

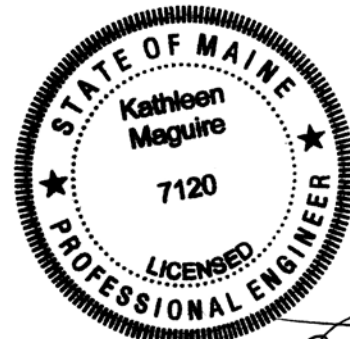
**MAINE DEPARTMENT OF TRANSPORTATION  
HIGHWAY PROGRAM  
GEOTECHNICAL SECTION  
AUGUSTA, MAINE**

**GEOTECHNICAL DESIGN REPORT**

*For the Construction of:*

**JARVIS GORE BRIDGE  
ROUTE 46  
EDDINGTON, MAINE**

*Prepared by:*  
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A handwritten signature in black ink, appearing to read "Kathleen Maguire", written over the bottom right portion of the professional seal.

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

Penobscot County  
WIN 18818.00

Soils Report 2018-08  
Bridge No. 6571

February 8, 2018

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### Sheets

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Sheet 1 - Location Map

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Appendix A - Boring Logs

Appendix B - Laboratory Test Results

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## **1.0 INTRODUCTION**

The purpose of this Geotechnical Design Report is to present subsurface information and make geotechnical recommendations for the replacement of an existing large culvert (#46678) on Route 46 in Eddington, Maine. A subsurface investigation has been completed at the site to evaluate subsurface conditions and to develop geotechnical design and construction recommendations for the replacement structure. This report presents the subsurface information obtained during the subsurface investigation and soil laboratory testing programs, and provides design and construction recommendations and geotechnical design parameters for the culvert replacement.

The existing structure consists of an approximately 84-foot long, 60-inch diameter steel multi-plate culvert on a skew of approximately 41 degrees to the roadway centerline on Route 46 in Eddington. The seam of the multi-plate culvert is pulling apart on the upstream end. Route 46 is a Highway Corridor Priority 2 road.

The proposed replacement structure will be a 16-foot span by 6-foot rise by 104-foot long precast concrete box culvert on a skew of approximately 48 degrees to the roadway centerline. The invert of the proposed culvert is approximately 10 feet below the existing road grade at the roadway centerline. The invert of the proposed culvert will be lined with approximately 2 feet of Special Fill with rock bands to facilitate fish passage. The roadway embankment slopes at the proposed culvert inlet and outlet shall be no steeper than 2H:1V to protect against erosion. Wingwalls are required on the northwest and southeast corners of the proposed structure.

## **2.0 GEOLOGIC SETTING**

The existing culvert carries an unnamed stream under Route 46 (Jarvis Gore Drive) in Eddington and is located approximately 0.53 of a mile north of the Sweets Hill Road as shown in Sheet 1 – Location Map.

The Maine Geological Survey (MGS) map titled Surficial Geology Chemo Pond Quadrangle, Maine Open File 12-16 (2012) the surficial soils at the site consist of till. These soils consist of a light- to dark-grey, non-sorted to poorly sorted (well graded) mixture of clay, silt, sand, pebbles, cobbles, and boulders. The till is predominantly a sandy to silty mixture containing some gravel.

The MGS map Bedrock Geology of Maine (1985), cites bedrock at the culvert as calcareous sandstone with interbedded sandstone and impure limestone of the Bucksport Formation.

## **3.0 SUBSURFACE INVESTIGATION**

One (1) boring (HB-EDD-101) and one (1) probe (HB-EDD-102) were drilled for this project on January 21, 2016 by Northern Test Boring (NTB) using a track mounted drill rig. Exploration locations are shown on Sheet 2 – Boring Location Plan & Interpretive Subsurface Profile with Boring Logs. Details and sampling methods used, field data obtained, and soil and groundwater conditions encountered are presented on the Boring Log in Appendix A.

Boring HB-EDD-101 was drilled using hollow stem auger techniques. Soil samples were obtained in boring HB-EDD-101 at 5-foot intervals using Standard Penetration Test (SPT) methods. The NTB drill rig is equipped with an automatic hammer to drive the split spoon. The NTB calibrated automatic hammer delivers approximately 65 percent more energy during driving than the standard rope and cathead system. All N-values discussed in this report are corrected values computed by applying an average energy transfer factor of 0.990 to the raw field N-values. The bedrock was cored in borings HB-EDD-101 using an NQ 2-inch core barrel and the Rock Quality Designation (RQD) of the core was calculated. Probe HB-EDD-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.

#### **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 two (2) standard grain size analyses with natural water content and one (1) grain size analysis with hydrometer and natural water content. The results of the laboratory testing program are discussed in the following section and are included in Appendix B – Laboratory Test Results. Laboratory test information is also shown on the Boring Logs in Appendix A.

#### **5.0 SUBSURFACE CONDITIONS**

Subsurface conditions encountered at the test boring and probe generally consisted sand fill overlying native silty sand (glacial till). An interpretive subsurface profile depicting the generalized soil stratigraphy at the boring location is shown on Sheet 2 - Boring Location Plan & Interpretive Subsurface Profile with Boring Logs.

