MAINE DEPARTMENT OF TRANSPORTATION
HIGHWAY PROGRAM
GEOTECHNICAL SECTION
AUGUSTA, MAINE

GEOTECHNICAL DESIGN REPORT

For the Replacement of:

LARGE CULVERT #46827
ROUTE 32
BREMEN, MAINE

Prepared by:
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Geotechnical Engineer

STATE OF MAINE
Cody
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PROFESSIONAL ENGINEER

Reviewed by:
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Senior Geotechnical Engineer

Lincoln County
WIN 24283.00

Soils Report 2022-08
Federal Project No. 2428300

March 30, 2022

PROJECT DETAILS

The purpose of this Geotechnical Design Report is to present subsurface information and make geotechnical recommendations for the replacement of an existing large culvert (#46827) on Route 32 in Bremen. 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 a 60-inch diameter, approximately 40-foot-long corrugated metal pipe (CMP) culvert. The CMP is in poor condition with unzipping on the inlet end. Route 32 is a Highway Corridor Priority 4 road.

The proposed replacement structure will be a 11-foot span by 3.5-foot rise by 68-foot-long structural plate single radius arch culvert founded on cast-in-place pedestal footings pinned into bedrock. The invert of the proposed culvert is approximately 8 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.

SUBSURFACE INVESTIGATION

Five (5) probes (HB-BRE-101, HB-BRE-102, HB-BRE-102A, HB-BRE-104, and HB-BRE-105) and one (1) boring (HB-BRE-103) were drilled for this project on July 23, 2019 by the MaineDOT drill crew using a trailer mounted drill rig. Exploration locations are shown on the attached Boring Location Plan & Interpretive Subsurface Profile. Details and sampling methods used, field data obtained, and soil and groundwater conditions encountered are presented on the attached Boring Logs.

Probes HB-BRE-101, HB-BRE-102, HB-BRE-102A, HB-BRE-104, and HB-BRE-105 were drilled using solid stem auger techniques. No soil samples were obtained in the probes. Boring HB-BRE-103 was drilled using solid stem auger and rock core drilling techniques. Soil samples were obtained in the boring 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 0.886 to the raw field N-values. The bedrock was cored in boring HB-BRE-103 using an NQ 2-inch core barrel.

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 probes were located in the field by taping to surveyed site features after completion of the drilling program.

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 two (2) standard grain size analyses with natural water content. The results of the laboratory testing program are discussed in the following section and are shown in the attached boring logs, Laboratory Testing Summary Sheet and Grain Size Distribution Curves.

SUBSURFACE CONDITIONS

Subsurface conditions encountered in the test boring and probes generally consisted fill sand underlain by bedrock. An interpretive subsurface profile depicting the generalized soil stratigraphy at the boring location is shown on the attached Boring Location Plan & Interpretive Subsurface Profile with Boring Logs.

Probes HB-BRE-101, HB-BRE-102, HB-BRE-102A, HB-BRE-104, and HB-BRE-105 drilled to depths ranging from approximately 2.2 feet below ground surface (bgs) to 10.8 feet bgs and where they all encountered a refusal surface. The exact nature of the refusal surface was not determined in the probes. Boring HB-BRE-103 was drilled to refusal at a depth of approximately 7.8 feet bgs. Bedrock was cored in the boring for a total boring depth of approximately 12.8 feet bgs.

The table below summarizes the field and laboratory information obtained in boring HB-BRE-102:

Approx. Depth BGS[1] (feet)	Soil Description	AASHTO[2] Classification	USCS[3]	WC%[4]
0.0 – 0.5	HMA Pavement			
0.5 – 7.6	Fill – Brown, damp, fine to coarse sand, some gravel, trace to little silt.	A-1-b	SW-SM or SM	4.6 to 7.8
7.6 – 7.8	Weathered Bedrock	--	--	--
7.8 – 12.8	Bedrock – Intrusive Devonian granite with biotite inclusions.	--	--	--

[1]BGS = below ground surface
[2]AASHTO = American Association of State Highway and Transportation Officials
[3]USCS = Unified Soil Classification System
[4]WC% = Water content in percent

Corrected N-values obtained in the fill ranged from 35 to 58 blows per foot (bpf), indicating that the fill is dense to very dense in consistency. The Rock Quality Designation (RQD) of the bedrock was determined to be 72.5 percent in boring HB-BRE-103 which correlates to a Rock Mass Quality of Fair.

Groundwater was not observed in the probes or boring. Groundwater levels can be expected to fluctuate subject to seasonal variations, local soil conditions, topography, precipitation, and construction activity.

GEOTECHNICAL DESIGN AND CONSTRUCTION RECOMMENDATIONS

The proposed replacement structure will consist of an 11-foot span by 3.5-foot rise by 68-foot-long structural plate single radius arch culvert founded on cast-in-place pedestal footings pinned into bedrock. 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.

