2:

Pile-head deflection	=	0.39000000 inches
Computed slope at pile head	=	-0.0023808 radians
Maximum bending moment	=	-3468300. inch-lbs
Maximum shear force	=	156410. lbs
Depth of maximum bending moment	=	0.000000 feet below pile head
Depth of maximum shear force	=	0.000000 feet below pile head
Number of iterations	=	8
Number of zero deflection points	=	7

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	y, in	0.3900	S, rad	0.00	386000.	0.3900	0.00	171126.	-4085689.
2	y, in	0.3900	M, in-lb	-3468300.	386000.	0.3900	-0.00238	156410.	-3468300.

Maximum pile-head deflection = 0.3900000000 inches
Maximum pile-head rotation = -0.0023807801 radians = -0.136409 deg.

The analysis ended normally.



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Integral Abutment LRFD Pile Design

Subject: Pile Design for the thermal contraction of the St. George River Bridge Replacement in Union, Maine at Abutment 1.

Reference:

- AASHTO LRFD Bridge Design Specifications, 10th Edition, 2024
- Maine BDG Chapter 5 - Substructures 2014
- VTRANS Integral Abutment Bridge Design Guidelines 2008

Design Steps - Maine BDG

Step 1 - Determine the foundation displacements and the load effects (P_u and M_u) from the superstructure and substructure designs.

$P_u := 386 \cdot \text{kip}$ Maximum Factored Axial Load from Stantec

The limitations of the software require the plastic hinge evaluations be complete using a single deflection. Stantec provided a total deflection of 0.720 inches with 0.004 radians of end rotation.

Step 2 - If applicable, determine the magnitude of scour.
Step 3 - Select preliminary pile size.

Analysis by others concludes that with additional detailing, scour is prevented.

HP14 x 117 Weak Axis Properties

Steel yield strength	$F_{y50} := 50 \text{ ksi}$
Modulus of elasticity for steel	$E := 29000 \text{ ksi}$
Cross sectional area of pile	$A_g := 34.4 \text{ in}^2$
Radius of gyration	$r_y := 3.59 \text{ in}$
Width of Flange	$b_f := 14.9 \text{ in}$
Thickness of Flange	$t_f := 0.805 \text{ in}$
Elastic Section Modulus	$S_y := 59.5 \text{ in}^3$
Plastic Section Modulus	$Z_y := 91.4 \text{ in}^3$

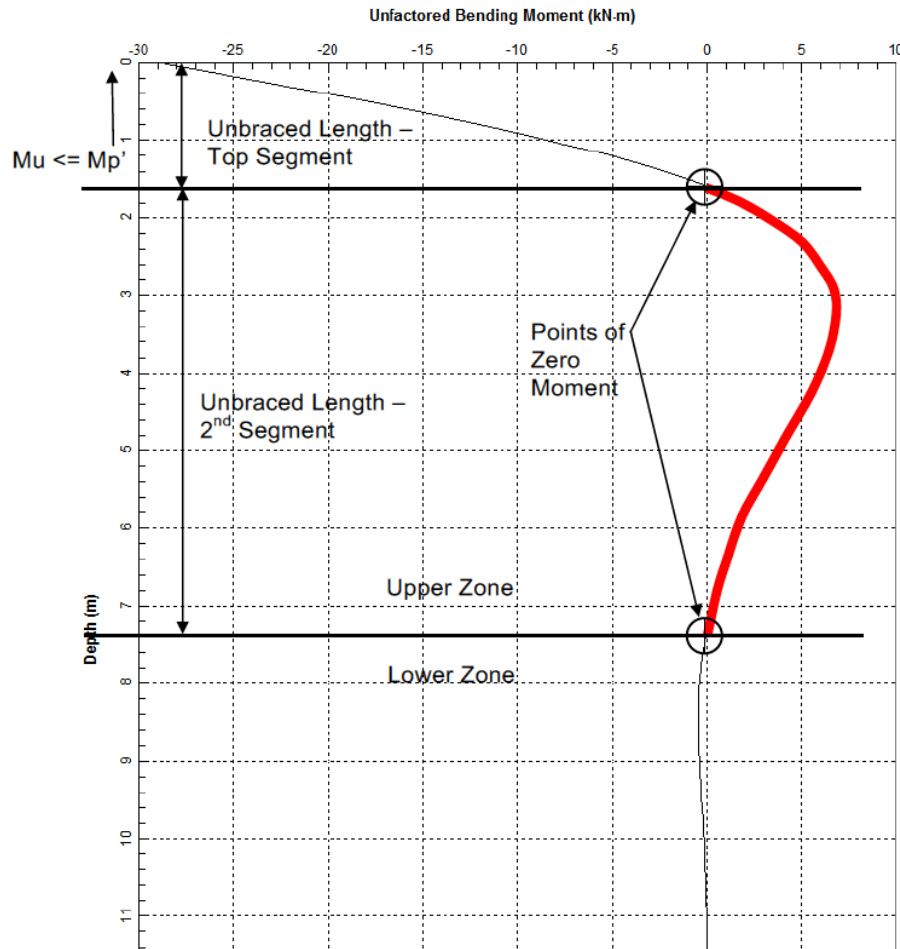
Step 4 - Determine the pile unbraced length and maximum moment at the top of the pile by running LPILE software for top translation = 0.720 inches, $P_u = 386 \text{ kip}$, and Live Load Rotation = 0.004



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EXAMPLE FIGURE: NOT TAKEN FROM THIS ANALYSIS

Maximum moment from LPile output (page 40)

$$M_u := 4152 \text{ kip} \cdot \text{in} = 346 \cdot \text{kip} \cdot \text{ft}$$

Unbraced lengths from LPile output (pages 40-41)

Upper segment

$$L_1 := 5.1 \cdot \text{ft}$$

Lower segment

$$L_2 := 13.2 \cdot \text{ft}$$

Step 5 - Determine if the applied moment on the pile will cause pile head plastic deformation considering the interaction of combined axial and flexural load effects on a single pile (LRFD 6.9.2.2)

- Obtain the unbraced lengths of the top and lower segments of the pile and calculate the column slenderness factor (λ) for each segment.

See above for unbraced lengths (critical lengths L_1 and L_2).



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Upper segment slenderness factor

$$\lambda_1 := \frac{(L_1)}{r_y} = 17.0$$

Lower segment slenderness factor

$$\lambda_2 := \frac{(L_2)}{r_y} = 44.1$$

b. Determine K values for top and bottom of the pile per LRFD Table C4.6.2.5-1

	(a)	(b)	(c)	(d)	(e)	(f)
Buckled shape of column is shown by dashed line						
Theoretical K value	0.5	0.7	1.0	1.0	2.0	2.0
Design value of K when ideal conditions are approximated	0.65	0.80	1.0	1.2	2.1	2.0
End condition code		Rotation fixed Rotation free Rotation fixed Rotation free		Translation fixed Translation fixed Translation free Translation free		

Upper segment K value (Type d)

$$K_1 := 1.2$$

Lower segment K value (Type c)

$$K_2 := 1$$

c. Calculate the nominal and factored structural pile resistance P_n , per AASHTO LRFD 6.9.4.1 using the λ values



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Elastic critical buckling resistance, P_e based on flexural buckling (AASHTO LRFD Eq. 6.9.4.1.2-1)

$$\text{Upper } P_e \quad P_{e1} := \frac{(\pi^2 \cdot E) \cdot A_g}{(K_1 \cdot \lambda_1)^2} = 23528 \cdot \text{kip}$$

$$\text{Lower } P_e \quad P_{e2} := \frac{(\pi^2 \cdot E) \cdot A_g}{(K_2 \cdot \lambda_2)^2} = 5057 \cdot \text{kip}$$

$$\text{Nominal yield resistance, } P_o \quad P_o := F_{y50} \cdot A_g = 1720 \cdot \text{kip}$$

Check that the ratio of P_e to P_o is > 0.44

If $P_e/P_o > 0.44$ then use AASHTO LRFD Eq. 6.9.4.1.1-1

If $P_e/P_o < 0.44$ then use AASHTO LRFD Eq. 6.9.4.1.1-2

$$P_n = \left[0.658^{\left(\frac{P_o}{P_e} \right)} \right] P_o \quad (6.9.4.1.1-1)$$

$$P_n = 0.877 P_e \quad (6.9.4.1.1-2)$$

$$\frac{P_{e1}}{P_o} = 13.679 \quad \frac{P_{e2}}{P_o} = 2.94$$

Both ratios are greater than 0.44, therefore, use AASHTO LRFD Eq. 6.9.4.1.1-1: Nominal structural axial Pile resistance, P_n for both segments

$$P_{n1} := \left[0.658^{\left(\frac{P_o}{P_{e1}} \right)} \right] \cdot P_o = 1668 \cdot \text{kip}$$

$$P_{n2} := \left[0.658^{\left(\frac{P_o}{P_{e2}} \right)} \right] \cdot P_o = 1492 \cdot \text{kip}$$



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Factored structural axial Pile Resistance, $P_r = \phi_c (P_n)$

$$\phi_c := 0.7 \quad \text{for axial resistance according to AASHTO LRFD 6.5.4.2}$$

$$P_{r1} := \phi_c \cdot P_{n1} = 1167.7 \cdot \text{kip}$$

$$P_{r2} := \phi_c \cdot P_{n2} = 1 \times 10^3 \cdot \text{kip}$$

d. Compare the ratio of P_u , the maximum factored axial load, to P_r , the structural resistance in the specified portion of the pile - the pile size should be such that the ratio is not less than 0.20.

Check for both segments

$$\frac{P_u}{P_{r1}} = 0.331 \quad > 0.20, \text{ OK} \qquad \frac{P_u}{P_{r2}} = 0.37 \quad > 0.20, \text{ OK}$$

e. Determine the nominal and factored flexural resistance about H-Pile weak axis, (AASHTO LRFD Eq. 6.12.2.2)

Check slenderness ratio for flange, limiting slenderness ratio for compact flange, and limiting slenderness ratio for a noncompact flange.

$$\lambda_f := \frac{b_f}{2 \cdot t_f} = 9.255 \quad \text{slenderness ratio for flange (AASHTO LRFD Eq. 6.12.2.2.1-3)}$$

$$\lambda_{pf} := 0.38 \cdot \left(\frac{E}{F_{y50}} \right)^{.5} = 9.152$$

$$\lambda_{rf} := 0.83 \cdot \left(\frac{E}{F_{y50}} \right)^{.5} = 19.989$$

If $\lambda_{pf} < \lambda_f < \lambda_{rf}$ Use AASHTO LRFD Eq. 6.12.2.2.1-2 to find the nominal flexural resistance

$$M_n := \left[1 - \left(1 - \frac{S_y}{Z_y} \right) \cdot \left[\frac{\lambda_f - \lambda_{pf}}{0.45 \cdot \left(\frac{E}{F_{y50}} \right)^{.5}} \right] \right] \cdot F_{y50} \cdot Z_y = 379.57 \cdot \text{ft} \cdot \text{kip}$$



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$\phi_f := 1.0$ for flexural resistance according to AASHTO LRFD 6.5.4.2

$$M_r := M_n \cdot \phi_f = 379.6 \cdot \text{ft} \cdot \text{kip}$$

$$M_u = 346 \cdot \text{ft} \cdot \text{kip}$$

$$\frac{P_u}{P_{r1}} + \frac{8}{9} \cdot \frac{M_u}{M_r} = 1.14$$

If less than 1, remains in elastic zone. Since it exceeds 1, yielding is expected at the base of the pile cap.

f. Calculate the moment that will cause a plastic hinge at the top of the pile, M_p' ,
 Note: M_p' will be lower than M_n due to the inclusion of the axial load in the interaction equation for pile over stresses

$$\frac{P_u}{P_r} + \frac{8.0}{9.0} \left(\frac{M_{ux}}{M_{rx}} + \frac{M_{uy}}{M_{ry}} \right) \leq 1.0$$

AASHTO LRFD Eq. 6.9.2.2 Interaction equation

Use the interaction equation to find the moment that will cause a plastic hinge at the top of the pile. Assume M_{ux} and $M_{rx} = 0$ (out-of-plane), $M_{ry} = M_r$ and $M_u = M_p'$, solve for M_p'

$$M_p := \left(\frac{9}{8} \right) \cdot \left[1 - \left(\frac{P_u}{P_{r1}} \right) \right] \cdot M_r = 285.9 \cdot \text{ft} \cdot \text{kip} \quad M_p = 3430.3 \cdot \text{in} \cdot \text{kip}$$

g. The calculated moment from LPILE Run 1 (shown in step 4) exceeds the moment that would cause a plastic hinge (above), therefore a plastic hinge forms, and the moment (M_p') represents the limiting moment reaction at the pile top for the subsequent analysis.

Step 6 - For fixed head piles, run a second LPILE analysis with end conditions 1) Top moment = M_p' , top translation = 0.720 in; and axial load equal to P_u . Recalculate unbraced lengths from the moment vs. depth curve.



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New unbraced lengths were determined from the second LPILE analysis

Upper segment $L_{1p} := 4.7 \cdot \text{ft}$

Lower segment $L_{2p} := 13.3 \cdot \text{ft}$

6a. Repeat steps 5a through 5d above.

6b- If the pile size is such that the ratio of P_u to structural resistance exceeds 0.2, check the upper segment of the pile with the interaction equation of AASHTO LRFD Eq. 6.9.2.2. If a plastic hinge forms at the top of the pile, the K value of the upper segment changes from 1.2, for a rotation fixed head condition, to 2.1, for a rotation free head condition. With the new K value and lengths repeat step 5.

5a.

Upper segment slenderness factor $\lambda_{1p} := \frac{(L_{1p})}{r_y} = 15.71$

Lower segment slenderness factor $\lambda_{2p} := \frac{(L_{2p})}{r_y} = 44.457$

5b.

Upper segment K value (Type e) $K_{1p} := 2.1$

Lower segment K value (Type c) $K_{2p} := 1$

5c.

Elastic critical buckling resistance, P_e based on flexural buckling

Upper P_e $P_{ep1} := \frac{(\pi^2 \cdot E) \cdot A_g}{(K_{1p} \cdot \lambda_{1p})^2} = 9046 \cdot \text{kip}$

Lower P_e $P_{ep2} := \frac{(\pi^2 \cdot E) \cdot A_g}{(K_{2p} \cdot \lambda_{2p})^2} = 4982 \cdot \text{kip}$

Nominal yield resistance, P_o $P_o := F_{y50} \cdot A_g = 1720 \cdot \text{kip}$



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Check that the ratio of P_e to P_o is > 0.44

If $P_e/P_o > 0.44$ then use equation 6.9.4.1.1-1

If $P_e/P_o < 0.44$ then use equation 6.9.4.1.1-2

$$\frac{P_{ep1}}{P_o} = 5.259 \quad \frac{P_{ep2}}{P_o} = 2.896$$

Both ratios are greater than 0.44, therefore, use eq. 6.9.4.1.1-1: Nominal structural Pile resistance, P_n for both segments

$$P_{np1} := \left[0.658 \left(\frac{P_o}{P_{ep1}} \right) \right] \cdot P_o = 1588 \cdot \text{kip}$$

$$P_{np2} := \left[0.658 \left(\frac{P_o}{P_{ep2}} \right) \right] \cdot P_o = 1489 \cdot \text{kip}$$

Factored structural Pile Resistance, $P_r = \phi_c (P_n)$

$$P_{rp1} := \phi_c \cdot P_{np1} = 1111.9 \cdot \text{kip}$$

$$P_{rp2} := \phi_c \cdot P_{np2} = 1 \times 10^3 \cdot \text{kip}$$

5d. Compare the ratio of P_u to the structural resistance in the upper portion of the pile - the pile size should be such that the ratio is not less than 0.20.

Check for both segments

$$\frac{P_u}{P_{rp1}} = 0.347 \quad > 0.20, \text{ OK} \quad \frac{P_u}{P_{rp2}} = 0.37 \quad > 0.20, \text{ OK}$$

From VTrans Integral Abutment Design Section 4.5.2 - Check the axial capacity of the upper segment and the interaction equation for the second segment to assess suitability of pile section.



GZA
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*Engineers and
Scientists*

JOB: 09.0026237.01
SUBJECT: Pile Evaluation for Abut 1 Contraction
SHEET: 9 OF 9
CALCULATED BY J. Barnes 04/18/2026
CHECKED BY J. Keohane 04/21/2026

Upper Segment

Check that $P_u/P_{rp1} < 1$

$$\frac{P_u}{P_{rp1}} = 0.347 < 1, \text{OK}$$

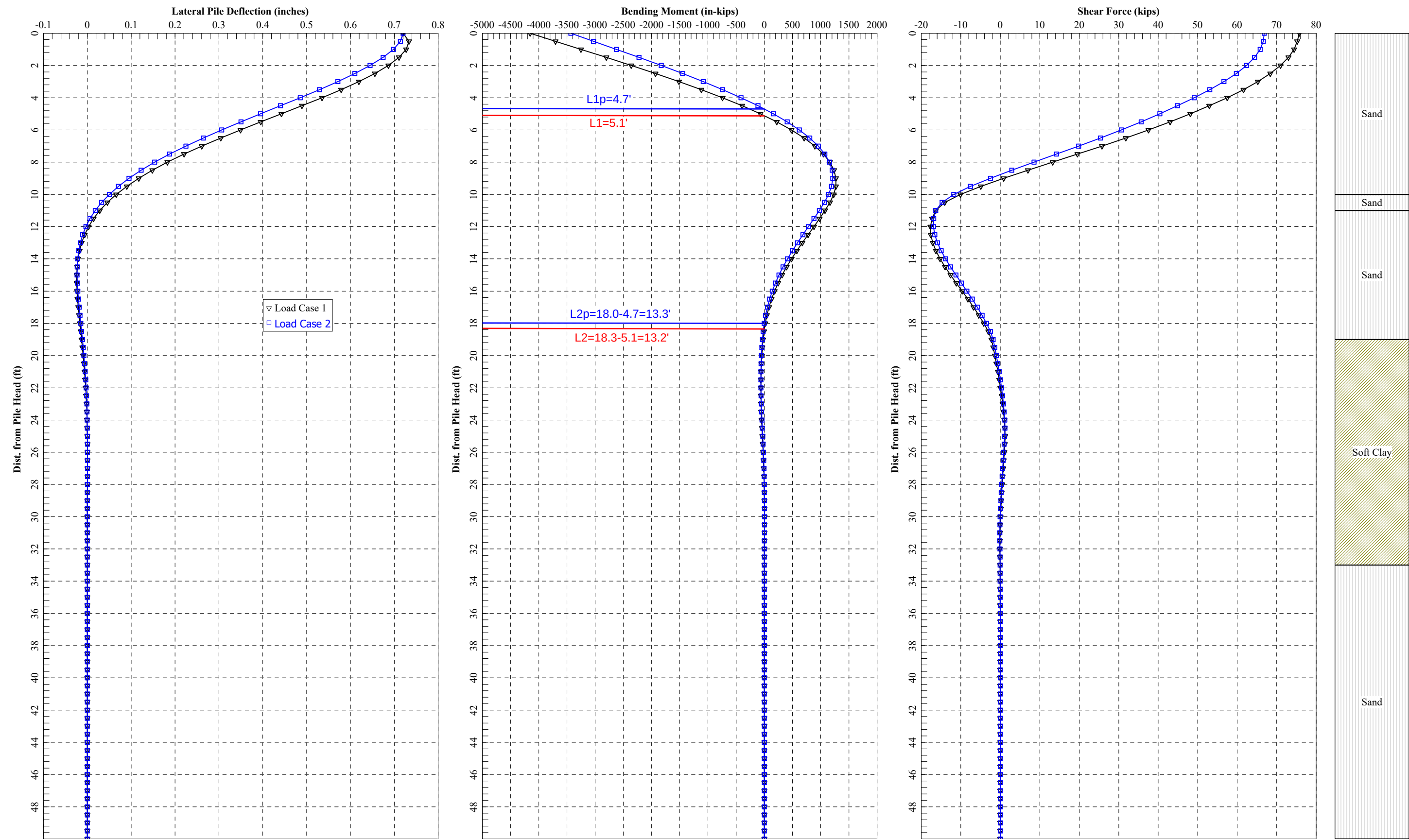
Lower Segment

Ultimate moment along the lower segment from LPile output

$$M_{\max p2} := 1214 \cdot \text{in} \cdot \text{kip}$$

$$\frac{P_u}{P_{rp2}} + \frac{8}{9} \cdot \frac{M_{\max p2}}{M_r} = 0.61 < 1, \text{OK}$$

Abutment 1 - Contraction Case



=====

LPile Version 2022-12.013

License ID : 161635470
License Type : (Single User License)

Analysis of Individual Piles and Drilled Shafts
Subjected to Lateral Loading Using the p-y Method
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This software is licensed for exclusive use by:
GZA GeoEnvironmental, Inc.
Portland, ME

=====

This model was prepared by:
Jason.Keohane

Files Used for Analysis

Path to file locations:
\\09 Jobs\0026200s\09.0026237.00 - Stantec Union Bridge\01 - Final Design\Work\Calcs\LPile\Abutment 1\Contraction\

Name of input data file:
Abutment 1 Contraction.lp12d

Name of output report file:
Abutment 1 Contraction.lp12o

Name of plot output file:
Abutment 1 Contraction.lp12p

Name of runtime message file:
Abutment 1 Contraction.lp12r

Date and Time of Analysis

Date: June 11, 2026 Time: 9:36:19

Problem Title

Project Name: St. George River Bridge, Union, Maine

Job Number: 09.0026237.01

Client: Stantec

Engineer: Jason Barnes

Description: Abutment 1 Contraction

Program Options and Settings

Computational Options:
- Conventional Analysis

Engineering Units Used for Data Input and Computations:
- US Customary System Units (pounds, feet, inches)

Analysis Control Options:

- Maximum number of iterations allowed	=	500
- Deflection tolerance for convergence	=	1.0000E-05 in
- Maximum allowable deflection	=	100.0000 in
- Number of pile increments	=	100

Loading Type and Number of Cycles of Loading:
- Static loading specified

- Use of p-y modification factors for p-y curves not selected
- Analysis uses layering correction (Method of Georgiadis)
- No distributed lateral loads are entered
- Loading by lateral soil movements acting on pile not selected
- Input of shear resistance at the pile tip not selected
- Input of moment resistance at the pile tip not selected
- Computation of pile-head foundation stiffness matrix not selected
- Push-over analysis of pile not selected
- Buckling analysis of pile not selected

Output Options:
- Output files use decimal points to denote decimal symbols.
- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (nodal spacing of output points) = 1
- No p-y curves to be computed and reported for user-specified depths
- Print using wide report formats

Pile Structural Properties and Geometry

Number of pile sections defined = 1
Total length of pile = 50.000 ft
Depth of ground surface below top of pile = 0.0000 ft

Pile diameters used for p-y curve computations are defined using 2 points.

p-y curves are computed using pile diameter values interpolated with depth over the length of the pile. A summary of values of pile diameter vs. depth follows.

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	14.9000
2	50.000	14.9000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is a H weak axis steel pile
Length of section = 50.000000 ft
Pile width = 14.200000 in

Soil and Rock Layering Information

The soil profile is modelled using 5 layers

Layer 1 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 0.0000 ft
Distance from top of pile to bottom of layer = 10.000000 ft
Effective unit weight at top of layer = 125.000000 pcf
Effective unit weight at bottom of layer = 125.000000 pcf
Friction angle at top of layer = 36.000000 deg.
Friction angle at bottom of layer = 36.000000 deg.
Subgrade k at top of layer = 164.000000 pci
Subgrade k at bottom of layer = 164.000000 pci

Layer 2 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 10.000000 ft
Distance from top of pile to bottom of layer = 11.000000 ft
Effective unit weight at top of layer = 62.600000 pcf
Effective unit weight at bottom of layer = 62.600000 pcf
Friction angle at top of layer = 36.000000 deg.
Friction angle at bottom of layer = 36.000000 deg.

Subgrade k at top of layer = 97.000000 pci
Subgrade k at bottom of layer = 97.000000 pci

Layer 3 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 11.000000 ft
Distance from top of pile to bottom of layer = 19.000000 ft
Effective unit weight at top of layer = 57.600000 pcf
Effective unit weight at bottom of layer = 57.600000 pcf
Friction angle at top of layer = 32.000000 deg.
Friction angle at bottom of layer = 32.000000 deg.
Subgrade k at top of layer = 55.000000 pci
Subgrade k at bottom of layer = 55.000000 pci

Layer 4 is soft clay, p-y criteria by Matlock, 1970

Distance from top of pile to top of layer = 19.000000 ft
Distance from top of pile to bottom of layer = 33.000000 ft
Effective unit weight at top of layer = 47.600000 pcf
Effective unit weight at bottom of layer = 47.600000 pcf
Undrained cohesion at top of layer = 500.000000 psf
Undrained cohesion at bottom of layer = 500.000000 psf
Epsilon-50 at top of layer = 0.010000
Epsilon-50 at bottom of layer = 0.010000

Layer 5 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 33.000000 ft
Distance from top of pile to bottom of layer = 50.000000 ft
Effective unit weight at top of layer = 67.600000 pcf
Effective unit weight at bottom of layer = 67.600000 pcf
Friction angle at top of layer = 38.000000 deg.
Friction angle at bottom of layer = 38.000000 deg.
Subgrade k at top of layer = 120.000000 pci
Subgrade k at bottom of layer = 120.000000 pci

(Depth of the lowest soil layer extends 0.000 ft below the pile tip)

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Cohesion psf	Angle of Friction deg.	E50 or krm	kpy pci
1	Sand	0.00	125.0000	--	36.0000	--	164.0000
	(Reese, et al.)	10.0000	125.0000	--	36.0000	--	164.0000
2	Sand	10.0000	62.6000	--	36.0000	--	97.0000
	(Reese, et al.)	11.0000	62.6000	--	36.0000	--	97.0000

3	Sand	11.0000	57.6000	--	32.0000	--	55.0000
	(Reese, et al.)	19.0000	57.6000	--	32.0000	--	55.0000
4	Soft	19.0000	47.6000	500.0000	--	0.01000	--
	Clay	33.0000	47.6000	500.0000	--	0.01000	--
5	Sand	33.0000	67.6000	--	38.0000	--	120.0000
	(Reese, et al.)	50.0000	67.6000	--	38.0000	--	120.0000

Static Loading Type

Static loading criteria were used when computing p-y curves for all analyses.

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 2

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length	Run Analysis
1	5	y = 0.720000 in	S = 0.004000 in/in	386000.	N.A.	Yes
2	4	y = 0.720000 in	M = -3430300. in-lbs	386000.	N.A.	Yes

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Dimensions and Properties of Steel H Weak Axis:

Length of Section	=	50.000000 ft
Flange Width	=	14.900000 in
Section Depth	=	14.200000 in

Flange Thickness	=	0.805000 in
Web Thickness	=	0.805000 in
Yield Stress of Pipe	=	50.000000 ksi
Elastic Modulus	=	29000. ksi
Cross-sectional Area	=	34.123950 sq. in.
Moment of Inertia	=	444.363799 in^4
Elastic Bending Stiffness	=	12886550. kip-in^2
Plastic Modulus, Z	=	91.398684in^3
Plastic Moment Capacity = Fy Z	=	4570.in-kip

Axial Structural Capacities:

Nom. Axial Structural Capacity = Fy As	=	1706.197 kips
Nominal Axial Tensile Capacity	=	-1706.197 kips

Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

Number	Axial Thrust Force kips
-----	-----
1	386.000

Definition of Run Messages:

Y = part of pipe section has yielded.