Boring HB-EDD-101 was drilled to refusal at a depth of approximately 14.7 feet below ground surface (bgs) including approximately 4.0 feet of weathered bedrock. Bedrock was cored in the boring for a total depth of approximately 17.0 feet bgs. Probe HB-EDD-102 to a depth of approximately 14.0 feet bgs where it encountered a refusal surface. The exact nature of the refusal surface in the probe was not determined during the drilling activities.

The table below summarizes the field and laboratory information obtained in boring HB-EDD-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 – 9.0	Fill – Brown, damp, fine to coarse sand, some silt, little to some gravel.	A-2-4 or A-1-b	SM	11.7 - 8.4
9.0 – 10.7	Glacial Till – Brown, wet, silty fine to coarse sand, little gravel, trace clay.	A-4	SC-SM	10.8
10.7 – 14.7	Weathered bedrock	--	--	--
14-7	Bedrock – Calcareous sandstone (Bucksport Formation)	--	--	--

<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

<sup>4</sup>WC% = Water content in percent

One corrected N-value obtained in the fill was 25 blows per foot (bpf) indicating that the fill is medium dense in consistency. No N-values were obtained in the till due to the spoon encountering refusal in weathered bedrock. The bedrock is described as calcareous sandstone of the Bucksport Formation. The Rock Quality Designation (RQD) of the bedrock was determined to be 36 percent in boring HB-EDD-101 which correlates to a Rock Mass Quality of Poor.

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

## 6.0 GEOTECHNICAL DESIGN AND CONSTRUCTION RECOMMENDATIONS

The proposed replacement structure will consist of a 16-foot span by 6-foot rise by 104-foot long precast concrete box culvert on a skew of approximately 48 degrees to the roadway centerline. The invert of the proposed culvert will be lined with approximately 2 feet of Special Fill and rock bands to facilitate fish passage. The proposed structure inlet and outlet slopes shall be riprapped with slopes no steeper than 2H:1V to protect against erosion. Wingwalls are required on the northwest and southeast corners of the proposed structure. The following sections discuss geotechnical recommendations for the design and construction of the proposed culvert.

### 6.1 Precast Concrete Box Culvert Design and Construction

The proposed replacement structure will consist of a 16-foot span by 6-foot rise by 104-foot long precast concrete box culvert at a skew of approximately 48 degrees to the roadway centerline. The

proposed box culvert shall be designed and constructed in accordance with MaineDOT Standard Specification 534.

The inverts of the proposed box culvert range from approximately 263.72 feet at the inlet to approximately 260.60 feet at the outlet with a 3.0 percent slope and will be lined with approximately 2 feet of Special Fill with rock bands to facilitate fish passage.

The full nature of the culvert bearing surface will not become evident until the culvert excavation is made. Any cobbles or boulders in excess of 6 inches encountered at the bedding elevation shall be removed and replaced with compacted Granular Borrow Material for Underwater Backfill or Crushed Stone  $\frac{3}{4}$ -Inch. The prepared subgrade shall be proof-rolled using a static roller to visually confirm the prepared subgrade is firm and stable. The exposed subgrade shall be free of ponded water so that bedding material placement and compaction can be completed in the dry.

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

## **6.2 Bedrock Removal and Subgrade Preparation**

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

The nature, slope, and degree of fracturing in the bedrock bearing surfaces will not be evident until the excavation from the precast concrete box culvert is made. The final bedrock surface slope shall be less than 4H:1V or it shall be benched in level steps. The bottom elevation of the excavation shall take into account the wall thickness of the box culvert and the required 1-foot layer of bedding material.

The Contractor shall remove any overburden soil and weathered bedrock that can be removed using ordinary excavation equipment to the bottom of bedding material elevation. The prepared bearing surface shall be proof-rolled using a static roller to visually confirm the material is firm and stable. The bearing surface should be confirmed and accepted by the Resident prior to placing the bedding material. Any cobbles, boulders or weathered bedrock pieces encountered in excess of 6 inches shall be removed and replaced with compacted Granular Borrow Material for Underwater Backfill or Crushed Stone  $\frac{3}{4}$ -Inch.

Blasting shall be conducted in accordance with MaineDOT Standard Specifications Sections 105.2.7 and 203. The Contractor is required to conduct a pre-blast survey, as well as blast

vibration monitoring at nearby structures in accordance with industry standards at the time of the blast.

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

### 6.3 Settlement

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

### 6.4 Bearing Resistance

The factored bearing resistances for the precast concrete box culvert and wingwalls bearing on compacted granular bedding material placed on native soils or weathered bedrock at the service and strength limit states are presented in the table below. Supporting calculations in accordance with AASHTO LRFD Bridge Design Specifications 8<sup>th</sup> Edition 2017 (LRFD) are provided in Appendix C – Calculations.

Limit State	Resistance Factor $\phi_b$	AASHTO LRFD Reference	Factored Bearing Resistance (ksf)
Service	1.0	Article 10.5.5.1	5.0
Strength	0.45	Table 10.5.5.2.2-1	8.0

### 6.5 Modulus of Subgrade Reaction

A modulus of subgrade reaction ( $k_s$ ) equal to 210 pounds per cubic inch shall be used for the structural design of the box culvert's base slab. Calculations are included in Appendix C - Calculations.