Structural Plate Single Radius Arch Culvert Design and Construction – The proposed replacement structure will consist of an 11-foot span by 3.5-foot rise by 68-foot-long structural plate single radius arch culvert founded on cast-in-place pedestal footings pinned into bedrock. The top-of-footing elevations of the proposed structural plate single radius arch culvert range from approximately 73.15 feet at the inlet to approximately 71.64 feet at the outlet with a 2.22 percent slope. The proposed structural plate single radius arch culvert shall be designed and constructed in accordance with MaineDOT Standard Specification 509.

The full nature of the bearing surface will not become evident until the culvert excavation is made. Prior to placement of the footings, the bedrock surface will be cleaned of all weathered bedrock, fractured material, loose soil, and/or ponded water. Smooth bedrock should be roughened or serrated prior to placing concrete to enhance sliding stability. The foundation bearing area should be approximately level.

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 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.

Bedrock Removal and Subgrade Preparation – The structural design intends for the pedestal footings to bear on and be pinned into the prepared bedrock surface; a mixed subgrade surface consisting of bedrock and soil/aggregate fill shall not be accepted. The bedrock shall be prepared in accordance with MaineDOT standard practices. The footing bearing area should be approximately level. The nature, slope, and degree of fracturing in the bedrock bearing surfaces will not be evident until the excavation for the pedestal footings for the culvert is made. Bedrock surface slope shall be less than 6H:1V or it shall be benched in level steps.

Construction activities should not be permitted to create any open fissures. Any irregularities in the existing bedrock surface or irregularities created during the excavation process shall be addressed using Concrete Fill (Pay Item 502.565) prior to footing construction.

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, and loose rock. The cleanliness and condition of the bedrock surface should be confirmed and accepted by the Resident prior to placing the cast-in-place concrete pedestal footings. If soil is encountered at bedding material subgrade it shall be overexcavated to expose the underlying bedrock surface.

Blasting shall be conducted in accordance with Section 105.2.7 and Section 203.042 of the MaineDOT Standard Specifications. It is also recommended that the Contractor conduct pre- and post-blast surveys, as well as blast vibration monitoring at nearby structures in accordance with the MaineDOT Standard Specifications and industry standards at the time of the blast. The Contractor's blasting submittals shall address blasting procedures adjacent to an active roadway, including flyrock controls.

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.

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 structure will be constructed on bedrock. Any settlement due to elastic compression of the bedrock will be immediate and negligible.

Bearing Resistance – The factored bearing resistances for the cast-in-place pedestal footings bearing on 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	160.0
Strength	0.45	Table 10.5.5.2.2-1	160.0

Scour and Riprap – Both the inlet and outlet of the structural plate single radius arch 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 (Standard Specification Section 703.19). The toe of the riprap sections shall be keyed into the existing soils 1 foot below the streambed elevation.

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.

Construction Considerations – Construction activities will 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 structural plate single radius arch culvert founded on cast-in-place pedestal footings will require deep soil excavation. Earth support systems shall be implemented if laying back slopes is not feasible. It is possible that the use of complex (four-sided) braced excavations with dewatering will be necessary due to maintenance of traffic and the depth of the excavation. If this is the case, adequate embedment 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 soils as backfill around the culvert or as roadway base material shall not be permitted. The excavated 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.

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 (#46827) under Route 32 in Bremen, 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.

