

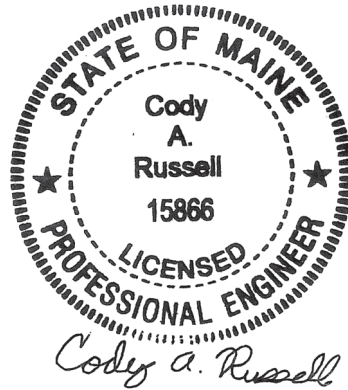
**MAINE DEPARTMENT OF TRANSPORTATION
HIGHWAY PROGRAM
GEOTECHNICAL SECTION
AUGUSTA, MAINE**

GEOTECHNICAL DESIGN REPORT

For the Construction of

**LOG CABIN BRIDGE
LOG CABIN ROAD
ARUNDEL, MAINE**

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York County
WIN 25397.00

May 15, 2023

Soils Report 2023-08
Bridge No. 6683

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1.0 INTRODUCTION

The purpose of this Geotechnical Design Report is to present subsurface information and make geotechnical recommendations for the replacement of an existing large culvert (#46490) on Log Cabin Road in Arundel, Maine. A subsurface investigation has been completed at the site to evaluate subsurface conditions and to develop geotechnical design and construction recommendations for the replacement structure. This report presents the subsurface information obtained during the subsurface investigation and soil laboratory testing programs and provides design and construction recommendations and geotechnical design parameters for the culvert replacement.

The existing structure consists of an approximately 60-inch diameter, 56-foot long corrugated metal pipe (CMP) culvert on a skew of approximately 5 degrees to the roadway centerline. The CMP is in poor condition and showing sign of deterioration. Log Cabin Road is a Highway Corridor Priority 4 road.

The proposed replacement structure will be a 13-foot span by 8-foot rise by 102-foot-long precast concrete box culvert on a skew of approximately 10 degrees to the roadway centerline. To facilitate fish passage, Habitat Connectivity Design elements will be used inside the precast concrete box culvert as shown on the Special Details Sheet in the Plans. The invert of the proposed culvert is approximately 13 feet below the existing road grade at the roadway centerline. The roadway embankment slopes at the proposed culvert inlet and outlet shall be no steeper than 2H:1V to protect against erosion.

2.0 GEOLOGIC SETTING

The existing culvert carries an unnamed stream under Log Cabin Road in Arundel and is located approximately 0.04 of a mile south of Old Post Road as shown on Sheet 1 – Location Map.

According to the Maine Geological Survey (MGS) map titled Surficial Geology Kennebunk Quadrangle, Maine, Open File 99-86 (1999) the surficial soils at the site consist of Presumpscot Formation, consisting of silt and silty clay that may contain sand, gravel, or boulders, and shallow bedrock.

According to the map titled Bedrock Geologic Map of Maine (1985) published by the MGS, the bedrock in the vicinity of the site consists of calcareous feldspathic sandstone of the Kittery Formation.

3.0 SUBSURFACE INVESTIGATION

One (1) boring (HB-ARU-101) and four (4) probes (HB-ARU-102, HB-ARU-102A, HB-ARU-103, and HB-ARU-104) were drilled for this project on August 31, 2021 by the MaineDOT drill crew using a trailer mounted drill rig. Exploration locations are shown on Sheet 2 – Boring Location Plan & Interpretive Subsurface Profile. Details and sampling methods used, field data

obtained, and soil and groundwater conditions encountered are presented on the Boring Log in Appendix A.

Boring HB-ARU-101 was drilled using solid stem auger, cased wash boring, and rock core drilling techniques. Soil samples were obtained in boring HB-ARU-101 at 5-foot intervals using Standard Penetration Test (SPT) methods. The MaineDOT drill rig is equipped with an automatic hammer to drive the split spoon. The MaineDOT calibrated automatic hammer delivers approximately 48 percent more energy during driving than the standard rope and cathead system. All N-values discussed in this report are corrected values (N_{60}) computed by applying an average energy transfer factor of 0.89 to the raw field N-values. The bedrock was cored in boring HB-ARU-101 using an NQ 2-inch core barrel and the Rock Quality Designation (RQD) of the core was calculated. Probes HB-ARU-102, HB-ARU-102A, HB-ARU-103, and HB-ARU-104 were drilled using solid stem auger techniques. No soil samples were obtained in the probes.

The MaineDOT Geotechnical Team member selected the boring and probe locations, drilling methods, designated type and depth of sampling, reviewed field logs for accuracy and identified field and laboratory testing requirements. An experienced Northeast Transportation Training and Certification Program (NETTCP) certified subsurface inspector logged the subsurface conditions encountered. The boring and probe were located in the field by taping to surveyed site features after completion of the drilling program.

4.0 LABORATORY TESTING

A laboratory testing program was conducted to assist in soil classification, evaluation of engineering properties of the soils and geologic assessment of the project site. Laboratory testing consisted of one (1) standard grain size analysis with natural water content. The results of the laboratory testing program are discussed in the following section and are included in Appendix B – Laboratory Test Results. Laboratory test information is also shown on the Boring Logs in Appendix A.

5.0 SUBSURFACE CONDITIONS

Subsurface conditions encountered at the test boring and probe generally consisted of sand fill underlain by bedrock. An interpretive subsurface profile depicting the generalized soil stratigraphy at the boring location is shown on Sheet 2 – Boring Location Plan & Interpretive Subsurface Profile.

Boring HB-ARU-101 was drilled to refusal at a depth of approximately 7.6 feet below ground surface (bgs) and roller-coned into the bedrock to a depth of approximately 7.8 feet. Bedrock was cored in the boring for a total depth of approximately 12.8 feet bgs. Probe HB-ARU-102 was drilled to a depth of approximately 6.0 feet bgs where it encountered a refusal surface. Probes HB-ARU-102A, HB-ARU-103, and HB-ARU-104 were drilled to depths ranging from approximately 13.2 to 15.2 feet bgs where they encountered a refusal surface. The exact nature of the refusal surface was not determined in the probes.

The table below summarizes the field and laboratory information obtained in boring HB-ARU-101:

Approx. Depth BGS ¹ (feet)	Soil Description	AASHTO ² Classification	USCS ³	WC% ⁴
0.0 – 7.6	Fill – Brown, damp to moist, fine to coarse sand, little gravel, trace silt, occasional cobble.	A-1-b	SW-SM	2.5
7.6 – 12.8	Bedrock – Calcareous feldspathic sandstone of the Kittery Formation.	--	--	--

¹BGS = below ground surface

²AASHTO = American Association of State Highway and Transportation Officials

³USCS = Unified Soil Classification System

⁴WC% = Water content in percent

Two N₆₀-values obtained in the fill were 12 blows per foot (bpf) and 90 bpf, indicating that the fill is medium dense to very dense in consistency. The Rock Quality Designation (RQD) of the bedrock was determined to be 58 percent in boring HB-ARU-101 correlating to a Rock Quality of Fair.