### 6.6 Scour and Riprap

Both the inlet and outlet of the precast concrete box culvert shall be protected against scour with riprap conforming to MaineDOT Standard Specification Section 703.26 Plain and Hand Laid Riprap. Slopes shall be no steeper than 2H:1V. No specific scour protection recommendations are needed other than armoring with riprap. The riprap on the slopes shall be underlain by a non-woven, Class 1 Erosion Control Geotextile meeting the requirements of MaineDOT Standard Specification 722.03 that is underlain by a 1-foot layer of protective aggregate cushion consisting of Granular Borrow Material for Underwater Backfill (703.19). The toe of the riprap sections shall be keyed into the existing soils 1 foot below the streambed elevation

## 6.7 Wingwall Design and Construction

Wingwalls are required on the northwest and southeast corners of the proposed structure. It is recommended that the proposed wingwalls be Precast Concrete Modular Gravity (PCMG) walls. These PCMG wingwalls shall be designed by a Professional Engineer subcontracted by the Contractor as a design-build item. The walls shall be designed in accordance with all relevant strength and service limit states and load combinations as specified in LRFD Articles 3.4.1, 11.5.5 and 11.6 and Standard Specification 674.

The PCMG wingwalls shall be founded on leveling slabs that are bedded on a 1-foot thick layer of compacted Granular Borrow Material for Underwater Backfill (MaineDOT 703.19). The subgrade for the bedding material shall be proof-rolled using multiple passes of a static roller to identify loose or weaving areas and to achieve a firm and stable surface for construction. Any loose soils or soft or unsuitable materials encountered in the bedding layer subgrade shall be removed and replaced with Granular Borrow Material for Underwater Backfill (MaineDOT 703.19) or Crushed Stone  $\frac{3}{4}$ -Inch (MaineDOT 703.13).

The PCMG wingwalls shall be designed to resist lateral earth pressures, vehicular loads, creep and temperature and shrinkage deformations of the precast concrete box culvert. The PCMG wingwalls shall be designed considering a live load surcharge equal to a uniform horizontal earth pressure due to an equivalent height of soil ( $h_{eq}$ ) of 2.0 feet per LRFD Article 3.11.6.4. PCMG wingwalls that are fixed to the precast concrete box culvert should be designed to resist movement using an at-rest earth pressure coefficient,  $K_o$ , of 0.47 assuming a horizontal backslope. The at-rest earth pressure coefficient will change if the backslope conditions are different. PCMG wingwall sections that are independent of the precast concrete box culvert should be designed using the Rankine active earth pressure coefficient,  $K_a$ , of 0.46 assuming a 2H:1V backslope. See Appendix C – Calculations for supporting documentation.

Slopes above the PCMG wingwalls shall constructed with riprap and shall not exceed 2H:1V.

The designer may assume Soil Type 4 as presented in the MaineDOT Bridge Design Guide Section 3.6.1 for wingwall backfill material soil properties. The backfill properties are as follows:  $\phi = 32$  degrees,  $\gamma = 125$  pcf.

The calculated bearing resistance should not exceed those given in Section 6.4. Regardless of the calculated bearing resistance, the leveling slab shall be at least 2 feet wide. The designer shall apply a sliding resistance factor  $\phi_\tau$  of 0.90 to the nominal sliding resistance of precast concrete wall on the leveling slab. For footings on soil the eccentricity of loading at the strength limit state, based on factored loads, shall not exceed one-third (1/3) of the footing dimensions in either direction (LRFD Article 10.6.3.3). Sliding computations for resistance to lateral loads shall assume a maximum frictional coefficient of  $\tan 30^\circ$  at the foundation soil to soil infill interface and a maximum frictional coefficient of  $0.8 \times (\tan 30^\circ)$  at the foundation soil to concrete module interface. Recommended values of sliding frictional coefficients are based on LRFD Article 11.11.4.2, Table 10.5.5.2.2-1 and Table 3.11.5.3-1.

The highwater elevation shall be indicated on the PCMG wingwall plans per the design requirements for hydrostatic conditions in Standard Specification 674.

## **6.8 Seismic Design Considerations**

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

## **6.9 Construction Considerations**

Construction activities may include construction of cofferdams and earth support systems to control stream flow during construction. Construction activities will also include common earth excavation. Construction of the proposed precast concrete box culvert will require 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 the till or weathered bedrock will be necessary to allow for the excavation and maintenance of a stable excavation bottom. All earth support systems shall be designed by a Professional Engineer licensed in the State of Maine. Regardless of the method of excavation, all excavations and earth support systems shall meet all applicable OSHA regulations.

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

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

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

## **7.0 CLOSURE**

This report has been prepared for the use of the MaineDOT Highway Program and their design consultant for specific application to the proposed replacement of a large culvert under Route 46 in Eddington, Maine in accordance with generally accepted geotechnical and foundation engineering practices. No other intended use or warranty is expressed or implied.

