

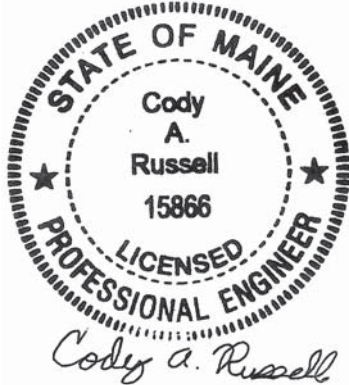
**MAINE DEPARTMENT OF TRANSPORTATION
HIGHWAY PROGRAM
GEOTECHNICAL SECTION
AUGUSTA, MAINE**

GEOTECHNICAL DESIGN REPORT

For the Construction of:

**WEBB BROOK BRIDGE
ROUTE 11 / 159
PATTEN, MAINE**

Prepared by:
Cody Russell, P.E.
Geotechnical Engineer



Reviewed by:
Kathleen Maguire, P.E.
Senior Geotechnical Engineer

Aroostook County
WIN 21810.00

January 7, 2020

Soils Report 2020-01
Bridge No. 6567

Table of Contents

1.0	INTRODUCTION	1
2.0	GEOLOGIC SETTING	1
3.0	SUBSURFACE INVESTIGATION	1
4.0	LABORATORY TESTING.....	2
5.0	SUBSURFACE CONDITIONS.....	2
6.0	GEOTECHNICAL DESIGN AND CONSTRUCTION RECOMMENDATIONS ...	3
6.1	PRECAST CONCRETE BOX CULVERT DESIGN AND CONSTRUCTION	4
6.2	PRECAST CONCRETE BOX CULVERT CONSTRUCTED ON BEDROCK.....	4
6.3	BEDROCK REMOVAL AND SUBGRADE PREPARATION	5
6.4	SETTLEMENT	5
6.5	BEARING RESISTANCE	5
6.6	MODULUS OF SUBGRADE REACTION	6
6.7	SCOUR AND RIPRAP	6
6.8	SEISMIC DESIGN CONSIDERATIONS	6
6.9	CONSTRUCTION CONSIDERATIONS	6
7.0	CLOSURE.....	7

Sheets

Sheet 1 - Location Map

Sheet 2 - Boring Location Plan & Interpretive Subsurface Profile with Boring Logs

Appendices

Appendix A - Boring Logs

Appendix B - Laboratory Test Results

Appendix C - Calculations

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 (#282919) consisting of twin corrugated metal pipes (CMPs) on Route 11 / 159 in Patten, 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 approximately 90-foot long, 60-inch diameter, twin, bituminous, coated, CMP culverts on a skew of approximately 34 degrees to the roadway centerline. The CMPs are structurally deficient. Route 11 / 159 is a Highway Corridor Priority 2 road.

The proposed replacement structure will be a 15-foot span by 6-foot rise by 140-foot long precast concrete box culvert on a skew of approximately 40 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 11 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 culverts carry Webb Brook under Route 11 / 159 in Patten and is located approximately 0.04 of a mile south of the Shin Pond Road intersection as shown on Sheet 1 – Location Map.

According to the Maine Geological Survey (MGS) map titled Reconnaissance Surficial Geology of the Sherman Quadrangle, Maine, Open File 80-17 (1980) the surficial soils at the site consist of Till. These soils consist of a mixture of sand, silt, clay, and stones and are generally underlain by 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 undifferentiated conglomerates and coarse-grained sandstones, in part of the Allsbury formation and in part unnamed.

3.0 SUBSURFACE INVESTIGATION

One (1) boring (HB-PAT-101) and one (1) probe (HB-PAT-102) were drilled for this project on August 16, 2018 by the MaineDOT drill crew using a trailer mounted drill rig. Exploration locations are shown on Sheet 2 – Boring Location Plan & Interpretive Subsurface Profile with

Boring Logs. 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-PAT-101 was drilled using solid stem auger, cased wash boring and rock core drilling techniques. Soil samples were obtained in boring HB-PAT-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 57 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 0.943 to the raw field N-values. The bedrock was cored in boring HB-PAT-101 using an NQ 2-inch core barrel and the Rock Quality Designation (RQD) of the core was calculated. Probe HB-PAT-102 was drilled using solid stem auger techniques. No soil samples were obtained in the probe.

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 three (3) standard grain size analyses with natural water content and one (1) grain size analysis with hydrometer and 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 fill underlain by native glacial till, 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 with Boring Logs.