Axial Thrust Force = 386.000 kips

Bending Curvature rad/in.	Bending Moment in-kip	Bending Stiffness kip-in2	Depth to N Axis in	Max Total Stress ksi	Run Msg
0.00000447	57.6462319	12886018.	94.6422382	12.2685485	
0.00000895	115.2924638	12886018.	51.0461191	13.2253936	
0.00001342	172.9386957	12886018.	36.5140794	14.1822388	
0.00001789	230.5849276	12886018.	29.2480595	15.1390839	
0.00002237	288.2311595	12886018.	24.8884476	16.0959290	
0.00002684	345.8773914	12886018.	21.9820397	17.0527742	
0.00003131	403.5236233	12886018.	19.9060340	18.0096193	
0.00003579	461.1698552	12886018.	18.3490298	18.9664645	
0.00004026	518.8160871	12886018.	17.1380265	19.9233096	
0.00004474	576.4623190	12886018.	16.1692238	20.8801547	
0.00004921	634.1085509	12886018.	15.3765671	21.8369998	
0.00005368	691.7547828	12886018.	14.7160198	22.7938450	
0.00005816	749.4010147	12886018.	14.1570952	23.7506902	
0.00006263	807.0472466	12886018.	13.6780170	24.7075353	
0.00006710	864.6934785	12886018.	13.2628159	25.6643804	
0.00007158	922.3397104	12886018.	12.8995149	26.6212255	
0.00007605	979.9859423	12886018.	12.5789552	27.5780707	
0.00008052	1038.	12886018.	12.2940132	28.5349159	
0.00008500	1095.	12886018.	12.0390652	29.4917610	

0.00008947	1153.	12886018.	11.8096119	30.4486061
0.00009394	1211.	12886018.	11.6020113	31.4054512
0.00009842	1268.	12886018.	11.4132836	32.3622964
0.0001029	1326.	12886018.	11.2409669	33.3191415
0.0001074	1384.	12886018.	11.0830099	34.2759867
0.0001118	1441.	12886018.	10.9376895	35.2328318
0.0001163	1499.	12886018.	10.8035476	36.1896769
0.0001208	1556.	12886018.	10.6793422	37.1465221
0.0001253	1614.	12886018.	10.5640085	38.1033672
0.0001297	1672.	12886018.	10.4566289	39.0602124
0.0001342	1729.	12886018.	10.3564079	40.0170575
0.0001387	1787.	12886018.	10.2626528	40.9739027
0.0001432	1845.	12886018.	10.1747574	41.9307478
0.0001476	1902.	12886018.	10.0921890	42.8875929
0.0001521	1960.	12886018.	10.0144776	43.8444381
0.0001566	2018.	12886018.	9.9412068	44.8012832
0.0001610	2075.	12886018.	9.8720066	45.7581283
0.0001655	2133.	12886018.	9.8065470	46.7149735
0.0001700	2191.	12886018.	9.7445326	47.6718186
0.0001745	2248.	12886018.	9.6856984	48.6286637
0.0001834	2363.	12880749.	9.5773618	50.0000000 Y
0.0001924	2470.	12840834.	9.4840016	50.0000000 Y
0.0002013	2570.	12768566.	9.4041633	50.0000000 Y
0.0002103	2665.	12673800.	9.3354859	50.0000000 Y
0.0002192	2754.	12562505.	9.2762732	50.0000000 Y
0.0002282	2838.	12438357.	9.2252878	50.0000000 Y
0.0002371	2918.	12306445.	9.1811140	50.0000000 Y
0.0002460	2994.	12169194.	9.1428293	50.0000000 Y
0.0002550	3067.	12028124.	9.1097379	50.0000000 Y
0.0002639	3137.	11885299.	9.0810754	50.0000000 Y
0.0002729	3204.	11742499.	9.0561571	50.0000000 Y
0.0002818	3269.	11599906.	9.0346493	50.0000000 Y
0.0002908	3332.	11458160.	9.0161572	50.0000000 Y
0.0002997	3391.	11315153.	8.9995889	50.0000000 Y
0.0003087	3446.	11165153.	8.9834339	50.0000000 Y
0.0003176	3497.	11010132.	8.9676295	50.0000000 Y
0.0003266	3544.	10851774.	8.9521181	50.0000000 Y
0.0003355	3587.	10691278.	8.9368150	50.0000000 Y
0.0003445	3627.	10529443.	8.9220161	50.0000000 Y
0.0003534	3664.	10367974.	8.9074630	50.0000000 Y
0.0003624	3699.	10207487.	8.8930399	50.0000000 Y
0.0003713	3731.	10048587.	8.8788483	50.0000000 Y
0.0003803	3761.	9891088.	8.8651582	50.0000000 Y
0.0003892	3789.	9736626.	8.8515813	50.0000000 Y
0.0003981	3816.	9584692.	8.8384468	50.0000000 Y
0.0004071	3841.	9435131.	8.8254390	50.0000000 Y
0.0004160	3864.	9288415.	8.8125282	50.0000000 Y
0.0004250	3886.	9144891.	8.8001206	50.0000000 Y
0.0004339	3907.	9004567.	8.7877958	50.0000000 Y
0.0004429	3927.	8866737.	8.7756499	50.0000000 Y
0.0004518	3946.	8732758.	8.7639374	50.0000000 Y
0.0004608	3963.	8601248.	8.7520754	50.0000000 Y
0.0004697	3980.	8472925.	8.7407916	50.0000000 Y
0.0004787	3996.	8347887.	8.7293769	50.0000000 Y
0.0004876	4011.	8225455.	8.7184233	50.0000000 Y
0.0004966	4025.	8106088.	8.7075862	50.0000000 Y

0.0005055	4039.	7989935.	8.6967283	50.0000000 Y
0.0005145	4052.	7875951.	8.6863676	50.0000000 Y
0.0005234	4064.	7765141.	8.6761208	50.0000000 Y
0.0005324	4076.	7656911.	8.6657339	50.0000000 Y
0.0005681	4119.	7249468.	8.6267508	50.0000000 Y
0.0006039	4155.	6879165.	8.5901242	50.0000000 Y
0.0006397	4185.	6542344.	8.5560686	50.0000000 Y
0.0006755	4211.	6234472.	8.5236973	50.0000000 Y
0.0007113	4234.	5953047.	8.4930774	50.0000000 Y
0.0007471	4255.	5694837.	8.4642335	50.0000000 Y
0.0007829	4272.	5457235.	8.4371145	50.0000000 Y
0.0008187	4288.	5238005.	8.4111949	50.0000000 Y
0.0008544	4302.	5034908.	8.3865498	50.0000000 Y
0.0008902	4315.	4846683.	8.3632788	50.0000000 Y
0.0009260	4327.	4672143.	8.3410937	50.0000000 Y
0.0009618	4337.	4508710.	8.3199547	50.0000000 Y
0.0009976	4346.	4356518.	8.2999221	50.0000000 Y

Summary of Results for Nominal Moment Capacity for Section 1

Load No.	Axial Thrust kips	Nominal Moment Capacity in-kips
1	386.000000000	4346.

Note that the values in the above table are not factored by a strength reduction factor for LRFD.

The value of the strength reduction factor depends on the provisions of the LRFD code being followed.

The above values should be multiplied by the appropriate strength reduction factor to compute ultimate moment capacity according to the LRFD structural design standard being followed.

Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	0.00	0.00	N.A.	No	0.00	149998.
2	10.0000	9.9999	Yes	No	149998.	43423.

3	11.0000	12.5650	Yes	No	193422.	475355.
4	19.0000	123.0852	No	No	668777.	78225.
5	33.0000	20.0648	No	No	747002.	N.A.

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays, non-liquefied sands, and cemented c-phi soil.

Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 1

Pile-head conditions are Displacement and Pile-head Rotation (Loading Type 5)
Displacement of pile head = 0.720000 inches
Rotation of pile head = 4.000E-03 radians
Axial load on pile head = 386000.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/inch	Soil Spr. Es*H lb/inch	Distrib. Lat. Load lb/inch
0.00	0.7200	-4152055.	75744.	0.00400	80923.	6.90E+09	0.00	0.00	0.00
0.5000	0.7332	-3704579.	75184.	5.84E-04	73421.	6.90E+09	-80.720	660.5856	0.00
1.0000	0.7270	-3252548.	74400.	-0.00187	65842.	1.16E+10	-180.889	1493.	0.00
1.5000	0.7108	-2803145.	72998.	-0.00338	58308.	1.25E+10	-286.246	2416.	0.00
2.0000	0.6865	-2360927.	70978.	-0.00460	50894.	1.29E+10	-387.281	3385.	0.00
2.5000	0.6556	-1930105.	68369.	-0.00560	43671.	1.29E+10	-482.267	4414.	0.00
3.0000	0.6193	-1514563.	65230.	-0.00640	36704.	1.29E+10	-564.101	5465.	0.00
3.5000	0.5788	-1117695.	61598.	-0.00701	30050.	1.29E+10	-646.656	6704.	0.00
4.0000	0.5351	-742902.	57483.	-0.00745	23767.	1.29E+10	-724.726	8126.	0.00
4.5000	0.4894	-393398.	52953.	-0.00771	17907.	1.29E+10	-785.361	9628.	0.00
5.0000	0.4426	-71742.	48139.	-0.00782	12514.	1.29E+10	-819.517	11110.	0.00
5.5000	0.3956	220488.	43017.	-0.00779	15008.	1.29E+10	-887.516	13462.	0.00
6.0000	0.3492	480530.	37538.	-0.00762	19368.	1.29E+10	-938.844	16134.	0.00
6.5000	0.3041	706256.	31773.	-0.00735	23152.	1.29E+10	-982.860	19393.	0.00
7.0000	0.2610	895837.	25761.	-0.00697	26331.	1.29E+10	-1021.	23475.	0.00
7.5000	0.2204	1047689.	19560.	-0.00652	28877.	1.29E+10	-1046.	28471.	0.00
8.0000	0.1828	1160759.	13267.	-0.00601	30772.	1.29E+10	-1052.	34525.	0.00
8.5000	0.1483	1234720.	7003.	-0.00545	32012.	1.29E+10	-1037.	41933.	0.00
9.0000	0.1174	1270029.	891.8956	-0.00487	32604.	1.29E+10	-1000.	51132.	0.00
9.5000	0.08995	1267961.	-4933.	-0.00427	32570.	1.29E+10	-941.357	62794.	0.00
10.0000	0.06607	1230636.	-10064.	-0.00369	31944.	1.29E+10	-769.053	69840.	0.00
10.5000	0.04563	1164299.	-14044.	-0.00314	30832.	1.29E+10	-557.696	73332.	0.00
11.0000	0.02844	1076628.	-16337.	-0.00261	29362.	1.29E+10	-206.502	43560.	0.00
11.5000	0.01426	980363.	-17281.	-0.00213	27748.	1.29E+10	-108.271	45540.	0.00
12.0000	0.00282	879143.	-17673.	-0.00170	26051.	1.29E+10	-22.374	47520.	0.00
12.5000	-0.00616	776169.	-17588.	-0.00132	24325.	1.29E+10	50.8115	49500.	0.00
13.0000	-0.01297	674188.	-17101.	-9.79E-04	22615.	1.29E+10	111.3211	51480.	0.00
13.5000	-0.01791	575487.	-16289.	-6.88E-04	20960.	1.29E+10	159.5469	53460.	0.00
14.0000	-0.02123	481909.	-15222.	-4.42E-04	19391.	1.29E+10	196.1722	55440.	0.00

14.5000	-0.02321	394874.	-13967.	-2.38E-04	17932.	1.29E+10	222.1072	57420.	0.00
15.0000	-0.02408	315409.	-12585.	-7.24E-05	16600.	1.29E+10	238.4263	59400.	0.00
15.5000	-0.02408	244186.	-11131.	5.79E-05	15406.	1.29E+10	246.3084	61380.	0.00
16.0000	-0.02339	181568.	-9651.	1.57E-04	14356.	1.29E+10	246.9824	63360.	0.00
16.5000	-0.02219	127645.	-8185.	2.29E-04	13452.	1.29E+10	241.6779	65340.	0.00
17.0000	-0.02064	82285.	-6765.	2.78E-04	12691.	1.29E+10	231.5831	67320.	0.00
17.5000	-0.01886	45174.	-5417.	3.08E-04	12069.	1.29E+10	217.8085	69300.	0.00
18.0000	-0.01695	15854.	-4160.	3.22E-04	11578.	1.29E+10	201.3583	71280.	0.00
18.5000	-0.01500	-6233.	-3006.	3.24E-04	11416.	1.29E+10	183.1076	73260.	0.00
19.0000	-0.01306	-21722.	-2228.	3.18E-04	11676.	1.29E+10	76.2122	35010.	0.00
19.5000	-0.01119	-34444.	-1783.	3.04E-04	11889.	1.29E+10	72.3791	38822.	0.00
20.0000	-0.00941	-44523.	-1360.	2.86E-04	12058.	1.29E+10	68.3237	43574.	0.00
20.5000	-0.00775	-52094.	-963.296	2.64E-04	12185.	1.29E+10	64.0634	49573.	0.00
21.0000	-0.00625	-57303.	-592.272	2.38E-04	12272.	1.29E+10	59.6115	57271.	0.00
21.5000	-0.00490	-60304.	-248.509	2.11E-04	12323.	1.29E+10	54.9761	67363.	0.00
22.0000	-0.00372	-61261.	66.8929	1.82E-04	12339.	1.29E+10	50.1580	80971.	0.00
22.5000	-0.00271	-60347.	352.8039	1.54E-04	12323.	1.29E+10	45.1457	100033.	0.00
23.0000	-0.00187	-57742.	607.9552	1.27E-04	12280.	1.29E+10	39.9048	128202.	0.00
23.5000	-0.00119	-53638.	830.7241	1.01E-04	12211.	1.29E+10	34.3515	173401.	0.00
24.0000	-6.60E-04	-48239.	1019.	7.70E-05	12120.	1.29E+10	28.2728	257213.	0.00
24.5000	-2.65E-04	-41771.	1166.	5.60E-05	12012.	1.29E+10	20.9744	474578.	0.00
25.0000	1.25E-05	-34502.	1210.	3.82E-05	11890.	1.29E+10	-6.433	3095248.	0.00
25.5000	1.94E-04	-27428.	1135.	2.38E-05	11772.	1.29E+10	-18.537	574119.	0.00
26.0000	2.98E-04	-20992.	1015.	1.26E-05	11664.	1.29E+10	-21.498	432334.	0.00
26.5000	3.44E-04	-15307.	882.7065	4.10E-06	11568.	1.29E+10	-22.583	393514.	0.00
27.0000	3.48E-04	-10419.	746.9445	-1.89E-06	11486.	1.29E+10	-22.671	391382.	0.00
27.5000	3.22E-04	-6335.	612.6191	-5.79E-06	11418.	1.29E+10	-22.104	412320.	0.00
28.0000	2.78E-04	-3040.	483.1085	-7.97E-06	11363.	1.29E+10	-21.066	454543.	0.00
28.5000	2.26E-04	-500.868	360.9104	-8.80E-06	11320.	1.29E+10	-19.667	522159.	0.00
29.0000	1.73E-04	1331.	247.9604	-8.60E-06	11334.	1.29E+10	-17.983	625482.	0.00
29.5000	1.23E-04	2515.	145.8114	-7.71E-06	11354.	1.29E+10	-16.067	785380.	0.00
30.0000	8.00E-05	3117.	55.7683	-6.40E-06	11364.	1.29E+10	-13.948	1046042.	0.00
30.5000	4.60E-05	3213.	-20.950	-4.92E-06	11366.	1.29E+10	-11.625	1517188.	0.00
31.0000	2.09E-05	2888.	-82.827	-3.50E-06	11360.	1.29E+10	-9.001	2581631.	0.00
31.5000	3.93E-06	2236.	-115.125	-2.31E-06	11349.	1.29E+10	-1.765	2693043.	0.00
32.0000	-6.81E-06	1517.	-102.668	-1.44E-06	11337.	1.29E+10	5.9179	5217008.	0.00
32.5000	-1.33E-05	1010.	-62.328	-8.48E-07	11329.	1.29E+10	7.5288	3394730.	0.00
33.0000	-1.70E-05	773.2698	-37.321	-4.33E-07	11325.	1.29E+10	0.8071	285120.	0.00
33.5000	-1.85E-05	564.4588	-32.222	-1.22E-07	11321.	1.29E+10	0.8926	289440.	0.00
34.0000	-1.84E-05	387.1715	-26.835	1.00E-07	11318.	1.29E+10	0.9030	293760.	0.00
34.5000	-1.73E-05	241.9742	-21.547	2.46E-07	11316.	1.29E+10	0.8596	298080.	0.00
35.0000	-1.55E-05	127.4615	-16.627	3.32E-07	11314.	1.29E+10	0.7805	302400.	0.00
35.5000	-1.33E-05	40.9087	-12.244	3.72E-07	11312.	1.29E+10	0.6806	306720.	0.00
36.0000	-1.10E-05	-21.188	-8.488	3.76E-07	11312.	1.29E+10	0.5716	311040.	0.00
36.5000	-8.80E-06	-62.685	-5.386	3.57E-07	11313.	1.29E+10	0.4624	315360.	0.00
37.0000	-6.74E-06	-87.468	-2.920	3.22E-07	11313.	1.29E+10	0.3594	319680.	0.00
37.5000	-4.94E-06	-99.219	-1.043	2.78E-07	11313.	1.29E+10	0.2666	324000.	0.00
38.0000	-3.41E-06	-101.267	0.3162	2.32E-07	11313.	1.29E+10	0.1863	328320.	0.00
38.5000	-2.16E-06	-96.498	1.2339	1.86E-07	11313.	1.29E+10	0.1196	332640.	0.00
39.0000	-1.18E-06	-87.321	1.7910	1.43E-07	11313.	1.29E+10	0.06615	336960.	0.00
39.5000	-4.43E-07	-75.668	2.0651	1.05E-07	11313.	1.29E+10	0.02520	341280.	0.00
40.0000	8.04E-08	-63.026	2.1268	7.26E-08	11313.	1.29E+10	-0.00463	345600.	0.00
40.5000	4.28E-07	-50.483	2.0380	4.61E-08	11313.	1.29E+10	-0.02495	349920.	0.00
41.0000	6.34E-07	-38.784	1.8508	2.54E-08	11312.	1.29E+10	-0.03744	354240.	0.00
41.5000	7.32E-07	-28.390	1.6072	9.72E-09	11312.	1.29E+10	-0.04375	358560.	0.00
42.0000	7.51E-07	-19.542	1.3397	-1.44E-09	11312.	1.29E+10	-0.04541	362880.	0.00

42.5000	7.15E-07	-12.307	1.0722	-8.85E-09	11312.	1.29E+10	-0.04375	367200.	0.00
43.0000	6.45E-07	-6.634	0.8212	-1.33E-08	11312.	1.29E+10	-0.03992	371520.	0.00
43.5000	5.56E-07	-2.391	0.5970	-1.54E-08	11312.	1.29E+10	-0.03482	375840.	0.00
44.0000	4.60E-07	0.6019	0.4051	-1.58E-08	11312.	1.29E+10	-0.02917	380160.	0.00
44.5000	3.66E-07	2.5436	0.2471	-1.50E-08	11312.	1.29E+10	-0.02349	384480.	0.00
45.0000	2.80E-07	3.6372	0.1223	-1.36E-08	11312.	1.29E+10	-0.01813	388800.	0.00
45.5000	2.03E-07	4.0742	0.02796	-1.18E-08	11312.	1.29E+10	-0.01332	393120.	0.00
46.0000	1.38E-07	4.0274	-0.03942	-9.92E-09	11312.	1.29E+10	-0.00914	397440.	0.00
46.5000	8.41E-08	3.6471	-0.08376	-8.14E-09	11312.	1.29E+10	-0.00563	401760.	0.00
47.0000	4.04E-08	3.0600	-0.109	-6.58E-09	11312.	1.29E+10	-0.00273	406080.	0.00
47.5000	5.22E-09	2.3712	-0.118	-5.31E-09	11312.	1.29E+10	-3.57E-04	410400.	0.00
48.0000	-2.33E-08	1.6670	-0.114	-4.37E-09	11312.	1.29E+10	0.00161	414720.	0.00
48.5000	-4.72E-08	1.0191	-0.09962	-3.75E-09	11312.	1.29E+10	0.00330	419040.	0.00
49.0000	-6.83E-08	0.4889	-0.07527	-3.40E-09	11312.	1.29E+10	0.00482	423360.	0.00
49.5000	-8.80E-08	0.1316	-0.04199	-3.25E-09	11312.	1.29E+10	0.00627	427680.	0.00
50.0000	-1.07E-07	0.00	0.00	-3.22E-09	11312.	1.29E+10	0.00773	216000.	0.00

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 1:

Pile-head deflection = 0.72000000 inches
 Computed slope at pile head = 0.00400000 radians
 Maximum bending moment = -4152055. inch-lbs
 Maximum shear force = 75744. lbs
 Depth of maximum bending moment = 0.000000 feet below pile head
 Depth of maximum shear force = 0.000000 feet below pile head
 Number of iterations = 12
 Number of zero deflection points = 5

Computed Values of Pile Loading and Deflection for Lateral Loading for Load Case Number 2

Pile-head conditions are Displacement and Moment (Loading Type 4)

Displacement of pile head = 0.720000 inches
 Moment at pile head = -3430300.0 in-lbs
 Axial load at pile head = 386000.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/inch	Soil Spr. Es*H lb/inch	Distrib. Lat. Load lb/inch
0.00	0.7200	-3430300.	66836.	-1.26E-04	68823.	1.12E+10	0.00	0.00	0.00
0.5000	0.7137	-3026866.	66594.	-0.00185	62059.	1.12E+10	-80.720	678.5744	0.00
1.0000	0.6977	-2622585.	65809.	-0.00328	55281.	1.27E+10	-180.888	1555.	0.00
1.5000	0.6743	-2221950.	64407.	-0.00442	48564.	1.29E+10	-286.244	2547.	0.00

2.0000	0.6447	-1829224.	62387.	-0.00536	41980.	1.29E+10	-387.278	3604.	0.00
2.5000	0.6100	-1448467.	59778.	-0.00613	35596.	1.29E+10	-482.263	4744.	0.00
3.0000	0.5712	-1083510.	56639.	-0.00672	29477.	1.29E+10	-564.095	5925.	0.00
3.5000	0.5294	-737691.	53065.	-0.00714	23680.	1.29E+10	-627.167	7108.	0.00
4.0000	0.4855	-413656.	49133.	-0.00741	18247.	1.29E+10	-683.580	8448.	0.00
4.5000	0.4405	-113782.	44879.	-0.00753	13219.	1.29E+10	-734.346	10002.	0.00
5.0000	0.3952	159777.	40401.	-0.00752	13990.	1.29E+10	-758.593	11518.	0.00
5.5000	0.3503	405855.	35672.	-0.00739	18116.	1.29E+10	-817.734	14008.	0.00
6.0000	0.3065	622056.	30635.	-0.00715	21741.	1.29E+10	-861.123	16857.	0.00
6.5000	0.2645	806587.	25355.	-0.00682	24835.	1.29E+10	-898.993	20394.	0.00
7.0000	0.2247	957883.	19861.	-0.00641	27371.	1.29E+10	-932.061	24887.	0.00
7.5000	0.1876	1074593.	14220.	-0.00593	29328.	1.29E+10	-948.320	30327.	0.00
8.0000	0.1535	1156004.	8538.	-0.00541	30693.	1.29E+10	-945.883	36965.	0.00
8.5000	0.1227	1202117.	2929.	-0.00486	31466.	1.29E+10	-923.586	45174.	0.00
9.0000	0.09517	1213685	2483.	-0.00430	31660.	1.29E+10	-880.479	55512.	0.00
9.5000	0.07105	1192246.	-7571.	-0.00374	31300.	1.29E+10	-815.625	68873.	0.00
10.0000	0.05027	1140159.	-11774.	-0.00320	30427.	1.29E+10	-585.177	69840.	0.00
10.5000	0.03268	1065776.	-14727.	-0.00268	29180.	1.29E+10	-399.377	73332.	0.00
11.0000	0.01806	975867.	-16319.	-0.00221	27673.	1.29E+10	-131.103	43560.	0.00
11.5000	0.00617	880185.	-16852.	-0.00178	26068.	1.29E+10	-46.801	45540.	0.00
12.0000	-0.00327	781870.	-16915.	-0.00139	24420.	1.29E+10	25.8759	47520.	0.00
12.5000	-0.01052	683642.	-16577.	-0.00105	22773.	1.29E+10	86.7576	49500.	0.00
13.0000	-0.01586	587801.	-15909.	-7.53E-04	21167.	1.29E+10	136.0366	51480.	0.00
13.5000	-0.01955	496223.	-14978.	-5.01E-04	19631.	1.29E+10	174.2078	53460.	0.00
14.0000	-0.02186	410382.	-13850.	-2.90E-04	18192.	1.29E+10	202.0093	55440.	0.00
14.5000	-0.02303	331370.	-12582.	-1.17E-04	16867.	1.29E+10	220.3638	57420.	0.00
15.0000	-0.02326	259935.	-11230.	2.08E-05	15670.	1.29E+10	230.3216	59400.	0.00
15.5000	-0.02278	196510.	-9840.	1.27E-04	14606.	1.29E+10	233.0078	61380.	0.00
16.0000	-0.02174	141262.	-8453.	2.06E-04	13680.	1.29E+10	229.5746	63360.	0.00
16.5000	-0.02031	94126.	-7100.	2.61E-04	12890.	1.29E+10	221.1594	65340.	0.00
17.0000	-0.01861	54850.	-5810.	2.95E-04	12231.	1.29E+10	208.8489	67320.	0.00
17.5000	-0.01677	23034.	-4603.	3.13E-04	11698.	1.29E+10	193.6501	69300.	0.00
18.0000	-0.01485	-1836.	-3493.	3.18E-04	11342.	1.29E+10	176.4674	71280.	0.00
18.5000	-0.01295	-20350.	-2489.	3.13E-04	11653.	1.29E+10	158.0852	73260.	0.00
19.0000	-0.01110	-33152.	-1798.	3.01E-04	11868.	1.29E+10	72.1920	39033.	0.00
19.5000	-0.00934	-43319.	-1377.	2.83E-04	12038.	1.29E+10	68.1657	43791.	0.00
20.0000	-0.00770	-50986.	-980.667	2.61E-04	12167.	1.29E+10	63.9335	49798.	0.00
20.5000	-0.00621	-56296.	-610.340	2.36E-04	12256.	1.29E+10	59.5089	57505.	0.00
21.0000	-0.00487	-59403.	-267.112	2.09E-04	12308.	1.29E+10	54.9005	67606.	0.00
21.5000	-0.00370	-60469.	47.9173	1.81E-04	12326.	1.29E+10	50.1094	81224.	0.00
22.0000	-0.00270	-59666.	333.6208	1.53E-04	12312.	1.29E+10	45.1251	100289.	0.00
22.5000	-0.00186	-57175.	588.7398	1.26E-04	12270.	1.29E+10	39.9146	128444.	0.00
23.0000	-0.00119	-53185.	811.6759	1.00E-04	12203.	1.29E+10	34.3975	173565.	0.00
23.5000	-6.62E-04	-47899.	999.9776	7.67E-05	12115.	1.29E+10	28.3698	257036.	0.00
24.0000	-2.69E-04	-41540.	1149.	5.58E-05	12008.	1.29E+10	21.1782	472033.	0.00
24.5000	7.79E-06	-34374.	1198.	3.82E-05	11888.	1.29E+10	-4.615	3552705.	0.00
25.0000	1.89E-04	-27337.	1130.	2.38E-05	11770.	1.29E+10	-18.271	580800.	0.00
25.5000	2.93E-04	-20928.	1011.	1.26E-05	11663.	1.29E+10	-21.306	435797.	0.00
26.0000	3.39E-04	-15264.	879.7432	4.13E-06	11568.	1.29E+10	-22.419	396265.	0.00
26.5000	3.43E-04	-10390.	744.9236	-1.84E-06	11486.	1.29E+10	-22.521	394023.	0.00
27.0000	3.17E-04	-6316.	611.4772	-5.73E-06	11418.	1.29E+10	-21.962	415177.	0.00
27.5000	2.74E-04	-3026.	482.8148	-7.90E-06	11362.	1.29E+10	-20.926	457928.	0.00
28.0000	2.23E-04	-486.065	361.4571	-8.72E-06	11320.	1.29E+10	-19.527	526496.	0.00
28.5000	1.70E-04	1352.	249.3583	-8.52E-06	11334.	1.29E+10	-17.840	631430.	0.00
29.0000	1.20E-04	2546.	148.0875	-7.61E-06	11354.	1.29E+10	-15.917	794009.	0.00
29.5000	7.82E-05	3164.	58.9576	-6.28E-06	11365.	1.29E+10	-13.793	1058841.	0.00

30.0000	4.49E-05	3282.	-16.831	-4.78E-06	11367.	1.29E+10	-11.470	1533705.	0.00
30.5000	2.08E-05	2984.	-77.882	-3.32E-06	11362.	1.29E+10	-8.880	2566685.	0.00
31.0000	4.98E-06	2363.	-121.145	-2.08E-06	11351.	1.29E+10	-5.541	6674374.	0.00
31.5000	-4.19E-06	1540.	-122.235	-1.17E-06	11338.	1.29E+10	5.1773	7405556.	0.00
32.0000	-9.07E-06	901.7185	-86.553	-6.02E-07	11327.	1.29E+10	6.7167	4444306.	0.00
32.5000	-1.14E-05	504.2116	-44.625	-2.75E-07	11320.	1.29E+10	7.2593	3813395.	0.00
33.0000	-1.24E-05	367.4955	-21.084	-7.20E-08	11318.	1.29E+10	0.5877	285120.	0.00
33.5000	-1.23E-05	251.5398	-17.543	7.21E-08	11316.	1.29E+10	0.5927	289440.	0.00
34.0000	-1.15E-05	156.6488	-14.075	1.67E-07	11314.	1.29E+10	0.5631	293760.	0.00
34.5000	-1.03E-05	81.8613	-10.854	2.23E-07	11313.	1.29E+10	0.5107	298080.	0.00
35.0000	-8.83E-06	25.3710	-7.987	2.48E-07	11312.	1.29E+10	0.4450	302400.	0.00
35.5000	-7.31E-06	-15.126	-5.531	2.50E-07	11312.	1.29E+10	0.3736	306720.	0.00
36.0000	-5.83E-06	-42.158	-3.504	2.37E-07	11312.	1.29E+10	0.3022	311040.	0.00
36.5000	-4.47E-06	-58.265	-1.892	2.13E-07	11313.	1.29E+10	0.2348	315360.	0.00
37.0000	-3.27E-06	-65.855	-0.665	1.84E-07	11313.	1.29E+10	0.1742	319680.	0.00
37.5000	-2.26E-06	-67.103	0.2226	1.53E-07	11313.	1.29E+10	0.1218	324000.	0.00
38.0000	-1.43E-06	-63.895	0.8223	1.23E-07	11313.	1.29E+10	0.07814	328320.	0.00
38.5000	-7.79E-07	-57.805	1.1864	9.46E-08	11313.	1.29E+10	0.04321	332640.	0.00
39.0000	-2.92E-07	-50.097	1.3653	6.95E-08	11313.	1.29E+10	0.01642	336960.	0.00
39.5000	5.47E-08	-41.744	1.4052	4.81E-08	11312.	1.29E+10	-0.00311	341280.	0.00
40.0000	2.85E-07	-33.457	1.3466	3.06E-08	11312.	1.29E+10	-0.01642	345600.	0.00
40.5000	4.22E-07	-25.726	1.2235	1.68E-08	11312.	1.29E+10	-0.02462	349920.	0.00
41.0000	4.87E-07	-18.854	1.0633	6.46E-09	11312.	1.29E+10	-0.02877	354240.	0.00
41.5000	5.00E-07	-12.996	0.8874	-9.51E-10	11312.	1.29E+10	-0.02986	358560.	0.00
42.0000	4.76E-07	-8.200	0.7115	-5.89E-09	11312.	1.29E+10	-0.02878	362880.	0.00
42.5000	4.29E-07	-4.431	0.5464	-8.83E-09	11312.	1.29E+10	-0.02626	367200.	0.00
43.0000	3.70E-07	-1.602	0.3989	-1.02E-08	11312.	1.29E+10	-0.02291	371520.	0.00
43.5000	3.06E-07	0.4037	0.2726	-1.05E-08	11312.	1.29E+10	-0.01919	375840.	0.00
44.0000	2.44E-07	1.7183	0.1687	-1.00E-08	11312.	1.29E+10	-0.01545	380160.	0.00
44.5000	1.86E-07	2.4750	0.08663	-9.04E-09	11312.	1.29E+10	-0.01193	384480.	0.00
45.0000	1.35E-07	2.7997	0.02455	-7.81E-09	11312.	1.29E+10	-0.00877	388800.	0.00
45.5000	9.24E-08	2.8058	-0.01991	-6.51E-09	11312.	1.29E+10	-0.00605	393120.	0.00
46.0000	5.72E-08	2.5909	-0.04944	-5.25E-09	11312.	1.29E+10	-0.00379	397440.	0.00
46.5000	2.94E-08	2.2368	-0.06672	-4.13E-09	11312.	1.29E+10	-0.00197	401760.	0.00
47.0000	7.73E-09	1.8094	-0.07418	-3.18E-09	11312.	1.29E+10	-5.23E-04	406080.	0.00
47.5000	-8.85E-09	1.3613	-0.07394	-2.45E-09	11312.	1.29E+10	6.05E-04	410400.	0.00
48.0000	-2.16E-08	0.9335	-0.06764	-1.91E-09	11312.	1.29E+10	0.00149	414720.	0.00
48.5000	-3.18E-08	0.5585	-0.05649	-1.56E-09	11312.	1.29E+10	0.00222	419040.	0.00
49.0000	-4.04E-08	0.2629	-0.04128	-1.37E-09	11312.	1.29E+10	0.00285	423360.	0.00
49.5000	-4.83E-08	0.06954	-0.02241	-1.30E-09	11312.	1.29E+10	0.00344	427680.	0.00
50.0000	-5.59E-08	0.00	0.00	-1.28E-09	11312.	1.29E+10	0.00403	216000.	0.00

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 2:

Pile-head deflection = 0.72000000 inches
 Computed slope at pile head = -0.0001265 radians
 Maximum bending moment = -3430300. inch-lbs
 Maximum shear force = 66836. lbs

Depth of maximum bending moment = 0.000000 feet below pile head
 Depth of maximum shear force = 0.000000 feet below pile head
 Number of iterations = 11
 Number of zero deflection points = 5

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
 Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
 Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
 Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
 Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	y, in	0.7200	S, rad	0.00400	386000.	0.7200	0.00400	75744.	-4152055.
2	y, in	0.7200	M, in-lb	-3430300.	386000.	0.7200	-1.26E-04	66836.	-3430300.