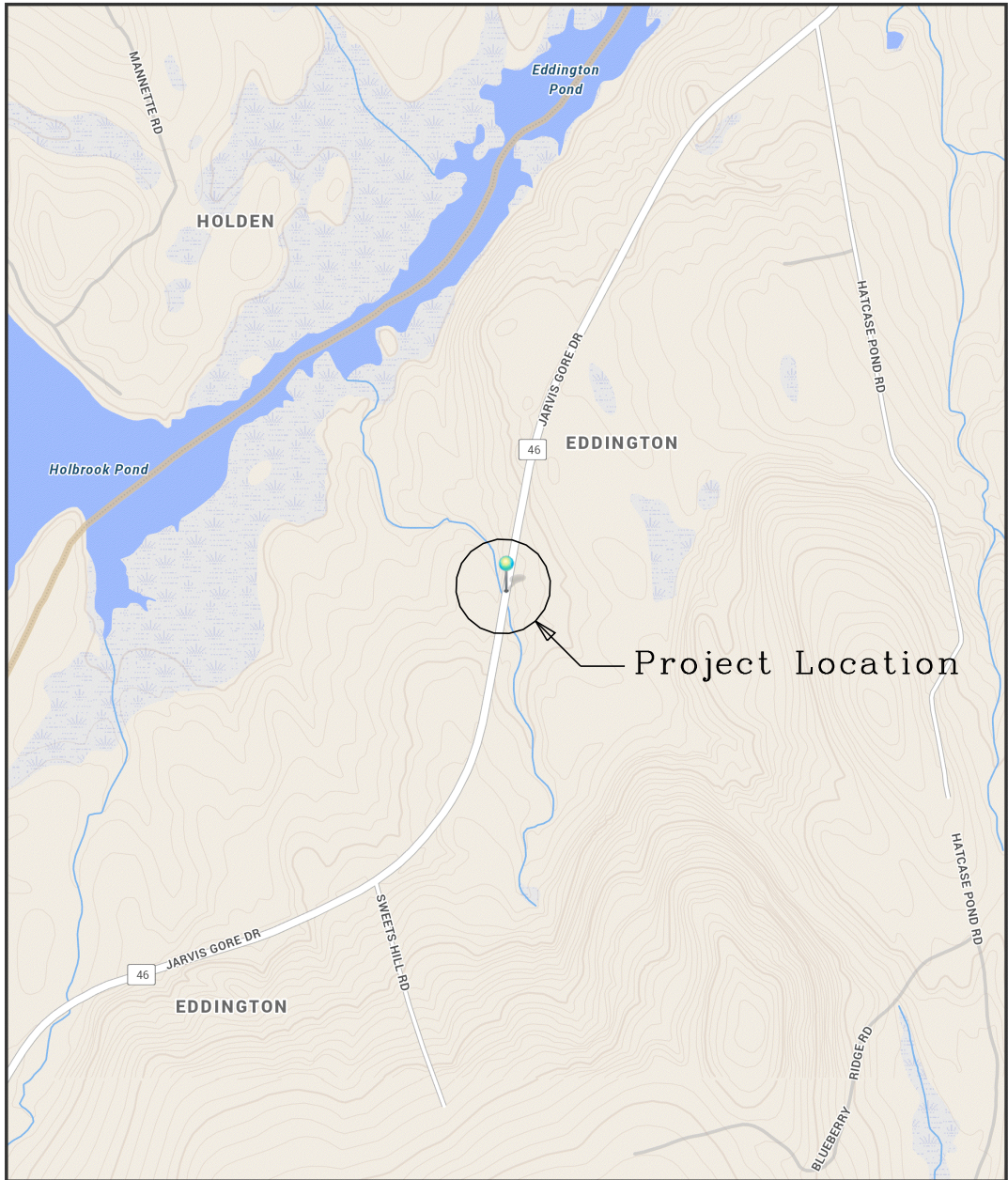
In the event that any changes in the nature, design, or location of the proposed project are planned, this report should be reviewed by a geotechnical engineer to assess the appropriateness of the

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**

# EDDINGTON, MAINE



The Maine Department of Transportation provides this publication for information only. Reliance upon this information is at user risk. It is subject to revision and may be incomplete depending upon changing conditions. The Department assumes no liability if injuries or damages result from this information. This map is not intended to support emergency dispatch.

0.25 Miles  
1 inch = 0.28 miles

Date: 1/23/2018  
Time: 7:05:24 AM

SHEET NUMBER  <b>1</b>  OF 2	ROUTE 46 JARVIS GORE BRIDGE	STATE OF MAINE DEPARTMENT OF TRANSPORTATION
	EDDINGTON PENOBSCOT COUNTY	<b>018818.00</b>
LOCATION MAP		<b>WIN</b> BRIDGE NO. 6571 <b>18818.00</b> HIGHWAY PLANS



