GEOTECHNICAL DESIGN REPORT

20-1403

November 17, 2021

Geotechnical Engineering Services

Route 161 over Perley Brook
Perley Brook Bridge #3468
Fort Kent, Maine
WIN 021882.00

PREPARED FOR:
Maine Department of Transportation
Attention: Laura Krusinski, P.E.
State House Station 16
Augusta, ME 04333-0016

PREPARED BY:
S. W. Cole Engineering, Inc.
26 Coles Crossing Drive
Sidney, ME 04330
T: (207) 626-0600

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Dear Laura:

In accordance with our Proposal, dated February 25, 2021, and project specific Assignment Letter #3, dated March 3, 2021, we have completed geotechnical services for the subject project. The purpose of our services was to review the provided subsurface information, laboratory testing and progress plan in order to provide geotechnical parameters and recommendations for foundations and earthwork associated with the proposed construction.

The services provided by S. W. Cole Engineering, Inc. (S.W.COLE) were conducted in accordance with our Multi-PIN Agreement with the Maine Department of Transportation (MaineDOT), No. 20200623000000000765, dated June 22, 2020. The contents herein are subject to the limitations set forth in Appendix A.

1.0 INTRODUCTION

1.1 Site Conditions

The site is Perley Brook Bridge (MaineDOT Bridge #3468) carrying State Route 161 over Perley Brook in Fort Kent, Maine. The site location is shown on the “Site Location Map” attached in Appendix B. We understand the existing crossing was originally constructed in 1967 and consists of twin ±13-foot diameter corrugated metal pipe (CMP) multi-plate culverts with an overall span of about 28 feet and 15-degree skew.

1.2 Proposed Construction

Based on the information provided by MaineDOT, we understand the existing crossing will be replaced with a new 94 foot single-span, Integral Abutment Bridge (IAB) with a 15-degree skew supported on single row of steel H-piles at each abutment. We anticipate the superstructure will consist of steel beam girders with a reinforced concrete deck and integral wearing surface. We understand the replacement structure will be constructed on the existing alignment and the vertical grade will be raised slightly (less than 1 foot). We understand the existing crossing will

be removed and the stream restored to a “natural” channel. We understand the new bridge will have a total width of about 50 feet. We understand 1.75H:1V riprap slopes will wrap around and in front of the abutments for scour protection and will match into the approach side slopes.

2.0 EXPLORATIONS AND TESTING

2.1 Explorations

Two test borings (BB-FKPB-101 and -102) were made at the site for the proposed replacement structure between May 18, 2017, and May 25, 2017, by the MaineDOT Drill Crew using a trailer-mounted CME 45C drill rig. The exploration locations were selected and established in the field by MaineDOT. The explorations were logged in the field by MaineDOT. The “as-drilled” exploration locations, as provided by MaineDOT, are shown on the “Boring Location Plan” attached in Appendix B. Logs of these test borings, as provided by MaineDOT, and a Key to Soil and Rock Descriptions and Terms used on the logs are attached as Appendix C.

2.2 Testing

The test borings were drilled using a combination of solid-stem auger, cased wash boring, and NQ2 rock core drilling techniques. The soils were sampled at approximate 5-foot intervals using a split-spoon sampler and Standard Penetration Testing (SPT) methods using a calibrated automatic hammer. Upon encountering refusal, borings BB-FKPB-101 and BB-FKPB-102 were advanced about 7 to 11 feet into bedrock using NQ2 rock coring.

The MaineDOT drill rig was equipped with an automatic hammer to drive the split-spoon sampler. The hammer was calibrated per ASTM D4633-10 “Standard Test Method for Energy Measurement for Dynamic Penetrometers.” Corrected N-values discussed in this report were computed by applying the corresponding average energy transfer factor of 0.854 (for the MaineDOT hammer) to the raw field N-values. The hammer efficiency factor (0.854), uncorrected SPT blow counts, uncorrected and corrected SPT N-values and rock core intervals and Rock Quality Designation (RQD) are shown on the boring logs provided in Appendix C.

Laboratory testing was performed on disturbed SPT samples obtained during the explorations. Laboratory testing was performed by the MaineDOT Materials Testing and Exploration Central Laboratory in Bangor, Maine, following applicable American Association of State Highway and Transportation Officials (AASHTO) testing procedures. Laboratory testing included seven natural water content tests and seven grain size analyses (one with hydrometer and six without hydrometer). Moisture contents are shown on the boring logs in Appendix C. A summary and results of the laboratory testing are provided in Appendix D.

3.0 SUBSURFACE CONDITIONS

3.1 Surficial and Bedrock Geology

According to the Maine Geological Survey's (MGS's) mapping of the Eagle Lake Quadrangle, Maine (Open-File Map 81-12)[1], surficial geologic units within the site vicinity consist of Stream Alluvium (sand, gravel and silt), Glacial Outwash Deposits (sand and gravel) and Glacial Till. The surficial geologic units encountered were generally consistent with the mapped geology; however, the explorations also encountered Fill soils from previous site development.

According to the MGS Bedrock Geologic Map of Maine Bedrock[2], bedrock in the site vicinity is mapped as early Devonian age interbedded Pelite and Sandstone. The observed bedrock is generally consistent with the mapped bedrock geology.

3.2 Soil and Bedrock

Subsurface conditions at the project site were explored by drilling two test borings. Borings BB-FKPB-101 and BB-FKPB-102 were drilled behind the existing south and north abutments, respectively. Test borings BB-FKPB-101 and -102 encountered a subsurface profile generally consisting of fill overlying glacial outwash overlying glacial till mantling bedrock. The principal strata encountered in the explorations are summarized below. An Interpretive Subsurface Profile is attached in Appendix B. Refer to the boring logs in Appendix C for more detailed subsurface information at the exploration locations.

Surficial: Test borings BB-FKPB-101 and BB-FKPB-102, made within the roadway of State Route 161 encountered a 9.5- and 8-inch thick layer of pavement, respectively.

Fill: Below the pavement, the borings encountered fill extending to depths of 17 to 18 feet below ground surface (bgs), respectively, corresponding to Elevation (El.) 511.7 to 513.5 feet. The fill generally consisted of:

- Brown, moist, SAND, some gravel, little silt,
- Brown, damp, Gravelly SAND, some silt,
- Brown-grey, damp, SAND, some silt, some gravel, trace clay,
- Brown-grey, wet, SAND, some gravel, with cobbles, and
- Brown, wet, Sandy SILT, little gravel.

The granular fill was generally medium dense to very dense with SPT N_{60} values ranging from 24 to 107 blows per foot (bpf). The fine-grained (cohesive) fill was generally medium stiff with an SPT N_{60} value of 6 bpf where sampled.

[1] Genes, Andrew N., 1981, Reconnaissance Surficial Geology of the Eagle Lake Quadrangle, Maine: Maine Geological Survey, Open-File Map 81-12, map, scale 1:62,500.
[2] Osberg, Philip H., Hussey, Arthur M. and Boone, Gary M., 1985, Bedrock Geology Map of Maine: Maine Geological Survey, map, scale 1:500,000.

Glacial Outwash: Below the fill, the borings encountered glacial outwash to depths of 27 to 33 feet bgs, corresponding to El. 498.5 to 501.7 feet. The glacial outwash deposit generally consisted of:

- Grey-brown, wet, Gravelly SAND, little silt,
- Brown, wet, Silty SAND, trace gravel, trace clay, and
- Grey-brown, wet, SAND, trace to some gravel, trace silt.

The glacial outwash deposit was generally medium dense to very dense with SPT N_{60} values ranging from 30 to 61 bpf.

Glacial Till: Underlying the glacial outwash deposit, the borings encountered glacial till to depths of 42.5 to 56.3 feet bgs, corresponding to El. 472.4 to 489.0 feet. The glacial till deposit generally consisted of:

- Grey-brown, wet, SAND, some to little gravel, some silt, and
- Grey-brown, wet, Gravelly SAND, some silt;

Below a depth of about 42.5 feet, boring BB-FKPB-101 encountered cemented glacial till to a depth of 74.5 feet bgs, corresponding to El. 457 feet. The cemented glacial till generally consisted of:

- Grey, wet, Silty SAND, and
- Grey, wet, SAND, little silt.

The glacial till was generally dense to very dense with SPT N_{60} values ranging from 50 bpf to greater than 50 blows for a 6 inch drive increment (sampler refusal). The cemented glacial till was generally very dense with SPT N_{60} values greater than 50 blows for a 6 inch drive increment (sampler refusal). Cobbles and boulders were noted throughout the glacial till deposit.

Bedrock: Bedrock was encountered and sampled in each boring. The top of bedrock varied from about 74.5 feet bgs (El. 457.0 feet) at the south abutment to 56.3 feet bgs (El. 472.4 feet) at the north abutment. In BB-FKPB-101, an approximate 5 foot layer of weathered bedrock was encountered from about 74.5 to 80.6 feet bgs. The bedrock generally consisted of grey, hard, fresh, metasiltstone of the Seboomook Formation. Joints were generally low angle to horizontal, very close to close and open to healed with calcite infilling.

The following table summarizes the approximate depths to more competent bedrock, corresponding top of bedrock elevations and Rock Quality Designation (RQD) where encountered.

Boring Number (Substructure)	Approximate Depth to Competent Bedrock (feet)	Approximate Bedrock Elevation (feet)	RQD (Rock Quality)
BB-FKPB-101 (Abutment No. 1)	80.6	450.9	R3: 12% (Very Poor) R4: 0% (Very Poor) R5: 0% (Very Poor)
BB-FKPB-102 (Abutment No. 2)	56.3	472.4	R1: 0% (Very Poor) R2: 82% (Good) R3: 60% (Fair)

RQD values for the bedrock generally ranged from 0 to 82 percent corresponding to a Rock Quality of very poor to good. Detailed descriptions of the rock core and RQD values for each core run are shown on the exploration logs in Appendix C.

3.3 Groundwater

The soils encountered at the test borings were generally damp to moist from the ground surface. Water levels were measured in the borings at a depth of about 17 feet bgs. It should be noted that water was introduced during drilling; therefore, water levels indicated may not represent stabilized ground water conditions. Long term groundwater information is not available. It should be anticipated that groundwater levels will fluctuate seasonally, particularly in response to periods of snowmelt and precipitation, changes in site use and the water level of Perley Brook.

4.0 GEOTECHNICAL EVALUATIONS

S.W.COLE conducted geotechnical engineering evaluations in accordance with 2020 AASHTO LRFD Bridge Design Specifications, 9th Edition (LRFD) and the MaineDOT Bridge Design Guide, 2003 Edition with revisions through June 2018 (MaineDOT BDG). Geotechnical engineering calculations and reference documents used to support the recommendations within this memorandum are provided in Appendix E.

4.1 Foundation Options and Discussion

We understand a pile-supported Integral Abutment Bridge (IAB) is the preferred replacement structure and driven piles are the preferred foundation option. The following sections provide geotechnical design considerations and recommendations for an H-pile supported IAB.

4.2 Integral Abutment H-Piles

The site is underlain by dense glacial outwash overlying very dense glacial till with cobbles and boulders overlying bedrock at Elevation (El.) 450.9 feet at Abutments No. 1 (South) to El. 472.4 feet at Abutment No. 2 (North). We understand the abutments will be integral abutments founded on a single row of steel HP14x117 H-piles. We anticipate the Abutment No. 1 piles will be end bearing within the glacial till before encountering bedrock and the Abutment No. 2 piles will be end bearing on bedrock. H-piles shall be 50 ksi, Grade A572 steel with pile tips

conforming to 2020 MaineDOT Standard Specification 711.10 to help reduce damage to the piles during driving and improve penetration.

Based on the critical embedment (20 diameters) in the glacial till at Abutment No. 1 and depth to bedrock at Abutment No. 2, we estimate the following pile lengths:

Location	Approx. Bottom of Proposed Abutment	Anticipate Pile Tip	Estimated Pile Length (feet)
	Elevation (feet)		
Abutment No. 1 BB-FKPB-101	521	470 (cobbles/boulders)	51
Abutment No. 2 BB-FKPB-102	519	472.4 (bedrock)	47

The estimated pile lengths do not take into account variations in the bedrock surface elevation, pile damage, additional footage (5 feet typical) of pile required for dynamic testing instrumentation (per ASTM D4945), additional pile length needed to accommodate leads and driving equipment, or additional pile length needed for embedment in the abutment or pile cap.

Based on the presence of numerous cobbles and boulders, a minimum 15 feet of additional pile length per pile location at Abutment No. 1 should be specified on Contract Plans to reduce construction delays in the event that piles penetrate the cobble and boulder layer at Abutment No. 1.

4.2.1 Strength Limit State Design

Design of pile foundations at the strength limit state shall consider;

- Compressive axial geotechnical resistance of individual piles bearing on bedrock,
- Drivability resistance of individual piles,
- Structural resistance of individual piles in axial compression, and
- Structural resistance of individual piles in combined axial loading and flexure.

Pile groups should be designed to resist all lateral earth loads, vehicular loads, dead and live loads, and lateral forces transferred through the abutments. The pile group resistance after scour due to the design flood shall provide adequate foundation resistance using the resistance factors given in this section.

Per LRFD Article 6.5.4.2, at the strength limit state, the axial resistance factor ϕ_c = 0.50, for severe driving conditions shall be applied to the structural compressive resistance of the pile. The H-piles will be subjected to lateral loading, therefore the piles shall be evaluated for resistance against combined axial compression and flexure in accordance with LRFD Articles 6.9.2.2 and 6.15.2. Per LRFD Article 6.5.4.2, at the strength limit state, the axial resistance factor ϕ_c = 0.70 and the flexural resistance factor ϕ_f = 1.0 shall be applied to the combined axial and flexural resistance of the pile in the interaction equation (LRFD Eq. 6.9.2.2-1 or -2).

Abutment H-piles should be analyzed for determination of unbraced lengths and fixity using LPile® 2016 (LPile) software. The calculated unbraced lengths should be used to analyze the piles in combined axial compression and flexure resistance provided in LRFD Articles 6.9.2.2 and 6.15.2.

Structural Resistance. The nominal axial compressive structural resistance (P_n) for piles loaded in compression shall be as specified in LRFD Article 6.9.4.1. The nominal axial structural compressive resistance (P_n) subject to the combined axial compression and flexure shall be evaluated based on unbraced lengths (l) and effective length factors (K) as determined from LPile once structural loads are available. The nominal axial structural resistance should be evaluated based on combined axial compression and flexure.

Preliminary estimates of the structural axial resistance for selected H-pile sections were calculated using a resistance factor, ϕ_c = 0.50, for severe driving conditions. The unbraced pile lengths (l) and effective length factors (K) in these evaluations have been assumed. It is the responsibility of the structural engineer to calculate the nominal axial structural compressive resistance (P_n) based on unbraced lengths (l) and effective length factors (K) determined from LPile.

Geotechnical Resistance. The nominal axial geotechnical resistances at the strength limit state for Abutment No. 1 was evaluated using the guidance in LRFD Article 10.7.3.8.6 and utilizing the Nordlund/Thurman static pile resistance method (LRFD Article 10.7.3.8.6f) and SPT-Meyerhof method (LRFD Article 10.7.3.8.6g) limiting the side resistance below the pile's critical depth of 20 pile diameters for very dense glacial till. The nominal axial geotechnical resistances at the strength limit state for Abutment No. 2 was calculated using the guidance in LRFD Article 10.7.3.2.3 which states the nominal bearing resistance of piles driven to point bearing on hard rock shall not exceed the structural pile resistances obtained from LRFD Article 6.9.4.1 with a resistance factor ϕ_c = 0.50 for severe driving conditions.

Drivability Analyses. Drivability analyses were performed to determine the pile resistance that might be achieved considering available diesel hammers. The maximum driving stresses in the pile, assuming the use of 50 ksi steel, shall be less than 45 ksi. The drivability resistances shall be calculated using the resistance factor, φ_{dyn}, of 0.65, for a single pile in axial compression when a dynamic test is performed as specified in LRFD Table 10.5.5.2.3-1.

A summary of the calculated factored axial compressive structural, geotechnical, and drivability resistances for the strength limit states are provided in the following table.

Factored Axial Pile Resistances for HP 14x117 Strength Limit State (kips)				
Location	**Structural Resistance ϕ_c = 0.5**	**Geotechnical Resistance ϕ_{dyn} = 0.65**	**Drivability Resistance[1] ϕ_{dyn} = 0.65**	**Controlling Axial Pile Resistance[2,3]**
Abutment No. 1	860	439	345 (534)	345 (439)
Abutment No. 2	860	860	345 (534)	345 (534)

Notes:
1. Drivability resistances based on Delmag D19-42. Drivability resistances based on Delmag D25-52 shown in parentheses.
2. For Abutment No. 1, controlling axial pile resistance based on drivability resistance for pile driven with Delmag D19-42 hammer and geotechnical resistance for pile driven with Delmag D25-32 hammer shown in parentheses.
3. For Abutment No. 2, controlling axial pile resistance based on drivability resistance for pile driven with Delmag D19-42 hammer and Delmag D25-32 hammer shown in parentheses.

LRFD Article 10.7.3.2.3 states the nominal axial compressive resistance of piles driven to hard rock is typically controlled by the structural resistance with a resistance factor for severe driving conditions applied. However, the estimated factored axial pile resistance from the drivability analyses for the H-pile sections are generally less than the controlling factored axial structural resistance per LRFD Article 10.7.3.2.3 therefore, drivability controls. The exception is the Abutment No. 1 piles when driven with a Delmag D25-32, the factored geotechnical resistance controls. The maximum applied factored axial pile load for the strength limit states should not exceed the controlling factored pile resistances shown in above table.

4.2.2 Service and Extreme Limit State Design

The design of H-piles at the service limit state shall consider tolerable transverse and longitudinal movement of piles and pile group movement considering changes in soil conditions due to scour based on the design flood (Q_{100}). For the service limit state, resistance factors of φ = 1.0 should be used in accordance with LRFD Article 10.5.5.1. The exception is the overall global stability of the foundation which should be investigated at the Service I load combination and a resistance factor, φ, of 0.65.

Extreme limit state design shall include pile axial compressive resistance, overall global stability of the pile group, pile failure by uplift in tension, and structural failure. The extreme event load combinations are those related to seismic forces, ice loads, debris loads, and hydraulic events. Extreme limit state design shall also check that the nominal pile foundation resistance remaining after scour due to the check flood (Q_{500}) can support the extreme limit state loads. Resistance factors for extreme limit states, per LRFD Article 10.5.5.3, shall be taken as φ = 1.0 with the exception of uplift of piles, for which the resistance factor, φ_{up}, shall be 0.80 or less per LRFD Article 10.5.5.3.2.

The nominal axial geotechnical pile resistance at the service and extreme limit state was calculated using the guidance in LRFD Article 10.7.3.2.3. A summary of the calculated factored axial structural, geotechnical, and drivability resistances of selected H-piles for the extreme and service limit states are provided in the following table.

Factored Axial Pile Resistances for HP 14x117 Service and Extreme Limit State (kips)				
Location	**Structural Resistance ϕ_c = 0.5**	**Geotechnical Resistance ϕ_{dyn} = 0.65**	**Drivability Resistance[1] ϕ_{dyn} = 0.65**	**Controlling Axial Pile Resistance[2,3]**
Abutment No. 1	1,720	676	531 (822)	531 (676)
Abutment No. 2	1,720	1,720	531 (822)	531 (822)

Notes:
1. Drivability resistance based on Delmag D19-42. Drivability resistance based on Delmag D25-52 shown in parentheses.
2. For Abutment No. 1, controlling axial pile resistance based on drivability resistance for pile driven with Delmag D19-42 hammer and geotechnical resistance for pile driven with Delmag D25-32 hammer shown in parentheses.
3. For Abutment No. 2, controlling axial pile resistance based on drivability resistance for pile driven with Delmag D19-42 hammer and Delmag D25-32 hammer shown in parentheses.

LRFD Article 10.7.3.2.3 states that the nominal axial compressive resistance of piles driven to hard rock is typically controlled by the structural resistance with a resistance factor for severe driving conditions applied. However, the estimated factored axial pile resistances from the drivability analyses for the H-pile sections are generally less than the controlling factored axial structural resistance per LRFD Article 10.7.3.2.3 and the nominal structural resistances. The exception is the Abutment No. 1 piles when driven with a Delmag D25-32, the factored geotechnical resistance controls. The maximum applied factored axial pile load for the extreme and service limit states should not exceed the controlling factored pile resistance shown in above table.

4.2.3 Downdrag

The bridge will be constructed on the existing alignment and vertical grades will be raised less than 1 foot. Based on the subsurface conditions encountered, settlement resulting from the proposed raise in roadway grade is anticipated to be negligible. Therefore, downdrag is not considered to be an issue.

14.2.4 Lateral Pile Resistance

In accordance with LRFD Article 6.15.1, the structural analysis of pile groups subjected to lateral loads shall include consideration of soil-structure interaction effects as specified in LRFD Article 10.7.3.9. Assumptions regarding a fixed or pinned condition at the pile tip should be also confirmed with soil-structure interaction analyses.

A series of lateral pile analyses were performed to evaluate pile behavior using LPile® Plus 5.0 (LPile) software using pile head deflections and axial loads supplied by the structural engineer. Preliminary evaluations at each abutment for an HP 14x117 pile are included in Appendix E. The analyses confirm the pile lengths are adequate to achieve full fixity and prevent translation of the pile tip. The designer should utilize the results of the LPile analyses to recalculate axial compressive structural pile resistances based on unbraced pile segments and K-factors and verify pile bending stresses do not exceed allowable stresses.

Geotechnical parameters for generation of soil-resistance (p-y) curves in lateral pile analyses using LPile® software are shown in the following Table. In general, the model developed emulates the soil at the site by using the soil layers, appropriate pile material properties, section parameters, and pile-head boundary conditions for the pile section being analyzed.

Recommended LPILE® Soil Parameters							
Elevation Range[1,2] (Depth Range)		Soil Layer[2] (Soil Model)	K_{static}	Soil Parameters			
Top	Bottom		(pci)	Effective Unit Wt. γ', (pcf)	Cohesion c, (psf)	e_{50}	Friction Angle ϕ', (deg)
Abutment No. 1 (Boring BB-FKPB-101)							
521.0 (0)	517.5 (3.5)	dense Sand Fill (Sand-Reese)	125	62.6	-	-	34
517.5 (3.5)	513.5 (7.5)	medium stiff Sandy SILT Fill (Sand-Reese)	20	57.6	-	-	29
513.5 (7.5)	498.5 (22.5)	dense Glacial Outwash (Sand-Reese)	125	65.6	-	-	36
498.5 (22.5)	489.0 (32.0)	dense / v. dense Glacial Till (Sand-Reese)	125	67.6	-	-	40
489.0 (32.0)	457.0 (64.0)	v. dense Cemented Glacial Till (Sand-Reese)	125	67.6	-	-	42
Abutment No. 2 (Boring BB-FKPB-102)							
519.0 (0)	511.7 (7.3)	dense Sand Fill (Sand-Reese)	125	62.6	-	-	34
511.7 (7.3)	501.7 (17.3)	dense Glacial Outwash (Sand-Reese)	125	65.6	-	-	36
501.7 (17.3)	472.4 (46.6)	dense / v. dense Glacial Till (Sand-Reese)	125	67.6	-	-	40

Notes: 1. Bottom of pile cap at El. 521 feet for Abutment 1
2. Bottom of pile cap at El. 519 feet for Abutment 2.

4.2.5 Driven Pile Resistance and Pile Quality Control

The contract documents shall require the contractor to perform a wave equation analysis for the proposed pile-hammer system and conduct dynamic pile load tests with signal matching. The first pile driven at each abutment should be dynamically tested to confirm nominal pile resistance and verify the stopping criteria developed by the contractor in the wave equation analysis. Minimum 24-hour restrike tests will be required and should be noted on the plans because piles end bearing in glacial till may "relax." Additional dynamic tests may be required as part of the pile field quality control program if:

- Pile behavior vary radically between adjacent piles,
- Pile refusal on a boulder or in a cobble layer above the minimum pile tip elevation at Abutment No. 1,
- Pile tip is not firmly embedded in bedrock at Abutment No. 2, or
- Pile is out of tolerance.

Piles should be driven to an acceptable penetration resistance based on the results of a wave equation analysis provided by the contractor and as approved by the design team. Pile load

testing should be completed by PDA testing with signal matching, including one pile at each abutment. Driving stresses in the pile determined in the drivability analysis and confirmed by PDA testing shall be less than 45 ksi, in accordance with LRFD Article 10.7.8. The pile hammer should be selected such that the required pile resistance when the penetration resistance for the final 3 to 6 inches is between 3 to 15 blows per inch (bpi). If an abrupt increase in driving resistance is encountered, the driving may be terminated when the penetration is less than 0.5-inch in 10 consecutive blows. Termination criteria shall be confirmed and evaluated for the selected pile hammer.

4.3 Integral Abutment Design

Integral abutment sections shall be designed for all relevant strength, service, and extreme limit states and load combinations specified in LRFD Articles 3.4.1 and 11.5.5. Stub abutments shall be designed to resist all lateral earth loads, vehicular loads, dead and live loads, and lateral forces transferred through the integral superstructure. The design of the integral abutment at the strength limit state shall consider reinforced-concrete structural design. Strength limit state design shall also consider changes in foundation conditions and foundation resistance after scour due to the design (Q_{100}) flood.

A resistance factor (φ) of 1.0 shall be used to assess abutment design at the service limit state, including: settlement, excessive horizontal movement, and movement resulting after scour due to the design (Q_{100}) flood. The overall stability of the foundation should be investigated at the Service I Load Combination and a resistance factor, φ, of 0.65.

Extreme limit state design of integral abutment supported on H-piles shall include pile structural resistance, pile geotechnical resistance, pile resistance in combined axial and flexure, and overall stability. Resistance factors for extreme limit state shall be taken as 1.0. Extreme limit state design shall also check that the nominal foundation resistance remaining after scour due to the check (Q_{500}) flood can support the extreme limit state loads with a resistance factor of 1.0.

The designer may assume Soil Type 4 (MaineDOT Bridge Design Guide (BDG) Section 3.6.1) for abutment backfill material soil properties. The backfill properties are as follows:

- Angle of internal friction (ϕ) of 32 degrees,
- Total unit weight (γ) of 125 pcf, and
- Soil-concrete interface friction angle (δ) of 20 degrees.

Integral abutments shall be designed to withstand a lateral earth load equal to the passive pressure state. AASHTO LRFD Article C3.11.5.4 suggests full passive pressure is mobilized when the ratio of lateral abutment movement to abutment height (y/H) is 0.05H in loose cohesionless soils (sands) and less than 0.05H in dense cohesionless soils. Additionally, Federal Highway Authority (FHWA) NHI-06-089 Figure 10-4, indicates mobilization of full passive pressure in dense cohesionless soils occurs at a y/H ratio of 0.02H.

Considering the above information, the structural designer should estimate the abutment rotation and then select a passive pressure coefficient, K_p, in accordance with Figure 3.10.8-1 of the Massachusetts Department of Transportation (MassDOT) Bridge Design Manual.

Additional lateral earth pressure due to live load surcharge is required per Section 3.6.8 of the MaineDOT BDG for abutments if an approach slab is not specified. When a structural approach slab is specified, reduction, not elimination, of the surcharge load is permitted per LRFD Article 3.11.6.5. The live load surcharge may be estimated as a uniform horizontal earth pressure due to an equivalent height of soil (h_{eq}) based on LRFD Table 3.11.6.4-1.

The abutment design shall include a drainage system behind the abutment to mitigate excessive hydrostatic pressures. Drainage behind the structure shall be in accordance with MaineDOT BDG Section 5.4.2.13.

Backfill within 10 feet of the abutments and side slope fill shall conform to MaineDOT Specification 703.19 “Granular Borrow for Underwater Backfill.”

Slopes in front of the pile supported integral abutments should be protected with riprap and erosion control geotextile. The riprap covered slopes should not exceed 1.75:1(H:V) in accordance with MaineDOT Standard Detail 610(03). The 1.75H:1V riprap slopes shall “toe-in” at least 2 feet.

4.4 Frost Considerations

According to MaineDOT BDG Section 5.2.1, pile supported integral abutments shall be embedded a minimum of 4.0 feet for frost protection. Foundations bearing on soil should be designed with an appropriate embedment for frost protection. Based on the MaineDOT BDG Figure 5-1, Maine Design Freezing Index Map, the design freezing index for the Fort Kent, Maine area is approximately 2,600 freezing degree-days. Based on the MaineDOT BDG, Section 5.2.1 and Table 5-1 and subsurface soils encountered, the maximum seasonal frost penetration is estimated to be on the order of about 9 feet; consequently, we recommend foundations should have at least 9 feet of soil cover to provide frost protection.

Riprap is not to be considered as contributing to the overall thickness of soils required for frost protection.

4.5 Seismic Design Considerations

Seismic site class was evaluated in accordance with LRFD Article 3.10.3.1 Method B (average N-value method). AASHTO allows for an N-value of 100 to be used for bedrock in the upper 100 feet of the soil profile. Based on the subsurface information and an N-value of 100 for the bedrock, the average N-value was above 50 bpf corresponding to an AASHTO Site Class C as defined in LRFD Table 3.10.3.1-1.

The United States Geological Survey (USGS) Seismic Design Parameters program (Version 2.1) was used to obtain the seismic design parameters for the site. Based on the assigned site

class (AASHTO Site Class C) and site coordinates, the software provides the recommended AASHTO Response Spectrum for a 7 percent probability of exceedance in 75 years (1,000-year return period). The results for the project site are summarized below and program output are provided in Appendix E.

RECOMMENDED SEISMIC DESIGN PARAMETERS	
Site Class	C
PGA	0.101 g
S_s	0.223 g
S_1	0.062 g
F_{pga}	1.2
F_a	1.2
F_v	1.7
A_s	0.12 g
S_{DS}	0.27 g
S_{D1}	0.11 g
Seismic Zone (based on S_{D1})	Zone 1

NOTE: Site Coordinates: N47.241094, W68.579231

4.6 Recommendations for Scour Evaluation

Laboratory grain size analyses were performed on soil samples taken near the approximate streambed elevation (El. 98 feet) to generate parameters to be used in scour analyses. Results of the grain size analyses tests are included in Appendix D and summarized in the following table:

Boring No.	Sample No.	Depth (ft)	Elevation (ft)	Estimated D_{95} (mm)	Estimated D_{50} (mm)
BB-FKPB-101	4D	20.0	511.5	19	3.3
BB-FKPB-102	4D	20.5	508.2	3.1	0.6

Design at the strength limit state should consider loss of lateral and vertical support due to scour. Design at the extreme limit state should check that the nominal foundation resistance due to the check flood (Q_{500}) event is no less than the extreme limit state loads. At the service limit state, the design shall limit movements and ensure overall stability considering scour at the design load.

For scour protection of the pile-supported abutments, the bridge and abutment slopes will be armored with riprap. It is our understanding the existing abutments will remain at or below the streambed to provide additional protection to the new abutments. In accordance with MaineDOT BDG Section 2.3.11.3, the top of the riprap shall be located at the Q_{50} elevation. It is our understanding that new riprap slopes in front of the new abutments will be keyed-in behind the existing abutments that remain at or below the streambed. The toe of the new riprap slopes outside of the existing abutments that remain should be keyed into the existing soils at least 2 feet.

Riprap shall conform to MaineDOT Standard Specification 703.26 “Plain and Hand Laid Riprap” and should be placed at a maximum slope of 1.75H:1V. The riprap section shall be underlain by

a 1 foot layer of MaineDOT Standard Specification 703.19 “Granular Borrow Material for Underwater Backfill” and a Class 1 nonwoven erosion control geotextile per MaineDOT Standard Specification 722.03.

4.7 Construction Considerations

Construction of the abutments will require pile driving. The new integral abutments will be constructed behind the existing crossing. Temporary lateral earth support systems may be needed for construction of the detour structure. Construction will require removal of existing culverts and excavation of existing fills to the streambed. Construction shall avoid disturbance of the sensitive soils outside the excavation limits and avoiding placement of fills in the brook.