Maximum pile-head deflection = 0.7200000000 inches
 Maximum pile-head rotation = 0.0040000000 radians = 0.229183 deg.

The analysis ended normally.



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JOB: 09.0026237.01
SUBJECT: Pile Evaluation for Abutment 2 Expansion
SHEET: 1 OF 8
CALCULATED BY J. Barnes 04/19/2026
CHECKED BY J. Keohane 04/20/2026

Integral Abutment LRFD Pile Design

Subject: Pile Design for the thermal expansion of the St. George River Bridge Replacement in Union, Maine at Abutment 2.

Reference:

- AASHTO LRFD Bridge Design Specifications, 10th Edition, 2024
- Maine BDG Chapter 5 - Substructures 2014
- VTRANS Integral Abutment Bridge Design Guidelines 2008

Design Steps - Maine BDG

Step 1 - Determine the foundation displacements and the load effects (P_u and M_u) from the superstructure and substructure designs.

$P_u := 386 \cdot \text{kip}$ Maximum Factored Axial Load from Stantec

The limitations of the software require the plastic hinge evaluations be complete using a single deflection. Stantec provided a total deflection of 0.39 inches for these analyses.

Step 2 - If applicable, determine the magnitude of scour.

Step 3 - Select preliminary pile size.

HP14 x 117 Weak Axis Properties

Steel yield strength	$F_{y50} := 50 \text{ ksi}$
Modulus of elasticity for steel	$E := 29000 \text{ ksi}$
Cross sectional area of pile	$A_g := 34.4 \text{ in}^2$
Radius of gyration	$r_y := 3.59 \text{ in}$
Width of Flange	$b_f := 14.9 \cdot \text{in}$
Thickness of Flange	$t_f := 0.805 \cdot \text{in}$
Elastic Section Modulus	$S_y := 59.5 \cdot \text{in}^3$
Plastic Section Modulus	$Z_y := 91.4 \cdot \text{in}^3$

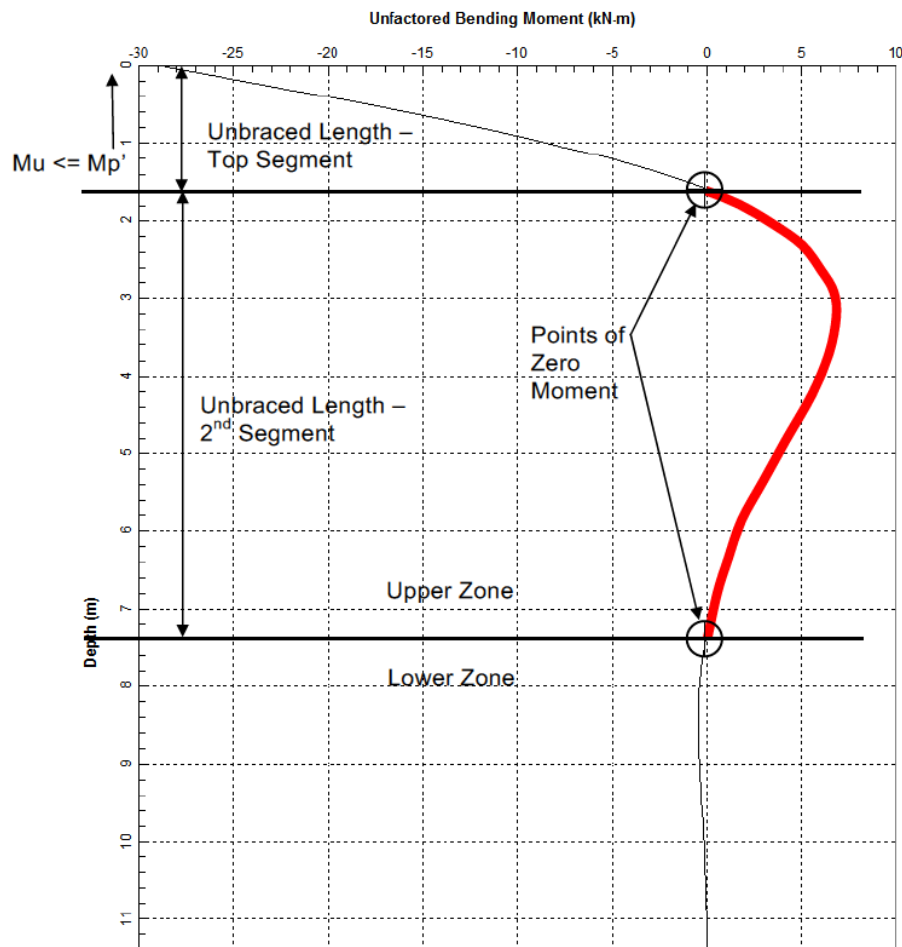
Step 4 - Determine the pile unbraced length and maximum moment at the top of the pile by running LPILE software for top translation = 0.39 inches, $P_u = 386 \text{ kip}$. No pile head rotation.



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EXAMPLE FIGURE: NOT TAKEN FROM THIS ANALYSIS

Maximum moment from LPILE output (page 40)

$$M_u := 4083 \text{ kip} \cdot \text{in} = 340.25 \cdot \text{kip} \cdot \text{ft}$$

Unbraced lengths from LPILE output (pages 40-41)

Upper segment

$$L_1 := 2.8 \cdot \text{ft}$$

Lower segment

$$L_2 := 9.4 \cdot \text{ft}$$

Step 5 - Determine if the applied moment on the pile will cause pile head plastic deformation considering the interaction of combined axial and flexural load effects on a single pile (LRFD 6.9.2.2)

- a. Obtain the unbraced lengths of the top and lower segments of the pile and calculate the column slenderness factor (λ) for each segment.



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See previous page for unbraced lengths (critical lengths L_1 and L_2).

Upper segment slenderness factor

$$\lambda_1 := \frac{(L_1)}{r_y} = 9.4$$

Lower segment slenderness factor

$$\lambda_2 := \frac{(L_2)}{r_y} = 31.4$$

b. Determine K values for top and bottom of the pile per LRFD Table C4.6.2.5-1

	(a)	(b)	(c)	(d)	(e)	(f)
Buckled shape of column is shown by dashed line						
Theoretical K value	0.5	0.7	1.0	1.0	2.0	2.0
Design value of K when ideal conditions are approximated	0.65	0.80	1.0	1.2	2.1	2.0
End condition code		Rotation fixed Rotation free Rotation fixed Rotation free		Translation fixed Translation fixed Translation free Translation free		

Upper segment K value (Type d)

$$K_1 := 1.2$$

Lower segment K value (Type c)

$$K_2 := 1$$

c. Calculate the nominal and factored structural pile resistance P_n , per AASHTO LRFD 6.9.4.1 using the λ values



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Elastic critical buckling resistance, P_e based on flexural buckling (AASHTO LRFD Eq. 6.9.4.1.2-1)

$$\text{Upper } P_e \quad P_{e1} := \frac{(\pi^2 \cdot E) \cdot A_g}{(K_1 \cdot \lambda_1)^2} = 78056 \cdot \text{kip}$$

$$\text{Lower } P_e \quad P_{e2} := \frac{(\pi^2 \cdot E) \cdot A_g}{(K_2 \cdot \lambda_2)^2} = 9973 \cdot \text{kip}$$

$$\text{Nominal yield resistance, } P_o \quad P_o := F_{y50} \cdot A_g = 1720 \cdot \text{kip}$$

Check that the ratio of P_e to P_o is > 0.44

If $P_e/P_o > 0.44$ then use AASHTO LRFD Eq. 6.9.4.1.1-1

If $P_e/P_o < 0.44$ then use AASHTO LRFD Eq. 6.9.4.1.1-2

$$P_n = \left[0.658^{\left(\frac{P_o}{P_e} \right)} \right] P_o \quad (6.9.4.1.1-1)$$

$$P_n = 0.877 P_e \quad (6.9.4.1.1-2)$$

$$\frac{P_{e1}}{P_o} = 45.381 \quad \frac{P_{e2}}{P_o} = 5.798$$

Both ratios are greater than 0.44, therefore, use AASHTO LRFD Eq. 6.9.4.1.1-1: Nominal structural axial Pile resistance, P_n for both segments

$$P_{n1} := \left[0.658^{\left(\frac{P_o}{P_{e1}} \right)} \right] \cdot P_o = 1704 \cdot \text{kip}$$

$$P_{n2} := \left[0.658^{\left(\frac{P_o}{P_{e2}} \right)} \right] \cdot P_o = 1600 \cdot \text{kip}$$



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Factored structural axial Pile Resistance, $P_r = \phi_c (P_n)$

$$\phi_c := 0.7 \quad \text{for axial resistance according to AASHTO LRFD 6.5.4.2}$$

$$P_{r1} := \phi_c \cdot P_{n1} = 1192.9 \cdot \text{kip}$$

$$P_{r2} := \phi_c \cdot P_{n2} = 1.1 \times 10^3 \cdot \text{kip}$$

d. Compare the ratio of P_u , the maximum factored axial load, to P_r , the structural resistance in the specified portion of the pile - the pile size should be such that the ratio is not less than 0.20.

Check for both segments

$$\frac{P_u}{P_{r1}} = 0.324 > 0.20, \text{ OK} \qquad \frac{P_u}{P_{r2}} = 0.345 > 0.20, \text{ OK}$$

e. Determine the nominal and factored flexural resistance about H-Pile weak axis, (AASHTO LRFD Eq. 6.12.2.2)

Check slenderness ratio for flange, limiting slenderness ratio for compact flange, and limiting slenderness ratio for a noncompact flange.

$$\lambda_f := \frac{b_f}{2 \cdot t_f} = 9.255 \qquad \text{slenderness ratio for flange (AASHTO LRFD Eq. 6.12.2.2.1-3)}$$

$$\lambda_{pf} := 0.38 \cdot \left(\frac{E}{F_{y50}} \right)^{.5} = 9.152$$

$$\lambda_{rf} := 0.83 \cdot \left(\frac{E}{F_{y50}} \right)^{.5} = 19.989$$

If $\lambda_{pf} < \lambda_f < \lambda_{rf}$ Use AASHTO LRFD Eq. 6.12.2.2.1-2 to find the nominal flexural resistance

$$M_n := \left[1 - \left(1 - \frac{S_y}{Z_y} \right) \cdot \left[\frac{\lambda_f - \lambda_{pf}}{0.45 \cdot \left(\frac{E}{F_{y50}} \right)^{.5}} \right] \right] \cdot F_{y50} \cdot Z_y = 379.57 \cdot \text{ft} \cdot \text{kip}$$



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$\phi_f := 1.0$ for flexural resistance according to AASHTO LRFD 6.5.4.2

$$M_r := M_n \cdot \phi_f = 379.6 \cdot \text{ft} \cdot \text{kip}$$

$$M_u = 340.2 \cdot \text{ft} \cdot \text{kip}$$

$$\frac{P_u}{P_{r1}} + \frac{8}{9} \cdot \frac{M_u}{M_r} = 1.12$$

If less than 1, remains in elastic zone. Since it exceeds 1, yielding is expected at the base of the pile cap.

f. Calculate the moment that will cause a plastic hinge at the top of the pile, M_p' ,

Note: M_p' will be lower than M_n due to the inclusion of the axial load in the interaction equation for pile overstresses

$$\frac{P_u}{P_r} + \frac{8.0}{9.0} \left(\frac{M_{ux}}{M_{rx}} + \frac{M_{uy}}{M_{ry}} \right) \leq 1.0$$

AASHTO LRFD Eq. 6.9.2.2 Interaction equation

Use the interaction equation to find the moment that will cause a plastic hinge at the top of the pile. Assume M_{ux} and $M_{rx} = 0$ (out-of-plane), $M_{ry} = M_r$ and $M_u = M_p'$, solve for M_p'

$$M_p' := \left(\frac{9}{8} \right) \cdot \left[1 - \left(\frac{P_u}{P_{r1}} \right) \right] \cdot M_r = 288.8 \cdot \text{ft} \cdot \text{kip} \quad M_p = 3466.2 \cdot \text{in} \cdot \text{kip}$$

g. The calculated moment from LPile Run 1 (shown in step 4) exceeds the moment that would cause a plastic hinge (above), therefore a plastic hinge forms, and the moment (M_p') represents the limiting moment reaction at the pile top for the subsequent analysis.

Step 6 - For fixed head piles, run a second LPILE analysis with end conditions 1) Top moment = M_p' , top translation = 0.39 in; and axial load equal to P_u . Recalculate unbraced lengths from the moment vs. depth curve.

New unbraced lengths were determined from the second LPile analysis

Upper segment

$$L_{1p} := 2.5 \cdot \text{ft}$$

Lower segment

$$L_{2p} := 9.7 \cdot \text{ft}$$



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6a. Repeat steps 5a through 5d above.

6b- If the pile size is such that the ratio of P_u to structural resistance exceeds 0.2, check the upper segment of the pile with the interaction equation of AASHTO LRFD Eq. 6.9.2.2. If a plastic hinge forms at the top of the pile, the K value of the upper segment changes from 1.2, for a rotation fixed head condition, to 2.1, for a rotation free head condition. With the new K value and lengths repeat step 5.

5a.

Upper segment slenderness factor

$$\lambda_{1p} := \frac{(L_{1p})}{r_y} = 8.357$$

Lower segment slenderness factor

$$\lambda_{2p} := \frac{(L_{2p})}{r_y} = 32.423$$

5b.

Upper segment K value (Type e)

$$K_{1p} := 2.1$$

Lower segment K value (Type c)

$$K_{2p} := 1$$

5c.

Elastic critical buckling resistance, P_e based on flexural buckling

Upper P_e

$$P_{ep1} := \frac{(\pi^2 \cdot E) \cdot A_g}{(K_{1p} \cdot \lambda_{1p})^2} = 31972 \cdot \text{kip}$$

Lower P_e

$$P_{ep2} := \frac{(\pi^2 \cdot E) \cdot A_g}{(K_{2p} \cdot \lambda_{2p})^2} = 9366 \cdot \text{kip}$$

Nominal yield resistance, P_o

$$P_o := F_{y50} \cdot A_g = 1720 \cdot \text{kip}$$

Check that the ratio of P_e to P_o is > 0.44

If $P_e/P_o > 0.44$ then use equation 6.9.4.1.1-1

If $P_e/P_o < 0.44$ then use equation 6.9.4.1.1-2

$$\frac{P_{ep1}}{P_o} = 18.588$$

$$\frac{P_{ep2}}{P_o} = 5.445$$



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Both ratios are greater than 0.44, therefore, use eq. 6.9.4.1.1-1: Nominal structural Pile resistance,
 P_n for both segments

$$P_{np1} := \left[0.658 \left(\frac{P_o}{P_{ep1}} \right) \right] \cdot P_o = 1682 \cdot \text{kip}$$

$$P_{np2} := \left[0.658 \left(\frac{P_o}{P_{ep2}} \right) \right] \cdot P_o = 1593 \cdot \text{kip}$$

Factored structural Pile Resistance, $P_r = \phi_c (P_n)$

$$P_{rp1} := \phi_c \cdot P_{np1} = 1177.2 \cdot \text{kip}$$

$$P_{rp2} := \phi_c \cdot P_{np2} = 1.1 \times 10^3 \cdot \text{kip}$$

5d. Compare the ratio of P_u to the structural resistance in the upper portion of the pile - the pile size should be such that the ratio is not less than 0.20.

Check for both segments

$$\frac{P_u}{P_{rp1}} = 0.328 \quad > 0.20, \text{ OK} \qquad \frac{P_u}{P_{rp2}} = 0.346 \quad > 0.20, \text{ OK}$$

From VTrans Integral Abutment Design Section 4.5.2 - Check the axial capacity of the upper segment and the interaction equation for the second segment to assess suitability of pile section.

Upper Segment

Check that P_u/P_{rp1} is < 1

$$\frac{P_u}{P_{rp1}} = 0.328 \qquad < 1, \text{ OK}$$

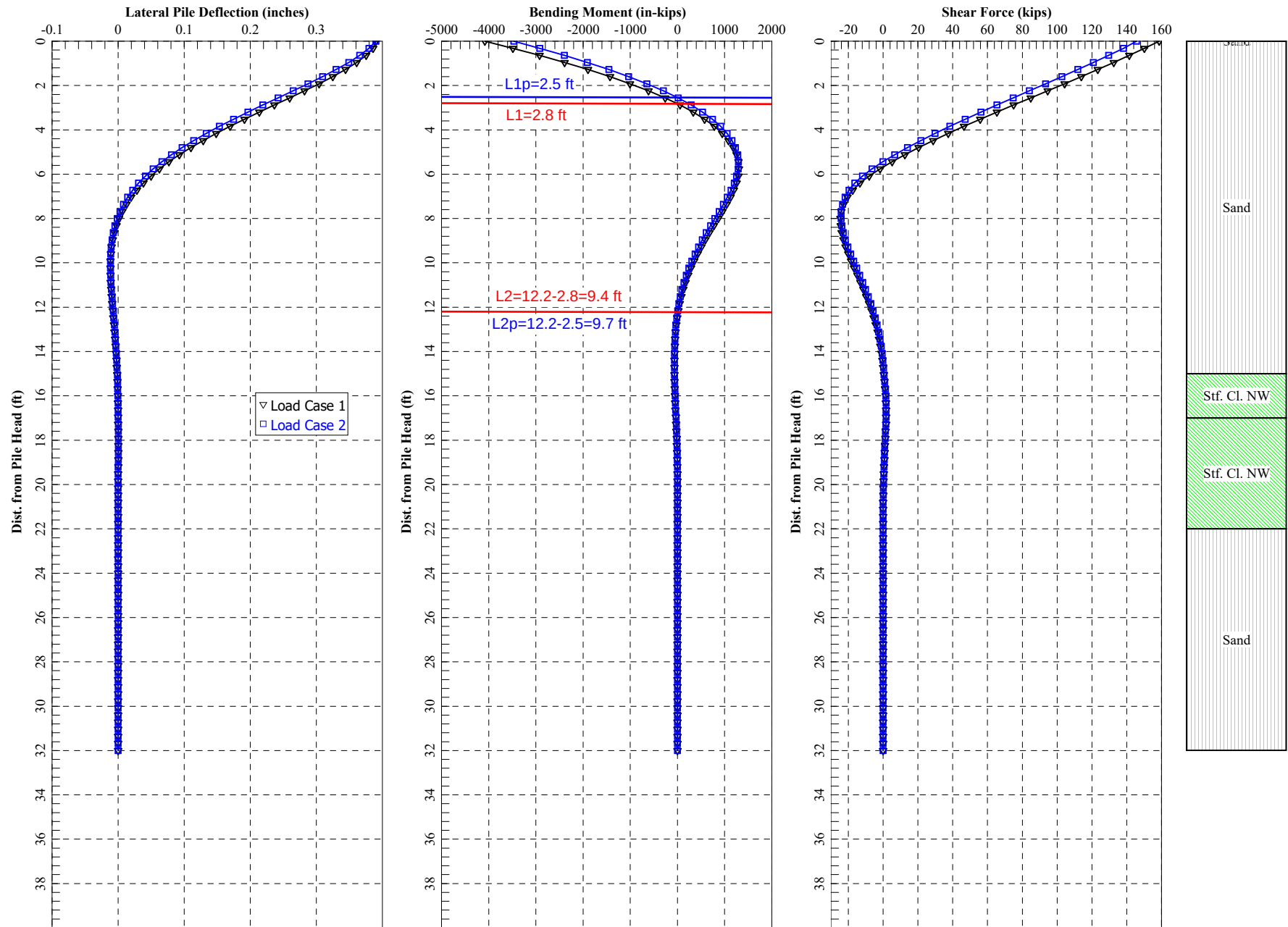
Lower Segment

Ultimate moment along the lower segment from LPile output

$$M_{maxp2} := 1294 \cdot \text{in} \cdot \text{kip}$$

$$\frac{P_u}{P_{rp2}} + \frac{8}{9} \cdot \frac{M_{maxp2}}{M_r} = 0.6 \qquad < 1, \text{ OK}$$

Abutment 2 - Expansion Case



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LPILE Version 2022-12.013

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License Type : (Single User License)

Analysis of Individual Piles and Drilled Shafts
Subjected to Lateral Loading Using the p-y Method
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Portland, ME

=====

This model was prepared by:
jason.barnes

Files Used for Analysis

Path to file locations:
\\09 Jobs\0026200s\09.0026237.00 - Stantec Union Bridge\01 - Final Design\Work\Calcs\Lpile\Abutment 2\Expansion\

Name of input data file:
Abutment 2 Expansion.lp12d

Name of output report file:
Abutment 2 Expansion.lp12o

Name of plot output file:
Abutment 2 Expansion.lp12p

Name of runtime message file:
Abutment 2 Expansion.lp12r

Date and Time of Analysis

Date: April 20, 2026 Time: 13:39:48

Problem Title

Project Name: St. George River Bridge, Union, Maine

Job Number: 09.0026237.01

Client: Stantec

Engineer: Jason Barnes

Description: Abutment 2 Expansion

Program Options and Settings

Computational Options:

- Conventional Analysis

Engineering Units Used for Data Input and Computations:

- US Customary System Units (pounds, feet, inches)

Analysis Control Options:

- Maximum number of iterations allowed = 500
- Deflection tolerance for convergence = 1.0000E-05 in
- Maximum allowable deflection = 100.0000 in
- Number of pile increments = 100

Loading Type and Number of Cycles of Loading:

- Static loading specified
- Use of p-y modification factors for p-y curves not selected
- Analysis uses layering correction (Method of Georgiadis)
- No distributed lateral loads are entered
- Loading by lateral soil movements acting on pile not selected
- Input of shear resistance at the pile tip not selected
- Input of moment resistance at the pile tip not selected
- Computation of pile-head foundation stiffness matrix not selected
- Push-over analysis of pile not selected
- Buckling analysis of pile not selected

Output Options:

- Output files use decimal points to denote decimal symbols.
- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (nodal spacing of output points) = 1
- No p-y curves to be computed and reported for user-specified depths
- Print using wide report formats

Pile Structural Properties and Geometry

Number of pile sections defined = 1

Total length of pile = 32.000 ft
Depth of ground surface below top of pile = -10.0000 ft

Pile diameters used for p-y curve computations are defined using 2 points.

p-y curves are computed using pile diameter values interpolated with depth over the length of the pile. A summary of values of pile diameter vs. depth follows.

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	14.9000
2	32.000	14.9000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is a H weak axis steel pile
Length of section = 32.000000 ft
Pile width = 14.200000 in

Soil and Rock Layering Information

The soil profile is modelled using 5 layers

Layer 1 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = -10.00000 ft
Distance from top of pile to bottom of layer = 0.0000 ft
Effective unit weight at top of layer = 125.000000 pcf
Effective unit weight at bottom of layer = 125.000000 pcf
Friction angle at top of layer = 32.000000 deg.

Friction angle at bottom of layer = 32.000000 deg.
Subgrade k at top of layer = 83.000000 pci
Subgrade k at bottom of layer = 83.000000 pci

Layer 2 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 0.0000 ft
Distance from top of pile to bottom of layer = 15.000000 ft
Effective unit weight at top of layer = 125.000000 pcf
Effective unit weight at bottom of layer = 125.000000 pcf
Friction angle at top of layer = 36.000000 deg.
Friction angle at bottom of layer = 36.000000 deg.
Subgrade k at top of layer = 164.000000 pci
Subgrade k at bottom of layer = 164.000000 pci

Layer 3 is stiff clay without free water

Distance from top of pile to top of layer = 15.000000 ft
Distance from top of pile to bottom of layer = 17.000000 ft
Effective unit weight at top of layer = 110.000000 pcf
Effective unit weight at bottom of layer = 110.000000 pcf
Undrained cohesion at top of layer = 800.000000 psf
Undrained cohesion at bottom of layer = 800.000000 psf
Epsilon-50 at top of layer = 0.007000
Epsilon-50 at bottom of layer = 0.007000

Layer 4 is stiff clay without free water

Distance from top of pile to top of layer = 17.000000 ft
Distance from top of pile to bottom of layer = 22.000000 ft
Effective unit weight at top of layer = 47.600000 pcf
Effective unit weight at bottom of layer = 47.600000 pcf
Undrained cohesion at top of layer = 800.000000 psf
Undrained cohesion at bottom of layer = 800.000000 psf
Epsilon-50 at top of layer = 0.007000
Epsilon-50 at bottom of layer = 0.007000

Layer 5 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 22.000000 ft
Distance from top of pile to bottom of layer = 32.000000 ft
Effective unit weight at top of layer = 67.600000 pcf
Effective unit weight at bottom of layer = 67.600000 pcf
Friction angle at top of layer = 38.000000 deg.
Friction angle at bottom of layer = 38.000000 deg.
Subgrade k at top of layer = 120.000000 pci
Subgrade k at bottom of layer = 120.000000 pci

(Depth of the lowest soil layer extends 0.000 ft below the pile tip)

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Cohesion psf	Angle of Friction deg.	E50 or krm	kpy pci
1	Sand	-10.000	125.0000	--	32.0000	--	83.0000
	(Reese, et al.)	0.00	125.0000	--	32.0000	--	83.0000
2	Sand	0.00	125.0000	--	36.0000	--	164.0000
	(Reese, et al.)	15.0000	125.0000	--	36.0000	--	164.0000
3	Stiff Clay	15.0000	110.0000	800.0000	--	0.00700	--
	w/o Free Water	17.0000	110.0000	800.0000	--	0.00700	--
4	Stiff Clay	17.0000	47.6000	800.0000	--	0.00700	--
	w/o Free Water	22.0000	47.6000	800.0000	--	0.00700	--
5	Sand	22.0000	67.6000	--	38.0000	--	120.0000
	(Reese, et al.)	32.0000	67.6000	--	38.0000	--	120.0000

Static Loading Type

Static loading criteria were used when computing p-y curves for all analyses.

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 2

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length	Run Analysis
1	5	y = 0.390000 in	S = 0.0000 in/in	386000.	N.A.	Yes
2	4	y = 0.390000 in	M = -3466200. in-lbs	386000.	N.A.	Yes

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Dimensions and Properties of Steel H Weak Axis:

Length of Section = 32.000000 ft
Flange Width = 14.900000 in
Section Depth = 14.200000 in
Flange Thickness = 0.805000 in
Web Thickness = 0.805000 in
Yield Stress of Pipe = 50.000000 ksi
Elastic Modulus = 29000. ksi
Cross-sectional Area = 34.123950 sq. in.
Moment of Inertia = 444.363799 in^4
Elastic Bending Stiffness = 12886550. kip-in^2
Plastic Modulus, Z = 91.398684in^3
Plastic Moment Capacity = Fy Z = 4570.in-kip

Axial Structural Capacities:

Nom. Axial Structural Capacity = Fy As = 1706.197 kips
Nominal Axial Tensile Capacity = -1706.197 kips

Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

Number	Axial Thrust Force kips
1	386.000

Definition of Run Messages:

Y = part of pipe section has yielded.