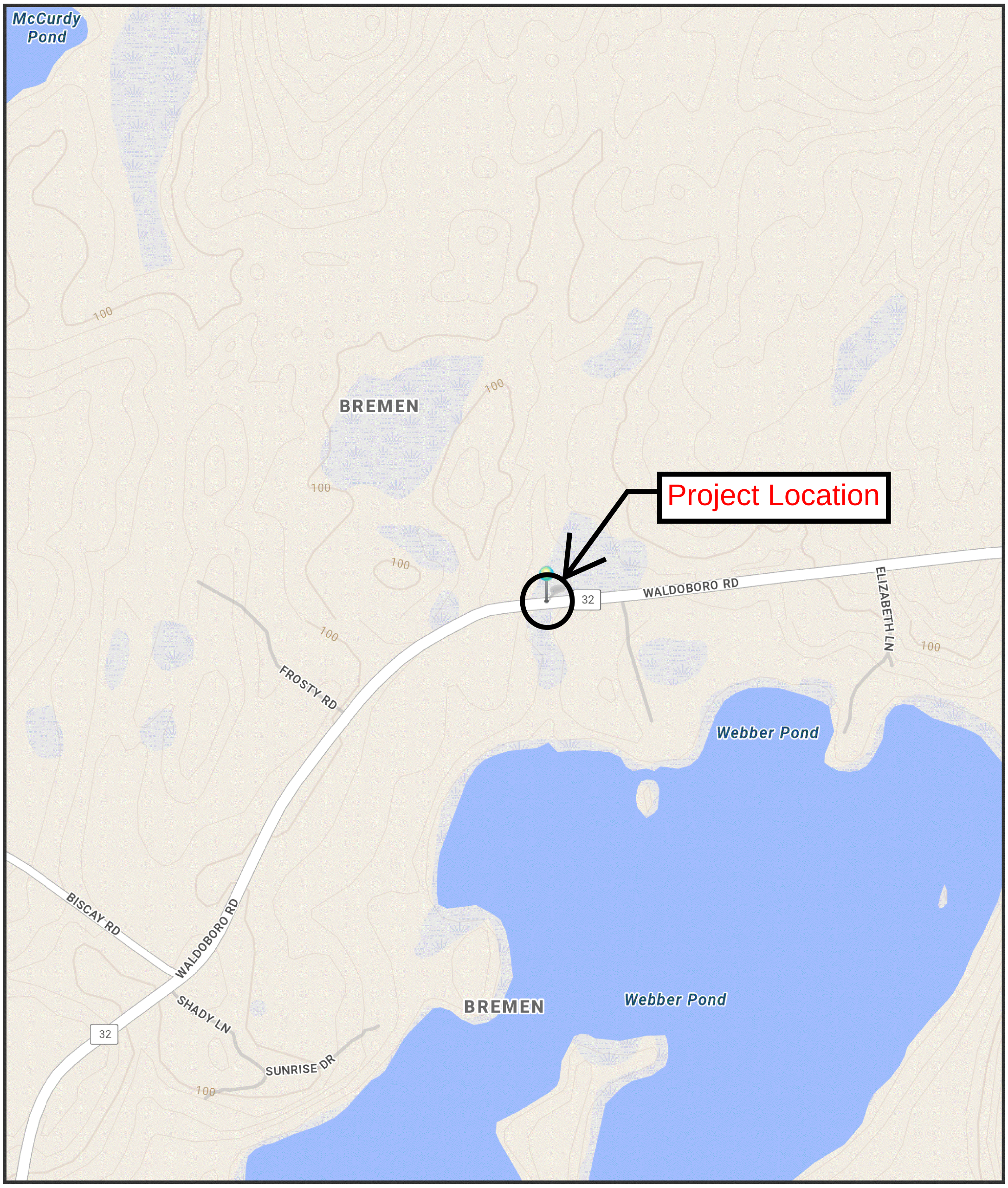
It is recommended that a geotechnical engineer be provided the opportunity for a review of the design and specifications in order that the earthwork and foundation recommendations and construction considerations presented in this report are properly interpreted and implemented in the design and specifications.

Attachments

Location Map
Boring Location Plan & Interpretive Subsurface Profile
Key to Soil and Rock Descriptions and Terms
Boring Logs
Laboratory Testing Summary Sheet
Grain Size Distribution Curve Sheet
Calculations