Cobbles were encountered in the glacial till and cemented glacial till deposits. There is potential for these obstructions to impede the driving of H-piles for abutment foundations. Obstructions may be cleared by conventional excavation methods, pre-augering, predrilling or spudding. Alternative methods to clear obstructions may be used as approved by the Resident. Care should be taken to drive H-piles within allowable tolerances without damaging the H-piles.

Excavations for the proposed abutments may expose pockets of soft or unsuitable material. Soft or unsuitable material shall be removed and replaced with compacted granular borrow or crushed stone. Sloughing and instability of the soils due to runoff, traffic vibrations, and construction activity is likely. The contractor should monitor the stability of slopes, excavation, soils at the roadway grade and the temporary earth retaining systems during construction. The contractor should control groundwater, surface water infiltration and soil erosion. Water should be controlled by pumping from sumps.

5.0 CLOSURE

We trust this information meets your present needs. Please contact us if you have any questions or need further assistance.

Sincerely,

S. W. Cole Engineering, Inc.

STATE OF MAINE
No. 12519
LICENSED
PROFESSIONAL ENGINEER

Digitally signed by Michael St. Pierre, P.E.
Date: 2021.11.17 15:16:45 -05'00'

Michael A. St. Pierre, P.E.
Senior Geotechnical Engineer

Robert E. Chaput, Jr., P.E.
Principal Engineer

MAS/tjb-rec

APPENDIX A
Limitations

This report has been prepared for the exclusive use of the Maine Department of Transportation for specific application to the Proposed Perley Brook Bridge (#3649) Replacement carrying State Route 193 over Perley Brook (MaineDOT WIN 022230.00) in Fort Kent, Maine. S. W. Cole Engineering, Inc. (S.W.COLE) has endeavored to conduct our services in accordance with generally accepted soil and foundation engineering practices. No warranty, expressed or implied, is made.

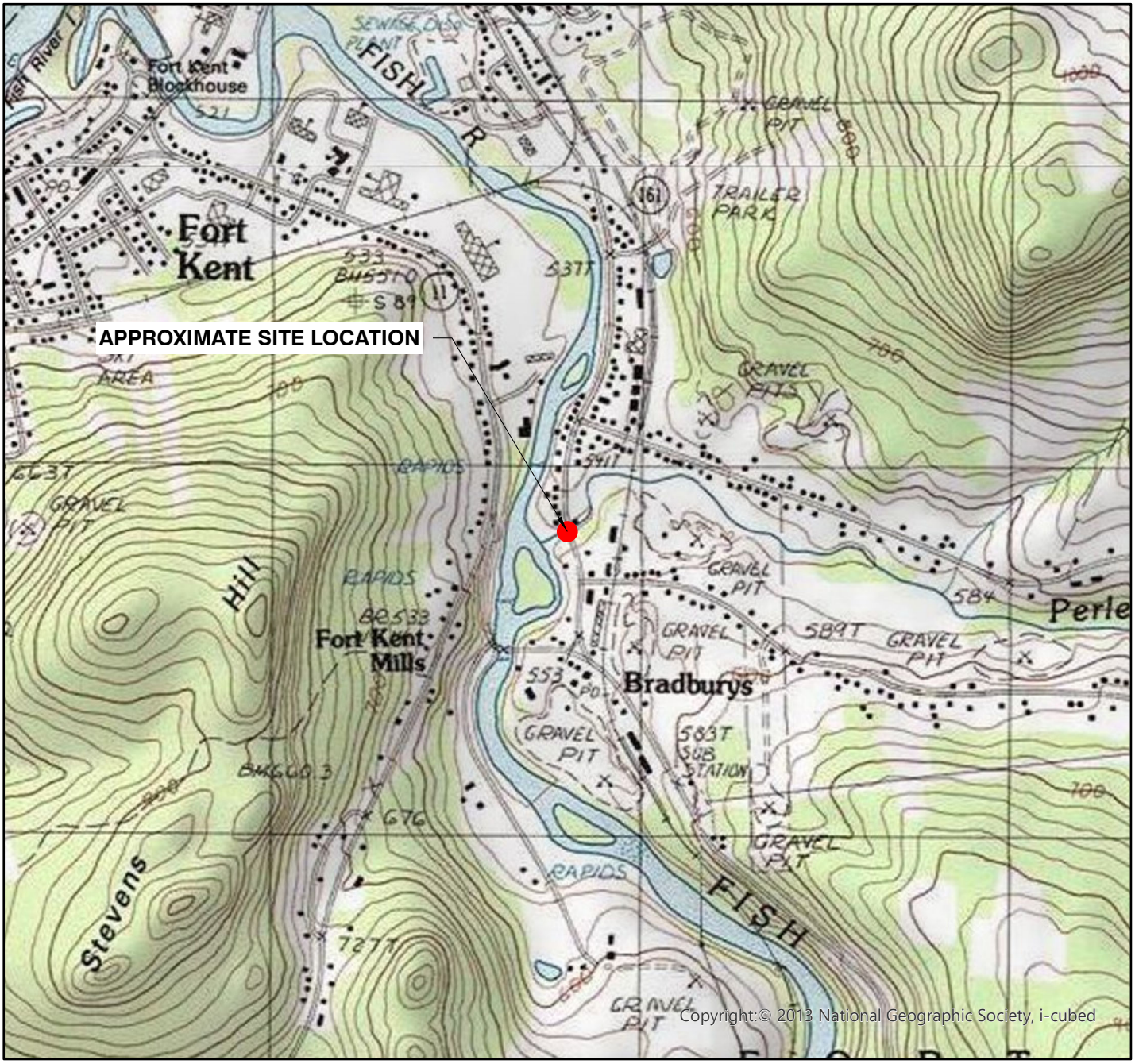
The soil profiles described in the report are intended to convey general trends in subsurface conditions. The boundaries between strata are approximate and are based upon interpretation of exploration data and samples.

The analyses performed during this investigation and recommendations presented in this report are based in part upon the data obtained from subsurface explorations made at the site. Variations in subsurface conditions may occur between explorations and may not become evident until construction. If variations in subsurface conditions become evident after submission of this report, it will be necessary to evaluate their nature and to review the recommendations of this report.

Observations have been made during exploration work to assess site groundwater levels. Fluctuations in water levels will occur due to variations in rainfall, temperature, and other factors.

Recommendations contained in this report are based substantially upon information provided by others regarding the proposed project. In the event that any changes are made in the design, nature, or location of the proposed project; S.W.COLE, should review such changes as they relate to analyses associated with this report. Recommendations contained in this report shall not be considered valid unless the changes are reviewed by S.W.COLE.

APPENDIX B
Figures



2,000 0 2,000 4,000

Scale in Feet

S.W.COLE ENGINEERING, INC.

MAINEDOT

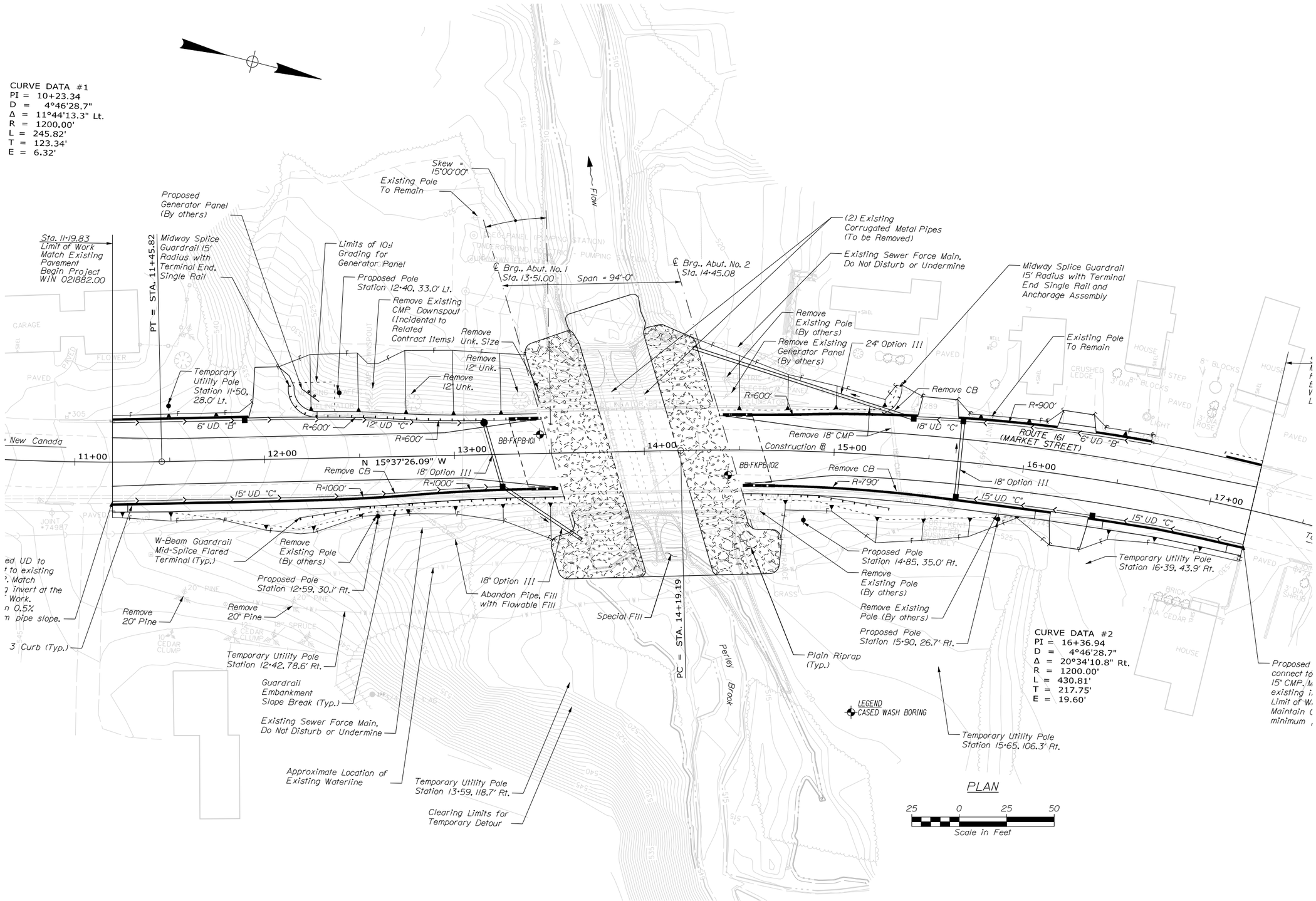
SITE LOCATION MAP

ROUTE 161 OVER PERLEY BROOK
PERLEY BROOK BRIDGE #3468 REPLACEMENT
FORT KENT, MAINE
WIN 021882.00

Job No.	20-1403-021182	Scale	1" = 2000'
Date:	06/11/2021	Sheet	1

NOTE:
SITE LOCATION MAP PREPARED FROM ESRI ArcGIS ONLINE AND DATA PARTNERS INCLUDING USGS AND © 2007 NATIONAL GEOGRAPHIC SOCIETY.

R:\2020\20-1403\ArcProject\20-1403.aprx, 6/11/2021 11:20 AM, 1:0,



STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

STP-2188(200)

WIN 21882.00

BRIDGE NO. 3468

BRIDGE PLANS

		BY	DATE
PROJ. MANAGER	M. WIGHT		
DESIGN-DETAILED			
CHECKED-REVIEWED			
DESIGN2-DETAILED2	M.ST.PIERRE	T.WHITE	NOV 2021
DESIGN3-DETAILED3			
REVISIONS 1			
REVISIONS 2			
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			

SIGNATURE

P.E. NUMBER

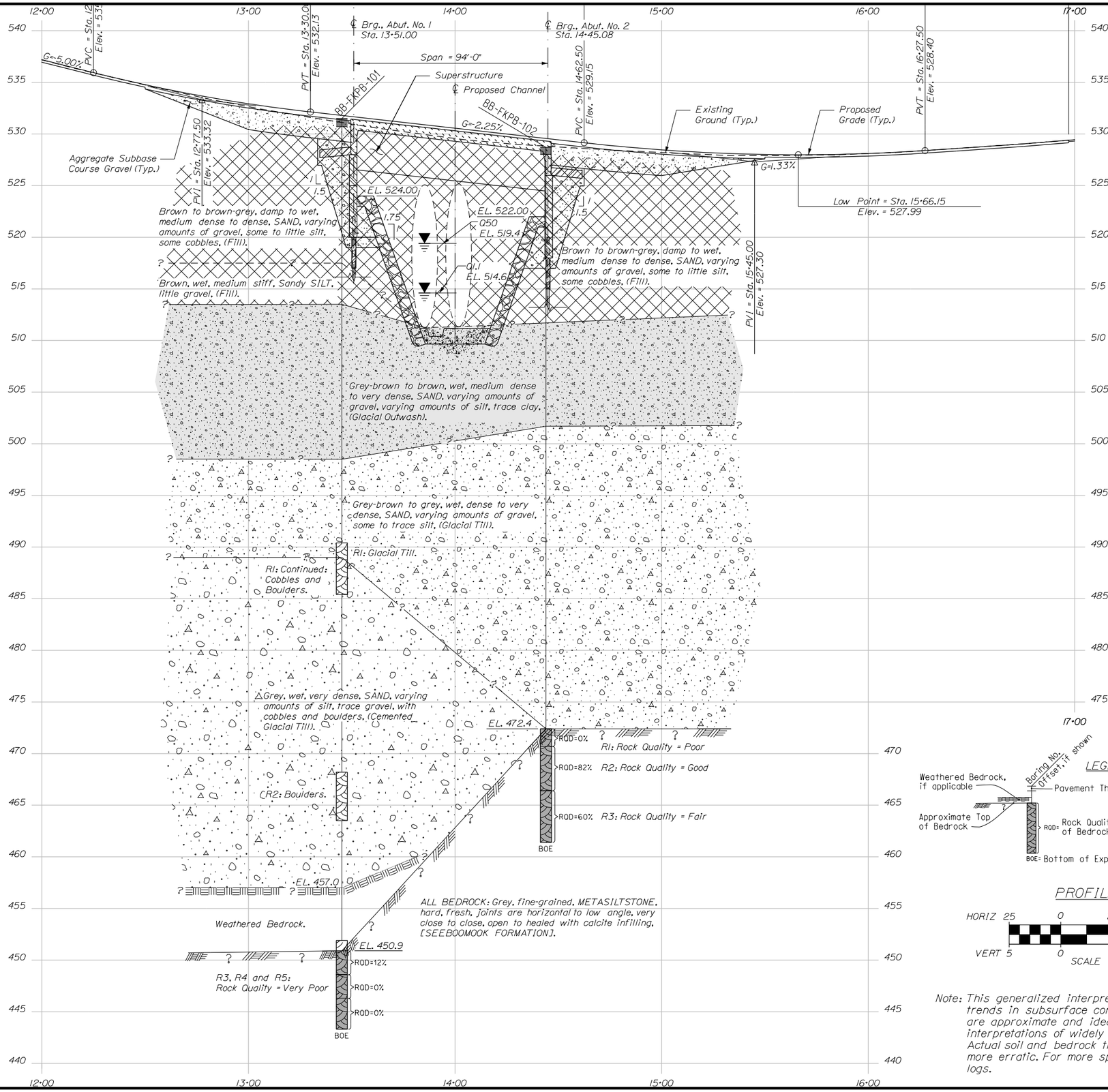
DATE

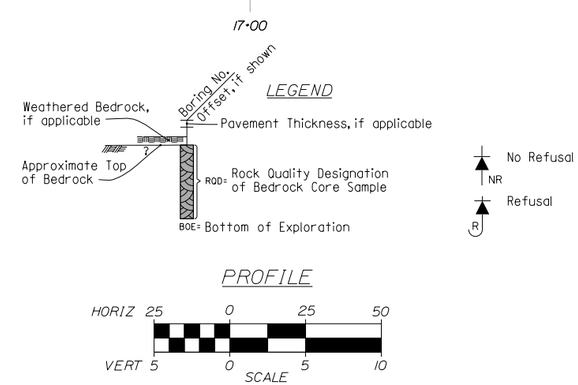
PERLEY BROOK BRIDGE
PERLEY BROOK
FORT KENT AROOSTOOK COUNTY

BORING LOCATION PLAN

SHEET NUMBER
2
OF 3

Filename: ...\00\GEOTECH\MSTA\005_BLP1.dgn Division: GEOTECH Username: terry.white Date:11/12/2021





Note: This generalized interpretive soil 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 and bedrock transitions may vary and are probably more erratic. For more specific information refer to the exploration logs.

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

STP-2188(200)

WIN 21882.00

BRIDGE NO. 3468

BRIDGE PLANS

PROJ. MANAGER	M. WIGHT	BY	DATE
DESIGN-DETAILED			
CHECKED-REVIEWED			
DESIGN2-DETAILED2	M.ST.PIERRE	T.WHITE	NOV 2021
DESIGN3-DETAILED3			
REVISIONS 1			
REVISIONS 2			
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			

SIGNATURE

P.E. NUMBER

DATE

PERLEY BROOK BRIDGE
PERLEY BROOK
FORT KENT AROOSTOOK COUNTY

INTERPRETIVE SUBSURFACE PROFILE

SHEET NUMBER
3
OF 3

Filename: ...\00\GEOTECH\MSTA\006_ISP1.dgn Division: GEOTECH Username: terry.white Date:11/12/2021

APPENDIX C

Boring Logs & Key to Soil and Rock Descriptions and Terms

UNIFIED SOIL CLASSIFICATION 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 (little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.
			GP	Poorly-graded gravels, gravel sand mixtures, little or no fines.
		GRAVEL WITH FINES (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixtures.
			GC	Clayey gravels, gravel-sand-clay mixtures.
	SANDS (more than half of coarse fraction is smaller than No. 4 sieve size)	CLEAN SANDS (little or no fines)	SW	Well-graded sands, Gravelly sands, little or no fines
			SP	Poorly-graded sands, Gravelly sand, little or no fines.
		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

Maine Department of Transportation
Geotechnical Section
Key to Soil and Rock Descriptions and Terms
Field Identification Information

MODIFIED BURMISTER SYSTEM

Descriptive Term	Portion of Total (%)
trace	0 - 10
little	11 - 20
some	21 - 35
adjective (e.g. Sandy, Clayey)	36 - 50

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).

Density of Cohesionless Soils	Standard Penetration Resistance N-Value (blows per foot)
Very loose	0 - 4
Loose	5 - 10
Medium Dense	11 - 30
Dense	31 - 50
Very Dense	> 50

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.

Consistency of Cohesive soils	SPT N-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 Designation (RQD):

$$\text{RQD (\%)} = \frac{\text{sum of the lengths of intact pieces of core* > 4 inches}}{\text{length of core advance}}$$

*Minimum NQ rock core (1.88 in. OD of core)

Rock Quality Based on RQD

Rock Quality	RQD (%)
Very Poor	≤25
Poor	26 - 50
Fair	51 - 75
Good	76 - 90
Excellent	91 - 100

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))

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: Perley Brook Bridge #3468 carries Route 161 over Perley Brook
Location: Fort Kent, Maine

Boring No.: BB-FKPB-101

WIN: 21882.00

Driller:	MaineDOT	**Elevation (ft.)**	531.5	**Auger ID/OD:**	5" Soild Stem
Operator:	Travis/James/Rick	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	B. Wilder	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	5/18,25/2017	**Drilling Method:**	Cased Wash Boring	**Core Barrel:**	NQ-2"
Boring Location:	13+45.2, 10.0 ft Lt.	**Casing ID/OD:**	HW-4" & NW-3"	**Water Level*:**	17.0 ft bgs.
Hammer Efficiency Factor:	0.854	**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_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

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.)	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
0							SSA	530.7	9½" HMA. 0.8	
5	1D	24/19	5.00 - 7.00	21/46/29/27	75	107			Brown, damp, very dense, Gravelly SAND, some silt, (Fill).	
10	2D	24/12	10.00 - 12.00	10/15/23/27	38	54	35		Similar to above.	
							74			
							98			
							48			
							20	517.5	14.0	
15	3D	24/13	15.00 - 17.00	3/2/2/2	4	6	11		Brown, wet, medium stiff, Sandy SILT, little gravel, (Fill).	G#304393 A-4, SM WC=24.7%
							10			
							22	513.5	18.0	
							58			
							78			
20	4D	24/15	20.00 - 22.00	16/21/22/70	43	61	30		Grey-brown, wet, very dense, Gravelly SAND, trace silt, (Glacial Outwash).	G#304394 A-1-a, SW-SM WC=10.6%
							48		Hole caved in at 21.5 ft bgs.	
							61			
							55			
25	5D	24/17	24.00 - 26.00	14/13/13/13	26	37	17		Grey, wet, dense, Gravelly SAND, little silt.	

Remarks:

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.

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Perley Brook Bridge #3468 carries Route 161 over Perley Brook
Location: Fort Kent, Maine

Boring No.: BB-FKPB-101
WIN: 21882.00

Driller:	MaineDOT	**Elevation (ft.)**	531.5	**Auger ID/OD:**	5" Soild Stem
Operator:	Travis/James/Rick	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	B. Wilder	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	5/18,25/2017	**Drilling Method:**	Cased Wash Boring	**Core Barrel:**	NQ-2"
Boring Location:	13+45.2, 10.0 ft Lt.	**Casing ID/OD:**	HW-4" & NW-3"	**Water Level*:**	17.0 ft bgs.
Hammer Efficiency Factor:	0.854	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

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SSA = Solid Stem Auger
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RC = Roller Cone
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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
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WC = Water Content, percent
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PL = Plastic Limit
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G = Grain Size Analysis
C = Consolidation Test

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.)	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
25							46			
							62			
							72			
							75			
	6D	24/19	29.00 - 31.00	8/9/12/13	21	30	25		Brown, wet, medium dense, Silty fine SAND, trace gravel, trace clay.	G#304395 A-4, SC-SM WC=19.8%
30							34			
							66			
							67			
							84	498.5	33.0	
	7D	24/15	34.00 - 36.00	17/20/15/20	35	50	46		Grey-brown, wet, dense, SAND, some gravel, some silt, (Glacial Till).	
35							77			
							66			
							67			
							90			
	8D	24/10	39.00 - 41.00	14/16/22/23	38	54	44		Grey-brown, wet, very dense, Gravelly SAND, some silt.	
40							60			
	R1	60/30	41.10 - 46.10				88		R1: 50% Recovery	
							154	489.0	42.5	
							158			
	9D		44.00 - 44.10	30(1.2")	---		43		Grey, damp, very dense, Gravelly SAND, some silt, (Cemented Glacial Till).	
45							52			
							45			
							56			
							69			
50							OPEN			

Remarks:

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.

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Perley Brook Bridge #3468 carries Route 161 over Perley Brook
Location: Fort Kent, Maine

Boring No.: BB-FKPB-101
WIN: 21882.00

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Operator:	Travis/James/Rick	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
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Date Start/Finish:	5/18,25/2017	**Drilling Method:**	Cased Wash Boring	**Core Barrel:**	NQ-2"
Boring Location:	13+45.2, 10.0 ft Lt.	**Casing ID/OD:**	HW-4" & NW-3"	**Water Level*:**	17.0 ft bgs.
Hammer Efficiency Factor:	0.854	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

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SSA = Solid Stem Auger
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$S_{u(lab)}$ = Lab Vane Undrained Shear Strength (psf)
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Hammer Efficiency Factor = Rig Specific Annual Calibration Value
N_{60} = SPT N-uncorrected Corrected for Hammer Efficiency
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G = Grain Size Analysis
C = Consolidation Test

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.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
50							HOLE			Roller Coned ahead to 54.0 ft bgs.	
	10D	6/6	54.00 - 54.50	55	---					Grey, wet, very dense, Silty SAND, (Cemented Glacial Till). Roller Coned ahead to 59.0 ft bgs.	
55											
	11D	2.4/2.4	59.00 - 59.20	55(2.4")	---					Similar to above.	
60							28			Pulled out NW Casing, then drove HW Casing back down to 60.0 ft bgs. Roller Coned ahead to 77.2 ft bgs, then set in NW Casing back in to 74.5 ft bgs.	
							100				
							138				
	R2	56.4/28	63.30 - 68.00				[a]68			[a]68 blows for 0.3 ft. R2: Boulders.	
							99			R2: Core Times (min:sec)	
65							OPEN HOLE			63.3-64.3 ft (2:37) 64.3-65.3 ft (2:16) 65.3-66.3 ft (2:40) 66.3-67.3 ft (0:38) 67.3-68.0 ft (0:25)	
	12D	9.6/5	68.00 - 68.80	50/70(3.6")	---					Grey, wet, very dense, SAND, little silt.	
70											
75								457.0		74.5	

Remarks:

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.

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Perley Brook Bridge #3468 carries Route 161 over Perley Brook
Location: Fort Kent, Maine

Boring No.: BB-FKPB-101
WIN: 21882.00

Driller:	MaineDOT	**Elevation (ft.)**	531.5	**Auger ID/OD:**	5" Soild Stem
Operator:	Travis/James/Rick	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	B. Wilder	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	5/18,25/2017	**Drilling Method:**	Cased Wash Boring	**Core Barrel:**	NQ-2"
Boring Location:	13+45.2, 10.0 ft Lt.	**Casing ID/OD:**	HW-4" & NW-3"	**Water Level*:**	17.0 ft bgs.
Hammer Efficiency Factor:	0.854	**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 No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N_{60}	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
75										Roller Coned ahead from 77.2-79.6 ft bgs.	
	R3	39.6/39.6	79.60 - 82.90	RQD = 12%			NQ-2			R3: Weathered Bedrock from 74.5-80.4 ft bgs, cemented SILT seam from 80.4 to 80.6 ft bgs:	
80								450.9		R3: Core Times (min:sec) 79.6-80.6 ft (2:52) 80.6	
	R4	27.6/27.6	82.90 - 85.20	RQD = 0%						Top of Bedrock at Elev. 450.9 ft. R3: Bedrock: Grey, fine grained, METASILTSTONE, hard, fresh, very close to close breaks along steep bedding, joints are low angle to horizontal, open to healed by calcite infilling . [SEBOOMOOK FORMATION] Rock Quality = Very Poor. R3: Core Times (min:sec): 80.6-81.6 ft (5:27) 81.6-82.6 ft (10:02) 82.6-82.9 ft (5:08) 100% Recovery Core Blocked	
85	R5	36/36	85.20 - 88.20	RQD = 0%							
								443.3		R4: Bedrock: Similar to above. Rock Quality = Very Poor. R4: Core Times (min:sec) 82.9-83.9 ft (2:53) 83.9-84.9 ft (4:06) 84.9-85.2 ft (7:03) 100% Recovery Core Blocked	
90										R5: Bedrock: Similar to above. Rock Quality = Very Poor. R5: Core Times (min:sec) 85.2-86.2 ft (3:11) 86.2-87.2 ft (3:01) 87.2-88.2 ft (6:37) 100% Recovery 88.2	
95										**Bottom of Exploration at 88.2 feet below ground surface.**	
100											

Remarks:

Stratification lines represent approximate boundaries between soil types; transitions may be gradual.

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Maine Department of Transportation

Soil/Rock Exploration Log

US CUSTOMARY UNITS

Project: Perley Brook Bridge #3468 carries Route 161 over Perley Brook
Location: Fort Kent, Maine

Boring No.: BB-FKPB-102

WIN: 21882.00

Driller:	MaineDOT	**Elevation (ft.)**	528.7	**Auger ID/OD:**	5" Soild Stem
Operator:	Travis/James/Rick	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	B. Wilder/Bickford	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	5/23/2017-5/24/2017	**Drilling Method:**	Cased Wash Boring	**Core Barrel:**	NQ-2"
Boring Location:	14+44, 13.3 ft Rt.	**Casing ID/OD:**	HW-4" & NW-3"	**Water Level*:**	17.0 ft bgs.
Hammer Efficiency Factor:	0.854	**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_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

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.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
0							SSA	528.0		8" HMA. 0.7	
5	1D	24/20	5.00 - 7.00	10/13/13/16	26	37				Brown, moist, medium dense, SAND, some gravel, little silt, (Fill).	G#304396 A-1-b, SM WC=5.2%
10	2D	24/16	10.00 - 12.00	5/7/10/7	17	24	61			Brown grey, damp, dense, SAND, some silt, some gravel, trace clay, (Fill).	
							82				
							52				
							112				
							117				
15	3D	24/8	15.00 - 17.00	10/15/30/35	45	64	11			Tan grey, wet, very dense, SAND, some gravel, some cobbles.	
							21				
							48	511.7		17.0 Roller Coned ahead to 20.0 ft bgs.	
							54				
							94				
20	4D	24/20	20.50 - 22.50	10/12/14/15	26	37	51			Grey brown, wet, dense, medium to fine SAND, trace gravel, trace silt, (Glacial Outwash).	G#304397 A-1-b, SP-SM WC=17.0%
							78				
							128				
							151				
25							163				

Remarks:

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Boring No.: BB-FKPB-102

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Perley Brook Bridge #3468 carries Route 161 over Perley Brook
Location: Fort Kent, Maine

Boring No.: BB-FKPB-102
WIN: 21882.00

Driller:	MaineDOT	**Elevation (ft.)**	528.7	**Auger ID/OD:**	5" Soild Stem
Operator:	Travis/James/Rick	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	B. Wilder/Bickford	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	5/23/2017-5/24/2017	**Drilling Method:**	Cased Wash Boring	**Core Barrel:**	NQ-2"
Boring Location:	14+44, 13.3 ft Rt.	**Casing ID/OD:**	HW-4" & NW-3"	**Water Level*:**	17.0 ft bgs.
Hammer Efficiency Factor:	0.854	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:
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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
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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
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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.)	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
25	5D	24/20	25.00 - 27.00	14/16/15/17	31	44	OPEN HOLE		Grey, wet, dense, SAND, some gravel.	
								501.7	27.0	
									Roller coned ahead to 30.0 ft bgs.	
30	6D	24/18	30.00 - 32.00	18/19/35/61	54	77			Grey, wet, very dense, Gravelly SAND, little silt, (Glacial Till).	G#304398 A-1-a, SM WC=12.1%
									Roller Coned ahead ro 35.0 ft bgs.	
35	7D	24/16	35.00 - 37.00	28/29/35/29	64	91			Grey, very dense, SAND, some gravel, quartz seam, (Glacial Till).	
40	8D	19.2/15	40.00 - 41.60	18/12/49/50(1.2)	61	87			Grey, wet, very dense, SAND, some gravel, some silt.	G#304399 A-1-b, SM WC=14.7%
									Cobble from 41.6-42.0 ft bgs.	
45	9D	12/7	45.00 - 46.00	21/70	---				Grey, wet, very dense, fine SAND, some silt, some gravel, (Glacial Till).	
50										

Remarks:

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.