Groundwater was recorded at a depth of 2.9 feet bgs in the boring. Groundwater was not observed in the probes. Groundwater levels can be expected to fluctuate subject to seasonal variations, local soil conditions, topography, precipitation, and construction activity.

6.0 GEOTECHNICAL DESIGN AND CONSTRUCTION RECOMMENDATIONS

The following sections discuss geotechnical recommendations for the design and construction of the proposed culvert.

6.1 Precast Concrete Box Culvert Design and Construction

The proposed replacement structure will consist of a 13-foot span by 8-foot rise by 102-foot-long precast concrete box culvert on a skew of approximately 10 degrees to the roadway centerline. The proposed box culvert shall be designed and constructed in accordance with MaineDOT Standard Specification 534.

The inverts of the proposed box culvert range from approximately 69.25 feet at the inlet to approximately 67.75 feet at the outlet with a slope of approximately 1.5 percent. To facilitate fish passage, Habitat Connectivity Design elements will be used inside the precast concrete box culvert as shown on the Special Details Sheet in the Plans.

Due to the presence of shallow bedrock at the proposed culvert location, bedrock removal will be necessary to construct the culvert at the planned elevations. Prior to placing the culvert bedding

material, the bedrock surface shall be cleaned of all weathered bedrock, fractured material, loose soil, and/or ponded water. The full nature of the culvert bearing surface will not become evident until the culvert excavation is made.

Any cobbles or boulders in excess of 6 inches encountered at the bedding elevation shall be removed and replaced with compacted Granular Borrow Material for Underwater Backfill or Crushed Stone $\frac{3}{4}$ -Inch. The prepared subgrade shall be proof-rolled using a static roller to visually confirm the prepared subgrade is firm and stable. The exposed subgrade shall be free of ponded water so that bedding material placement and compaction can be completed in the dry.

The proposed structure shall be bedded on a 1-foot-thick layer of Granular Borrow, Material for Underwater Backfill meeting the requirements of MaineDOT Standard Specification 703.19. The soil envelope and backfill shall consist of Standard Specification 703.19 - Granular Borrow with a maximum particle size of 4 inches. The Granular Borrow bedding and backfill material shall be placed in lifts of 6 to 8 inches loose measure and compacted to the manufacturer's specifications or, in the absence of manufacturer's specifications, the bedding and backfill soil shall be compacted to at least 92 percent of the AASHTO T-180 maximum dry density.

6.2 Bedrock Removal and Subgrade Preparation

A refusal surface was encountered in the boring and probes at elevations ranging from approximately 67.1 feet to 75.9 feet in the vicinity of the proposed box culvert. The approximate invert of the proposed box culvert ranges from approximately elevation 69.25 feet at the inlet to approximately elevation 67.75 feet at the outlet. Constructing the box culvert at these elevations will require removal of bedrock. The need for and depth of bedrock removal will vary over the length of the precast concrete structure. The bottom elevation of the excavation shall take into account the wall thickness of the box culvert and the required 1-foot layer of bedding material. The boring indicates that the Rock Quality of the bedrock is fair with an RQD of approximately 58 percent.

The bedrock surface shall be prepared in accordance with MaineDOT standard practices. Construction activities should not be permitted to create any open fissures in the bedrock to remain. Any irregularities in the existing bedrock surface or irregularities created during the excavation process should be backfilled with crushed stone to the bottom of the required bedding material.

The nature, slope, and degree of fracturing in the bedrock bearing surfaces will not be evident until the excavation from the precast concrete box culvert is made. The final bedrock surface slope shall be less than 4H:1V or it shall be benched in level steps.

The Contractor shall remove any overburden soil and weathered bedrock that can be removed using ordinary excavation equipment to expose competent bedrock at the required elevation. In accordance with MaineDOT standard practices, the bedrock shall be clean and free of debris, soil, or loose rock. The cleanliness and condition of the bedrock surface should be confirmed and accepted by the Resident prior to placing the structural bedding material. If soil is encountered at bedding material subgrade it shall be proof-rolled using multiple passes of a static roller to identify

loose or weaving areas and to achieve a firm and stable surface for construction. Any cobbles or boulders encountered in excess of 6 inches shall be removed and replaced with compacted Granular Borrow Material for Underwater Backfill or Crushed Stone ¾-Inch.

Blasting shall be conducted in accordance with MaineDOT Standard Specifications Sections 105.2.7 and 203. The Contractor is required to conduct pre- and post-blast surveys, as well as blast vibrations monitoring at nearby structures in accordance with industry standards at the time of the blast.

It is anticipated that there will be seepage of water from fractures and joints exposed in the bedrock surface. Water should be controlled by pumping from sumps. The Contractor should maintain the excavation so that all work is completed in the dry.

6.3 Settlement

No settlement issues are anticipated at the site. No changes to the existing vertical or horizontal alignment are currently planned for this project. The proposed precast concrete box culvert is larger than the existing culvert and will result in a net unloading of the site soils at the structure location. Any settlement due to elastic compression of the bedding material and subgrade materials will be immediate and negligible.

6.4 Bearing Resistance

The factored bearing resistances for the precast concrete box culvert bearing on compacted granular bedding material placed on native soils or bedrock at the service and strength limit states are presented in the table below. Supporting calculations in accordance with AASHTO LRFD Bridge Design Specifications 9th Edition 2020 (LRFD) are provided in Appendix C – Calculations.

Limit State	Resistance Factor ϕ_b	AASHTO LRFD Reference	Factored Bearing Resistance (ksf)
Service	1.0	Article 10.5.5.1	6.0
Strength	0.45	Table 10.5.5.2.2-1	9.0

6.5 Modulus of Subgrade Reaction

A modulus of subgrade reaction (k_s) equal to 130 pounds per cubic inch shall be used for the structural design of the box culvert’s base slab. Calculations are included in Appendix C – Calculations.

6.6 Scour and Riprap

Both the inlet and outlet of the precast concrete box culvert shall be protected against scour with riprap conforming to MaineDOT Standard Specification Section 703.26 Plain and Hand Laid Riprap. Slopes shall be no steeper than 2H:1V. No specific scour protection recommendations are

needed other than armoring with riprap. The riprap on the slopes shall be underlain by a non-woven, Class 1 Erosion Control Geotextile meeting the requirements of MaineDOT Standard Specification 722.03 that is underlain by a 1-foot layer of protective aggregate cushion consisting of Granular Borrow Material for Underwater Backfill (703.19). The toe of the riprap sections shall be keyed into the existing soils 1 foot below the streambed elevation.