Boring HB-PAT-101 was drilled to refusal at a depth of approximately 12.0 feet below ground surface (bgs). Bedrock was cored in the boring for a total depth of approximately 17.0 feet bgs. Probe HB-PAT-102 was drilled to a depth of approximately 12.4 feet bgs, where it encountered a refusal surface. The nature of the refusal surface was not determined in the probe.

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

Approx. Depth BGS ¹ (feet)	Soil Description	AASHTO ² Classification	USCS ³	WC% ⁴
0.0 – 0.4	Pavement	--	--	--
0.4 – 5.5	Fill – Brown, damp, fine to coarse sand, some gravel, trace silt. Brown, damp, gravelly fine to coarse sand, little silt.	A-1-b	SW-SM	3.8 3.2
5.5 – 10.5	Glacial Till – Brown, moist to wet, fine to coarse sand, little to some gravel, little to some silt, trace clay.	A-1-b A-2-4	SM SC-SM	9.6 to 13.6
10.5 – 12.0	Weathered Bedrock	--	--	--
12.0 – 17.0	Bedrock – Undifferentiated conglomerate and coarse-grained sandstone.	--	--	--

¹BGS = below ground surface

²AASHTO = American Association of State Highway and Transportation Officials

³USCS = Unified Soil Classification System

⁴WC% = Water content in percent

One (1) corrected N-value obtained in the fill was 33 blows per foot (bpf), indicating that the fill is dense consistency. One (1) corrected N-value obtained in the glacial till was 11 bpf, indicating that the till was medium dense in consistency. The Rock Quality Designation (RQD) of the bedrock was determined to be 23 percent in boring HB-PAT-101, correlating to a Rock Quality of Very Poor.

Groundwater was not recorded in the boring or the probe. 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 proposed replacement structure will consist of a 15-foot span by 6-foot rise by 140-foot long precast concrete box culvert on a skew of approximately 40 degrees to the roadway centerline. The proposed structure inlet and outlet slopes shall be riprapped with slopes no steeper than 2H:1V to protect against erosion. 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 15-foot span by 6-foot rise by 140-foot long precast concrete box culvert on a skew of approximately 40 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 583.0 at the inlet to approximately 580.9 at the outlet with a 1.5 percent slope. 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 Precast Concrete Box Culvert Constructed on Bedrock

A refusal surface was encountered at elevations ranging from approximately 580.6 to 581.6 feet in the vicinity of the proposed box culvert. Weathered bedrock was encountered at an elevation of approximately 583.1. The approximate invert of the proposed box culvert ranges from approximately 583.0 feet at the inlet to approximately 580.9 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 borings indicate that the Rock Quality of the bedrock is very poor with an RQD of approximately 23 percent.

6.3 Bedrock Removal and Subgrade Preparation

To construct the culvert at the planned elevations bedrock removal will be necessary. 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.

6.4 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.

6.5 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 8th Edition 2017 (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	8.0

6.6 Modulus of Subgrade Reaction

A modulus of subgrade reaction (k_s) equal to 170 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.

6.7 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.

6.8 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.

6.9 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 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 embedment into the till or weathered bedrock 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 native soils as backfill around the culvert shall not be permitted. The 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.