## **Appendix A**

Boring Logs

UNIFIED SOIL CLASSIFICATION SYSTEM				MODIFIED BURMISTER SYSTEM																																																					
MAJOR DIVISIONS		GROUP SYMBOLS	TYPICAL NAMES	Descriptive Term	Portion of Total (%)																																																				
COARSE-GRAINED SOILS  (more than half of material is larger than No. 200 sieve size)	GRAVELS  (more than half of coarse fraction is larger than No. 4 sieve size)	CLEAN GRAVELS	GW Well-graded gravels, gravel-sand mixtures, little or no fines. GP Poorly-graded gravels, gravel sand mixtures, little or no fines.	trace little some adjective (e.g. sandy, clayey)	0 - 10 11 - 20 21 - 35 36 - 50																																																				
		GRAVEL WITH FINES (Appreciable amount of fines)	GM Silty gravels, gravel-sand-silt mixtures. GC Clayey gravels, gravel-sand-clay mixtures.	<b>TERMS DESCRIBING DENSITY/CONSISTENCY</b> <b>Coarse-grained soils</b> (more than half of material is larger than No. 200 sieve): Includes (1) clean gravels; (2) silty or clayey gravels; and (3) silty, clayey or gravelly sands. Density is rated according to standard penetration resistance (N-value).  <table border="1"> <thead> <tr> <th>Density of Cohesionless Soils</th> <th>Standard Penetration Resistance N-Value (blows per foot)</th> </tr> </thead> <tbody> <tr><td>Very loose</td><td>0 - 4</td></tr> <tr><td>Loose</td><td>5 - 10</td></tr> <tr><td>Medium Dense</td><td>11 - 30</td></tr> <tr><td>Dense</td><td>31 - 50</td></tr> <tr><td>Very Dense</td><td>&gt; 50</td></tr> </tbody> </table> <b>Fine-grained soils</b> (more than half of material is smaller than No. 200 sieve): Includes (1) inorganic and organic silts and clays; (2) gravelly, sandy or silty clays; and (3) clayey silts. Consistency is rated according to undrained shear strength as indicated.  <table border="1"> <thead> <tr> <th>Consistency of Cohesive soils</th> <th>SPT N-Value (blows per foot)</th> <th>Approximate Undrained Shear Strength (psf)</th> <th>Field Guidelines</th> </tr> </thead> <tbody> <tr><td>Very Soft</td><td>WOH, WOR, WOP, &lt;2</td><td>0 - 250</td><td>Fist easily penetrates</td></tr> <tr><td>Soft</td><td>2 - 4</td><td>250 - 500</td><td>Thumb easily penetrates</td></tr> <tr><td>Medium Stiff</td><td>5 - 8</td><td>500 - 1000</td><td>Thumb penetrates with moderate effort</td></tr> <tr><td>Stiff</td><td>9 - 15</td><td>1000 - 2000</td><td>Indented by thumb with great effort</td></tr> <tr><td>Very Stiff</td><td>16 - 30</td><td>2000 - 4000</td><td>Indented by thumbnail</td></tr> <tr><td>Hard</td><td>&gt;30</td><td>over 4000</td><td>Indented by thumbnail with difficulty</td></tr> </tbody> </table> <b>Rock Quality Designation (RQD):</b> RQD (%) = $\frac{\text{sum of the lengths of intact pieces of core} * > 4 \text{ inches}}{\text{length of core advance}}$ *Minimum NQ rock core (1.88 in. OD of core)  Correlation of RQD to Rock Mass Quality <table border="1"> <thead> <tr> <th>Rock Mass Quality</th> <th>RQD (%)</th> </tr> </thead> <tbody> <tr><td>Very Poor</td><td>≤25</td></tr> <tr><td>Poor</td><td>26 - 50</td></tr> <tr><td>Fair</td><td>51 - 75</td></tr> <tr><td>Good</td><td>76 - 90</td></tr> <tr><td>Excellent</td><td>91 - 100</td></tr> </tbody> </table> <b>Desired Rock Observations (in this order, if applicable):</b> Color (Munsell color chart) Texture (aphanitic, fine-grained, etc.) Rock Type (granite, schist, sandstone, etc.) Hardness (very hard, hard, mod. hard, etc.) Weathering (fresh, very slight, slight, moderate, mod. severe, severe, etc.) Geologic discontinuities/jointing: -dip (horiz - 0-5 deg., low angle - 5-35 deg., mod. dipping - 35-55 deg., steep - 55-85 deg., vertical - 85-90 deg.) -spacing (very close - <2 inch, close - 2-12 inch, mod. close - 1-3 feet, wide - 3-10 feet, very wide >10 feet) -tightness (tight, open, or healed) -infilling (grain size, color, etc.) Formation (Waterville, Ellsworth, Cape Elizabeth, etc.) RQD and correlation to rock mass quality (very poor, poor, etc.) ref: ASTM D6032 and AASHTO Standard Specification for Highway Bridges, 17th Ed. Table 4.4.8.1.2A Recovery (inch/inch and percentage) Rock Core Rate (X.X ft - Y.Y ft (min:sec))			Density of Cohesionless Soils	Standard Penetration Resistance N-Value (blows per foot)	Very loose	0 - 4	Loose	5 - 10	Medium Dense	11 - 30	Dense	31 - 50	Very Dense	> 50	Consistency of Cohesive soils	SPT N-Value (blows per foot)	Approximate Undrained Shear Strength (psf)	Field Guidelines	Very Soft	WOH, WOR, WOP, <2	0 - 250	Fist easily penetrates	Soft	2 - 4	250 - 500	Thumb easily penetrates	Medium Stiff	5 - 8	500 - 1000	Thumb penetrates with moderate effort	Stiff	9 - 15	1000 - 2000	Indented by thumb with great effort	Very Stiff	16 - 30	2000 - 4000	Indented by thumbnail	Hard	>30	over 4000	Indented by thumbnail with difficulty	Rock Mass Quality	RQD (%)	Very Poor	≤25	Poor	26 - 50	Fair	51 - 75	Good	76 - 90	Excellent
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Excellent	91 - 100																																																								
FINE-GRAINED SOILS  (more than half of material is smaller than No. 200 sieve size)	SILTS AND CLAYS  (liquid limit less than 50)	ML Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity.	<b>Desired Soil Observations (in this order, if applicable):</b> Color (Munsell color chart) Moisture (dry, damp, moist, wet) Density/Consistency (from above right hand side) Texture (fine, medium, coarse, etc.) Name (sand, silty sand, clay, etc., including portions - trace, little, etc.) Gradation (well-graded, poorly-graded, uniform, etc.) Plasticity (non-plastic, slightly plastic, moderately plastic, highly plastic) Structure (layering, fractures, cracks, etc.) Bonding (well, moderately, loosely, etc., ) Cementation (weak, moderate, or strong) Geologic Origin (till, marine clay, alluvium, etc.) Groundwater level																																																						
		CL Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.																																																							
		OL Organic silts and organic silty clays of low plasticity.																																																							
	SILTS AND CLAYS  (liquid limit greater than 50)	MH Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	<b>Sample Container Labeling Requirements:</b> WIN Blow Counts Bridge Name / Town Sample Recovery Boring Number Date Sample Number Personnel Initials Sample Depth																																																						
CH Inorganic clays of high plasticity, fat clays. OH Organic clays of medium to high plasticity, organic silts.																																																									
HIGHLY ORGANIC SOILS	Pt Peat and other highly organic soils.																																																								

