



FOUNDATION INVESTIGATION AND DESIGN REPORT

for

UNNAMED CREEK CULVERT REPLACEMENT

SITE NO. 39W-115/C

HIGHWAY 11- STATION 16+935 - KOHLER TOWNSHIP

DISTRICT OF NEW LISKEARD, ONTARIO

ASSIGNMENT NO. 5015-E-0009

GWP 5130-13-00

WP 5130-13-01

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PML Ref.: 16TF013A
Index No.: 102FIR and 103FDR
GEOCRES No.: 42F046
March 6, 2017



PART A - FOUNDATION INVESTIGATION REPORT

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PART A
FOUNDATION INVESTIGATION REPORT

for
Unnamed Creek Culvert Replacement
Site No. 39W-115/C
Highway 11- Station 16+935
Kohler Township, New Liskeard District, Ontario
Assignment No. 5015-E-0009, GWP 5130-13-00, WP 5130-13-01

1. INTRODUCTION

GHD Ltd. has retained Peto MacCallum Ltd. (PML) on behalf of the Ministry of Transportation Ontario (MTO) to conduct the geotechnical investigation for the replacement or rehabilitation of thirteen (13) structures located on Highway 11 and three (3) structures located on Highway 583. This foundation investigation work is part of an assignment to prepare the detail design for the replacement/rehabilitation of fifteen culverts and Fraser River Bridge. This assignment involves five contracts that were assigned to be carried out under four different General Work Plans (GWPs).

This report presents the factual findings obtained from the geotechnical investigation carried out for the proposed replacement of the culvert located on Highway 11, 35.2 km west of Highway 631. The location of the culvert is at the approximate Sta. 16+935 on Highway 11, in the Township of Kohler, District of New Liskeard, Ontario.

The purpose of the investigation was to explore the subsurface conditions expected to influence the design of the culvert replacement and to aid the designer in selecting the suitable type of replacement structure.

2. SITE DESCRIPTION

The topography of the project area is generally flat, except for the highway embankments. The culvert is oriented in the north-south direction and the Unnamed Creek flows from south to north. Generally, the site surrounding the culvert is covered with bushes and grass. The area along the highway on both, north and south sides are heavily wooded.

Based on the Request for Quotation (RFQ) dated March 2016, the existing structure is a 5.6 m span, 2.0 m rise and 23 m long cast-in-place concrete box culvert. The fill height above the deck is 2.5 m high. This culvert was constructed in 1958 and the roadway accommodates two lanes of vehicular traffic. Further, RFQ indicates that this structure has no record of rehabilitation.



Based on the inspection carried out on June 16, 2015 (report dated November 20, 2015), severe concrete disintegration in the barrel at the north end was observed. In addition, active leakage through a stained crack on the barrel wall and wide longitudinal cracks on the soffit were observed.

3. FIELD INVESTIGATION PROCEDURES

The PML staff visited the site on July 22, 2016, to mark out the borehole locations. The north-west quadrant of the site was inaccessible with the drilling equipment and a borehole near the outlet could not be located, and the borehole was advanced on the highway shoulder. The underground services at the borehole locations were cleared by the respective utility companies. Public and private utility authorities were informed and all the utility clearance documents were obtained before the commencement of drilling work.

The fieldwork was carried out from July 23 to 25, 2016. The location of boreholes in the field was established by PML staff using a portable GPS device. Subsequently, Callon Dietz Inc. of London, Ontario under contract to PML carried out the survey of the borehole locations and elevations and provided the co-ordinates for locations in MTM NAD 83 northing and easting. PML used the survey data provided by Callon Dietz Inc. for this report. All elevations reported in this report are referred to Geodetic datum and expressed in meters.

The drilling equipment was owned and operated by Landcore Drilling of Chelmsford, Ontario, a specialist drilling contractor. The fieldwork was carried out under the full-time supervision of a PML field supervisor. The investigation included advancing four (4) boreholes numbered 16-115-1, 16-115-2, 16-115-3 and 16-115-4 to maximum depths ranging from 3.5 m to 10.5 m (El. 249.5 to El. 244.1). Boreholes 16-115-1 and 16-115-4 were located on the roadway and boreholes 16-115-2 and 16-115-3 were located at the outlet and inlet of the culvert, respectively. These boreholes were advanced using hollow stem augers powered by a track-mounted drill rig. Rock coring was carried out in Boreholes 16-115-3 and 16-115-4 using NQ size double core barrel. Location of boreholes is shown on the attached Drawing 115/C-1.



