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

# **GEOTECHNICAL DESIGN REPORT**

For the Replacement of

LARGE CULVERT #1063182 ROUTE 22 BUXTON, MAINE

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*Reviewed by:* Cody Russell, P.E. Senior Geotechnical Engineer

York County WIN 26380.00 Soils Report 2024-38 November 13, 2024

#### **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 (#1063182) on Route 22 in Buxton. 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 dual 36-inch diameter, approximately 58-foot-long corrugated metal pipe (CMP) culverts. The CMPs are in poor condition and need replacement both from an infrastructure and environmental standpoint. Route 22 is a Highway Corridor Priority 3 road.

The proposed replacement structure will be an approximately 57-inch span by 38-inch rise by 66-foot-long corrugated metal pipe arch culvert. The invert of the proposed culvert is approximately 9 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**

One (1) boring (HB-BUXT-101) and one (1) probe (HB-BUXT-102) were drilled for this project on September 8, 2022 by the MaineDOT drill crew using a trailer mounted drill rig. Exploration locations are shown on the attached Boring Location Plan. Details and sampling methods used, field data obtained, and soil and groundwater conditions encountered are presented on the attached Boring Logs.

Boring HB-BUXT-101 was drilled using solid stem auger, cased wash boring, open hole, and hydraulic push techniques. Soil samples were obtained in the upper approximately 22 feet of 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 62 percent more energy during driving than the standard rope and cathead system. All N-values discussed in this report are corrected values (N<sub>60</sub>) computed by applying an average energy transfer factor of 0.974 to the raw field N-values. Probe HB-BUXT-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 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 one (1) standard grain size analyses with natural water content, four (4) standard grain size analyses with hydrometer and natural water content, and two (2) Atterberg Limits tests. 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, Grain Size Distribution Curve Sheet, and Atterberg Limits Plots.

#### **SUBSURFACE CONDITIONS**

Subsurface conditions encountered in the test boring and probe generally consisted of sand fill underlain by Presumpscot Formation consisting of silty clay, clay, and clayey silt. An interpretive subsurface profile depicting the generalized soil stratigraphy at the boring location is shown on the attached Interpretive Subsurface Profile.

Boring HB-BUXT-101 was drilled to a depth of approximately 72.7 feet below ground surface (bgs), where it encountered a refusal surface. The exact nature of the refusal surface was not determined in the boring. Probe HB-BUXT-102 was drilled to depth of approximately 15.5 feet bgs without encountering a refusal surface.

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

Approx. Depth BGS <sup>1</sup> (feet)	Soil Description	AASHTO <sup>2</sup> Classification	USCS <sup>3</sup>	WC% <sup>4</sup>
0.0 - 3.5	Fill: Brown, moist, fine to coarse sand, little gravel, little silt.	A-1-b	SM	5.3
3.5 - 4.0	Cobbles			
4.0 – 72.7	Presumpscot Formation: Brown, moist, clayey silt, trace fine to coarse sand, trace gravel, trace organics. Grey, wet, clay, some silt, trace fine to medium sand. Grey, wet, silty clay, trace fine to coarse sand, trace gravel.	A-4 or A-6	CL	21.9 to 49.9

 $^{1}BGS = below ground surface$ 

<sup>2</sup>AASHTO = American Association of State Highway and Transportation Officials

<sup>3</sup>USCS = Unified Soil Classification System

 $^{4}WC\% = Water content in percent$ 

One (1) N<sub>60</sub>-value obtained in the fill was 32 blows per foot (bpf), indicating that the fill is dense in consistency. Four (4) N<sub>60</sub>-values obtained in the Presumpscot Formation ranged from Weight of

Hammer (WOH) to 19 bpf, indicating that the Presumpscot Formation is very soft to very stiff in consistency. Two (2) vane shear tests conducted within the Presumpscot Formation showed measured undrained shear strength of 670 pounds per square foot (psf) and 491 psf with remolded shear strengths of 45 psf for both tests. Based on the ratio of undrained to remolded shear strength from the vane shear test, the Presumpscot Formation was determined to have sensitivities of 10.9 and 14.9 and are classified as very sensitive.

The following table summarizes the results of Atterberg Limits tests done on two (2) samples of the clay and silty clay:

Boring No. and	Water	Liquid	Plastic	Plasticity	Liquidity
Sample No.	Content (%)	Limit	Limit	Index	Index
HB-BUXT-101 3D	34.1	40	21	19	0.69
HB-BUXT-101 5D	48.0	34	21	13	2.08

Interpretation of these results indicate that the clay and silty clay have medium plasticity. The clay in sample 3D from boring HB-BUXT-101 is overconsolidated. The silty clay in sample 5D from boring HB-BUXT-101 is on the verge of being a viscous liquid if disturbed. Overburden pressure and interparticle cementation is providing stability to keep the soil in its current state, but the slightest disturbance causing remolding could convert the soil into a viscous fluid.

Groundwater was recorded at depth 5.0 feet bgs in boring HB-BUXT-101. 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 approximately 57-inch span by 38-inch rise by 66-foot-long corrugated metal pipe arch culvert. The proposed structure inlet and outlet slopes shall be riprapped with slopes no steeper than 2H:1V on the inlet end to protect against erosion. The following sections discuss geotechnical recommendations for the design and construction of the proposed culvert.

**Corrugated Metal Pipe Arch Culvert Design and Construction** – The proposed replacement structure will be a 57-inch span by 38-inch rise by 66-foot-long corrugated metal pipe arch culvert. The proposed corrugated metal arch pipe culvert shall be furnished and installed in accordance with MaineDOT Standard Specification 603. The invert of the proposed corrugated metal pipe arch culvert ranges from approximately 169.5 feet at the inlet end to approximately 168.8 feet at the outlet end with a 1.3% slope.

The proposed structure shall be bedded on a 2-foot thick, geotextile wrapped, geogrid reinforced, crushed stone mat (Culvert Bedding Stone; Pay Item 203.55). The geogrid reinforcement shall meet the requirements of Special Provision 620, attached. The Reinforcement Geotextile shall meet the requirements of MaineDOT Standard Specification 722.01. The soils at the bedding elevation shall be excavated using a smooth-edged backhoe bucket to limit disturbance. Any disturbed soils at the bedding elevation resulting from excavation activities shall be removed by

hand prior to placement of the geotextile wrapped, geogrid reinforced, crushed stone mat. All subgrade surfaces should be protected from construction traffic in order to limit disturbance. Groundwater and surface water levels shall be depressed sufficiently to allow work in the dry.

The soil backfill shall consist of Granular Borrow (703.19) with a maximum particle size of 4 inches. The Granular Borrow backfill 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, to at least 92 percent of the AASHTO T-180 maximum dry density. In no case shall the backfill soil be compacted less than 92 percent of the AASHTO T-180 maximum dry density.

**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 corrugated metal pipe arch culvert is larger than the existing culvert and will result in a net unloading of the site soils at the proposed structure location. Placement of fill soils at the location of the existing structure is not anticipated to exceed the past loading condition of the site soils. Any settlement due to elastic compression of the bedding material will be immediate and negligible.

**Scour and Riprap** – Both the inlet and outlet of the corrugated metal pipe arch culvert shall be protected against scour with riprap conforming to MaineDOT Standard Specification Section 703.26 Plain and Hand Laid Riprap. The roadway embankment slopes at the proposed culvert inlet and outlet 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 1-foot layer of protective aggregate cushion consisting of Granular Borrow Material for Underwater Backfill (703.19) that is underlain by a non-woven, Class 1 Erosion Control Geotextile meeting the requirements of MaineDOT Standard Specification 722.03. 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 corrugated metal pipe arch 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 native soils 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 soils at the bedding elevation shall be excavated using a smooth-edged backhoe bucket to limit disturbance. Any disturbed soils at the bedding elevation resulting from excavation activities shall be removed by hand prior to placement of the geotextile wrapped, geogrid reinforced, crushed stone mat. All subgrade surfaces should be protected from construction traffic in order to

limit disturbance. Groundwater and surface water levels shall be depressed sufficiently to allow work in the dry.

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.

#### 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 (#1063182) under Route 22 in Buxton, 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 Atterberg Limits Plots Special Provision 620 – Geotextile (Reinforcement Geogrid)





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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