Boring No.: BB-FKPB-102

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Perley Brook Bridge #3468 carries Route 161 over Perley Brook
Location: Fort Kent, Maine

Boring No.: BB-FKPB-102
WIN: 21882.00

Driller:	MaineDOT	**Elevation (ft.)**	528.7	**Auger ID/OD:**	5" Soild Stem
Operator:	Travis/James/Rick	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	B. Wilder/Bickford	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	5/23/2017-5/24/2017	**Drilling Method:**	Cased Wash Boring	**Core Barrel:**	NQ-2"
Boring Location:	14+44, 13.3 ft Rt.	**Casing ID/OD:**	HW-4" & NW-3"	**Water Level*:**	17.0 ft bgs.
Hammer Efficiency Factor:	0.854	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:
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MD = Unsuccessful Split Spoon Sample Attempt
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SSA = Solid Stem Auger
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WOH = Weight of 140 lb. Hammer
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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

Sample Information

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.)	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
50	10D	12/12	50.00 - 51.00	45/52	---				Grey, wet, very dense, fine SAND, some silt, little gravel, trace cobble.	
55	MD	1.2/0	55.00 - 55.10	30	---				Failed sample attempt. Cobble from 55.0-55.5 ft bgs. Roller Coned ahead to 56.3 ft bgs.	
	R1	20.4/20.4	56.30 - 58.00	RQD = 0%			NQ-2	472.4	56.3 — Top of Bedrock at Elev. 472.4 ft. R1: Bedrock: Grey, fine grained, METASILTSTONE, hard, fresh, steep bedding, joints are steep to horizontal, close, open. [SEEBOOMOOK FORMATION] Rock Quality = Poor. R1: Core Times (min:sec) 56.3-57.3 ft (4:38) 57.3-58.0 ft (8:56) 100% Recovery Core Blocked	
	R2	51.6/51.6	58.00 - 62.30	RQD = 82%					R2: Bedrock: Similar to above, except joints are horizontal, wide. Rock Quality = Good. R2: Core Times (min:sec) 58.0-59.0 ft (4:37) 59.0-60.0 ft (3:09) 60.0-61.0 ft (3:04) 61.0-62.0 ft (2:50) 62.0-62.3 ft (1:17) 100% Recovery Core Blocked	
60										
	R3	60/58	62.30 - 67.30	RQD = 60%					R3: Bedrock: Similar to above. Rock Quality = Fair. R3: Core Times (min:sec) 62.3-63.3 ft (2:00) 63.3-64.3 ft (2:14) 64.3-65.3 ft (2:15) 65.3-66.3 ft (2:15) 66.3-67.3 ft (2:05) 96% Recovery	
65								461.4		
70									67.3 — **Bottom of Exploration at 67.3 feet below ground surface.**	
75										

Remarks:

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.

APPENDIX D
Laboratory Test Results

State of Maine - Department of Transportation

Laboratory Testing Summary Sheet

Town(s): Fort Kent Work Number: 21882.00

Boring & Sample Identification Number	Station (Feet)	Offset (Feet)	Depth (Feet)	Reference Number	G.S.D.C. Sheet	W.C. %	L.L.	P.I.	Classification		
									Unified	AASHTO	Frost
BB-FKPB-101, 3D	13+45.2	10.0 Lt.	15.0-17.0	304393	1	24.7			SM	A-4	III
BB-FKPB-101, 4D	13+45.2	10.0 Lt.	20.0-22.0	304394	1	10.6			SW-SM	A-1-a	0
BB-FKPB-101, 6D	13+45.2	10.0 Lt.	29.0-31.0	304395	1	19.8			SC-SM	A-4	II
BB-FKPB-102, 1D	14+44	13.3 Rt.	5.0-7.0	304396	2	5.2			SM	A-1-b	II
BB-FKPB-102, 4D	14+44	13.3 Rt.	20.5-22.5	304397	2	17			SP-SM	A-1-b	0
BB-FKPB-102, 6D	14+44	13.3 Rt.	30.0-32.0	304398	2	12.1			SM	A-1-a	0
BB-FKPB-102, 8D	14+44	13.3 Rt.	40.0-41.6	304399	2	14.7			SM	A-1-b	II

Classification of these soil samples is in accordance with AASHTO Classification System M-145-40. This classification is followed by the "Frost Susceptibility Rating" from zero (non-frost susceptible) to Class IV (highly frost susceptible). The "Frost Susceptibility Rating" is based upon the MaineDOT and Corps of Engineers Classification Systems.

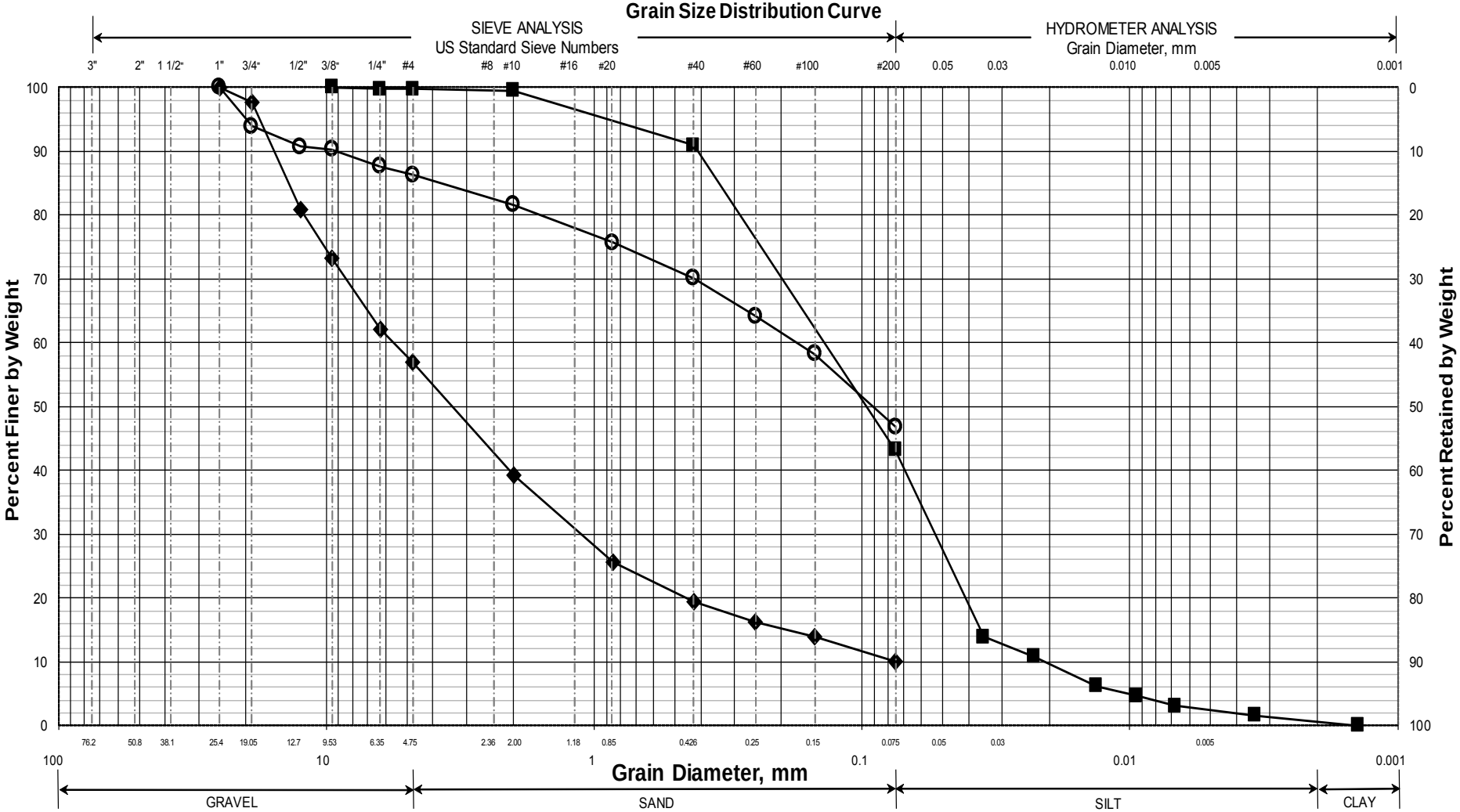
GSDC = Grain Size Distribution Curve as determined by AASHTO T 88-93 (1996) and/or ASTM D 422-63 (Reapproved 1998)

WC = water content as determined by AASHTO T 265-93 and/or ASTM D 2216-98

LL = Liquid limit as determined by AASHTO T 89-96 and/or ASTM D 4318-98 NP = Non Plastic

PI = Plasticity Index as determined by AASHTO 90-96 and/or ASTM D4318-98

Maine Department of Transportation
Grain Size Distribution Curve



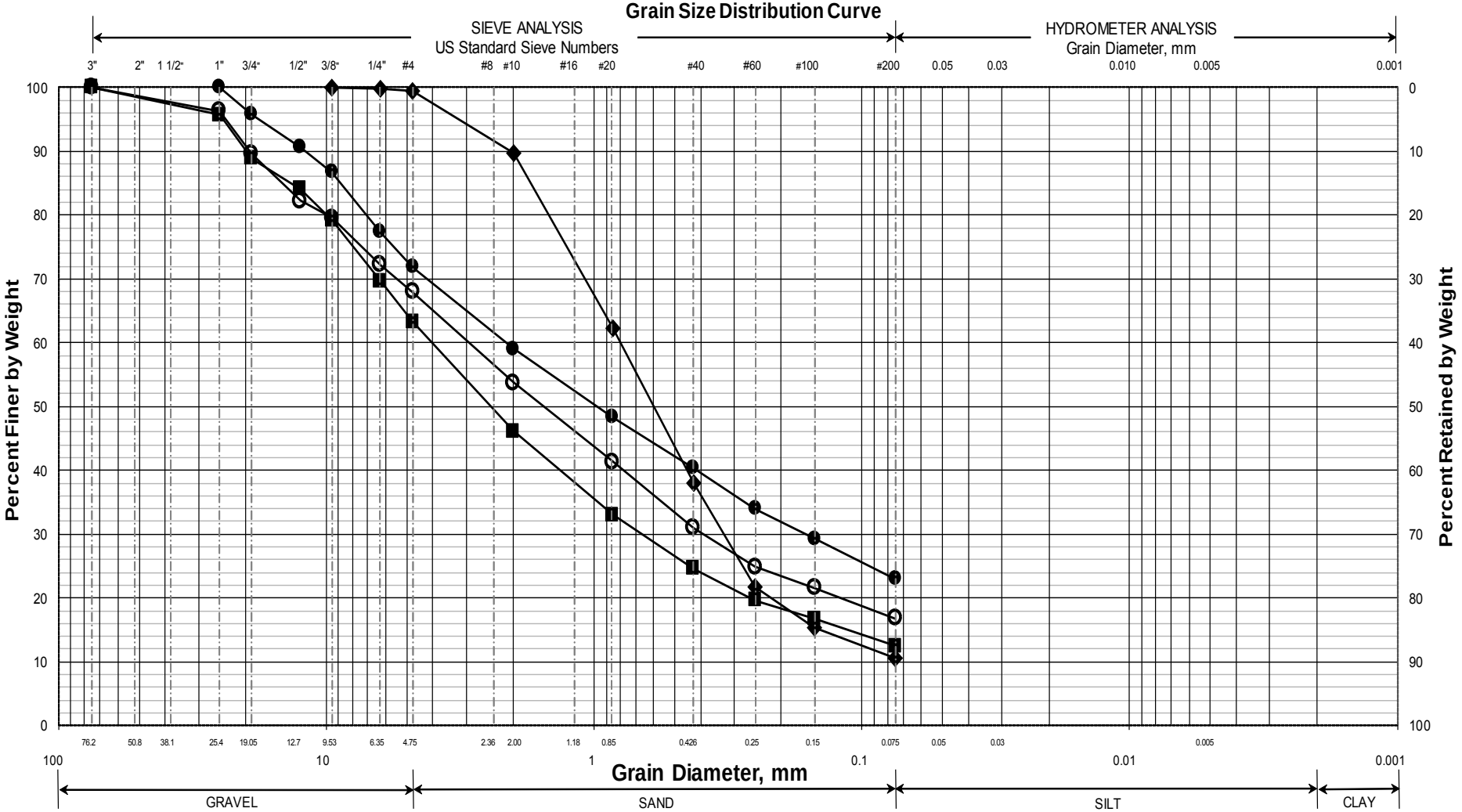
UNIFIED CLASSIFICATION

	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	WC, %	LL	PL	PI
○	BB-FKPB-101/3D	13+45.2	10.0 LT	15.0-17.0	Sandy SILT, little gravel.	24.7			
◆	BB-FKPB-101/4D	13+45.2	10.0 LT	20.0-22.0	Gravelly SAND, trace silt.	10.6			
■	BB-FKPB-101/6D	13+45.2	10.0 LT	29.0-31.0	Silty SAND, trace clay, trace gravel.	19.8			
●									
▲									
×									

WIN
021882.00
Town
Fort Kent
Reported by/Date
WHITE, TERRY A 2/15/2019

SHEET 1

Maine Department of Transportation
Grain Size Distribution Curve



UNIFIED CLASSIFICATION

	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	WC, %	LL	PL	PI
○	BB-FKPB-102/1D	14+44	13.3 RT	5.0-7.0	SAND, some gravel, little silt.	5.2			
◆	BB-FKPB-102/4D	14+44	13.3 RT	20.5-22.5	SAND, trace silt, trace gravel.	17			
■	BB-FKPB-102/6D	14+44	13.3 RT	30.0-32.0	Gravelly SAND, little silt.	12.1			
●	BB-FKPB-102/8D	14+44	13.3 RT	40.0-41.6	SAND, some gravel, some silt.	14.7			
▲									
×									

WIN
021882.00
Town
Fort Kent
Reported by/Date
WHITE, TERRY A 2/15/2019

SHEET 2

APPENDIX E
Calculations

S.W.COLE ENGINEERING, INC.

SPT Correlation

SPT BLOW COUNT CONVERSION AND FRICTION ANGLE CORRELATION FOR GRANULAR SOILS

Project Name: Perley Brook Bridge #3468 Replacement
Project No.: 20-1403-021882
Evaluated By/Date: MAS / March 2021
Reviewed By/Date: TSD

85.4 Hammer Efficiency
u = 17 Depth to Water

		BORING		BB-FKPB-101			Correction Factors							
Soil Layer	Stratum	Sample No.	Top of Sample Depth (ft)	Field N-Value N_m	Total Stress at Sample Depth (psf)	Effective Stress at Sample Depth (psf)	Overburden Stress[1] C_N	Hammer Efficiency C_E	Borehole Diameter[2] C_B	Rod Length[2] C_R	Sampler[2] C_S	N_{60}	$(N1)_{60}$	Friction Angle[3] (degrees)
1	Fill	1D	5	75	625	625	1.39	1.42	1.0	0.75	1.0	107	149	53
1	Fill	2D	10	38	1250	1250	1.16	1.42	1.0	0.75	1.0	55	64	42
2	Fill	3D	15	4	1861	1861	1.03	1.42	1.0	0.85	1.0	6	7	29
3	Glacial Outwash	4D	20	43	2481	2294	0.96	1.42	1.0	0.95	1.0	62	60	44
3	Glacial Outwash	5D	24	26	2993	2556	0.92	1.42	1.0	0.95	1.0	38	35	38
3	Glacial Outwash	6D	29	21	3633	2884	0.88	1.42	1.0	0.95	1.0	30	27	36
4	Glacial Till	7D	34	35	4277	3216	0.84	1.42	1.0	1.00	1.0	50	43	41
4	Glacial Till	8D	39	38	4927	3554	0.81	1.42	1.0	1.00	1.0	55	45	42
5	Cemented Glacial Till	9D	44	R	5577	3892	0.78	1.42	1.0	1.00	1.0			
5	Cemented Glacial Till	10D	54	R	6877	4568	0.73	1.42	1.0	1.00	1.0			
5	Cemented Glacial Till	11D	59	R	7527	4906	0.70	1.42	1.0	1.00	1.0			
5	Cemented Glacial Till	12D	68	R	8697	5515	0.66	1.42	1.0	1.00	1.0			

1. Determination of overburden stress correction factor (CN) based on Peck, Hanson and Thornburn (1974) and guidance from AASHTO LRFD Section 10.4.6.2.4 (AASHTO LRFD 8th Ed., 2017).
2. Determination of correction factors (CB, CR, CS) based on guidance from Seed et al. (1985) and Skempton (1986) as presented in Das (2014) Principles of Foundation Engineering, 8th Ed. Table 3.5.
3. Estimated friction angle based on guidance from Peck, Hanson and Thornburn (1974)
4. Refusal field N-values reported as 100 bpf.

SPT BLOW COUNT CONVERSION AND FRICTION ANGLE CORRELATION FOR GRANULAR SOILS

Project Name: Perley Brook Bridge #3468 Replacement
Project No.: 20-1403-021882
Evaluated By/Date: MAS / March 2021
Reviewed By/Date: TSD

85.4 Hammer Efficiency
u = 17 Depth to Water

		BORING		BB-FKPB-102			Correction Factors							
Soil Layer	Stratum	Sample No.	Top of Sample Depth (ft)	Field N-Value N_m	Total Stress at Sample Depth (psf)	Effective Stress at Sample Depth (psf)	Overburden Stress[1] C_N	Hammer Efficiency C_E	Borehole Diameter[2] C_B	Rod Length[2] C_R	Sampler[2] C_S	N_{60}	$(N1)_{60}$	Friction Angle[3] (degrees)
1	Fill	1D	5	26	625	625	1.39	1.42	1.0	0.75	1.0	38	53	38
1	Fill	2D	10	17	1250	1250	1.16	1.42	1.0	0.75	1.0	25	29	34
1	Fill	3D	15	45	1875	1875	1.02	1.42	1.0	0.85	1.0	65	67	44
2	Glacial Outwash	4D	20.5	26	2640	2422	0.94	1.42	1.0	0.95	1.0	38	36	38
2	Glacial Outwash	5D	25	31	3280	2781	0.89	1.42	1.0	0.95	1.0	45	41	40
3	Glacial Till	6D	30	54	3928	3117	0.85	1.42	1.0	0.95	1.0	77	66	47
3	Glacial Till	7D	35	64	4578	3455	0.82	1.42	1.0	1.00	1.0	92	76	50
3	Glacial Till	8D	40	61	5228	3793	0.79	1.42	1.0	1.00	1.0	87	69	49
3	Glacial Till	9D	45	R	5878	4131	0.76	1.42	1.0	1.00	1.0			
3	Glacial Till	10D	50	R	6528	4469	0.73	1.42	1.0	1.00	1.0			

1. Determination of overburden stress correction factor (CN) based on Peck, Hanson and Thornburn (1974) and guidance from AASHTO LRFD Section 10.4.6.2.4 (AASHTO LRFD 8th Ed., 2017).
2. Determination of correction factors (CB, CR, CS) based on guidance from Seed et al. (1985) and Skempton (1986) as presented in Das (2014) Principles of Foundation Engineering, 8th Ed. Table 3.5.
3. Estimated friction angle based on guidance from Peck, Hanson and Thornburn (1974)
4. Refusal field N-values reported as 100 bpf.

S.W.COLE ENGINEERING, INC.

H Pile Resistance

Design of Bearing H-Piles

Reference:

1. AASHTO LRFD Bridge Design Specifications, 9th Edition, 2020. (LRFD)
2. AASHTO Standard Specifications for Highway Bridges 17th Edition, 2002. (AASHTO)

Bedrock Properties

RQD:	BB-FKPB-101	R3, R4, R5 = 12, 0, 0%	Range: 0-82%
	BB-FKPB-102	R1, R2, R3 = 0, 82, 60%	Weighted Average: 35%

Rock Type: META-SILTSTONE, hard, fresh, fine-grained, generally low angle to horizontal (0 to 35 degrees), very close to close, open to healed joints

Friction Angle: ϕ = 27 to 34 degrees (LRFD Table C10.4.6.4-1)

Co = 1,400 - 17,000 psi (AASHTO Table 4.4.8.1.2B)

Pile Properties:

HP14x117

$f_y := 50\ ksi$

$A_s := 34.4 \cdot in^2$

$d := 14.2 \cdot in$

$b := 14.9 \cdot in$

$A_p := \overrightarrow{(d \cdot b)} = 211.58\ in^2$ Area of Plugged Pile

$P_p := \overrightarrow{(2 \cdot d + 2 \cdot b)} = 58.2\ in$ Perimeter of Pile

Nominal and Factored Structural Compressive Resistance

Find Nominal Axial Structural Resistance

$P_o := f_y \cdot A_s = 1720\ kip$

Structural Resistance of unbraced segment

Assume 4 foot unbraced section due to scour
Determine elastic critical buckling resistance, Pe

$E_s := 29000\ ksi$

$K_{eff} := 1.0$ effective length factor / LRFD Table C4.6.2.5-1

$l_{unbraced} := 4\ ft$ unbraced length top of pile

$r_y := 3.59 \cdot in$ radius of gyration, weak axis / LRFD Article C6.9.4.1.2

LRFD Eqn 6.9.4.1.2-1

$$P_e := \overrightarrow{\left(\frac{\pi^2 \cdot E_s}{\left(\frac{K_{eff} \cdot l_{unbraced}}{r_y}\right)^2} \cdot A_s\right)} = 55076\ kip$$

LRFD Article 6.9.4.1.1

$$\frac{P_e}{P_o} = 32.021 \qquad P_n := \begin{cases} \text{if } \left(\frac{P_e}{P_o} \geq 0.44\right) \\ \quad \overrightarrow{0.658^{\left(\frac{P_o}{P_e}\right)} \cdot P_o} \\ \text{if } \left(\frac{P_e}{P_o} < 0.44\right) \\ \quad 0.877 \cdot P_e \end{cases} = 1698\ kip$$

Find Factored Axial Structural Resistance at Strength Limit State

$\phi_{cu} := 0.7$ For combined axial and flexural resistance of H piles
LRFD Article 6.5.4.2

$P_r := \phi_{cu} \cdot P_n = 1188\ kip$ LRFD Eqn 6.9.2.1-1

Find Factored Axial Structural Resistance at Strength Limit State

Structural Resistance of braced length

$l_{braced} := 0.1\ ft$

LRFD Eqn 6.9.4.1.2-1

$$P_e := \overrightarrow{\left(\frac{\pi^2 \cdot E_s}{\left(\frac{K_{eff} \cdot l_{braced}}{r_y} \right)^2} \cdot A_s \right)} = 88121644\ kip$$

LRFD Article 6.9.4.1.1

Check if Pe/Po >/= 0.44

$$\frac{P_e}{P_o} = 51234 \qquad P_n := \left\| \begin{array}{l} \text{if } \left\| \frac{P_e}{P_o} \geq 0.44 \right\| \\ \left\| \overrightarrow{0.658^{\left(\frac{P_o}{P_e}\right)} \cdot P_o} \right. \\ \text{if } \left\| \frac{P_e}{P_o} < 0.44 \right\| \\ \left\| 0.877 \cdot P_e \right. \end{array} \right. = 1720\ kip$$

<u>Find Factored Axial Structural Resistance at Strength Limit State</u>

$\phi_c := 0.5$ LRFD Article 6.5.4.2

$P_r := \phi_c \cdot P_n = 860\ kip$ LRFD Eqn 6.9.2.1-1

<u>Find Factored Axial Structural Resistance at Service and Extreme Limit State</u>

$\phi_{s_ex} := 1.0$

$P_{r_e} := \phi_{s_ex} \cdot P_n = 1720\ kip$ LRFD Eqn 6.9.2.1-1

Nominal and Factored Geotechnical Resistance

Abutment No. 1

Evaluate the Static Analysis of piles driven to end bearing in the glacial till using Nordlund/ Thurman static pile resistance method (LRFD Article 10.7.3.8.6f) and SPT-Meyerhof method (LRFD Article 10.7.3.8.6g) limiting the side resistance below the pile's critical depth of 20 pile diameters for very dense glacial till.

Nominal Geotechnical Resistance from Axial Pile Worksheet(s)
Assume pile tip driven to Elevation 470

$P_{n1} := 676\ kip$

Find Factored Geotechnical Resistance for Abutment 1 at Strength Limit States

$\phi_{dyn} := 0.65$ LRFD Table 10.5.5.2.3-1 for dynamic testing

$P_{r1} := \phi_{dyn} \cdot P_{n1} = 439\ kip$

Find Factored Geotechnical Resistance for Abutment 1 at Service and Extreme Limit State

$\phi_{s_ex} := 1.0$ LRFD 6.9.2.1-1 for the Services and Extreme Limit States

$P_{r1_e} := \phi_{s_ex} \cdot P_{n1} = 676\ kip$

Abutment No. 2

LRFD Article 10.7.3.2.3 states "the nominal resistance of piles driven to point bearing on hard rock where pile penetration into the rock formation is minimal is controlled by the structural limit state. The nominal bearing resistance shall not exceed the values obtained from Article 6.9.4.1 with the resistance factor specified in Article 6.5.4.2 and Article 6.15 for severe driving conditions. A pile-driving acceptance criteria shall be developed that will prevent pile damage."

Nominal Structural Resistance

$P_{n2} := 1720\ kip$

Find Factored Geotechnical Resistance for Abutment 2 at Strength Limit States

$\phi_c := 0.5$ LRFD 6.9.2.1-1 for Strength Limit State

$P_{r2} := \phi_c \cdot P_n = 860\ kip$

Find Factored Geotechnical Resistance for Abutment 1 at Service and Extreme Limit State

$\phi_{s_ex} := 1.0$ LRFD 6.9.2.1-1 for the Services and Extreme Limit States

$P_{r_e} := \phi_{s_ex} \cdot P_n = 1720\ kip$

Drivability Analysis

From LRFD Article 10.7.8

For steel piles in compression or tension, limit driving stresses to 90% fy

$\phi_{da} := 1.0$ LRFD Table 10.5.5.2.3-1, Drivability Analysis, Steel Piles (See LRFD 6.5.4.2)

$\sigma_{da} := 0.9 \cdot f_y \cdot \phi_{da} = 45\ ksi$ LRFD Eqn 10.7.8.1

Per LRFD, limit driving stresses to 45 ksi or less or
Per BDG Section 501, limit blow counts to 5-15 blows to inch (bpi) with 6-10 bpi optimal
limit blow counts to 3-5 bpi on sloping bedrock.

Find maximum resistance from drivability analysis:

$\phi_{dyn} := 0.65$ LRFD Table 10.5.5.2.3-1 Strength Limit State

$\phi_s := 1$ Service and Extreme Limit States

GRLWeap Soil and Pile Model Assumptions

Assume worse case for piles at Abutment 1 hung up in very dense glacial till at about Elevation 470 feet.

Abutment 1: El 521 ft (bottom of pile cap) - El 470 ft = 51 ft

Assume contractor drives **60 ft piles** to account for additional pile length for testing (5 ft), rock embedment (< 1 ft), pile cap embedment (3 ft) and cut off.

Delmag D19-42 and D25-52 hammers were chosen as typical pile hammers capable of producing energy of about 42,000 and 66,000 ft-lbs, respectively. The following pile hammer and cushion parameters were used in the analysis:

Delmag D 19-42

Hammer parameters

Efficiency	0.8				
Pressure	1600	psi	Fixed	100	%
Stroke	10.81	ft	Fixed		

Delmag D 25-52

Hammer parameters

Efficiency	0.8				
Pressure	1500	psi	Fixed	100	%
Stroke	12.04	ft	Fixed		

From GRLWeap output:

Cushion Information

	Hammer	Pile	
Area	227.	0.	in^2
Elastic Modulus	530.	0.	ksi
Thickness	2.	0.	in
C.O.R.	0.8	0.	
Stiffness	0.	0.	kips/in
Helmet Weight	1.9		kips

$R_{ndr} := \begin{bmatrix} 531 \\ 822 \end{bmatrix} kip$ Delmag D 19-42 Delmag D 25-52

Strength Limit State

$R_{fdr} := \overrightarrow{R_{ndr}} \cdot \phi_{dyn} = \begin{bmatrix} 345 \\ 534 \end{bmatrix} kip$

Service and Extreme Limit States

$R_{dr} := \overrightarrow{R_{ndr}} \cdot \phi_s = \begin{bmatrix} 531 \\ 822 \end{bmatrix} kip$

TABLE 4.4.8.1.2B Typical Range of Uniaxial Compressive Strength (C_o) as a Function of Rock Category and Rock Type

Rock Category	General Description	Rock Type	C_o[1] (ksf)	C_o[1] (psi)
A	Carbonate rocks with well-developed crystal cleavage	Dolostone	700- 6,500	4,800-45,000
		Limestone	500- 6,000	3,500-42,000
		Carbonatite	800- 1,500	5,500-10,000
		Marble	800- 5,000	5,500-35,000
		Tactite-Skam	2,700- 7,000	19,000-49,000
B	Lithified argillaceous rock	Argillite	600- 3,000	4,200-21,000
		Claystone	30- 170	200- 1,200
		Marlstone	1,000- 4,000	7,600-28,000
		Phyllite	500- 5,000	3,500-35,000
		Siltstone	200- 2,500	1,400-17,000
		Shale[2]	150- 740	1,000- 5,100
		Slate	3,000- 4,400	21,000-30,000
C	Arenaceous rocks with strong crystals and poor cleavage	Conglomerate	700- 4,600	4,800-32,000
		Sandstone	1,400- 3,600	9,700-25,000
		Quartzite	1,300- 8,000	9,000-55,000
D	Fine-grained igneous crystalline rock	Andesite	2,100- 3,800	14,000-26,000
		Diabase	450-12,000	3,100-83,000
E	Coarse-grained igneous and metamorphic crystalline rock	Amphibolite	2,500- 5,800	17,000-40,000
		Gabbro	2,600- 6,500	18,000-45,000
		Gneiss	500- 6,500	3,500-45,000
		Granite	300- 7,000	2,100-49,000
		Quartzdiorite	200- 2,100	1,400-14,000
		Quartzmonzonite	2,700- 3,300	19,000-23,000
		Schist	200- 3,000	1,400-21,000
		Syenite	3,800- 9,000	26,000-62,000

[1]Range of Uniaxial Compressive Strength values reported by various investigations.
[2]Not including oil shale.

$$p = q_o (1 - \nu^2) B I_\rho / E_m, \text{ with } I_\rho = (L/B)^{1/2}/\beta_z \qquad (4.4.8.2.2\text{-}2)$$

Values of I_ρ may be computed using the β_z values presented in Table 4.4.7.2.2B from Article 4.4.7.2.2 for rigid footings. Values of Poisson's ratio (ν) for typical rock types are presented in Table 4.4.8.2.2A. Determination of the rock mass modulus (E_m) should be based on the results of in-situ and laboratory tests. Alternatively, values of E_m may be estimated by multiplying the intact rock modulus (E_o) obtained from uniaxial compression tests by a reduction factor (α_E) which accounts for frequency of discontinuities by the rock quality designation (RQD), using the following relationships (Gardner, 1987):

$$E_m = \alpha_E E_o \qquad (4.4.8.2.2\text{-}3)$$

$$\alpha_E = 0.0231(RQD) - 1.32 \geq 0.15 \qquad (4.4.8.2.2\text{-}4)$$

For preliminary design or when site-specific test data cannot be obtained, guidelines for estimating values of E_o (such as presented in Table 4.4.8.2.2B or Figure 4.4.8.2.2A) may be used. For preliminary analyses or for final design when in-situ test results are not available, a value of $\alpha_E = 0.15$ should be used to estimate E_m.

4.4.8.2.3 Tolerable Movement

Refer to Article 4.4.7.2.3.