6.7 Seismic Design Considerations

In conformance with LRFD Article 3.10.1, seismic analysis is not required for buried structures, except where they cross active faults. There are no known active faults in Maine; therefore, seismic analysis is not required.

6.8 Construction Considerations

Construction activities may include construction of cofferdams and earth support systems to control stream flow during construction. Construction activities will also include common earth excavation. Construction of the proposed precast concrete box culvert will require soil and bedrock excavation. Earth support systems shall be implemented if laying back slopes is not feasible. It is likely that the use of complex (four-sided) braced excavations with dewatering will be necessary due to the depth of the excavation. If this is the case, adequate bracing will be necessary to allow for the excavation and maintenance of a stable excavation bottom. All earth support systems shall be designed by a Professional Engineer licensed in the State of Maine. Regardless of the method of excavation, all excavations and earth support systems shall meet all applicable OSHA regulations.

The Contractor shall control groundwater and surface water infiltration using temporary ditches, sumps, granular drainage blankets, stone ditch protection or hand-laid riprap with geotextile underlayment to divert groundwater and surface water as needed to maintain a stable excavation and allow work in the dry.

Using the excavated and native soils as backfill around the culvert shall not be permitted. The excavated and native soils may only be used as common borrow in accordance with MaineDOT Standard Specifications 203 and 703.

The Contractor will have to excavate the existing subbase and subgrade fill soils in the vicinity of the culvert. These materials should not be used to re-base the roadway. Excavated subbase sand and gravel may be used as fill below roadway subgrade level in fill areas provided all other requirements of MaineDOT Standard Specifications 203 and 703 are met.

7.0 CLOSURE

This report has been prepared for the use of the MaineDOT Highway Program for specific application to the proposed replacement of an existing large culvert (#46490) under Log Cabin Road in Arundel, Maine in accordance with generally accepted geotechnical and foundation engineering practices. No other intended use or warranty is expressed or implied.

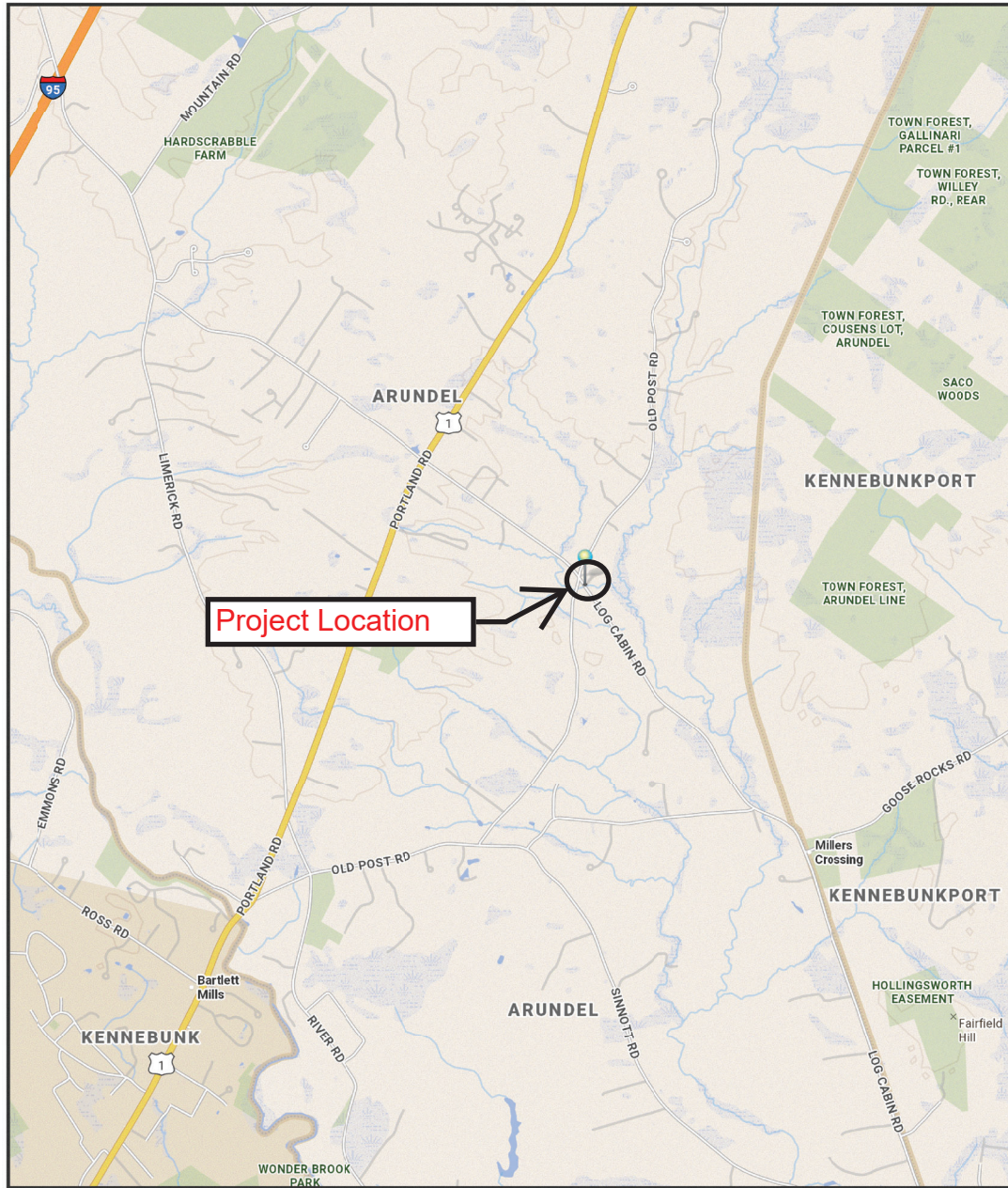
In the event that any changes in the nature, design, or location of the proposed project are planned, this report should be reviewed by a geotechnical engineer to assess the appropriateness of the conclusions and recommendations and to modify the recommendations as appropriate to reflect the changes in design. These analyses and recommendations are based in part upon a limited subsurface investigation at discrete exploratory location completed at the site. If variations from the conditions encountered during the investigation appear evident during construction, it may also become necessary to re-evaluate the recommendations made in this report.

It is recommended that a geotechnical engineer be provided the opportunity for a review of the design and specifications in order that the earthwork and foundation recommendations and construction considerations presented in this report are properly interpreted and implemented in the design and specifications.