Axial Thrust Force = 386.000 kips

Bending Curvature	Bending Moment	Bending Stiffness	Depth to N Axis	Max Total Stress	Run Msg
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rad/in.	in-kip	kip-in2	in	ksi
0.00000447	57.6462319	12886018.	94.6422382	12.2685485
0.00000895	115.2924638	12886018.	51.0461191	13.2253936
0.00001342	172.9386957	12886018.	36.5140794	14.1822388
0.00001789	230.5849276	12886018.	29.2480595	15.1390839
0.00002237	288.2311595	12886018.	24.8884476	16.0959290
0.00002684	345.8773914	12886018.	21.9820397	17.0527742
0.00003131	403.5236233	12886018.	19.9060340	18.0096193
0.00003579	461.1698552	12886018.	18.3490298	18.9664645
0.00004026	518.8160871	12886018.	17.1380265	19.9233096
0.00004474	576.4623190	12886018.	16.1692238	20.8801547
0.00004921	634.1085509	12886018.	15.3765671	21.8369998
0.00005368	691.7547828	12886018.	14.7160198	22.7938450
0.00005816	749.4010147	12886018.	14.1570952	23.7506902
0.00006263	807.0472466	12886018.	13.6780170	24.7075353
0.00006710	864.6934785	12886018.	13.2628159	25.6643804
0.00007158	922.3397104	12886018.	12.8995149	26.6212255
0.00007605	979.9859423	12886018.	12.5789552	27.5780707
0.00008052	1038.	12886018.	12.2940132	28.5349159
0.00008500	1095.	12886018.	12.0390652	29.4917610
0.00008947	1153.	12886018.	11.8096119	30.4486061
0.00009394	1211.	12886018.	11.6020113	31.4054512
0.00009842	1268.	12886018.	11.4132836	32.3622964
0.0001029	1326.	12886018.	11.2409669	33.3191415
0.0001074	1384.	12886018.	11.0830099	34.2759867
0.0001118	1441.	12886018.	10.9376895	35.2328318
0.0001163	1499.	12886018.	10.8035476	36.1896769
0.0001208	1556.	12886018.	10.6793422	37.1465221
0.0001253	1614.	12886018.	10.5640085	38.1033672
0.0001297	1672.	12886018.	10.4566289	39.0602124
0.0001342	1729.	12886018.	10.3564079	40.0170575
0.0001387	1787.	12886018.	10.2626528	40.9739027
0.0001432	1845.	12886018.	10.1747574	41.9307478
0.0001476	1902.	12886018.	10.0921890	42.8875929
0.0001521	1960.	12886018.	10.0144776	43.8444381
0.0001566	2018.	12886018.	9.9412068	44.8012832
0.0001610	2075.	12886018.	9.8720066	45.7581283
0.0001655	2133.	12886018.	9.8065470	46.7149735
0.0001700	2191.	12886018.	9.7445326	47.6718186

0.0001745	2248.	12886018.	9.6856984	48.6286637	
0.0001834	2363.	12880749.	9.5773618	50.0000000	Y
0.0001924	2470.	12840834.	9.4840016	50.0000000	Y
0.0002013	2570.	12768566.	9.4041633	50.0000000	Y
0.0002103	2665.	12673800.	9.3354859	50.0000000	Y
0.0002192	2754.	12562505.	9.2762732	50.0000000	Y
0.0002282	2838.	12438357.	9.2252878	50.0000000	Y
0.0002371	2918.	12306445.	9.1811140	50.0000000	Y
0.0002460	2994.	12169194.	9.1428293	50.0000000	Y
0.0002550	3067.	12028124.	9.1097379	50.0000000	Y
0.0002639	3137.	11885299.	9.0810754	50.0000000	Y
0.0002729	3204.	11742499.	9.0561571	50.0000000	Y
0.0002818	3269.	11599906.	9.0346493	50.0000000	Y
0.0002908	3332.	11458160.	9.0161572	50.0000000	Y
0.0002997	3391.	11315153.	8.9995889	50.0000000	Y
0.0003087	3446.	11165153.	8.9834339	50.0000000	Y
0.0003176	3497.	11010132.	8.9676295	50.0000000	Y
0.0003266	3544.	10851774.	8.9521181	50.0000000	Y
0.0003355	3587.	10691278.	8.9368150	50.0000000	Y
0.0003445	3627.	10529443.	8.9220161	50.0000000	Y
0.0003534	3664.	10367974.	8.9074630	50.0000000	Y
0.0003624	3699.	10207487.	8.8930399	50.0000000	Y
0.0003713	3731.	10048587.	8.8788483	50.0000000	Y
0.0003803	3761.	9891088.	8.8651582	50.0000000	Y
0.0003892	3789.	9736626.	8.8515813	50.0000000	Y
0.0003981	3816.	9584692.	8.8384468	50.0000000	Y
0.0004071	3841.	9435131.	8.8254390	50.0000000	Y
0.0004160	3864.	9288415.	8.8125282	50.0000000	Y
0.0004250	3886.	9144891.	8.8001206	50.0000000	Y
0.0004339	3907.	9004567.	8.7877958	50.0000000	Y
0.0004429	3927.	8866737.	8.7756499	50.0000000	Y
0.0004518	3946.	8732758.	8.7639374	50.0000000	Y
0.0004608	3963.	8601248.	8.7520754	50.0000000	Y
0.0004697	3980.	8472925.	8.7407916	50.0000000	Y
0.0004787	3996.	8347887.	8.7293769	50.0000000	Y
0.0004876	4011.	8225455.	8.7184233	50.0000000	Y
0.0004966	4025.	8106088.	8.7075862	50.0000000	Y
0.0005055	4039.	7989935.	8.6967283	50.0000000	Y
0.0005145	4052.	7875951.	8.6863676	50.0000000	Y
0.0005234	4064.	7765141.	8.6761208	50.0000000	Y

Summary of Results for Nominal Moment Capacity for Section 1

The above values should be multiplied by the appropriate strength reduction factor to compute ultimate moment capacity according to the LRFD structural design standard being followed.

Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 1

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/inch	Soil Spr. Es*H lb/inch	Distrib. Lat. Load lb/inch
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0.00	0.3900	-4083056.	158634.	0.00	79766.	7.60E+09	-1753.	8630.	0.00
0.3200	0.3860	-3488767.	150153.	-0.00191	69803.	7.60E+09	-2194.	21820.	0.00
0.6400	0.3753	-2924210.	141539.	-0.00325	60338.	1.23E+10	-2293.	23458.	0.00
0.9600	0.3611	-2392107.	132578.	-0.00407	51417.	1.29E+10	-2375.	25255.	0.00
1.2800	0.3441	-1893961.	123334.	-0.00470	43065.	1.29E+10	-2440.	27228.	0.00
1.6000	0.3249	-1430955.	113872.	-0.00520	35302.	1.29E+10	-2488.	29407.	0.00
1.9200	0.3041	-1004008.	104255.	-0.00556	28144.	1.29E+10	-2521.	31826.	0.00
2.2400	0.2822	-613788.	94542.	-0.00580	21602.	1.29E+10	-2538.	34534.	0.00
2.5600	0.2596	-260720.	84791.	-0.00593	15683.	1.29E+10	-2541.	37589.	0.00
2.8800	0.2366	54996.	75054.	-0.00596	12234.	1.29E+10	-2530.	41060.	0.00
3.2000	0.2138	333378.	65390.	-0.00591	16901.	1.29E+10	-2503.	44964.	0.00
3.5200	0.1913	574706.	55865.	-0.00577	20947.	1.29E+10	-2458.	49359.	0.00
3.8400	0.1694	779529.	46542.	-0.00557	24381.	1.29E+10	-2397.	54332.	0.00
4.1600	0.1485	948658.	37485.	-0.00531	27216.	1.29E+10	-2320.	59989.	0.00
4.4800	0.1286	1083163.	28757.	-0.00501	29472.	1.29E+10	-2226.	66465.	0.00
4.8000	0.1100	1184361.	20415.	-0.00467	31168.	1.29E+10	-2118.	73932.	0.00
5.1200	0.09275	1253804.	12518.	-0.00431	32332.	1.29E+10	-1995.	82619.	0.00
5.4400	0.07692	1293269.	5116.	-0.00393	32994.	1.29E+10	-1860.	92834.	0.00
5.7600	0.06257	1304741.	-1740.	-0.00354	33186.	1.29E+10	-1711.	105009.	0.00
6.0800	0.04972	1290407.	-8003.	-0.00316	32946.	1.29E+10	-1551.	119776.	0.00
6.4000	0.03834	1252636.	-13356.	-0.00278	32313.	1.29E+10	-1237.	123937.	0.00
6.7200	0.02839	1196065.	-17525.	-0.00241	31364.	1.29E+10	-934.293	126355.	0.00
7.0400	0.01982	1125190.	-20595.	-0.00207	30176.	1.29E+10	-664.573	128773.	0.00
7.3600	0.01253	1044018.	-22693.	-0.00174	28815.	1.29E+10	-428.041	131192.	0.00
7.6800	0.00643	956073.	-23945.	-0.00144	27341.	1.29E+10	-223.896	133610.	0.00
8.0000	0.00143	864404.	-24472.	-0.00117	25804.	1.29E+10	-50.831	136028.	0.00
8.3200	-0.00258	771604.	-24392.	-9.30E-04	24248.	1.29E+10	92.8684	138446.	0.00
8.6400	-0.00570	679832.	-23812.	-7.13E-04	22709.	1.29E+10	209.2299	140865.	0.00
8.9600	-0.00805	590846.	-22833.	-5.24E-04	21218.	1.29E+10	300.5036	143283.	0.00
9.2800	-0.00973	506030.	-21547.	-3.60E-04	19796.	1.29E+10	369.0832	145701.	0.00
9.6000	-0.01082	426432.	-20037.	-2.22E-04	18461.	1.29E+10	417.4353	148120.	0.00
9.9200	-0.01143	352801.	-18375.	-1.05E-04	17227.	1.29E+10	448.0365	150538.	0.00
10.2400	-0.01163	285622.	-16626.	-1.03E-05	16100.	1.29E+10	463.3210	152956.	0.00
10.5600	-0.01151	225147.	-14842.	6.58E-05	15086.	1.29E+10	465.6366	155374.	0.00
10.8800	-0.01113	171440.	-13070.	1.25E-04	14186.	1.29E+10	457.2094	157793.	0.00
11.2000	-0.01055	124399.	-11347.	1.69E-04	13397.	1.29E+10	440.1169	160211.	0.00
11.5200	-0.00983	83792.	-9703.	2.00E-04	12717.	1.29E+10	416.2680	162629.	0.00
11.8400	-0.00901	49287.	-8160.	2.20E-04	12138.	1.29E+10	387.3911	165048.	0.00
12.1600	-0.00814	20472.	-6735.	2.30E-04	11655.	1.29E+10	355.0270	167466.	0.00
12.4800	-0.00725	-3117.	-5437.	2.33E-04	11364.	1.29E+10	320.5278	169884.	0.00

12.8000	-0.00635	-21978.	-4275.	2.29E-04	11680.	1.29E+10	285.0606	172302.	0.00
13.1200	-0.00549	-36626.	-3248.	2.20E-04	11926.	1.29E+10	249.6140	174721.	0.00
13.4400	-0.00466	-47577.	-2356.	2.08E-04	12109.	1.29E+10	215.0087	177139.	0.00
13.7600	-0.00389	-55336.	-1594.	1.92E-04	12239.	1.29E+10	181.9101	179557.	0.00
14.0800	-0.00318	-60389.	-955.115	1.75E-04	12324.	1.29E+10	150.8415	181975.	0.00
14.4000	-0.00254	-63191.	-430.874	1.57E-04	12371.	1.29E+10	122.2005	184394.	0.00
14.7200	-0.00198	-64163.	-11.405	1.38E-04	12387.	1.29E+10	96.2734	186812.	0.00
15.0400	-0.00149	-63687.	369.9434	1.19E-04	12379.	1.29E+10	102.3453	264387.	0.00
15.3600	-0.00107	-61674.	747.3104	1.00E-04	12346.	1.29E+10	94.2000	339047.	0.00
15.6800	-7.18E-04	-58244.	1092.	8.22E-05	12288.	1.29E+10	85.3144	456351.	0.00
16.0000	-4.36E-04	-53531.	1400.	6.56E-05	12209.	1.29E+10	75.2907	663835.	0.00
16.3200	-2.14E-04	-47684.	1640.	5.05E-05	12111.	1.29E+10	49.2803	882550.	0.00
16.6400	-4.79E-05	-41089.	1755.	3.72E-05	12001.	1.29E+10	11.0045	882550.	0.00
16.9600	7.16E-05	-34314.	1745.	2.60E-05	11887.	1.29E+10	-16.465	882550.	0.00
17.2800	1.52E-04	-27767.	1646.	1.68E-05	11777.	1.29E+10	-34.910	882550.	0.00
17.6000	2.00E-04	-21721.	1491.	9.39E-06	11676.	1.29E+10	-46.052	882550.	0.00
17.9200	2.24E-04	-16346.	1303.	3.72E-06	11586.	1.29E+10	-51.481	882550.	0.00
18.2400	2.29E-04	-11722.	1104.	-4.66E-07	11508.	1.29E+10	-52.612	882550.	0.00
18.5600	2.20E-04	-7869.	905.2909	-3.38E-06	11444.	1.29E+10	-50.660	882550.	0.00
18.8800	2.03E-04	-4759.	718.4798	-5.27E-06	11391.	1.29E+10	-46.638	882550.	0.00
19.2000	1.80E-04	-2336.	549.5158	-6.32E-06	11351.	1.29E+10	-41.364	882550.	0.00
19.5200	1.54E-04	-520.461	401.9817	-6.75E-06	11320.	1.29E+10	-35.476	882550.	0.00
19.8400	1.28E-04	771.7063	277.3195	-6.71E-06	11325.	1.29E+10	-29.452	882550.	0.00
20.1600	1.03E-04	1629.	175.4024	-6.35E-06	11339.	1.29E+10	-23.630	882550.	0.00
20.4800	7.93E-05	2138.	95.0181	-5.79E-06	11348.	1.29E+10	-18.237	882550.	0.00
20.8000	5.83E-05	2376.	34.2643	-5.12E-06	11352.	1.29E+10	-13.406	882550.	0.00
21.1200	4.00E-05	2416.	-9.138	-4.41E-06	11352.	1.29E+10	-9.200	882550.	0.00
21.4400	2.45E-05	2319.	-37.609	-3.70E-06	11351.	1.29E+10	-5.629	882550.	0.00
21.7600	1.16E-05	2138.	-53.539	-3.04E-06	11348.	1.29E+10	-2.668	882550.	0.00
22.0800	1.17E-06	1917.	-58.766	-2.43E-06	11344.	1.29E+10	-0.05419	177390.	0.00
22.4000	-7.07E-06	1694.	-58.237	-1.89E-06	11340.	1.29E+10	0.3298	179159.	0.00
22.7200	-1.34E-05	1475.	-56.394	-1.42E-06	11336.	1.29E+10	0.6301	180929.	0.00
23.0400	-1.80E-05	1265.	-53.540	-1.01E-06	11333.	1.29E+10	0.8559	182698.	0.00
23.3600	-2.12E-05	1067.	-49.946	-6.66E-07	11330.	1.29E+10	1.0164	184467.	0.00
23.6800	-2.31E-05	883.4847	-45.843	-3.75E-07	11327.	1.29E+10	1.1206	186237.	0.00
24.0000	-2.40E-05	716.0720	-41.431	-1.37E-07	11324.	1.29E+10	1.1771	188006.	0.00
24.3200	-2.42E-05	565.6996	-36.879	5.38E-08	11321.	1.29E+10	1.1939	189776.	0.00
24.6400	-2.36E-05	432.6825	-32.324	2.03E-07	11319.	1.29E+10	1.1786	191545.	0.00
24.9600	-2.26E-05	316.8534	-27.876	3.14E-07	11317.	1.29E+10	1.1379	193315.	0.00
25.2800	-2.12E-05	217.6628	-23.622	3.94E-07	11315.	1.29E+10	1.0778	195084.	0.00

25.6000	-1.96E-05	134.2682	-19.626	4.46E-07	11314.	1.29E+10	1.0036	196854.	0.00
25.9200	-1.78E-05	65.6128	-15.933	4.76E-07	11313.	1.29E+10	0.9200	198623.	0.00
26.2400	-1.59E-05	10.4943	-12.571	4.87E-07	11312.	1.29E+10	0.8308	200393.	0.00
26.5600	-1.40E-05	-32.378	-9.557	4.84E-07	11312.	1.29E+10	0.7393	202162.	0.00
26.8800	-1.22E-05	-64.335	-6.893	4.70E-07	11313.	1.29E+10	0.6480	203932.	0.00
27.2000	-1.04E-05	-86.709	-4.576	4.47E-07	11313.	1.29E+10	0.5589	205701.	0.00
27.5200	-8.77E-06	-100.803	-2.593	4.19E-07	11313.	1.29E+10	0.4736	207471.	0.00
27.8400	-7.21E-06	-107.868	-0.929	3.88E-07	11314.	1.29E+10	0.3931	209240.	0.00
28.1600	-5.78E-06	-109.090	0.4358	3.56E-07	11314.	1.29E+10	0.3178	211010.	0.00
28.4800	-4.48E-06	-105.576	1.5226	3.24E-07	11313.	1.29E+10	0.2482	212779.	0.00
28.8000	-3.30E-06	-98.356	2.3528	2.94E-07	11313.	1.29E+10	0.1842	214548.	0.00
29.1200	-2.22E-06	-88.377	2.9470	2.66E-07	11313.	1.29E+10	0.1253	216318.	0.00
29.4400	-1.26E-06	-76.511	3.3245	2.41E-07	11313.	1.29E+10	0.07128	218087.	0.00
29.7600	-3.73E-07	-63.560	3.5023	2.20E-07	11313.	1.29E+10	0.02134	219857.	0.00
30.0800	4.37E-07	-50.266	3.4949	2.03E-07	11313.	1.29E+10	-0.02522	221626.	0.00
30.4000	1.19E-06	-37.322	3.3136	1.90E-07	11312.	1.29E+10	-0.06918	223396.	0.00
30.7200	1.90E-06	-25.382	2.9671	1.81E-07	11312.	1.29E+10	-0.111	225165.	0.00
31.0400	2.58E-06	-15.072	2.4607	1.75E-07	11312.	1.29E+10	-0.152	226935.	0.00
31.3600	3.24E-06	-7.002	1.7973	1.72E-07	11312.	1.29E+10	-0.193	228704.	0.00
31.6800	3.90E-06	-1.777	0.9775	1.70E-07	11312.	1.29E+10	-0.234	230474.	0.00
32.0000	4.55E-06	0.00	0.00	1.70E-07	11312.	1.29E+10	-0.275	116122.	0.00

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 1:

Pile-head deflection = 0.3900000 inches
 Computed slope at pile head = 0.000000 radians
 Maximum bending moment = -4083056. inch-lbs
 Maximum shear force = 158634. lbs
 Depth of maximum bending moment = 0.000000 feet below pile head
 Depth of maximum shear force = 0.000000 feet below pile head
 Number of iterations = 10
 Number of zero deflection points = 4

Computed Values of Pile Loading and Deflection for Lateral Loading for Load Case Number 2

Pile-head conditions are Displacement and Moment (Loading Type 4)

Displacement of pile head = 0.390000 inches
 Moment at pile head = -3466200.0 in-lbs
 Axial load at pile head = 386000.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/inch	Soil Spr. Es*H lb/inch	Distrib. Lat. Load lb/inch
0.00	0.3900	-3466200.	145656.	-0.00205	69424.	1.11E+10	-1753.	8630.	0.00
0.3200	0.3798	-2915875.	138126.	-0.00316	60198.	1.11E+10	-2169.	21925.	0.00
0.6400	0.3658	-2396034.	129639.	-0.00402	51483.	1.29E+10	-2252.	23642.	0.00
0.9600	0.3490	-1908337.	120862.	-0.00466	43306.	1.29E+10	-2320.	25524.	0.00
1.2800	0.3300	-1454001.	111855.	-0.00516	35689.	1.29E+10	-2372.	27598.	0.00
1.6000	0.3093	-1033991.	102678.	-0.00553	28647.	1.29E+10	-2408.	29897.	0.00
1.9200	0.2875	-649037.	93388.	-0.00578	22193.	1.29E+10	-2430.	32463.	0.00
2.2400	0.2649	-299633.	84039.	-0.00592	16335.	1.29E+10	-2439.	35350.	0.00
2.5600	0.2420	13942.	74682.	-0.00597	11545.	1.29E+10	-2434.	38628.	0.00
2.8800	0.2191	291614.	65372.	-0.00592	16201.	1.29E+10	-2415.	42319.	0.00
3.2000	0.1965	533553.	56170.	-0.00580	20257.	1.29E+10	-2378.	46470.	0.00
3.5200	0.1746	740187.	47138.	-0.00561	23721.	1.29E+10	-2326.	51159.	0.00
3.8400	0.1535	912199.	38339.	-0.00536	26605.	1.29E+10	-2257.	56483.	0.00
4.1600	0.1334	1050522.	29832.	-0.00507	28924.	1.29E+10	-2173.	62565.	0.00
4.4800	0.1145	1156334.	21675.	-0.00474	30698.	1.29E+10	-2075.	69561.	0.00
4.8000	0.09699	1231041.	13925.	-0.00438	31951.	1.29E+10	-1962.	77677.	0.00
5.1200	0.08086	1276275.	6633.	-0.00401	32709.	1.29E+10	-1836.	87187.	0.00
5.4400	0.06619	1293874	50.487	-0.00363	33004.	1.29E+10	-1697.	98472.	0.00
5.7600	0.05299	1285874.	-6379.	-0.00324	32870.	1.29E+10	-1547.	112081.	0.00
6.0800	0.04127	1254499.	-11857.	-0.00287	32344.	1.29E+10	-1306.	121518.	0.00
6.4000	0.03099	1203309.	-16285.	-0.00250	31486.	1.29E+10	-1000.	123937.	0.00
6.7200	0.02208	1136840.	-19600.	-0.00215	30371.	1.29E+10	-726.611	126355.	0.00
7.0400	0.01448	1059154.	-21927.	-0.00182	29069.	1.29E+10	-485.432	128773.	0.00

7.3600	0.00808	973842.	-23389.	-0.00152	27639.	1.29E+10	-276.080	131192.	0.00
7.6800	0.00280	884030.	-24107.	-0.00124	26133.	1.29E+10	-97.447	133610.	0.00
8.0000	-0.00147	792389.	-24194.	-9.94E-04	24597.	1.29E+10	52.0009	136028.	0.00
8.3200	-0.00483	701166.	-23760.	-7.71E-04	23067.	1.29E+10	174.1340	138446.	0.00
8.6400	-0.00739	612201.	-22905.	-5.75E-04	21576.	1.29E+10	271.0683	140865.	0.00
8.9600	-0.00925	526962.	-21722.	-4.06E-04	20147.	1.29E+10	345.0867	143283.	0.00
9.2800	-0.01050	446579.	-20294.	-2.61E-04	18799.	1.29E+10	398.5666	145791.	0.00
9.6000	-0.01125	371876.	-18696.	-1.39E-04	17546.	1.29E+10	433.9167	148120.	0.00
9.9200	-0.01157	303407.	-16992.	-3.80E-05	16398.	1.29E+10	453.5229	150538.	0.00
10.2400	-0.01154	241491.	-15238.	4.32E-05	15360.	1.29E+10	459.7019	152956.	0.00
10.5600	-0.01124	186247.	-13483.	1.07E-04	14434.	1.29E+10	454.6646	155374.	0.00
10.8800	-0.01072	137626.	-11764.	1.55E-04	13619.	1.29E+10	440.4865	157793.	0.00
11.2000	-0.01004	95439.	-10114.	1.90E-04	12912.	1.29E+10	419.0864	160211.	0.00
11.5200	-0.00926	59389.	-8556.	2.13E-04	12307.	1.29E+10	392.2112	162629.	0.00
11.8400	-0.00841	29096.	-7109.	2.26E-04	11800.	1.29E+10	361.4276	165048.	0.00
12.1600	-0.00752	4120.	-5785.	2.31E-04	11381.	1.29E+10	328.1191	167466.	0.00
12.4800	-0.00663	-16019.	-4592.	2.29E-04	11580.	1.29E+10	293.4870	169884.	0.00
12.8000	-0.00576	-31824.	-3532.	2.22E-04	11845.	1.29E+10	258.5565	172302.	0.00
13.1200	-0.00493	-43802.	-2605.	2.11E-04	12046.	1.29E+10	224.1852	174721.	0.00
13.4400	-0.00414	-52455.	-1808.	1.97E-04	12191.	1.29E+10	191.0741	177139.	0.00
13.7600	-0.00342	-58267.	-1134.	1.80E-04	12289.	1.29E+10	159.7810	179557.	0.00
14.0800	-0.00276	-61697.	-576.172	1.62E-04	12346.	1.29E+10	130.7345	181975.	0.00
14.4000	-0.00217	-63173.	-125.004	1.44E-04	12371.	1.29E+10	104.2489	184394.	0.00
14.7200	-0.00166	-63083.	229.7906	1.25E-04	12369.	1.29E+10	80.5399	186812.	0.00
15.0400	-0.00121	-61778.	571.1999	1.06E-04	12347.	1.29E+10	97.2775	308138.	0.00
15.3600	-8.40E-04	-59011.	928.3684	8.82E-05	12301.	1.29E+10	88.7478	405852.	0.00
15.6800	-5.35E-04	-54910.	1251.	7.13E-05	12232.	1.29E+10	79.2809	569418.	0.00
16.0000	-2.92E-04	-49615.	1532.	5.57E-05	12144.	1.29E+10	67.2111	882550.	0.00
16.3200	-1.07E-04	-43307.	1709.	4.18E-05	12038.	1.29E+10	24.5923	882550.	0.00
16.6400	2.89E-05	-36618.	1743.	2.99E-05	11926.	1.29E+10	-6.637	882550.	0.00
16.9600	1.23E-04	-30010.	1676.	2.00E-05	11815.	1.29E+10	-28.236	882550.	0.00
17.2800	1.82E-04	-23805.	1541.	1.20E-05	11711.	1.29E+10	-41.942	882550.	0.00
17.6000	2.15E-04	-18208.	1366.	5.72E-06	11617.	1.29E+10	-49.387	882550.	0.00
17.9200	2.26E-04	-13332.	1171.	1.02E-06	11535.	1.29E+10	-52.044	882550.	0.00
18.2400	2.23E-04	-9217.	972.9732	-2.34E-06	11466.	1.29E+10	-51.194	882550.	0.00
18.5600	2.09E-04	-5852.	782.6715	-4.58E-06	11410.	1.29E+10	-47.921	882550.	0.00
18.8800	1.88E-04	-3192.	607.8949	-5.93E-06	11365.	1.29E+10	-43.108	882550.	0.00
19.2000	1.63E-04	-1166.	453.2104	-6.58E-06	11331.	1.29E+10	-37.456	882550.	0.00
19.5200	1.37E-04	308.0266	320.8189	-6.71E-06	11317.	1.29E+10	-31.498	882550.	0.00
19.8400	1.11E-04	1318.	211.1536	-6.46E-06	11334.	1.29E+10	-25.620	882550.	0.00

20.1600	8.74E-05	1949.	123.3937	-5.98E-06	11344.	1.29E+10	-20.089	882550.	0.00
20.4800	6.56E-05	2283.	55.8897	-5.35E-06	11350.	1.29E+10	-15.070	882550.	0.00
20.8000	4.63E-05	2394.	6.5048	-4.65E-06	11352.	1.29E+10	-10.652	882550.	0.00
21.1200	2.99E-05	2347.	-27.123	-3.94E-06	11351.	1.29E+10	-6.863	882550.	0.00
21.4400	1.61E-05	2197.	-47.387	-3.27E-06	11349.	1.29E+10	-3.691	882550.	0.00
21.7600	4.78E-06	1992.	-56.582	-2.64E-06	11345.	1.29E+10	-1.098	882550.	0.00
22.0800	-4.23E-06	1771.	-58.314	-2.08E-06	11341.	1.29E+10	0.1953	177390.	0.00
22.4000	-1.12E-05	1551.	-56.935	-1.59E-06	11338.	1.29E+10	0.5229	179159.	0.00
22.7200	-1.64E-05	1338.	-54.447	-1.16E-06	11334.	1.29E+10	0.7733	180929.	0.00
23.0400	-2.01E-05	1136.	-51.127	-7.87E-07	11331.	1.29E+10	0.9556	182698.	0.00
23.3600	-2.25E-05	947.7202	-47.221	-4.77E-07	11328.	1.29E+10	1.0788	184467.	0.00
23.6800	-2.37E-05	774.8426	-42.939	-2.20E-07	11325.	1.29E+10	1.1517	186237.	0.00
24.0000	-2.41E-05	618.6046	-38.457	-1.25E-08	11322.	1.29E+10	1.1823	188006.	0.00
24.3200	-2.38E-05	479.5269	-33.925	1.51E-07	11320.	1.29E+10	1.1783	189776.	0.00
24.6400	-2.30E-05	357.6119	-29.461	2.76E-07	11318.	1.29E+10	1.1466	191545.	0.00
24.9600	-2.17E-05	252.4466	-25.160	3.67E-07	11316.	1.29E+10	1.0936	193315.	0.00
25.2800	-2.02E-05	163.2955	-21.093	4.29E-07	11314.	1.29E+10	1.0247	195084.	0.00
25.6000	-1.84E-05	89.1822	-17.311	4.66E-07	11313.	1.29E+10	0.9448	196854.	0.00
25.9200	-1.66E-05	28.9614	-13.850	4.84E-07	11312.	1.29E+10	0.8580	198623.	0.00
26.2400	-1.47E-05	-18.620	-10.728	4.85E-07	11312.	1.29E+10	0.7678	200393.	0.00
26.5600	-1.29E-05	-54.870	-7.954	4.75E-07	11313.	1.29E+10	0.6770	202162.	0.00
26.8800	-1.11E-05	-81.113	-5.525	4.54E-07	11313.	1.29E+10	0.5879	203932.	0.00
27.2000	-9.37E-06	-98.652	-3.433	4.27E-07	11313.	1.29E+10	0.5020	205701.	0.00
27.5200	-7.79E-06	-108.745	-1.661	3.97E-07	11314.	1.29E+10	0.4207	207471.	0.00
27.8400	-6.33E-06	-112.587	-0.192	3.64E-07	11314.	1.29E+10	0.3447	209240.	0.00
28.1600	-4.99E-06	-111.297	0.9967	3.30E-07	11314.	1.29E+10	0.2744	211010.	0.00
28.4800	-3.79E-06	-105.912	1.9267	2.98E-07	11313.	1.29E+10	0.2100	212779.	0.00
28.8000	-2.71E-06	-97.383	2.6201	2.68E-07	11313.	1.29E+10	0.1512	214548.	0.00
29.1200	-1.73E-06	-86.583	3.0979	2.40E-07	11313.	1.29E+10	0.09768	216318.	0.00
29.4400	-8.61E-07	-74.304	3.3793	2.16E-07	11313.	1.29E+10	0.04891	218087.	0.00
29.7600	-7.34E-08	-61.271	3.4813	1.96E-07	11313.	1.29E+10	0.00420	219857.	0.00
30.0800	6.44E-07	-48.149	3.4179	1.80E-07	11313.	1.29E+10	-0.03718	221626.	0.00
30.4000	1.31E-06	-35.554	3.2006	1.67E-07	11312.	1.29E+10	-0.07602	223396.	0.00
30.7200	1.93E-06	-24.064	2.8375	1.58E-07	11312.	1.29E+10	-0.113	225165.	0.00
31.0400	2.52E-06	-14.231	2.3341	1.53E-07	11312.	1.29E+10	-0.149	226935.	0.00
31.3600	3.30E-06	-6.591	1.6932	1.50E-07	11312.	1.29E+10	-0.185	228704.	0.00
31.6800	3.67E-06	-1.671	0.9155	1.48E-07	11312.	1.29E+10	-0.220	230474.	0.00
32.0000	4.24E-06	0.00	0.00	1.48E-07	11312.	1.29E+10	-0.256	116122.	0.00

* This analysis computed pile response using nonlinear moment-curvature rela-

tionships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 2:

Pile-head deflection = 0.39000000 inches
 Computed slope at pile head = -0.0020537 radians
 Maximum bending moment = -3466200. inch-lbs
 Maximum shear force = 145656. lbs
 Depth of maximum bending moment = 0.000000 feet below pile head
 Depth of maximum shear force = 0.000000 feet below pile head
 Number of iterations = 8
 Number of zero deflection points = 4

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
 Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
 Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
 Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
 Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	y, in	0.3900	S, rad	0.00	386000.	0.3900	0.00	158634.	-4083056.
2	y, in	0.3900	M, in-lb	-3466200.	386000.	0.3900	-0.00205	145656.	-3466200.