Date:3/17/2022
Division: GEOTECH
Username: Cody.A.Russell

BREMEN, MAINE

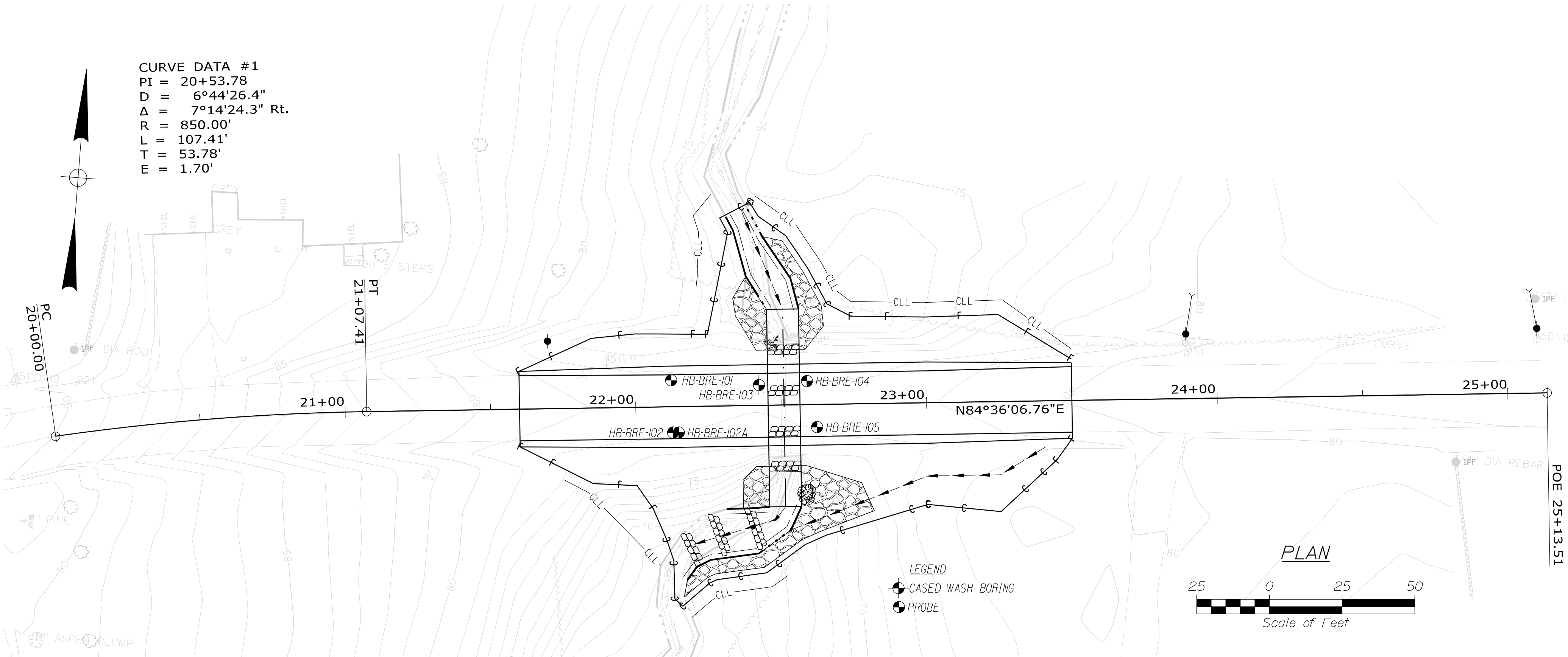


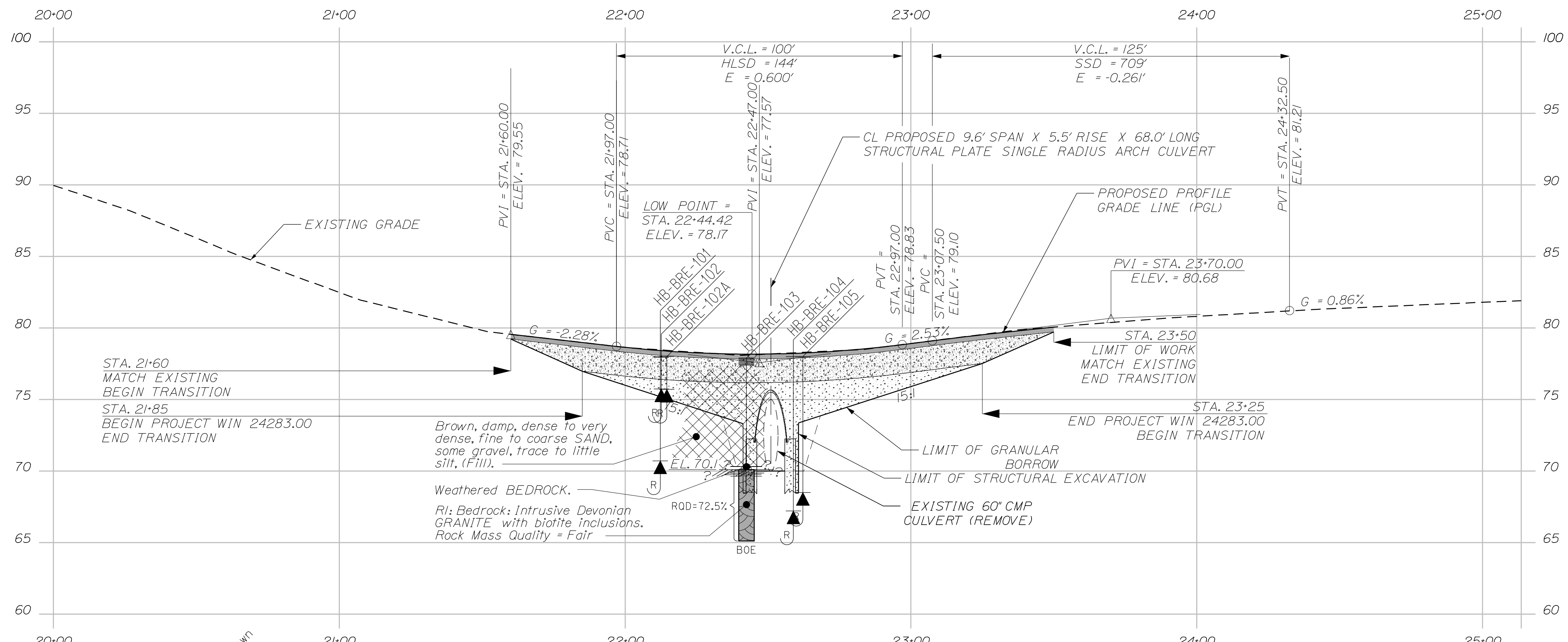
0.1 Miles
1 inch = 0.14 miles

Date: 3/16/2022
Time: 8:24:42 AM

SHEET NUMBER	BREMEN ROUTE 32	STATE OF MAINE DEPARTMENT OF TRANSPORTATION
1		2428300
OF 2	LOCATION MAP	WIN 24283.00 HIGHWAY PLANS

Filename: ...\GEOTECH\MSTA\002_BLP&SP1.dgn Division: GEOTECH Username: terry.white Date:4/13/2022





LEGEND

Boring No., Offset, if shown

Weathered Bedrock, if applicable

Pavement Thickness, if applicable

Approximate Top of Bedrock

RQD= Rock Quality Designation of Bedrock Core Sample

BOE= Bottom of Exploration

NR No Refusal

R Refusal

PROFILE

HORIZ 25 0 25 50

VERT 5 0 5 10

SCALE

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

2428300

WIN 24283.00

HIGHWAY PLANS

	BY	DATE
PROJ. MANAGER		
DESIGN-DETAILED		
CHECKED-REVIEWED		
DESIGN2-DETAILED2	C.RUSSELL	
DESIGN3-DETAILED3	T.WHITE	MAR 2022
REVISIONS 1		
REVISIONS 2		
REVISIONS 3		
REVISIONS 4		
FIELD CHANGES		