	UNIFIE	ED SOIL C	LASSIFIC	CATION SYSTEM	MODIFIED BURMISTER SYSTEM					
MA		ONS	GROUP SYMBOLS	TYPICAL NAMES						
COARSE- GRAINED	GRAVELS	CLEAN GRAVELS	GW	Well-graded gravels, gravel- sand mixtures, little or no fines.	Descrip tr	<u>tive Term</u> race ittle	Port	<u>ion of Total (%)</u> 0 - 10 11 - 20 21 - 25		
SUILS	f coarse ıan No. 4 )	(little or no fines)	GP	Poorly-graded gravels, gravel sand mixtures, little or no fines.	adjective (e.g.	. Sandy, Clayey)		21 - 35 36 - 50		
	half o ger th e size						S DESCRIBIN	G		
	than is lar sieve	GRAVEL	GM	Silty gravels, gravel-sand-silt	Coarse-grained	soils (more than half	of material is larger t	han No. 200		
5	more	WITH FINES		mixtures.	sieve): Includes (1 Clayey or Gravelly	1) clean gravels; (2) S y sands. Density is ra	ilty or Clayey gravels ated according to star	s; and (3) Silty, ndard		
s large (e)	ţı.	(Appreciable amount of	GC	Clayey gravels, gravel-sand-clay mixtures.	penetration resista	ance (N-value).	Ũ			
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than than	rse Vo. 4	(little or no	SP	Poorly-graded sands, Gravelly	Very	Dense		> 50		
(mc	of coa than I e)	fines)		sand, little of no fines.	Fine-grained soi	<u>Is</u> (more than half of r	material is smaller the	an No. 200		
	an half c smaller ieve size	SANDS WITH	SM	Silty sands, sand-silt mixtures	sieve): Includes (1 or Silty clays; and strength as indica	<ol> <li>inorganic and orgar</li> <li>Clayey silts. Con ted</li> </ol>	nic silts and clays; (2 sistency is rated acc	) Gravelly, Sandy ording to undrained shear		
	ore th ion is s	FINES			ou onger do maiou	iou.	Approximate			
	(m fract	(Appreciable amount of	SC	Clayey sands, sand-clay mixtures.	Consistency of	SPT N-Value	<u>Shear</u>	<u>Field</u>		
		fines)			Cohesive soils	(blows per foot) WOH, WOR,	Strength (psf)	<u>Guidelines</u>		
			ML	Inorganic silts and very fine	Very Soft	WOP, <2	0 - 250 250 - 500	Fist easily penetrates		
				fine sands, or Clayey silts with	Medium Stiff	5 - 8	500 - 1000	Thumb penetrates with		
	SILTS AN	ID CLAYS		slight plasticity.	Stiff	9 - 15	1000 - 2000	Indented by thumb with		
FINE- GRAINED			CL	Inorganic clays of low to medium plasticity. Gravelly clays. Sandy	Verv Stiff	16 - 30	2000 - 4000	great effort Indented by thumbnail		
SOILS	(liquid limit l	ess than 50)		clays, Silty clays, lean clays.	Hard	>30	over 4000	Indented by thumbnail		
	(inquid innici	000 11011 000	OL	Organic silts and organic Silty	Rock Quality Des	signation (RQD):		with dimodity		
e e				clays of low plasticity.	RQD (%) =	sum of the lengths	of intact pieces of length of core a	f <u>core* &gt; 4 inches_</u> dvance		
erial is ve siz			мн	Inorganic silts micaceous or	1	*Minimu	um NQ rock core (	1.88 in. OD of core)		
f mate 00 sie				diatomaceous fine Sandy or		Rock Quality Ba	ased on RQD			
half o Vo. 2(	SIL IS AN	ID CLATS		Sitty solis, elastic sits.		Very Poor	<u>KQD (%)</u> ≤25			
than than 1			СН	Inorganic clays of high plasticity, fat clays.		Poor Fair	26 - 50 51 - 75			
aller	(liquid limit or	eater than 50)	ОН	Organic clave of medium to		Good Excellent	76 - 90 91 - 100			
) ms	լոգտա ուուէ ցլ			high plasticity, organic silts.	Desired Rock C	Observations (in the	his order, if appli	cable):		
					Texture (aphan	color cnart) itic, fine-grained, ef	tc.)			
	HIGHLY SC	ORGANIC 0ILS	Pt	Peat and other highly organic soils.	Rock Type (gra Hardness (verv	nite, schist, sandst hard, hard, mod. h	one, etc.) ard, etc.)			
					Weathering (fre	sh, very slight, slig	ht, moderate, mod	l. severe, severe, etc.)		
Desired So Color (Mun	bil Observat sell color ch	<b>tions (in thi</b> art)	s order, it	rapplicable):	Geologic discor	ntinuities/jointing: -dip (horiz - 0-5 de	a., low angle - 5-3	5 dea mod. dippina -		
Moisture (d	ry, damp, m	oist, wet)		-:		35-55 deg., ste	ep - 55-85 deg., ve	ertical - 85-90 deg.)		
Density/Col Texture (fin	e, medium,	om above ri coarse, etc.	gnt hand : )	side)		-spacing (very close close - 1-3 feet,	se - <2 inch, close , wide - 3-10 feet, *	- 2-12 incn, mod. very wide >10 feet)		
Name (San Gradation (	d, Silty San	d, Clay, etc.	, including	portions - trace, little, etc.)		-tightness (tight, op	pen, or healed)	,		
Plasticity (n	on-plastic, s	slightly plast	ic, modera	ately plastic, highly plastic)	Formation (Wat	terville, Ellsworth, C	Cape Elizabeth, etc.)	c.)		
Structure (la	ayering, frac	tures, crack	s, etc.)		RQD and correl	lation to rock qualit	y (very poor, poor,	, etc.) Geotechnical		
Cementatio	n (weak, mo	oderate, or s	strong)		Site Characte	erization, Table 4-12	2	Conconnical		
Geologic O Groundwate	rigin (till, ma er level	arine clay, al	luvium, et	c.)	Recovery (inch/ Rock Core Rate	/inch and percenta e (X.X ft - Y.Y ft (mi	ge) in:sec))			
					Sample Cont	ainer Labeling I	Requirements:			
	Maine L	Jepartme Geotechi	nt of Tra nical Se	ansportation ction	WIN	/ Tour	Blow Counts	_		
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1	Main	e Dep	artment	of Transport	ation	1	Project	Large	Culv	ert #1063182 Replacement on	Boring No.:	HB-BU	JXT-101
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			US CUSTOM	ARY UNITS							WIN:	263	80.00
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Bori	ing Loca	tion:	11+40.7, 12.2	ft Lt.	Casing	g ID/	OD:	NW	-3"		Water Level*:	5.0 ft bgs.	
Ham	nmer Effi	iciency F	actor: 0.974		Hamm	er T	ype:	Autom	ntic 🛛	Hydraulic 🗆	Rope & Cathead 🗆		
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Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N60	Casing Blows	Elevation (ft.)	Graphic Log	Visual De	scription and Remarks		Laboratory Testing Results/ AASHTO and Unified Class.
0	1D	24/16	0.00 - 2.00	5/10/10/8	20 3	32	SSA			Brown, moist, dense, fine t	o coarse SAND, little gra	vel, little silt,	G#379800
		24/10	0.00 - 2.00	5/10/10/8	20 3			172.2		(Fill).		3.5	A-1-b, SM WC=5.3%
							<u> </u>	171.7		Layer of Cobbles from 3.5-	4.0 ft bgs.		
- 5 -	2D	24/20	5.00 - 7.00	4/5/7/14	12 1	19	20	-		Brown, moist, very stiff, Cl gravel, trace organics.	layey SILT, trace fine to o	coarse sand, trace	G#379855 A-4, CL WC=21.9%
							26						
							37						
							42	167.7					
							72	-					
10							52						
10	3D	24/24	10.00 - 12.00	3/3/3/3	6 1	10	39 44	-		Grey, wet, stiff, CLAY, sor	ne silt, trace fine to medi	um sand.	G#379856 A-6, CL WC=34.1%
								-					PL=21
							42	-					PI=19
							38					14.0	
							36	161.7				14.0	
- 15 -	4D V1 V2	24/10	15.00 - 17.00 15.63 - 16.00 16.63 - 17.00	WOH/WOH/WOH/ WOH Su=670/45 psf Su=491/45 psf			OPEN HOLE	-		Grey, wet, very soft, Silty 0 gravel. 55x110 mm vane raw torqu V1: 15.0/1.0 ft-lbs V2: 11.0/1.0 ft-lbs	CLAY, trace fine to coars te readings:	e sand, trace	G#379857 A-6, CL WC=49.9%
								-					
20 .				WOILING			$-\psi$	-		Grev wat very ooft Silter	JAV trace fine cond		G#270050
	5D	24/18	20.00 - 22.00	WOH/WOH/WOH/ WOH			HP			Hydraulic Pushed drill rods	s to 72.7 ft bgs.		A-6, CL WC=48.0%
								-		No samples taken after 5D, 22.0 ft bgs.	Hydraulic Push through	soft soils after	PL=21 PI=13
25													
Rem	narks:												
HP	= Hydrau	ılic Push											
Stratit	fication line	s represent	approximate bou	ndaries between soil types:	transitions ma	ay be	gradual				Page 1 of 3		
* Wat	er level rea	dings have	been made at tim	nes and under conditions sta	ited. Ground	water	fluctuatio	ons may c	ccur d	ue to conditions other	Boring No.	• HR_RITY	T-101
thar	i mose pres	sent at the t	me measuremen	is were made.								IID-DUA	1-101

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				Soil/Rock Exp US CUSTOM	oloration Log IARY UNITS		Loc	atio	Route n: Bux	22 ton, N	Iaine	WIN:	2638	30.00	
Durlar : Munck101   Elevation (H)   177   Auge 1000: Value Sampler : Subadra Spit Spit - Logget 1   189, Type: CM 45°C   Hanner WLF3H: 1445(3)   1															
Upper bin in the state of the state is a state of the st	Drille	er:		MaineDOT		Elevatio	on (ft.)	)	175.	7		Auger ID/OD:	5" Solid Stem	6	
Undput top:     No. No.2021     Undput top:     No.2022     Undput top:     No.2022     No.2022       Best particination:     11-400.12.0110.     Case ing IDOO:     NO.21     NO.21     No.2022       Best particination:     11-400.12.0110.     Case ing IDOO:     NO.21     No.21     No.2022       Imput the description:     11-400.12.0110.     Case ing IDOO:     NO.21     No.21     No.2022       Imput the description:     11-400.12.0110.     Case ing IDOO:     NO.21     No.21     No.2022       Imput the description:     11-400.12.0110.     Case ing IDOO:     NO.21     No.21     No.2022       Imput the description:     Imput the description:     Imput the description:     No.21     No.21     No.21       Imput the description:     Imput the description:     Imput the description:     Imput the description:     No.21     No.21       Imput the description:     Impu ttee description:     <	Oper	ator:		Daggett		Datum:			NAV CMI	D88		Sampler:	Standard Split	Spoon	
Under during         Volume         Output carding         Output carding <td>Logg</td> <td>Stort/E</td> <td>inich</td> <td>B. wilder</td> <td>00 15:20</td> <td>Drilling</td> <td>e: Moth</td> <td>od:</td> <td>Con</td> <td>1 45C</td> <td>ah Danin a</td> <td></td> <td>140#/30"</td> <td></td>	Logg	Stort/E	inich	B. wilder	00 15:20	Drilling	e: Moth	od:	Con	1 45C	ah Danin a		140#/30"		
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The second se	Ham	mor Eff	icionev l	actor: 0.074	2 It Lt.	Hammo	r Typ	,. 	Autom	tio M	Hydraulia 🗆	Pope & Cathood	5.0 ft bgs.		
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Sample Information         Laboration           q         g         <	D = Sp MD = U U = Th MU = U V = Fie MV = U	olit Spoon Jnsucces in Wall Tu Jnsucces old Vane S Jnsucces	Sample sful Split Sp ube Sample sful Thin W Shear Test, sful Field Va	all Tube Sample Atte all Tube Sample A PP = Pocket Po ane Shear Test A	SSA = Soli           mpt         HSA = Hol           RC = Rolle           Attempt         WOH = Wo           enetrometer         WOR/C = '           ttempt         WO1P = W	d Stem Auger ow Stem Auge r Cone sight of 140 lb. I Weight of Rods leight of One P	r Hamme or Casi erson	er ing	S <sub>u(la</sub> q <sub>p</sub> = N-un Ham N <sub>60</sub> : N <sub>60</sub> :	b) = La Uncon correct ner Efi = SPT = (Harr	ab Vane Undrained Shear Strength fined Compressive Strength (ksf) ed = Raw Field SPT N-value ficiency Factor = Rig Specific Annua N-uncorrected Corrected for Harm mer Efficiency Factor/60%)*N-uncc	(psf) WC LL : PL Il Calibration Value PI er Efficiency G = rrected C =	<ul> <li>Water Content, pero</li> <li>Liquid Limit</li> <li>Plastic Limit</li> <li>Plasticity Index</li> <li>Grain Size Analysis</li> <li>Consolidation Test</li> </ul>	cent	
etc       e					Sample Information									Laboratory	
<sup>2</sup> 	Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	Casind	Blows	Elevation (ft.)	Graphic Log	Visual De	escription and Remarks	5	Testing Results/ AASHTO and Unified Class.	
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	* Wate than	r level rea those pre	adings have sent at the	been made at tir time measuremer	nes and under conditions stant	ited. Groundwa	ater fluc	tuatio	ns may o	ccur dı	ue to conditions other	Borina Na	<b>.:</b> HB-BUX	Г-101	