Sheets



ARUNDEL, MAINE

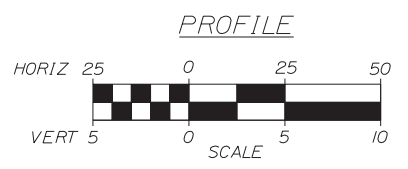
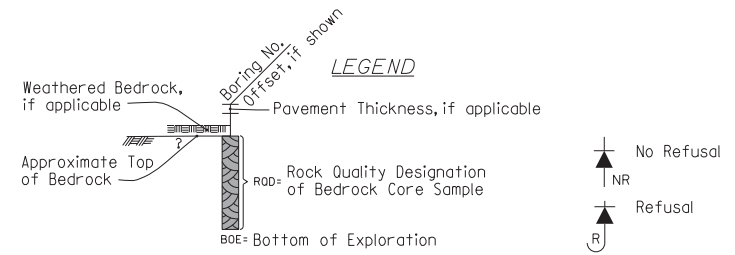
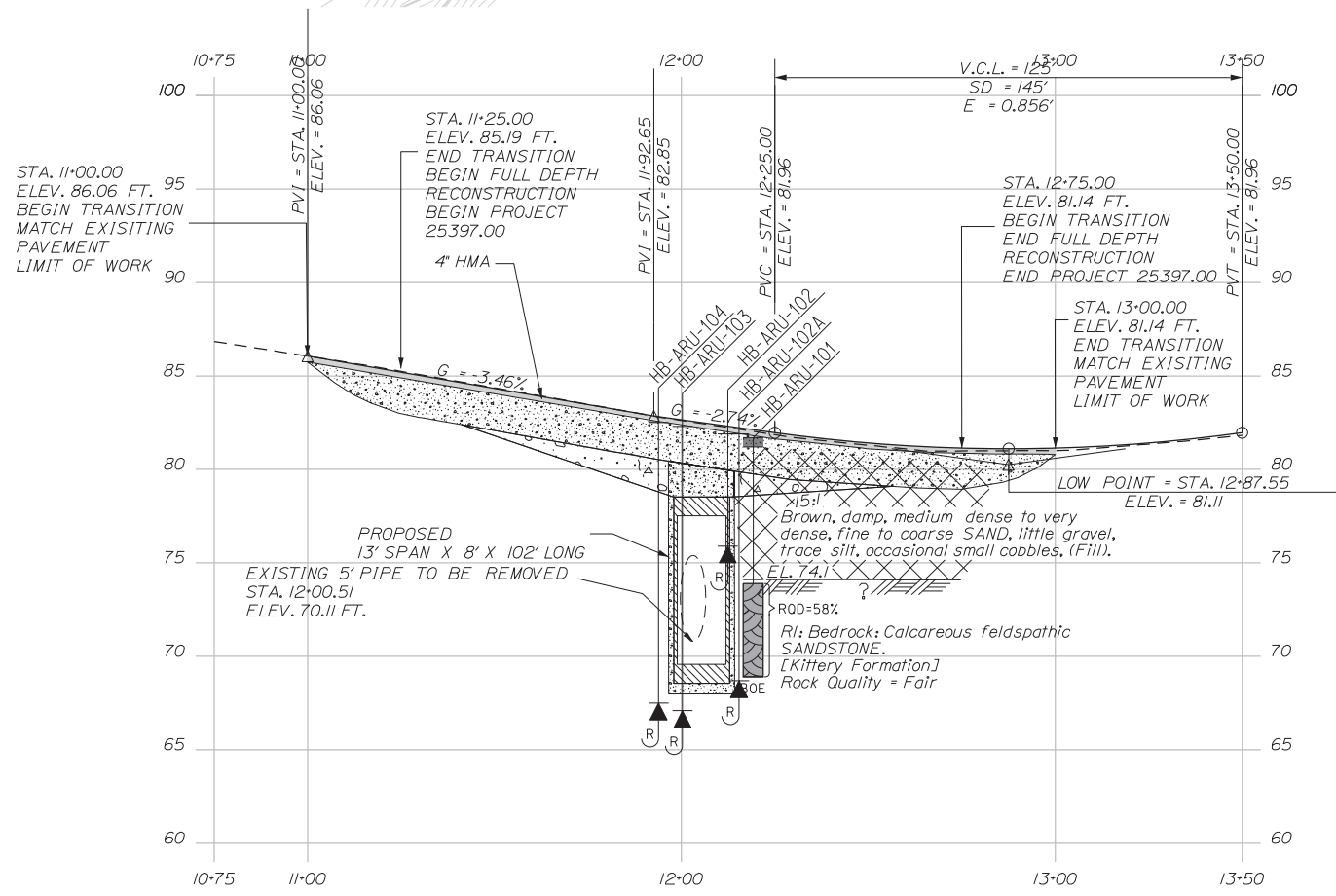
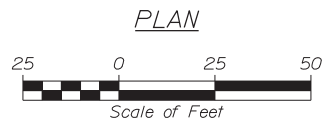
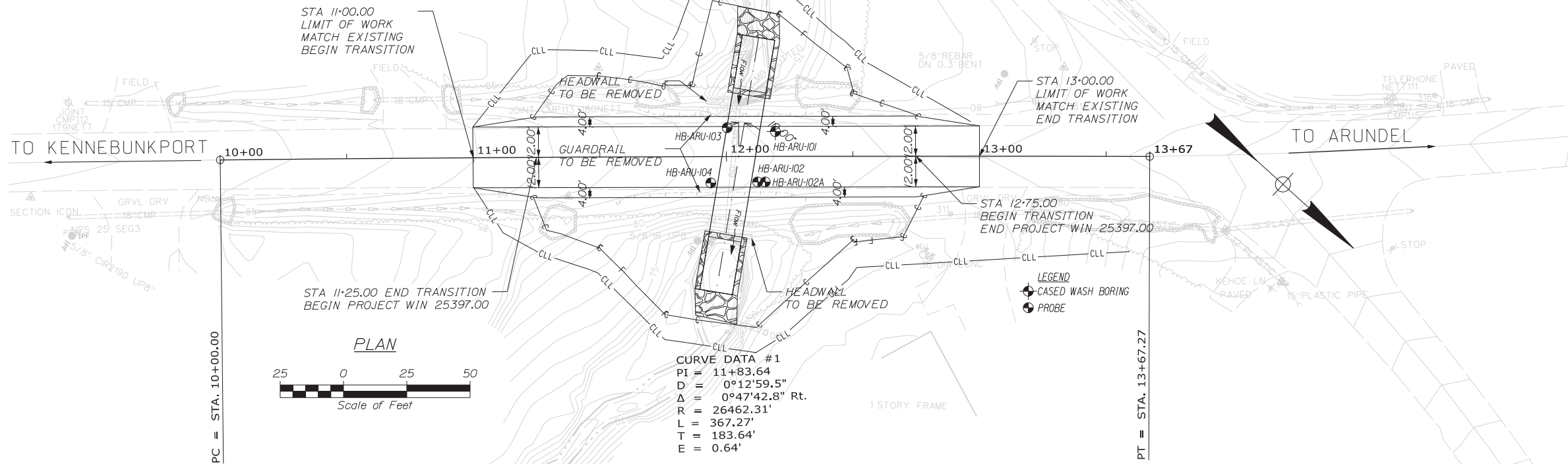