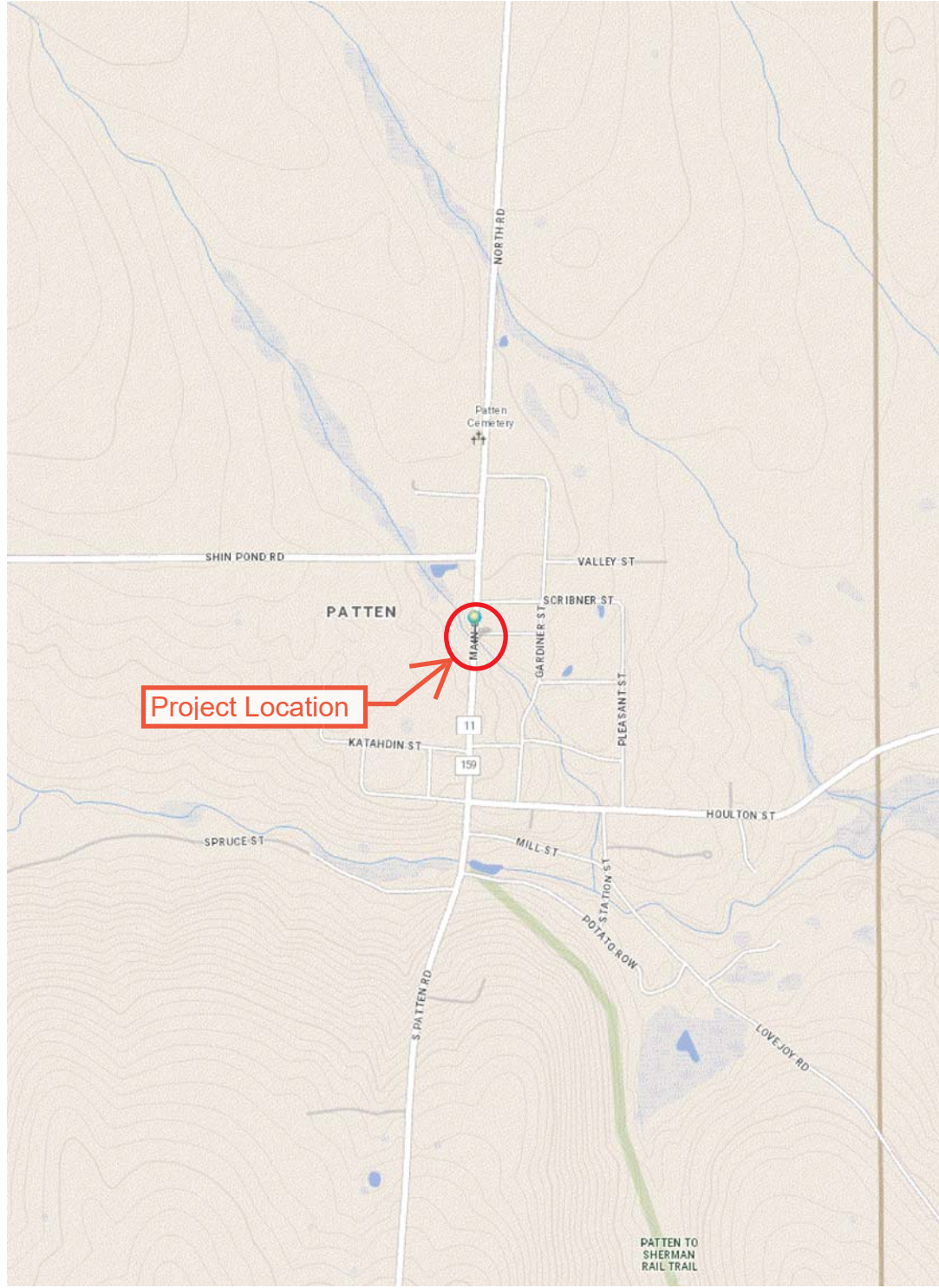
7.0 CLOSURE

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 (#282919) under Route 11 / 159 in Patten, 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



SHEET NUMBER 1 OF 2	PATTEN ROUTE 11	STATE OF MAINE DEPARTMENT OF TRANSPORTATION	
		021810.00	
	LOCATION MAP	WIN 021810.00	HIGHWAY PLANS