Ι	Main	e Dep	artment	of Transport	ation	Р	roject	Large	Culve	Ivert #1063182 Replacement on Boring No.: HB-BU			XT-101
		-	Soil/Rock Exp US CUSTOM	Dioration Log ARY UNITS			ocatio	Route n: Bux	22 ton, M	aine	WIN:	2638	30.00
Drill	er:		MaineDOT		Elevatio	on (f	it.)	175.	7		Auger ID/OD:	5" Solid Stem	
Ope	rator:		Daggett		Datum:		,	NAV	, /D88		Sampler:	Standard Split	Spoon
Log	ed By:		B. Wilder		Ria Typ	e:		CMI	E 45C		Hammer Wt./Fall:	140#/30"	-1
Date	Start/Fi	inish:	9/8/2022: 13:	00-15:30	Drilling	Met	thod:	Case	d Was	sh Boring	Core Barrel:	N/A	
Bori	ng Loca	ation:	11+40.7, 12.2	? ft Lt.	Casing	ID/C	DD:	NW	.3"		Water Level*:	5.0 ft bgs.	
Ham	mer Effi	iciency F	actor: 0 974		Hamme	r Tv	vpe:	Automa	ntic 🛛	Hydraulic 🗆	Rone & Cathead □	6	
Defini	tions:	<u> </u>		R = Rock C	ore Sample		· · ·	S <sub>u</sub> =	Peak/R	temolded Field Vane Undrained Sh	ear Strength (psf) T	v = Pocket Torvane She	ar Strength (psf)
MD = 5	Unsuccess	sampie sful Split Sp	oon Sample Atter	mpt HSA = Hollo	w Stem Auger	r		Su(la q <sub>p</sub> =	b) = La Unconf	ined Compressive Strength (ksf)	(psr) v	L = Liquid Limit	ent
U = TI MU =	nin Wall Tu Unsuccess	ube Sample sful Thin Wa	all Tube Sample A	Attempt RC = Roller	Cone ght of 140 lb. I	Hamı	mer	N-un Ham	correcte ner Effi	ed = Raw Field SPT N-value ciency Factor = Rig Specific Annua	I Calibration Value P	'L = Plastic Limit I = Plasticity Index	
V = Fi MV =	eld Vane S Unsuccess	Shear Test, sful Field Va	PP = Pocket Pe ane Shear Test At	enetrometer WOR/C = W ttempt WO1P = We	eight of Rods	or C	asing า	N <sub>60</sub> : N <sub>60</sub> :	= SPT N = (Ham	N-uncorrected Corrected for Hammer mer Efficiency Factor/60%)*N-unco	er Efficiency G rrected C	G = Grain Size Analysis C = Consolidation Test	
				Sample Information									Laboratory
			pth		ted				5				Testing
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Dep	San	Pen	San (ft.)	Stre Stre or F	N-U	3	Cas Blo	(ff.)	Gra				Unified Class.
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<u>rtem</u>	arks:	1											
HP	= Hydrau	unc Push											
Stratif	ication line	s represent	approximate bo	Indaries between soil types: t	ransitions may	v be r	aradual				Page 3 of 3		
* Wate	er level rea	adings have	been made at tin	nes and under conditions stat	ed. Groundwa	, 20 g	uctuatio	ins may o	ccur du	e to conditions other			
than	those pres	sent at the t	ime measuremer	nts were made.			Journall		sour uu		Boring N	lo.: HB-BUX	Г-101
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N	laine	Dep	artment	of Transp	ortat	tion	Pro	oject:	Large	Culvert #1063182 Replacement on	ement on Boring No.: HB-BUXT-10			
			Soil/Rock Exp US CUSTOM	loration Log ARY UNITS			Loc	cation	Route Bux	22 ton, Maine	WIN:	263	80.00	
Drillin	a Cont	actor	MainaDOT			Flovatio	n (ft	<u>,</u>	175	5	Augor ID/OD:	5" Dia		
Onera	ator:	actor.	Daggett			Datum:	n (n.	)	NA'	5 VD88	Sampler:	N/A		
Loga	ed Bv:		B. Wilder			Ria Type	e:		CM	E 45C	Hammer Wt./Fall:	N/A		
Date	Start/Fin	nish:	9/8/2022; 12:3	30-13:00		Drilling	Meth	od:	Soil	d Stem Auger	Core Barrel:	N/A		
Borin	g Locat	ion:	11+64.2, 12.0	ft Rt.		Casing I	D/OD	D:	N/A		Water Level*:	None Observe	ł	
Definitio	ons: D =	Spilt Spoo	n Sample	MU =	Unsucces	sful Thin Wa	II Tube	e Sampl	e Atten	pt WO1P = Weight of 1 Person	adrained Shear Strength (pef)			
B = Buo MD = U U = Thi MV = U	npie on Ad cket Samp Insuccessf n Wall Tub Insuccessf	e off Auge ul Split Sp e Sample ul Field Va	r Flights oon Sample Atten ne Shear Test Att	npt HSA RC = tempt WOF	= Solid Ste = Hollow S Roller Cor	em Auger Stem Auger ne of 140lb. Hai	mmer			$S_u(lab) = Lab Vane Undrained Sheiqp = Unconfined Compressive StrenN-value = Raw Field SPT N-valueTv = Pocket Torvane Shear Strengt$	ar Strength (psf) ngth (ksf)	LL = Liquid Lim PL = Plastic Lir PI = Plasticity I G = Grain Size	it nit ndex Analysis	
V - FIE	iu varie Sr	iear rest,	PP- POCKel Per	Sample Inform	ation		Casin	ig		wc - water content, percent ≅ - c		C - Consolidat		
epth (ft.)	ample No.	en./Rec. (in.)	ample Depth :.)	ows (/6 in.) near trength sf)	. RQD (%)	-value asing	SWO	evation t.)	raphic Log	Visual Descr	iption and Remarks		Laboratory Testing Results/ AASHTO and Unified Class.	
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15						l V		160.0				15.5		
							$\neg$			Bottom of Exploration at NO REFUSAL	15.5 feet below ground s	surface.		
- 20 -														
25														
Rema	irks:													
Stratific	ation lines	represent	approximate bou	ndaries between soi	l types; trar	nsitions may	be gra	adual.			Page 1 of 1			
* Water	level read	ings have	been made at tim	tes and under condit	tions stated	I. Groundwa	iter fluc	ctuation	s may c	ccur due to conditions other	Boring No.	• HR_RITY	$T_{-102}$	
uian t	nose prese	an ai ine t	me measuremen	la were made.									1 102	

#### State of Maine - Department of Transportation Laboratory Testing Summary Sheet

Town(s):	Buxto	n			Work	ς Νι	ımk	ber	: 263	80.00	
Boring & Sample	Station	Offset	Depth	Reference	G.S.D.C.	W.C.	L.L.	P.I.	Cla	assificatio	n
Identification Number	(Feet)	(Feet)	(Feet)	Number	Sheet	%			Unified	AASHTO	Frost
HB-BUXT-101, 1D	11+40.7	12.2 Lt.	0.0-2.0	379800	1	5.3			SM	A-1-b	
HB-BUXT-101, 2D	11+40.7	12.2 Lt.	5.0-7.0	379855	1	21.9			CL	A-4	IV
HB-BUXT-101, 3D	11+40.7	12.2 Lt.	10.0-12.0	379856	1	34.1	40	19	CL	A-6	
HB-BUXT-101, 4D	11+40.7	12.2 Lt.	15.0-17.0	379857	1	49.9			CL	A-6	
HB-BUXT-101, 5D	11+40.7	12.2 Lt.	20.0-22.0	379858	1	48.0	34	13	CL	A-6	
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GSDC = Grain Size Distribu	ition Curve as	determined	by AASHTO T	88-93 (1996)	and/or AS	TM D 4	22-63	Rean	proved 10	98)	
			~,				00 1	up	p. 0100 10		

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



UNIFIED CLASSIFICATION

	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	WC, %	LL	PL	PI
0	HB-BUXT-101/1D	11+40.7	12.2 LT	0.0-2.0	SAND, little gravel, little silt.	5.3			
۲	HB-BUXT-101/2D	11+40.7	12.2 LT	5.0-7.0	Clayey SILT, trace sand, trace gravel.	21.9			
	HB-BUXT-101/3D	11+40.7	12.2 LT	10.0-12.0	CLAY, some silt, trace sand.	34.1	40	21	19
	HB-BUXT-101/4D	11+40.7	12.2 LT	15.0-17.0	Silty CLAY, trace sand, trace gravel.	49.9			
	HB-BUXT-101/5D	11+40.7	12.2 LT	20.0-22.0	Silty CLAY, trace sand.	48.0	34	21	13
X									

WI	N
026380.00	
Tow	/n
Buxton	
Reported	by/Date
WHITE, TERRY A	10/17/2022

TOWN	Buxton	Reference No.	379856
WIN	026380.00	Water Content, %	34.1
Sampled	9/8/2022	Liquid Limit @ 25 blows (T 89), %	40
Boring No./Sample No.	HB-BUXT-101/3D	Plastic Limit (T 90), %	21
Station	11+40.7	Plasticity Index (T 90), %	19
Depth	10.0-12.0	Tested By	BBURR



TOWN	Buxton	Reference No.	379858
WIN	026380.00	Water Content, %	48
Sampled	9/8/2022	Liquid Limit @ 25 blows (T 89), %	34
Boring No./Sample No.	HB-BUXT-101/5D	Plastic Limit (T 90), %	21
Station	11+40.7	Plasticity Index (T 90), %	13
Depth	20.0-22.0	Tested By	BBURR



#### SPECIAL PROVISION SECTION 620 – GEOTEXTILES (Reinforcement Geogrid)

Amend Standard Specification 620 – GEOTEXTILES to include the following:

<u>620.01</u> Description This work shall consist of furnishing and installing Reinforcement Geogrid within the Culvert Bedding Stone in accordance with these specifications and in reasonably close conformity with the lines, grades, and dimensions shown on the plans or as directed by the Resident.

<u>620.02 Material</u> Reinforcement Geogrid shall consist of a regular network of integrally connected, polymeric tensile elements with aperture geometry sufficient to permit significant mechanical interlock with the surrounding soil, aggregate or other material. The Reinforcement Geogrid structure shall be dimensionally stable to retain its geometry under construction stresses and shall have high resistance to damage during construction, ultraviolet degradation, and all forms of chemical and biological degradation encountered in the soil being reinforced.

The Reinforcement Geogrid shall meet or exceed the Minimum Average Roll Values (MARV) of the properties in Table 1. Acceptable manufacturers for Reinforcement Geogrids must be approved by the Resident.

Reinforcement Geogrid Mechanical Property	Test Method	Minimum Average Roll Value (MARV) <sup>1</sup>
Tensile strength at 5% Strain MD or XD	ASTM D 6637	1,200 lb/ft
Rib Junction Strength	GRI-GG2	1,000 lb/ft in both directions
Aperture Openings		Between 0.75 and 3 inches
Percent Open Area		50 to 80%

#### Table 1 - Physical Property Requirements (Biaxial Reinforcement Geogrid)

<sup>1</sup> Values are minimum average roll values determined in accordance with ASTM D 4759

A biaxial Reinforcement Geogrid shall be used in this application.

<u>620.03 Placement</u> Reinforcement Geogrid shall be installed, in accordance with the manufacturer's recommendations, unless otherwise modified by this Special Provision. The Reinforcement Geogrid shall be placed within the layers of Crushed Stone Bedding at the proper elevation and alignment as shown on the Plans or as directed by the Resident.

1. The Reinforcement Geogrid shall be placed in continuous longitudinal strips. Splicing along the length will not be allowed. Reinforcement Geogrid shall be oriented such that the roll length runs either parallel or perpendicular to the construction centerline. The Contractor shall verify correct orientation of the Reinforcement Geogrid.

2. Reinforcement Geogrid may be temporarily secured in-place with staples, pins, sand bags or backfill as required by fill properties, fill placement procedures, or weather conditions, or as directed by the Resident.