Maximum pile-head deflection = 0.390000000 inches
 Maximum pile-head rotation = -0.0020536943 radians = -0.117668 deg.

The analysis ended normally.



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*Engineers and
 Scientists*

JOB: 09.0026237.01
 SUBJECT: Pile Evaluation for Abutment 2 Contraction
 SHEET: 1 OF 9
 CALCULATED BY J. Barnes 05/18/2026
 CHECKED BY J. Keohane 05/18/2026

Integral Abutment LRFD Pile Design

Subject: Pile Design for the thermal contraction of the St. George River Bridge Replacement in Union, Maine at Abutment 2.

Reference:

- AASHTO LRFD Bridge Design Specifications, 10th Edition, 2024
- Maine BDG Chapter 5 - Substructures 2014
- VTRANS Integral Abutment Bridge Design Guidelines 2008

Design Steps - Maine BDG

Step 1 - Determine the foundation displacements and the load effects (P_u and M_u) from the superstructure and substructure designs.

$P_u := 386 \cdot \text{kip}$ Maximum Factored Axial Load from Stantec

The limitations of the software require the plastic hinge evaluations be complete using a single deflection. Stantec provided a total deflection of 0.720 inches with 0.004 radians of end rotation.

Step 2 - If applicable, determine the magnitude of scour.
 Step 3 - Select preliminary pile size.

Analysis by others concludes that with additional detailing, scour is prevented.

HP14 x 117 Weak Axis Properties

Steel yield strength	$F_y := 50 \text{ ksi}$
Modulus of elasticity for steel	$E := 29000 \text{ ksi}$
Cross sectional area of pile	$A_g := 34.4 \text{ in}^2$
Radius of gyration	$r_y := 3.59 \text{ in}$
Width of Flange	$b_f := 14.9 \text{ in}$
Thickness of Flange	$t_f := 0.805 \text{ in}$
Elastic Section Modulus	$S_y := 59.5 \text{ in}^3$
Plastic Section Modulus	$Z_y := 91.4 \text{ in}^3$

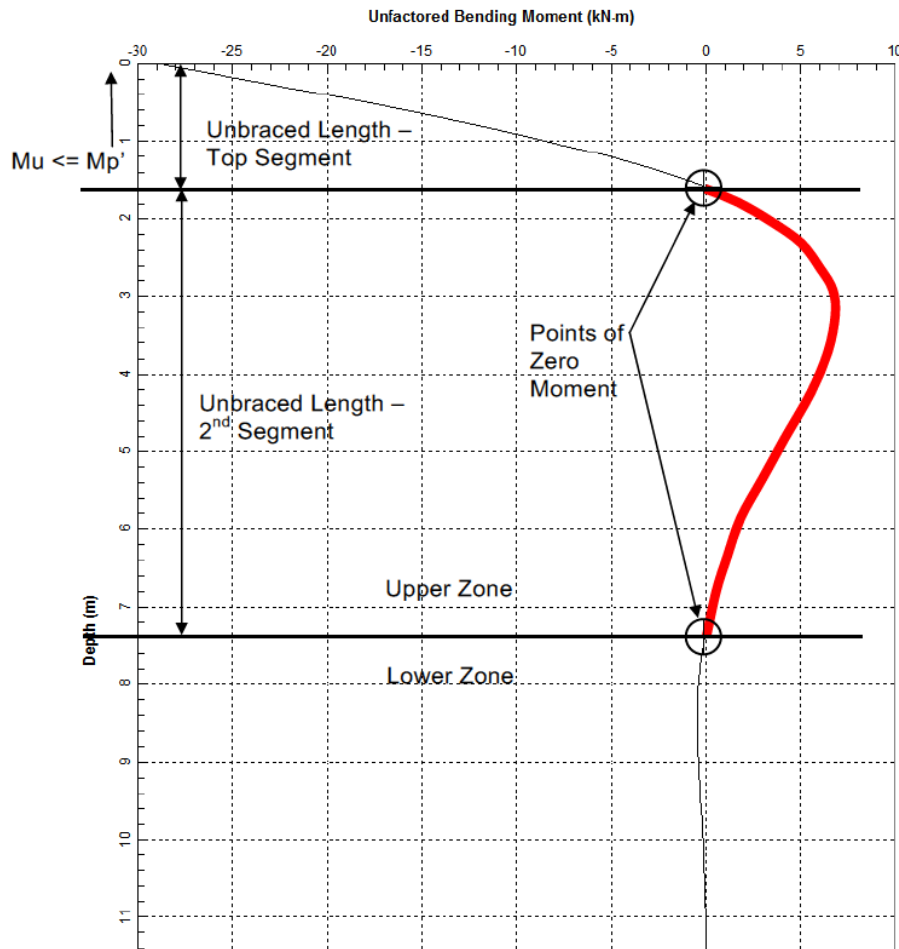
Step 4 - Determine the pile unbraced length and maximum moment at the top of the pile by running LPILE software for top translation = 0.720 inches, $P_u = 386 \text{ kip}$, and Live Load Rotation = 0.004



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*Engineers and
Scientists*

JOB: 09.0026237.01
SUBJECT: Pile Evaluation for Abutment 2 Contraction
SHEET: 2 OF 9
CALCULATED BY J. Barnes 05/18/2026
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EXAMPLE FIGURE: NOT TAKEN FROM THIS ANALYSIS

Maximum moment from LPile output (page 40)

$$M_u := 4218 \text{ kip}\cdot\text{in} = 351.5 \text{ kip}\cdot\text{ft}$$

Unbraced lengths from LPile output (pages 40-41)

Upper segment

$$L_1 := 5.2 \cdot \text{ft}$$

Lower segment

$$L_2 := 12.6 \cdot \text{ft}$$

Step 5 - Determine if the applied moment on the pile will cause pile head plastic deformation considering the interaction of combined axial and flexural load effects on a single pile (LRFD 6.9.2.2)



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 Scientists*

JOB: 09.0026237.01
 SUBJECT: Pile Evaluation for Abutment 2 Contraction
 SHEET: 3 OF 9
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a. Obtain the unbraced lengths of the top and lower segments of the pile and calculate the column slenderness factor (λ) for each segment.

See above for unbraced lengths (critical lengths L_1 and L_2).

Upper segment slenderness factor

$$\lambda_1 := \frac{(L_1)}{r_y} = 17.4$$

Lower segment slenderness factor

$$\lambda_2 := \frac{(L_2)}{r_y} = 42.1$$

b. Determine K values for top and bottom of the pile per LRFD Table C4.6.2.5-1

Buckled shape of column is shown by dashed line	(a)	(b)	(c)	(d)	(e)	(f)
Theoretical K value	0.5	0.7	1.0	1.0	2.0	2.0
Design value of K when ideal conditions are approximated	0.65	0.80	1.0	1.2	2.1	2.0
End condition code		Rotation fixed Rotation free Rotation fixed Rotation free		Translation fixed Translation fixed Translation free Translation free		

Upper segment K value (Type d)

$$K_1 := 1.2$$

Lower segment K value (Type c)

$$K_2 := 1$$

c. Calculate the nominal and factored structural pile resistance P_n , per AASHTO LRFD 6.9.4.1 using the λ values



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Elastic critical buckling resistance, P_e based on flexural buckling (AASHTO LRFD Eq. 6.9.4.1.2-1)

$$\text{Upper } P_e \quad P_{e1} := \frac{(\pi^2 \cdot E) \cdot A_g}{(K_1 \cdot \lambda_1)^2} = 22632 \cdot \text{kip}$$

$$\text{Lower } P_e \quad P_{e2} := \frac{(\pi^2 \cdot E) \cdot A_g}{(K_2 \cdot \lambda_2)^2} = 5551 \cdot \text{kip}$$

$$\text{Nominal yield resistance, } P_o \quad P_o := F_y 50 \cdot A_g = 1720 \cdot \text{kip}$$

Check that the ratio of P_e to P_o is > 0.44

If $P_e/P_o > 0.44$ then use AASHTO LRFD Eq. 6.9.4.1.1-1

If $P_e/P_o < 0.44$ then use AASHTO LRFD Eq. 6.9.4.1.1-2

$$P_n = \left[0.658^{\left(\frac{P_o}{P_e} \right)} \right] P_o \quad (6.9.4.1.1-1)$$

$$P_n = 0.877 P_e \quad (6.9.4.1.1-2)$$

$$\frac{P_{e1}}{P_o} = 13.158 \quad \frac{P_{e2}}{P_o} = 3.227$$

Both ratios are greater than 0.44, therefore, use AASHTO LRFD Eq. 6.9.4.1.1-1: Nominal structural axial Pile resistance, P_n for both segments

$$P_{n1} := \left[0.658^{\left(\frac{P_o}{P_{e1}} \right)} \right] \cdot P_o = 1666 \cdot \text{kip}$$

$$P_{n2} := \left[0.658^{\left(\frac{P_o}{P_{e2}} \right)} \right] \cdot P_o = 1511 \cdot \text{kip}$$



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Factored structural axial pile resistance, $P_r = \phi_c (P_n)$

$$\phi_c := 0.7 \quad \text{for axial resistance according to AASHTO LRFD 6.5.4.2}$$

$$P_{r1} := \phi_c \cdot P_{n1} = 1166.3 \cdot \text{kip}$$

$$P_{r2} := \phi_c \cdot P_{n2} = 1.1 \times 10^3 \cdot \text{kip}$$

d. Compare the ratio of P_u , the maximum factored axial load, to P_r , the structural resistance in the specified portion of the pile - the pile size should be such that the ratio is not less than 0.20.

Check for both segments

$$\frac{P_u}{P_{r1}} = 0.331 \quad > 0.20, \text{ OK}$$

$$\frac{P_u}{P_{r2}} = 0.365 \quad > 0.20, \text{ OK}$$

e. Determine the nominal and factored flexural resistance about H-Pile weak axis, (AASHTO LRFD Eq. 6.12.2.2)

Check slenderness ratio for flange, limiting slenderness ratio for compact flange, and limiting slenderness ratio for a noncompact flange.

$$\lambda_f := \frac{b_f}{2 \cdot t_f} = 9.255 \quad \text{slenderness ratio for flange (AASHTO LRFD Eq. 6.12.2.2.1-3)}$$

$$\lambda_{pf} := 0.38 \cdot \left(\frac{E}{F_{y50}} \right)^{.5} = 9.152$$

$$\lambda_{rf} := 0.83 \cdot \left(\frac{E}{F_{y50}} \right)^{.5} = 19.989$$

If $\lambda_{pf} < \lambda_f < \lambda_{rf}$ Use AASHTO LRFD Eq. 6.12.2.2.1-2 to find the nominal flexural resistance

$$M_n := \left[1 - \left(1 - \frac{S_y}{Z_y} \right) \cdot \left[\frac{\lambda_f - \lambda_{pf}}{0.45 \cdot \left(\frac{E}{F_{y50}} \right)^{.5}} \right] \right] \cdot F_{y50} \cdot Z_y = 379.57 \cdot \text{ft} \cdot \text{kip}$$



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$$\phi_f := 1.0 \quad \text{for flexural resistance according to AASHTO LRFD 6.5.4.2}$$

$$M_r := M_n \cdot \phi_f = 379.6 \cdot \text{ft} \cdot \text{kip}$$

$$M_u = 351.5 \cdot \text{ft} \cdot \text{kip}$$

$$\frac{P_u}{P_{r1}} + \frac{8}{9} \cdot \frac{M_u}{M_r} = 1.15 \quad \text{If less than 1, remains in elastic zone. Since it exceeds 1, yielding is expected at the base of the pile cap.}$$

f Calculate the moment that will cause a plastic hinge at the top of the pile, M_p' ,

Note: M_p' will be lower than M_n due to the inclusion of the axial load in the interaction equation for pile over stresses

$$\frac{P_u}{P_r} + \frac{8.0}{9.0} \left(\frac{M_{ux}}{M_{rx}} + \frac{M_{uy}}{M_{ry}} \right) \leq 1.0 \quad \text{AASHTO LRFD Eq. 6.9.2.2 Interaction equation}$$

Use the interaction equation to find the moment that will cause a plastic hinge at the top of the pile. Assume M_{ux} and $M_{rx} = 0$ (out-of-plane), $M_{ry} = M_r$ and $M_u = M_p'$, solve for M_p'

$$M_p := \left(\frac{9}{8} \right) \cdot \left[1 - \left(\frac{P_u}{P_{r1}} \right) \right] \cdot M_r = 285.7 \cdot \text{ft} \cdot \text{kip} \quad M_p = 3428.3 \cdot \text{in} \cdot \text{kip}$$

g. The calculated moment from LPILE Run 1 (shown in step 4) exceeds the moment that would cause a plastic hinge (above), therefore a plastic hinge forms, and the moment (M_p') represents the limiting moment reaction at the pile top for the subsequent analysis.

Step 6 - For fixed head piles, run a second LPILE analysis with end conditions 1) Top moment = M_p' , top translation = 0.720 in; and axial load equal to P_u . Recalculate unbraced lengths from the moment vs. depth curve.



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New unbraced lengths were determined from the second LPILE analysis

Upper segment $L_{1p} := 4.7 \cdot \text{ft}$

Lower segment $L_{2p} := 12.7 \cdot \text{ft}$

6a. Repeat steps 5a through 5d above.

6b- If the pile size is such that the ratio of P_u to structural resistance exceeds 0.2, check the upper segment of the pile with the interaction equation of AASHTO LRFD Eq. 6.9.2.2. If a plastic hinge forms at the top of the pile, the K value of the upper segment changes from 1.2, for a rotation fixed head condition, to 2.1, for a rotation free head condition. With the new K value and lengths repeat step 5.

5a.

Upper segment slenderness factor

$$\lambda_{1p} := \frac{(L_{1p})}{r_y} = 15.71$$

Lower segment slenderness factor

$$\lambda_{2p} := \frac{(L_{2p})}{r_y} = 42.451$$

5b.

Upper segment K value (Type e)

$$K_{1p} := 2.1$$

Lower segment K value (Type c)

$$K_{2p} := 1$$

5c.

Elastic critical buckling resistance, P_e based on flexural buckling

Upper P_e

$$P_{ep1} := \frac{(\pi^2 \cdot E) \cdot A_g}{(K_{1p} \cdot \lambda_{1p})^2} = 9046 \cdot \text{kip}$$

Lower P_e

$$P_{ep2} := \frac{(\pi^2 \cdot E) \cdot A_g}{(K_{2p} \cdot \lambda_{2p})^2} = 5464 \cdot \text{kip}$$

Nominal yield resistance, P_o

$$P_o := F_{y50} \cdot A_g = 1720 \cdot \text{kip}$$



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Check that the ratio of P_e to P_o is > 0.44

If $P_e/P_o > 0.44$ then use equation 6.9.4.1.1-1

If $P_e/P_o < 0.44$ then use equation 6.9.4.1.1-2

$$\frac{P_{ep1}}{P_o} = 5.259 \quad \frac{P_{ep2}}{P_o} = 3.176$$

Both ratios are greater than 0.44, therefore, use eq. 6.9.4.1.1-1: Nominal structural Pile resistance, P_n for both segments

$$P_{np1} := \left[0.658 \left(\frac{P_o}{P_{ep1}} \right) \right] \cdot P_o = 1588 \cdot \text{kip}$$

$$P_{np2} := \left[0.658 \left(\frac{P_o}{P_{ep2}} \right) \right] \cdot P_o = 1508 \cdot \text{kip}$$

Factored structural Pile Resistance, $P_r = \phi_c (P_n)$

$$P_{rp1} := \phi_c \cdot P_{np1} = 1111.9 \cdot \text{kip}$$

$$P_{rp2} := \phi_c \cdot P_{np2} = 1.1 \times 10^3 \cdot \text{kip}$$

5d. Compare the ratio of P_u to the structural resistance in the upper portion of the pile - the pile size should be such that the ratio is not less than 0.20.

Check for both segments

$$\frac{P_u}{P_{rp1}} = 0.347 \quad > 0.20, \text{ OK} \quad \frac{P_u}{P_{rp2}} = 0.366 \quad > 0.20, \text{ OK}$$

From VTrans Integral Abutment Design Section 4.5.2 - Check the axial capacity of the upper segment and the interaction equation for the second segment to assess suitability of pile section.

Upper Segment

Check that P_u/P_{rp1} is < 1

$$\frac{P_u}{P_{rp1}} = 0.347 \quad < 1, \text{ OK}$$



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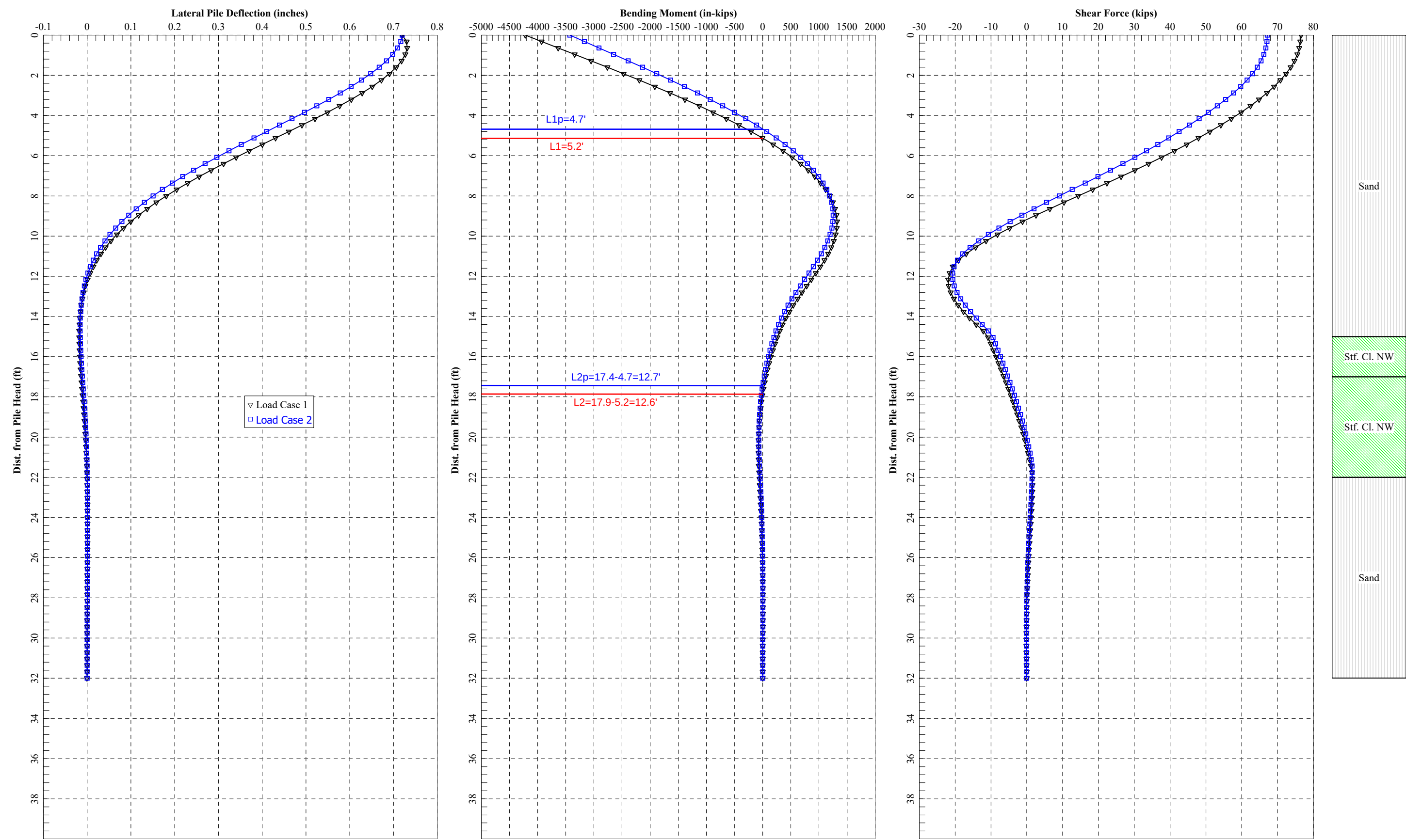
Lower Segment

Ultimate moment along the lower segment from LPile output

$$M_{\max p2} := 1254 \cdot \text{in} \cdot \text{kip}$$

$$\frac{P_u}{P_{rp2}} + \frac{8}{9} \cdot \frac{M_{\max p2}}{M_r} = 0.61 \quad < 1, \text{OK}$$

Abutment 2 - Contraction Case



=====

LPILE Version 2022-12.013

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Analysis of Individual Piles and Drilled Shafts
Subjected to Lateral Loading Using the p-y Method
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=====

This model was prepared by:
Jason.Keohane

Files Used for Analysis

Path to file locations:
\\09 Jobs\0026200s\09.0026237.00 - Stantec Union Bridge\01 - Final Design\Work\Calcs\Lpile\Abutment 2\Contraction\

Name of input data file:
Abutment 2 Contraction.lp12d

Name of output report file:
Abutment 2 Contraction.lp12o

Name of plot output file:
Abutment 2 Contraction.lp12p

Name of runtime message file:
Abutment 2 Contraction.lp12r

Date and Time of Analysis

Date: May 18, 2026

Time: 15:40:39

Problem Title

Project Name: St. George River Bridge, Union, Maine

Job Number: 09.0026237.01

Client: Stantec

Engineer: Jason Barnes

Description: Abutment 2 Contraction

Program Options and Settings

Computational Options:
- Conventional Analysis
Engineering Units Used for Data Input and Computations:
- US Customary System Units (pounds, feet, inches)

Analysis Control Options:
- Maximum number of iterations allowed = 500
- Deflection tolerance for convergence = 1.0000E-05 in

- Maximum allowable deflection = 100.0000 in
- Number of pile increments = 100

Loading Type and Number of Cycles of Loading:

- Static loading specified
- Use of p-y modification factors for p-y curves not selected
- Analysis uses layering correction (Method of Georgiadis)
- No distributed lateral loads are entered
- Loading by lateral soil movements acting on pile not selected
- Input of shear resistance at the pile tip not selected
- Input of moment resistance at the pile tip not selected
- Computation of pile-head foundation stiffness matrix not selected
- Push-over analysis of pile not selected
- Buckling analysis of pile not selected

Output Options:

- Output files use decimal points to denote decimal symbols.
- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (nodal spacing of output points) = 1
- No p-y curves to be computed and reported for user-specified depths
- Print using wide report formats

----- Pile Structural Properties and Geometry -----

- Number of pile sections defined = 1
- Total length of pile = 32.000 ft
- Depth of ground surface below top of pile = 0.0000 ft

Pile diameters used for p-y curve computations are defined using 2 points.

p-y curves are computed using pile diameter values interpolated with depth over the length of the pile. A summary of values of pile diameter vs. depth follows.

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	14.9000
2	32.000	14.9000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

- Section 1 is a H weak axis steel pile
- Length of section = 32.000000 ft
- Pile width = 14.200000 in

----- Soil and Rock Layering Information -----

The soil profile is modelled using 4 layers

Layer 1 is sand, p-y criteria by Reese et al., 1974

- Distance from top of pile to top of layer = 0.0000 ft
- Distance from top of pile to bottom of layer = 15.000000 ft
- Effective unit weight at top of layer = 125.000000 pcf
- Effective unit weight at bottom of layer = 125.000000 pcf
- Friction angle at top of layer = 36.000000 deg.
- Friction angle at bottom of layer = 36.000000 deg.
- Subgrade k at top of layer = 164.000000 pci
- Subgrade k at bottom of layer = 164.000000 pci

Layer 2 is stiff clay without free water

- Distance from top of pile to top of layer = 15.000000 ft
- Distance from top of pile to bottom of layer = 17.000000 ft
- Effective unit weight at top of layer = 110.000000 pcf
- Effective unit weight at bottom of layer = 110.000000 pcf

Undrained cohesion at top of layer = 800.000000 psf
Undrained cohesion at bottom of layer = 800.000000 psf
Epsilon-50 at top of layer = 0.007000
Epsilon-50 at bottom of layer = 0.007000

Layer 3 is stiff clay without free water

Distance from top of pile to top of layer = 17.000000 ft
Distance from top of pile to bottom of layer = 22.000000 ft
Effective unit weight at top of layer = 47.600000 pcf
Effective unit weight at bottom of layer = 47.600000 pcf
Undrained cohesion at top of layer = 800.000000 psf
Undrained cohesion at bottom of layer = 800.000000 psf
Epsilon-50 at top of layer = 0.007000
Epsilon-50 at bottom of layer = 0.007000

Layer 4 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 22.000000 ft
Distance from top of pile to bottom of layer = 32.000000 ft
Effective unit weight at top of layer = 67.600000 pcf
Effective unit weight at bottom of layer = 67.600000 pcf
Friction angle at top of layer = 38.000000 deg.
Friction angle at bottom of layer = 38.000000 deg.
Subgrade k at top of layer = 120.000000 pci
Subgrade k at bottom of layer = 120.000000 pci

(Depth of the lowest soil layer extends 0.000 ft below the pile tip)

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Cohesion psf	Angle of Friction deg.	E50 or krm	kpy pci
1	Sand	0.00	125.0000	--	36.0000	--	164.0000
	(Reese, et al.)	15.0000	125.0000	--	36.0000	--	164.0000
2	Stiff Clay	15.0000	110.0000	800.0000	--	0.00700	--
	w/o Free Water	17.0000	110.0000	800.0000	--	0.00700	--
3	Stiff Clay	17.0000	47.6000	800.0000	--	0.00700	--
	w/o Free Water	22.0000	47.6000	800.0000	--	0.00700	--
4	Sand	22.0000	67.6000	--	38.0000	--	120.0000
	(Reese, et al.)	32.0000	67.6000	--	38.0000	--	120.0000

Static Loading Type

Static loading criteria were used when computing p-y curves for all analyses.