Appendix A

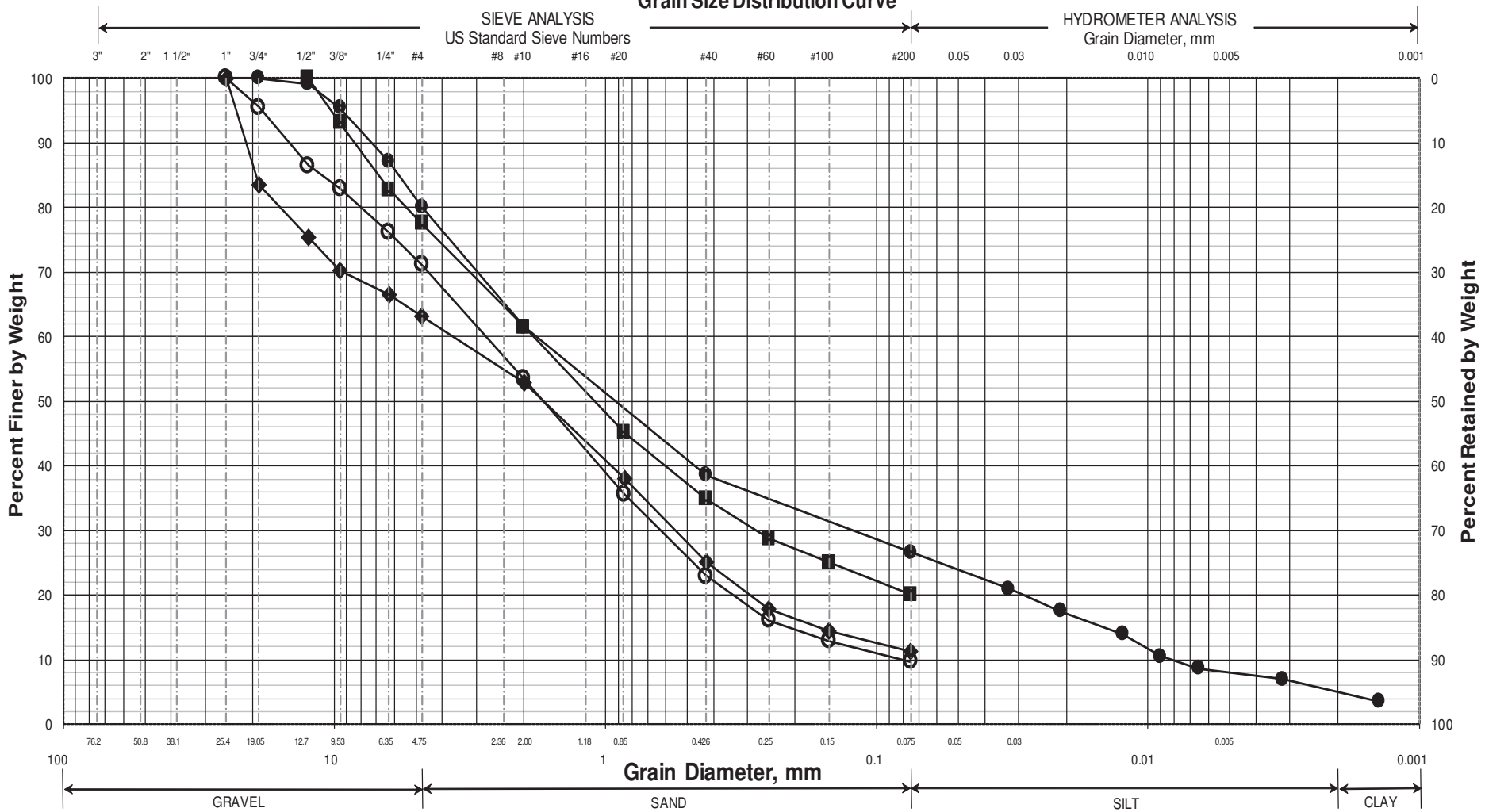
Boring Logs

UNIFIED SOIL CLASSIFICATION SYSTEM				MODIFIED BURMISTER SYSTEM																									
MAJOR DIVISIONS		GROUP SYMBOLS	TYPICAL NAMES	Descriptive Term	Portion of Total (%)																								
COARSE-GRAINED SOILS (more than half of material is larger than No. 200 sieve size)	GRAVELS (more than half of coarse fraction is larger than No. 4 sieve size)	CLEAN GRAVELS	GW Well-graded gravels, gravel-sand mixtures, little or no fines.	trace little some adjective (e.g. sandy, clayey)	0 - 10 11 - 20 21 - 35 36 - 50																								
		(little or no fines)	GP Poorly-graded gravels, gravel sand mixtures, little or no fines.																										
	SANDS (more than half of coarse fraction is smaller than No. 4 sieve size)	GRAVEL WITH FINES (Appreciable amount of fines)	GM Silty gravels, gravel-sand-silt mixtures.			TERMS DESCRIBING DENSITY/CONSISTENCY																							
		CLEAN SANDS (little or no fines)	SW Well-graded sands, gravelly sands, little or no fines			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).																							
			SP Poorly-graded sands, gravelly sand, little or no fines.			Density of Cohesionless Soils																							
		SANDS WITH FINES (Appreciable amount of fines)	SM Silty sands, sand-silt mixtures			Standard Penetration Resistance N-Value (blows per foot)																							
SC Clayey sands, sand-clay mixtures.	<table border="0"> <tr> <td>Very loose</td> <td>0 - 4</td> </tr> <tr> <td>Loose</td> <td>5 - 10</td> </tr> <tr> <td>Medium Dense</td> <td>11 - 30</td> </tr> <tr> <td>Dense</td> <td>31 - 50</td> </tr> <tr> <td>Very Dense</td> <td>> 50</td> </tr> </table>			Very loose	0 - 4	Loose	5 - 10	Medium Dense	11 - 30	Dense	31 - 50	Very Dense	> 50																
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 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.	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.																										
		CL Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Consistency of Cohesive soils																										
		OL Organic silts and organic silty clays of low plasticity.	Approximate Undrained Shear Strength (psf)																										
	SILTS AND CLAYS (liquid limit greater than 50)	MH Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	Field Guidelines																										
		CH Inorganic clays of high plasticity, fat clays.	<table border="0"> <tr> <td>Very Soft</td> <td>WOH, WOR, WOP, <2</td> <td>0 - 250</td> <td>Fist easily penetrates</td> </tr> <tr> <td>Soft</td> <td>2 - 4</td> <td>250 - 500</td> <td>Thumb easily penetrates</td> </tr> <tr> <td>Medium Stiff</td> <td>5 - 8</td> <td>500 - 1000</td> <td>Thumb penetrates with moderate effort</td> </tr> <tr> <td>Stiff</td> <td>9 - 15</td> <td>1000 - 2000</td> <td>Indented by thumb with great effort</td> </tr> <tr> <td>Very Stiff</td> <td>16 - 30</td> <td>2000 - 4000</td> <td>Indented by thumbnail</td> </tr> <tr> <td>Hard</td> <td>>30</td> <td>over 4000</td> <td>Indented by thumbnail with difficulty</td> </tr> </table>			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