3. Coverage of less than 100 percent shall not be allowed.

4. The Reinforcement Geogrid shall be lightly anchored and pulled taut to reduce any slack as directed by the Resident.

5. Fill shall not be dumped directly onto the Reinforcement Geogrid. It shall be dumped at the edge of the Reinforcement Geogrid or on a previous course of fill with a minimum compacted depth of 8 inches.

6. The Reinforcement Geogrid shall be covered with fill materials within 7 days of placement to protect against unnecessary exposure.

7. Fill may then be pushed onto the Reinforcement Geogrid using a track mounted bulldozer. At no time shall construction equipment be allowed directly onto the Reinforcement Geogrid. Track mounted equipment shall be allowed on previous courses of fill with a minimum compacted depth of 8 inches. Smooth drum roller compaction equipment shall be allowed on previous courses of fill with a minimum depth of 12 inches, loose measure. At no time shall rubber tired or sheeps-foot rollers be allowed onto the reinforced fill. Turning of vehicles should be kept to a minimum to prevent tracks from displacing the fill and damaging the Reinforcement Geogrid. Sudden breaking and sharp turning shall be avoided. Equipment speeds over 10 MPH shall not be allowed.

8. Placement, spreading, and compaction of soil on top of the Reinforcement Geogrid shall advance from one end of the Reinforcement Geogrid and move towards the other. Care shall be taken to minimize the development of wrinkles and to ensure that the Reinforcement Geogrid doesn't move from its position during fill placement. A spotter shall observe all fill placement operations to ensure the Reinforcement Geogrid does not slip, achieves the minimum coverage specified on the Plans, and is not damaged by the work.

9. Fill shall be compacted as specified in (1) the Standard Specifications or (2) to at least 90 percent of the maximum dry density determined in accordance with AASHTO T-180, whichever is greater. Density testing shall be made at a minimum frequency of one (1) test per lift or as otherwise specified in the Standard Specifications. Care shall be taken not to drive test apparatus through the Reinforcement Geogrid tensile elements.

10. All rutting formed during construction shall be filled with new Culvert Bedding Stone. In no case shall rutting be filled by blading down

620.04 Overlap Adjacent rolls of Reinforcement Geogrid shall be overlapped a minimum of 1 foot.

<u>620.05 Seams</u> Seams along adjacent lengths of Reinforcement Geogrid shall be tied together with hog rings or cable ties every 3 to 6 feet.

<u>620.06</u> Certification Prior to construction the Contractor shall submit to the Resident the Manufacturer's certification that the Reinforcement Geogrid supplied has been evaluated in full compliance with this Specification and is fit for long-term, critical soil reinforcement applications.

The Contractor's submittal package shall include, but not be limited to, actual tests for tension/creep, durability/aging, construction damage, and quality control tensile testing.

<u>620.08</u> Shipment, Storage, Protection, and Repair of Fabric The Contractor shall check the Reinforcement Geogrid upon delivery to ensure that the proper material has been received. Each Reinforcement Geogrid roll shall be shipped in a protective bag and clearly marked with roll number, lot number, geogrid style and principle strength direction. During all periods of shipment and storage, the Reinforcement Geogrid shall be protected from temperatures greater than 140°F and all deleterious materials that might otherwise become affixed to the Reinforcement Geogrid and effect its performance. The manufacturer's recommendations shall be followed with regard to protection from direct sunlight. The Reinforcement Geogrid shall be stored off the ground in a clean, dry environment out of the pathway of construction equipment.

Any Reinforcement Geogrid damage shall be repaired or replaced in accordance with the manufacturer's recommendations. The Contractor shall replace any Reinforcement Geogrid damaged during installation at no additional cost to the Department.

<u>620.09 Method of Measurement</u> Reinforcement Geogrid will be measured by the number of Square Yards of surface area installed. Overlaps for connections, splices, patches, and repairs of damaged Reinforcement Geogrid, etc. are incidental to this Pay Item.

<u>620.10 Basis of Payment R</u>einforcement Geogrid placement will be paid for per Square Yard inplace which shall be full compensation for all off-loading, inspection, storage, labor, materials, equipment, tools and any incidentals to complete the installation.

Payment will be made under:

Pay Item 620.65 Reinforcement Geogrid Pay Unit Square Yard

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

# **GEOTECHNICAL DESIGN REPORT**

For the Construction of

LONG PLAINS BRIDGE ROUTE 22 BUXTON, MAINE

Prepared by: Yueh-Ti Lee Assistant Geotechnical Engineer



*Reviewed by:* Cody Russell, P.E. Senior Geotechnical Engineer

York County WIN 26382.00 Soils Report 2024-40 Bridge No. 6698

November 18, 2024

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Appendix A - Boring Logs

Appendix B - Laboratory Test Results

Appendix C - Special Provision 620 – Geotextile (Reinforcement Geogrid)

Appendix D - 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 (#1063141) on Route 22 in Buxton. 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 dual 48-inch diameter, approximately 56-foot-long corrugated metal pipe (CMP) culverts. The CMPs are in poor condition and need replacement both from an infrastructure and environmental standpoint. Route 22 is a Highway Corridor Priority 3 road.

The proposed replacement structure will be an approximately 11-foot span by 5-foot rise by 72-foot-long precast concrete box culvert. The invert of the proposed culvert is approximately 9.5 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 Route 22 in Buxton and is located approximately 0.01 of a mile southeast of Rankin Road as shown on Sheet 1 – Location Map.

According to the Maine Geological Survey (MGS) map titled Surficial Geology of the Standish Quadrangle, Maine, Open File 99-101 (1999) the surficial soils at the site consist of Marine Regressive Sand Deposits. Marine Regressive Sand Deposits consist of sand and typically overlie Presumpscot Formation silt and clay.

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 interbedded pelite and sandstone of the Waterville Formation.

## **3.0** SUBSURFACE INVESTIGATION

One (1) boring (HB-BUXN-101) and one (1) probe (HB-BUXN-102) were drilled for this project on September 8, 2022 by the MaineDOT drill crew using a trailer-mounted drill rig. Exploration locations are shown on Sheet 2 – Boring Location Plan. Details and sampling methods used, field data obtained, and soil and groundwater conditions encountered are presented on the Boring Logs in Appendix A.

Boring HB-BUXN-101 was drilled using solid stem auger, cased wash boring, open hole, and hydraulic push techniques. Soil samples were obtained in the upper approximately 25 feet of 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 62 percent more energy during driving than the standard rope and cathead system. All N-values discussed in this report are corrected values (N<sub>60</sub>) computed by applying an average energy transfer factor of 0.974 to the raw field N-values. Probe HB-BUXN-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. A NorthEast Transportation Training and Certification (NETTCP) certified Subsurface Investigator 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 analyses with natural water content, six (6) standard grain size analyses with hydrometer and natural water content, and five (5) Atterberg Limits tests. 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 in the test boring and probe generally consisted of sand fill underlain by Presumpscot Formation consisting of silt and silty clay underlain by sand. An interpretive subsurface profile depicting the generalized soil stratigraphy at the boring location is shown on Sheet 3 – Interpretive Subsurface Profile.

Boring HB-BUXN-101 was drilled to depth of approximately 64.3 feet below ground surface (bgs) without encountering a refusal surface. Probe HB-BUXN-102 was drilled to depth of approximately 20.0 feet bgs without encountering a refusal surface.

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

Approx. Depth BGS <sup>1</sup> (feet)	Soil Description	AASHTO <sup>2</sup> Classification	USCS <sup>3</sup>	WC% <sup>4</sup>
0.0 - 5.0	Fill: Brown, damp, fine to coarse sand, some gravel, trace silt.	A-1-b	SW-SM	4.1
5.0-60.0	Presumpscot Formation:	A-4 or	CL	32.4 to

	Grey, wet, silt, some clay, trace fine to coarse sand, trace gravel, trace organics. Olive and grey, wet, silty clay, trace fine sand.	A-6	45.1
60.0 - 64.3	Sand.		 

<sup>1</sup>BGS = below ground surface

<sup>2</sup>AASHTO = American Association of State Highway and Transportation Officials

<sup>3</sup>USCS = Unified Soil Classification System

 $^{4}WC\% = Water content in percent$ 

One (1)  $N_{60}$ -value obtained in the fill was 28 blows per foot (bpf) indicating that the fill is medium dense in consistency. Seven (7)  $N_{60}$ -values obtained in the Presumpscot Formation ranged from Weight of Hammer (WOH) to 8 bpf, indicating that the Presumpscot Formation is very soft to medium stiff in consistency. Ten (10) vane shear tests conducted within the Presumpscot Formation showed measured undrained shear strengths ranging from approximately 179 pounds per square foot (psf) to 491 psf with remolded shear strengths ranging from approximately 22 psf to 134 psf. Based on the ratio of undrained to remolded shear strength from the vane shear test, the Presumpscot Formation was determined to have sensitivities of ranging from 3.3 to 12.2 and are classified as moderately sensitive to very sensitive.

The following table summarizes the results of Atterberg Limits tests done on five (5) samples of the silt and silty clay:

Boring No. and	Water	Liquid	Plastic	Plasticity	Liquidity
Sample No.	Content (%)	Limit	Limit	Index	Index
HB-BUXN-101 2D	32.4	29	21	8	1.43
HB-BUXN-101 3D	34.7	39	21	18	0.76
HB-BUXN-101 4D	44.7	35	20	15	1.65
HB-BUXN-101 6D	45.1	39	20	19	1.32
HB-BUXN-101 7D	41.8	35	21	14	1.49

Interpretation of these results indicate that the silt and silty clay have low to medium plasticity. The silty clay in sample 3D from boring HB-BUXN-101 is overconsolidated. The silt and silty clay in samples 2D, 4D, 6D and 7D from boring HB-BUXN-101 are on the verge of being a viscous liquid if disturbed. Overburden pressure and interparticle cementation is providing stability to keep the soil in its current state, but the slightest disturbance causing remolding could convert the soil into a viscous fluid.

Groundwater was recorded at depth 8.0 feet bgs in boring HB-BUXN-101. 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 Culvert Design and Construction

The proposed replacement structure will consist of a 11-foot span by 5-foot rise by 72-foot-long precast concrete box culvert. The proposed box culvert shall be designed and constructed in accordance with MaineDOT Standard Specification 534.

The approximate invert of the proposed box culvert will be set at an elevation of 165.00 feet with a 0% slope. To facilitate fish passage, Habitat Connectivity Design elements will be used inside the precast concrete box culvert as shown on the Streambed Details Sheet in the Plans.

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 <sup>3</sup>/<sub>4</sub>-Inch. Any disturbed soils at the bedding elevation resulting from excavation activities should be removed by hand prior to placement of the bedding material. 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 2-foot thick, geotextile wrapped, geogrid reinforced, crushed stone mat (Culvert Bedding Stone; Pay Item 203.55). The geogrid reinforcement shall meet the requirements shown on Appendix C – Special Provision 620 – Geotextile (Reinforcement Geogrid). The Reinforcement Geotextile shall meet the requirements of MaineDOT Standard Specification 722.01. The soils at the bedding elevation shall be excavated using a smooth-edged backhoe bucket to limit disturbance. Any disturbed soils at the bedding elevation resulting from excavation activities shall be removed by hand prior to placement of the geotextile wrapped, geogrid reinforced, crushed stone mat. All subgrade surfaces should be protected from construction traffic in order to limit disturbance. Groundwater and surface water levels shall be depressed sufficiently to allow work in the dry.