4.4.9 Overall Stability

The overall stability of footings, slopes, and foundation soil or rock shall be evaluated for footings located on

AXIAL PILE RESISTANCE Abutment No. 1

Evaluated By/Date: MAS / March 2021
Reviewed By: TSD

PROJECT DATA

S.W. Cole Engineering, Inc.
Project: Perley Brook Bridge #3468 Replacement
Project No.: 20-1403-021882
Soil profile based on: BB-FKPB-101

PILE DATA

Pile Size:	HP14x117	
Depth/Diameter:	1.18	ft
Web Thickness:	0.07	ft
Flange Width:	1.24	ft
Flange Thickness:	0.07	ft
Perimeter:	4.85	ft
Section Area:	0.24	ft^2
Cutting Shoe End Area:	0.48	ft^2
Plugged Section Area:	1.47	ft^2
Ground Surface El.:	531.0	ft
Pile Head El.:	523.0	ft
Pile Cap El.:	521.0	ft
Q50 Water El.:	520.0	ft

20D 23.7 ft

LRFD (2017) Soil Resistance Factors
Table 10.5.5.2.3-1
Static Side/End Resistance Dynamic Resistance
ϕ_{stat} = 0.45 ϕ_{dyn} = 0.65
Use ϕ_{dyn} based on LRFD Article C10.5.5.2.3

SOIL LAYER DATA

	Depth (ft)		γ_{moist} (pcf)	γ_{sat} (pcf)	See SPT Correlation ϕ (deg)	Su (psf)	$N1_{60}$	K_δ	C_F	α_t	N'_q	q_L
Fill	0	14	125	62.6	32	0	50	1.00	0.93	0.61	40	50
Fill	14	18	122	59.6	30	0	6	0.85	0.95	0.58	30	25
Glacial Outwash	18	33	135	72.6	38	0	30	1.10	0.92	0.68	100	250
Glacial Till	33	43	140	77.6	40	0	50	1.70	0.91	0.71	170	400
Glacial Till	43	74.5	145	82.6	40	0	100	1.70	0.9	0.75	170	800

Soil Layer	Pile Tip Elevation (ft)	Pile Length (ft)	Total Unit Wt. (pcf)	Eff. Unit Wt (lb/ft3)	Effective Stress (ksf)	Db/D	K_δ	C_F	α_t	N_q	10.7.3.8.6g-3 Meyerhoff Unit Side q_s ksf	10.7.3.8.6f-1 Nordlund Unit Side q_s ksf	Meyerhoff Unit Tip q_p ksf	10.7.3.8.6f-2 Nordlund Unit Tip q_p ksf	Meyerhoff Meyerhoff Nominal Side Rs kips	10.7.3.8.6a-4 Nordlund Nominal Side Rs kips	Meyerhoff Nominal Tip Rp kips	Meyerhoff Nominal Axial Res. kips	Nordlund Nominal Axial Res. kips	LRFD Method Factored Side Resist (kips)	Factored End Resist (kips)	Meyerhoff Factored Axial Res. kips	Nordlund Factored Axial Res. (kips)
0	531																						
1	530																						
1	529																						
1	528																						
1	527																						
1	526											Bottom of Pile Cap at Elevation ±521 feet											
1	525																						
1	524																						
1	523																						
1	522																						
1	521																						
1	520	1	125	62.6	0.06		1.00	0.93	0.61	40.00	1.00	0.02	0.00	1.5	4.9	0.1	0.0	4.9	0.8	0.1	0.5	3.2	0.6
1	519	2	125	62.6	0.13		1.00	0.93	0.61	40.00	1.00	0.05	0.00	3.1	9.7	0.3	0.0	9.7	1.8	0.2	1.0	6.3	1.2
1	518	3	125	62.6	0.19		1.00	0.93	0.61	40.00	1.00	0.07	0.00	4.6	14.6	0.7	0.0	14.6	2.9	0.4	1.4	9.5	1.9
1	517	4	125	62.6	0.25		1.00	0.93	0.61	40.00	1.00	0.09	0.00	6.1	19.4	1.1	0.0	19.4	4.1	0.7	1.9	12.6	2.6
2	516	5	122	59.6	0.31		0.85	0.95	0.58	30.00	0.12	0.10	0.00	5.4	20.0	1.6	0.0	20.0	4.2	1.0	1.7	13.0	2.7
2	515	6	122	59.6	0.37		0.85	0.95	0.58	30.00	0.12	0.12	0.00	6.4	20.6	2.1	0.0	20.6	5.2	1.4	2.0	13.4	3.4
2	514	7	122	59.6	0.43		0.85	0.95	0.58	30.00	0.12	0.12	0.00	7.5	21.1	2.7	0.0	21.1	6.3	1.8	2.4	13.7	4.1
2	513	8	122	59.6	0.49		0.85	0.95	0.58	30.00	0.12	0.12	0.00	8.5	21.7	3.3	0.0	21.7	7.4	2.1	2.7	14.1	4.8
3	512	9	135	72.6	0.56		1.10	0.92	0.68	100.00	0.60	0.22	0.00	38.2	24.6	4.4	0.0	24.6	22.9	2.8	12.0	16.0	14.9
3	511	10	135	72.6	0.63		1.10	0.92	0.68	100.00	0.60	0.25	0.00	43.1	27.5	5.6	0.0	27.5	26.5	3.6	13.6	17.9	17.2
3	510	11	135	72.6	0.71		1.10	0.92	0.68	100.00	0.60	0.28	0.00	48.0	30.5	6.9	0.0	30.5	30.2	4.5	15.1	19.8	19.6
3	509	12	135	72.6	0.78		1.10	0.92	0.68	100.00	0.60	0.31	0.00	53.0	33.4	8.4	0.0	33.4	34.1	5.5	16.7	21.7	22.1
3	508	13	135	72.6	0.85		1.10	0.92	0.68	100.00	0.60	0.34	0.00	57.9	36.3	10.1	0.0	36.3	38.1	6.5	18.2	23.6	24.8
3	507	14	135	72.6	0.92		1.10	0.92	0.68	100.00	0.60	0.36	0.00	62.9	39.2	11.8	0.0	39.2	42.3	7.7	19.8	25.5	27.5
3	506	15	135	72.6	1.00		1.10	0.92	0.68	100.00	0.60	0.39	0.00	67.8	42.1	13.7	0.0	42.1	46.5	8.9	21.3	27.4	30.3
3	505	16	135	72.6	1.07		1.10	0.92	0.68	100.00	0.60	0.42	0.00	72.7	45.0	15.8	0.0	45.0	51.0	10.3	22.9	29.3	33.1
3	504	17	135	72.6	1.14		1.10	0.92	0.68	100.00	0.60	0.45	0.00	77.7	47.9	18.0	0.0	47.9	55.6	11.7	24.4	31.1	36.1
3	503	18	135	72.6	1.21		1.10	0.92	0.68	100.00	0.60	0.48	0.00	82.6	50.8	20.3	0.0	50.8	60.3	13.2	26.0	33.0	39.2
3	502	19	135	72.6	1.29		1.10	0.92	0.68	100.00	0.60	0.51	0.00	87.5	53.7	22.7	0.0	53.7	65.1	14.8	27.5	34.9	42.3
3	501	20	135	72.6	1.36		1.10	0.92	0.68	100.00	0.60	0.54	0.00	92.5	56.6	25.3	0.0	56.6	70.1	16.5	29.1	36.8	45.6
3	500	21	135	72.6	1.43		1.10	0.92	0.68	100.00	0.60	0.56	0.00	97.4	59.6	28.1	0.0	59.6	75.2	18.2	30.7	38.7	48.9
3	499	22	135	72.6	1.51		1.10	0.92	0.68	100.00	0.60	0.59	0.00	102.4	62.5	30.9	0.0	62.5	80.5	20.1	32.2	40.6	52.3
3	498	23	135	72.6	1.58		1.10	0.92	0.68	100.00	0.60	0.62	0.00	107.3	65.4	34.0	0.0	65.4	85.9	22.1	33.8	42.5	55.8
4	497	24	140	77.6	1.66	0.85	1.70	0.91	0.71	170.00	1.00	1.00	33.80	199.8	70.2	38.8	16.4	86.6	135.5	25.2	62.9	56.3	88.1
4	496	25	140	77.6	1.73	1.69	1.70	0.91	0.71	170.00	1.00	1.04	67.61	209.2	75.1	43.9	32.7	107.8	145.1	28.5	65.8	70.1	94.3
4	495	26	140	77.6	1.81	2.54	1.70	0.91	0.71	170.00	1.00	1.09	101.41	218.5	79.9	49.2	49.1	129.0	155.0	32.0	68.8	83.9	100.7
4	494	27	140	77.6	1.89	3.38	1.70	0.91	0.71	170.00	1.00	1.14	135.21	227.9	84.8	54.7	65.5	150.2	165.0	35.5	71.7	97.7	107.3
4	493	28	140	77.6	1.97	4.23	1.70	0.91	0.71	170.00	1.00	1.18	169.01	237.3	89.6	60.4	81.8	171.5	175.3	39.3	74.7	111.4	113.9
4	492	29	140	77.6	2.04	5.07	1.70	0.91	0.71	170.00	1.00	1.23	202.82	246.6	94.5	66.4	98.2	192.7	185.8	43.2	77.6	125.2	120.8
4	491	30	140	77.6	2.12	5.92	1.70	0.91	0.71	170.00	1.00	1.28	236.62	256.0	99.3	72.6	114.6	213.9	196.5	47.2	80.6	139.0	127.7
4	490	31	140	77.6	2.20	6.76	1.70	0.91	0.71	170.00	1.00	1.32	270.42	265.4	104.2	79.0	130.9	235.1	207.5	51.4	83.5	152.8	134.9
4	489	32	140	77.6	2.28	7.61	1.70	0.91	0.71	170.00	1.00	1.37	304.23	274.7	109.0	85.7	147.3	256.3	218.7	55.7	86.5	166.6	142.1
4	488	33	140	77.6	2.35	8.45	1.70	0.91	0.71	170.00	1.00	1.42	338.03	284.1	113.9	92.5	163.6	277.5	230.1	60.1	89.4	180.4	149.5
5	487	34	145	82.6	2.44	9.30	1.70	0.90	0.75	170.00	2.00	1.45	743.66	310.6	123.6	99.6	360.0	483.6	250.0	64.7	97.8	314.3	162.5
5	486	35	145	82.6	2.52	10.14	1.70	0.90	0.75	170.00	2.00	1.50	800.00	321.2	133.3	106.9	387.3	520.6	262.3	69.5	101.1	338.4	170.5
5	485	36	145	82.6	2.60	10.99	1.70	0.90	0.75	170.00	2.00	1.55	800.00	331.7	143.0	114.4	387.3	530.3	275.0	74.3	104.4	344.7	178.7
5	484	37	145	82.6	2.68	11.83	1.70	0.90	0.75	170.00	2.00	1.60	800.00	342.2	152.7	122.1	387.3	540.0	287.8	79.4	107.7	351.0	187.1
5	483	38	145	82.6	2.77	12.68	1.70	0.90	0.75	170.00	2.00	1.65	800.00	352.8	162.4	130.1	387.3	549.7	300.9	84.6	111.0	357.3	195.6
5	482	39	145	82.6	2.85	13.52	1.70	0.90	0.75	170.00	2.00	1.70	800.00	363.3	172.1	138.4	387.3	559.4	314.2	89.9	114.3	363.6	204.3
5	481	40	145	82.6	2.93	14.37	1.70	0.90	0.75	170.00	2.00	1.75	800.00	373.8	181.8	146.8	387.3	569.1	327.8	95.4	117.6	369.9	213.1
5	480	41	145	82.6	3.01	15.21	1.70	0.90	0.75	170.00	2.00	1.80	800.00	384.4	191.5	155.5	387.3	578.8	341.6	101.1	120.9	376.2	222.1
5	479	42	145	82.6	3.10	16.06	1.70	0.90	0.75	170.00	2.00	1.85	800.00	394.9	201.2	164.5	387.3	588.5	355.7	106.9	124.3	382.5	231.2
5	478	43	145	82.6	3.18	16.90	1.70	0.90	0.75	170.00	2.00	1.89	800.00	405.4	210.9	173.7	387.3	598.2	370.0	112.9	127.6	388.8	240.5
5	477	44	145	82.6	3.26	17.75	1.70	0.90	0.75	170.00	2.00	1.94	800.00	416.0	220.6	183.1	387.3	607.9	384.5	119.0	130.9	395.1	249.9
5	476	45	145	82.6	3.35	18.59	1.70	0.90	0.75	170.00	2.00	1.99	800.00	426.5	230.3	192.8	387.3	617.6	399.2	125.3	134.2	401.4	259.5
5	475	46	145	82.6	3.43	19.44	1.70	0.90	0.75	170.00	2.00	2.04	800.00	437.0	240.0	202.7	387.3	627.3	414.2	131.7	137.5	407.7	269.3
5	474	47	145	82.6	3.51	20.28	1.70	0.90	0.75	170.00	2.00	2.09	800.00	447.6	249.7	212.8	387.3	637.0	429.5	138.3	140.8	414.0	279.2
5	473	48	145	82.6	3.59	21.13	1.70	0.90	0.75	170.00	2.00	2.14	800.00	458.1	259.4	223.2	387.3	646.7	445.0	145.1	144.1	420.3	289.2

AXIAL PILE RESISTANCE **Abutment No. 1**

Evaluated By/Date: MAS / March 2021
Reviewed By: TSD

PROJECT DATA

S.W. Cole Engineering, Inc.
Project: Perley Brook Bridge #3468 Replacement
Project No.: 20-1403-021882
Soil profile based on: BB-FKPB-101

PILE DATA

Pile Size:	HP14x117	
Depth/Diameter:	1.18	ft
Web Thickness:	0.07	ft
Flange Width:	1.24	ft
Flange Thickness:	0.07	ft
Perimeter:	4.85	ft
Section Area:	0.24	ft^2
Cutting Shoe End Area:	0.48	ft^2
Plugged Section Area:	1.47	ft^2
Ground Surface El.:	531.0	ft
Pile Head El.:	523.0	ft
Pile Cap El.:	521.0	ft
Q50 Water El.:	520.0	ft

20D
23.7 ft

LRFD (2017) Soil Resistance Factors
Table 10.5.5.2.3-1
Static Side/End Resistance Dynamic Resistance
ϕ_{stat} = 0.45 ϕ_{dyn} = 0.65
Use ϕ_{dyn} based on LRFD Article C10.5.5.2.3

SOIL LAYER DATA

	Depth (ft)		γ_{moist} (pcf)	γ_{sat} (pcf)	See SPT Correlation ϕ (deg)	Su (psf)	$N1_{60}$	K_δ	C_F	α_t	N'_q	q_L
Fill	0	14	125	62.6	32	0	50	1.00	0.93	0.61	40	50
Fill	14	18	122	59.6	30	0	6	0.85	0.95	0.58	30	25
Glacial Outwash	18	33	135	72.6	38	0	30	1.10	0.92	0.68	100	250
Glacial Till	33	43	140	77.6	40	0	50	1.70	0.91	0.71	170	400
Glacial Till	43	74.5	145	82.6	40	0	100	1.70	0.9	0.75	170	800

Soil Layer	Pile Tip Elevation (ft)	Pile Length (ft)	Total Unit Wt. (pcf)	Eff. Unit Wt (lb/ft3)	Effective Stress (ksf)	Db/D	K_δ	C_F	α_t	N_q	10.7.3.8.6g-3 Meyerhoff Unit Side q_s ksf	10.7.3.8.6f-1 Nordlund Unit Side q_s ksf	Meyerhoff Unit Tip q_p ksf	10.7.3.8.6f-2 Nordlund Unit Tip q_p ksf	Meyerhoff Meyerhoff Nominal Side Rs kips	10.7.3.8.6a-4 Nordlund Nominal Side Rs kips	Meyerhoff Nominal Tip Rp kips	Meyerhoff Nominal Axial Res. kips	Nordlund Nominal Axial Res. kips	LRFD Method Factored Side Resist (kips)	Factored End Resist (kips)	Meyerhoff Factored Axial Res. kips	Nordlund Factored Axial Res. (kips)
5	472	49	145	82.6	3.68	21.97	1.70	0.90	0.75	170.00	2.00	2.19	800.00	468.6	269.1	233.8	387.3	656.4	460.7	152.0	147.5	426.6	299.4
5	471	50	145	82.6	3.76	22.82	1.70	0.90	0.75	170.00	2.00	2.24	800.00	479.1	278.8	244.7	387.3	666.1	476.6	159.0	150.8	432.9	309.8
5	470	51	145	82.6	3.84	23.66	1.70	0.90	0.75	170.00	2.00	2.29	800.00	489.7	288.5	255.8	387.3	675.8	492.8	166.3	154.1	439.3	320.3
5	469	52	145	82.6	3.92	24.51	1.70	0.90	0.75	170.00	2.00	2.34	800.00	500.2	298.2	267.1	387.3	685.5	509.3	173.6	157.4	445.6	331.0
5	468	53	145	82.6	4.01	25.35	1.70	0.90	0.75	170.00	2.00	2.39	800.00	510.7	307.9	278.7	387.3	695.2	526.0	181.2	160.7	451.9	341.9
5	467	54	145	82.6	4.09	26.20	1.70	0.90	0.75	170.00	2.00	2.44	800.00	521.3	317.6	290.5	387.3	704.9	542.9	188.8	164.0	458.2	352.9
5	466	55	145	82.6	4.17	27.04	1.70	0.90	0.75	170.00	2.00	2.49	800.00	531.8	327.3	302.6	387.3	714.6	560.0	196.7	167.3	464.5	364.0
5	465	56	145	82.6	4.25	27.89	1.70	0.90	0.75	170.00	2.00	2.53	800.00	542.3	337.0	314.9	387.3	724.3	577.4	204.7	170.7	470.8	375.3
5	464	57	145	82.6	4.34	28.73	1.70	0.90	0.75	170.00	2.00	2.58	800.00	552.9	346.7	327.4	387.3	734.0	595.0	212.8	174.0	477.1	386.8
5	463	58	145	82.6	4.42	29.58	1.70	0.90	0.75	170.00	2.00	2.63	800.00	563.4	356.4	340.2	387.3	743.7	612.9	221.1	177.3	483.4	398.4
5	462	59	145	82.6	4.50	30.42	1.70	0.90	0.75	170.00	2.00	2.68	800.00	573.9	366.1	353.2	387.3	753.4	631.0	229.6	180.6	489.7	410.2
5	461	60	145	82.6	4.58	31.27	1.70	0.90	0.75	170.00	2.00	2.73	800.00	584.5	375.8	366.4	387.3	763.1	649.4	238.2	183.9	496.0	422.1
5	460	61	145	82.6	4.67	32.11	1.70	0.90	0.75	170.00	2.00	2.78	800.00	595.0	385.5	379.9	387.3	772.8	667.9	246.9	187.2	502.3	434.2
5	459	62	145	82.6	4.75	32.96	1.70	0.90	0.75	170.00	2.00	2.83	800.00	605.5	395.2	393.6	387.3	782.5	686.8	255.8	190.5	508.6	446.4
5	458	63	145	82.6	4.83	33.80	1.70	0.90	0.75	170.00	2.00	2.88	800.00	616.1	404.9	407.6	387.3	792.2	705.8	264.9	193.9	514.9	458.8
5	457	64	145	82.6	4.91	34.65	1.70	0.90	0.75	170.00	2.00	2.93	800.00	626.6	414.6	421.8	387.3	801.9	725.1	274.2	197.2	521.2	471.3

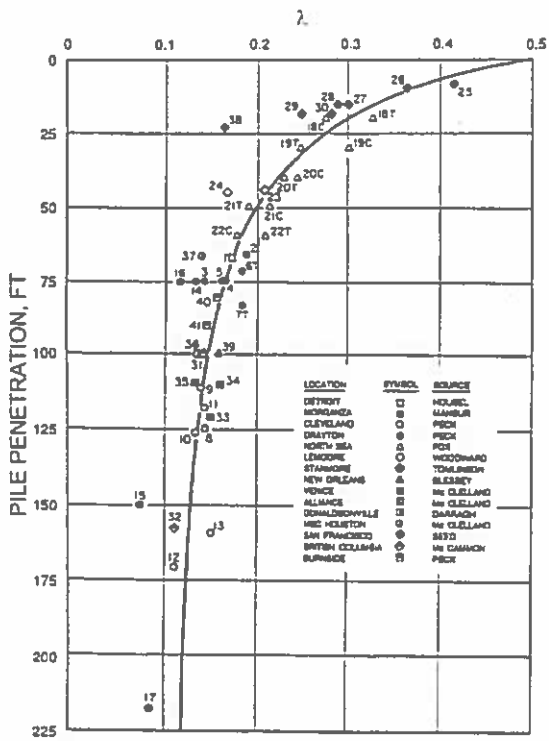


Figure 10.7.3.8.6d-1—λ Coefficient for Driven Pipe Piles after Vijayvergiya and Focht (1972)

10.7.3.8.6e—Tip Resistance in Cohesive Soils

The nominal unit tip resistance of piles in saturated clay, in ksf, shall be taken as:

$$q_p = 9S_u \qquad (10.7.3.8.6e\text{-}1)$$

where:

S_u = undrained shear strength of the clay near the pile tip (ksf)

10.7.3.8.6f—Nordlund/Thurman Method in Cohesionless Soils

This effective stress method should be applied only to sands and nonplastic silts. The nominal unit side resistance, q_s, for this method, in ksf, shall be taken as:

$$q_s = K_\delta C_f \sigma'_v \frac{\sin(\delta + \omega)}{\cos\ \omega} \qquad (10.7.3.8.6f\text{-}1)$$

where:

K_δ = coefficient of lateral earth pressure at mid-point of soil layer under consideration from Figures 10.7.3.8.6f-1 through 10.7.3.8.6f-4 (dim)

C10.7.3.8.6f

Detailed design procedures for the Nordlund/Thurman method are provided in Hannigan et al. (2006). This method was derived based on load test data for piles in sand. In practice, it has been used for gravelly soils as well.

The effective overburden stress is not limited in Eq. 10.7.3.8.6f-1.

For H-piles, the perimeter or "box" area should generally be used to compute the surface area of the pile side.

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C_F = correction factor for K_δ when $\delta \neq \phi_f$, from Figure 10.7.3.8.6f-5

σ'_v = effective overburden stress at midpoint of soil layer under consideration (ksf)

δ = friction angle between pile and soil obtained from Figure 10.7.3.8.6f-6 (degrees)

ω = angle of pile taper from vertical (degrees)

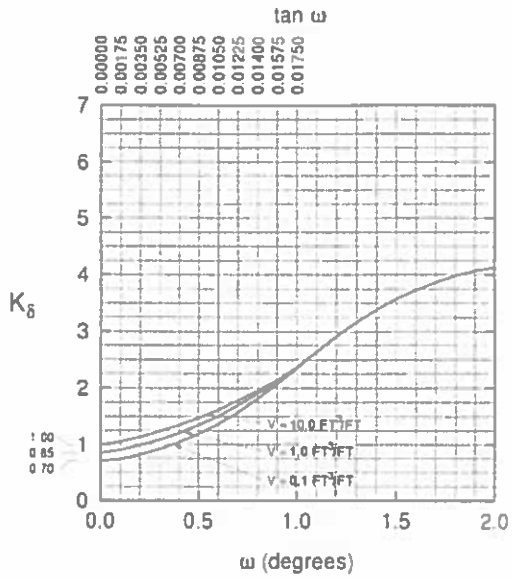

Figure 10.7.3.8.6f-1—Design Curve for Evaluating K_δ for Piles where ϕ_f = 25 degrees (Hannigan et al., 2006 after Nordlund, 1979)

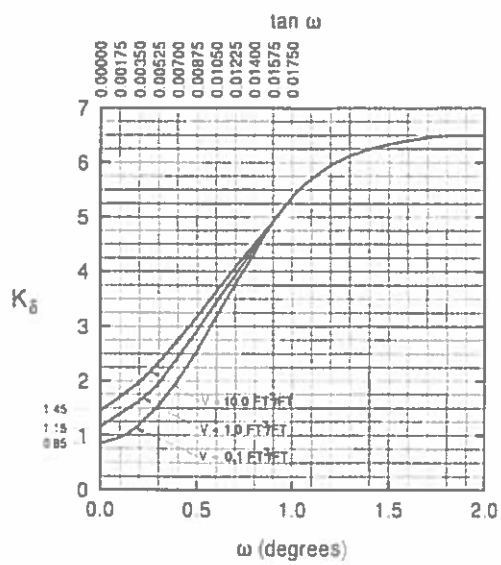

Figure 10.7.3.8.6f-2—Design Curve for Evaluating K_δ for Piles where ϕ_f = 30 degrees (Hannigan et al., 2006 after Nordlund, 1979)

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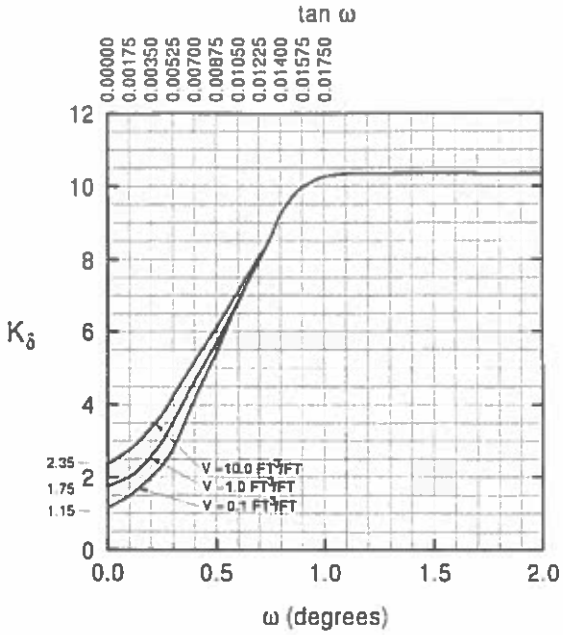

Figure 10.7.3.8.6f-3—Design Curve for Evaluating K_δ for Piles where ϕ_f = 35 degrees (Hannigan et al., 2006 after Nordlund, 1979)

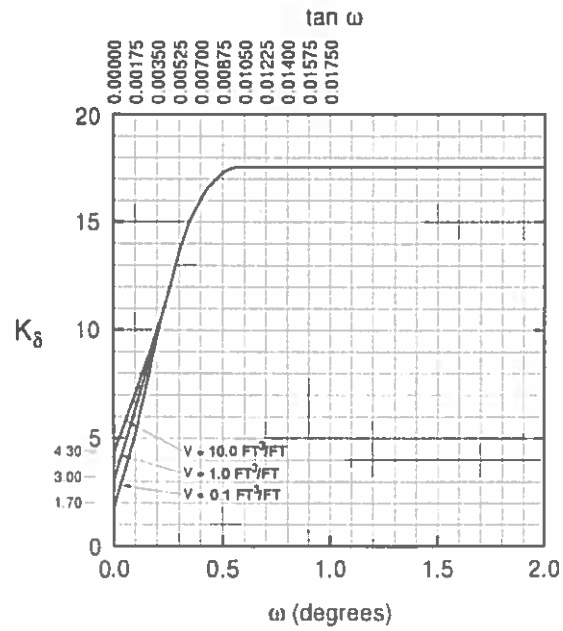

Figure 10.7.3.8.6f-4—Design Curve for Evaluating K_δ for Piles where ϕ_f = 40 degrees (Hannigan et al., 2006 after Nordlund, 1979)

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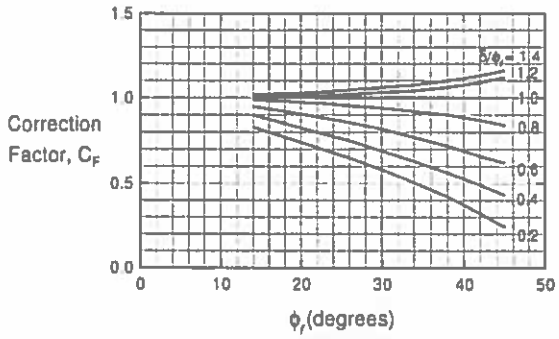

Figure 10.7.3.8.6f-5—Correction Factor for K_δ where $\delta \neq \phi_f$ (Hannigan et al., 2006 after Nordlund, 1979)

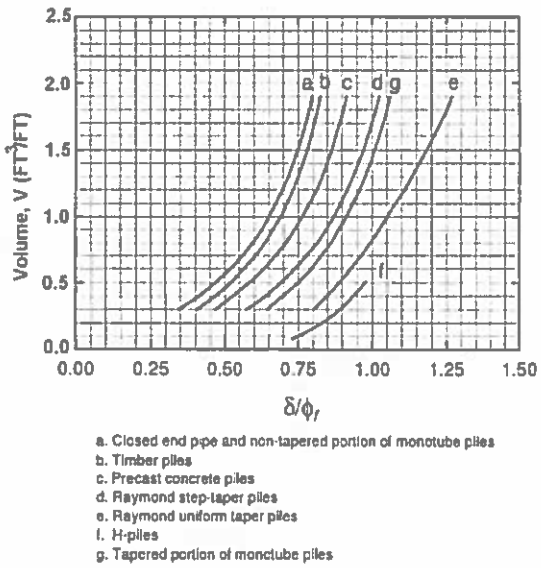

Figure 10.7.3.8.6f-6—Relation of δ/ϕ_f and Pile Displacement, V, for Various Types of Piles (Hannigan et al., 2006 after Nordlund, 1979)

The nominal unit tip resistance, q_p, in ksf by the Nordlund/Thurman method shall be taken as:

$$q_p = \alpha_t N'_q \sigma'_v \leq q_L \qquad (10.7.3.8.6f\text{-}2)$$

where:

α_t = coefficient from Figure 10.7.3.8.6f-7 (dim)
N'_q = bearing capacity factor from Figure 10.7.3.8.6f-8
σ'_v = effective overburden stress at pile tip (ksf) $\leq$3.2 ksf
q_L = limiting unit tip resistance from Figure 10.7.3.8.6f-9

If the friction angle, ϕ_f, is estimated from average, corrected *SPT* blow counts, $N1_{60}$, the $N1_{60}$ values should be averaged over the zone from the pile tip to two diameters below the pile tip.