Representative soil samples were recovered from the boreholes at 0.75 m intervals using a conventional 51 mm O.D split spoon sampler in accordance with the Standard Penetration Test (SPT) procedure. Standard penetration tests were conducted simultaneously with the sampling operation to assess the strength characteristics of the substrata.

The groundwater conditions at the borehole locations were observed during the drilling by visual examination of the soil samples, sampler and drill rods as the samples were retrieved. In addition, water level measurements were taken in open boreholes. Upon completion of drilling, the boreholes were backfilled with bentonite/cement grout in accordance with the MTO guidelines and MOE Regulation 903 for borehole abandonment procedures.

The recovered soil samples were returned to our laboratory for detailed visual examination, and index tests.

4. LABORATORY TEST PROCEDURES

Laboratory tests on representative SPT samples recovered during the fieldwork were carried out by the certified PML laboratory in Toronto. The laboratory testing program included the following:

- Natural moisture content determinations (27)
- Grain size distribution analyses (7)
- Atterberg limits (5)

The laboratory tests to determine the index properties were performed in accordance with the MTO test procedures, which follow American Society for Testing Materials (ASTM) test procedures, with the exception of hydrometer test (LS-702). The results of the grain size distribution analyses are presented on Figures 115-GS-1 and 115-GS-2. Results of the Atterberg limit test are provided on Figure PC-115-1. All of the test results are summarized on the attached Record of Borehole sheets.

One soil sample from the clayey silt layer was submitted to AGAT Laboratories in Mississauga, Ontario, for testing of chemical properties relevant to exposure of concrete elements to sulphate as well as potential soil corrosion effects. Detail test results are presented in Appendix B.



5. SITE GEOLOGY AND SUBSURFACE CONDITIONS

5.1 Site Geology

Based on the Quaternary Geology map published in 1991 by the Ontario Ministry of Northern Development and Mines (MNDM), the surface conditions in the project area consist of glacial till composed of undifferentiated, fine grained, predominantly silty clay to silt matrix. The bedrock in the region is composed of Granite and Meta Granite Gneiss with distinct light and dark bands. The granitic-gneiss belongs to the migmatitic metasedimentary-metavolcanic complex of the region.

5.2 Subsurface Conditions

The subsurface conditions encountered during the course of the investigation, together with the field and laboratory test results are shown on the Record of Borehole Sheets attached to the report. The borehole locations plan and a stratigraphic profile section are shown on Drawing 115/C-1. The boundaries between soil strata have been established at the borehole locations only. The boundaries of soil strata between and beyond the boreholes are assumed and may vary from location to location.

In general, the subsoil conditions consist of 2.2 m to 5.0 m of silty sand fill below the existing surface, which is followed by clayey silt with sand and gravel (glacial till) to the maximum investigation depth of 10.5 m below the grade. In the case of Borehole 16-115-2, a 200-mm thick topsoil was encountered immediately below the surface which is underlain by till layer. A 200-mm thick topsoil was also encountered immediately below the fill layer in Borehole 16-115-1. For classification purposes, the soils encountered at this site can be divided into three distinct zones.

- a) Silty Sand, Trace Clay, Trace Gravel (Fill)
- b) Topsoil
- c) Clayey Silt with Sand and Gravel (Glacial Till)

5.2.1 Silty Sand, Trace Clay, Trace Gravel (Fill)

Silty sand fill was encountered in three of the boreholes (16-115-1 and 16-115-4) immediately below the surface. In the case of Borehole 16-115-3, this silty sand fill was encountered immediately below a 150-mm thick topsoil. The fill layer ranges in thickness from 2.2 m to 5.0 m, and extends to a maximum



depth of 5.0 m (El. 252.2) below the existing grade. The SPT N values in this fill layer vary from 3 blows to 14 blows, indicating very loose to compact state of denseness.

The moisture content of this fill material varies from 9.1% to 18.1% with an average value of 14.6%. The result of the sieve analysis test performed on one representative sample from this layer is provided on Figure 115-GS-1. The test results indicate that this deposit consists of 6% gravel, 54% sand, 31% silt and 9% clay.

5.2.2 Topsoil

Topsoil was encountered in Boreholes 16-115-2 and 16-115-3, immediately below ground surface. The thickness of this layer was observed to vary between 150 mm and 200 mm and extends to a maximum El. 252.8. In Borehole 16-115-1, a 200-mm thick topsoil was encountered immediately below the fill layer, which extends to a maximum depth of 5.2 m (El. 252.0).