The soil backfill shall consist of Granular Borrow (703.19) with a maximum particle size of 4 inches. The Granular Borrow backfill 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, to at least 92 percent of the AASHTO T-180 maximum dry density. In no case shall the backfill soil be compacted less than 92 percent of the AASHTO T-180 maximum dry density.

#### 6.2 Settlement

No settlement issues are anticipated at the site. The precast concrete box culvert will be constructed at a new location east (up station) of the existing culvert. 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 proposed structure location. Placement of fill soils at the location of the existing structure is not anticipated to exceed the past loading condition of the site soils. Any settlement due to elastic compression of the bedding material will be immediate and negligible.

#### 6.3 Bearing Resistance

The factored bearing resistances for the precast concrete box culvert bearing on compacted granular bedding material placed on native soils and/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 9<sup>th</sup> Edition 2020 (LRFD) are provided in Appendix D – Calculations.

Limit State	Resistance Factor	AASHTO LRFD	Factored Bearing		
	Фb	Reference	Resistance (ksf)		
Service	1.0	Article 10.5.5.1	3.0		
Strength	0.45	Table 10.5.5.2.2-1	8.5		

## 6.4 Modulus of Subgrade Reaction

A modulus of subgrade reaction ( $k_s$ ) equal to 35 pounds per cubic inch shall be used for the structural design of the box culvert's base slab. Calculations are included in Appendix D – Calculations.

## 6.5 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 on the inlet and outlet end. No specific scour protection recommendations are needed other than armoring with riprap. The riprap on the slopes shall be underlain by a 1-foot layer of protective aggregate cushion consisting of Granular Borrow Material for Underwater Backfill (703.19) that is underlain by a non-woven, Class 1 Erosion Control Geotextile meeting the requirements of MaineDOT Standard Specification 722.03. The toe of the riprap sections shall be keyed into the existing soils 1 foot below the streambed elevation.

#### 6.6 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.

#### 6.7 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 deep 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 sand or 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 (#1063141) under Route 22 in Buxton, 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** 





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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

No Refusal

Refusal

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# Appendix A

Boring Logs

	UNIFIE	ED SOIL C	LASSIFIC	CATION SYSTEM		MODIFIED B	BURMISTER S	YSTEM	
MA		DNS	GROUP SYMBOLS	TYPICAL NAMES					
COARSE- GRAINED	GRAVELS	CLEAN GRAVELS	GW	Well-graded gravels, gravel- sand mixtures, little or no fines.	<u>Descrip</u> tr li	<u>tive Term</u> race ittle	Port	<u>ion of Total (%)</u> 0 - 10 11 - 20 21 - 25	
SUILS	f coarse nan No. 4 )	(little or no fines)	GP	Poorly-graded gravels, gravel sand mixtures, little or no fines.	adjective (e.g.	Sandy, Clayey)		21 - 35 36 - 50	
	half o ger th e size						S DESCRIBIN	G	
	than is lar sieve	GRAVEL	GM	Silty gravels, gravel-sand-silt	Coarse-grained s	soils (more than half	of material is larger t	han No. 200	
5	more	WITH FINES		mixtures.	sieve): Includes (1 Clavev or Gravelly	1) clean gravels; (2) S v sands.  Densitv is ra	ilty or Clayey gravels ated according to sta	s; and (3) Silty, ndard	
is large ze)	fra fra	(Appreciable amount of	GC	Clayey gravels, gravel-sand-clay mixtures.	penetration resista	ance (N-value).	5		
aterial ieve siz		fines)			Den Cohesior	<u>isity of</u> nless Soils	<u>Standard Po</u> <u>N-Value</u>	enetration Resistance e (blows per foot)	
f of m 200 s		CLEAN	SW	Well-graded sands, Gravelly	Very Lc	/ loose oose		0 - 4 5 - 10	
No. 3	SANDS	SANDS		sands, little or no fines	Mediur	m Dense		11 - 30	
e thai than	9. e	(little or no	SP	Poorly-graded sands, Gravelly	Very	Dense		> 50	
(mor	an N	fines)		sand, little or no fines.	Fine grained coil	le (mara than half of r	natorial is smaller th	an No. 200	
	alf of ller th size)				sieve): Includes (1	) inorganic and organ	nic silts and clays; (2	) Gravelly, Sandy	
	lan ha smal	SANDS WITH	SM	Silty sands, sand-silt mixtures	or Silty clays; and strength as indicated	<li>(3) Clayey silts. Con ted.</li>	sistency is rated acc	ording to undrained shear	
	ore th ion is s	FINES	60		g		Approximate		
	(m fract	(Appreciable amount of	30	clayey sands, sand-clay mixtures.	Consistency of	SPT N-Value	Shear	Field	
		fines)			Cohesive soils	(blows per foot) WOH_WOR	Strength (psf)	Guidelines	
			ML	Inorganic silts and very fine	Very Soft	WOP, <2	0 - 250	Fist easily penetrates	
	SILTS AND CLAYS			sands, rock flour, Silty or Clayey fine sands, or Clayey silts with	Soπ Medium Stiff	2 - 4 5 - 8	250 - 500 500 - 1000	Thumb easily penetrates Thumb penetrates with	
				slight plasticity.	Stiff	9 - 15	1000 - 2000	moderate effort Indented by thumb with	
FINE-			CL	Inorganic clays of low to medium	Vom Ctiff	16 20	2000 4000	great effort	
SOILS				clays, Silty clays, lean clays.	Hard	>30	over 4000	Indented by thumbhail	
			OI	Organic silts and organic Silty	Rock Quality Des	signation (RQD):		with difficulty	
			01	clays of low plasticity.	RQD (%) =	sum of the lengths	of intact pieces of	f core* > 4 inches	
al is size)					*Minimum NQ rock core (1.88 in. OD of core)				
nateri sieve				Inorganic silts, micaceous or diatomaceous fine Sandy or		Rock Quality Ba	ased on RQD		
lf of r 200	SILTS AN	ID CLAYS		Silty soils, elastic silts.		Rock Quality	RQD (%)		
an ha in No			СН	Inorganic clays of high		Poor	≤25 26 - 50		
re tha				plasticity, fat clays.		Fair Good	51 - 75 76 - 90		
(mc small	(liquid limit gr	eater than 50)	ОН	Organic clays of medium to	Desired Beak C	Excellent	91 - 100	cable).	
				ngn plasticity, organic sitts.	Color (Munsell	color chart)	ina order, if appli		
	HIGHLY	ORGANIC	Pt	Peat and other highly organic	Texture (aphani Rock Type (gra	itic, fine-grained, et nite, schist, sandste	tc.) one, etc.)		
	SO	ILS		soils.	Hardness (very	hard, hard, mod. h	ard, etc.)	· · · ·	
Desired So	il Observat	ions (in thi	s order. if	applicable):	vveatnering (fre	sn, very slight, slig ntinuities/iointina	nt, moderate, mod	i. severe, severe, etc.)	
Color (Mun	sell color ch	art)		<u> </u>		-dip (horiz - 0-5 de	g., low angle - 5-3	5 deg., mod. dipping -	
ivioisture (d Density/Coi	ry, ɑamp, m nsistency (fr	oıst, wet) om above ri	ght hand s	side)		35-55 deg., stee -spacing (very clos	ep - 55-85 deg., ve se - <2 inch, close	ertical - 85-90 deg.) - 2-12 inch, mod.	
Texture (fin	e, medium,	coarse, etc.	) inclusion	, nortional trace little -t- )		close - 1-3 feet,	, wide - 3-10 feet,	very wide >10 feet)	
Gradation (	u, Silty Sand well-graded	u, ciay, etc. , poorly-grad	, including ded, unifor	m, etc.)		<ul> <li>-ugntness (tight, op -infilling (grain size)</li> </ul>	e, color, etc.)		
Plasticity (n	on-plastic, s	lightly plast	ic, modera	tely plastic, highly plastic)	Formation (Wat	erville, Ellsworth, C	Cape Elizabeth, etc	c.) etc.)	
Bonding (w	ell, moderat	ely, loosely,	etc., )		ref: ASTM D6	032 and FHWA NF	y (very poor, poor, II-16-072 GEC 5 -	Geotechnical	
Cementatio	n (weak, mo	oderate, or s	trong)	<b>~</b> )	Site Characte	rization, Table 4-12	2		
Groundwate	er level	inne ciay, al	iuvium, et	s.j	Recovery (Inch/ Rock Core Rate	e (X.X ft - Y.Y ft (mi	je) in:sec))		
	Maina	)onort	nt of To	nonortotion	Sample Cont	ainer Labeling I	Requirements:		
	wane L	vepartme Geotechi	nt of Tra nical Se	ansportation ction	WIN Bridge North	/ Town	Blow Counts	0.01/	
Ke	y to Soil a	and Rock	Descrip	otions and Terms	Boring Numbe	/ IOWN er	Sample Recov	ery	
	Fiel	d Identific	ation Inf	ormation	Sample Numb	ber	Personnel Initia	als	
					Sample Deptr	I			