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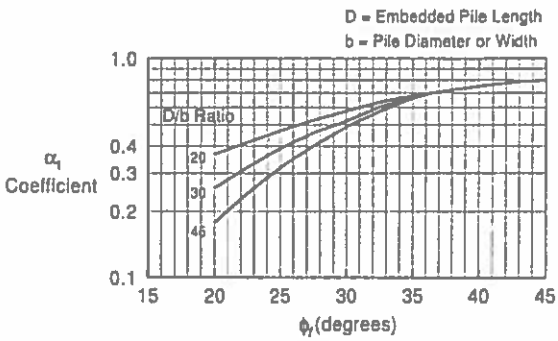

Figure 10.7.3.8.6f-7—α_t Coefficient (Hannigan et al., 2006 modified after Bowles, 1977)

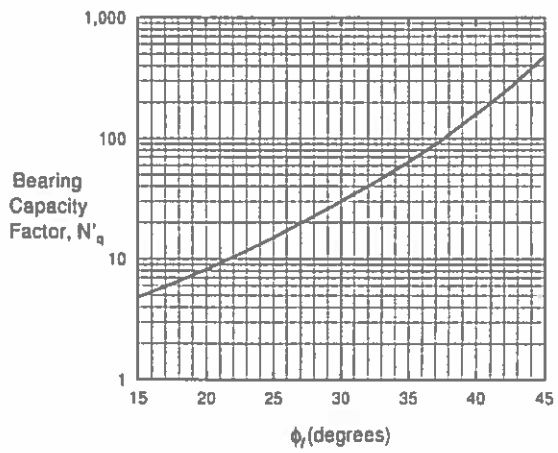

Figure 10.7.3.8.6f-8—Bearing Capacity Factor, N'_q (Hannigan et al., 2006 modified after Bowles, 1977)

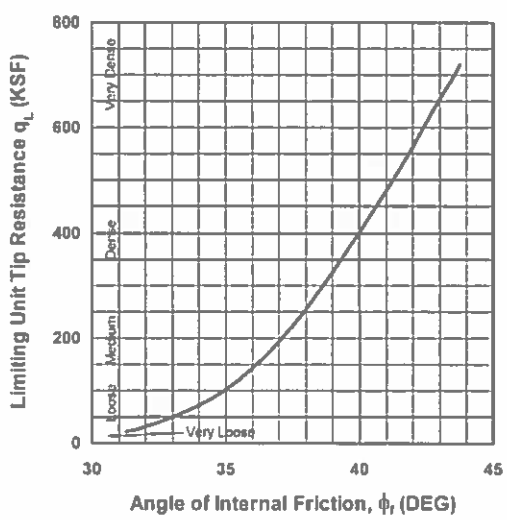

Figure 10.7.3.8.6f-9—Limiting Unit Pile Tip Resistance (Hannigan et al., 2006 after Meyerhof, 1976)

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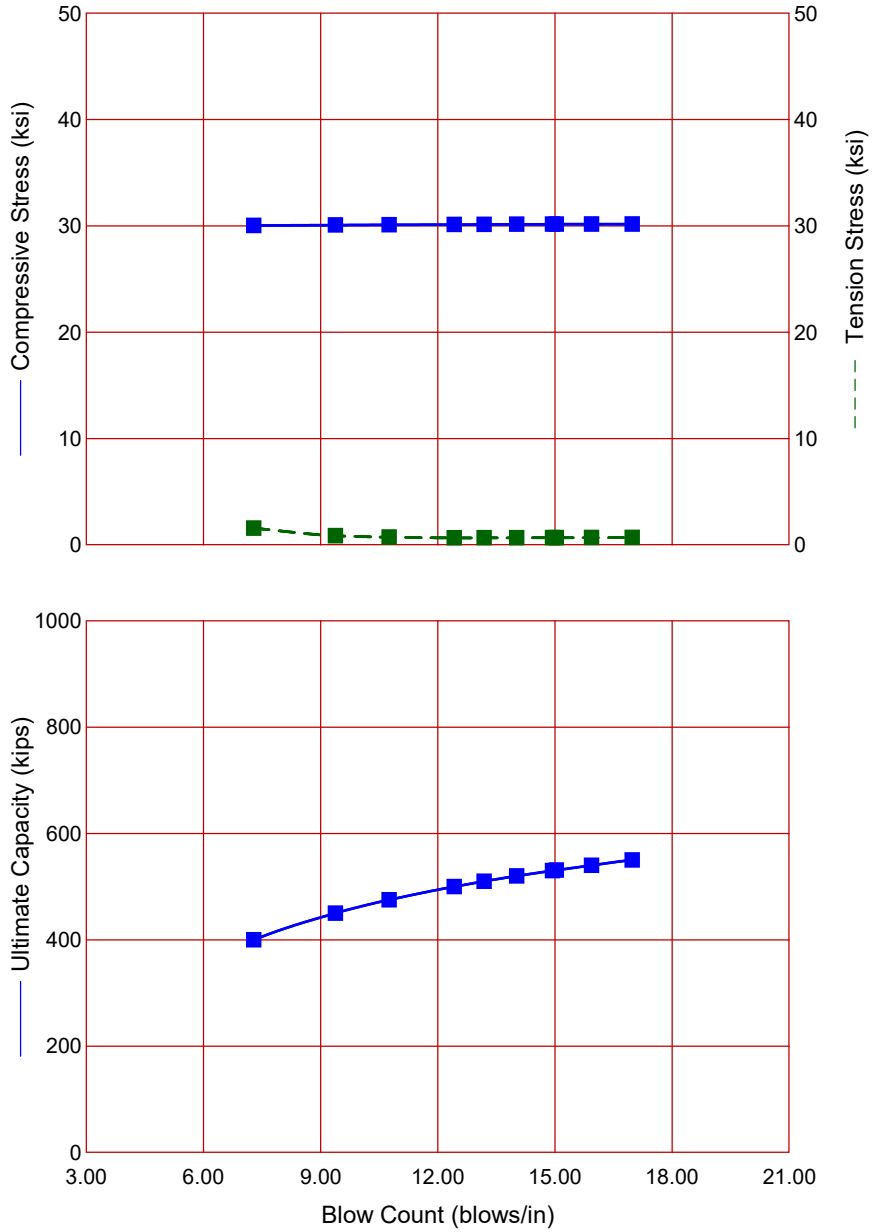
Drivability

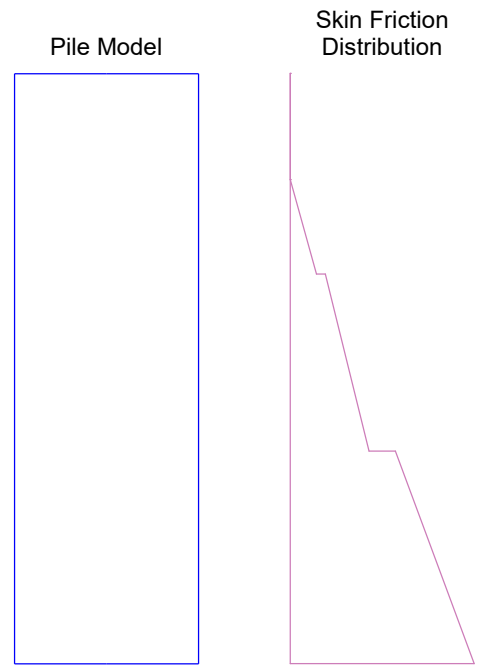
S.W. Cole Engineering, Inc.
WIN 021882 - HP14x117 - Delmag D19-42

15-Mar-2021
GRLWEAP Version 2010



DELMAG D 19-42

Stroke	10.81	ft
Ram Weight	4.00	kips
Efficiency	0.800	
Pressure	Variable	
Helmet Weight	1.90	kips
Hammer Cushion	60155	kips/in
COR of H.C.	0.800	
Skin Quake	0.100	in
Toe Quake	0.300	in
Skin Damping	0.050	s/ft
Toe Damping	0.150	s/ft
Pile Length	50.00	ft
Pile Penetration	41.00	ft
Pile Top Area	34.40	in2



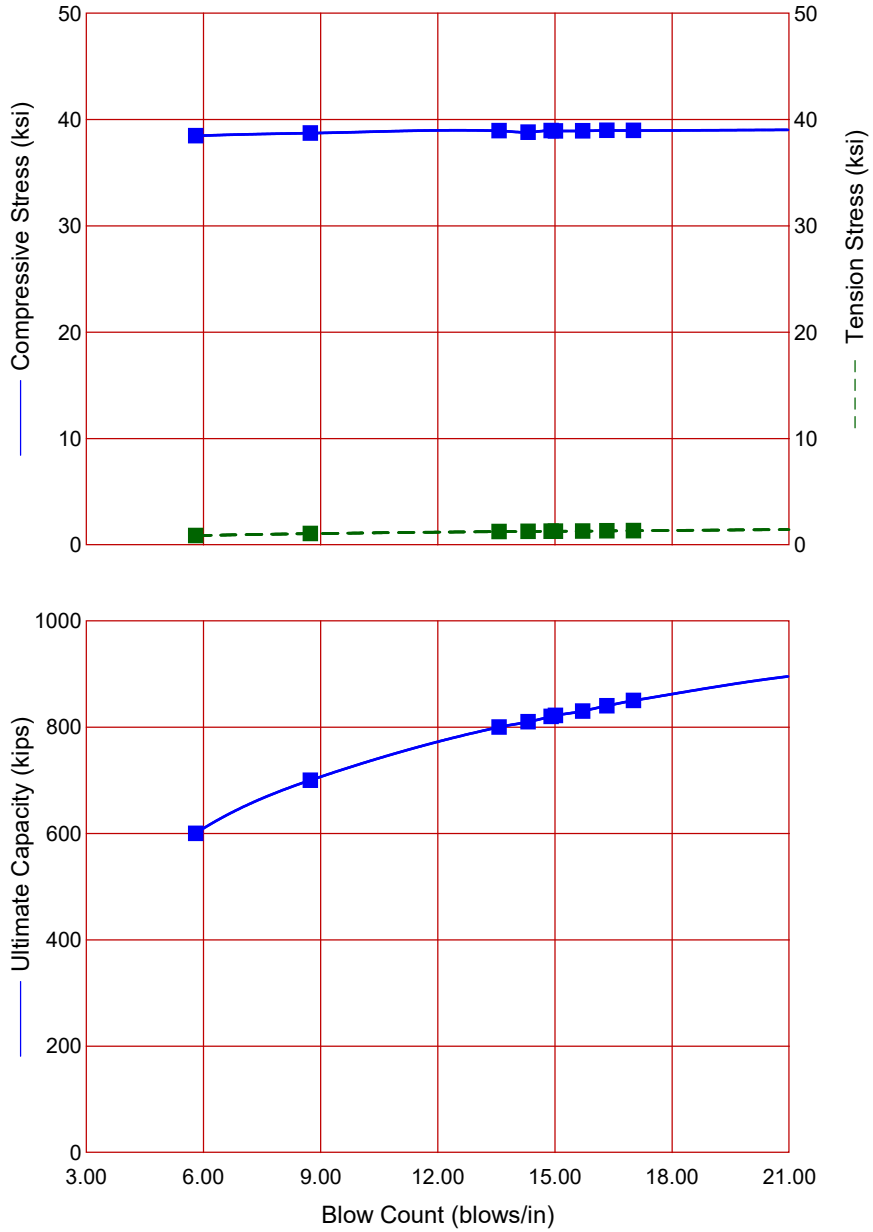
Res. Shaft = 30 %
(Proportional)

S.W. Cole Engineering, Inc. 15-Mar-2021
WIN 021882 - HP14x117 - Delmag D19-42 GRLWEAP Version 2010

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/in	Stroke ft	Energy kips-ft
400.0	30.04	1.58	7.3	10.81	23.27
450.0	30.07	0.87	9.4	10.81	22.72
475.0	30.10	0.73	10.8	10.81	22.47
500.0	30.12	0.67	12.4	10.81	22.46
510.0	30.13	0.67	13.2	10.81	22.46
520.0	30.15	0.67	14.0	10.81	22.46
530.0	30.16	0.68	14.9	10.81	22.46
531.0	30.16	0.68	15.0	10.81	22.46
540.0	30.17	0.69	15.9	10.81	22.45
550.0	30.16	0.70	17.0	10.81	22.44

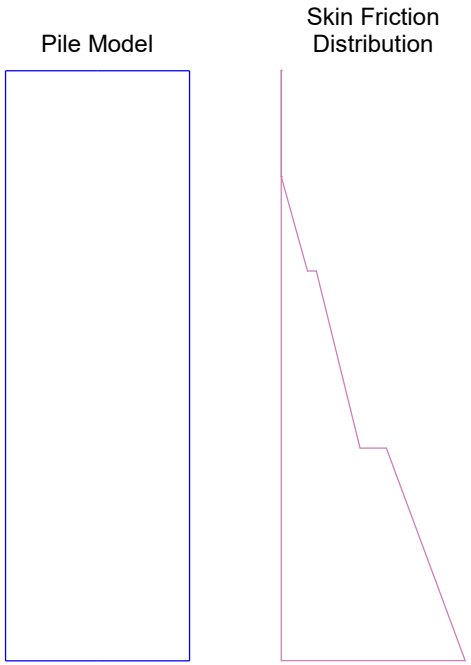
S.W. Cole Engineering, Inc.
WIN 021882 - HP14x117 - Delmag D25-52

15-Mar-2021
GRLWEAP Version 2010



DELMAG D 25-52

Stroke	12.04	ft
Ram Weight	5.51	kips
Efficiency	0.800	
Pressure	Variable	
Helmet Weight	1.90	kips
Hammer Cushion	60155	kips/in
COR of H.C.	0.800	
Skin Quake	0.100	in
Toe Quake	0.300	in
Skin Damping	0.050	s/ft
Toe Damping	0.150	s/ft
Pile Length	50.00	ft
Pile Penetration	41.00	ft
Pile Top Area	34.40	in2



Res. Shaft = 30 %
(Proportional)

S.W. Cole Engineering, Inc. 15-Mar-2021
WIN 021882 - HP14x117 - Delmag D25-52 GRLWEAP Version 2010

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/in	Stroke ft	Energy kips-ft
600.0	38.47	0.87	5.8	12.04	39.30
700.0	38.72	1.06	8.7	12.04	39.18
800.0	38.94	1.25	13.6	12.04	39.10
810.0	38.80	1.26	14.3	12.04	38.98
820.0	38.95	1.28	14.9	12.04	39.03
822.0	38.92	1.29	15.0	12.04	39.05
830.0	38.93	1.30	15.7	12.04	38.91
840.0	38.97	1.32	16.3	12.04	38.98
850.0	38.96	1.34	17.0	12.04	39.00
900.0	39.03	1.46	21.5	12.04	38.88

S.W.COLE ENGINEERING, INC.

Lateral Pile

Integral Abutment Pile Design - Abutment 1

Maximum Vertical Load From Structural Engineer
(provided by email on 05/17/2021)

$P_{u_total} := 2094\ kip$ Total per abutment

$N_p := 6$ Number of piles

$P_u := \frac{P_{u_total}}{N_p} = 349\ kip$ Vertical Load per Pile

AASHTO Reduction Factors

$\phi_{cl} := 0.5$ Hard driving with Tips - Lower Zone

$\phi_{cu} := 0.7$ Upper Zone of Pile (AASHTO 6.5.4.2)

$\phi_f := 1$ Flexural Resistance in Lower Zone of Pile

$\phi_v := 1$ Shear in Pile

Required Axial Resistance

$R_{n.upper} := \frac{P_u}{\phi_{cu}} = 498.571\ kip$

$R_{n.lower} := \frac{P_u}{\phi_{cl}} = 698\ kip$

$R_n := \max(R_{n.upper}, R_{n.lower}) = 698\ kip$

Required Area of Steel

$f_y := 50\ ksi$

$E := 29000\ ksi$

$A_{s.required} := \frac{R_n}{0.8 \cdot f_y} = 17.45\ in^2$

Select Pile Section Properties HP 14x117

$d := 14.2\ in$ $b_f := 14.9\ in$ $t_w := 0.805\ in$ $t_f := 0.805\ in$ $h := d - 2\ t_f = 12.59\ in$

Allow 1/16 inch section loss on all surfaces for corrosion $t_{cor} := 0.0625\ in$

$d_c := d - 2 \cdot t_{cor} = 14.075\ in$ $t_{w_c} := t_w - 2 \cdot t_{cor} = 0.68\ in$

$b_{f_c} := b_f - 2 \cdot t_{cor} = 14.775\ in$ $t_{f_c} := t_f - 2 \cdot t_{cor} = 0.68\ in$

Calculate Corroded Section Properties

$$A_{s_c} := 2 \cdot (b_{f_c} \cdot t_{f_c}) + h \cdot t_{w_c} = 28.66\ in^2$$

$$S_{y_c} := \frac{b_{f_c}^{\ 2} \cdot (2\ t_{f_c})}{6} + \frac{((b_{f_c}) - (b_{f_c} - t_{w_c}))^3 \cdot (d_c - 2 \cdot t_{f_c})}{6 \cdot b_f} = 49.5\ in^3$$

$$Z_{y_c} := \frac{(b_{f_c}^{\ 2} \cdot t_{f_c})}{2} + .25 \cdot t_{w_c}^{\ 2} \cdot (d_c - 2\ t_{f_c}) = 75.7\ in^3$$

$$I_{y_c} := \frac{2 \cdot t_{f_c} \cdot b_{f_c}^{\ 3} + h \cdot t_{w_c}^{\ 3}}{12} = 365.87\ in^4$$

from L-pile calculation
$I_{LPILE} := 365.88\ in^4$

$$r_{y_c} := \sqrt{\frac{I_{y_c}}{A_{s_c}}} = 3.57\ in$$

From AASHTO 6.10.8.2.2-3

$$\lambda_f := \frac{b_f}{2 \cdot t_f} = 9.255$$

$$\lambda_w := \frac{h}{t_w} = 15.64$$

From AASHTO Table 6.9.4.2.1-1

$k_f := 0.56$ $k_w := 1.49$

Check

$\lambda_f \le k_f \cdot \sqrt{\frac{E}{f_y}} = 1$ $\lambda_f = 9.255$ $k_f \cdot \sqrt{\frac{E}{f_y}} = 13.487$ *ok*

$\lambda_w \le k_w \cdot \sqrt{\frac{E}{f_y}} = 1$ $\lambda_w = 15.64$ $k_w \cdot \sqrt{\frac{E}{f_y}} = 35.884$ *ok*

Total thermal deflection for bridge deck
Per Structural Designer

$\delta_{total} := 1.04\ in$

$\delta_{per_abut} := \frac{\delta_{total}}{2} = 0.52\ in$

$\theta := 0$ Assume no rotation $P_u = 349\ kip$ From Structural Engineer

From L-pile model run output for bending of pile in the Weak Axis

$M_{u.top} := 1719.2\ in \cdot kip$ $M_{u.2nd} := 671.73\ kip \cdot in$ $V_u := 28.74\ kip$

Obtain unbraced Lengths from L-pile

$l_{b.top} := 5.5 \cdot ft = 66\ in$ $l_{b.2nd} := 17.8 \cdot ft = 214\ in$

Calculate Slenderness Factor, λ

$k_{top} := 1.2$ Fixed- pined $k_{2nd} := 1.0$ Pinned- pined

$\lambda_{top} := \left(\frac{k_{top} \cdot l_{b.top}}{r_{y_c} \cdot \pi}\right)^2 \cdot \frac{f_y}{E} = 0.086$ $\lambda_{2nd} := \left(\frac{k_{2nd} \cdot l_{b.2nd}}{r_{y_c} \cdot \pi}\right)^2 \cdot \frac{f_y}{E} = 0.624$

Check Nominal Compressive Resistance

For $\lambda \le 2.25$

$P_{n.top} := 0.66^{\lambda_{top}} \cdot f_y \cdot A_{s_c} = \left(1.4 \cdot 10^3\right)\ kip$ AASHTO 6.9.5.1-1

$P_{r.top} := \phi_{cu} \cdot P_{n.top} = 967.8\ kip$

$P_{n.2nd} := 0.66^{\lambda_{2nd}} \cdot f_y \cdot A_{s_c} = \left(1.1 \cdot 10^3\right)\ kip$ AASHTO 6.9.5.1-1

$P_{r.2nd} := \phi_{cu} \cdot P_{n.2nd} = 773.8\ kip$

$P_{n.bot} := 0.66^0 \cdot f_y \cdot A_{s_c} = \left(1.4 \cdot 10^3\right)\ kip$ Full Braced λ=0

$P_{r.bot} := \phi_{cl} \cdot P_{n.bot} = 716.4\ kip$

Check Ratio of Applied Load to Structural Resistance Should NOT be Less than 0.2

$\frac{P_u}{P_{r.top}} = 0.361$ $\frac{P_u}{P_{r.2nd}} = 0.451$ $\frac{P_u}{P_{r.bot}} = 0.487$

Compute Nominal Flexural Resistance

$\lambda_{pf} := 0.38 \cdot \sqrt{\frac{E}{f_y}} = 9.152$ AASHTO Eq. 6.12.2.2.1-4

$\lambda_{rf} := 0.83 \cdot \sqrt{\frac{E}{f_y}} = 19.989$ AASHTO Eq. 6.12.2.2.1-5

$\lambda_f := \frac{b_f}{2\ t_f} = 9.255$

Calculate Nominal Flexural Resistance (AASHTO Eq. 6.12.2.2.1-1)

$$M_{ny} := \begin{cases} \text{if } \lambda_f \le \lambda_{pf} \\ \quad f_y \cdot Z_{y_c} \\ \text{if } \lambda_{pf} < \lambda_f \le \lambda_{rf} \\ \quad \left(1 - \left(1 - \frac{S_{y_c}}{(Z_{y_c})}\right) \cdot \left(\frac{\lambda_f - \lambda_{pf}}{.45 \cdot \sqrt{\frac{E}{f_y}}}\right)\right) \cdot f_y \cdot Z_{y_c} \\ \text{if } \lambda_f > \lambda_{rf} \\ \quad \text{“Pick New Pile Section”} \end{cases} = 3772.2\ kip \cdot in$$

$M_{ry} := \phi_f \cdot M_{ny} = 3772.2\ kip \cdot in$ AASHTO Eq. 6.12.1.2.1-1

Check Pile Size

$$PileSizeCheck := \begin{cases} \text{if } \frac{P_u}{P_{r.top}} \ge 0.2 \\ \quad \text{“Pile Size OK”} \\ \text{if } \frac{P_u}{P_{r.top}} < 0.2 \\ \quad \text{“Pile Size Too Big”} \end{cases} = \text{“Pile Size OK”}$$

Find Moment Causing Plastic Hinge

Solving AASHTO Eq. 6.9.2.2-2 for Mu

$$M_{uy} := \frac{9}{8} \cdot \left(1 - \frac{P_u}{P_{r.top}}\right) M_{ry} = 2713.4\ kip \cdot in$$

$$M_{p'} := M_{uy} = 2713.4\ kip \cdot in$$

Check If Pile is in Plastic Range

if $M_{u.top} > M_{p'}$
  "Plastic Hinge Formed/Iterate in LPile"
if $M_{u.top} \le M_{p'}$
  "Pile Not in Plastic Range/Continue"
= "Pile Not in Plastic Range/Continue"

From L-pile model run output for bending of pile in the Weak Axis with plastic hinge

$M_{u.top} := 2713.4\ in \cdot kip$ $M_{u.2nd} := 776.1\ kip \cdot in$ $V_u := 39.1\ kip$

Obtain unbraced Lengths from L-pile

$l_{b.top} := 6.6 \cdot ft = 79\ in$ $l_{b.2nd} := 18.6 \cdot ft = 223\ in$

Calculate Slenderness Factor λ

$k_{top} := 2.1$ Plastic Hinge

$k_{2nd} := 1.0$ Pinned-Pinned

$$\lambda_{top} := \left(\frac{k_{top} \cdot l_{b.top}}{r_{y_c} \cdot \pi}\right)^2 \cdot \frac{f_y}{E} = 0.378$$

$$\lambda_{2nd} := \left(\frac{k_{2nd} \cdot l_{b.2nd}}{r_{y_c} \cdot \pi}\right)^2 \cdot \frac{f_y}{E} = 0.682$$

Check Nominal Compressive Resistance

For $\lambda \le 2.25$

$P_{n.top} := 0.66^{\lambda_{top}} \cdot f_y \cdot A_{s_c} = 1224.27\ kip$ AASHTO 6.9.5.1-1

$P_{r.top} := \phi_{cu} \cdot P_{n.top} = 856.99\ kip$

$P_{n.2nd} := 0.66^{\lambda_{2nd}} \cdot f_y \cdot A_{s_c} = 1079.38\ kip$ AASHTO 6.9.5.1-1

$P_{r.2nd} := \phi_{cu} \cdot P_{n.2nd} = 755.565\ kip$

$P_{n.bot} := 0.66^{0} \cdot f_y \cdot A_{s_c} = 1432.76\ kip$ Full Braced $\lambda = 0$

$P_{r.bot} := \phi_{cl} \cdot P_{n.bot} = 716.38\ kip$

Check Ratio of Applied Load to Structural Resistance Should NOT be Less than 0.2

$\frac{P_u}{P_{r.top}} = 0.407$ $\frac{P_u}{P_{r.2nd}} = 0.462$ $\frac{P_u}{P_{r.bot}} = 0.487$

Check Pile Size

$$PileSizeCheck := \begin{cases} \text{if } \frac{P_u}{P_{r.top}} \geq 0.2 \\ \quad \text{"Pile Size OK"} \\ \text{if } \frac{P_u}{P_{r.top}} < 0.2 \\ \quad \text{"Pile Size Too Big"} \end{cases} = \text{"Pile Size OK"}$$

Check Second Segment of Pile for Combined Stress

$$\frac{P_u}{2\ P_{r.2nd}} + \frac{M_{u.2nd}}{M_{ry}} = 0.437$$

$$\frac{P_u}{P_{r.2nd}} + \frac{8}{9} \cdot \frac{M_{u.2nd}}{M_{ry}} = 0.645$$

AASHTO 6.9.2.2-1 and 6.9.2.2-2

$$Check1 := \begin{cases} \text{if } \frac{P_u}{P_{r.2nd}} < 0.2 \\ \quad \frac{P_u}{2\ P_{r.2nd}} + \frac{M_{u.2nd}}{M_{ry}} \\ \text{if } \frac{P_u}{P_{r.2nd}} \geq 0.2 \\ \quad \frac{P_u}{P_{r.2nd}} + \frac{8}{9} \cdot \frac{M_{u.2nd}}{M_{ry}} \end{cases} = 0.645$$

$$\begin{cases} \text{if } Check1 < 1 \\ \quad \text{"OK"} \\ \text{if } Check1 \geq 1 \\ \quad \text{"Pile Undersized"} \end{cases} = \text{"OK"}$$

Check Bottom Segment of Pile

$$Check2 := \frac{P_u}{P_{r.bot}} = 0.487$$

$$\left\| \begin{array}{l} \text{if } Check2 < 1 \\ \quad \text{"OK"} \\ \text{if } Check2 \geq 1 \\ \quad \text{"Pile Undersized""} \end{array} \right. = \text{"OK"}$$

Check Shear

AASHTO does not address weak axis shear - Use AISC Steel Manual

$K_v := 1.2$

$C_v := 1$

$A_w := 2\ b_f \cdot t_f = 23.989\ in^2$

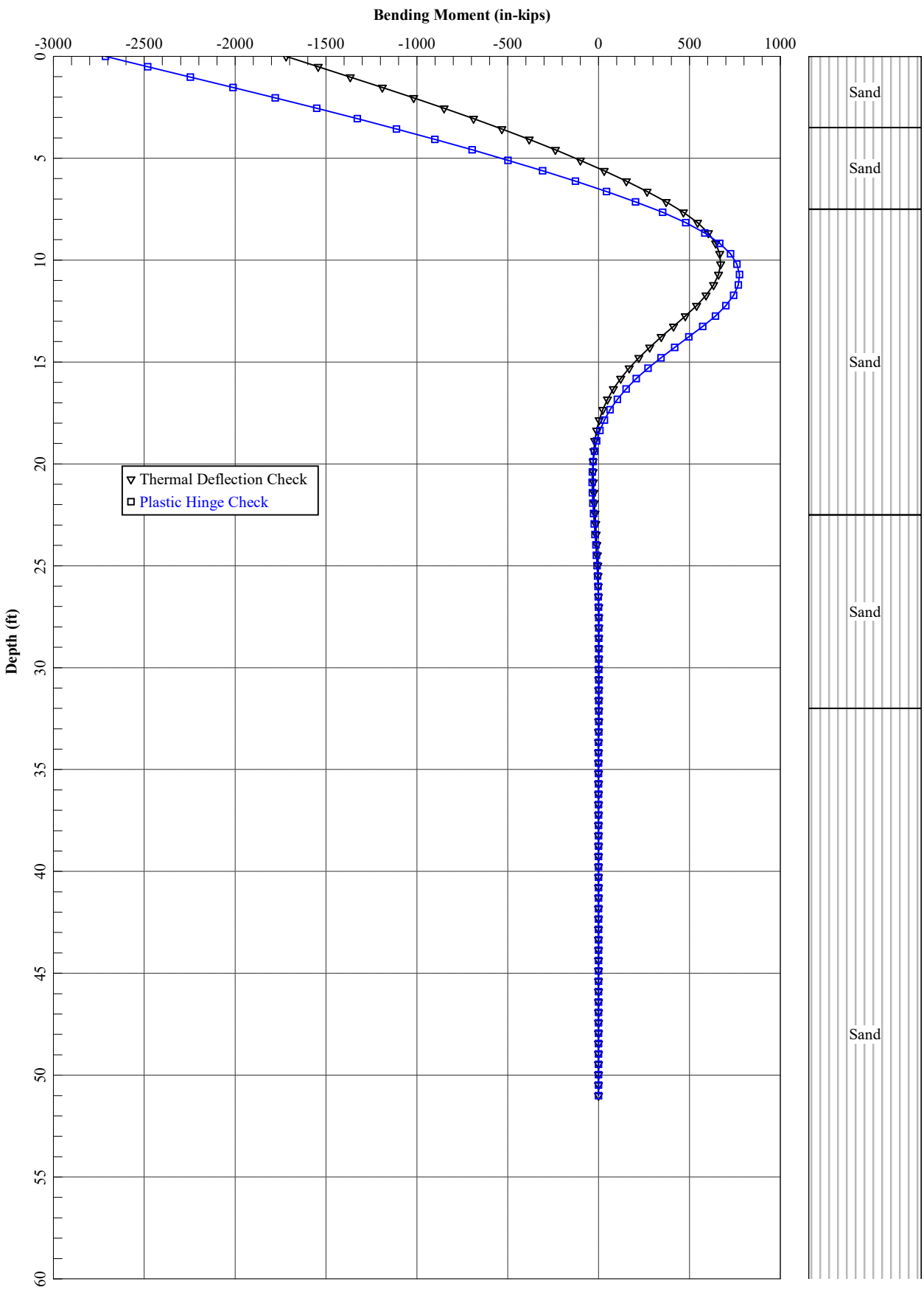
$V_n := 0.6\ f_y \cdot A_w \cdot C_v = 719.67\ kip$

$V_r := \phi_v \cdot V_n = 719.7\ kip$

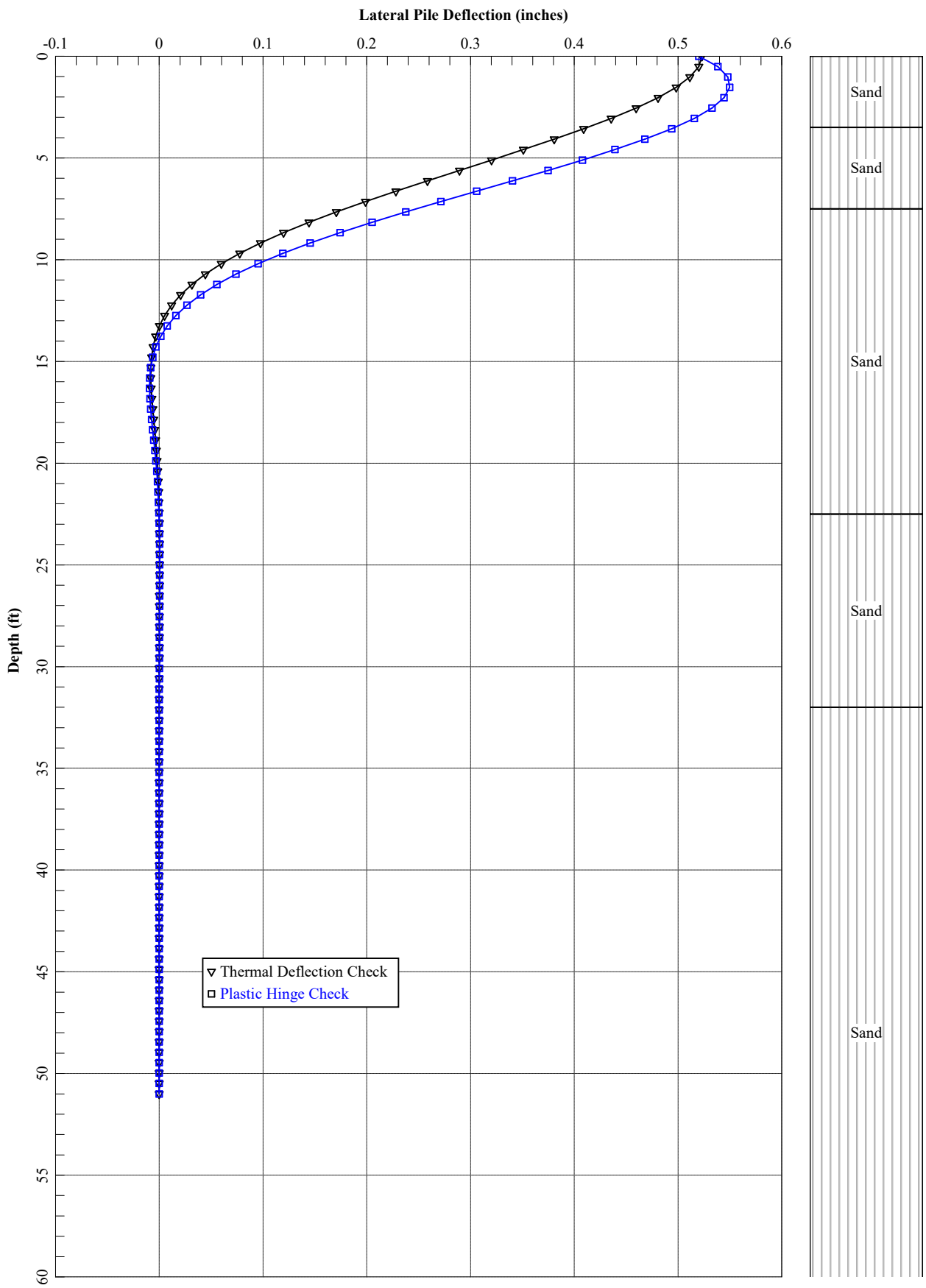
$$Check3 := \frac{V_u}{V_r} = 0.054$$

$$\left\| \begin{array}{l} \text{if } Check3 < 1 \\ \quad \text{"OK"} \\ \text{if } Check3 \geq 1 \\ \quad \text{"Pile Undersized"} \end{array} \right. = \text{"OK"}$$

Abutment No. 1



Abutment No. 1



Abutment No. 1

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

                     LPile for Windows, Version 2016-09.010

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

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--------------------------------------------------------------------------------
                             Files Used for Analysis
--------------------------------------------------------------------------------

Path to file locations:
\Users\mike.st.pierre\Desktop\LPile Output Files\20-1403-021882 Fort Kent\

Name of input data file:
Abutment 1 HP14x117.lp9d

Name of output report file:
Abutment 1 HP14x117.lp9o

Name of plot output file:
Abutment 1 HP14x117.lp9p

Name of runtime message file:
Abutment 1 HP14x117.lp9r



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

               Date:  June 10, 2021               Time:  16:59:01



--------------------------------------------------------------------------------
                                  Problem Title
--------------------------------------------------------------------------------

Perley Brook Bridge #3468 Replacement


WIN 021882


MaineDOT


MAS


Abutment No. 1 - HP14x117
```

```
--------------------------------------------------------------------------------
                          Program Options and Settings
--------------------------------------------------------------------------------

Computational Options:
 - Use unfactored loads in computations (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
 - 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
 - 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                                   =       51.000 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.