<b>Driller:</b> Northern Test Boring	<b>Elevation (ft.):</b> 272.6	<b>Auger ID/OD:</b> HSA to 10.0 ft.
<b>Operator:</b> Daggett, Mike/Adam	<b>Datum:</b> NAVD88	<b>Sampler:</b> Standard Split Spoon
<b>Logged By:</b> B. Wilder	<b>Rig Type:</b> Diedrich D-50	<b>Hammer Wt./Fall:</b> 140#/30"
<b>Date Start/Finish:</b> 1/21/2016; 11:30-14:30	<b>Drilling Method:</b> Cased Wash Boring	<b>Core Barrel:</b> NQ-2"
<b>Boring Location:</b> 12+64.3, 7.6 ft Rt.	<b>Casing ID/OD:</b> NW	<b>Water Level*:</b> None Observed

**Hammer Efficiency Factor:** 0.9901     
 **Hammer Type:** Automatic  Hydraulic  Rope & Cathead

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

Depth (ft.)	Sample Information								Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N <sub>60</sub>	Casing Blows					
0								HSA	272.18	5" PAVEMENT.		
	1D	6/6	2.00 - 2.50	50	---					Brown, damp, very dense, fine to coarse SAND, some silt, some gravel, (Fill).	G#301163 A-2-4, SM WC=11.7%	
5	2D	24/13	5.00 - 7.00	10/7/8/9	15	25				Brown, damp, medium dense, fine to coarse SAND, some silt, little gravel, (Fill).	G#301164 A-1-b, SM WC=8.4%	
10	3D	8.4/8.4	10.00 - 10.70	7/40(2.4")	---				263.60 261.90	Brown, wet, dense, Silty fine to coarse SAND, little gravel, trace clay, (Till). Weathered BEDROCK.	G#301165 A-4, SC-SM WC=10.8%	
15	R1	27.6/27.6	14.70 - 17.00	RQD = 36%				NQ-2	257.90 255.60	Top of Bedrock at Elev. 257.9 ft. R1:Bedrock: Calcareous SANDSTONE with interbedded sandstone and impure limestone of the Bucksport Formation. Rock Mass Quality = Poor R1:Core Times (min:sec) 14.7-15.7 ft (3:00) 15.7-16.7 ft (2:45) 16.7-17.0 ft (3:00) 100% Recovery Core Blocked		
20										Bottom of Exploration at 17.00 feet below ground surface.		
25												