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 2

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length	Run Analysis
1	5	y = 0.720000 in	S = 0.004000 in/in	386000.	N.A.	Yes
2	4	y = 0.720000 in	M = -3428300. in-lbs	386000.	N.A.	Yes

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with
specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Dimensions and Properties of Steel H Weak Axis:

Length of Section	=	32.000000 ft
Flange Width	=	14.900000 in
Section Depth	=	14.200000 in
Flange Thickness	=	0.805000 in
Web Thickness	=	0.805000 in
Yield Stress of Pipe	=	50.000000 ksi
Elastic Modulus	=	29000. ksi
Cross-sectional Area	=	34.123950 sq. in.
Moment of Inertia	=	444.363799 in^4
Elastic Bending Stiffness	=	12886550. kip-in^2
Plastic Modulus, Z	=	91.398684in^3
Plastic Moment Capacity = Fy Z	=	4570.in-kip

Axial Structural Capacities:

Nom. Axial Structural Capacity = Fy As	=	1706.197 kips
Nominal Axial Tensile Capacity	=	-1706.197 kips

Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

Number	Axial Thrust Force kips
-----	-----
1	386.000

Definition of Run Messages:

Y = part of pipe section has yielded.

Axial Thrust Force = 386.000 kips

Bending Curvature rad/in.	Bending Moment in-kip	Bending Stiffness kip-in2	Depth to N Axis in	Max Total Stress ksi	Run Msg
-----	-----	-----	-----	-----	-----
0.00000447	57.6462319	12886018.	94.6422382	12.2685485	
0.00000895	115.2924638	12886018.	51.0461191	13.2253936	
0.00001342	172.9386957	12886018.	36.5140794	14.1822388	
0.00001789	230.5849276	12886018.	29.2480595	15.1390839	
0.00002237	288.2311595	12886018.	24.8884476	16.0959290	
0.00002684	345.8773914	12886018.	21.9820397	17.0527742	
0.00003131	403.5236233	12886018.	19.9060340	18.0096193	
0.00003579	461.1698552	12886018.	18.3490298	18.9664645	
0.00004026	518.8160871	12886018.	17.1380265	19.9233096	
0.00004474	576.4623190	12886018.	16.1692238	20.8801547	
0.00004921	634.1085509	12886018.	15.3765671	21.8369998	
0.00005368	691.7547828	12886018.	14.7160198	22.7938450	
0.00005816	749.4010147	12886018.	14.1570952	23.7506902	
0.00006263	807.0472466	12886018.	13.6780170	24.7075353	
0.00006710	864.6934785	12886018.	13.2628159	25.6643804	
0.00007158	922.3397104	12886018.	12.8995149	26.6212255	
0.00007605	979.9859423	12886018.	12.5789552	27.5780707	
0.00008052	1038.	12886018.	12.2940132	28.5349159	
0.00008500	1095.	12886018.	12.0390652	29.4917610	
0.00008947	1153.	12886018.	11.8096119	30.4486061	
0.00009394	1211.	12886018.	11.6020113	31.4054512	
0.00009842	1268.	12886018.	11.4132836	32.3622964	
0.0001029	1326.	12886018.	11.2409669	33.3191415	
0.0001074	1384.	12886018.	11.0830099	34.2759867	
0.0001118	1441.	12886018.	10.9376895	35.2328318	
0.0001163	1499.	12886018.	10.8035476	36.1896769	
0.0001208	1556.	12886018.	10.6793422	37.1465221	
0.0001253	1614.	12886018.	10.5640085	38.1033672	
0.0001297	1672.	12886018.	10.4566289	39.0602124	

0.0001342	1729.	12886018.	10.3564079	40.0170575
0.0001387	1787.	12886018.	10.2626528	40.9739027
0.0001432	1845.	12886018.	10.1747574	41.9307478
0.0001476	1902.	12886018.	10.0921890	42.8875929
0.0001521	1960.	12886018.	10.0144776	43.8444381
0.0001566	2018.	12886018.	9.9412068	44.8012832
0.0001610	2075.	12886018.	9.8720066	45.7581283
0.0001655	2133.	12886018.	9.8065470	46.7149735
0.0001700	2191.	12886018.	9.7445326	47.6718186
0.0001745	2248.	12886018.	9.6856984	48.6286637
0.0001834	2363.	12880749.	9.5773618	50.0000000 Y
0.0001924	2470.	12840834.	9.4840016	50.0000000 Y
0.0002013	2570.	12768566.	9.4041633	50.0000000 Y
0.0002103	2665.	12673800.	9.3354859	50.0000000 Y
0.0002192	2754.	12562505.	9.2762732	50.0000000 Y
0.0002282	2838.	12438357.	9.2252878	50.0000000 Y
0.0002371	2918.	12306445.	9.1811140	50.0000000 Y
0.0002460	2994.	12169194.	9.1428293	50.0000000 Y
0.0002550	3067.	12028124.	9.1097379	50.0000000 Y
0.0002639	3137.	11885299.	9.0810754	50.0000000 Y
0.0002729	3204.	11742499.	9.0561571	50.0000000 Y
0.0002818	3269.	11599906.	9.0346493	50.0000000 Y
0.0002908	3332.	11458160.	9.0161572	50.0000000 Y
0.0002997	3391.	11315153.	8.9995889	50.0000000 Y
0.0003087	3446.	11165153.	8.9834339	50.0000000 Y
0.0003176	3497.	11010132.	8.9676295	50.0000000 Y
0.0003266	3544.	10851774.	8.9521181	50.0000000 Y
0.0003355	3587.	10691278.	8.9368150	50.0000000 Y
0.0003445	3627.	10529443.	8.9220161	50.0000000 Y
0.0003534	3664.	10367974.	8.9074630	50.0000000 Y
0.0003624	3699.	10207487.	8.8930399	50.0000000 Y
0.0003713	3731.	10048587.	8.8788483	50.0000000 Y
0.0003803	3761.	9891088.	8.8651582	50.0000000 Y
0.0003892	3789.	9736626.	8.8515813	50.0000000 Y
0.0003981	3816.	9584692.	8.8384468	50.0000000 Y
0.0004071	3841.	9435131.	8.8254390	50.0000000 Y
0.0004160	3864.	9288415.	8.8125282	50.0000000 Y
0.0004250	3886.	9144891.	8.8001206	50.0000000 Y
0.0004339	3907.	9004567.	8.7877958	50.0000000 Y
0.0004429	3927.	8866737.	8.7756499	50.0000000 Y
0.0004518	3946.	8732758.	8.7639374	50.0000000 Y
0.0004608	3963.	8601248.	8.7520754	50.0000000 Y
0.0004697	3980.	8472925.	8.7407916	50.0000000 Y
0.0004787	3996.	8347887.	8.7293769	50.0000000 Y
0.0004876	4011.	8225455.	8.7184233	50.0000000 Y
0.0004966	4025.	8106088.	8.7075862	50.0000000 Y
0.0005055	4039.	7989935.	8.6967283	50.0000000 Y
0.0005145	4052.	7875951.	8.6863676	50.0000000 Y
0.0005234	4064.	7765141.	8.6761208	50.0000000 Y
0.0005324	4076.	7656911.	8.6657339	50.0000000 Y
0.0005681	4119.	7249468.	8.6267508	50.0000000 Y
0.0006039	4155.	6879165.	8.5901242	50.0000000 Y
0.0006397	4185.	6542344.	8.5560686	50.0000000 Y
0.0006755	4211.	6234472.	8.5236973	50.0000000 Y
0.0007113	4234.	5953047.	8.4930774	50.0000000 Y
0.0007471	4255.	5694837.	8.4642335	50.0000000 Y
0.0007829	4272.	5457235.	8.4371145	50.0000000 Y
0.0008187	4288.	5238005.	8.4111949	50.0000000 Y
0.0008544	4302.	5034908.	8.3865498	50.0000000 Y
0.0008902	4315.	4846683.	8.3632788	50.0000000 Y
0.0009260	4327.	4672143.	8.3410937	50.0000000 Y
0.0009618	4337.	4508710.	8.3199547	50.0000000 Y
0.0009976	4346.	4356518.	8.2999221	50.0000000 Y

Summary of Results for Nominal Moment Capacity for Section 1

Load No.	Axial Thrust kips	Nominal Moment Capacity in-kips
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1	386.000000000	4346.

Note that the values in the above table are not factored by a strength reduction factor for LRFD.

The value of the strength reduction factor depends on the provisions of the LRFD code being followed.

The above values should be multiplied by the appropriate strength reduction

factor to compute ultimate moment capacity according to the LRFD structural design standard being followed.

Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	0.00	0.00	N.A.	No	0.00	463146.
2	15.0000	55.3843	No	No	463146.	17880.
3	17.0000	57.3985	Yes	No	481026.	44700.
4	22.0000	15.6663	No	No	525726.	N.A.

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays, non-liquefied sands, and cemented c-phi soil.

Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 1

Pile-head conditions are Displacement and Pile-head Rotation (Loading Type 5)
Displacement of pile head = 0.720000 inches
Rotation of pile head = 4.000E-03 radians
Axial load on pile head = 386000.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/inch	Soil Spr. Es*H lb/inch	Distrib. Lat. Load lb/inch
0.00	0.7200	-4218141.	76575.	0.00400	82031.	6.16E+09	0.00	0.00	0.00
0.3200	0.7303	-3928563.	76354.	0.00146	77176.	6.16E+09	-48.561	255.3380	0.00
0.6400	0.7312	-3636068.	76054.	-4.32E-04	72272.	1.05E+10	-107.570	564.9117	0.00
0.9600	0.7270	-3343186.	75516.	-0.00166	67362.	1.14E+10	-172.533	911.3246	0.00
1.2800	0.7185	-3051184.	74725.	-0.00271	62466.	1.21E+10	-239.811	1282.	0.00
1.6000	0.7062	-2761277.	73675.	-0.00361	57606.	1.26E+10	-306.877	1669.	0.00
1.9200	0.6907	-2474643.	72374.	-0.00441	52800.	1.28E+10	-370.684	2061.	0.00
2.2400	0.6724	-2192378.	70827.	-0.00510	48068.	1.29E+10	-434.974	2484.	0.00
2.5600	0.6515	-1915559.	69045.	-0.00572	43427.	1.29E+10	-493.254	2907.	0.00
2.8800	0.6285	-1645166.	67048.	-0.00625	38894.	1.29E+10	-546.679	3340.	0.00
3.2000	0.6035	-1382108.	64856.	-0.00670	34483.	1.29E+10	-595.467	3789.	0.00
3.5200	0.5770	-1127220.	62465.	-0.00707	30210.	1.29E+10	-649.813	4324.	0.00
3.8400	0.5492	-881416.	59873.	-0.00737	26089.	1.29E+10	-699.913	4894.	0.00
4.1600	0.5204	-645544.	57095.	-0.00760	22135.	1.29E+10	-746.783	5510.	0.00
4.4800	0.4909	-420398.	54158.	-0.00776	18360.	1.29E+10	-783.058	6126.	0.00
4.8000	0.4608	-206613.	51106.	-0.00785	14776.	1.29E+10	-806.832	6723.	0.00
5.1200	0.4306	-4634.	47951.	-0.00788	11389.	1.29E+10	-836.253	7458.	0.00
5.4400	0.4003	185016.	44658.	-0.00786	14414.	1.29E+10	-878.841	8431.	0.00
5.7600	0.3702	361625.	41214.	-0.00777	17375.	1.29E+10	-914.634	9486.	0.00
6.0800	0.3406	524588.	37648.	-0.00764	20107.	1.29E+10	-943.026	10632.	0.00
6.4000	0.3115	673414.	33973.	-0.00746	22602.	1.29E+10	-970.790	11965.	0.00
6.7200	0.2833	807627.	30194.	-0.00724	24852.	1.29E+10	-997.662	13524.	0.00
7.0400	0.2559	926772.	26321.	-0.00698	26850.	1.29E+10	-1019.	15296.	0.00
7.3600	0.2296	1030475.	22375.	-0.00669	28588.	1.29E+10	-1036.	17318.	0.00
7.6800	0.2045	1118452.	18382.	-0.00637	30063.	1.29E+10	-1044.	19603.	0.00
8.0000	0.1807	1190538.	14372.	-0.00603	31272.	1.29E+10	-1044.	22194.	0.00
8.3200	0.1582	1246699.	10377.	-0.00567	32213.	1.29E+10	-1036.	25145.	0.00
8.6400	0.1372	1287032.	6431.	-0.00529	32889.	1.29E+10	-1019.	28525.	0.00
8.9600	0.1176	1311768.	2568.	-0.00490	33304.	1.29E+10	-993.190	32425.	0.00
9.2800	0.09955	1321280.	-1179.	-0.00451	33464.	1.29E+10	-958.248	36962.	0.00
9.6000	0.08300	1316078.	-4774.	-0.00412	33376.	1.29E+10	-914.168	42296.	0.00
9.9200	0.06795	1296816.	-8182.	-0.00373	33054.	1.29E+10	-860.833	48650.	0.00
10.2400	0.05438	1264286.	-11367.	-0.00334	32508.	1.29E+10	-798.057	56353.	0.00
10.5600	0.04226	1219431.	-14292.	-0.00297	31756.	1.29E+10	-725.484	65918.	0.00
10.8800	0.03154	1163339.	-16919.	-0.00262	30816.	1.29E+10	-642.396	78214.	0.00
11.2000	0.02215	1097261.	-19089.	-0.00228	29708.	1.29E+10	-488.157	84640.	0.00
11.5200	0.01401	1023500.	-20636.	-0.00197	28471.	1.29E+10	-317.639	87058.	0.00
11.8400	0.00705	944603.	-21561.	-0.00167	27148.	1.29E+10	-164.163	89476.	0.00

12.1600	0.00116	862869.	-21930.	-0.00140	25778.	1.29E+10	-27.781	91895.	0.00
12.4800	-0.00374	780374.	-21807.	-0.00116	24395.	1.29E+10	91.7617	94313.	0.00
12.8000	-0.00774	698826.	-21257.	-9.39E-04	23028.	1.29E+10	194.9781	96731.	0.00
13.1200	-0.01094	619875.	-20340.	-7.42E-04	21704.	1.29E+10	282.5900	99149.	0.00
13.4400	-0.01344	544818.	-19115.	-5.69E-04	20446.	1.29E+10	355.4762	101568.	0.00
13.7600	-0.01531	474761.	-17636.	-4.17E-04	19271.	1.29E+10	414.6223	103986.	0.00
14.0800	-0.01664	410609.	-15955.	-2.85E-04	18196.	1.29E+10	461.0720	106404.	0.00
14.4000	-0.01750	353074.	-14117.	-1.71E-04	17231.	1.29E+10	495.8791	108823.	0.00
14.7200	-0.01795	302695.	-12167.	-7.32E-05	16387.	1.29E+10	520.0633	111241.	0.00
15.0400	-0.01806	259851.	-10801.	1.06E-05	15668.	1.29E+10	191.0932	40630.	0.00
15.3600	-0.01787	219710.	-10068.	8.20E-05	14995.	1.29E+10	190.5901	40952.	0.00
15.6800	-0.01743	182283.	-9339.	1.42E-04	14368.	1.29E+10	189.4036	41726.	0.00
16.0000	-0.01678	147567.	-8615.	1.91E-04	13786.	1.29E+10	187.6142	42931.	0.00
16.3200	-0.01596	115554.	-7899.	2.30E-04	13249.	1.29E+10	185.2840	44571.	0.00
16.6400	-0.01501	86221.	-7193.	2.60E-04	12757.	1.29E+10	182.4619	46671.	0.00
16.9600	-0.01396	59540.	-6499.	2.82E-04	12310.	1.29E+10	179.1869	49276.	0.00
17.2800	-0.01285	35476.	-5818.	2.96E-04	11906.	1.29E+10	175.4896	52456.	0.00
17.6000	-0.01169	13983.	-5152.	3.04E-04	11546.	1.29E+10	171.3940	56307.	0.00
17.9200	-0.01051	-4988.	-4502.	3.05E-04	11395.	1.29E+10	166.9184	60958.	0.00
18.2400	-0.00935	-21496.	-3870.	3.01E-04	11672.	1.29E+10	162.0755	66586.	0.00
18.5600	-0.00820	-35604.	-3258.	2.92E-04	11909.	1.29E+10	156.8727	73432.	0.00
18.8800	-0.00710	-47384.	-2666.	2.80E-04	12106.	1.29E+10	151.3114	81829.	0.00
19.2000	-0.00605	-56911.	-2097.	2.65E-04	12266.	1.29E+10	145.3858	92245.	0.00
19.5200	-0.00507	-64270.	-1550.	2.47E-04	12389.	1.29E+10	139.0808	105365.	0.00
19.8400	-0.00416	-69549.	-1029.	2.27E-04	12478.	1.29E+10	132.3681	122218.	0.00
20.1600	-0.00333	-72846.	-534.672	2.05E-04	12533.	1.29E+10	125.1991	144432.	0.00
20.4800	-0.00258	-74264.	-68.705	1.83E-04	12557.	1.29E+10	117.4916	174751.	0.00
20.8000	-0.00192	-73917.	366.3556	1.61E-04	12551.	1.29E+10	109.1027	218222.	0.00
21.1200	-0.00134	-71929.	767.3848	1.40E-04	12518.	1.29E+10	99.7666	285361.	0.00
21.4400	-8.48E-04	-68437.	1130.	1.19E-04	12459.	1.29E+10	88.9231	402906.	0.00
21.7600	-4.31E-04	-63605.	1445.	9.90E-05	12378.	1.29E+10	75.0729	669175.	0.00
22.0800	-8.69E-05	-57637.	1594.	8.10E-05	12278.	1.29E+10	2.7622	122094.	0.00
22.4000	1.91E-04	-51603.	1587.	6.47E-05	12177.	1.29E+10	-6.164	123863.	0.00
22.7200	4.10E-04	-45637.	1550.	5.02E-05	12077.	1.29E+10	-13.414	125633.	0.00
23.0400	5.77E-04	-39849.	1487.	3.75E-05	11980.	1.29E+10	-19.134	127402.	0.00
23.3600	6.98E-04	-34325.	1406.	2.64E-05	11887.	1.29E+10	-23.473	129171.	0.00
23.6800	7.80E-04	-29132.	1309.	1.70E-05	11800.	1.29E+10	-26.584	130941.	0.00
24.0000	8.28E-04	-24319.	1203.	9.00E-06	11719.	1.29E+10	-28.619	132710.	0.00
24.3200	8.49E-04	-19917.	1091.	2.41E-06	11646.	1.29E+10	-29.724	134480.	0.00
24.6400	8.47E-04	-15944.	976.7017	-2.93E-06	11579.	1.29E+10	-30.039	136249.	0.00
24.9600	8.26E-04	-12407.	862.0085	-7.16E-06	11520.	1.29E+10	-29.697	138019.	0.00
25.2800	7.92E-04	-9302.	749.6589	-1.04E-05	11468.	1.29E+10	-28.819	139788.	0.00
25.6000	7.46E-04	-6619.	641.4958	-1.28E-05	11423.	1.29E+10	-27.516	141558.	0.00
25.9200	6.94E-04	-4338.	538.9565	-1.44E-05	11384.	1.29E+10	-25.890	143327.	0.00
26.2400	6.36E-04	-2437.	443.1175	-1.54E-05	11353.	1.29E+10	-24.027	145097.	0.00
26.5600	5.75E-04	-888.923	354.7391	-1.59E-05	11327.	1.29E+10	-22.004	146866.	0.00
26.8800	5.14E-04	334.8107	274.3111	-1.60E-05	11317.	1.29E+10	-19.886	148636.	0.00
27.2000	4.53E-04	1265.	202.0964	-1.57E-05	11333.	1.29E+10	-17.726	150405.	0.00
27.5200	3.93E-04	1934.	138.1732	-1.53E-05	11344.	1.29E+10	-15.567	152175.	0.00
27.8400	3.35E-04	2372.	82.4751	-1.46E-05	11351.	1.29E+10	-13.442	153944.	0.00
28.1600	2.80E-04	2610.	34.8278	-1.39E-05	11355.	1.29E+10	-11.374	155714.	0.00
28.4800	2.29E-04	2680.	-5.016	-1.31E-05	11357.	1.29E+10	-9.378	157483.	0.00
28.8000	1.80E-04	2611.	-37.348	-1.23E-05	11355.	1.29E+10	-7.461	159252.	0.00
29.1200	1.34E-04	2430.	-62.474	-1.16E-05	11352.	1.29E+10	-5.625	161022.	0.00
29.4400	9.12E-05	2165.	-80.694	-1.09E-05	11348.	1.29E+10	-3.864	162791.	0.00
29.7600	5.06E-05	1842.	-92.281	-1.03E-05	11343.	1.29E+10	-2.170	164561.	0.00
30.0800	1.22E-05	1487.	-97.466	-9.78E-06	11337.	1.29E+10	-0.530	166330.	0.00
30.4000	-2.45E-05	1123.	-96.429	-9.39E-06	11331.	1.29E+10	1.0706	168100.	0.00
30.7200	-5.99E-05	774.1210	-89.288	-9.11E-06	11325.	1.29E+10	2.6486	169869.	0.00
31.0400	-9.44E-05	464.1118	-76.101	-8.92E-06	11319.	1.29E+10	4.2196	171639.	0.00
31.3600	-1.28E-04	216.1185	-56.866	-8.82E-06	11315.	1.29E+10	5.7985	173408.	0.00
31.6800	-1.62E-04	53.5317	-31.530	-8.78E-06	11313.	1.29E+10	7.3974	175178.	0.00
32.0000	-1.96E-04	0.00	0.00	-8.77E-06	11312.	1.29E+10	9.0246	88474.	0.00

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 1:

Pile-head deflection = 0.72000000 inches
Computed slope at pile head = 0.00400000 radians
Maximum bending moment = -4218141. inch-lbs
Maximum shear force = 76575. lbs
Depth of maximum bending moment = 0.000000 feet below pile head
Depth of maximum shear force = 0.000000 feet below pile head
Number of iterations = 22
Number of zero deflection points = 3

Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 2

Pile-head conditions are Displacement and Moment (Loading Type 4)
Displacement of pile head = 0.720000 inches
Moment at pile head = -3428300.0 in-lbs
Axial load at pile head = 386000.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/inch	Soil Spr. Es*H lb/inch	Distrib. Lat. Load lb/inch
0.00	0.7200	-3428300.	67119.	-2.84E-04	68789.	1.12E+10	0.00	0.00	0.00
0.3200	0.7167	-3169274.	67025.	-0.00141	64446.	1.12E+10	-48.561	260.2023	0.00
0.6400	0.7091	-2909356.	66726.	-0.00241	60089.	1.23E+10	-107.570	582.4877	0.00
0.9600	0.6982	-2649679.	66188.	-0.00326	55735.	1.27E+10	-172.534	948.9751	0.00
1.2800	0.6841	-2391358.	65396.	-0.00402	51404.	1.29E+10	-239.813	1346.	0.00
1.6000	0.6673	-2135516.	64346.	-0.00470	47115.	1.29E+10	-306.880	1766.	0.00
1.9200	0.6480	-1883255.	63045.	-0.00530	42886.	1.29E+10	-370.687	2197.	0.00
2.2400	0.6266	-1635629.	61499.	-0.00582	38734.	1.29E+10	-434.979	2666.	0.00
2.5600	0.6033	-1393694.	59716.	-0.00627	34678.	1.29E+10	-493.260	3139.	0.00
2.8800	0.5784	-1158417.	57720.	-0.00665	30733.	1.29E+10	-546.686	3629.	0.00
3.2000	0.5522	-930690.	55534.	-0.00696	26915.	1.29E+10	-591.668	4114.	0.00
3.5200	0.5250	-711276.	53194.	-0.00721	23237.	1.29E+10	-627.230	4588.	0.00
3.8400	0.4969	-500797.	50723.	-0.00739	19708.	1.29E+10	-659.782	5099.	0.00
4.1600	0.4682	-299825.	48112.	-0.00751	16338.	1.29E+10	-700.102	5742.	0.00
4.4800	0.4392	-109045.	45367.	-0.00757	13140.	1.29E+10	-729.679	6379.	0.00
4.8000	0.4101	71025.	42532.	-0.00757	12502.	1.29E+10	-746.729	6992.	0.00
5.1200	0.3811	240051.	39620.	-0.00753	15336.	1.29E+10	-769.745	7757.	0.00
5.4400	0.3523	397622.	36594.	-0.00743	17978.	1.29E+10	-806.448	8790.	0.00
5.7600	0.3240	543125.	33439.	-0.00729	20417.	1.29E+10	-836.771	9918.	0.00
6.0800	0.2963	676050.	30181.	-0.00711	22646.	1.29E+10	-860.218	11148.	0.00
6.4000	0.2694	795992.	26832.	-0.00689	24657.	1.29E+10	-884.014	12601.	0.00
6.7200	0.2434	902546.	23391.	-0.00664	26443.	1.29E+10	-907.857	14324.	0.00
7.0400	0.2184	995315.	19871.	-0.00636	27999.	1.29E+10	-925.701	16276.	0.00
7.3600	0.1946	1073995.	16296.	-0.00605	29318.	1.29E+10	-936.424	18481.	0.00
7.6800	0.1720	1138392.	12694.	-0.00572	30397.	1.29E+10	-939.661	20982.	0.00
8.0000	0.1507	1188430.	9094.	-0.00537	31236.	1.29E+10	-935.111	23833.	0.00
8.3200	0.1307	1224155.	5527.	-0.00501	31835.	1.29E+10	-922.534	27100.	0.00
8.6400	0.1122	1245736.	2025.	-0.00464	32197.	1.29E+10	-901.748	30867.	0.00
8.9600	0.09506	1253469 Mmax2	1382.	-0.00427	32327.	1.29E+10	-872.617	35248.	0.00
9.2800	0.07938	1247782.	-4661.	-0.00390	32231.	1.29E+10	-835.035	40393.	0.00
9.6000	0.06513	1229230.	-7779.	-0.00353	31920.	1.29E+10	-788.895	46514.	0.00
9.9200	0.05228	1198503.	-10703.	-0.00317	31405.	1.29E+10	-734.044	53915.	0.00
10.2400	0.04081	1156422.	-13399.	-0.00282	30700.	1.29E+10	-670.199	63070.	0.00
10.5600	0.03065	1103948.	-15831.	-0.00248	29820.	1.29E+10	-596.798	74764.	0.00
10.8800	0.02176	1042186.	-17872.	-0.00216	28785.	1.29E+10	-465.988	82221.	0.00
11.2000	0.01407	973093.	-19362.	-0.00186	27626.	1.29E+10	-310.043	84640.	0.00
11.5200	0.00748	898998.	-20283.	-0.00158	26384.	1.29E+10	-169.650	87058.	0.00
11.8400	0.00193	822005.	-20695.	-0.00132	25093.	1.29E+10	-44.935	89476.	0.00
12.1600	-0.00269	743985.	-20658.	-0.00109	23785.	1.29E+10	64.2655	91895.	0.00
12.4800	-0.00645	666585.	-20230.	-8.81E-04	22487.	1.29E+10	158.3678	94313.	0.00
12.8000	-0.00945	591226.	-19469.	-6.93E-04	21224.	1.29E+10	237.9945	96731.	0.00
13.1200	-0.01177	519114.	-18429.	-5.28E-04	20015.	1.29E+10	303.9309	99149.	0.00
13.4400	-0.01350	451256.	-17160.	-3.83E-04	18877.	1.29E+10	357.0815	101568.	0.00
13.7600	-0.01471	388463.	-15709.	-2.58E-04	17824.	1.29E+10	398.4268	103986.	0.00
14.0800	-0.01548	331373.	-14121.	-1.51E-04	16867.	1.29E+10	428.9823	106404.	0.00
14.4000	-0.01587	280463.	-12433.	-5.95E-05	16014.	1.29E+10	449.7594	108823.	0.00
14.7200	-0.01594	236061.	-10683.	1.74E-05	15269.	1.29E+10	461.7294	111241.	0.00
15.0400	-0.01574	198363.	-9442.	8.21E-05	14637.	1.29E+10	184.6660	45061.	0.00
15.3600	-0.01531	163301.	-8736.	1.36E-04	14050.	1.29E+10	183.3992	46006.	0.00
15.6800	-0.01469	130871.	-8035.	1.80E-04	13506.	1.29E+10	181.5315	47446.	0.00
16.0000	-0.01393	101059.	-7342.	2.14E-04	13006.	1.29E+10	179.1250	49391.	0.00
16.3200	-0.01305	73845.	-6660.	2.40E-04	12550.	1.29E+10	176.2282	51874.	0.00
16.6400	-0.01208	49196.	-5990.	2.59E-04	12137.	1.29E+10	172.8796	54957.	0.00
16.9600	-0.01106	27075.	-5333.	2.70E-04	11766.	1.29E+10	169.1092	58727.	0.00
17.2800	-0.01000	7436.	-4692.	2.75E-04	11436.	1.29E+10	164.9402	63307.	0.00
17.6000	-0.00894	-9775.	-4067.	2.75E-04	11476.	1.29E+10	160.3900	68868.	0.00
17.9200	-0.00789	-24616.	-3461.	2.70E-04	11724.	1.29E+10	155.4698	75638.	0.00
18.2400	-0.00687	-37154.	-2874.	2.61E-04	11935.	1.29E+10	150.1850	83937.	0.00
18.5600	-0.00589	-47461.	-2308.	2.48E-04	12107.	1.29E+10	144.5343	94211.	0.00
18.8800	-0.00497	-55616.	-1765.	2.33E-04	12244.	1.29E+10	138.5078	107105.	0.00
19.2000	-0.00410	-61703.	-1245.	2.15E-04	12346.	1.29E+10	132.0839	123581.	0.00
19.5200	-0.00331	-65816.	-751.103	1.96E-04	12415.	1.29E+10	125.2239	145136.	0.00
19.8400	-0.00260	-68053.	-284.378	1.76E-04	12453.	1.29E+10	117.8615	174245.	0.00
20.1600	-0.00196	-68523.	152.8890	1.56E-04	12461.	1.29E+10	109.8820	215328.	0.00
20.4800	-0.00140	-67341.	557.9294	1.36E-04	12441.	1.29E+10	101.0766	277218.	0.00
20.8000	-9.18E-04	-64640.	926.7664	1.16E-04	12395.	1.29E+10	91.0261	380883.	0.00
21.1200	-5.09E-04	-60568.	1253.	9.73E-05	12327.	1.29E+10	78.7147	593508.	0.00