SIGNATURE

P.E. NUMBER

DATE

BREMEN
ROUTE 32

BORING LOCATION PLAN & INTERPRETIVE SUBSURFACE PROFILE

SHEET NUMBER

2

OF 2

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):

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

*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: Large Culvert Replacement on Route 32
Location: Bremen, Maine

Boring No.: HB-BRE-101
WIN: 24283.00

Drilling Contractor:	MaineDOT	**Elevation (ft.)**	78.1	**Auger ID/OD:**	5" Dia.
Operator:	Daggett/Niles	**Datum:**	NAVD88	**Sampler:**	N/A
Logged By:	C. Russell	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	N/A
Date Start/Finish:	7/23/2019; 11:15-11:25	**Drilling Method:**	Solid Stem Auger	**Core Barrel:**	N/A
Boring Location:	22+12.3, 9.1 ft Lt.	**Casing ID/OD:**	N/A	**Water Level*:**	None Observed

Definitions: D = Spilt Spoon Sample
S = Sample off Auger Flights
B = Bucket Sample off Auger Flights
MD = Unsuccessful Split Spoon Sample Attempt
U = Thin Wall Tube Sample
MV = Unsuccessful Field Vane Shear Test Attempt
V = Field Vane Shear Test, PP= Pocket Penetrometer
MU = Unsuccessful Thin Wall Tube Sample 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 1 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-value = Raw Field SPT N-value
T_V = Pocket Torvane Shear Strength (psf)
WC = Water Content, percent ≅ = Similar or Equal too
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-value	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
0						SSA			Probe, no soil samples taken.	
5										
							70.8		7.3 **Bottom of Exploration at 7.3 feet below ground surface.** REFUSAL	
10										
15										
20										
25										

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: Large Culvert Replacement on Route 32
Location: Bremen, Maine

Boring No.: HB-BRE-102
WIN: 24283.00

Drilling Contractor:	MaineDOT	**Elevation (ft.)**	78.0	**Auger ID/OD:**	5" Dia.
Operator:	Daggett/Niles	**Datum:**	NAVD88	**Sampler:**	N/A
Logged By:	C. Russell	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	N/A
Date Start/Finish:	7/23/2019; 11:35-11:50	**Drilling Method:**	Solid Stem Auger	**Core Barrel:**	N/A
Boring Location:	22+12.7, 8.9 ft Rt.	**Casing ID/OD:**	N/A	**Water Level*:**	None Observed

Definitions: D = Spilt Spoon Sample
S = Sample off Auger Flights
B = Bucket Sample off Auger Flights
MD = Unsuccessful Split Spoon Sample Attempt
U = Thin Wall Tube Sample
MV = Unsuccessful Field Vane Shear Test Attempt
V = Field Vane Shear Test, PP= Pocket Penetrometer
MU = Unsuccessful Thin Wall Tube Sample 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 1 Person
S_u = Peak/Remolded Field Vane Undrained Shear Strength (psf)
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q_p = Unconfined Compressive Strength (ksf)
N-value = Raw Field SPT N-value
T_v = Pocket Torvane Shear Strength (psf)
WC = Water Content, percent ≅ = Similar or Equal too
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-value	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
0						SSA			Probe, no soil samples taken.	
							75.8		2.2	
									Bottom of Exploration at 2.2 feet below ground surface. REFUSAL	
5										
10										
15										
20										
25										

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: Large Culvert Replacement on Route 32
Location: Bremen, Maine

Boring No.: HB-BRE-102A
WIN: 24283.00

Drilling Contractor:	MaineDOT	**Elevation (ft.)**	78.0	**Auger ID/OD:**	5" Dia.
Operator:	Daggett/Niles	**Datum:**	NAVD88	**Sampler:**	N/A
Logged By:	C. Russell	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	N/A
Date Start/Finish:	7/23/2019; 11:50-12:00	**Drilling Method:**	Solid Stem Auger	**Core Barrel:**	N/A
Boring Location:	22+14.6, 8.9 ft Rt.	**Casing ID/OD:**	N/A	**Water Level*:**	None Observed

Definitions: D = Spilt Spoon Sample
S = Sample off Auger Flights
B = Bucket Sample off Auger Flights
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U = Thin Wall Tube Sample
MV = Unsuccessful Field Vane Shear Test Attempt
V = Field Vane Shear Test, PP= Pocket Penetrometer
MU = Unsuccessful Thin Wall Tube Sample Attempt
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HSA = Hollow Stem Auger
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$S_{u(lab)}$ = Lab Vane Undrained Shear Strength (psf)
q_p = Unconfined Compressive Strength (ksf)
N-value = Raw Field SPT N-value
T_v = Pocket Torvane Shear Strength (psf)
WC = Water Content, percent ≅ = Similar or Equal too
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-value	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
0						SSA			Probe, no soil samples taken.	
							75.7		2.3 **Bottom of Exploration at 2.3 feet below ground surface.** REFUSAL	
5										
10										
15										
20										
25										