            Depth Below           Pile
Point        Pile Head          Diameter
 No.            feet             inches
-----      -------------     -------------
  1             0.000           14.0750
  2            51.000           14.0750


Input Structural Properties for Pile Sections:
----------------------------------------------

Pile Section No. 1:

   Section 1 is an elastic pile
   Cross-sectional Shape                               =   Weak H-Pile
   Length of section                                   =    51.000000 ft
   Flange Width                                        =    14.775000 in
   Section Depth                                       =    14.075000 in
   Flange Thickness                                    =     0.680000 in
   Web Thickness                                       =     0.680000 in
```

```
   Section Area                                        =    28.740200 sq. in
   Moment of Inertia                                   =   365.877563 in^4
   Elastic Modulus                                     =    29000000. psi



--------------------------------------------------------------------------------
                       Ground Slope and Pile Batter Angles
--------------------------------------------------------------------------------

Ground Slope Angle                                     =        0.000 degrees
                                                       =        0.000 radians

Pile Batter Angle                                      =        0.000 degrees
                                                       =        0.000 radians


--------------------------------------------------------------------------------
                       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        =     3.500000 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                      =    34.000000 deg.
   Friction angle at bottom of layer                   =    34.000000 deg.
   Subgrade k at top of layer                          =   125.000000 pci
   Subgrade k at bottom of layer                       =   125.000000 pci


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

   Distance from top of pile to top of layer           =     3.500000 ft
   Distance from top of pile to bottom of layer        =     7.500000 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                      =    29.000000 deg.
   Friction angle at bottom of layer                   =    29.000000 deg.
   Subgrade k at top of layer                          =    20.000000 pci
   Subgrade k at bottom of layer                       =    20.000000 pci


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

   Distance from top of pile to top of layer           =     7.500000 ft
   Distance from top of pile to bottom of layer        =    22.500000 ft
   Effective unit weight at top of layer               =    65.600000 pcf
   Effective unit weight at bottom of layer            =    65.600000 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                          =   125.000000 pci
   Subgrade k at bottom of layer                       =   125.000000 pci


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

   Distance from top of pile to top of layer           =    22.500000 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                      =    40.000000 deg.
   Friction angle at bottom of layer                   =    40.000000 deg.
   Subgrade k at top of layer                          =   125.000000 pci
   Subgrade k at bottom of layer                       =   125.000000 pci


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

```
   Distance from top of pile to top of layer          =    32.000000 ft
   Distance from top of pile to bottom of layer       =    64.000000 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                     =    42.000000 deg.
   Friction angle at bottom of layer                  =    42.000000 deg.
   Subgrade k at top of layer                         =   125.000000 pci
   Subgrade k at bottom of layer                      =   125.000000 pci


 (Depth of the lowest soil layer extends 13.000 ft below the pile tip)



--------------------------------------------------------------------------------
                        Summary of Input Soil Properties
--------------------------------------------------------------------------------

Layer         Soil Type          Layer      Effective    Angle of
Layer           Name             Depth       Unit Wt.    Friction        kpy
 Num.     (p-y Curve Type)        ft           pcf          deg.         pci
-----   -------------------   ----------   ----------   ----------   ----------
  1           Sand                 0.00      62.6000      34.0000     125.0000
          (Reese, et al.)        3.5000      62.6000      34.0000     125.0000
  2           Sand                3.5000      57.6000      29.0000      20.0000
          (Reese, et al.)        7.5000      57.6000      29.0000      20.0000
  3           Sand                7.5000      65.6000      36.0000     125.0000
          (Reese, et al.)       22.5000      65.6000      36.0000     125.0000
  4           Sand               22.5000      67.6000      40.0000     125.0000
          (Reese, et al.)       32.0000      67.6000      40.0000     125.0000
  5           Sand               32.0000      67.6000      42.0000     125.0000
          (Reese, et al.)       64.0000      67.6000      42.0000     125.0000


--------------------------------------------------------------------------------
                                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    Load         Condition               Condition            Axial Thrust      Compute Top y
 No.    Type             1                       2                 Force, lbs      vs. Pile Length
-----   ----   --------------------   ------------------------   ----------------   ---------------
   1     5     y =     0.520000 in    S =       0.0000 in/in           349000.          N.A.
   2     4     y =     0.520000 in    M =    -2713400. in-lbs          349000.          N.A.

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:

Moment-curvature properties were derived from elastic section properties

---

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	5565.
2	3.5000	3.5000	Yes	No	5565.	15491.
3	7.5000	7.5000	Yes	No	21056.	705291.
4	22.5000	22.5000	Yes	No	726346.	1768205.
5	32.0000	32.0000	Yes	No	2494551.	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 = 0.520000 inches
Rotation of pile head = 0.000E+00 radians
Axial load on pile head = 349000.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness in-lb^2	Soil Res. p lb/inch	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0.00	0.5230	-1719179.	28741.	0.00	45211.	1.06E+10	0.00	0.00	0.00
0.5100	0.5200	-1542985.	28511.	-9.41E-04	41822.	1.06E+10	-34.7299	408.7446	0.00
1.0200	0.5115	-1366190.	28171.	-0.00178	38421.	1.06E+10	-76.2421	912.1885	0.00
1.5300	0.4982	-1190567.	27578.	-0.00252	35043.	1.06E+10	-117.4564	1443.	0.00
2.0400	0.4807	-1017878.	26746.	-0.00315	31722.	1.06E+10	-154.6962	1969.	0.00
2.5500	0.4596	-849728.	25704.	-0.00369	28487.	1.06E+10	-185.6603	2472.	0.00
3.0600	0.4355	-687485.	24497.	-0.00414	25367.	1.06E+10	-208.9100	2936.	0.00
3.5700	0.4090	-532220.	23380.	-0.00449	22380.	1.06E+10	-156.1107	2336.	0.00
4.0800	0.3806	-382147.	22379.	-0.00475	19494.	1.06E+10	-170.8006	2747.	0.00
4.5900	0.3508	-237999.	21310.	-0.00493	16721.	1.06E+10	-178.7304	3118.	0.00
5.1000	0.3202	-100253.	20169.	-0.00503	14072.	1.06E+10	-193.9397	3706.	0.00
5.6100	0.2893	30353.	18935.	-0.00505	12727.	1.06E+10	-209.4156	4430.	0.00
6.1200	0.2584	153078.	17609.	-0.00500	15088.	1.06E+10	-223.9149	5302.	0.00
6.6300	0.2281	267227.	16195.	-0.00487	17283.	1.06E+10	-238.3919	6395.	0.00
7.1400	0.1988	372119.	14701.	-0.00469	19301.	1.06E+10	-249.7771	7690.	0.00
7.6500	0.1707	467197.	12535.	-0.00445	21130.	1.06E+10	-458.0121	16416.	0.00
8.1600	0.1444	544545.	9698.	-0.00416	22617.	1.06E+10	-468.9672	19882.	0.00
8.6700	0.1199	603657.	6821.	-0.00382	23754.	1.06E+10	-471.4409	24067.	0.00
9.1800	0.09754	644368.	3955.	-0.00346	24537.	1.06E+10	-464.9532	29172.	0.00
9.6900	0.07748	666870.	1158.	-0.00309	24970.	1.06E+10	-449.2080	35484.	0.00
10.2000	0.05976	671727.	-1514.	-0.00270	25064.	1.06E+10	-424.0747	43426.	0.00
10.7100	0.04442	659872.	-4004.	-0.00232	24836.	1.06E+10	-389.5406	53665.	0.00
11.2200	0.03141	632614.	-6253.	-0.00194	24311.	1.06E+10	-345.6021	67333.	0.00
11.7300	0.02063	591633.	-8205.	-0.00159	23523.	1.06E+10	-292.0186	86613.	0.00
12.2400	0.01194	538985.	-9769.	-0.00126	22510.	1.06E+10	-219.2876	112363.	0.00
12.7500	0.00516	477460.	-10742.	-9.71E-04	21327.	1.06E+10	-98.6158	117045.	0.00
13.2600	5.44E-05	411653.	-11047.	-7.15E-04	20061.	1.06E+10	-1.0822	121727.	0.00

13.7700	-0.00359	345299.	-10823.	-4.97E-04	18785.	1.06E+10	74.2433	126409.	0.00
14.2800	-0.00602	281300.	-10201.	-3.16E-04	17554.	1.06E+10	129.0429	131090.	0.00
14.7900	-0.00746	221787.	-9300.	-1.71E-04	16409.	1.06E+10	165.5313	135772.	0.00
15.3000	-0.00812	168201.	-8223.	-5.84E-05	15379.	1.06E+10	186.2508	140454.	0.00
15.8100	-0.00818	121384.	-7060.	2.51E-05	14478.	1.06E+10	193.8904	145136.	0.00
16.3200	-0.00781	81680.	-5882.	8.37E-05	13714.	1.06E+10	191.1331	149818.	0.00
16.8300	-0.00715	49033.	-4745.	1.21E-04	13086.	1.06E+10	180.5339	154499.	0.00
17.3400	-0.00632	23088.	-3689.	1.42E-04	12587.	1.06E+10	164.4283	159181.	0.00
17.8500	-0.00541	3273.	-2742.	1.50E-04	12206.	1.06E+10	144.8714	163863.	0.00
18.3600	-0.00449	-11120.	-1921.	1.48E-04	12357.	1.06E+10	123.6024	168545.	0.00
18.8700	-0.00360	-20869.	-1231.	1.38E-04	12545.	1.06E+10	102.0328	173227.	0.00
19.3800	-0.00280	-26772.	-669.6459	1.25E-04	12658.	1.06E+10	81.2533	177908.	0.00
19.8900	-0.00208	-29598.	-231.1238	1.08E-04	12713.	1.06E+10	62.0545	182590.	0.00
20.4000	-0.00147	-30064.	96.3364	9.11E-05	12722.	1.06E+10	44.9586	187272.	0.00
20.9100	-9.65E-04	-28808.	326.4959	7.41E-05	12697.	1.06E+10	30.2569	191954.	0.00
21.4200	-5.62E-04	-26384.	474.3167	5.82E-05	12651.	1.06E+10	18.0505	196636.	0.00
21.9300	-2.52E-04	-23251.	554.9232	4.39E-05	12590.	1.06E+10	8.2915	201317.	0.00
22.4400	-2.44E-05	-19779.	582.8077	3.15E-05	12524.	1.06E+10	0.8211	205999.	0.00
22.9500	1.33E-04	-16252.	571.2628	2.11E-05	12456.	1.06E+10	-4.5940	210681.	0.00
23.4600	2.34E-04	-12877.	532.0162	1.27E-05	12391.	1.06E+10	-8.2317	215363.	0.00
23.9700	2.89E-04	-9795.	475.0373	6.17E-06	12332.	1.06E+10	-10.3888	220045.	0.00
24.4800	3.09E-04	-7089.	408.4842	1.30E-06	12280.	1.06E+10	-11.3606	224726.	0.00
24.9900	3.05E-04	-4800.	338.7588	-2.13E-06	12236.	1.06E+10	-11.4255	229408.	0.00
25.5000	2.83E-04	-2934.	270.6405	-4.36E-06	12200.	1.06E+10	-10.8353	234090.	0.00
26.0100	2.51E-04	-1469.	207.4712	-5.63E-06	12172.	1.06E+10	-9.8082	238772.	0.00
26.5200	2.14E-04	-370.0391	151.3684	-6.16E-06	12150.	1.06E+10	-8.5260	243454.	0.00
27.0300	1.76E-04	410.0591	103.4482	-6.15E-06	12151.	1.06E+10	-7.1342	248135.	0.00
27.5400	1.39E-04	922.4459	64.0428	-5.77E-06	12161.	1.06E+10	-5.7434	252817.	0.00
28.0500	1.05E-04	1219.	32.9026	-5.15E-06	12167.	1.06E+10	-4.4331	257499.	0.00
28.5600	7.60E-05	1347.	9.3750	-4.41E-06	12169.	1.06E+10	-3.2556	262181.	0.00
29.0700	5.14E-05	1352.	-7.4434	-3.63E-06	12169.	1.06E+10	-2.2406	266863.	0.00
29.5800	3.15E-05	1272.	-18.5824	-2.87E-06	12168.	1.06E+10	-1.3996	271544.	0.00
30.0900	1.62E-05	1137.	-25.1018	-2.18E-06	12165.	1.06E+10	-0.7309	276226.	0.00
30.6000	4.86E-06	973.6481	-28.0206	-1.57E-06	12162.	1.06E+10	-0.2229	280908.	0.00
31.1100	-3.04E-06	800.7436	-28.2684	-1.06E-06	12159.	1.06E+10	0.1420	285590.	0.00
31.6200	-8.12E-06	632.1704	-26.6561	-6.47E-07	12155.	1.06E+10	0.3849	290272.	0.00
32.1300	-1.10E-05	477.2356	-23.8622	-3.27E-07	12152.	1.06E+10	0.5281	294953.	0.00
32.6400	-1.21E-05	341.4923	-20.4313	-9.06E-08	12150.	1.06E+10	0.5931	299635.	0.00
33.1500	-1.21E-05	227.5432	-16.7804	7.35E-08	12148.	1.06E+10	0.6000	304317.	0.00
33.6600	-1.12E-05	135.7859	-13.2118	1.78E-07	12146.	1.06E+10	0.5662	308999.	0.00
34.1700	-9.88E-06	65.0685	-9.9291	2.36E-07	12145.	1.06E+10	0.5066	313681.	0.00
34.6800	-8.32E-06	13.2446	-7.0541	2.59E-07	12144.	1.06E+10	0.4330	318362.	0.00
35.1900	-6.72E-06	-22.3796	-4.6446	2.56E-07	12144.	1.06E+10	0.3545	323044.	0.00
35.7000	-5.19E-06	-44.6996	-2.7099	2.37E-07	12144.	1.06E+10	0.2778	327726.	0.00
36.2100	-3.82E-06	-56.5608	-1.2256	2.08E-07	12144.	1.06E+10	0.2073	332408.	0.00
36.7200	-2.65E-06	-60.5882	-0.1454	1.74E-07	12144.	1.06E+10	0.1457	337090.	0.00
37.2300	-1.69E-06	-59.0833	0.5890	1.39E-07	12144.	1.06E+10	0.09429	341771.	0.00
37.7400	-9.40E-07	-53.9738	1.0404	1.07E-07	12144.	1.06E+10	0.05321	346453.	0.00
38.2500	-3.82E-07	-46.8047	1.2703	7.77E-08	12144.	1.06E+10	0.02192	351135.	0.00
38.7600	1.07E-08	-38.7569	1.3355	5.30E-08	12144.	1.06E+10	-6.23E-04	355817.	0.00
39.2700	2.67E-07	-30.6847	1.2855	3.30E-08	12144.	1.06E+10	-0.01571	360499.	0.00
39.7800	4.14E-07	-23.1631	1.1618	1.74E-08	12144.	1.06E+10	-0.02472	365180.	0.00
40.2900	4.80E-07	-16.5388	0.9974	5.99E-09	12144.	1.06E+10	-0.02902	369862.	0.00
40.8000	4.88E-07	-10.9811	0.8172	-1.94E-09	12143.	1.06E+10	-0.02984	374544.	0.00
41.3100	4.56E-07	-6.5275	0.6394	-6.99E-09	12143.	1.06E+10	-0.02828	379226.	0.00
41.8200	4.02E-07	-3.1251	0.4757	-9.78E-09	12143.	1.06E+10	-0.02522	383908.	0.00
42.3300	3.37E-07	-0.6634	0.3331	-1.09E-08	12143.	1.06E+10	-0.02138	388589.	0.00
42.8400	2.69E-07	0.9984	0.2148	-1.08E-08	12143.	1.06E+10	-0.01729	393271.	0.00
43.3500	2.05E-07	2.0115	0.1211	-9.91E-09	12143.	1.06E+10	-0.01332	397953.	0.00
43.8600	1.48E-07	2.5233	0.05063	-8.60E-09	12143.	1.06E+10	-0.00972	402635.	0.00
44.3700	9.96E-08	2.6679	5.99E-04	-7.10E-09	12143.	1.06E+10	-0.00663	407317.	0.00
44.8800	6.08E-08	2.5609	-0.03222	-5.59E-09	12143.	1.06E+10	-0.00410	411998.	0.00
45.3900	3.11E-08	2.2974	-0.05124	-4.19E-09	12143.	1.06E+10	-0.00212	416680.	0.00
45.9000	9.55E-09	1.9516	-0.05974	-2.97E-09	12143.	1.06E+10	-6.57E-04	421362.	0.00
46.4100	-5.16E-09	1.5788	-0.06066	-1.95E-09	12143.	1.06E+10	3.59E-04	426044.	0.00
46.9200	-1.43E-08	1.2175	-0.05648	-1.14E-09	12143.	1.06E+10	0.00101	430726.	0.00
47.4300	-1.91E-08	0.8924	-0.04924	-5.33E-10	12143.	1.06E+10	0.00136	435407.	0.00
47.9400	-2.08E-08	0.6171	-0.04050	-9.73E-11	12143.	1.06E+10	0.00150	440089.	0.00
48.4500	-2.03E-08	0.3971	-0.03140	1.95E-10	12143.	1.06E+10	0.00148	444771.	0.00
48.9600	-1.84E-08	0.2319	-0.02275	3.77E-10	12143.	1.06E+10	0.00135	449453.	0.00
49.4700	-1.57E-08	0.1171	-0.01504	4.77E-10	12143.	1.06E+10	0.00117	454135.	0.00
49.9800	-1.26E-08	0.04576	-0.00859	5.24E-10	12143.	1.06E+10	9.43E-04	458816.	0.00
50.4900	-9.29E-09	0.00971	-0.00355	5.40E-10	12143.	1.06E+10	7.04E-04	463498.	0.00

51.0000	-5.97E-09	0.00	0.00	5.43E-10	12143.	1.06E+10	4.56E-04	234090.	0.00

* The above values of total stress are combined axial and bending stresses.

Output Summary for Load Case No. 1:

```
Pile-head deflection             =     0.52303431 inches
Computed slope at pile head      =       0.000000 radians
Maximum bending moment           =      -1719179. inch-lbs
Maximum shear force              =         28741. 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 =              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                              =     0.520000 inches
Moment at pile head                                    =   -2713400.0 in-lbs
Axial load at pile head                                =     349000.0 lbs
```

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness in-lb^2	Soil Res. p lb/inch	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0.00	0.5200	-2713400.	39092.	0.00379	64334.	1.06E+10	0.00	0.00	0.00
0.5100	0.5384	-2480587.	38985.	0.00230	59856.	1.06E+10	-34.9717	397.5054	0.00
1.0200	0.5481	-2246029.	38641.	9.32E-04	55345.	1.06E+10	-77.3939	864.1784	0.00
1.5300	0.5498	-2011602.	38035.	-2.96E-04	50836.	1.06E+10	-120.8078	1345.	0.00
2.0400	0.5445	-1779222.	37169.	-0.00139	46366.	1.06E+10	-162.0833	1822.	0.00
2.5500	0.5328	-1550720.	36063.	-0.00235	41971.	1.06E+10	-199.2742	2289.	0.00
3.0600	0.5157	-1327772.	34755.	-0.00318	37682.	1.06E+10	-228.2948	2709.	0.00
3.5700	0.4939	-1111738.	33525.	-0.00388	33527.	1.06E+10	-173.5293	2150.	0.00
4.0800	0.4682	-900835.	32402.	-0.00446	29470.	1.06E+10	-193.6544	2531.	0.00
4.5900	0.4393	-696075.	31174.	-0.00492	25532.	1.06E+10	-207.4402	2890.	0.00
5.1000	0.4079	-498227.	29841.	-0.00527	21726.	1.06E+10	-228.3944	3427.	0.00
5.6100	0.3748	-308319.	28379.	-0.00550	18074.	1.06E+10	-249.4049	4072.	0.00
6.1200	0.3406	-127373.	26793.	-0.00563	14593.	1.06E+10	-268.8082	4830.	0.00
6.6300	0.3059	43662.	25091.	-0.00565	12983.	1.06E+10	-287.2917	5747.	0.00
7.1400	0.2714	203883.	23286.	-0.00558	16065.	1.06E+10	-302.6021	6823.	0.00
7.6500	0.2376	352518.	20647.	-0.00542	18924.	1.06E+10	-559.9736	14422.	0.00
8.1600	0.2051	479747.	17157.	-0.00518	21371.	1.06E+10	-580.5986	17325.	0.00
8.6700	0.1742	584638.	13569.	-0.00487	23389.	1.06E+10	-591.7910	20786.	0.00
9.1800	0.1455	666643.	9944.	-0.00451	24966.	1.06E+10	-592.8273	24943.	0.00
9.6900	0.1190	725624.	6345.	-0.00411	26100.	1.06E+10	-583.2144	29987.	0.00
10.2000	0.09516	761866.	2839.	-0.00368	26797.	1.06E+10	-562.6788	36189.	0.00
10.7100	0.07398	776095.	-508.1507	-0.00324	27071.	1.06E+10	-531.1476	43942.	0.00
11.2200	0.05553	769474.	-3629.	-0.00279	26944.	1.06E+10	-488.6995	53856.	0.00
11.7300	0.03981	743602.	-6457.	-0.00235	26446.	1.06E+10	-435.4582	66944.	0.00
12.2400	0.02671	700503.	-8926.	-0.00194	25617.	1.06E+10	-371.3546	85089.	0.00
12.7500	0.01608	642633.	-10966.	-0.00155	24504.	1.06E+10	-295.5305	112464.	0.00
13.2600	0.00772	572901.	-12341.	-0.00120	23163.	1.06E+10	-153.6139	121727.	0.00
13.7700	0.00139	496711.	-12898.	-8.92E-04	21697.	1.06E+10	-28.6401	126409.	0.00
14.2800	-0.00320	418836.	-12777.	-6.28E-04	20199.	1.06E+10	68.4715	131090.	0.00
14.7900	-0.00630	343010.	-12139.	-4.08E-04	18741.	1.06E+10	139.7955	135772.	0.00
15.3000	-0.00820	271997.	-11136.	-2.31E-04	17375.	1.06E+10	188.0817	140454.	0.00
15.8100	-0.00913	207693.	-9898.	-9.27E-05	16138.	1.06E+10	216.4959	145136.	0.00
16.3200	-0.00933	151242.	-8537.	1.08E-05	15052.	1.06E+10	228.3915	149818.	0.00
16.8300	-0.00900	103159.	-7143.	8.42E-05	14127.	1.06E+10	227.1163	154499.	0.00
17.3400	-0.00830	63456.	-5787.	1.32E-04	13364.	1.06E+10	215.8598	159181.	0.00
17.8500	-0.00738	31759.	-4522.	1.60E-04	12754.	1.06E+10	197.5389	163863.	0.00
18.3600	-0.00634	7422.	-3383.	1.71E-04	12286.	1.06E+10	174.7207	168545.	0.00
18.8700	-0.00528	-10380.	-2391.	1.70E-04	12343.	1.06E+10	149.5798	173227.	0.00
19.3800	-0.00426	-22567.	-1554.	1.61E-04	12577.	1.06E+10	123.8827	177908.	0.00
19.8900	-0.00332	-30087.	-871.9096	1.45E-04	12722.	1.06E+10	98.9972	182590.	0.00
20.4000	-0.00248	-33861.	-336.6691	1.27E-04	12795.	1.06E+10	75.9181	187272.	0.00

20.9100	-0.00176	-34750.	64.8798	1.07E-04	12812.	1.06E+10	55.3071	191954.	0.00
21.4200	-0.00117	-33525.	348.9897	8.76E-05	12788.	1.06E+10	37.5393	196636.	0.00
21.9300	-6.92E-04	-30852.	533.4877	6.90E-05	12737.	1.06E+10	22.7541	201317.	0.00
22.4400	-3.24E-04	-27290.	636.4861	5.22E-05	12668.	1.06E+10	10.9055	205999.	0.00
22.9500	-5.26E-05	-23285.	675.3968	3.76E-05	12591.	1.06E+10	1.8104	210681.	0.00
23.4600	1.37E-04	-19184.	666.2261	2.54E-05	12512.	1.06E+10	-4.8074	215363.	0.00
23.9700	2.58E-04	-15239.	623.1187	1.55E-05	12436.	1.06E+10	-9.2800	220045.	0.00
24.4800	3.26E-04	-11623.	558.1146	7.71E-06	12367.	1.06E+10	-11.9632	224726.	0.00
24.9900	3.52E-04	-8440.	481.0785	1.92E-06	12306.	1.06E+10	-13.2120	229408.	0.00
25.5000	3.49E-04	-5742.	399.7617	-2.17E-06	12254.	1.06E+10	-13.3621	234090.	0.00
26.0100	3.26E-04	-3538.	319.9613	-4.84E-06	12211.	1.06E+10	-12.7165	238772.	0.00
26.5200	2.90E-04	-1805.	245.7419	-6.38E-06	12178.	1.06E+10	-11.5383	243454.	0.00
27.0300	2.48E-04	-502.8451	179.6919	-7.05E-06	12153.	1.06E+10	-10.0467	248135.	0.00
27.5400	2.04E-04	424.0901	123.1922	-7.07E-06	12151.	1.06E+10	-8.4172	252817.	0.00
28.0500	1.61E-04	1035.	76.6785	-6.65E-06	12163.	1.06E+10	-6.7833	257499.	0.00
28.5600	1.22E-04	1391.	39.8843	-5.95E-06	12170.	1.06E+10	-5.2409	262181.	0.00
29.0700	8.84E-05	1549.	12.0565	-5.10E-06	12173.	1.06E+10	-3.8531	266863.	0.00
29.5800	5.99E-05	1560.	-7.8611	-4.21E-06	12173.	1.06E+10	-2.6559	271544.	0.00
30.0900	3.69E-05	1471.	-21.0793	-3.33E-06	12172.	1.06E+10	-1.6637	276226.	0.00
30.6000	1.91E-05	1317.	-28.8468	-2.53E-06	12169.	1.06E+10	-0.8746	280908.	0.00
31.1100	5.90E-06	1128.	-32.3653	-1.82E-06	12165.	1.06E+10	-0.2752	285590.	0.00
31.6200	-3.28E-06	928.3004	-32.7316	-1.23E-06	12161.	1.06E+10	0.1555	290272.	0.00
32.1300	-9.18E-06	732.9536	-30.9024	-7.52E-07	12157.	1.06E+10	0.4423	294953.	0.00
32.6400	-1.25E-05	553.2689	-27.6782	-3.81E-07	12154.	1.06E+10	0.6114	299635.	0.00
33.1500	-1.38E-05	395.8024	-23.7005	-1.08E-07	12151.	1.06E+10	0.6885	304317.	0.00
33.6600	-1.38E-05	263.6355	-19.4605	8.24E-08	12148.	1.06E+10	0.6971	308999.	0.00
34.1700	-1.28E-05	157.2540	-15.3139	2.04E-07	12146.	1.06E+10	0.6580	313681.	0.00
34.6800	-1.13E-05	75.3233	-11.4996	2.71E-07	12145.	1.06E+10	0.5885	318362.	0.00
35.1900	-9.52E-06	15.3413	-8.1608	2.97E-07	12144.	1.06E+10	0.5026	323044.	0.00
35.7000	-7.68E-06	-25.8339	-5.3647	2.94E-07	12144.	1.06E+10	0.4111	327726.	0.00
36.2100	-5.92E-06	-51.5788	-3.1221	2.72E-07	12144.	1.06E+10	0.3218	332408.	0.00
36.7200	-4.35E-06	-65.2089	-1.4040	2.38E-07	12145.	1.06E+10	0.2397	337090.	0.00
37.2300	-3.01E-06	-69.7798	-0.1558	1.99E-07	12145.	1.06E+10	0.1682	341771.	0.00
37.7400	-1.92E-06	-67.9665	0.6907	1.59E-07	12145.	1.06E+10	0.1085	346453.	0.00
38.2500	-1.06E-06	-62.0067	1.2089	1.22E-07	12144.	1.06E+10	0.06088	351135.	0.00
38.7600	-4.25E-07	-53.6904	1.4707	8.85E-08	12144.	1.06E+10	0.02470	355817.	0.00
39.2700	2.18E-08	-44.3827	1.5424	6.02E-08	12144.	1.06E+10	-0.00128	360499.	0.00
39.7800	3.12E-07	-35.0683	1.4816	3.73E-08	12144.	1.06E+10	-0.01860	365180.	0.00
40.2900	4.78E-07	-26.4075	1.3363	1.95E-08	12144.	1.06E+10	-0.02888	369862.	0.00
40.8000	5.51E-07	-18.7960	1.1447	6.50E-09	12144.	1.06E+10	-0.03372	374544.	0.00
41.3100	5.58E-07	-12.4242	0.9358	-2.50E-09	12144.	1.06E+10	-0.03455	379226.	0.00
41.8200	5.20E-07	-7.3311	0.7302	-8.20E-09	12143.	1.06E+10	-0.03264	383908.	0.00
42.3300	4.57E-07	-3.4515	0.5415	-1.13E-08	12143.	1.06E+10	-0.02903	388589.	0.00
42.8400	3.82E-07	-0.6550	0.3775	-1.25E-08	12143.	1.06E+10	-0.02454	393271.	0.00
43.3500	3.04E-07	1.2231	0.2419	-1.23E-08	12143.	1.06E+10	-0.01979	397953.	0.00
43.8600	2.31E-07	2.3584	0.1348	-1.13E-08	12143.	1.06E+10	-0.01520	402635.	0.00
44.3700	1.66E-07	2.9215	0.05448	-9.77E-09	12143.	1.06E+10	-0.01105	407317.	0.00
44.8800	1.11E-07	3.0669	-0.00231	-8.04E-09	12143.	1.06E+10	-0.00750	411998.	0.00
45.3900	6.76E-08	2.9276	-0.03936	-6.32E-09	12143.	1.06E+10	-0.00460	416680.	0.00
45.9000	3.41E-08	2.6122	-0.06064	-4.72E-09	12143.	1.06E+10	-0.00235	421362.	0.00
46.4100	9.88E-09	2.2055	-0.06994	-3.33E-09	12143.	1.06E+10	-6.88E-04	426044.	0.00
46.9200	-6.60E-09	1.7704	-0.07062	-2.18E-09	12143.	1.06E+10	4.64E-04	430726.	0.00
47.4300	-1.68E-08	1.3504	-0.06554	-1.28E-09	12143.	1.06E+10	0.00120	435407.	0.00
47.9400	-2.23E-08	0.9736	-0.05697	-6.12E-10	12143.	1.06E+10	0.00160	440089.	0.00
48.4500	-2.43E-08	0.6557	-0.04666	-1.42E-10	12143.	1.06E+10	0.00177	444771.	0.00
48.9600	-2.40E-08	0.4031	-0.03585	1.63E-10	12143.	1.06E+10	0.00176	449453.	0.00
49.4700	-2.23E-08	0.2162	-0.02539	3.42E-10	12143.	1.06E+10	0.00166	454135.	0.00
49.9800	-1.98E-08	0.09093	-0.01577	4.31E-10	12143.	1.06E+10	0.00149	458816.	0.00
50.4900	-1.70E-08	0.02131	-0.00727	4.63E-10	12143.	1.06E+10	0.00129	463498.	0.00
51.0000	-1.42E-08	0.00	0.00	4.69E-10	12143.	1.06E+10	0.00108	234090.	0.00

* The above values of total stress are combined axial and bending stresses.

Output Summary for Load Case No. 2:

```
Pile-head deflection             =     0.52000000 inches
Computed slope at pile head      =     0.00379316 radians
Maximum bending moment           =      -2713400. inch-lbs
Maximum shear force              =         39092. 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 = 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	0.5200	S, rad	0.00	349000.	0.5230	0.00	28741.	-1719179.
2	y, in	0.5200	M, in-lb	-2713400.	349000.	0.5200	0.00379	39092.	-2713400.