21.4400	-1.70E-04	-55308.	1479.	8.01E-05	12239.	1.29E+10	39.1095	882550.	0.00
21.7600	1.06E-04	-49447.	1507.	6.45E-05	12141.	1.29E+10	-24.284	882550.	0.00
22.0800	3.25E-04	-43923.	1441.	5.06E-05	12048.	1.29E+10	-10.330	122094.	0.00
22.4000	4.94E-04	-38531.	1390.	3.83E-05	11958.	1.29E+10	-15.931	123863.	0.00
22.7200	6.19E-04	-33357.	1321.	2.76E-05	11871.	1.29E+10	-20.245	125633.	0.00
23.0400	7.06E-04	-28467.	1237.	1.83E-05	11789.	1.29E+10	-23.407	127402.	0.00
23.3600	7.60E-04	-23910.	1143.	1.05E-05	11713.	1.29E+10	-25.553	129171.	0.00
23.6800	7.86E-04	-19719.	1043.	4.04E-06	11642.	1.29E+10	-26.817	130941.	0.00
24.0000	7.91E-04	-15914.	938.6999	-1.27E-06	11579.	1.29E+10	-27.325	132710.	0.00
24.3200	7.77E-04	-12506.	834.0129	-5.51E-06	11521.	1.29E+10	-27.199	134480.	0.00
24.6400	7.48E-04	-9493.	730.8078	-8.78E-06	11471.	1.29E+10	-26.553	136249.	0.00
24.9600	7.09E-04	-6867.	630.8841	-1.12E-05	11427.	1.29E+10	-25.490	138019.	0.00
25.2800	6.62E-04	-4614.	535.6599	-1.29E-05	11389.	1.29E+10	-24.106	139788.	0.00
25.6000	6.10E-04	-2715.	446.2106	-1.40E-05	11357.	1.29E+10	-22.483	141558.	0.00
25.9200	5.54E-04	-1146.	363.3085	-1.46E-05	11331.	1.29E+10	-20.696	143327.	0.00
26.2400	4.98E-04	118.5986	287.4618	-1.48E-05	11314.	1.29E+10	-18.808	145097.	0.00
26.5600	4.41E-04	1106.	218.9541	-1.46E-05	11330.	1.29E+10	-16.873	146866.	0.00
26.8800	3.86E-04	1843.	157.8820	-1.41E-05	11343.	1.29E+10	-14.935	148636.	0.00
27.2000	3.33E-04	2360.	104.1906	-1.35E-05	11351.	1.29E+10	-13.029	150405.	0.00
27.5200	2.82E-04	2684.	57.7081	-1.28E-05	11357.	1.29E+10	-11.181	152175.	0.00
27.8400	2.35E-04	2841.	18.1760	-1.19E-05	11359.	1.29E+10	-9.409	153944.	0.00
28.1600	1.91E-04	2859.	-14.722	-1.11E-05	11360.	1.29E+10	-7.725	155714.	0.00
28.4800	1.50E-04	2761.	-41.334	-1.02E-05	11358.	1.29E+10	-6.135	157483.	0.00
28.8000	1.12E-04	2571.	-62.019	-9.45E-06	11355.	1.29E+10	-4.638	159252.	0.00
29.1200	7.70E-05	2313.	-77.126	-8.72E-06	11350.	1.29E+10	-3.230	161022.	0.00
29.4400	4.49E-05	2005.	-86.979	-8.08E-06	11345.	1.29E+10	-1.902	162791.	0.00
29.7600	1.50E-05	1668.	-91.864	-7.53E-06	11340.	1.29E+10	-0.642	164561.	0.00
30.0800	-1.30E-05	1322.	-92.018	-7.09E-06	11334.	1.29E+10	0.5620	166330.	0.00
30.4000	-3.94E-05	982.8064	-87.625	-6.74E-06	11328.	1.29E+10	1.7259	168100.	0.00
30.7200	-6.48E-05	668.8285	-78.811	-6.50E-06	11323.	1.29E+10	2.8645	169869.	0.00
31.0400	-8.93E-05	396.7933	-65.647	-6.34E-06	11318.	1.29E+10	3.9921	171639.	0.00
31.3600	-1.13E-04	183.4490	-48.148	-6.25E-06	11315.	1.29E+10	5.1219	173408.	0.00
31.6800	-1.37E-04	45.5490	-26.286	-6.22E-06	11312.	1.29E+10	6.2643	175178.	0.00
32.0000	-1.61E-04	0.00	0.00	-6.21E-06	11312.	1.29E+10	7.4264	88474.	0.00

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 2:

Pile-head deflection = 0.72000000 inches
 Computed slope at pile head = -0.0002837 radians
 Maximum bending moment = -3428300. inch-lbs
 Maximum shear force = 67119. lbs
 Depth of maximum bending moment = 0.000000 feet below pile head
 Depth of maximum shear force = 0.000000 feet below pile head
 Number of iterations = 13
 Number of zero deflection points = 3

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
 Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
 Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
 Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
 Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	y, in	0.7200	S, rad	0.00400	386000.	0.7200	0.00400	76575.	-4218141.
2	y, in	0.7200	M, in-lb	-3428300.	386000.	0.7200	-2.84E-04	67119.	-3428300.

Maximum pile-head deflection = 0.7200000000 inches
 Maximum pile-head rotation = 0.0040000000 radians = 0.229183 deg.

The analysis ended normally.

Objective

Evaluate the axial geotechnical resistance of the abutment and pier piles for the St. George River Bridge No. 5893 in Union, Maine. Evaluations were conducted to assess a suitable driving system to install a HP 14x117 pile to the required geotechnical nominal resistance of 595 kips for Abutments 1 and 2.

Has increased to 616 kips, by inspection this will not change this calculation but final results will be interpolated.

Methodology

Evaluate proposed pile section for governing factored axial compression resistance as follows.

1. Nominal Compressive Resistance
2. Factored Structural Compressive Resistance - Strength Limit State
3. Factored Structural Compressive Resistance - Extreme/Service Limit State
4. Geotechnical Resistance (Static Analysis)
5. Geotechnical Resistance (Drivability Analysis)
6. Factored Geotechnical Resistance - Strength Limit State
7. Factored Geotechnical Resistance - Extreme/Service Limit State

References

1. American Association of State Highway and Transportation Officials, AASHTO LRFD Bridge Design Specifications: Customary U.S. Units, 10th edition. (AASHTO LRFD)

Soil Properties

Consider St. George Bridge Interpretive Subsurface Profile (see Figure 3), subsurface layering and properties relative to pile design are presented in the Apile outputs attached.

Structural Properties

ASTM A572, Gr. 50 piles

Yield Strength of Steel

$$F_y := 50 \text{ ksi}$$

Young's Modulus of Steel

$$E_s := 30000 \cdot \text{ksi}$$

Pier: HP14x117

Radius of gyration (weak axis)

$$r_y := 3.59 \text{ in}$$

Radius of gyration (strong axis)

$$r_x := 5.96 \text{ in}$$

Area of section

$$A_s := 34.4 \text{ in}^2$$

1. Nominal Structural Compressive Resistance P_n

Nominal Compressive Resistance: $P_n := 0.66 \cdot F_y \cdot A_s$ AASHTO Eq. 6.9.5.1-1

Determine normalized column slenderness factor λ

$$\lambda := \left(\frac{K \cdot l}{r_y \cdot \pi} \right)^2 \cdot \frac{F_y}{E_s} \quad \text{AASHTO Eq. 6.9.4.1-3} \quad \text{pg. 6-74}$$

$\lambda := 0$ Where the pile is fully embedded, AASHTO 10.7.3.13.1.

Giving: $P_n := 0.66 \cdot F_y \cdot A_s$ $P_n = 1720 \cdot \text{kip}$

2. Factored Structural Compressive Resistance - Strength Limit State:

Factor for piles in compression under hard driving conditions:

From Article 6.5.4.2 $\phi_c := 0.5$

Factored Compressive Resistance for Strength Limit State per AASHTO Eq. 6.9.2.1-1:

$$P_r := \phi_c \cdot P_n = 860 \cdot \text{kip}$$

3. Factored Structural Compressive Resistance - Service/Extreme Limit State:

Resistance Factors for Extreme Limit States:

From Article 10.5.5.1 and 10.5.5.3 $\phi := 1$

Factored Compressive Resistance for Service/Extreme Limit State per AASHTO Eq. 6.9.2.1-1:

$$P_{r,1} := \phi \cdot P_n = 1720 \cdot \text{kip}$$

4. Geotechnical Axial Resistance - Static Analysis

AASHTO Article 10.7.3.2.3 states that the nominal resistance of piles driven to point bearing on hard rock is controlled by the structural limit state or potential for driving damage to occur during hard driving.

Abutments 1 and 2: Required nominal resistance of 595 kips for the pile configuration based on a maximum factored pile load of 387 kips and a 0.65 resistance factor.

The driving resistance is anticipated to be minimal in the soils above glacial till. Therefore, the estimated % skin friction resistance during driving is 0% in the upper 35 feet of the piles, and 25% in the lower 15 feet of the piles for Abutment 1 at the required nominal pile resistance. The estimated % skin friction resistance during driving is 0% in the upper 25 feet for the piles, and 5% in the lower 5 feet of the piles for Abutment 2 at the required nominal pile resistance, based on the estimated friction resistance.

5. Geotechnical Axial Resistance - Drivability Analysis

$$\sigma_{dr} := 0.9 \cdot \phi_{da} \cdot f_y \quad \text{AASHTO Eq. 10.7.8.1}$$

$$f_y := 50 \text{ ksi} \quad \text{yield strength of steel}$$

$$\phi_{da} := 1.0 \quad \text{AASHTO Table 10.5.5.2.3-1 Refers to Article 6.5.4.2, Pg. 6-28}$$

$$\sigma_{dr} := 0.9 \cdot \phi_{da} \cdot f_y \quad \sigma_{dr} = 45 \cdot \text{ksi} \quad \text{Driving Stress in pile cannot exceed 45 ksi}$$

Abutment 1 Piles - Drive piles plumb through 50 feet of soil to rock with toe quake representative of tip resistance on rock (0.1 in) and no plug. Model pile length as 60 feet (10 foot stickup at end of drive).

Drive Abutment 1 piles with a Pileco D30-32 open-ended diesel hammer with a maximum rated energy of 69,895 ft-lbs (fuel setting 3, 90% of max).

Abutment 2 Piles - Drive piles plumb through 30 feet of soil to rock with toe quake representative of tip resistance on rock (0.04 in) and no plug. Model pile length as 40 feet (10 foot stickup at end of drive).

Drive abutment piles with a Pileco D30-32 open-ended diesel hammer with a maximum rated energy of 69,895 ft-lbs (fuel setting 3, 90% of max)

GRLWEAP Output is attached for the piles.

$$R_{ndr1} := 595 \text{ kip} \quad \begin{array}{l} \text{Abutment 1 Required nominal geotechnical resistance:} \\ \text{Toe quake 0.1 in - pile driving stress=36 ksi, final penetration resistance=6 bpi.} \end{array}$$

$$R_{ndr2} := 595 \text{ kip} \quad \begin{array}{l} \text{Abutment 2 Required nominal geotechnical resistance:} \\ \text{Toe quake 0.04 in - pile driving stress=45 ksi, final penetration resistance=5 bpi.} \end{array}$$

6. Factored Drivability Resistance - Strength Limit State:

Strength Limit State Factored Drivability Resistance:

PDA, WEAP and CAPWAP used to establishing driving criteria

$$\phi_{\text{dyn}} := 0.65$$

AASHTO Table 10.5.5.2.3-1

Abutment 1:

$$R_{\text{ndr1_factored}} := R_{\text{ndr1}} \cdot \phi_{\text{dyn}}$$

$$R_{\text{ndr1_factored}} = 387 \cdot \text{kip} \quad \text{maximum factored axial load}$$

Abutment 2:

$$R_{\text{ndr2_factored}} := R_{\text{ndr2}} \cdot \phi_{\text{dyn}}$$

$$R_{\text{ndr2_factored}} = 387 \cdot \text{kip} \quad \text{maximum factored axial load}$$

7. Factored Drivability Resistance - Service/Extreme Limit States:

Service and Extreme Limit State Factored Drivability Resistance:

Resistance Factors for Extreme Limit States:

$$\phi_{\text{serv_ext}} := 1$$

From Article 10.5.5.1 and 10.5.5.3

Abutment 1:

$$R_{\text{ndr1_serv_ext}} := R_{\text{ndr1}} \cdot \phi_{\text{serv_ext}}$$

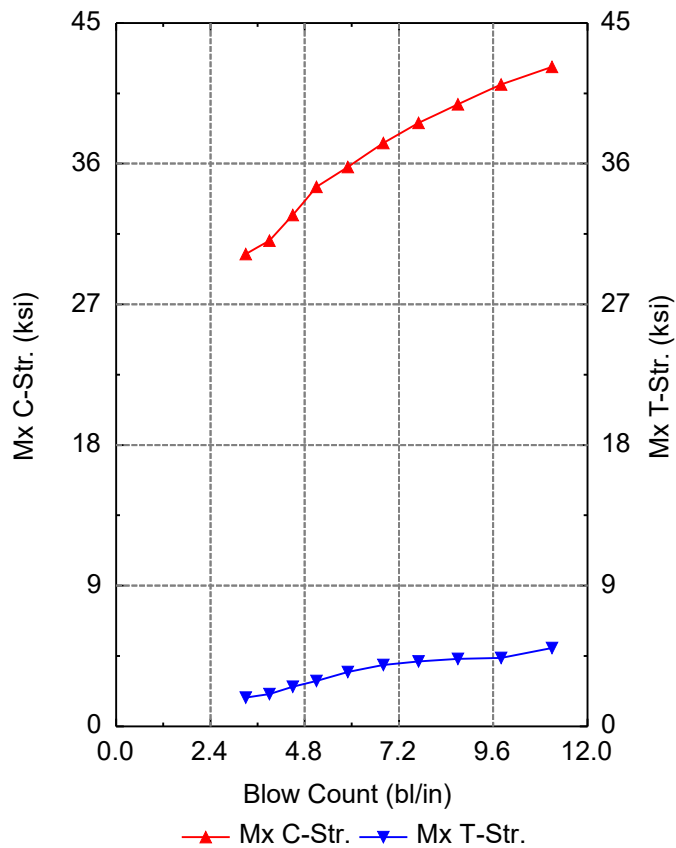
$$R_{\text{ndr1_serv_ext}} = 595 \cdot \text{kip}$$

Abutment 2:

$$R_{\text{ndr2_serv_ext}} := R_{\text{ndr2}} \cdot \phi_{\text{serv_ext}}$$

$$R_{\text{ndr2_serv_ext}} = 595 \cdot \text{kip}$$

Since the driving stresses do not exceed the limiting driving stress of 45 ksi for ASTM A572 steel (50 ksi yield stress), and the calculated penetration resistance for the piles are within the MaineDOT preferred range of 6 to 15 blows per inch, the analyzed hammer system is acceptable to install the piles to the required nominal resistances.

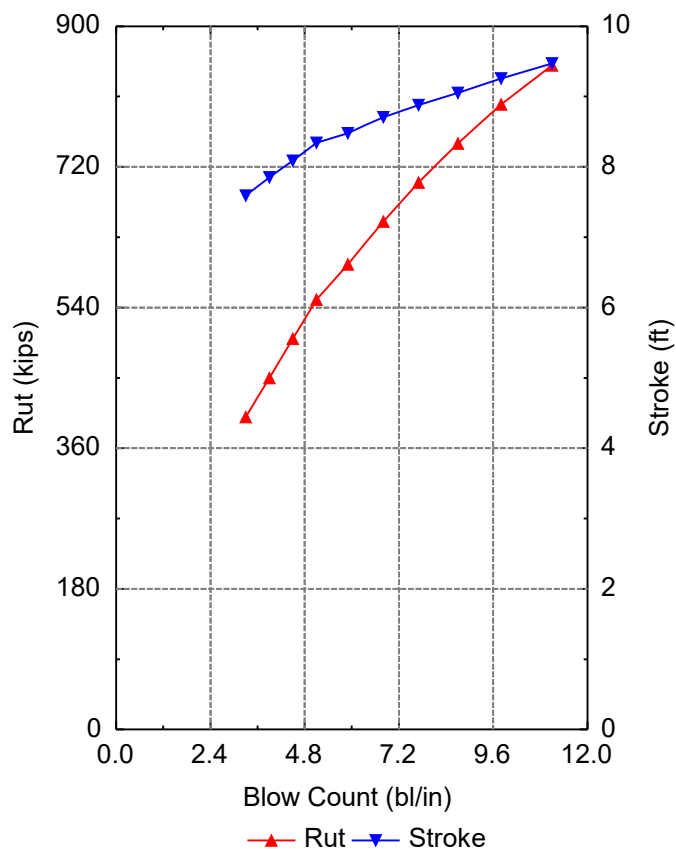


PILECO D30-32

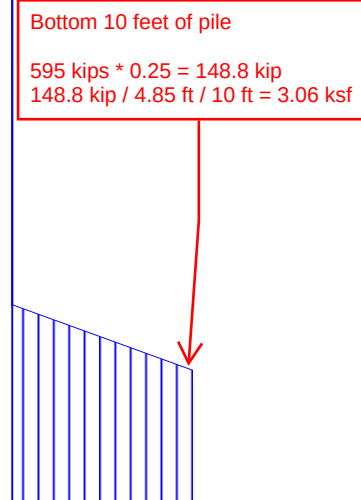
Ram Weight	6.61	kips
Efficiency	0.800	
Pressure	1240.0 (90%)	psi
Helmet Weight	1.900	kips
Hammer Cushion	60155.6	kips/in
COR of H.C.	0.800	
Skin Quake	0.100	in
Toe Quake	0.100	in
Skin Damping	0.050	s/ft
Toe Damping	0.150	s/ft
Pile Length	60.00	ft
Pile Penetration	50.00	ft
Pile Top Area	34.40	in ²

RSA

No



Pile Model

Shaft=25%
(Prop.)

Bearing Graph Summary — PILECO D30-32

Fuel Setting 3 of 4

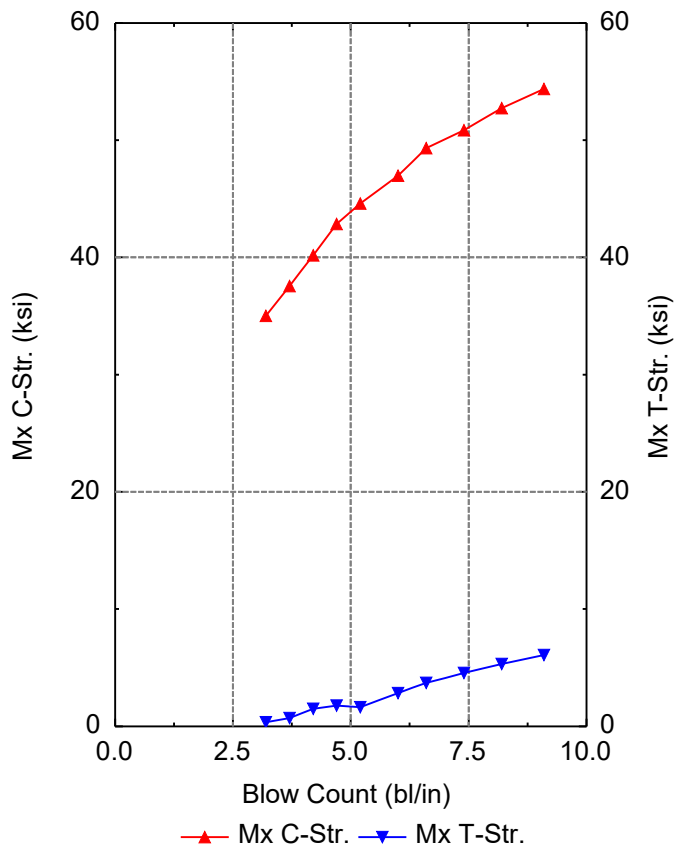
Rut kips	Mx C-Str. ksi	Top Str. ksi	Mx T-Str. ksi	Blow Ct bl/in	Stroke ft	ENTHRU kip-ft	Ham. Pow. PILECO	Trfr. R. %
400.0	30.22	29.88	1.84	3.3	7.59	26.63	D30-32	38.0
450.0	31.07	30.72	2.06	3.9	7.85	27.30	D30-32	39.0
500.0	32.71	31.38	2.53	4.5	8.09	27.97	D30-32	39.9
550.0	34.50	32.14	2.90	5.1	8.34	28.94	D30-32	41.3
595.0	35.78	32.55	3.47	5.9	8.48	29.43	D30-32	42.0
650.0	37.32	33.19	3.92	6.8	8.70	30.26	D30-32	43.2
700.0	38.61	33.71	4.15	7.7	8.88	30.96	D30-32	44.2
750.0	39.79	34.18	4.32	8.7	9.05	31.62	D30-32	45.1
800.0	41.07	34.63	4.38	9.8	9.26	32.44	D30-32	46.3
850.0	42.20	35.17	5.02	11.0	9.47	33.30	D30-32	47.5

Interpolated results @616 kips:

Stroke Length = 8.6 ft

Max Driving Stress = 36.4 ksi

Final Blows per Inch = 6.3 bpi

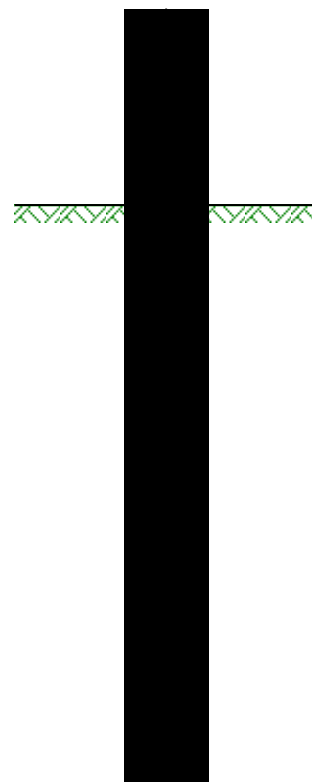
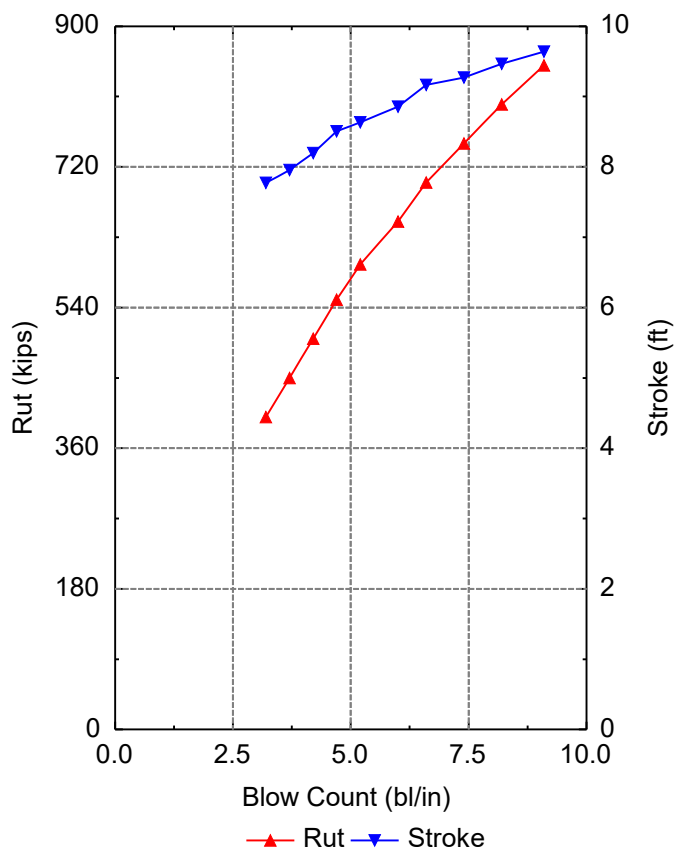


PILECO D30-32

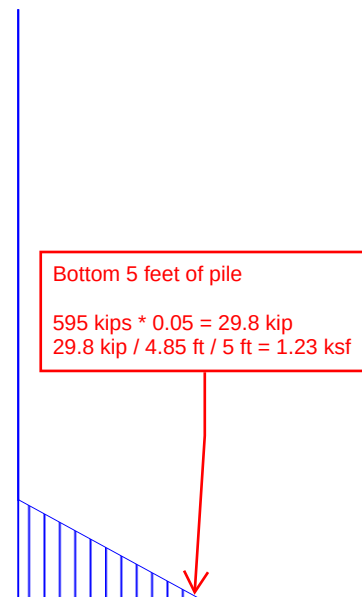
Ram Weight	6.61	kips
Efficiency	0.800	
Pressure	1240.0 (90%)	psi
Helmet Weight	1.900	kips
Hammer Cushion	60155.6	kips/in
COR of H.C.	0.800	
Skin Quake	0.100	in
Toe Quake	0.040	in
Skin Damping	0.050	s/ft
Toe Damping	0.150	s/ft
Pile Length	40.00	ft
Pile Penetration	30.00	ft
Pile Top Area	34.40	in ²

RSA

No



Pile Model



Bottom 5 feet of pile

$$595 \text{ kips} \times 0.05 = 29.8 \text{ kip}$$

$$29.8 \text{ kip} / 4.85 \text{ ft} / 5 \text{ ft} = 1.23 \text{ ksf}$$
Shaft=5%
(Prop.)

Bearing Graph Summary — PILECO D30-32

Fuel Setting 3 of 4

Rut kips	Mx C-Str. ksi	Top Str. ksi	Mx T-Str. ksi	Blow Ct bl/in	Stroke ft	ENTHRU kip-ft	Ham. Pow. PILECO	Trfr. R. %
400.0	35.02	30.19	0.36	3.2	7.77	25.67	D30-32	36.6
450.0	37.56	30.68	0.69	3.7	7.95	25.88	D30-32	36.9
500.0	40.17	31.39	1.49	4.2	8.20	26.58	D30-32	37.9
550.0	42.84	32.25	1.78	4.6	8.51	27.83	D30-32	39.7
595.0	44.61	32.63	1.64	5.2	8.63	28.31	D30-32	40.4
650.0	46.97	33.17	2.84	6.0	8.86	29.21	D30-32	41.7
700.0	49.31	33.98	3.71	6.6	9.17	30.49	D30-32	43.5
750.0	50.85	34.28	4.54	7.4	9.27	30.90	D30-32	44.1
800.0	52.74	34.77	5.31	8.2	9.47	31.70	D30-32	45.2
850.0	54.39	36.25	6.08	9.1	9.64	32.40	D30-32	46.2

Interpolated results @616 kips:

Stroke Length = 8.7 ft

Max Driving Stress = 45.3 ksi

Final Blows per Inch = 5.5 bpi



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Engineers and
 Scientists

JOB: 09.0026237.01 St George Bridge,
Union
 SUBJECT: Lateral Earth Pressures
 SHEET: 1 OF 1
 CALCULATED BY J. Keohane 4/30/2026
 CHECKED BY A. Blaisdell 5/2/2026

Subject: Evaluate lateral earth pressure coefficients

References:

1. MaineDOT Bridge Design Guide, Chapter 3
2. AASHTO LRFD Bridge Design Specifications, 9th Edition (2020)
3. Massachusetts Department of Transportation Highway Division LRFD Bridge Manual Part I, section 3.10.8

Input Parameters:

$\beta := 0\text{deg}$ Angle of backfill to the horizontal
 $\theta := 90\text{deg}$ Angle of backface of wall to the horizontal
 $\phi := 32\text{deg}$ Effective angle of internal friction (*Granular borrow, Soil Type 4, BDG Table 3-3*)
 $\delta_f := 19.5\text{deg}$ Average value of friction angle between, precast concrete and clean sand/silty sand-gravel mixture (*AASHTO LRFD Table 3.11.5.3-1*)

Passive Earth Pressure on Integral Backwall:

Per BDG Section 5.4.2.11, developing full passive pressure requires that ratio of lateral abutment movement (y) to abutment height (H_b) exceeds 0.005. If the calculated rotation is significantly less, Rankine earth pressure may be considered.

$y := 0.39\text{in}$ Expansion deflection From structural engineer
 $H_b := 11\text{ft}$ Abutment Height
 $\frac{y}{H_b} = 0.003$ Ratio of lateral movement to abutment height.

Earth Pressure Coefficients:

Since the ratio is greater than 0.005, GZA evaluated the passive earth pressure coefficient by using the Massachusetts DOT methodology. The MassDOT Section 3.10.8 presents the plot and calculation shown below for a gravel borrow material.

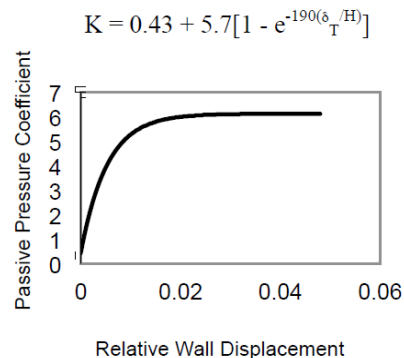


Figure 3.10.8-1: Plot of Passive Pressure Coefficient, K, vs. Relative Wall Displacement, δ_f/H .

$$K_{p,\text{mass}} := 0.43 + 5.7 \left(1 - \exp \left(-190 \cdot \frac{y}{H_b} \right) \right) = 2.88$$

$$K_{p,\text{mass}} = 2.88$$

The passive earth pressure coefficient (K_p) for structural fill is 2.88 using the MassDOT methodology.