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.: HB-BRE-102A

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Large Culvert Replacement on Route 32
Location: Bremen, Maine

Boring No.: HB-BRE-103
WIN: 24283.00

Driller:	MaineDOT	**Elevation (ft.)**	77.9	**Auger ID/OD:**	5" Solid Stem
Operator:	Daggett/Niles	**Datum:**	NAVD88	**Sampler:**	Stand Split Spoon
Logged By:	C. Russell	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	7/23/2019; 09:15-10:45	**Drilling Method:**	Cased Wash Boring	**Core Barrel:**	NQ-2"
Boring Location:	22+42.5, 7.0 ft Lt.	**Casing ID/OD:**	NW-3"	**Water Level*:**	None Observed
Hammer Efficiency Factor:	0.886	**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

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	77.4		6" HMA. — 0.5	
	1D	24/10	1.00 - 3.00	8/10/14/9	24	35				Brown, damp, dense, fine to coarse SAND, some gravel, little silt, (Fill).	G#337339 A-1-b, SW-SM WC=4.6%
5	2D	24/5	5.00 - 7.00	42/32/7/5	39	58				Brown, damp, very dense, fine to coarse SAND, some gravel, trace silt, (Fill).	G#337340 A-1-b, SM WC=7.8%
	R1	60/60	7.80 - 12.80	RQD = 72.5%			NQ-2	70.3		— 7.6	
								70.1		Weathered Rock. — 7.8	
10										Top of Bedrock at Elev. 70.1 ft. Auger Refusal at 7.8 ft bgs. R1: Bedrock: Intrusive Devonian GRANITE with biotite inclusions. Rock Mass Quality = Fair R1: Core Times (min:sec) 7.8-8.8 ft (1:48) 8.8-9.8 ft (2:47) 9.8-10.8 ft (2:59) 10.8-11.8 ft (2:26) 11.8-12.8 ft (2:13) 100% Recovery	
								65.1		— 12.8	
										Bottom of Exploration at 12.8 feet below ground surface.	
15											
20											
25											

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: Large Culvert Replacement on Route 32
Location: Bremen, Maine

Boring No.: HB-BRE-104
WIN: 24283.00

Drilling Contractor:	MaineDOT	**Elevation (ft.)**	78.0	**Auger ID/OD:**	5" Dia.
Operator:	Daggett/Niles	**Datum:**	NAVD88	**Sampler:**	N/A
Logged By:	C. Russell	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	N/A
Date Start/Finish:	7/23/2019; 10:45-11:15	**Drilling Method:**	Solid Stem Auger	**Core Barrel:**	N/A
Boring Location:	22+58.9, 8.1 ft Lt.	**Casing ID/OD:**	N/A	**Water Level*:**	None Observed

Definitions: D = Spilt Spoon Sample
S = Sample off Auger Flights
B = Bucket Sample off Auger Flights
MD = Unsuccessful Split Spoon Sample Attempt
U = Thin Wall Tube Sample
MV = Unsuccessful Field Vane Shear Test Attempt
V = Field Vane Shear Test, PP= Pocket Penetrometer
MU = Unsuccessful Thin Wall Tube Sample 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 1 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-value = Raw Field SPT N-value
T_v = Pocket Torvane Shear Strength (psf)
WC = Water Content, percent ≅ = Similar or Equal too
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-value	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
0						SSA			Probe, no soil samples taken.	
10.8							67.2		**Bottom of Exploration at 10.8 feet below ground surface.** REFUSAL	

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: Large Culvert Replacement on Route 32
Location: Bremen, Maine

Boring No.: HB-BRE-105
WIN: 24283.00

Drilling Contractor:	MaineDOT	**Elevation (ft.)**	78.0	**Auger ID/OD:**	5" Dia.
Operator:	Daggett/Niles	**Datum:**	NAVD88	**Sampler:**	N/A
Logged By:	C. Russell	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	N/A
Date Start/Finish:	7/23/2019; 12:00-12:15	**Drilling Method:**	Solid Stem Auger	**Core Barrel:**	N/A
Boring Location:	22+62.2, 7.8 ft Rt.	**Casing ID/OD:**	N/A	**Water Level*:**	None Observed

Definitions: D = Spilt Spoon Sample
S = Sample off Auger Flights
B = Bucket Sample off Auger Flights
MD = Unsuccessful Split Spoon Sample Attempt
U = Thin Wall Tube Sample
MV = Unsuccessful Field Vane Shear Test Attempt
V = Field Vane Shear Test, PP= Pocket Penetrometer
MU = Unsuccessful Thin Wall Tube Sample 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 1 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-value = Raw Field SPT N-value
T_V = Pocket Torvane Shear Strength (psf)
WC = Water Content, percent ≅ = Similar or Equal too
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-value	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
0						SSA			Probe, no soil samples taken.	
5										
							68.5		9.5	
10									**Bottom of Exploration at 9.5 feet below ground surface.** REFUSAL	
15										
20										
25										

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.: HB-BRE-105

State of Maine - Department of Transportation

Laboratory Testing Summary Sheet

Town(s): Bremen Work Number: 24283.00

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
HB-BRE-103, 1D	22+42.5	7.0 Lt.	1.0-3.0	337340	1	4.6			SW-SM	A-1-b	0
HB-BRE-103, 2D	22+42.5	7.0 Lt.	5.0-7.0	337339	1	7.8			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.