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0.5 Miles
1 inch = 0.57 miles

Date: 3/29/2023
Time: 8:46:49 AM

SHEET NUMBER 1 OF 2	ARUNDEL LOG CABIN ROAD	STATE OF MAINE DEPARTMENT OF TRANSPORTATION	
		25397.00	
	LOCATION MAP	WIN 25397.00 HIGHWAY PLANS	



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		25397.00
ARUNDEL LOG CABIN ROAD		WIN 25397.00
BORING LOCATION PLAN & INTERPRETIVE SUBSURFACE PROFILE		HIGHWAY PLANS
PROJ. MANAGER	DATE	SIGNATURE
C. RUSSELL	MAY 2023	
CHECKED-REVIEWED	BY	P.E. NUMBER
	T. WHITE	
DESIGNS-DETAILED	DATE	DATE
REVISIONS 1		
REVISIONS 2		
REVISIONS 3		
REVISIONS 4		
FIELD CHANGES		
SHEET NUMBER		
2		
OF 2		

Appendix A

Boring Logs

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS	Project: Large Culvert Replacement on the Log Cabin Road. Location: Arundel, Maine	Boring No.: HB-ARU-101 WIN: 25397.00
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Driller: MaineDOT	Elevation (ft.): 81.7	Auger ID/OD: 5" Solid Stem
Operator: Dagget/Jay	Datum: NAVD88	Sampler: Standard Split Spoon
Logged By: B. Wilder	Rig Type: CME 45C	Hammer Wt./Fall: 140#/30"
Date Start/Finish: 8/31/2021; 07:00-12:00	Drilling Method: Cased Wash Boring	Core Barrel: NQ-2"
Boring Location: 12+19.2, 10.0 ft Lt.	Casing ID/OD: NW-3"	Water Level*: 2.9 ft bgs.

Hammer Efficiency Factor: 0.89	Hammer Type: Automatic <input checked="" type="checkbox"/> Hydraulic <input type="checkbox"/> Rope & Cathead <input type="checkbox"/>
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Definitions: R = Rock Core Sample, SSA = Solid Stem Auger, HSA = Hollow Stem Auger, RC = Roller Cone, WOH = Weight of 140lb. Hammer, WOR/C = Weight of Rods or Casing, WO1P = Weight of One Person
 S_u = Peak/Remolded Field Vane Undrained Shear Strength (psf), S_{u(lab)} = Lab Vane Undrained Shear Strength (psf), q_p = Unconfined Compressive Strength (ksf), N-uncorrected = Raw Field SPT N-value, Hammer Efficiency Factor = Rig Specific Annual Calibration Value, N₆₀ = SPT N-uncorrected Corrected for Hammer Efficiency, N₆₀ = (Hammer Efficiency Factor/60%)*N-uncorrected
 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
 T_v = Pocket Torvane Shear Strength (psf), WC = Water Content, percent, LL = Liquid Limit, PL = Plastic Limit, PI = Plasticity Index, G = Grain Size Analysis, C = Consolidation Test

Depth (ft.)	Sample Information								Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/AASHTO and Unified Class.
	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing Blows					
0									81.2	6" HMA.		
	1D	24/14	1.50 - 3.50	17/31/30/19	61	90					Brown, damp, very dense, fine to coarse SAND, little gravel, trace silt, occasional small cobbles. (Fill).	G#337010 A-1-b, SW-SM WC=2.5%
5	2D	24/9	5.00 - 7.00	4/4/4/4	8	12	14				Brown, damp, medium dense, fine to coarse SAND, little gravel, trace silt, occasional small cobbles. (Fill).	
	R1	60/58	7.80 - 12.80	RQD = 58%			a150		74.1		a150 blows for 0.6 ft.	
10											Top of Bedrock at Elev. 74.1 ft. Roller Coned ahead to 7.8 ft bgs. R1: Bedrock: Calcareous feldspathic SANDSTONE [Kittery Formation]. Rock Quality = Fair R1: Core Times (min:sec) 7.8-8.8 ft (1:47) 8.8-9.8 ft (1:53) 9.8-10.8 ft (2:41) 10.8-11.8 ft (3:57) 11.8-12.8 ft (4:52) 97% Recovery	
15									68.9		Bottom of Exploration at 12.8 feet below ground surface.	
20												
25												

Remarks:

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS	Project: Large Culvert Replacement on the Log Cabin Road. Location: Arundel, Maine	Boring No.: HB-ARU-102 WIN: 25397.00
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Driller: MaineDOT	Elevation (ft.): 81.9	Auger ID/OD: 5" Dia.
Operator: Dagget/Jay	Datum: NAVD88	Sampler: N/A
Logged By: B. Wilder	Rig Type: CME 45C	Hammer Wt./Fall: N/A
Date Start/Finish: 8/31/2021; 07:00-12:00	Drilling Method: Solid Stem Auger	Core Barrel: N/A
Boring Location: 12+12.4, 10.1 ft Rt.	Casing ID/OD: N/A	Water Level*: None Observed

Hammer Efficiency Factor: _____
 Hammer Type: Automatic Hydraulic Rope & Cathead

Definitions: R = Rock Core Sample S_u = Peak/Remolded Field Vane Undrained Shear Strength (psf) T_v = Pocket Torvane Shear Strength (psf)
 D = Split Spoon Sample SSA = Solid Stem Auger S_{u(lab)} = Lab Vane Undrained Shear Strength (psf) WC = Water Content, percent
 MD = Unsuccessful Split Spoon Sample Attempt HSA = Hollow Stem Auger q_p = Unconfined Compressive Strength (ksf) LL = Liquid Limit
 U = Thin Wall Tube Sample RC = Roller Cone N-uncorrected = Raw Field SPT N-value PL = Plastic Limit
 MU = Unsuccessful Thin Wall Tube Sample Attempt WOH = Weight of 140lb. Hammer Hammer Efficiency Factor = Rig Specific Annual Calibration Value PI = Plasticity Index
 V = Field Vane Shear Test, PP = Pocket Penetrometer WOR/C = Weight of Rods or Casing N₆₀ = SPT N-uncorrected Corrected for Hammer Efficiency G = Grain Size Analysis
 MV = Unsuccessful Field Vane Shear Test Attempt WO1P = Weight of One Person N₆₀ = (Hammer Efficiency Factor/60%)*N-uncorrected C = Consolidation Test