**Remarks:**  
 Hammer #283

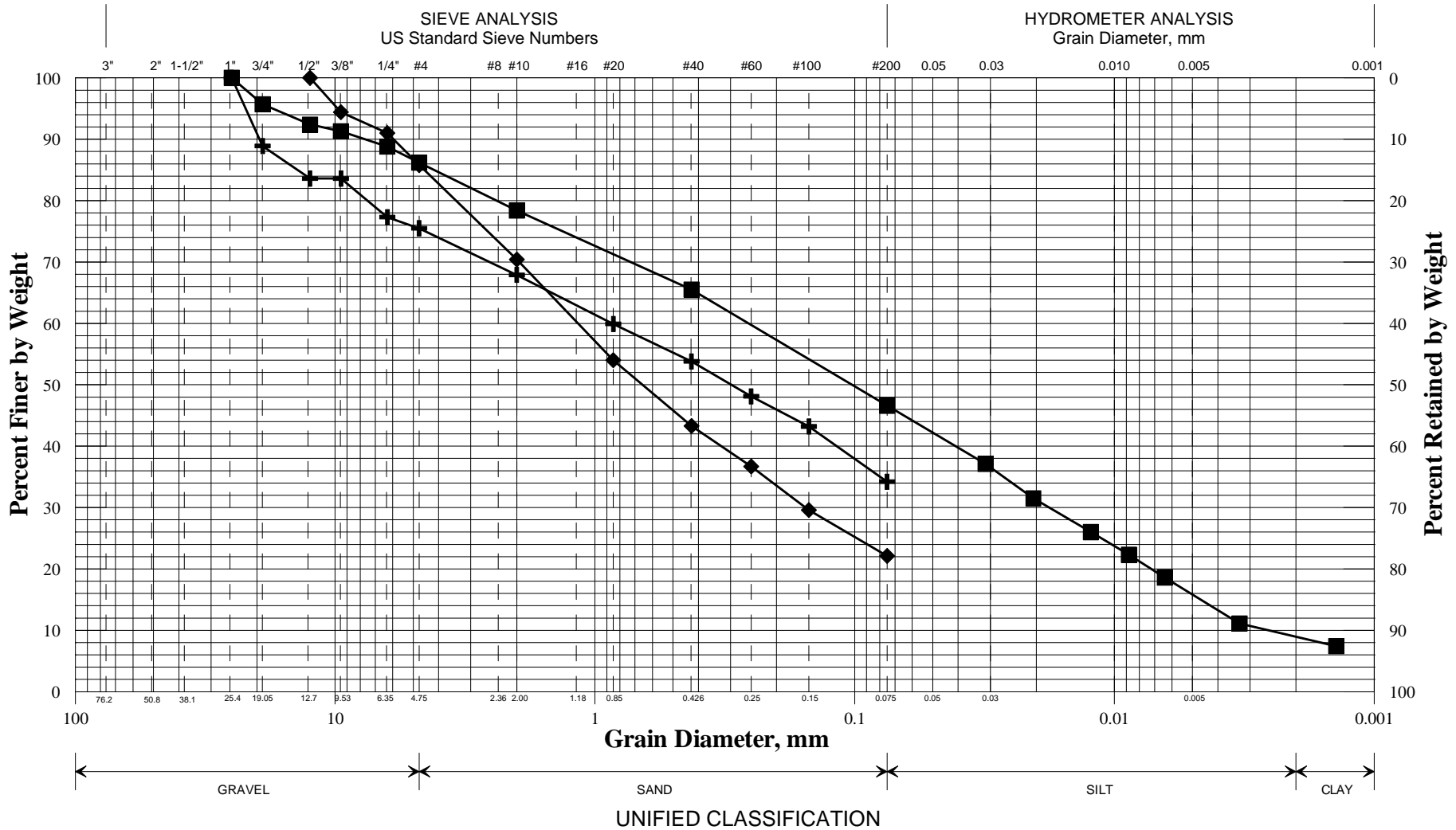


## **Appendix B**

Laboratory Test Results



**State of Maine Department of Transportation**  
**GRAIN SIZE DISTRIBUTION CURVE**



	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	W, %	LL	PL	PI
+	HB-EDD-101/1D	12+64.3	7.6 RT	2.0-2.5	SAND, some silt, some gravel.	11.7			
◆	HB-EDD-101/2D	12+64.3	7.6 RT	5.0-7.0	SAND, some silt, little gravel.	8.4			
■	HB-EDD-101/3D	12+64.3	7.6 RT	10.0-10.7	Silty SAND, little gravel, trace clay.	10.8			
●									
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WIN
018818.00
Town
Eddington
Reported by/Date
WHITE, TERRY A      4/6/2016

## **Appendix C**

Calculations

## **Bearing Resistance - Existing Soils:**

### **Part 1 - Service Limit State**

#### **Nominal and factored Bearing Resistance - Box Culvert or PCMG Walls on Silty Sand**

#### **Presumptive Bearing Resistance for Service Limit State ONLY**

Reference: AASHTO LRFD Bridge Design Specifications 8th Edition 2017  
Table C10.6.2.6.1-1 Presumptive Bearing Resistances for Spread Footings at the  
Service Limit State Modified after US Department of Navy (1982)

Type of Bearing Material: silty sand (SC-SM) (till)

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

Density In Place: dense

Bearing Resistance: Ordinary Range (ksf) 4 to 8

**Recommended Value of Use:**  $q_{nom} := 5 \cdot ksf$

Resistance factor at the **service limit state** = 1.0 (LRFD Article 10.5.5.1)  $\phi_{service\_bc} := 1.0$

$q_{factored\_service\_bc} := q_{nom} \cdot \phi_{service\_bc}$   $q_{factored\_service\_bc} = 5 \cdot ksf$

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

### **Part 2 - Strength Limit State**

#### **Nominal and factored Bearing Resistance - Box Culvert or PCMG Walls on Silty Sand**

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

Assumptions:

1. The box will be founded at ~ Elev 261 feet to 264 feet

Bottom of Construction will be 2 feet below box invert  $D_{footing} := 2.0 \cdot ft$

2. Assumed parameters for fill soils:

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

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

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

3. Box Culvert parameters

Width of box culvert, B  $B_{box} := 16 \cdot ft$

Length of box culvert, L  $L_{box} := 104 \cdot ft$

Nominal Bearing Resistance per LRFD Equation 10.6.3.1.2a-1

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

Bearing Capacity Factors - LRFD Table 10.6.3.1.2a-1

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

Shape Correction Factors LRFD Table 10.6.3.1.2a-3

for  $\phi=32$  degrees

$$s_c := 1 + \left( \frac{B_{\text{box}}}{L_{\text{box}}} \right) \left( \frac{N_q}{N_c} \right) \quad s_c = 1.1$$

$$s_\gamma := 1 - 0.4 \left( \frac{B_{\text{box}}}{L_{\text{box}}} \right) \quad s_\gamma = 0.9385$$

$$s_q := 1 + \left( \frac{B_{\text{box}}}{L_{\text{box}}} \cdot \tan(\phi_{\text{ns}}) \right) \quad s_q = 1.1$$