Maximum pile-head deflection = 0.5230343120 inches
Maximum pile-head rotation = 0.0037931564 radians = 0.217332 deg.

The analysis ended normally.

Integral Abutment Pile Design - Abutment 2

Maximum Vertical Load From Structural Engineer
(provided by email on 05/17/2021)

$P_{u_total} := 2094\ kip$ Total per abutment

$N_p := 6$ Number of piles

$P_u := \frac{P_{u_total}}{N_p} = 349\ kip$ Vertical Load per Pile

AASHTO Reduction Factors

$\phi_{cl} := 0.5$ Hard driving with Tips - Lower Zone

$\phi_{cu} := 0.7$ Upper Zone of Pile (AASHTO 6.5.4.2)

$\phi_f := 1$ Flexural Resistance in Lower Zone of Pile

$\phi_v := 1$ Shear in Pile

Required Axial Resistance

$R_{n.upper} := \frac{P_u}{\phi_{cu}} = 498.571\ kip$

$R_{n.lower} := \frac{P_u}{\phi_{cl}} = 698\ kip$

$R_n := \max(R_{n.upper}, R_{n.lower}) = 698\ kip$

Required Area of Steel

$f_y := 50\ ksi$

$E := 29000\ ksi$

$A_{s.required} := \frac{R_n}{0.8 \cdot f_y} = 17.45\ in^2$

Select Pile Section Properties HP 14x117

$d := 14.2\ in$ $b_f := 14.9\ in$ $t_w := 0.805\ in$ $t_f := 0.805\ in$ $h := d - 2\ t_f = 12.59\ in$

Allow 1/16 inch section loss on all surfaces for corrosion $t_{cor} := 0.0625\ in$

$d_c := d - 2 \cdot t_{cor} = 14.075\ in$ $t_{w_c} := t_w - 2 \cdot t_{cor} = 0.68\ in$

$b_{f_c} := b_f - 2 \cdot t_{cor} = 14.775\ in$ $t_{f_c} := t_f - 2 \cdot t_{cor} = 0.68\ in$

Calculate Corroded Section Properties

$$A_{s_c} := 2 \cdot (b_{f_c} \cdot t_{f_c}) + h \cdot t_{w_c} = 28.66\ in^2$$

$$S_{y_c} := \frac{b_{f_c}^{\ 2} \cdot (2\ t_{f_c})}{6} + \frac{((b_{f_c}) - (b_{f_c} - t_{w_c}))^3 \cdot (d_c - 2 \cdot t_{f_c})}{6 \cdot b_f} = 49.5\ in^3$$

$$Z_{y_c} := \frac{(b_{f_c}^{\ 2} \cdot t_{f_c})}{2} + .25 \cdot t_{w_c}^{\ 2} \cdot (d_c - 2\ t_{f_c}) = 75.7\ in^3$$

$$I_{y_c} := \frac{2 \cdot t_{f_c} \cdot b_{f_c}^{\ 3} + h \cdot t_{w_c}^{\ 3}}{12} = 365.87\ in^4$$

from L-pile calculation
$I_{LPILE} := 365.88\ in^4$

$$r_{y_c} := \sqrt{\frac{I_{y_c}}{A_{s_c}}} = 3.57\ in$$

From AASHTO 6.10.8.2.2-3

$$\lambda_f := \frac{b_f}{2 \cdot t_f} = 9.255$$

$$\lambda_w := \frac{h}{t_w} = 15.64$$

From AASHTO Table 6.9.4.2.1-1

$k_f := 0.56$ $k_w := 1.49$

Check

$\lambda_f \le k_f \cdot \sqrt{\frac{E}{f_y}} = 1$ $\lambda_f = 9.255$ $k_f \cdot \sqrt{\frac{E}{f_y}} = 13.487$ *ok*

$\lambda_w \le k_w \cdot \sqrt{\frac{E}{f_y}} = 1$ $\lambda_w = 15.64$ $k_w \cdot \sqrt{\frac{E}{f_y}} = 35.884$ *ok*

Total thermal deflection for bridge deck
Per Structural Designer

$\delta_{total} := 1.04\ in$

$\delta_{per_abut} := \frac{\delta_{total}}{2} = 0.52\ in$

$\theta := 0$ Assume no rotation $P_u = 349\ kip$ From Structural Engineer

From L-pile model run output for bending of pile in the Weak Axis

$M_{u.top} := 1842.9\ in \cdot kip$ $M_{u.2nd} := 683.24\ kip \cdot in$ $V_u := 32.0\ kip$

Obtain unbraced Lengths from L-pile

$l_{b.top} := 5.2 \cdot ft = 62\ in$ $l_{b.2nd} := 17.7 \cdot ft = 212\ in$

Calculate Slenderness Factor, λ

$k_{top} := 1.2$ Fixed- pined $k_{2nd} := 1.0$ Pinned- pined

$\lambda_{top} := \left(\frac{k_{top} \cdot l_{b.top}}{r_{y_c} \cdot \pi}\right)^2 \cdot \frac{f_y}{E} = 0.077$ $\lambda_{2nd} := \left(\frac{k_{2nd} \cdot l_{b.2nd}}{r_{y_c} \cdot \pi}\right)^2 \cdot \frac{f_y}{E} = 0.617$

Check Nominal Compressive Resistance

For $\lambda \le 2.25$

$P_{n.top} := 0.66^{\lambda_{top}} \cdot f_y \cdot A_{s_c} = \left(1.4 \cdot 10^3\right)\ kip$ AASHTO 6.9.5.1-1

$P_{r.top} := \phi_{cu} \cdot P_{n.top} = 971.5\ kip$

$P_{n.2nd} := 0.66^{\lambda_{2nd}} \cdot f_y \cdot A_{s_c} = \left(1.1 \cdot 10^3\right)\ kip$ AASHTO 6.9.5.1-1

$P_{r.2nd} := \phi_{cu} \cdot P_{n.2nd} = 776\ kip$

$P_{n.bot} := 0.66^0 \cdot f_y \cdot A_{s_c} = \left(1.4 \cdot 10^3\right)\ kip$ Full Braced λ=0

$P_{r.bot} := \phi_{cl} \cdot P_{n.bot} = 716.4\ kip$

Check Ratio of Applied Load to Structural Resistance Should NOT be Less than 0.2

$\frac{P_u}{P_{r.top}} = 0.359$ $\frac{P_u}{P_{r.2nd}} = 0.45$ $\frac{P_u}{P_{r.bot}} = 0.487$

Compute Nominal Flexural Resistance

$\lambda_{pf} := 0.38 \cdot \sqrt{\frac{E}{f_y}} = 9.152$ AASHTO Eq. 6.12.2.2.1-4

$\lambda_{rf} := 0.83 \cdot \sqrt{\frac{E}{f_y}} = 19.989$ AASHTO Eq. 6.12.2.2.1-5

$\lambda_f := \frac{b_f}{2\ t_f} = 9.255$

Calculate Nominal Flexural Resistance (AASHTO Eq. 6.12.2.2.1-1)

$$M_{ny} := \begin{cases} \text{if } \lambda_f \le \lambda_{pf} \\ \quad f_y \cdot Z_{y_c} \\ \text{if } \lambda_{pf} < \lambda_f \le \lambda_{rf} \\ \quad \left(1 - \left(1 - \frac{S_{y_c}}{(Z_{y_c})}\right) \cdot \left(\frac{\lambda_f - \lambda_{pf}}{.45 \cdot \sqrt{\frac{E}{f_y}}}\right)\right) \cdot f_y \cdot Z_{y_c} \\ \text{if } \lambda_f > \lambda_{rf} \\ \quad \text{“Pick New Pile Section”} \end{cases} = 3772.2\ kip \cdot in$$

$M_{ry} := \phi_f \cdot M_{ny} = 3772.2\ kip \cdot in$ AASHTO Eq. 6.12.1.2.1-1

Check Pile Size

$$PileSizeCheck := \begin{cases} \text{if } \frac{P_u}{P_{r.top}} \ge 0.2 \\ \quad \text{“Pile Size OK”} \\ \text{if } \frac{P_u}{P_{r.top}} < 0.2 \\ \quad \text{“Pile Size Too Big”} \end{cases} = \text{“Pile Size OK”}$$

Find Moment Causing Plastic Hinge

Solving AASHTO Eq. 6.9.2.2-2 for Mu

$$M_{uy} := \frac{9}{8} \cdot \left(1 - \frac{P_u}{P_{r.top}}\right) M_{ry} = 2719.1\ kip \cdot in$$

$$M_{p'} := M_{uy} = 2719.14\ kip \cdot in$$

Check If Pile is in Plastic Range

$$\begin{array}{l} \text{if } M_{u.top} > M_{p'} \\ \quad \text{"Plastic Hinge Formed/Iterate in LPile"} \\ \text{if } M_{u.top} \le M_{p'} \\ \quad \text{"Pile Not in Plastic Range/Continue"} \end{array} = \text{"Pile Not in Plastic Range/Continue"}$$

From L-pile model run output for bending of pile in the Weak Axis with plastic hinge

$M_{u.top} := 2719.14\ in \cdot kip$ $\quad M_{u.2nd} := 762.99\ kip \cdot in$ $\quad V_u := 41.47\ kip$

Obtain unbraced Lengths from L-pile

$l_{b.top} := 6.15 \cdot ft = 74\ in$ $\quad l_{b.2nd} := 18.2 \cdot ft = 218\ in$

Calculate Slenderness Factor λ

$k_{top} := 2.1$ Plastic Hinge

$k_{2nd} := 1.0$ Pinned-Pinned

$$\lambda_{top} := \left(\frac{k_{top} \cdot l_{b.top}}{r_{y_c} \cdot \pi}\right)^2 \cdot \frac{f_y}{E} = 0.329$$

$$\lambda_{2nd} := \left(\frac{k_{2nd} \cdot l_{b.2nd}}{r_{y_c} \cdot \pi}\right)^2 \cdot \frac{f_y}{E} = 0.653$$

Check Nominal Compressive Resistance

For $\lambda \le 2.25$

$P_{n.top} := 0.66^{\lambda_{top}} \cdot f_y \cdot A_{s_c} = 1249.89\ kip$ AASHTO 6.9.5.1-1

$P_{r.top} := \phi_{cu} \cdot P_{n.top} = 874.92\ kip$

$P_{n.2nd} := 0.66^{\lambda_{2nd}} \cdot f_y \cdot A_{s_c} = 1092.46\ kip$ AASHTO 6.9.5.1-1

$P_{r.2nd} := \phi_{cu} \cdot P_{n.2nd} = 764.725\ kip$

$P_{n.bot} := 0.66^{0} \cdot f_y \cdot A_{s_c} = 1432.76\ kip$ Full Braced $\lambda = 0$

$P_{r.bot} := \phi_{cl} \cdot P_{n.bot} = 716.38\ kip$

Check Ratio of Applied Load to Structural Resistance Should NOT be Less than 0.2

$\frac{P_u}{P_{r.top}} = 0.399$ $\frac{P_u}{P_{r.2nd}} = 0.456$ $\frac{P_u}{P_{r.bot}} = 0.487$

Check Pile Size

$$PileSizeCheck := \begin{cases} \text{if } \frac{P_u}{P_{r.top}} \geq 0.2 \\ \quad \text{"Pile Size OK"} \\ \text{if } \frac{P_u}{P_{r.top}} < 0.2 \\ \quad \text{"Pile Size Too Big"} \end{cases} = \text{"Pile Size OK"}$$

Check Second Segment of Pile for Combined Stress

$$\frac{P_u}{2\ P_{r.2nd}} + \frac{M_{u.2nd}}{M_{ry}} = 0.43$$

$$\frac{P_u}{P_{r.2nd}} + \frac{8}{9} \cdot \frac{M_{u.2nd}}{M_{ry}} = 0.636$$

AASHTO 6.9.2.2-1 and 6.9.2.2-2

$$Check1 := \begin{cases} \text{if } \frac{P_u}{P_{r.2nd}} < 0.2 \\ \quad \frac{P_u}{2\ P_{r.2nd}} + \frac{M_{u.2nd}}{M_{ry}} \\ \text{if } \frac{P_u}{P_{r.2nd}} \geq 0.2 \\ \quad \frac{P_u}{P_{r.2nd}} + \frac{8}{9} \cdot \frac{M_{u.2nd}}{M_{ry}} \end{cases} = 0.636$$

$$\begin{cases} \text{if } Check1 < 1 \\ \quad \text{"OK"} \\ \text{if } Check1 \geq 1 \\ \quad \text{"Pile Undersized"} \end{cases} = \text{"OK"}$$

Check Bottom Segment of Pile

$$Check2 := \frac{P_u}{P_{r.bot}} = 0.487$$

$$\left\| \begin{array}{l} \text{if } Check2 < 1 \\ \quad \text{"OK"} \\ \text{if } Check2 \geq 1 \\ \quad \text{"Pile Undersized""} \end{array} \right. = \text{"OK"}$$

Check Shear

AASHTO does not address weak axis shear - Use AISC Steel Manual

$K_v := 1.2$

$C_v := 1$

$A_w := 2\ b_f \cdot t_f = 23.989\ in^2$

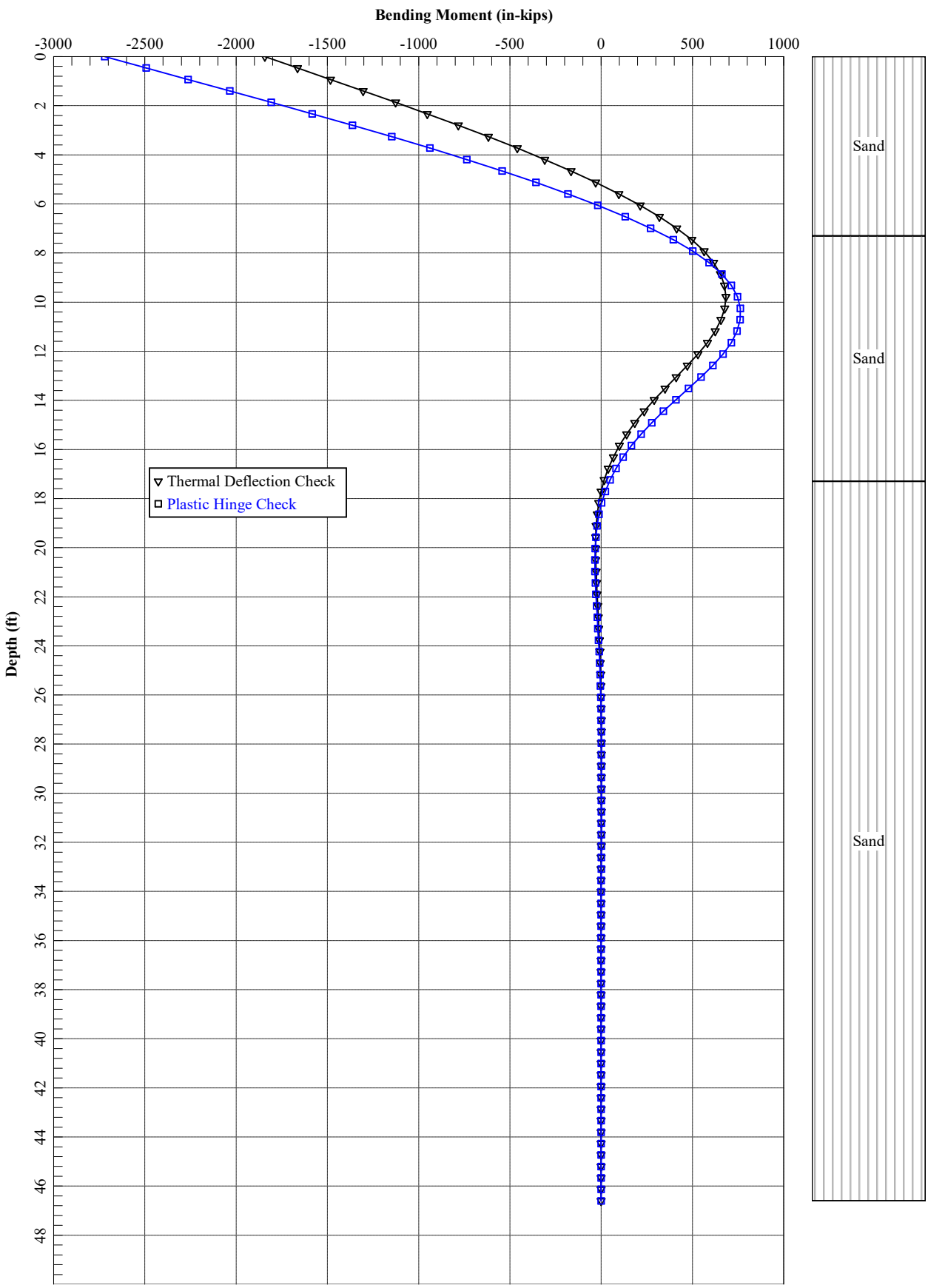
$V_n := 0.6\ f_y \cdot A_w \cdot C_v = 719.67\ kip$

$V_r := \phi_v \cdot V_n = 719.7\ kip$

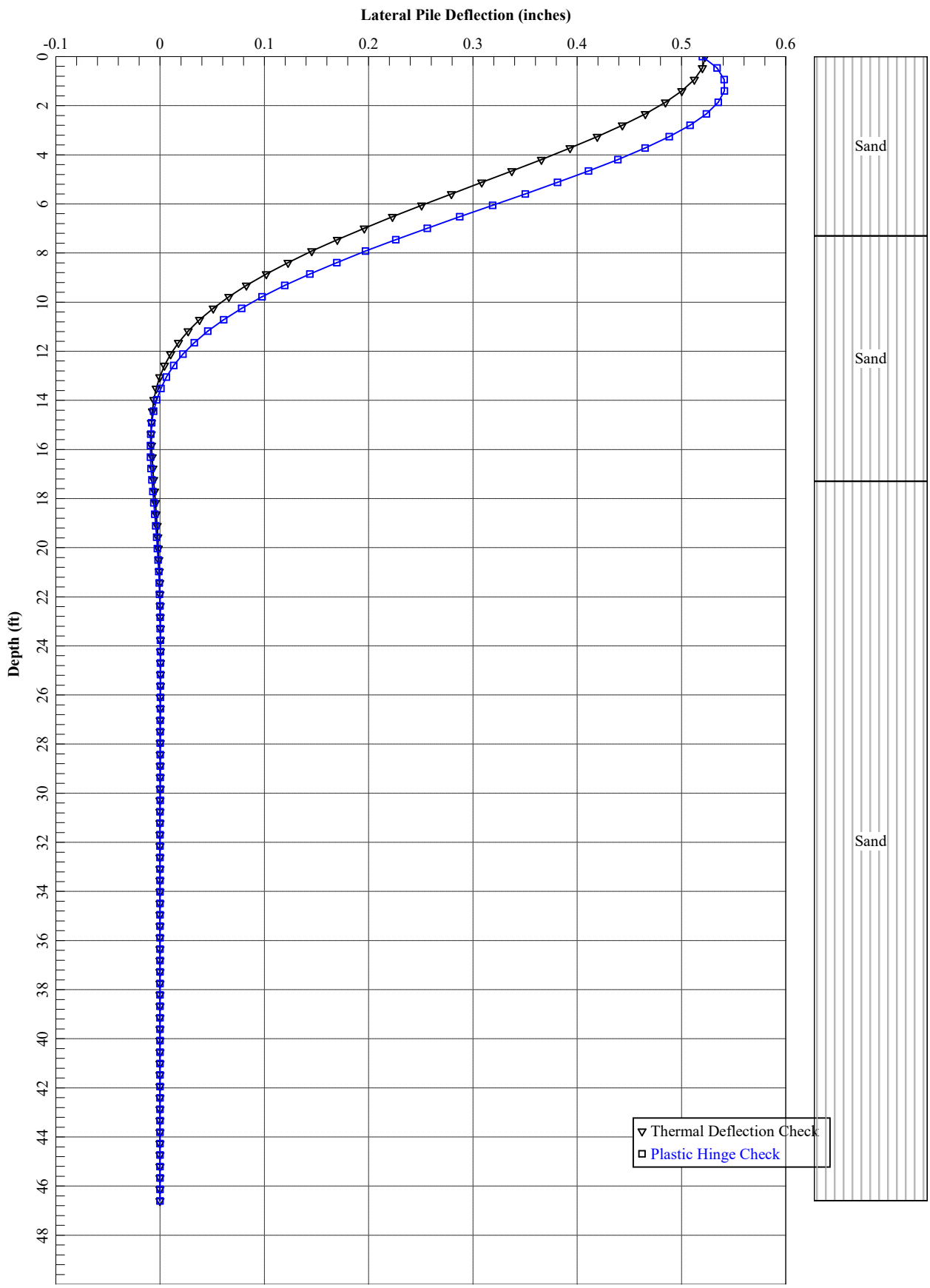
$$Check3 := \frac{V_u}{V_r} = 0.058$$

$$\left\| \begin{array}{l} \text{if } Check3 < 1 \\ \quad \text{"OK"} \\ \text{if } Check3 \geq 1 \\ \quad \text{"Pile Undersized"} \end{array} \right. = \text{"OK"}$$

Abutment No. 2



Abutment No. 2



Abutment No. 2

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                     LPile for Windows, Version 2016-09.010

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

Path to file locations:
\Users\mike.st.pierre\Desktop\LPile Output Files\20-1403-021882 Fort Kent\

Name of input data file:
Abutment 2 HP14x117.lp9d

Name of output report file:
Abutment 2 HP14x117.lp9o

Name of plot output file:
Abutment 2 HP14x117.lp9p

Name of runtime message file:
Abutment 2 HP14x117.lp9r



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

               Date:  June 11, 2021               Time:  14:43:40



--------------------------------------------------------------------------------
                                  Problem Title
--------------------------------------------------------------------------------

Perley Brook Bridge #3468 Replacement


WIN 021882


MaineDOT


MAS


Abutment No. 1 - HP14x117
```

```
--------------------------------------------------------------------------------
                          Program Options and Settings
--------------------------------------------------------------------------------

Computational Options:
 - Use unfactored loads in computations (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
 - 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
 - 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                                   =       46.600 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.

            Depth Below           Pile
Point        Pile Head          Diameter
 No.            feet             inches
-----      -------------     -------------
  1             0.000           14.0750
  2            46.600           14.0750


Input Structural Properties for Pile Sections:
----------------------------------------------

Pile Section No. 1:

   Section 1 is an elastic pile
   Cross-sectional Shape                               =   Weak H-Pile
   Length of section                                   =    46.600000 ft
   Flange Width                                        =    14.775000 in
   Section Depth                                       =    14.075000 in
   Flange Thickness                                    =     0.680000 in
   Web Thickness                                       =     0.680000 in
```

```
   Section Area                                        =    28.740200 sq. in
   Moment of Inertia                                   =   365.877563 in^4
   Elastic Modulus                                     =    29000000. psi



--------------------------------------------------------------------------------
                       Ground Slope and Pile Batter Angles
--------------------------------------------------------------------------------

Ground Slope Angle                                     =        0.000 degrees
                                                       =        0.000 radians

Pile Batter Angle                                      =        0.000 degrees
                                                       =        0.000 radians


--------------------------------------------------------------------------------
                       Soil and Rock Layering Information
--------------------------------------------------------------------------------

The soil profile is modelled using 3 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        =     7.300000 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                      =    34.000000 deg.
   Friction angle at bottom of layer                   =    34.000000 deg.
   Subgrade k at top of layer                          =   125.000000 pci
   Subgrade k at bottom of layer                       =   125.000000 pci


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

   Distance from top of pile to top of layer           =     7.300000 ft
   Distance from top of pile to bottom of layer        =    17.300000 ft
   Effective unit weight at top of layer               =    65.600000 pcf
   Effective unit weight at bottom of layer            =    65.600000 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                          =   125.000000 pci
   Subgrade k at bottom of layer                       =   125.000000 pci


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

   Distance from top of pile to top of layer           =    17.300000 ft
   Distance from top of pile to bottom of layer        =    46.600000 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                      =    40.000000 deg.
   Friction angle at bottom of layer                   =    40.000000 deg.
   Subgrade k at top of layer                          =   125.000000 pci
   Subgrade k at bottom of layer                       =   125.000000 pci


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



--------------------------------------------------------------------------------
                        Summary of Input Soil Properties
--------------------------------------------------------------------------------