Depth (ft.)	Sample Information								Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing Blows	Elevation (ft.)				
0							SSA			Probe, no material description given.		
5								75.9				
6.0										Bottom of Exploration at 6.0 feet below ground surface. Boulder REFUSAL		
10												
15												
20												
25												

Remarks:

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS	Project: Large Culvert Replacement on the Log Cabin Road. Location: Arundel, Maine	Boring No.: HB-ARU-102A WIN: 25397.00
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Driller: MaineDOT	Elevation (ft.): 81.9	Auger ID/OD: 5" Dia.
Operator: Dagget/Jay	Datum: NAVD88	Sampler: N/A
Logged By: B. Wilder	Rig Type: CME 45C	Hammer Wt./Fall: N/A
Date Start/Finish: 8/31/2021; 07:00-12:00	Drilling Method: Solid Stem Auger	Core Barrel: N/A
Boring Location: 12+15.4, 10.0 ft Rt.	Casing ID/OD: N/A	Water Level*: None Observed

Hammer Efficiency Factor: **Hammer Type:** Automatic Hydraulic Rope & Cathead

Definitions: R = Rock Core Sample S_u = Peak/Remolded Field Vane Undrained Shear Strength (psf) T_v = Pocket Torvane Shear Strength (psf)
 D = Split Spoon Sample SSA = Solid Stem Auger S_{u(lab)} = Lab Vane Undrained Shear Strength (psf) WC = Water Content, percent
 MD = Unsuccessful Split Spoon Sample Attempt HSA = Hollow Stem Auger q_p = Unconfined Compressive Strength (ksf) LL = Liquid Limit
 U = Thin Wall Tube Sample RC = Roller Cone N-uncorrected = Raw Field SPT N-value PL = Plastic Limit
 MU = Unsuccessful Thin Wall Tube Sample Attempt WOH = Weight of 140lb. Hammer Hammer Efficiency Factor = Rig Specific Annual Calibration Value PI = Plasticity Index
 V = Field Vane Shear Test, PP = Pocket Penetrometer WOR/C = Weight of Rods or Casing N₆₀ = SPT N-uncorrected Corrected for Hammer Efficiency G = Grain Size Analysis
 MV = Unsuccessful Field Vane Shear Test Attempt WO1P = Weight of One Person N₆₀ = (Hammer Efficiency Factor/60%)*N-uncorrected C = Consolidation Test

Depth (ft.)	Sample Information								Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing Blows	Elevation (ft.)				
0											Probe, no material description given.	
5												
10												
15												
20												
25									68.7		Bottom of Exploration at 13.2 feet below ground surface. REFUSAL	

Remarks:

* 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: Large Culvert Replacement on the Log Cabin Road. Location: Arundel, Maine	Boring No.: HB-ARU-103 WIN: 25397.00
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Driller: MaineDOT	Elevation (ft.): 82.3	Auger ID/OD: 5" Dia.
Operator: Dagget/Jay	Datum: NAVD88	Sampler: N/A
Logged By: B. Wilder	Rig Type: CME 45C	Hammer Wt./Fall: N/A
Date Start/Finish: 8/31/2021; 07:00-12:00	Drilling Method: Solid Stem Auger	Core Barrel: N/A
Boring Location: 12+00.3, 11.4 ft Lt.	Casing ID/OD: N/A	Water Level*: None Observed

Hammer Efficiency Factor: **Hammer Type:** Automatic Hydraulic Rope & Cathead

Definitions: R = Rock Core Sample S_u = Peak/Remolded Field Vane Undrained Shear Strength (psf) T_v = Pocket Torvane Shear Strength (psf)
 D = Split Spoon Sample SSA = Solid Stem Auger S_{u(lab)} = Lab Vane Undrained Shear Strength (psf) WC = Water Content, percent
 MD = Unsuccessful Split Spoon Sample Attempt HSA = Hollow Stem Auger q_p = Unconfined Compressive Strength (ksf) LL = Liquid Limit
 U = Thin Wall Tube Sample RC = Roller Cone N-uncorrected = Raw Field SPT N-value PL = Plastic Limit
 MU = Unsuccessful Thin Wall Tube Sample Attempt WOH = Weight of 140lb. Hammer Hammer Efficiency Factor = Rig Specific Annual Calibration Value PI = Plasticity Index
 V = Field Vane Shear Test, PP = Pocket Penetrometer WOR/C = Weight of Rods or Casing N₆₀ = SPT N-uncorrected Corrected for Hammer Efficiency G = Grain Size Analysis
 MV = Unsuccessful Field Vane Shear Test Attempt WO1P = Weight of One Person N₆₀ = (Hammer Efficiency Factor/60%)*N-uncorrected C = Consolidation Test

Depth (ft.)	Sample Information								Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing Blows					
0											Probe, no material description given.	
5												
10												
15									67.1		Bottom of Exploration at 15.2 feet below ground surface. REFUSAL	
20												
25												

Remarks:

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS	Project: Large Culvert Replacement on the Log Cabin Road. Location: Arundel, Maine	Boring No.: HB-ARU-104 WIN: 25397.00
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Driller: MaineDOT	Elevation (ft.): 82.5	Auger ID/OD: 5" Dia.
Operator: Dagget/Jay	Datum: NAVD88	Sampler: N/A
Logged By: B. Wilder	Rig Type: CME 45C	Hammer Wt./Fall: N/A
Date Start/Finish: 8/31/2021; 07:00-12:00	Drilling Method: Solid Stem Auger	Core Barrel: N/A
Boring Location: 11+93.9, 10.4 ft Rt.	Casing ID/OD: N/A	Water Level*: None Observed