Figure 5-1 Maine Design Freezing Index Map

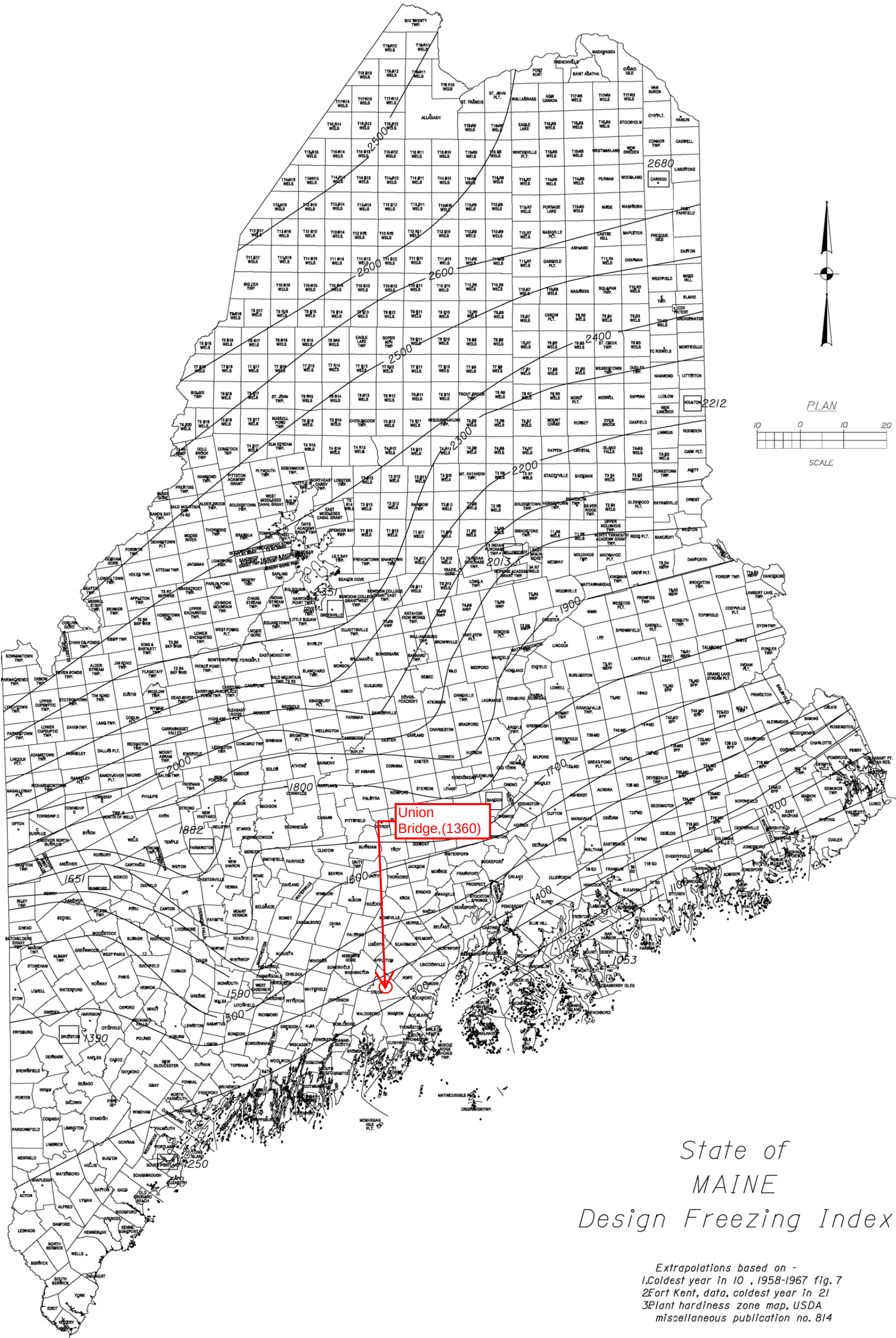


Table 5-1 Depth of Frost Penetration

Design Freezing Index	Frost Penetration (in)					
	Coarse Grained			Fine Grained		
	w=10%	w=20%	w=30%	w=10%	w=20%	w=30%
1000	66.3	55.0	47.5	47.1	40.7	36.9
1100	69.8	57.8	49.8	49.6	42.7	38.7
1200	73.1	60.4	52.0	52.0	44.7	40.5
1300	76.3	63.0	54.3	54.2	46.6	42.2
1400	79.2	65.5	56.4	56.3	48.5	43.9
1500	82.1	67.9	58.4	58.3	50.2	45.4
1600	84.8	70.2	60.3	60.2	51.9	46.9
1700	87.5	72.4	62.2	62.2	53.5	48.4
1800	90.1	74.5	64.0	64.0	55.1	49.8
1900	92.6	76.6	65.7	65.8	56.7	51.1
2000	95.1	78.7	67.5	67.6	58.2	52.5
2100	97.6	80.7	69.2	69.3	59.7	53.8
2200	100.0	82.6	70.8	71.0	61.1	55.1
2300	102.3	84.5	72.4	72.7	62.5	56.4
2400	104.6	86.4	74.0	74.3	63.9	57.6
2500	106.9	88.2	75.6	75.9	65.2	58.8
2600	109.1	89.9	77.1	77.5	66.5	60.0

- Notes: 1. w = water content
2. Where the Freezing Index and/or water content is between the presented values, linear interpretation may be used to determine the frost penetration.

Granular materials anticipated near the abutment bearing elevations have an average water content of approximately 10 percent. Based on the MaineDOT BDG, Section 5.2.1 and a Freezing index of 1,360 the estimated depth of frost penetration is 6.5 feet at each abutment. However, BDG Section 5.2.1 allows that the embedment of pile-supported integral abutments may be reduced to 4.0 feet for frost protection.



Seismic Site Class Calculation Summary

Project: St. George River Bridge No. 5893

Project No.: 09.0026237.01

Location: Union, ME

Evaluated By/Date: S. Miller

Date: 3/11/2026

Checked By/Date: J. Keohane

Date: 3/12/2026

Objective: Determine seismic site class and develop design acceleration response spectrum by performing calculations in accordance with the AASHTO LRFD Bridge Design Specifications, 10th Edition (2024).

Subsurface Data: Borings BB-USGR-101 through BB-USGR-103 were drilled by New England Boring Contractors of Hermon, Maine between May 28, 2024 and May 31, 2024. Borings BB-USGR-201 through BB-USGR-202 were drilled by Seaboard Drilling, LLC of Bangor, Maine between December 16, 2025 and January 14, 2026.

Borings extended to depths between 28 and 75 feet below ground surface and bedrock was encountered at depths of 18 and 63 feet below ground surface. Sampling and testing conducted included standard penetration tests (SPTs), in-situ vane undrained shear strength (S_u) testing, soil index testing, bedrock coring, and bedrock strength testing. Direct shear wave velocity (V_s) measurements were not made.

Approach: Refer to AASHTO Table C3.10.3.1-1 Steps for Site Classification.

- 1) Check for three categories of Site Class F in Table 3.10.3.1-1. If yes, recommend site-specific evaluation.
- 2) Check for a soft clay layer with thickness greater than 10' of material with $S_u < 500$ psf, water content (w) $> 40\%$, and $PI > 20$. If criteria are met, classify as Site Class E.
- 3) Estimate average shear wave velocity ($V_{s\text{-bar}}$) for top 100 ft of profile using the equation below. If measured V_s data are available, use the data directly. Consider uncertainty of $\pm 10\%$ for direct measurements. If direct measurement is not available, use published correlations with SPT, CPT, and/or S_u for the available data. For bedrock within the upper 100' of the profile, assume the median Site Class B (3,900 ft/sec) if direct data are not available, which is considered conservative for intact bedrock in Maine. Apply factors of $V_{s\text{-bar}}/1.33$ and $1.3 \cdot V_{s\text{-bar}}$ to develop three values for consideration.

$$\bar{V}_s = \frac{\sum_{i=1}^n d_i}{\sum_{i=1}^n \frac{d_i}{V_{si}}}$$

where:

$$\sum_{i=1}^n d_i = 100 \text{ ft}$$

V_{si} = shear wave velocity in ft/s of a layer

d_i = thickness of a layer between 0 and 100 ft

- 4) Based on $V_{s\text{-bar}}$, Use AASHTO Table 3.10.3.1-1 - Site Class Definitions to determine Site Class. Multiple Site Classes may be considered depending on the uncertainty determined from Step 3.
- 5) Develop a 5 percent-damped, risk targeted-design response spectrum using response spectral accelerations taken from the AASHTO USGS Seismic Ground Motion Database as described in AASHTO 3.10.4.1. If multiple site classes are considered, design spectra values are taken as the worst case from the considered site classes.

Note: AASHTO C3.10.3.1, correlation methods for SPT or CPT field data need to recognize the variability of those correlations by applying a typical factor of ± 1.33 to the result. Refer to PEER document (reference) for correlation between SPT and V_s .

Evaluation and Results: Calculations of the average shear wave velocity are attached and summarized in the table below

- 1) No highly organic soil, high plasticity clay, or very thick medium stiff clay encountered. Site Class F not appropriate.
- 2) No soft layer exceeding 10' with indicated index properties encountered. Site Class E not appropriate unless dictated by $V_{s\text{-bar}}$.
- 3) Calculations of the average shear wave velocity are attached and summarized in the table below. Direct V_s data not available so empirical correlation used. Used correlation by DeJong et al (2012) for Sand and Clay that is based on N60 values.

Table 4.11 Recommended SPT-stress- V_s correlation equations.

Soil Type	Shear Wave Velocity for Quaternary Soils (m/s)			Age Scaling Factors	
	N_{60}	σ'_v	(Eq #)	Holocene	Pleistocene
All Soils	30	$N_{60}^{0.215} \sigma'_v^{0.275}$	(4.17)	0.87	1.13
Clays & Silts	26	$N_{60}^{0.17} \sigma'_v^{0.32}$	(4.40)	0.88	1.12
Sands	30	$N_{60}^{0.23} \sigma'_v^{0.23}$	(4.77)	0.90	1.17
Gravels - Holocene	53	$N_{60}^{0.19} \sigma'_v^{0.38}$	(4.98)	-----	-----
Gravels - Pleistocene	115	$N_{60}^{0.17} \sigma'_v^{0.32}$	(4.102)	-----	-----

σ'_v , measured in kPa

Boring ID	BB-USGR-101/A	BB-USGR-102	BB-USGR-103	BB-USGR-201/A	BB-USGR-202	Average
V_s	868	1391	1339	779	1148	1105
$V_s / 1.3$	668	1070	1030	599	883	850
$V_s * 1.3$	1128	1809	1741	1013	1493	1437

Maximum = 1809

Minimum = 599

- 4) Based on the procedure outlined above, we recommend a range of from Site Class C (1,450 fps $< V_s < 2,100$) to D/E (500 fps $< V_s < 700$ fps), including Site Class C/D (1,000 fps $< V_s < 1,450$) and Site Class D (700 fps $< V_s < 1,000$) be used for design.

- 5) Review risk-targeted response spectrum values to determine SD1 (See attached). Based on the procedure, Site Class D is considered worst case. For design use an $SD1 = 0.09$. Since $SD1$ is less than 0.15 the Site is Classified as Seismic Zone 1 (AASHTO Table 3.10.6-1).

BB-USGR-101/A

Existing Ground Surface Elevation (ft NAVD 88)	68.8
Finish Ground Surface Elevation (ft NAVD 88)	68.8
New Fill Thickness (ft)	0
SPT Energy Transfer Ratio	0.76
Groundwater Depth (ft)	10.8

Geologic Epoch Pleistocene (Pleistocene, Holocene, or NA)

Sample ID	Existing Midpoint Depth	Midpoint Elev.	Stratum	Soil Type	Soil Age Scaling Factor	N (field)	N ₆₀	Total Unit Weight	Total Stress	Water Pressure	Effective Stress	PEER Silt/Clay Correlation	PEER Sand Correlation	Correlated Vs, PEER 2012	Layer Thickness, di	di/Vs
Units	(ft)	(ft)				(bpf)	(bpf)	(pcf)	(psf)	(psf)	(psf)	(m/s)	(m/s)	(fps)	(ft)	(fps)
1D	2	66.8	Fill	SAND	1.00	40	51	125	250	0	250	112.1	131.0	430	4.0	0.009
2D	6	62.8	Fill	SAND	1.00	13	16	125	750	0	750	131.7	130.2	427	4.2	0.010
3D	10.3	58.5	Fill	SAND	1.00	50	63	125	1288	0	1288	196.8	201.0	659	4.5	0.007
4D	15	53.8	Fill	SAND	1.00	13	16	125	1875	262	1613	168.2	155.3	509	4.9	0.010
5D	20	48.8	Fill	SAND	1.00	34	43	125	2500	574	1926	209.7	201.8	662	6.5	0.010
6D	25	43.8	Alluvium	SAND	0.90	3	4	120	3120	886	2234	131.0	107.5	353	2.0	0.006
7D	27.0	41.8	Alluvium	SAND	0.90	22	28	120	3360	1011	2349	186.7	172.0	564	2.5	0.004
8D	30.0	38.8	Alluvium	SAND	0.90	28	35	120	3720	1198	2522	199.0	184.8	606	2.5	0.004
9D	32.0	36.8	Marine Clay	SILT/CLAY	1.12	2	3	110	3950	1323	2627	160.2	126.5	526	10.7	0.020
3D	42.0	26.8	Glacial Till	SAND	1.17	52	66	130	5056	1947	3109	307.3	290.6	954	1.8	0.002
4D	45.0	23.8	Glacial Till	SAND	1.17	7	9	130	5446	2134	3312	223.0	185.9	610	4.0	0.007
5D	50.0	18.8	Glacial Till	SAND	1.17	77	98	130	6096	2446	3650	345.9	330.0	1083	5.0	0.005
6D	55.0	13.8	Glacial Till	SAND	1.17	11	14	130	6746	2758	3988	255.6	215.3	706	8.8	0.012
Rock	-	-	Bedrock	-		Bedrock is composed of hard Gneiss, use conservative estimate for Vs (see Note #3)								3900	38.7	0.010

Total 100 868

Notes: 1. Yellow cells indicate numerical input data; white cells indicate values calculated using formulas.

2. NF=New Fill, enter assumed blow count to calculate Vs.

3. Based on regional experience with geophysical seismic investigations, hard rocks like Schist, Granite and Gneiss typically have a Vs > 8,000 fps. Conservatively use 3,900 fps which is about the median Vs for "medium hard rock" (Site Class B) according to AASHTO LRFD.

Vs = 868 fps
Vs / 1.3 = 668 fps
Vs * 1.3 = 1128 fps

BB-USGR-102

Existing Ground Surface Elevation (ft NAVD 88)	36.9
Finish Ground Surface Elevation (ft NAVD 88)	36.9
New Fill Thickness (ft)	0
SPT Energy Transfer Ratio	0.76
Groundwater Depth (ft)	0

Geologic Epoch Pleistocene (Pleistocene, Holocene, or NA)

Sample ID	Existing Midpoint Depth	Midpoint Elev.	Stratum	Soil Type	Soil Age Scaling Factor	N (field)	N ₆₀	Total Unit Weight	Total Stress	Water Pressure	Effective Stress	PEER Silt/Clay Correlation	PEER Sand Correlation	Correlated Vs, PEER 2012	Layer Thickness, di	di/Vs
Units	(ft)	(ft)				(bpf)	(bpf)	(pcf)	(psf)	(psf)	(psf)	(m/s)	(m/s)	(fps)	(ft)	(fps)
1D	5	31.9	Alluvium	SAND	0.90	6	8	120	600	312	288	76.5	78.7	258	9.0	0.035
2D	10.0	26.9	Marine Clay	SILT/CLAY	1.12	18	23	110	1190	624	566	142.4	147.3	467	3.0	0.006
3D	15.0	21.9	Glacial Till	SAND	1.17	30	38	130	1800	936	864	185.8	190.8	626	6.0	0.010
Rock	-	-	Bedrock	-		Bedrock is composed of hard Gneiss & Granite, use conservative estimate for Vs (see Note #3)								3900	82.0	0.021

Total 100 1391

Notes: 1. Yellow cells indicate numerical input data; white cells indicate values calculated using formulas.

2. NF=New Fill, enter assumed blow count to calculate Vs.

3. Based on regional experience with geophysical seismic investigations, hard rocks like Schist, Granite and Gneiss typically have a Vs > 8,000 fps.

Conservatively use 3,900 fps which is about the median Vs for "medium hard rock" (Site Class B) according to AASHTO LRFD.

Vs = 1391 fps
Vs / 1.3 = 1070 fps
Vs * 1.3 = 1809 fps

BB-USGR-103

Existing Ground Surface Elevation (ft NAVD 88)	77.6
Finish Ground Surface Elevation (ft NAVD 88)	77.6
New Fill Thickness (ft)	0
SPT Energy Transfer Ratio	0.760
Groundwater Depth (ft)	18.8

Geologic Epoch Pleistocene (Pleistocene, Holocene, or NA)

Sample ID	Existing Midpoint Depth	Midpoint Elev.	Stratum	Soil Type	Soil Age Scaling Factor	N (field)	N ₆₀	Total Unit Weight	Total Stress	Water Pressure	Effective Stress	PEER Silt/Clay Correlation	PEER Sand Correlation	Correlated Vs, PEER 2012	Layer Thickness, di	di/Vs
Units	(ft)	(ft)				(bpf)	(bpf)	(pcf)	(psf)	(psf)	(psf)	(m/s)	(m/s)	(fps)	(ft)	(fps)
1D	2	75.6	Fill	SAND	1.00	33	42	125	250	0	250	108.5	125.3	411	3.5	0.009
2D	5.0	72.6	Fill	SAND	1.00	21	27	125	625	0	625	134.8	139.4	457	4.0	0.009
3D	10.0	67.6	Fill	SAND	1.00	14	18	125	1250	0	1250	157.0	149.0	489	5.0	0.010
4D	15.0	62.6	Fill	SAND	1.00	27	34	125	1875	0	1875	199.9	190.2	624	3.4	0.005
5D	16.8	60.8	Fill	SAND	1.00	32	41	125	2100	0	2100	213.3	203.0	666	2.5	0.004
6D	20.0	57.6	Fill	SAND	1.00	27	34	125	2500	75	2425	217.0	201.8	662	4.1	0.006
7D	25.0	52.6	Fill	SAND	1.00	12	15	125	3125	387	2738	196.6	172.2	565	4.8	0.008
Note 4	29.8	47.8	Glacial Till	SAND	1.17	NA	37	130	3738	686	3051	277.0	253.4	831	4.9	0.006
Rock	-	-	Bedrock	-		Bedrock is composed of hard Gneiss, use conservative estimate for Vs (see Note #3)								3900	67.8	0.017

Total 100 1339

Vs = 1339 fps

Vs / 1.3 = 1030 fps

Vs * 1.3= 1741 fps

Notes: 1. Yellow cells indicate numerical input data; white cells indicate values calculated using formulas.

2. NF=New Fill, enter assumed blow count to calculate Vs.

3. Based on regional experience with geophysical seismic investigations, hard rocks like Schist, Granite and Gneiss typically have a Vs > 8,000 fps.

Conservatively use 3,900 fps which is about the median Vs for "medium hard rock" (Site Class B) according to AASHTO LRFD.

4. No samples taken in 4.9' thick layer of Glacial Till, use N60 value from adjacent boring BB-USGR-202.

BB-USGR-201/A

Existing Ground Surface Elevation (ft NAVD 88)	69
Finish Ground Surface Elevation (ft NAVD 88)	69
New Fill Thickness (ft)	0
SPT Energy Transfer Ratio	1.011
Groundwater Depth (ft)	26.5

Geologic Epoch Pleistocene (Pleistocene, Holocene, or NA)

Sample ID	Existing Midpoint Depth	Midpoint Elev.	Stratum	Soil Type	Soil Age Scaling Factor	N (field)	N ₆₀	Total Unit Weight	Total Stress	Water Pressure	Effective Stress	PEER Silt/Clay Correlation	PEER Sand Correlation	Correlated Vs, PEER 2012	Layer Thickness, di	di/Vs
Units	(ft)	(ft)				(bpf)	(bpf)	(pcf)	(psf)	(psf)	(psf)	(m/s)	(m/s)	(fps)	(ft)	(fps)
2D	3.5	65.5	Fill	SAND	1.00	6	10	125	438	0	438	102.0	102.8	337	4.8	0.014
3D	6.0	63	Fill	SAND	1.00	7	12	125	750	0	750	124.4	120.6	396	3.8	0.009
4D	11.0	58	Fill	SAND	1.00	29	49	125	1375	0	1375	192.3	192.2	631	5.0	0.008
5D	16.0	53	Fill	SAND	1.00	38	64	125	2000	0	2000	227.0	223.0	732	5.0	0.007
6D	21.0	48	Fill	SAND	1.00	21	35	125	2625	0	2625	223.9	207.1	680	3.5	0.005
7D	26.0	43	Alluvium	SAND	0.90	26	44	120	3230	0	3230	223.3	205.3	674	8.3	0.012
8D	31.0	38	Marine Clay	SILT/CLAY	1.12	1	2	110	3823	281	3542	164.5	123.4	540	1.7	0.003
9D	33.0	36	Marine Clay	SILT/CLAY	1.12	0	0	110	4043	406	3637	0.0	0.0	300	2.0	0.007
10D	35.0	34.0	Marine Clay	SILT/CLAY	1.12	0	0	110	4263	530	3733	0.0	0.0	300	2.0	0.007
11D	37.0	32.0	Marine Clay	SILT/CLAY	1.12	0	0	110	4483	655	3828	0.0	0.0	300	2.0	0.007
12D	39.0	30.0	Marine Clay	SILT/CLAY	1.12	0	0	110	4703	780	3923	0.0	0.0	300	6.5	0.022
1D	46.0	23.0	Glacial Till	SAND	1.17	25	42	130	5503	1217	4286	315.7	282.3	926	4.0	0.004
2D	51.0	18.0	Glacial Till	SAND	1.17	18	30	130	6153	1529	4624	305.9	266.4	874	4.9	0.006
3D	55.7	13.3	Glacial Till	SAND	1.17	50	84	130	6764	1822	4942	371.7	342.2	1123	4.6	0.004
4D	60.1	8.9	Glacial Till	SAND	1.17	50	84	130	7336	2097	5239	378.7	346.8	1138	4.9	0.004
Rock	-	-	Bedrock	-		Bedrock is composed of hard Gneiss & Schist, use conservative estimate for Vs (see Note #3)								3900	37.2	0.010

Total 100 779

Notes: 1. Yellow cells indicate numerical input data; white cells indicate values calculated using formulas.

2. NF=New Fill, enter assumed blow count to calculate Vs.

3. Based on regional experience with geophysical seismic investigations, hard rocks like Schist, Granite and Gneiss typically have a Vs > 8,000 fps.

Conservatively use 3,900 fps which is about the median Vs for "medium hard rock" (Site Class B) according to AASHTO LRFD.

4. Based on regional experience with geophysical seismic investigations, for Marine Clay with N60 of zero, assume Vs = 300 fps.

Vs = 779 fps
Vs / 1.3 = 599 fps
Vs * 1.3= 1013 fps

BB-USGR-202

Existing Ground Surface Elevation (ft NAVD 88)	66.9
Finish Ground Surface Elevation (ft NAVD 88)	66.9
New Fill Thickness (ft)	0
SPT Energy Transfer Ratio	1.011
Groundwater Depth (ft)	10.2

Geologic Epoch Pleistocene (Pleistocene, Holocene, or NA)

Sample ID	Existing Midpoint Depth	Midpoint Elev.	Stratum	Soil Type	Soil Age Scaling Factor	N (field)	N ₆₀	Total Unit Weight	Total Stress	Water Pressure	Effective Stress	PEER Silt/Clay Correlation	PEER Sand Correlation	Correlated Vs, PEER 2012	Layer Thickness, di	di/Vs
Units	(ft)	(ft)				(bpf)	(bpf)	(pcf)	(psf)	(psf)	(psf)	(m/s)	(m/s)	(fps)	(ft)	(fps)
1D	1.0	65.9	Fill	SAND	1.00	3	5	125	125	0	125	60.7	65.7	216	4.0	0.019
2D	7.0	59.9	Fill	SAND	1.00	14	24	125	875	0	875	147.0	146.5	481	5.5	0.011
3D	12.0	54.9	Fill	SAND	1.00	10	17	125	1500	112	1388	160.9	150.8	495	6.8	0.014
4D	17.0	49.9	Marine Clay	SILT/CLAY	1.12	9	15	110	2115	424	1690	188.6	172.5	619	3.2	0.005
5D	22.0	44.9	Marine Clay	SILT/CLAY	1.12	3	5	110	2665	736	1928	163.2	138.1	535	5.2	0.010
6D	32.0	34.9	Glacial Till	SAND	1.17	22	37	130	3911	1360	2550	261.6	243.3	798	9.2	0.012
Rock	-	-	Bedrock	-		Bedrock is composed of hard Gneiss, use conservative estimate for Vs (see Note #3)								3900	66.1	0.017

Notes: 1. Yellow cells indicate numerical input data; white cells indicate values calculated using formulas.

2. NF=New Fill, enter assumed blow count to calculate Vs.

3. Based on regional experience with geophysical seismic investigations, hard rocks like Schist, Granite and Gneiss typically have a Vs > 8,000 fps.
Conservatively use 3,900 fps which is about the median Vs for "medium hard rock" (Site Class B) according to AASHTO LRFD.

Total 100 1148

Vs = 1148 fps

Vs / 1.3 = 883 fps

Vs * 1.3= 1493 fps

Longitude-69.278228Latitude44.216849

Design Spectrum Exported from AASHTO-2023 Web Services (https://earthquake.usgs.gov/ws/designmaps/aashto-2023/) on 4/21/2026

Option 1																						
Site Class C																						
Period (s)	0	0.01	0.02	0.03	0.05	0.075	0.1	0.15	0.2	0.25	0.3	0.4	0.5	0.75	1	1.5	2	3	4	5	7.5	10
Spectral Acceleration (g)	0.13	0.14	0.20	0.25	0.30	0.32	0.32	0.28	0.22	0.18	0.15	0.12	0.10	0.07	0.05	0.03	0.02	0.01	0.01	0.01	0.00	0.00
														100% TS _s	0.05	0.05	0.05	0.04	0.04	0.03		
														90% TS _s	0.05	0.05	0.04	0.04	0.03	0.03		
																			SD ₁ (90%) Max	0.05		
																			SD ₁ design	0.05		

Option 2																						
Site Class C/D																						
Period (s)	0	0.01	0.02	0.03	0.05	0.075	0.1	0.15	0.2	0.25	0.3	0.4	0.5	0.75	1	1.5	2	3	4	5	7.5	10
Spectral Acceleration (g)	0.13	0.14	0.20	0.23	0.28	0.30	0.31	0.28	0.24	0.21	0.19	0.16	0.14	0.10	0.07	0.05	0.03	0.02	0.01	0.01	0.00	0.00
														100% TS _s	0.07	0.07	0.06	0.05	0.05	0.04		
														90% TS _s	0.07	0.06	0.06	0.05	0.04	0.04		
																			SD ₁ (90%) Max	0.07		
																			SD ₁ design	0.07		

Option 3																						
Site Class D																						
Period (s)	0	0.01	0.02	0.03	0.05	0.075	0.1	0.15	0.2	0.25	0.3	0.4	0.5	0.75	1	1.5	2	3	4	5	7.5	10
Spectral Acceleration (g)	0.13	0.14	0.20	0.23	0.28	0.30	0.30	0.28	0.25	0.22	0.20	0.17	0.15	0.11	0.09	0.05	0.04	0.02	0.01	0.01	0.00	0.00
														100% TS _s	0.09	0.08	0.07	0.06	0.05	0.04		
														90% TS _s	0.08	0.07	0.06	0.05	0.04	0.04		
																			SD ₁ (90%) Max	0.08		
																			SD ₁ design	0.09		

Option 4																						
Site Class D/E																						
Period (s)	0	0.01	0.02	0.03	0.05	0.075	0.1	0.15	0.2	0.25	0.3	0.4	0.5	0.75	1	1.5	2	3	4	5	7.5	10
Spectral Acceleration (g)	0.12	0.13	0.19	0.23	0.27	0.28	0.28	0.26	0.23	0.21	0.19	0.16	0.15	0.11	0.08	0.05	0.04	0.02	0.01	0.01	0.00	0.00
														100% TS _s	0.08	0.08	0.07	0.06	0.05	0.04		
														90% TS _s	0.08	0.07	0.06	0.05	0.04	0.04		
																			SD ₁ (90%) Max	0.08		
																			SD ₁ design	0.08		

S _{D1} Summary Table								
Site Class		Period (s)						S _{D1}
		1	1.5	2	3	4	5	
C	TS _s	0.05	--	--	--	--	--	0.05
	90% TS _s	0.05	0.05	0.04	0.04	0.03	0.03	
C/D	TS _s	0.07	--	--	--	--	--	0.07
	90% TS _s	0.07	0.06	0.06	0.05	0.04	0.04	
D	TS _s	0.09	--	--	--	--	--	0.09
	90% TS _s	0.08	0.07	0.06	0.05	0.04	0.04	
D/E	TS _s	0.08	--	--	--	--	--	0.08
	90% TS _s	0.08	0.07	0.06	0.05	0.04	0.04	

S_{D1} = 90 percent of the maximum value of the product, TS_{as} , for periods from 1 to 2 s for sites with $\bar{v}_s > 1,450$ ft/s and for periods 1 to 5 s for sites with $\bar{v}_s \leq 1,450$ ft/s, but not less than 100 percent of the value of S_a at 1 s where T is the period of vibration for each value of S_a .