		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																										
OH Organic clays of medium to high plasticity, organic silts.	Rock Quality Designation (RQD):																												
HIGHLY ORGANIC SOILS	Pt Peat and other highly organic soils.	<p>RQD (%) = $\frac{\text{sum of the lengths of intact pieces of core} * > 4 \text{ inches}}{\text{length of core advance}}$</p> <p>*Minimum NQ rock core (1.88 in. OD of core)</p> <p style="text-align: center;">Correlation of RQD to Rock Mass Quality</p> <table border="0"> <tr> <td>Rock Mass Quality</td> <td>RQD (%)</td> </tr> <tr> <td>Very Poor</td> <td>≤25</td> </tr> <tr> <td>Poor</td> <td>26 - 50</td> </tr> <tr> <td>Fair</td> <td>51 - 75</td> </tr> <tr> <td>Good</td> <td>76 - 90</td> </tr> <tr> <td>Excellent</td> <td>91 - 100</td> </tr> </table>			Rock Mass Quality	RQD (%)	Very Poor	≤25	Poor	26 - 50	Fair	51 - 75	Good	76 - 90	Excellent	91 - 100													
Rock Mass Quality	RQD (%)																												
Very Poor	≤25																												
Poor	26 - 50																												
Fair	51 - 75																												
Good	76 - 90																												
Excellent	91 - 100																												
Desired Soil Observations (in this order, if applicable):				Desired Rock 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				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 mass quality (very poor, poor, etc.) ref: ASTM D6032 and AASHTO Standard Specification for Highway Bridges, 17th Ed. Table 4.4.8.1.2A Recovery (inch/inch and percentage) Rock Core Rate (X.X ft - Y.Y ft (min:sec))																									
Maine Department of Transportation Geotechnical Section Key to Soil and Rock Descriptions and Terms Field Identification Information				Sample Container Labeling Requirements:																									
				WIN Blow Counts Bridge Name / Town Sample Recovery Boring Number Date Sample Number Personnel Initials Sample Depth																									

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-PAT-101/1D	6+22	16.3 RT	1.0-3.0	SAND, some gravel, trace silt.	3.8			
◆	HB-PAT-101/2D	6+22	16.3 RT	5.0-5.5	Gravelly SAND, little silt.	3.2			
■	HB-PAT-101/2DA	6+22	16.3 RT	5.5-7.0	SAND, some gravel, little silt.	9.6			
●	HB-PAT-101/3D	6+22	16.3 RT	10.0-11.0	SAND, some silt, little gravel, trace clay.	13.6			
▲									
×									

WIN
021810.00
Town
Patten
Reported by/Date
WHITE, TERRY A 12/4/2019

Appendix C

Calculations

Bearing Resistance - Existing Soils:

Part 1 - Service Limit State

Nominal and factored Bearing Resistance - Box Culvert on Till

Presumptive Bearing Resistance for Service Limit State ONLY

Reference: AASHTO LRFD Bridge Design Specifications 8th Edition 2017
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: fine to coarse sand (SC-SM) (till)