Maine Department of Transportation					n	<b>Project:</b> Large Culvert #1063141 Replacement on					Boring No.:	HB-BU	XN-101	
		1	Soil/Rock Exp	loration Log			Locatio	Rou on: Bi	te 22 1xto:	2 n, Ma	ine			
			US CUSTOM	ARY UNITS						,		WIN:	263	82.00
Drill	er:		MaineDOT		Ele	evation	ı (ft.)	17	3.9			Auger ID/OD:	5" Solid Stem	
Operator: Daggett Datum:				tum:	. ,	N	AVE	088		Sampler:	Standard Split	Spoon		
Logged By: B Wilder Rig Ty				q Type	:	Cl	ME 4	45C		Hammer Wt./Fall:	140#/30"	1		
Date	Start/Fi	inish:	9/8/2022; 09:0	00-12:30	Dri	illina N	lethod:	Ca	ised	Wash	Boring	Core Barrel:	N/A	
Bori	ng Loca	tion:	42+07.5, 12.7	ft Lt.	Ca	isina IE	D/OD:	N	W-3	"	U	Water Level*:	8.0 ft bgs.	
Ham	mer Effi	iciency F	actor: 0.974		На	mmer	Type:	Auto	mati	ic 🖂	Hydraulic 🗆	Rope & Cathead □	6	
Defini	tions:			R = Rock (	Core San	nple	71	Su	= Pe	eak/Re	molded Field Vane Undrained She	ear Strength (psf) $T_V =$	Pocket Torvane She	ar Strength (psf)
D = S MD =	Dit Spoon	Sample sful Split Sp	oon Sample Atter	npt HSA = Hol	d Stem / low Sten	Auger n Auger		Su 9p	(lab) = Ur	) = Lab nconfin	Vane Undrained Shear Strength ( ed Compressive Strength (ksf)	pst) VVC = LL =	<ul> <li>Water Content, per Liquid Limit</li> </ul>	cent
U = TI MU =	hin Wall Tu	ibe Sample	all Tube Sample A	RC = Rolle	r Cone	140lb Ha	mmer	N- Ha	unco	rrected	I = Raw Field SPT N-value	PL = Calibration Value PL =	Plastic Limit	
V = Fi	eld Vane S	Shear Test,	PP = Pocket Pe	netrometer WOR/C = WOR	Neight of	of Rods o	r Casing	Ne	0 = 5	SPT N-	uncorrected Corrected for Hamme	er Efficiency G = C	Grain Size Analysis	
1010 -	Unsuccess			Sample Information	reigni or	Onerei	5011	ING	1	Tanin	er Enclency Factor/00 %) N-uncor		onsolidation rest	
		(·-	Ę	~	þ									Laboratory
	ġ	. <u>.</u>	Oep	3 in. (%)	ecte					Log	Visual Do	scription and Pomarks		Results/
۲.		Rec	ole [	s (/6 2D (	corr		DC s	tior		hic I	visual De			AASHTO
epti	amp	en./	t.)	hea hea sf) sf)	n-un	60	asir	leva	1	rapl				unified Class.
	Ű	<u> </u>	ũ.F	<u>a n n n n n</u>	Z	Z				() XXXX	Deserve de une de la deserve de se	CAND		C#270950
0	1D	24/17	0.00 - 2.00	3/8/9/7	17	28	SSA		K	***	silt, (Fill).	se, fine to coarse SAND,	some gravel, trace	A-1-b, SW-SM
								1	R	***				WC=4.1%
l I							+	-	×					
									Ķ	$\otimes$				
l I								1	Ř	***				
								-	Ŕ					
										***			5.0	
- 5 -	2D	24/20	5 00 - 7 00	1/2/2/3	4	6	7	$\begin{bmatrix} 168 \\ \end{bmatrix}$	.9	ĨĬĬĬ	Grey, wet, medium stiff, SI	LT, some clay, trace fine	5.0 to coarse sand,	G#379860
		220	0.000 /100	1.2.2.0			,	-			trace gravel, trace organics.			A-4, CL WC=32.4%
							8							LL=29
							9	1						PL=21 PI=8
								-						
							18	104					0.0	
							39	7 104	.9				9.0	
- 10 -								-	ł		Olive, wet, medium stiff, Si	ilty CLAY, trace fine sand	1.	G#379861
	3D	24/24	10.00 - 12.00	2/2/3/3	5	8	41		ł					A-6, CL
							36		ł					WC=34.7% LL=39
								-	ł					PL=21
							32	4	ł					PI=18
							34							
							31	1	ł					
- 15 -							51	-	ł		Grev wet verv soft Silty (	LAV trace fine sand		G#379862
	4D V1	24/24	15.00 - 17.00	Hydraulic Push Su=402/89 psf			24		ł		55x110 mm vane raw torqu	e readings:		A-6, CL
	V2		16.63 - 17.00	Su=357/89  psf			26	1	ł		V1: 9.0/2.0 ft-lbs	6		WC=44.7%
								-	ł		V2: 8.0/2.0 ft-lbs			PL=20
l I							27		ŧ					PI=15
l I							23		ŧ					
								-	ł					
- 20 -						ļ	24	_	ł		0	NLAN (m. C. 1		0#2700/22
	5D	24/24	20.00 - 22.00	WOH/WOH/WOH/			OPEN		ł		Grey, wet, very soft, Silty C	LAY, trace fine sand.		G#379863 A-6, CL
l I	V3		20.63 - 21.00	Su=402/45 psf			HOLE	-	ł		V3: 9.0/1.0 ft-lbs	e readings:		WC=40.8%
l I	V4		21.03 - 22.00	Su=402/67 psf		<u> </u>		-	ł		V4: 9.0/1.5 ft-lbs			
l I									Ĭ					
l I						1		1	ł					
l I							+	-	ł					
25									ł					
Rem	arks:							-		UT TO THE				
l I														
Stratif	ication line	s represent	approximate bou	ndaries between soil types;	transitio	ns may b	e gradual					Page 1 of 3		
* Wate	er level rea	dings have	been made at tim	es and under conditions sta	ated. Gr	oundwate	er fluctuati	ons may	/ 000	ur due	to conditions other			
than	those pres	sent at the t	ime measuremen	ts were made.								Boring No.	: HB-BUX	N-101
									_					

Ι	Maine	e Dep	artment	of Transporta	ation	Proje	ect:	Large	Culve	ert #1063141 Replacement on	Boring No.:	HB-BU	XN-101
			Soil/Rock Exp US CUSTOM	loration Log ARY UNITS		Loca	tio	Route n: Buxt	22 on, M	laine	WIN:	2638	32.00
Drill	or.		MaineDOT		Flevatio	 n (ft )		173 0	)			5" Solid Stem	
Ope	ator:		Daggett		Datum:			NAV	, D88		Sampler:	Standard Split	Spoon
Logo	aton		B Wilder		Rig Type			CME	450		Hammer Wt /Fall:	140#/30"	opeen
Date	Start/Fi	nish:	9/8/2022: 09:0	00-12:30	Drilling	Metho	d٠	Case	d Wa	sh Boring	Core Barrel:	N/4	
Bori		tion:	42+07 5 12 7	ft I t	Casing I		<u>u.</u>	NW-	2"	an Doring	Water Level*	8.0 ft bas	
Ham	mor Effi	ciency F	actor: 0.974		Hammer	Type		Automa	tic 🕅	Hydraulic 🗆	Rope & Cathead []	010 11 0 goi	
Definit	ions:			R = Rock C	ore Sample		-	S <sub>u</sub> =	Peak/F	Remolded Field Vane Undrained Sh	ear Strength (psf) $T_V$	= Pocket Torvane She	ar Strength (psf)
D = SI MD =	olit Spoon 8 Unsuccess	Sample sful Split Sp	oon Sample Atter	npt HSA = Solid	I Stem Auger ow Stem Auger			S <sub>u(lal</sub> q <sub>p</sub> = l	<sub>o)</sub> = La Jnconf	b Vane Undrained Shear Strength ( fined Compressive Strength (ksf)	(psf) Wi LL	C = Water Content, pero = Liquid Limit	cent
U = Tł MU =	nin Wall Tu Unsuccess	be Sample ful Thin Wa	all Tube Sample A	RC = Roller WOH = Wei	Cone ight of 140 lb. H	lammer		N-uno Hamn	orrectener Eff	ed = Raw Field SPT N-value iciency Factor = Rig Specific Annua	I Calibration Value PI	= Plastic Limit = Plasticity Index	
V = Fi MV =	eld Vane S Unsuccess	hear Test, ful Field Va	PP = Pocket Pe	tempt WOR/C = W	eight of Rods	or Casin	g	N <sub>60</sub> =	SPT I (Ham	N-uncorrected Corrected for Hamme mer Efficiency Factor/60%)*N-unco	er Efficiency G rrected C	= Grain Size Analysis = Consolidation Test	
				Sample Information				0				-	Laboratory
		Li	pth		fed				5				Testing
ft.)	Ň	. ()	De	/6 ir (%)	Lec			Ę	Ľő	Visual De	escription and Remark	s	Results/
oth (	Jple	./Re	aldr	ws ( ar ingtl () (QD	nco	ing	NS	/atic	phic				and
Dep	San	Pen	San (ft.)	Blov She Stre or F	N-U	Cas	Blo	Elev (ft.)	Gra				Unified Class.
25	6D	24/24	25.00 - 27.00	WOR/WOR/WOR/						Grey, wet, very soft, Silty (	CLAY, trace fine sand.		G#379864
	V5	2021	25.63 - 26.00	WOR Su=446/45 psf						55x110 mm vane raw torqu	ie readings:		A-6, CL WC=45.1%
	V6		26.63 - 27.00	Su=446/45 psf						V6: 10.0/1.0 ft-lbs			LL=39
													PL=20 PI=19
													-
						_							
- 30 -	7D	24/24	30.00 - 32.00	WOR/WOR/WOR/						Grey, wet, very soft, Silty (	CLAY, trace fine sand.		G#379865
	V7	2021	30.63 - 31.00	WOR Su=179/45 psf						55x110 mm vane raw torqu V7: 4 0/1 0 ft-lbs	ie readings:		A-0, CL WC=41.8%
	V8		31.63 - 32.00	Su=268/22 psf						V8: 6.0/0.5 ft-lbs			LL=35
													PL=21 PI=14
25													
- 55	8D	24/15	35.00 - 37.00	WOR/WOR/WOR/						Grey, wet, very soft, Silty (	CLAY, trace fine sand.		
	V9 V10		35.63 - 36.00	Su=446/134 psf			_			V9: 10.0/3.0 ft-lbs	ie readings:		
	V10		36.63 - 37.00	Su=491/45 pst						V10: 11.0/1.0 ft-lbs			
							/			No samples taken after 8D.			
							/						
						+	$\vdash$						
- 40 -						¥				Hudroulia Dushad Drill Pa	$d_{0}$ (450 pci) to 64.2 ft b		
						н	P			Hydraulic Pushed Drill Ro	us (450 psi) to 64.5 it bg	çs.	
										4			
- 45 -													
						+							
50													
Rem	arks:	1			I				แหน่หม่				
Stratif	cation lines	s represent	approximate bou	ndaries between soil types; t	ransitions may	be grad	ual.				Page 2 of 3		
* Wate	er level read	dings have	been made at tim	es and under conditions stat	ed. Groundwa	ter fluctu	atio	ns may oo	cur du	e to conditions other	Danimahi		NT 101
than	those pres	sent at the t	ime measuremen	ts were made.								D.: HB-BUXI	N-101

	Maine Department of Transportation					<b>Project:</b> Large Culvert #1063141 Replacement on Route 22				Boring No.:	HB-BU	XN-101	
			Soil/Rock Exp US CUSTOM	oloration Log ARY UNITS			Locatio	Route on: Bux	22 ton, M	aine	WIN:	2638	32.00
Drill	er:		MaineDOT		Elev	ation	(ft.)	173.	9		Auger ID/OD:	5" Solid Stem	
Ope	rator:		Daggett		Datu	im:	(-)	NA	/D88		Sampler:	Standard Split	Spoon
Log	ged By:		B. Wilder		Rig	Туре	:	СМ	E 45C		Hammer Wt./Fall:	140#/30"	
Date	Start/F	inish:	9/8/2022; 09:	00-12:30	Drilli	ing N	lethod:	Case	ed Was	h Boring	Core Barrel:	N/A	
Bori	ng Loca	tion:	42+07.5, 12.7	' ft Lt.	Casi	ng ID	D/OD:	NW	-3"		Water Level*:	8.0 ft bgs.	
Ham	mer Eff	iciency F	actor: 0.974		Ham	mer	Туре:	Autom	atic 🛛	Hydraulic 🗆	Rope & Cathead □		
Defini D = S MD = U = TI MU = V = Fi MV =	tions: plit Spoon Unsucces: hin Wall Tu Unsucces: ield Vane S <u>Unsucces:</u>	Sample sful Split Sp ube Sample sful Thin W Shear Test, sful Field Va	oon Sample Atter all Tube Sample A PP = Pocket Pe ane Shear Test At	R = Roc SSA = S mpt HSA = H RC = Ro Attempt WOR/C enteropt WOR/C Sample Informatio	Core Sampl olid Stem Aug ollow Stem A ller Cone Weight of 140 = Weight of R Weight of Or <b>1</b>	le ger Auger ) Ib. Ha Rods of ne Per	ammer r Casing son	S <sub>U</sub> = S <sub>U(la</sub> q <sub>p</sub> = N-un Ham N <sub>60</sub>	Peak/R (b) = Lal Unconfi correcte mer Effi = SPT N = (Hami	emolded Field Vane Undrained Sh b Vane Undrained Shear Strength ined Compressive Strength (ksf) d = Raw Field SPT N-value ciency Factor = Rig Specific Annua I-uncorrected Corrected for Hamm- mer Efficiency Factor/60%)'N-unco	ear Strength (psf)         Tv =           (psf)         WC           LL         LL           Il Calibration Value         PI =           er Efficiency         G =           rrected         C =	Pocket Torvane She = Water Content, perc Liquid Limit = Plastic Limit Plasticity Index Grain Size Analysis Consolidation Test	ar Strength (psf) ent
S Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N <sub>60</sub>	Casing Blows	Elevation (ft.)	Graphic Log	Visual De	escription and Remarks		Laboratory Testing Results/ AASHTO and Unified Class.
- 55 - 60 - 65 - 65 -								113.9		Sand layer at 60.0 ft bgs. Bottom of Exploratio FIRM	n at 64.3 feet below grou	60.0- 64.3- 64.3- und surface.	
- 70 - 75 Rem	arks:	s represent	approximate bou	Indaries between soil type	s; transitions	may b	pe gradual.	-			Page 3 of 3		
* Wate	er level rea	idings have	been made at tin	nes and under conditions	stated. Grou	ndwate	er fluctuatio	ons may c	ccur du	e to conditions other	-		
than	those pre	sent at the	time measuremer	its were made.							Boring No	HB-BUX	N-101