Hammer Efficiency Factor: **Hammer Type:** Automatic Hydraulic Rope & Cathead

Definitions: R = Rock Core Sample S_u = Peak/Remolded Field Vane Undrained Shear Strength (psf) T_v = Pocket Torvane Shear Strength (psf)
 D = Split Spoon Sample SSA = Solid Stem Auger S_{u(lab)} = Lab Vane Undrained Shear Strength (psf) WC = Water Content, percent
 MD = Unsuccessful Split Spoon Sample Attempt HSA = Hollow Stem Auger q_p = Unconfined Compressive Strength (ksf) LL = Liquid Limit
 U = Thin Wall Tube Sample RC = Roller Cone N-uncorrected = Raw Field SPT N-value PL = Plastic Limit
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 V = Field Vane Shear Test, PP = Pocket Penetrometer WOR/C = Weight of Rods or Casing N₆₀ = SPT N-uncorrected Corrected for Hammer Efficiency G = Grain Size Analysis
 MV = Unsuccessful Field Vane Shear Test Attempt WO1P = Weight of One Person N₆₀ = (Hammer Efficiency Factor/60%)*N-uncorrected C = Consolidation Test

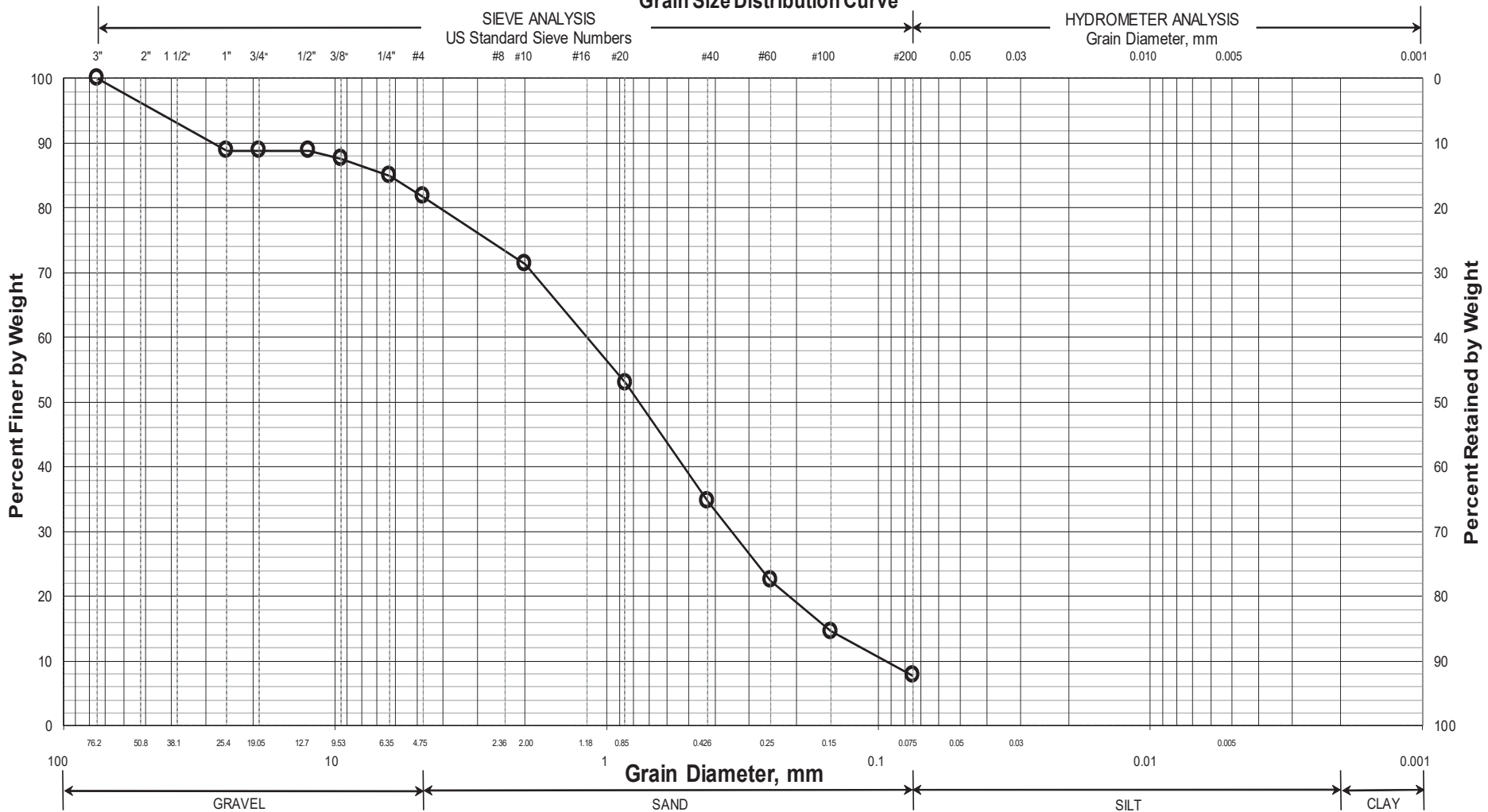
Depth (ft.)	Sample Information								Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing Blows	Elevation (ft.)				
0								SSA		Probe, no material description given.		
5												
10												
15									67.5	Bottom of Exploration at 15.0 feet below ground surface. REFUSAL	15.0	
20												
25												

Remarks:

Appendix B

Laboratory Test Results

Maine Department of Transportation Grain Size Distribution Curve



UNIFIED CLASSIFICATION

	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	WC, %	LL	PL	PI
○	HB-ARU-101/1D	12+19.2	10.0 LT	1.5-3.5	SAND, little gravel, trace silt.	2.5			
◆									
■									
●									
▲									
X									

WIN
025397.00
Town
Arundel
Reported by/Date
WHITE, TERRY A 2/15/2022

Appendix C

Calculations

Bearing Resistance - Existing Soils:

Part 1 - Service Limit State

Nominal and factored Bearing Resistance - Box Culvert on Sand

Presumptive Bearing Resistance for Service Limit State ONLY

Reference: AASHTO LRFD Bridge Design Specifications 9th Edition 2020
Table C10.6.2.6.1-1 Presumptive Bearing Resistances for Spread Footings at the Service Limit State Modified after US Department of Navy (1982)

Type of Bearing Material: Sand (SW-SM)

Based on N-values, soils are medium dense near the bearing elevation

Density In Place: Medium Dense

Bearing Resistance: Ordinary Range (ksf) 4 to 8 (sand with little gravel)

Recommended Value of Use:

$$q_{nom} := 6 \cdot ksf$$

Resistance factor at the **service limit state** = 1.0 (LRFD Article 10.5.5.1)

$$\phi_{service_bc} := 1.0$$

$$q_{factored_service_bc} := q_{nom} \cdot \phi_{service_bc}$$

$$q_{factored_service_bc} = 6 \cdot ksf$$

Note: This bearing resistance is settlement limited (1 inch) and applies only at the service limit state.