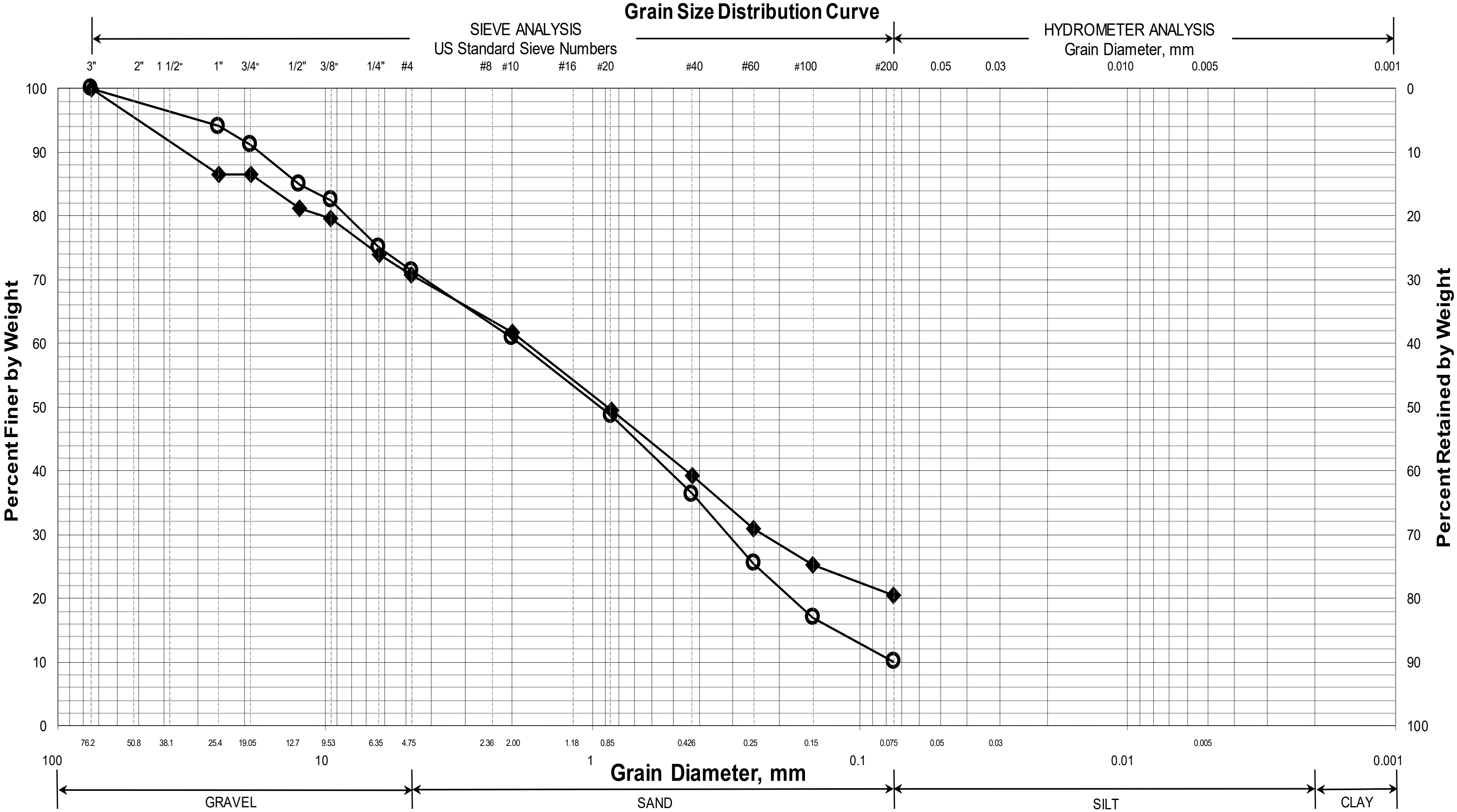
GSDC = Grain Size Distribution Curve as determined by AASHTO T 88-93 (1996) and/or ASTM D 422-63 (Reapproved 1998)

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
○	HB-BRE-103/1D	22+42.5	7.0 LT	1.0-3.0	SAND, some gravel, little silt.	4.6			
◆	HB-BRE-103/2D	22+42.5	7.0 LT	5.0-7.0	SAND, some gravel, trace silt.	7.8			
■									
●									
▲									
×									

WIN	
024283.00	
Town	
Bremen	
Reported by/Date	
WHITE, TERRY A	11/3/2021

SHEET 1

Bearing Resistance - Structural Plate Arch Culvert on Bedrock:

Part 1 - Service Limit State

Nominal and factored Bearing Resistance

Presumptive Bearing Resistance for Service Limit State ONLY

Reference: AASHTO LRFD Bridge Design Specifications 9th Edition 2020
Table C10.6.2.5.1-1 Presumptive Bearing Resistances for Spread Footings at the Service Limit State Modified after US Department of Navy (1982)