N	laine	Dep	artment	of Transport	tation		Project:	Large	Culvert #1063141 Replacement on	Boring No.:	HB-BUX	<u>N-102</u>
		<u>1</u> 	Soil/Rock Exp	loration Log ARY UNITS			Locatior	Route Bux	222 Iton, Maine	WIN:	263	82.00
Drillir	ng Conti	ractor:	MaineDOT		Elev	ation	(ft.)	173.	.4	Auger ID/OD:	5" Dia.	
Opera	ator:		Daggett		Datu	ım:	( )	NA	VD88	Sampler:	N/A	
Logg	ed By:		B. Wilder		Rig	Type:		CM	E 45C	Hammer Wt./Fall:	N/A	
Date	Start/Fir	nish:	9/8/2022-9/8/2	2022	Drilli	ing M	ethod:	Soil	d Stem Auger	Core Barrel:	N/A	
Borin	g Locat	ion:	42+13.6, 12.7	ft Rt.	Casi	ing ID	/OD:	N/A		Water Level*:	None Observe	d
Definitio	ons: D =	Spilt Spoo	n Sample	MU = Unsu R = Rock C	cessful Thi	in Wall	Tube Samp	le Atterr	npt WO1P = Weight of 1 Person	ndrained Shear Strength (nef)		
B = Buo MD = U U = Thi MV = U	npie on Ac cket Sampl Insuccessf n Wall Tub Insuccessf	le off Auge ul Split Sp le Sample ul Field Va	r Flights oon Sample Atten ne Shear Test Att	npt HSA = Hold RC = Roller tempt WOH = We	Stem Auge w Stem Au Cone ght of 140lb	er iger o. Hamr	ner		$S_{u}(lab) = Lab Vane Undrained Sheq_p = Unconfined Compressive StreiN-value = Raw Field SPT N-valueT_v = Pocket Torvane Shear Strengt$	ar Strength (psf) ngth (ksf) h (psf)	LL = Liquid Lim PL = Plastic Lir PI = Plasticity II G = Grain Size	it nit ndex Analysis
V = Fiel	ld Vane Sh	iear Test,	PP= Pocket Per	netrometer WOR/C = V Sample Information	/eight of Ro	ods or C	asing		WC = Water Content, percent ≅ = S	Similar or Equal too	C = Consolidat	on 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 Descr	iption and Remarks		Laboratory Testing Results/ AASHTO and Unified Class.
0		<u> </u>	0,0			SSA			Probe, no material samples taken.			
- 5 -							-					
- 10							-					
							-					
- 15 -							-					
							-					
- 20 -							_ 153.4		Bottom of Exploration at NO REFUSAL	20.0 feet below ground s	20.0- urface.	
25												
<u>Rema</u>	<u>ırks:</u>		1	1	· I		_		1			
Stratific	ation lines	represent	approximate bou	ndaries between soil types	transitions	may be	e gradual.			Page 1 of 1		
* Water than t	level read	ings have ent at the t	been made at tim ime measuremen	es and under conditions st ts were made.	ated. Grou	ndwate	r fluctuatior	s may c	occur due to conditions other	Boring No.	: HB-BUX	N-102

# <u>Appendix B</u>

Laboratory Test Results

#### State of Maine - Department of Transportation Laboratory Testing Summary Sheet

Town(s):	Buxto	n			Work	ς Νι	ımk	ber	: 2638	82.00	
Boring & Sample	Station	Offset	Depth	Reference	G.S.D.C.	W.C.	L.L.	P.I.	Cla	ssificatio	n
Identification Number	(Feet)	(Feet)	(Feet)	Number	Sheet	%			Unified	AASHTO	Frost
HB-BUXN-101, 1D	42+07.5	12.7 Lt.	0.0-2.0	379859	1	4.1			SW-SM	A-1-b	0
HB-BUXN-101, 2D	42+07.5	12.7 Lt.	5.0-7.0	379860	1	32.4	29	8	CL	A-4	IV
HB-BUXN-101, 3D	42+07.5	12.7 Lt.	10.0-12.0	379861	1	34.7	39	18	CL	A-6	
HB-BUXN-101, 4D	42+07.5	12.7 Lt.	15.0-17.0	379862	1	44.7	35	15	CL	A-6	
HB-BUXN-101, 5D	42+07.5	12.7 Lt.	20.0-22.0	379863	2	40.8			CL	A-6	
HB-BUXN-101, 6D	42+07.5	12.7 Lt.	25.0-27.0	379864	2	45.1	39	19	CL	A-6	
HB-BUXN-101, 7D	42+07.5	12.7 Lt.	30.0-32.0	379865	2	41.8	35	14	CL	A-6	
Classification of th	ese soil samp	les is in ac	ccordance with	h AASHTO C	lassificatio	on Syst	em M-	145-4	0. This cla	ssificatior	ו
is followed by the	is followed by the "Frost Susceptibility Rating" from zero (non-frost susceptible) to Class IV (highly frost susceptible).										
The "Frost Sus	ceptibility Rat	ing" is bas	ed upon the N	laineDOT an	d Corps of	Engin	eers C	lassif	ication Sy	stems.	
GSDC = Grain Size Distribu	ution Curve as	determined	by AASHTO T	88-93 (1996)	and/or AS	TM D 4	22-63	(Reap	proved 199	98)	

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



UNIFIED CLASSIFICATION

	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	WC, %	LL	PL	PI
0	HB-BUXN-101/1D	42+07.5	12.7 LT	0.0-2.0	SAND, some gravel, trace silt.	4.1			
	HB-BUXN-101/2D	42+07.5	12.7 LT	5.0-7.0	SILT, some clay, trace sand. trace gravel.	32.4	29	21	8
	HB-BUXN-101/3D	42+07.5	12.7 LT	10.0-12.0	Silty CLAY, trace sand.	34.7	39	21	18
	HB-BUXN-101/4D	42+07.5	12.7 LT	15.0-17.0	Silty CLAY, trace sand.	44.7	35	20	15
X									

WI	N					
026382.00						
Tov	vn					
Buxton						
Reported	Reported by/Date					
WHITE, TERRY A	10/17/2022					



	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	WC, %	LL	PL	PI
0	HB-BUXN-101/5D	42+07.5	12.7 LT	20.0-22.0	Silty CLAY, trace sand.	40.8			
۲	HB-BUXN-101/6D	42+07.5	12.7 LT	25.0-27.0	Silty CLAY, trace sand.	45.1	39	20	19
	HB-BUXN-101/7D	42+07.5	12.7 LT	30.0-32.0	Silty CLAY, trace sand.	41.8	35	21	14
۲									
X									

WI	N			
026382.00				
Tov	vn			
Buxton				
Reported by/Date				
WHITE, TERRY A	10/17/2022			

TOWN	Buxton	Reference No.	379860
WIN	026382.00	Water Content, %	32.4
Sampled	9/8/2022	Liquid Limit @ 25 blows (T 89), %	29
Boring No./Sample No.	HB-BUXN-101/2D	Plastic Limit (T 90), %	21
Station	42+07.5	Plasticity Index (T 90), %	8
Depth	5.0-7.0	Tested By	BBURR



TOWN	Buxton	Reference No.	379861
WIN	026382.00	Water Content, %	34.7
Sampled	9/8/2022	Liquid Limit @ 25 blows (T 89), %	39
Boring No./Sample No.	HB-BUXN-101/3D	Plastic Limit (T 90), %	21
Station	42+07.5	Plasticity Index (T 90), %	18
Depth	10.0-12.0	Tested By	BBURR



TOWN	Buxton	Reference No.	379862
WIN	026382.00	Water Content, %	44.7
Sampled	9/8/2022	Liquid Limit @ 25 blows (T 89), %	35
Boring No./Sample No.	HB-BUXN-101/4D	Plastic Limit (T 90), %	20
Station	42+07.5	Plasticity Index (T 90), %	15
Depth	15.0-17.0	Tested By	BBURR



TOWN	Buxton	Reference No.	379864
WIN	026382.00	Water Content, %	45.1
Sampled	9/8/2022	Liquid Limit @ 25 blows (T 89), %	39
Boring No./Sample No.	HB-BUXN-101/6D	Plastic Limit (T 90), %	20
Station	42+07.5	Plasticity Index (T 90), %	19
Depth	25.0-27.0	Tested By	BBURR



TOWN	Buxton	Reference No.	379865
WIN	026382.00	Water Content, %	41.8
Sampled	9/8/2022	Liquid Limit @ 25 blows (T 89), %	35
Boring No./Sample No.	HB-BUXN-101/7D	Plastic Limit (T 90), %	21
Station	42+07.5	Plasticity Index (T 90), %	14
Depth	30.0-32.0	Tested By	BBURR



# <u>Appendix C</u>

Special Provision 620 – Geotextile (Reinforcement Geogrid)

#### SPECIAL PROVISION SECTION 620 – GEOTEXTILES (Reinforcement Geogrid)

Amend Standard Specification 620 – GEOTEXTILES to include the following:

<u>620.01</u> Description This work shall consist of furnishing and installing Reinforcement Geogrid within the Culvert Bedding Stone in accordance with these specifications and in reasonably close conformity with the lines, grades, and dimensions shown on the plans or as directed by the Resident.

<u>620.02 Material</u> Reinforcement Geogrid shall consist of a regular network of integrally connected, polymeric tensile elements with aperture geometry sufficient to permit significant mechanical interlock with the surrounding soil, aggregate or other material. The Reinforcement Geogrid structure shall be dimensionally stable to retain its geometry under construction stresses and shall have high resistance to damage during construction, ultraviolet degradation, and all forms of chemical and biological degradation encountered in the soil being reinforced.

The Reinforcement Geogrid shall meet or exceed the Minimum Average Roll Values (MARV) of the properties in Table 1. Acceptable manufacturers for Reinforcement Geogrids must be approved by the Resident.