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

Density In Place: medium dense

Bearing Resistance: Ordinary Range (ksf) 4 to 8

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 Till

Reference: AASHTO LRFD Bridge Design Specifications 8th Edition 2017 - Article 10.6.3.1

Assumptions:

1. The box will be founded at ~ Elev 583.0 feet to 580.9 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 $B_{box} := 15 \cdot ft$

Length of box culvert, L $L_{box} := 140 \cdot ft$

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 $\phi=32$

$$s_c := 1 + \left(\frac{B_{\text{box}}}{L_{\text{box}}} \right) \left(\frac{N_q}{N_c} \right) \quad s_c = 1.07$$

$$s_\gamma := 1 - 0.4 \left(\frac{B_{\text{box}}}{L_{\text{box}}} \right) \quad s_\gamma = 0.9571$$

$$s_q := 1 + \left(\frac{B_{\text{box}}}{L_{\text{box}}} \cdot \tan(\phi_{ns}) \right) \quad s_q = 1.07$$

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 LRFD Table 10.6.3.1.2a-4

$$\frac{D_{\text{footing}}}{B_{\text{box}}} = 0.1333 \quad \text{for } \phi=32 \text{ degrees} \quad d_q := 1.2$$

$$N_{cm} := N_c \cdot s_c \cdot i_c \quad N_{cm} = 37.9857 \quad \text{LRFD Eq. 10.6.3.1.2a-2}$$

$$N_{qm} := N_q \cdot s_q \cdot d_q \cdot i_q \quad N_{qm} = 29.7 \quad \text{LRFD Eq. 10.6.3.1.2a-3}$$

$$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma \quad N_{\gamma m} = 28.91 \quad \text{LRFD Eq. 10.6.3.1.2a-4}$$

Coefficients for Groundwater Depths LRFD Table 10.6.3.1.2a-2

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

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

$$q_{\text{nominal}} = 17.3 \cdot \text{ksf}$$

Factored Bearing Resistance for Strength Limit State

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

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

$$q_{\text{factored}} = 7.8 \cdot \text{ksf}$$

Recommend a limiting factored bearing resistance of 8.0 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 $B_{\text{box}} := 15 \cdot \text{ft}$
 Length of box culvert, L $L_{\text{box}} := 140 \cdot \text{ft}$
 Thickness of box culvert, t $t_{\text{box}} := 12 \cdot \text{in}$ assumed
 Depth of box, D $D_{\text{box}} := 10 \cdot \text{ft}$
 Bearing Resistance: $q_{\text{factored_service_bc}} = 6 \cdot \text{ksf}$ Calculated above

Modulus of Elasticity: Site soils are Sand (medium dense)
 From Bowles Table 2-8 Modulus E_s for sand and gravel, dense ranges from 2,000 - 4,100 ksf
 Use Modulus of Elasticity, E_s $E_s := 2000 \cdot \text{ksf}$

Poisson's Ratio: Site soils are Sand (dense)
 From Bowles Table 2-7 Poisson's Ratio μ for Sand/Till ranges from 0.3 - 0.4
 Use Poisson's Ratio, μ $\mu := 0.35$

$$E_{\text{prime_s}} := \frac{1 - \mu^2}{E_s} \quad E_{\text{prime_s}} = 0.000439 \cdot \frac{\text{ft}^2}{\text{kip}}$$

Analyze corner:

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

$$H_{\text{inf}} := \frac{5 \cdot B_{\text{box}}}{B_{\text{box}}} \quad H_{\text{inf}} = 5 \quad \text{N in Table 5-2} \quad \text{From Table 5-2 for N=5 and M=9.3}$$

$$\frac{L_{\text{box}}}{B_{\text{box}}} = 9.3333 \quad \text{M in Table 5-2} \quad I_1 := 0.535$$

$$I_2 := 0.139 \quad \text{by interpolation}$$

Determine Steinbrenner influence factor - Bowles Section 5-6:

$$I_s := I_1 + \left[\frac{1 - (2 \cdot \mu)}{1 - \mu} \right] \cdot I_2 \quad I_s = 0.5992$$

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

$$\text{Depth ratio: } \frac{D_{\text{box}}}{B_{\text{box}}} = 0.6667 \quad \frac{L_{\text{box}}}{B_{\text{box}}} = 9.3333 \quad \mu = 0.35 \quad I_F := 0.87$$

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

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

$$k_s = 169 \cdot \text{pci}$$

Recommend Modulus of Subgrade Reaction of 170 pci