Type of Bearing Material: bedrock (granite)

Based on RQD of 72.5 percent

Consistency In Place: hard, sound rock

Bearing Resistance: Ordinary Range (ksf) 120 to 200

AASHTO Recommended Value of Use: $q_{nom} := 160 \cdot ksf$

Resistance factor at the **service limit state** = 1.0 (LRFD Article 10.5.5.1) $\phi := 1.0$

$q_{factored\_bc} := q_{nom} \cdot \phi$ $q_{factored\_bc} = 160 \cdot ksf$

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

Part 2 - Strength Limit State

Determine Bearing Resistance using RMR Method

Reference: AASHTO LRFD Bridge Design Specifications 6th Edition 2012
Section 10.4.6.4 Rock Mass Strength

Parent rock at the site is granite found to be "fair" in quality. RQD of 72.5%.

Determine RMR from Table 10.4.6.4-1 Geomechanics Classification of Rock Mass

From AASHTO - RMR is determined as the sum of the five relative ratings listed in Table 10.4.6.4-1

1. Strength of intact rock

From Standard Specifications for Highway Bridges 17th Edition - 2002
Table 4.4.8.1.2B uniaxial compressive strength for granite = 300 to 7,000 ksf = 21,000 to 49,000 psi

Use: $q_u := 4000 \cdot ksf$ $q_u = 27778 \cdot psi$

From Table 10.4.6.4.-1:
For Uniaxial Compressive Strength = 2160 - 4320 ksf: Relative Rating = 12

2. Drill Core Quality

Bedrock RQD = Average 72.5% (fair)

From Table 10.4.6.4.-1: RQD between 50% and 75% Relative Rating = 13

3. Spacing of joints
Assume spacing of 1 foot to 3 feet From Table 10.4.6.4.-1: Relative Rating = 20

4. Condition of joints

Assume slightly rough surfaces <0.05 in, soft joint wall rock — From Table 10.4.6.4.-1: Relative Rating = 12

5. Groundwater conditions

General Conditions = Water under moderate pressure — From Table 10.4.6.4.-1: Relative Rating = 4

Raw RMR = 61

Adjustment to RMR for joint Orientations from Table 10.4.6.4-2

Assume Strike and Dip Orientations of Joints = Fair — For Foundations: Rating = -7

Adjusted RMR = 54 $RMR := 54$

Determine Rock Mass Class from Adjusted RMR Rating

For Adjusted RMR = 54 From LRFD Table 10.4.6.4.-3: Class No. = III - Fair Rock

Determine Rock Type from LRFD Table 10.4.6.4.-4

Rock Type E - Coarse grained polyminerallic igneous & metamorphic crystalline rocks

Determine Rock Property constants *m* and *s:*

Reference: The Hoek and Brown Failure Criterion - a 1988 Update,
15th Canadian Rock Mechanics Symposium

m/m_i= exp ((RMR-100)/14) — Eq 18 - for disturbed rock masses

where m_i = m for intact rock $m_i := 25$ From LRFD Table 10.4.6.4-4

$$m_{Bfair} := m_i \cdot \exp\left(\frac{RMR - 100}{14}\right) \qquad m_{Bfair} = 0.935$$

s = exp ((RMR-100)/6) — Eq 19 - for disturbed rock masses

$$s_{Bfair} := \exp\left(\frac{RMR - 100}{6}\right) \qquad s_{Bfair} = 0.00047$$

<u>Determine nominal and factored bearing resistance of Bedrock:</u>

Foundation Shape correction factor:

$C_{f1} := 1.0$ From Foundations on Rock, Wyllie, Table 5.4 pg 138

Uniaxial Compressive Strength for granite = 3,000 to 4,400 ksf = 21,000 to 30,000 psi

$$q_{uc} := \begin{pmatrix} 2100 \\ 15000 \\ 30000 \\ 49000 \end{pmatrix} \cdot psi$$

Upper and lower bounds from from Standard Specifications for Highway Bridges 17th Edition - 2002 Table 4.4.8.1.2B

Determine Nominal Bearing Resistance:

From Foundations on Rock, Wyllie, Table 5.4 pg 138

$$q_{nom} := C_{f1} \cdot \sqrt{s_{Bfair}} \cdot q_{uc} \cdot \left[1 + \sqrt{m_{Bfair} \cdot \left(s_{Bfair}^{\frac{-1}{2}} \right) + 1} \right] \qquad q_{nom} = \begin{pmatrix} 50 \\ 358 \\ 715 \\ 1168 \end{pmatrix} \cdot ksf$$

<u>Determine Factored Bearing Resistance at the Strength Limit State:</u>

From Table 10.5.5.2.2-1 Resistance factor for footing on rock $\phi_b := 0.45$

The factored resistance $q_R = \phi_b \times q_n$ equation 10.6.3.1.1-1 AASHTO LRFD

$$q_R := \phi_b \cdot q_{nom} \qquad q_R = \begin{pmatrix} 23 \\ 161 \\ 322 \\ 526 \end{pmatrix} \cdot ksf$$

Recommend 160 ksf for Strength Limit State