Reinforcement Geogrid Mechanical Property	Test Method	Minimum Average Roll Value (MARV) <sup>1</sup>
Tensile strength at 5% Strain MD or XD	ASTM D 6637	1,200 lb/ft
Rib Junction Strength	GRI-GG2	1,000 lb/ft in both directions
Aperture Openings		Between 0.75 and 3 inches
Percent Open Area		50 to 80%

#### Table 1 - Physical Property Requirements (Biaxial Reinforcement Geogrid)

<sup>1</sup> Values are minimum average roll values determined in accordance with ASTM D 4759

A biaxial Reinforcement Geogrid shall be used in this application.

<u>620.03 Placement</u> Reinforcement Geogrid shall be installed, in accordance with the manufacturer's recommendations, unless otherwise modified by this Special Provision. The Reinforcement Geogrid shall be placed within the layers of Crushed Stone Bedding at the proper elevation and alignment as shown on the Plans or as directed by the Resident.

1. The Reinforcement Geogrid shall be placed in continuous longitudinal strips. Splicing along the length will not be allowed. Reinforcement Geogrid shall be oriented such that the roll length runs either parallel or perpendicular to the construction centerline. The Contractor shall verify correct orientation of the Reinforcement Geogrid.

2. Reinforcement Geogrid may be temporarily secured in-place with staples, pins, sand bags or backfill as required by fill properties, fill placement procedures, or weather conditions, or as directed by the Resident.

3. Coverage of less than 100 percent shall not be allowed.

4. The Reinforcement Geogrid shall be lightly anchored and pulled taut to reduce any slack as directed by the Resident.

5. Fill shall not be dumped directly onto the Reinforcement Geogrid. It shall be dumped at the edge of the Reinforcement Geogrid or on a previous course of fill with a minimum compacted depth of 8 inches.

6. The Reinforcement Geogrid shall be covered with fill materials within 7 days of placement to protect against unnecessary exposure.

7. Fill may then be pushed onto the Reinforcement Geogrid using a track mounted bulldozer. At no time shall construction equipment be allowed directly onto the Reinforcement Geogrid. Track mounted equipment shall be allowed on previous courses of fill with a minimum compacted depth of 8 inches. Smooth drum roller compaction equipment shall be allowed on previous courses of fill with a minimum depth of 12 inches, loose measure. At no time shall rubber tired or sheeps-foot rollers be allowed onto the reinforced fill. Turning of vehicles should be kept to a minimum to prevent tracks from displacing the fill and damaging the Reinforcement Geogrid. Sudden breaking and sharp turning shall be avoided. Equipment speeds over 10 MPH shall not be allowed.

8. Placement, spreading, and compaction of soil on top of the Reinforcement Geogrid shall advance from one end of the Reinforcement Geogrid and move towards the other. Care shall be taken to minimize the development of wrinkles and to ensure that the Reinforcement Geogrid doesn't move from its position during fill placement. A spotter shall observe all fill placement operations to ensure the Reinforcement Geogrid does not slip, achieves the minimum coverage specified on the Plans, and is not damaged by the work.

9. Fill shall be compacted as specified in (1) the Standard Specifications or (2) to at least 90 percent of the maximum dry density determined in accordance with AASHTO T-180, whichever is greater. Density testing shall be made at a minimum frequency of one (1) test per lift or as otherwise specified in the Standard Specifications. Care shall be taken not to drive test apparatus through the Reinforcement Geogrid tensile elements.

10. All rutting formed during construction shall be filled with new Culvert Bedding Stone. In no case shall rutting be filled by blading down

620.04 Overlap Adjacent rolls of Reinforcement Geogrid shall be overlapped a minimum of 1 foot.

<u>620.05 Seams</u> Seams along adjacent lengths of Reinforcement Geogrid shall be tied together with hog rings or cable ties every 3 to 6 feet.

<u>620.06</u> Certification Prior to construction the Contractor shall submit to the Resident the Manufacturer's certification that the Reinforcement Geogrid supplied has been evaluated in full compliance with this Specification and is fit for long-term, critical soil reinforcement applications.

The Contractor's submittal package shall include, but not be limited to, actual tests for tension/creep, durability/aging, construction damage, and quality control tensile testing.

620.08 Shipment, Storage, Protection, and Repair of Fabric The Contractor shall check the Reinforcement Geogrid upon delivery to ensure that the proper material has been received. Each Reinforcement Geogrid roll shall be shipped in a protective bag and clearly marked with roll number, lot number, geogrid style and principle strength direction. During all periods of shipment and storage, the Reinforcement Geogrid shall be protected from temperatures greater than 140°F and all deleterious materials that might otherwise become affixed to the Reinforcement Geogrid and effect its performance. The manufacturer's recommendations shall be followed with regard to protection from direct sunlight. The Reinforcement Geogrid shall be stored off the ground in a clean, dry environment out of the pathway of construction equipment.

Any Reinforcement Geogrid damage shall be repaired or replaced in accordance with the manufacturer's recommendations. The Contractor shall replace any Reinforcement Geogrid damaged during installation at no additional cost to the Department.

<u>620.09 Method of Measurement</u> Reinforcement Geogrid will be measured by the number of Square Yards of surface area installed. Overlaps for connections, splices, patches, and repairs of damaged Reinforcement Geogrid, etc. are incidental to this Pay Item.

<u>620.10 Basis of Payment R</u>einforcement Geogrid placement will be paid for per Square Yard inplace which shall be full compensation for all off-loading, inspection, storage, labor, materials, equipment, tools and any incidentals to complete the installation.

Payment will be made under:

Pay Item 620.65 Reinforcement Geogrid Pay Unit Square Yard

# <u>Appendix D</u>

Calculations

## Bearing Resistance - Existing Soils:

#### Part 1 - Service Limit State

#### Nominal and factored Bearing Resistance - Box Culvert on Silty Clay

#### 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: Silty Clay (CL)

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

Density In Place: medium stiff to stiff

Bearing Resistance: Ordinary Range (ksf) 2 to 6

Recommended Value of Use:  $q_{nom} := 3 \cdot ksf$ 

Resistance factor at the <b>service limit state</b> = 1.0 (LRFD Article 10.5.5.1)	$\phi_{\text{service bc}} := 1.0$
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 $q_{\text{factored\_service\_bc}} := q_{\text{nom}} \cdot \phi_{\text{service\_bc}}$ 

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

 $q_{factored\_service\_bc} = 3 \cdot ksf$ 

#### Part 2 - Strength Limit State

#### Nominal and factored Bearing Resistance - Box Culvert on Sandy Gravel

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

Assumptions:

1. The box will be founded at ~ Elev 165.00 feet

Bottom of Construction will be 3 feet below box invert  $D_{footing} \coloneqq 3.0 \cdot ft$ 

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	$B_{box} := 11 \cdot ft$
Length of box culvert, L	$L_{box} := 88 \cdot ft$

Nominal Bearing Resistance per LRFD Equation 10.6.3.1.2a-1

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

Bearing Capacity Factors - LRFD Table 10.6.3.1.2a-1

For 
$$\phi$$
=32 deg N<sub>c</sub> := 35.5 N<sub>a</sub> := 23.2 N<sub>v</sub> := 30.2

Shape Correction Factors LRFD Table 10.6.3.1.2a.-3

for  $\phi$ =32 degrees

$$s_{c} := 1 + \left(\frac{B_{box}}{L_{box}}\right) \left(\frac{N_{q}}{N_{c}}\right) \qquad s_{c} = 1.08$$
$$s_{\gamma} := 1 - 0.4 \left(\frac{B_{box}}{L_{box}}\right) \qquad s_{\gamma} = 0.95$$

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

Load Inclination Factors: Assume all are 1.0 (LRFD Article C10.6.3.1.2a)

 $i_c \coloneqq 1.0 \qquad \qquad i_q \coloneqq 1.0 \qquad \qquad i_\gamma \coloneqq 1.0$ 

Depth Correction Factor  $d_q := 1 + 2 \cdot tan(\phi_{ns}) \cdot (1 - sin(\phi_{ns}))^2 \cdot tan\left(\frac{D_{footing}}{B_{box}}\right)^{-1}$   $d_q = 1.9874$  LRFD Eq. 10.6.3.1.2a-10

$N_{cm} \coloneqq N_c \cdot s_c \cdot i_c$	$N_{cm} = 38.4$	LRFD Eq. 10.6.3.1.2a-2
$N_{qm} := N_q \cdot s_q \cdot d_q \cdot i_q$	$N_{qm} = 49.71$	LRFD Eq. 10.6.3.1.2a-3
$N_{\gamma m} \coloneqq N_{\gamma} \cdot s_{\gamma} \cdot i_{\gamma}$	$N_{\gamma m} = 28.69$	LRFD Eq. 10.6.3.1.2a-4

Coefficients for Groundwater Depths LRFD Table 10.6.3.1.2a-2

 $q_{nominal} = 19.2 \cdot ksf$ 

#### Factored Bearing Resistance for Strength Limit State

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

 $q_{factored} \coloneqq q_{nominal} \cdot \varphi_b$ 

 $q_{factored} = 8.6 \cdot ksf$ 

Recommend a limiting factored bearing resistance of 8.5 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		$B_{box} = 11 \text{ ft}$			
Length of box culvert, L		$L_{box} = 88 \text{ ft}$			
Thickness of box culver	t, t	$t_{box} := 12 \cdot in$	assumed		
Depth of box, D		$D_{box} := 9.5 \cdot ft$			
Bearing Resistance:		q <sub>factored_service_bc</sub> =	= 3 · ksf	Calculated above	
Modulus of Elasticity:	Site soils From Bo	at bearing elevatio wles Table 2-8 Moo	n are Silty Cla Iulus Es for Cl	y. Use values for Clay (mediur ay, ranges from 300 - 1050 ks	n stiff) ;f

Use Modulus of Elasticity	, Es	$E_s := 300 \cdot ksf$
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Poisson's Ratio: Site conditions at bearing elevation are Silty Clay. Use values for Clay (unsaturated) From Bowles Table 2-7 Poisson's Ration µ for Clay ranges from 0.1 - 0.3

$$\begin{array}{ccc} \text{Use} & \text{Possion's Ratio, } \mu & \mu := \\ \cdot & \cdot \\ E_{\text{prime}\_s} := \frac{1 - \mu^2}{E_s} & E_{\text{prime}\_s} = 0.003033 \cdot \frac{\text{ft}^2}{\text{kip}} \end{array}$$

Analyze corner:

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

$$\begin{array}{ll} H_{inf}\coloneqq \frac{5\cdot B_{box}}{B_{box}} & H_{inf}=5 & \text{N in Table 5-2} \end{array} \end{array} \begin{array}{ll} \text{From Table 5-2 for N=5 and M=6.5} \\ \hline I_1\coloneqq 0.546 \\ I_2\coloneqq 0.124 \end{array} \end{array}$$

0.3

Determine Steinbrenner influence factor - Bowles Section 5-6:

$$I_s := I_1 + \left[\frac{1 - (2 \cdot \mu)}{1 - \mu}\right] \cdot I_2$$
  $I_s = 0.6169$ 

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

Depth ratio: 
$$\frac{D_{box}}{B_{box}} = 0.8636$$
  $\frac{L_{box}}{B_{box}} = 8$   $\mu = 0.3$   $I_F := 0.82$ 

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

$$k_s \coloneqq \frac{1}{B_{box} \cdot E_{prime\_s} \cdot I_s \cdot I_F} \qquad \qquad \text{Bowles Eq. 9-7}$$

 $k_s = 34 \cdot pci$ 

Recommend Modulus of Subgrade Reaction of 35 pci