Part 2 - Strength Limit State

Nominal and factored Bearing Resistance - Box Culvert on Sand

Reference: AASHTO LRFD Bridge Design Specifications 9th Edition 2020 - Article 10.6.3.1

Assumptions:

1. The box will be founded at ~ Elev 69.6 feet

Bottom of Construction will be 2 feet below box invert

$$D_{footing} := 2.0 \cdot ft$$

2. Assumed parameters for fill soils:

Saturated unit weight: $\gamma_s := 125 \cdot pcf$

Internal friction angle: $\phi_{ns} := 32 \cdot deg$

Undrained shear strength: $c_{ns} := 0 \cdot psf$

3. Box Culvert parameters

Width of box culvert, B $B_{box} := 13 \cdot ft$

Length of box culvert, L $L_{box} := 102 \cdot ft$

Nominal Bearing Resistance per LRFD Equation 10.6.3.1.2a-1

$$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + 0.5\gamma B N_{\gamma m} C_{w\gamma}$$

Bearing Capacity Factors - LRFD Table 10.6.3.1.2a-1

For $\phi=32$ deg $N_c := 35.5$ $N_q := 23.2$ $N_\gamma := 30.2$

Shape Correction Factors LRFD Table 10.6.3.1.2a-3

for $\phi=32$ degrees

$$s_c := 1 + \left(\frac{B_{\text{box}}}{L_{\text{box}}} \right) \left(\frac{N_q}{N_c} \right) \quad s_c = 1.08$$

$$s_\gamma := 1 - 0.4 \left(\frac{B_{\text{box}}}{L_{\text{box}}} \right) \quad s_\gamma = 0.949$$

$$s_q := 1 + \left(\frac{B_{\text{box}}}{L_{\text{box}}} \cdot \tan(\phi_{ns}) \right) \quad s_q = 1.08$$

Load Inclination Factors:

Assume all are 1.0 (LRFD Article C10.6.3.1.2a)

$i_c := 1.0$ $i_q := 1.0$ $i_\gamma := 1.0$

Depth Correction Factor

$$d_q := 1 + 2 \cdot \tan(\phi_{ns}) \cdot (1 - \sin(\phi_{ns}))^2 \cdot \tan\left(\frac{D_{\text{footing}}}{B_{\text{box}}}\right)^{-1} \quad d_q = 2.7809$$

LRFD Eq.
10.6.3.1.2a-10

$N_{cm} := N_c \cdot s_c \cdot i_c$ $N_{cm} = 38.4569$ LRFD Eq.
10.6.3.1.2a-2

$N_{qm} := N_q \cdot s_q \cdot d_q \cdot i_q$ $N_{qm} = 69.65$ LRFD Eq.
10.6.3.1.2a-3

$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma$ $N_{\gamma m} = 28.66$ LRFD Eq.
10.6.3.1.2a-4

Coefficients for Groundwater Depths LRFD Table 10.6.3.1.2a-2

Depth the water table: $D_w := 0 \cdot \text{ft}$ $C_{wq} := 0.5$ $C_{w\gamma} := 0.5$

$$q_{\text{nominal}} := c_{ns} \cdot N_{cm} + \gamma_s \cdot D_{\text{footing}} \cdot N_{qm} \cdot C_{wq} + 0.5(\gamma_s) B_{\text{box}} \cdot N_{\gamma m} \cdot C_{w\gamma}$$

$q_{\text{nominal}} = 20.4 \cdot \text{ksf}$

Factored Bearing Resistance for Strength Limit State

Resistance Factor: $\phi_b := 0.45$ LRFD Table 10.5.5.2.2-1

$q_{\text{factored}} := q_{\text{nominal}} \cdot \phi_b$

$q_{\text{factored}} = 9.2 \cdot \text{ksf}$

Recommend a limiting factored bearing resistance of 9.0 ksf for the Strength Limit State.

Modulus of Subgrade Reaction:

Reference: Foundation Analysis and Design 5th Edition JE Bowles Section 9-6

Width of box culvert, B $B_{\text{box}} = 13 \text{ ft}$
 Length of box culvert, L $L_{\text{box}} = 102 \text{ ft}$
 Thickness of box culvert, t $t_{\text{box}} := 12 \cdot \text{in}$ assumed
 Depth of box, D $D_{\text{box}} := 12 \cdot \text{ft}$
 Bearing Resistance: $q_{\text{factored_service_bc}} = 6 \cdot \text{ksf}$ Calculated above
 Modulus of Elasticity: Site soils near bearing elevation are Sand. Use values for Sand (dense).
 From Bowles Table 2-8 Modulus E_s for Sand, dense ranges from 1000 - 1700 ksf

Use Modulus of Elasticity, E_s $E_s := 1300 \cdot \text{ksf}$
 Poisson's Ratio: Site conditions near bearing elevation are Sand. Use values for Sand (dense).
 From Bowles Table 2-7 Poisson's Ratio μ for Sand ranges from 0.3 - 0.4
 Use Poisson's Ratio, μ $\mu := 0.35$

$$E_{\text{prime_s}} := \frac{1 - \mu^2}{E_s} \quad E_{\text{prime_s}} = 0.000675 \cdot \frac{\text{ft}^2}{\text{kip}}$$

Analyze corner:

Take H as 5*B as recommended in Bowles Chapter 5

$$H_{\text{inf}} := \frac{5 \cdot B_{\text{box}}}{B_{\text{box}}} \quad H_{\text{inf}} = 5 \quad \text{N in Table 5-2} \quad \text{From Table 5-2 for N=5 and M=7.8}$$

$$\frac{L_{\text{box}}}{B_{\text{box}}} = 7.8462 \quad \text{M in Table 5-2} \quad I_1 := 0.540$$

$$I_2 := 0.132$$

Determine Steinbrenner influence factor - Bowles Section 5-6:

$$I_s := I_1 + \left[\frac{1 - (2 \cdot \mu)}{1 - \mu} \right] \cdot I_2 \quad I_s = 0.6009$$

Determine Influence factor for footing depth - Bowles Figure 5-7

$$\text{Depth ratio:} \quad \frac{D_{\text{box}}}{B_{\text{box}}} = 0.9231 \quad \frac{L_{\text{box}}}{B_{\text{box}}} = 7.8462 \quad \mu = 0.35 \quad I_F := 0.83$$

Calculate modulus of subgrade reaction - Bowles Eq. 9-7

$$k_s := \frac{1}{B_{\text{box}} \cdot E_{\text{prime_s}} \cdot I_s \cdot I_F} \quad \text{Bowles Eq. 9-7}$$

$$k_s = 132 \cdot \text{pci}$$

Recommend Modulus of Subgrade Reaction of 130 pci