Load Inclination Factors:

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

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

Depth Correction Factor LRFD Table 10.6.3.1.2a-4

$$\frac{D_{\text{footing}}}{B_{\text{box}}} = 0.125 \quad \text{for } \phi=32 \text{ degrees} \quad d_q := 1.2$$

$$N_{cm} := N_c \cdot s_c \cdot i_c \quad N_{cm} = 39.0692 \quad \text{LRFD Eq. 10.6.3.1.2a-2}$$

$$N_{qm} := N_q \cdot s_q \cdot d_q \cdot i_q \quad N_{qm} = 30.52 \quad \text{LRFD Eq. 10.6.3.1.2a-3}$$

$$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma \quad N_{\gamma m} = 28.34 \quad \text{LRFD Eq. 10.6.3.1.2a-4}$$

Coefficients for Groundwater Depths LRFD Table 10.6.3.1.2a-2

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

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

$$q_{\text{nominal}} = 18 \cdot \text{ksf}$$

**Factored Bearing Resistance for Strength Limit State**

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

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

$$q_{\text{factored}} = 8.1 \cdot \text{ksf}$$

Recommend a limiting factored bearing resistance of 8.0 ksf for the Strength Limit State.

## Modulus of Subgrade Reaction:

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

Width of box culvert, B  $B_{\text{box}} := 16 \cdot \text{ft}$   
 Length of box culvert, L  $L_{\text{box}} := 104 \cdot \text{ft}$   
 Thickness of box culvert, t  $t_{\text{box}} := 12 \cdot \text{in}$  assumed  
 Depth of box, D  $D_{\text{box}} := 11 \cdot \text{ft}$   
 Bearing Resistance:  $q_{\text{factored\_service\_bc}} = 5 \cdot \text{ksf}$  Calculated above  
 Modulus of Elasticity: Site soils at bearing elevation are Silty Sand (dense) and weathered bedrock. Use sand and gravel values due to the presence of weathered bedrock. From Bowles Table 2-8 Modulus  $E_s$  for sand and gravel, dense ranges from 2,000 - 4,100 ksf. Use Modulus of Elasticity,  $E_s := 2500 \cdot \text{ksf}$   
 Poisson's Ratio: Site soils are Silty Sand (dense) and weathered bedrock. From Bowles Table 2-7 Poisson's Ratio  $\mu$  for Sand/Till ranges from 0.3 - 0.35. Use Poisson's Ratio,  $\mu := 0.35$

$$E_{\text{prime\_s}} := \frac{1 - \mu^2}{E_s} \quad E_{\text{prime\_s}} = 0.000351 \cdot \frac{\text{ft}^2}{\text{kip}}$$

Analyze corner:

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

$$H_{\text{inf}} := \frac{5 \cdot B_{\text{box}}}{B_{\text{box}}} \quad H_{\text{inf}} = 5 \quad \text{N in Table 5-2} \quad \text{From Table 5-2 for N=5 and M=6.5}$$

$$\frac{L_{\text{box}}}{B_{\text{box}}} = 6.5 \quad \text{M in Table 5-2} \quad I_1 := 0.546$$

$$I_2 := 0.124 \quad \text{by interpolation}$$

Determine Steinbrenner influence factor - Bowles Section 5-6:

$$I_s := I_1 + \left[ \frac{1 - (2 \cdot \mu)}{1 - \mu} \right] \cdot I_2 \quad I_s = 0.6032$$

Determine Influence factor for footing depth - Bowles Figure

$$\text{Depth ratio: } \frac{D_{\text{box}}}{B_{\text{box}}} = 0.6875 \quad \frac{L_{\text{box}}}{B_{\text{box}}} = 6.5 \quad \mu = 0.35 \quad I_F := 0.82$$

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

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

$$k_s = 208 \cdot \text{pci}$$

Recommend Modulus of Subgrade Reaction of 210 pci

### Earth Pressures:

Precast concrete wingwalls fixed to the box culvert shall be designed to resist a maximum lateral applied load equal to the at-rest earth pressure,  $K_o$ .

#### At-Rest Earth Pressure, $K_o$ :

$$\phi := 32 \cdot \text{deg}$$

$$K_o := 1 - \sin(\phi) \quad \text{LRFD Equation 3.11.5.2-1}$$

$$K_o = 0.4701$$

#### Active Earth Pressure, $K_a$ (Rankine):

For a horizontal backfill surface:

$$\phi := 32 \cdot \text{deg}$$

$$K_a := \tan\left(45 \cdot \text{deg} - \frac{\phi}{2}\right)^2 \quad \text{Das Principals of Foundation Engineering Fourth Edition pg 342}$$

$$K_a = 0.3073$$

For sloping backfill surface - 2H:1V:

$$\phi := 32 \cdot \text{deg} \quad \beta := 26.6 \cdot \text{deg}$$

$$K_a := \cos(\beta) \cdot \frac{\cos(\beta) - \left(\cos(\beta)^2 - \cos(\phi)^2\right)^{0.5}}{\cos(\beta) + \left(\cos(\beta)^2 - \cos(\phi)^2\right)^{0.5}}$$

Das Principals of Foundation Engineering  
Fourth Edition Eq. 11-7a pg 603

$$K_a = 0.4637$$