Layer         Soil Type          Layer      Effective    Angle of
Layer           Name             Depth       Unit Wt.    Friction        kpy
 Num.     (p-y Curve Type)        ft           pcf          deg.         pci
-----   -------------------   ----------   ----------   ----------   ----------
  1            Sand                 0.00      62.6000      34.0000     125.0000
```

	(Reese, et al.)	7.3000	62.6000	34.0000	125.0000
2	Sand	7.3000	65.6000	36.0000	125.0000
	(Reese, et al.)	17.3000	65.6000	36.0000	125.0000
3	Sand	17.3000	67.6000	40.0000	125.0000
	(Reese, et al.)	46.6000	67.6000	40.0000	125.0000

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
1	5	y = 0.520000 in	S = 0.0000 in/in	349000.	N.A.
2	4	y = 0.520000 in	M = -2719140. in-lbs	349000.	N.A.

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:

Moment-curvature properties were derived from elastic section properties

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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	27441.
2	7.3000	7.3000	Yes	No	27441.	320659.
3	17.3000	17.3000	Yes	No	348100.	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 = 0.520000 inches
Rotation of pile head = 0.000E+00 radians
Axial load on pile head = 349000.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness in-lb^2	Soil Res. p lb/inch	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0.00	0.5227	-1842911.	32001.	0.00	47591.	1.06E+10	0.00	0.00	0.00
0.4660	0.5200	-1663595.	31809.	-9.24E-04	44142.	1.06E+10	-31.3274	336.8902	0.00
0.9320	0.5124	-1483548.	31529.	-0.00175	40679.	1.06E+10	-68.8834	751.7754	0.00
1.3980	0.5004	-1304128.	31038.	-0.00249	37228.	1.06E+10	-106.9924	1196.	0.00
1.8640	0.4846	-1126713.	30342.	-0.00313	33815.	1.06E+10	-141.6805	1635.	0.00
2.3300	0.4654	-952569.	29464.	-0.00368	30466.	1.06E+10	-172.2845	2070.	0.00
2.7960	0.4434	-782833.	28434.	-0.00413	27201.	1.06E+10	-196.2141	2474.	0.00
3.2620	0.4192	-618428.	27281.	-0.00450	24038.	1.06E+10	-216.2856	2885.	0.00
3.7280	0.3931	-460149.	26016.	-0.00479	20994.	1.06E+10	-235.9031	3356.	0.00
4.1940	0.3656	-308775.	24642.	-0.00499	18082.	1.06E+10	-255.8270	3913.	0.00
4.6600	0.3373	-165082.	23182.	-0.00511	15319.	1.06E+10	-266.3406	4416.	0.00
5.1260	0.3084	-29548.	21623.	-0.00517	12712.	1.06E+10	-291.1535	5279.	0.00
5.5920	0.2795	96911.	19932.	-0.00515	14007.	1.06E+10	-313.5447	6273.	0.00
6.0580	0.2509	213466.	18121.	-0.00507	16249.	1.06E+10	-334.2461	7451.	0.00
6.5240	0.2228	319350.	16192.	-0.00493	18286.	1.06E+10	-355.6801	8926.	0.00
6.9900	0.1958	413783.	14155.	-0.00473	20102.	1.06E+10	-372.9277	10653.	0.00
7.4560	0.1699	496129.	11841.	-0.00449	21686.	1.06E+10	-454.3927	14955.	0.00
7.9220	0.1455	563755.	9274.	-0.00421	22987.	1.06E+10	-464.0383	17833.	0.00
8.3880	0.1228	616291.	6671.	-0.00390	23997.	1.06E+10	-466.6542	21254.	0.00
8.8540	0.1019	653600.	4075.	-0.00357	24715.	1.06E+10	-461.8639	25356.	0.00
9.3200	0.08287	675794.	1527.	-0.00322	25142.	1.06E+10	-449.4184	30327.	0.00
9.7860	0.06587	683240.	-929.3706	-0.00286	25285.	1.06E+10	-429.1857	36435.	0.00
10.2520	0.05089	676562.	-3251.	-0.00250	25157.	1.06E+10	-401.1251	44080.	0.00
10.7180	0.03790	656645.	-5394.	-0.00215	24774.	1.06E+10	-365.2323	53895.	0.00
11.1840	0.02684	624632.	-7314.	-0.00181	24158.	1.06E+10	-321.4263	66968.	0.00
11.6500	0.01763	581925.	-8965.	-0.00149	23336.	1.06E+10	-269.2919	85438.	0.00
12.1160	0.01013	530199.	-10233.	-0.00120	22341.	1.06E+10	-184.0237	101629.	0.00
12.5820	0.00419	472172.	-10968.	-9.37E-04	21225.	1.06E+10	-79.0501	105538.	0.00
13.0480	-3.57E-04	411188.	-11170.	-7.05E-04	20052.	1.06E+10	6.9880	109447.	0.00
13.5140	-0.00369	350000.	-10941.	-5.04E-04	18875.	1.06E+10	74.8158	113355.	0.00
13.9800	-0.00599	290791.	-10380.	-3.35E-04	17737.	1.06E+10	125.6737	117264.	0.00
14.4460	-0.00744	235213.	-9578.	-1.96E-04	16667.	1.06E+10	161.1798	121173.	0.00
14.9120	-0.00819	184434.	-8615.	-8.59E-05	15691.	1.06E+10	183.2006	125082.	0.00
15.3780	-0.00840	139193.	-7562.	-6.03E-07	14821.	1.06E+10	193.7347	128991.	0.00
15.8440	-0.00820	99867.	-6475.	6.24E-05	14064.	1.06E+10	194.8110	132899.	0.00
16.3100	-0.00770	66531.	-5404.	1.06E-04	13423.	1.06E+10	188.4046	136808.	0.00
16.7760	-0.00701	39017.	-4384.	1.34E-04	12894.	1.06E+10	176.3706	140717.	0.00
17.2420	-0.00620	16979.	-3442.	1.49E-04	12470.	1.06E+10	160.3951	144626.	0.00
17.7080	-0.00534	-61.4240	-2597.	1.53E-04	12144.	1.06E+10	141.9621	148535.	0.00
18.1740	-0.00449	-12662.	-1858.	1.50E-04	12387.	1.06E+10	122.3358	152444.	0.00
18.6400	-0.00367	-21425.	-1229.	1.41E-04	12555.	1.06E+10	102.5547	156352.	0.00
19.1060	-0.00291	-26958.	-709.0289	1.28E-04	12662.	1.06E+10	83.4374	160261.	0.00
19.5720	-0.00223	-29855.	-292.3345	1.13E-04	12718.	1.06E+10	65.5949	164170.	0.00
20.0380	-0.00165	-30670.	29.3325	9.73E-05	12733.	1.06E+10	49.4505	168079.	0.00
20.5040	-0.00115	-29907.	266.1903	8.13E-05	12719.	1.06E+10	35.2625	171988.	0.00
20.9700	-7.36E-04	-28010.	429.5111	6.60E-05	12682.	1.06E+10	23.1498	175896.	0.00
21.4360	-4.08E-04	-25361.	530.9140	5.20E-05	12631.	1.06E+10	13.1173	179805.	0.00
21.9020	-1.55E-04	-22275.	581.7989	3.94E-05	12572.	1.06E+10	5.0818	183714.	0.00
22.3680	3.29E-05	-19008.	592.9177	2.85E-05	12509.	1.06E+10	-1.1051	187623.	0.00
22.8340	1.65E-04	-15755.	574.0702	1.94E-05	12446.	1.06E+10	-5.6357	191532.	0.00
23.3000	2.50E-04	-12663.	533.9106	1.19E-05	12387.	1.06E+10	-8.7275	195440.	0.00
23.7660	2.98E-04	-9830.	479.8489	5.97E-06	12332.	1.06E+10	-10.6079	199349.	0.00
24.2320	3.16E-04	-7320.	418.0292	1.45E-06	12284.	1.06E+10	-11.5021	203258.	0.00
24.6980	3.14E-04	-5161.	353.3696	-1.84E-06	12243.	1.06E+10	-11.6236	207167.	0.00
25.1640	2.96E-04	-3360.	289.6465	-4.09E-06	12208.	1.06E+10	-11.1672	211076.	0.00
25.6300	2.68E-04	-1906.	229.6101	-5.47E-06	12180.	1.06E+10	-10.3050	214984.	0.00
26.0960	2.35E-04	-770.9837	175.1182	-6.18E-06	12158.	1.06E+10	-9.1842	218893.	0.00

26.5620	1.99E-04	77.1373	127.2779	-6.36E-06	12145.	1.06E+10	-7.9261	222802.	0.00
27.0280	1.63E-04	677.3269	86.5867	-6.16E-06	12156.	1.06E+10	-6.6273	226711.	0.00
27.4940	1.30E-04	1070.	53.0669	-5.70E-06	12164.	1.06E+10	-5.3612	230620.	0.00
27.9600	9.97E-05	1293.	26.3879	-5.08E-06	12168.	1.06E+10	-4.1806	234528.	0.00
28.4260	7.32E-05	1385.	5.9753	-4.38E-06	12170.	1.06E+10	-3.1201	238437.	0.00
28.8920	5.07E-05	1377.	-8.8977	-3.65E-06	12170.	1.06E+10	-2.1993	242346.	0.00
29.3580	3.24E-05	1299.	-19.0339	-2.94E-06	12168.	1.06E+10	-1.4259	246255.	0.00
29.8240	1.78E-05	1176.	-25.2525	-2.29E-06	12166.	1.06E+10	-0.7982	250164.	0.00
30.2900	6.77E-06	1026.	-28.3439	-1.71E-06	12163.	1.06E+10	-0.3075	254073.	0.00
30.7560	-1.28E-06	865.2795	-29.0381	-1.21E-06	12160.	1.06E+10	0.05920	257981.	0.00
31.2220	-6.78E-06	705.7438	-27.9843	-7.98E-07	12157.	1.06E+10	0.3177	261890.	0.00
31.6880	-1.02E-05	555.4172	-25.7397	-4.65E-07	12154.	1.06E+10	0.4851	265799.	0.00
32.1540	-1.20E-05	419.6872	-22.7668	-2.08E-07	12151.	1.06E+10	0.5782	269708.	0.00
32.6200	-1.25E-05	301.6069	-19.4351	-1.84E-08	12149.	1.06E+10	0.6134	273617.	0.00
33.0860	-1.22E-05	202.3970	-16.0280	1.14E-07	12147.	1.06E+10	0.6052	277525.	0.00
33.5520	-1.13E-05	121.9030	-12.7521	2.00E-07	12146.	1.06E+10	0.5665	281434.	0.00
34.0180	-9.96E-06	58.9977	-9.7474	2.48E-07	12144.	1.06E+10	0.5081	285343.	0.00
34.4840	-8.49E-06	11.9212	-7.0993	2.66E-07	12143.	1.06E+10	0.4390	289252.	0.00
34.9500	-6.98E-06	-21.4404	-4.8488	2.64E-07	12144.	1.06E+10	0.3659	293161.	0.00
35.4160	-5.54E-06	-43.3370	-3.0032	2.47E-07	12144.	1.06E+10	0.2941	297069.	0.00
35.8820	-4.22E-06	-55.9913	-1.5456	2.21E-07	12144.	1.06E+10	0.2272	300978.	0.00
36.3480	-3.07E-06	-61.4837	-0.4423	1.90E-07	12144.	1.06E+10	0.1674	304887.	0.00
36.8140	-2.10E-06	-61.6779	0.3502	1.57E-07	12144.	1.06E+10	0.1160	308796.	0.00
37.2800	-1.31E-06	-58.1808	0.8799	1.26E-07	12144.	1.06E+10	0.07344	312705.	0.00
37.7460	-6.97E-07	-52.3273	1.1956	9.64E-08	12144.	1.06E+10	0.03947	316613.	0.00
38.2120	-2.35E-07	-45.1858	1.3436	7.07E-08	12144.	1.06E+10	0.01348	320522.	0.00
38.6780	9.37E-08	-37.5764	1.3661	4.89E-08	12144.	1.06E+10	-0.00544	324431.	0.00
39.1440	3.12E-07	-30.0984	1.2997	3.11E-08	12144.	1.06E+10	-0.01831	328340.	0.00
39.6100	4.41E-07	-23.1619	1.1752	1.70E-08	12144.	1.06E+10	-0.02621	332249.	0.00
40.0760	5.02E-07	-17.0212	1.0175	6.44E-09	12144.	1.06E+10	-0.03019	336157.	0.00
40.5420	5.13E-07	-11.8071	0.8458	-1.15E-09	12143.	1.06E+10	-0.03121	340066.	0.00
41.0080	4.89E-07	-7.5569	0.6744	-6.26E-09	12143.	1.06E+10	-0.03010	343975.	0.00
41.4740	4.43E-07	-4.2403	0.5131	-9.36E-09	12143.	1.06E+10	-0.02758	347884.	0.00
41.9400	3.85E-07	-1.7816	0.3684	-1.10E-08	12143.	1.06E+10	-0.02420	351793.	0.00
42.4060	3.21E-07	-0.07770	0.2437	-1.14E-08	12143.	1.06E+10	-0.02040	355702.	0.00
42.8720	2.57E-07	0.9882	0.1405	-1.12E-08	12143.	1.06E+10	-0.01651	359610.	0.00
43.3380	1.96E-07	1.5369	0.05877	-1.05E-08	12143.	1.06E+10	-0.01271	363519.	0.00
43.8040	1.39E-07	1.6866	-0.00227	-9.69E-09	12143.	1.06E+10	-0.00912	367428.	0.00
44.2700	8.72E-08	1.5492	-0.04397	-8.83E-09	12143.	1.06E+10	-0.00579	371337.	0.00
44.7360	4.00E-08	1.2293	-0.06766	-8.10E-09	12143.	1.06E+10	-0.00269	375246.	0.00
45.2020	-3.45E-09	0.8241	-0.07452	-7.56E-09	12143.	1.06E+10	2.34E-04	379154.	0.00
45.6680	-4.45E-08	0.4254	-0.06535	-7.23E-09	12143.	1.06E+10	0.00305	383063.	0.00
46.1340	-8.43E-08	0.1215	-0.04051	-7.09E-09	12143.	1.06E+10	0.00584	386972.	0.00
46.6000	-1.24E-07	0.00	0.00	-7.06E-09	12143.	1.06E+10	0.00865	195440.	0.00

* The above values of total stress are combined axial and bending stresses.

Output Summary for Load Case No. 1:

```
Pile-head deflection             =     0.52271566 inches
Computed slope at pile head      =       0.000000 radians
Maximum bending moment           =      -1842911. inch-lbs
Maximum shear force              =         32001. 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 =              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                              =     0.520000 inches
Moment at pile head                                    =   -2719140.0 in-lbs
Axial load at pile head                                =     349000.0 lbs
```

Depth X	Deflect. y	Bending Moment	Shear Force	Slope S	Total Stress	Bending Stiffness	Soil Res. p	Soil Spr. Es*h	Distrib. Lat. Load

feet	inches	in-lbs	lbs	radians	psi*	in-lb^2	lb/inch	lb/inch	lb/inch
0.00	0.5200	-2719140.	41472.	0.00325	64445.	1.06E+10	0.00	0.00	0.00
0.4660	0.5341	-2492168.	41383.	0.00187	60079.	1.06E+10	-31.5442	330.2369	0.00
0.9320	0.5409	-2263620.	41100.	6.20E-04	55683.	1.06E+10	-69.8633	722.2025	0.00
1.3980	0.5411	-2034928.	40598.	-5.13E-04	51284.	1.06E+10	-109.7953	1135.	0.00
1.8640	0.5352	-1807576.	39877.	-0.00153	46911.	1.06E+10	-147.7912	1544.	0.00
2.3300	0.5240	-1582987.	38953.	-0.00242	42591.	1.06E+10	-182.9358	1952.	0.00
2.7960	0.5082	-1362490.	37853.	-0.00319	38350.	1.06E+10	-210.3346	2315.	0.00
3.2620	0.4883	-1147168.	36609.	-0.00386	34209.	1.06E+10	-234.5484	2686.	0.00
3.7280	0.4650	-938002.	35228.	-0.00441	30185.	1.06E+10	-259.4564	3120.	0.00
4.1940	0.4390	-735984.	33703.	-0.00485	26300.	1.06E+10	-285.9673	3643.	0.00
4.6600	0.4108	-542151.	32055.	-0.00518	22571.	1.06E+10	-303.5011	4131.	0.00
5.1260	0.3810	-357251.	30269.	-0.00542	19015.	1.06E+10	-335.1073	4918.	0.00
5.5920	0.3502	-182463.	28314.	-0.00556	15653.	1.06E+10	-364.0990	5814.	0.00
6.0580	0.3188	-18872.	26204.	-0.00562	12506.	1.06E+10	-390.7511	6853.	0.00
6.5240	0.2874	132519.	23945.	-0.00559	14692.	1.06E+10	-417.1960	8118.	0.00
6.9900	0.2564	270728.	21548.	-0.00548	17351.	1.06E+10	-439.7804	9593.	0.00
7.4560	0.2261	394906.	18807.	-0.00530	19739.	1.06E+10	-540.6225	13370.	0.00
7.9220	0.1970	501772.	15736.	-0.00507	21795.	1.06E+10	-557.9443	15835.	0.00
8.3880	0.1694	590675.	12589.	-0.00478	23505.	1.06E+10	-567.5911	18733.	0.00
8.8540	0.1436	661222.	9411.	-0.00445	24862.	1.06E+10	-569.0324	22164.	0.00
9.3200	0.1197	713295.	6249.	-0.00409	25863.	1.06E+10	-561.8859	26259.	0.00
9.7860	0.09785	747063.	3151.	-0.00370	26513.	1.06E+10	-545.9174	31199.	0.00
10.2520	0.07824	762993.	168.0427	-0.00331	26819.	1.06E+10	-521.0302	37239.	0.00
10.7180	0.06088	761844.	-2651.	-0.00290	26797.	1.06E+10	-487.2393	44752.	0.00
11.1840	0.04577	744676.	-5257.	-0.00251	26467.	1.06E+10	-444.6171	54323.	0.00
11.6500	0.03285	712838.	-7599.	-0.00212	25854.	1.06E+10	-393.1818	66931.	0.00
12.1160	0.02203	667973.	-9628.	-0.00176	24991.	1.06E+10	-332.6566	84434.	0.00
12.5820	0.01318	612017.	-11254.	-0.00142	23915.	1.06E+10	-248.7836	105538.	0.00
13.0480	0.00614	547653.	-12286.	-0.00112	22677.	1.06E+10	-120.0954	109447.	0.00
13.5140	7.04E-04	478970.	-12661.	-8.45E-04	21356.	1.06E+10	-14.2747	113355.	0.00
13.9800	-0.00332	409348.	-12507.	-6.11E-04	20017.	1.06E+10	69.5387	117264.	0.00
14.4460	-0.00613	341480.	-11941.	-4.13E-04	18711.	1.06E+10	132.8308	121173.	0.00
14.9120	-0.00794	277414.	-11073.	-2.50E-04	17479.	1.06E+10	177.5459	125082.	0.00
15.3780	-0.00893	218615.	-10001.	-1.19E-04	16348.	1.06E+10	205.9288	128991.	0.00
15.8440	-0.00927	166030.	-8809.	-1.81E-05	15337.	1.06E+10	220.3834	132899.	0.00
16.3100	-0.00913	120166.	-7568.	5.74E-05	14455.	1.06E+10	223.3502	136808.	0.00
16.7760	-0.00863	81162.	-6336.	1.10E-04	13704.	1.06E+10	217.2045	140717.	0.00
17.2420	-0.00789	48868.	-5158.	1.45E-04	13083.	1.06E+10	204.1764	144626.	0.00
17.7080	-0.00701	22907.	-4067.	1.64E-04	12584.	1.06E+10	186.2926	148535.	0.00
18.1740	-0.00606	2749.	-3083.	1.70E-04	12196.	1.06E+10	165.3366	152444.	0.00
18.6400	-0.00511	-12242.	-2222.	1.68E-04	12379.	1.06E+10	142.8280	156352.	0.00
19.1060	-0.00419	-22754.	-1487.	1.59E-04	12581.	1.06E+10	120.0161	160261.	0.00
19.5720	-0.00333	-29490.	-877.5972	1.45E-04	12711.	1.06E+10	97.8859	164170.	0.00
20.0380	-0.00257	-33135.	-388.1270	1.28E-04	12781.	1.06E+10	77.1749	168079.	0.00
20.5040	-0.00190	-34332.	-9.0718	1.11E-04	12804.	1.06E+10	58.3956	171988.	0.00
20.9700	-0.00133	-33668.	271.2534	9.27E-05	12791.	1.06E+10	41.8638	175896.	0.00
21.4360	-8.62E-04	-31660.	465.8339	7.54E-05	12752.	1.06E+10	27.7287	179805.	0.00
21.9020	-4.87E-04	-28753.	588.1103	5.95E-05	12696.	1.06E+10	16.0040	183714.	0.00
22.3680	-1.97E-04	-25315.	651.3048	4.53E-05	12630.	1.06E+10	6.5978	187623.	0.00
22.8340	1.92E-05	-21645.	667.9094	3.29E-05	12560.	1.06E+10	-0.6591	191532.	0.00
23.3000	1.71E-04	-17974.	649.3231	2.25E-05	12489.	1.06E+10	-5.9883	195440.	0.00
23.7660	2.70E-04	-14471.	605.6212	1.39E-05	12422.	1.06E+10	-9.6418	199349.	0.00
24.2320	3.27E-04	-11255.	545.4356	7.13E-06	12360.	1.06E+10	-11.8838	203258.	0.00
24.6980	3.50E-04	-8398.	475.9282	1.96E-06	12305.	1.06E+10	-12.9758	207167.	0.00
25.1640	3.49E-04	-5939.	402.8351	-1.82E-06	12258.	1.06E+10	-13.1662	211076.	0.00
25.6300	3.30E-04	-3886.	330.5644	-4.41E-06	12218.	1.06E+10	-12.6816	214984.	0.00
26.0960	2.99E-04	-2225.	262.3311	-6.02E-06	12186.	1.06E+10	-11.7223	218893.	0.00
26.5620	2.63E-04	-928.6413	200.3121	-6.85E-06	12161.	1.06E+10	-10.4591	222802.	0.00
27.0280	2.23E-04	41.8269	145.8114	-7.09E-06	12144.	1.06E+10	-9.0333	226711.	0.00
27.4940	1.83E-04	729.7765	99.4246	-6.88E-06	12157.	1.06E+10	-7.5571	230620.	0.00
27.9600	1.46E-04	1181.	61.1952	-6.38E-06	12166.	1.06E+10	-6.1158	234528.	0.00
28.4260	1.12E-04	1439.	30.7571	-5.69E-06	12171.	1.06E+10	-4.7705	238437.	0.00
28.8920	8.22E-05	1547.	7.4604	-4.90E-06	12173.	1.06E+10	-3.5616	242346.	0.00
29.3580	5.70E-05	1542.	-9.5212	-4.09E-06	12173.	1.06E+10	-2.5119	246255.	0.00
29.8240	3.64E-05	1456.	-21.1032	-3.30E-06	12171.	1.06E+10	-1.6304	250164.	0.00
30.2900	2.01E-05	1319.	-28.2201	-2.57E-06	12169.	1.06E+10	-0.9150	254073.	0.00
30.7560	7.72E-06	1151.	-31.7744	-1.92E-06	12165.	1.06E+10	-0.3562	257981.	0.00
31.2220	-1.31E-06	970.6462	-32.5990	-1.36E-06	12162.	1.06E+10	0.06124	261890.	0.00
31.6880	-7.47E-06	791.4626	-31.4343	-8.94E-07	12158.	1.06E+10	0.3553	265799.	0.00
32.1540	-1.13E-05	622.5752	-28.9158	-5.22E-07	12155.	1.06E+10	0.5455	269708.	0.00
32.6200	-1.33E-05	470.1046	-25.5698	-2.34E-07	12152.	1.06E+10	0.6512	273617.	0.00

33.0860	-1.39E-05	337.5145	-21.8169	-2.09E-08	12150.	1.06E+10	0.6910	277525.	0.00
33.5520	-1.35E-05	226.1858	-17.9791	1.28E-07	12148.	1.06E+10	0.6816	281434.	0.00
34.0180	-1.25E-05	135.9387	-14.2904	2.23E-07	12146.	1.06E+10	0.6377	285343.	0.00
34.4840	-1.10E-05	65.4915	-10.9096	2.76E-07	12145.	1.06E+10	0.5715	289252.	0.00
34.9500	-9.41E-06	12.8484	-7.9325	2.97E-07	12144.	1.06E+10	0.4932	293161.	0.00
35.4160	-7.73E-06	-24.3845	-5.4053	2.94E-07	12144.	1.06E+10	0.4106	297069.	0.00
35.8820	-6.12E-06	-48.7514	-3.3357	2.74E-07	12144.	1.06E+10	0.3296	300978.	0.00
36.3480	-4.66E-06	-62.7625	-1.7038	2.45E-07	12144.	1.06E+10	0.2541	304887.	0.00
36.8140	-3.38E-06	-68.7635	-0.4712	2.10E-07	12145.	1.06E+10	0.1868	308796.	0.00
37.2800	-2.31E-06	-68.8531	0.4118	1.74E-07	12145.	1.06E+10	0.1290	312705.	0.00
37.7460	-1.43E-06	-64.8377	0.9996	1.39E-07	12145.	1.06E+10	0.08123	316613.	0.00
38.2120	-7.53E-07	-58.2155	1.3475	1.06E-07	12144.	1.06E+10	0.04318	320522.	0.00
38.6780	-2.44E-07	-50.1829	1.5078	7.79E-08	12144.	1.06E+10	0.01414	324431.	0.00
39.1440	1.18E-07	-41.6566	1.5279	5.37E-08	12144.	1.06E+10	-0.00693	328340.	0.00
39.6100	3.57E-07	-33.3043	1.4492	3.40E-08	12144.	1.06E+10	-0.02122	332249.	0.00
40.0760	4.98E-07	-25.5814	1.3062	1.85E-08	12144.	1.06E+10	-0.02994	336157.	0.00
40.5420	5.64E-07	-18.7683	1.1266	6.77E-09	12144.	1.06E+10	-0.03427	340066.	0.00
41.0080	5.74E-07	-13.0075	0.9321	-1.61E-09	12144.	1.06E+10	-0.03529	343975.	0.00
41.4740	5.46E-07	-8.3370	0.7386	-7.23E-09	12143.	1.06E+10	-0.03394	347884.	0.00
41.9400	4.93E-07	-4.7193	0.5570	-1.07E-08	12143.	1.06E+10	-0.03101	351793.	0.00
42.4060	4.26E-07	-2.0663	0.3945	-1.25E-08	12143.	1.06E+10	-0.02711	355702.	0.00
42.8720	3.54E-07	-0.2590	0.2551	-1.31E-08	12143.	1.06E+10	-0.02274	359610.	0.00
43.3380	2.80E-07	0.8375	0.1406	-1.29E-08	12143.	1.06E+10	-0.01821	363519.	0.00
43.8040	2.09E-07	1.3639	0.05130	-1.23E-08	12143.	1.06E+10	-0.01374	367428.	0.00
44.2700	1.42E-07	1.4594	-0.01348	-1.16E-08	12143.	1.06E+10	-0.00943	371337.	0.00
44.7360	7.94E-08	1.2584	-0.05475	-1.09E-08	12143.	1.06E+10	-0.00533	375246.	0.00
45.2020	2.04E-08	0.8895	-0.07352	-1.03E-08	12143.	1.06E+10	-0.00138	379154.	0.00
45.6680	-3.60E-08	0.4764	-0.07049	-9.95E-09	12143.	1.06E+10	0.00246	383063.	0.00
46.1340	-9.09E-08	0.1399	-0.04602	-9.79E-09	12143.	1.06E+10	0.00629	386972.	0.00
46.6000	-1.45E-07	0.00	0.00	-9.75E-09	12143.	1.06E+10	0.01017	195440.	0.00

* The above values of total stress are combined axial and bending stresses.

Output Summary for Load Case No. 2:

```
Pile-head deflection             =     0.52000000 inches
Computed slope at pile head      =     0.00324646 radians
Maximum bending moment           =      -2719140. inch-lbs
Maximum shear force              =         41472. 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 =              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	0.5200	S, rad	0.00	349000.	0.5227	0.00	32001.	-1842911.
2	y, in	0.5200	M, in-lb	-2719140.	349000.	0.5200	0.00325	41472.	-2719140.

Maximum pile-head deflection = 0.5227156576 inches
Maximum pile-head rotation = 0.0032464632 radians = 0.186009 deg.

The analysis ended normally.

Frost Depth

Estimated Frost Penetration Depth

Based on MaineDOT Bridge Design Guide Section 5.2.1

Site Location: Fort Kent, Maine

Soil Conditions: damp to moist, SAND, varying amounts of gravel and silt (Coarse Grained)

Step 1. From Figure 5-1: Design Freezing Index = ±2600 freezing degree-days

Step 2. From laboratory test result and soil description: natural soil water content < 10%

Step 3. From Table 5-1: Depth of frost penetration = 109.1 inches = 9 feet

USE 9 feet

Calculated by / Date: MAS / June 2021
Checked by: RSL

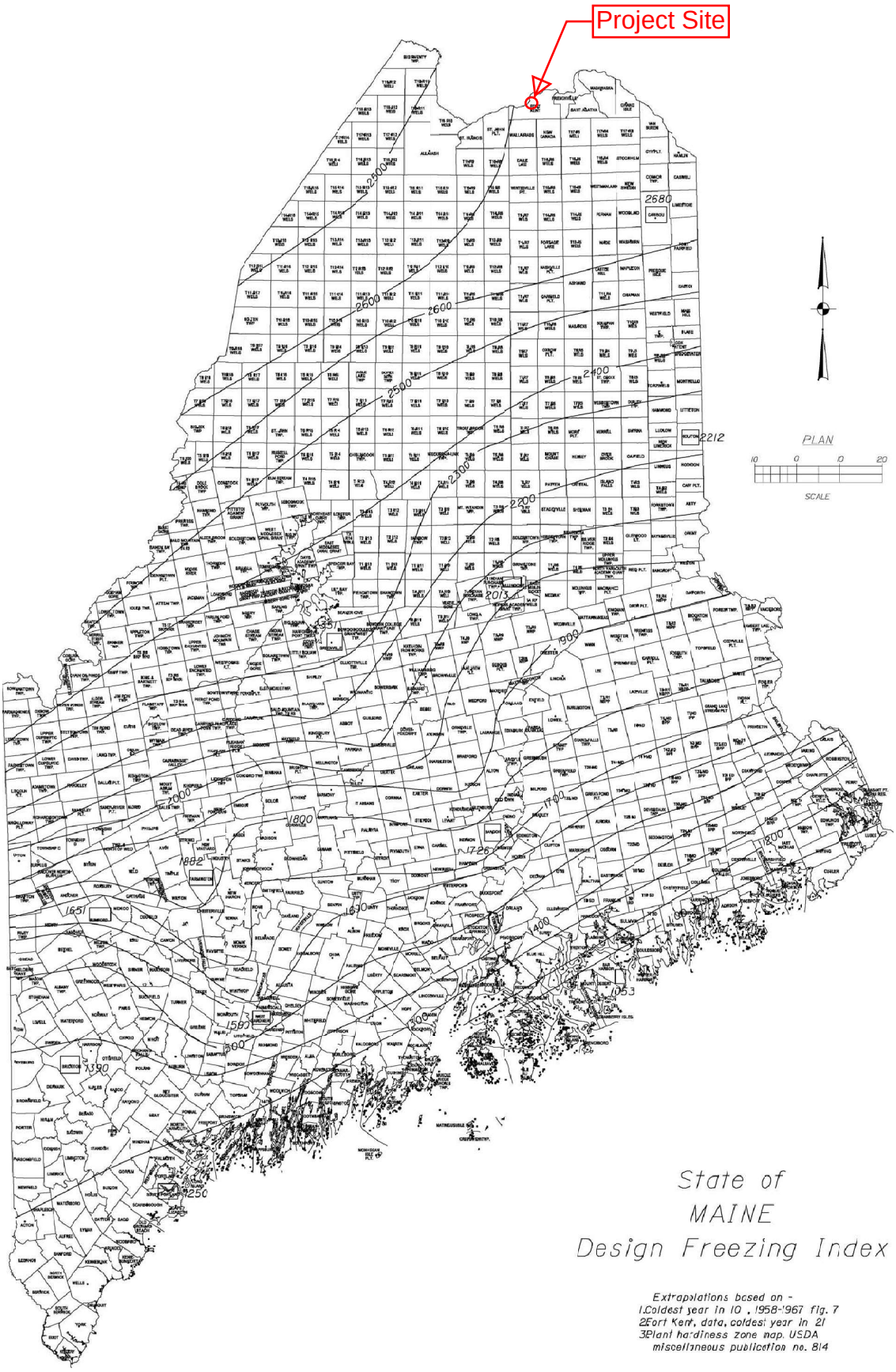

Figure 5-1 Maine Design Freezing Index Map

5.2 General

5.2.1 Frost

Any foundation placed on seasonally frozen soils must be embedded below the depth of frost penetration to provide adequate frost protection and to minimize the potential for freeze/thaw movements. Fine-grained soils with low cohesion tend to be most frost susceptible. Soils containing a high percentage of particles smaller than the No. 200 sieve also tend to promote frost penetration.

In order to estimate the depth of frost penetration at a site, Table 5-1 has been developed using the Modified Berggren equation and Figure 5-1 Maine Design Freezing Index Map. The use of Table 5-1 assumes site specific, uniform soil conditions where the Geotechnical Designer has evaluated subsurface conditions. Coarse-grained soils are defined as soils with sand as the major constituent. Fine-grained soils are those having silt and/or clay as the major constituent. If the make-up of the soil is not easily discerned, consult the Geotechnical Designer for assistance. In the event that specific site soil conditions vary, the depth of frost penetration should be calculated by the Geotechnical Designer.

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	51.9	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.

Seismic

Determine Seismic Site Classification per AASHTO LRFD Table C3.10.3.1-1 - Method B

Data From BB-FKPB-101

Layer No.	Layer Description	Depth Range (ft)		N_{60} values recorded within layer								Average N_{60} value	Layer Thickness	d_i/N_i
		Top	End									Ni	di	
1	Fill	0	14	100	54							77.0	14	0.18
2	Fill	14	18	6								6.0	4	0.67
3	Glacial Outwash	18	33	61	37	30						42.7	15	0.35
4	Glacial Till	33	80.6	50	54	100	100	100	100			84.0	47.6	0.57
5	Bedrock	80.6	100	100								100.0	19.4	0.19
												Σ =	**100**	**1.96**

N_bar = di/di/Ni = **51.00**
Site Class **C**

Data From BB-FKPB-102

Layer No.	Layer Description	Depth Range (ft)		N_{60} values recorded within layer								Average N_{60} value	Layer Thickness	d_i/N_i
		Top	End									Ni	di	
1	Fill	0	17	37	24	64						41.7	17	0.41
2	Glacial Outwash	17	27	37	44							40.5	10	0.25
3	Glacial Till	27	56.3	77	91	87	100	100	100			92.5	29.3	0.32
4	Bedrock	56.3	100	100								100.0	43.7	0.44
												Σ =	**100**	**1.41**

NOTES:
1. Weight of Rod (WOR) and Weight of Hammer (WOH) values taken as N=1
2. N60 values > 100 taken as N=100
3. N60 value for bedrock taken as N=100

N_bar = di/di/Ni = **70.99**
Site Class **C**

Calculated by/Date: MAS - June 2021
Checked by: RSL

WIN 021882 - Perley Brook Br (#3468) Replacement - Fort Kent, ME

Conterminous 48 States
2007 AASHTO Bridge Design Guidelines
AASHTO Spectrum for 7% PE in 75 years
Latitude = 47.241094
Longitude = -068.579231
Site Class B
Data are based on a 0.05 deg grid spacing.

Period (sec)	Sa (g)	
0.0	0.101	PGA - Site Class B
0.2	0.223	Ss - Site Class B
1.0	0.062	S1 - Site Class B

Conterminous 48 States
2007 AASHTO Bridge Design Guidelines
Spectral Response Accelerations SDs and SD1
Latitude = 47.241094
Longitude = -068.579231
As = FpgaPGA, SDs = FaSs, and SD1 = FvS1
Site Class C - Fpga = 1.20, Fa = 1.20, Fv = 1.70
Data are based on a 0.05 deg grid spacing.

Period (sec)	Sa (g)	
0.0	0.121	As - Site Class C
0.2	0.268	SDs - Site Class C
1.0	0.105	SD1 - Site Class C

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Map Response Spectra for Site Class B
Latitude = 47.241094
Longitude = -068.579231
Ss and S1 = Mapped Spectral Acceleration Values
Site Class B
Data are based on a 0.05 deg grid spacing.

Period (sec)	Sa (g)	Sd in.	
0.000	0.101	0.000	T = 0.0, Sa = PGA
0.056	0.223	0.007	T = To, Sa = Ss
0.200	0.223	0.087	T = 0.2, Sa = Ss
0.278	0.223	0.168	T = Ts, Sa = Ss
0.300	0.206	0.182	
0.400	0.155	0.242	
0.600	0.103	0.363	
0.800	0.077	0.484	
1.000	0.062	0.605	T = 1.0, Sa = S1
1.200	0.052	0.726	
1.400	0.044	0.847	
1.600	0.039	0.968	
1.800	0.034	1.089	
2.000	0.031	1.210	

2.200	0.028	1.331
2.400	0.026	1.452
2.600	0.024	1.573
2.800	0.022	1.694
3.000	0.021	1.815
3.200	0.019	1.936
3.400	0.018	2.057
3.600	0.017	2.179
3.800	0.016	2.300
4.000	0.015	2.421

Conterminous 48 States
2007 AASHTO Bridge Design Guidelines
Design Response Spectra for Site Class C
Latitude = 47.241094
Longitude = -068.579231
As = FpgaPGA, SDs = FaSs, SD1 = FvS1
Site Class C - Fpga = 1.20, Fa = 1.20, Fv = 1.70
Data are based on a 0.05 deg grid spacing.

Period (sec)	Sa (g)	Sd in.	
0.000	0.121	0.000	T = 0.0, Sa = As
0.079	0.268	0.016	
0.200	0.268	0.105	T = 0.2, Sa = SDs
0.393	0.268	0.405	T = Ts, Sa = SDs
0.400	0.263	0.411	
0.600	0.175	0.617	
0.800	0.132	0.823	
1.000	0.105	1.029	T = 1.0, Sa = SD1
1.200	0.088	1.234	
1.400	0.075	1.440	
1.600	0.066	1.646	
1.800	0.058	1.852	
2.000	0.053	2.057	
2.200	0.048	2.263	
2.400	0.044	2.469	
2.600	0.040	2.675	
2.800	0.038	2.880	
3.000	0.035	3.086	
3.200	0.033	3.292	
3.400	0.031	3.498	
3.600	0.029	3.703	
3.800	0.028	3.909	
4.000	0.026	4.115	