5.2.3 Clayey Silt with Sand and Gravel (Glacial Till)

The topsoil in Boreholes 16-115-1 and 16-115-2 and the silty sand fill layers in Boreholes 16-115-3 and 6-115-4 are immediately underlain by this clayey silt with sand and gravel (glacial till) deposit, which extends to a maximum investigation depth of 10.5 m (El. 244.1). The SPT N values in this layer vary from 5 blows to refusal, indicating firm to hard consistency. This layer was not fully penetrated to establish the thickness of this deposit.

The moisture content of samples tested from this deposit varied from 5.9% to 24.9% with an average value of 12.7%. The Atterberg limit test results of six representative samples are presented in Figure 115-PC-1. The test results indicate liquid limit values ranging from 14 to 21, plastic limit values ranging from 12 to 13, and corresponding plasticity index values ranging from 2 to 9. Based on the results of Atterberg limit tests, the soil may be classified as clayey silt of low plasticity (CL-ML) in the Unified Soil Classification System (USCS). The results of the sieve analysis test performed on six representative samples from this layer are provided on Figure 115-GS-2. The test result indicates that this deposit consists of 4% to 39% gravel, 26% to 41% sand, 23% to 56% silt and 4% to 15% clay.



5.3 Groundwater

The groundwater level was measured upon completion of drilling and was observed at depths ranging from 1.1 m to 5.79 m (El. 251.3 to El. 252.2), below the existing grade of the road.

The water level in the creek was observed at El. 252.8 during the fieldwork.

Groundwater levels may fluctuate due to the influence of precipitation and seasonal change. The groundwater levels were measured prior to backfilling the boreholes. Groundwater levels are shown on the Borehole Logs provided in Appendix B.

5.4 Chemical Analysis

A summary of the chemical test results provided by AGAT Laboratories is summarized in the table below. The detail test results provided by AGAT Laboratories are also presented in Appendix B.

Table 5-1-Soil Chemical Analysis Results

BOREHOLE NO.	SAMPLE	DEPTH / ELEVATION (m)	SOIL TYPE	SULPHATE (µg/g)	CHLORIDE (µg/g)	pH	RESISTIVITY (Ohm-cm)
16-115-03	SS-8	5.33-5.94 / 249.3-248.7	Clayey Silt (Glacial Till)	20	17	8.16	6210



6. CLOSURE

Mr. M. Rapsey and Mr. K. Daly, P.Eng., carried out the field investigations under the supervision of Mr. L. Yimam, Ph.D., P. Eng., Senior Engineer and Mr. C. M. P. Nascimento, P.Eng., Project Manager. LandCore Drilling Ltd. of Chelmsford, Ontario supplied the drilling equipment for the subsurface exploration. The laboratory testing of the selected samples was carried out in the PML laboratory in Toronto. Chemical tests on soil sample were performed by AGAT Laboratories of Mississauga, Ontario.

This report was prepared by Ms. Asieh Khadem, M.Sc. Eng., EIT, Project Supervisor and reviewed by Mr. Mark Vasavithasan, M.Sc. Eng., P.Eng., Senior Engineer, Geotechnical Services. Mr. C.M.P. Nascimento, P.Eng., Project Manager and MTO Designated Contact, conducted an independent review of the report.

Yours very truly
Peto MacCallum Ltd.

Asieh Khadem

Asieh Khadem, M.Sc. Eng., EIT
Project Supervisor, Geotechnical Services



Mark Vasavithasan, M.Sc. Eng., P.Eng.
Senior Engineer, Geotechnical Services



Carlos M.P. Nascimento, P.Eng
Project Manager and
MTO Designated Principal Contact



APPENDIX A

Site Photographs



Photograph P1: Looking south-east from Highway 11 eastbound lane shoulder at the location of Borehole 16-115-1 (July 23, 2016).



Photograph P2: Looking south-east from Highway 11 eastbound lane shoulder at the location of Borehole 16-115-3 (July 24, 2016).



Photograph P3: Looking north-west at the culvert inlet (July 23, 2016).



Photograph P4: Looking south-west at the culvert outlet (July 23, 2016).



Photograph P5: Boulders and cobbles at Borehole 16-115-4 (July 25, 2016).



Photograph P6: Boulders and cobbles at Borehole 16-115-3 (July 24, 2016).



APPENDIX B

Borehole Locations Plan and Soil Strata at Structure 39W-115/C

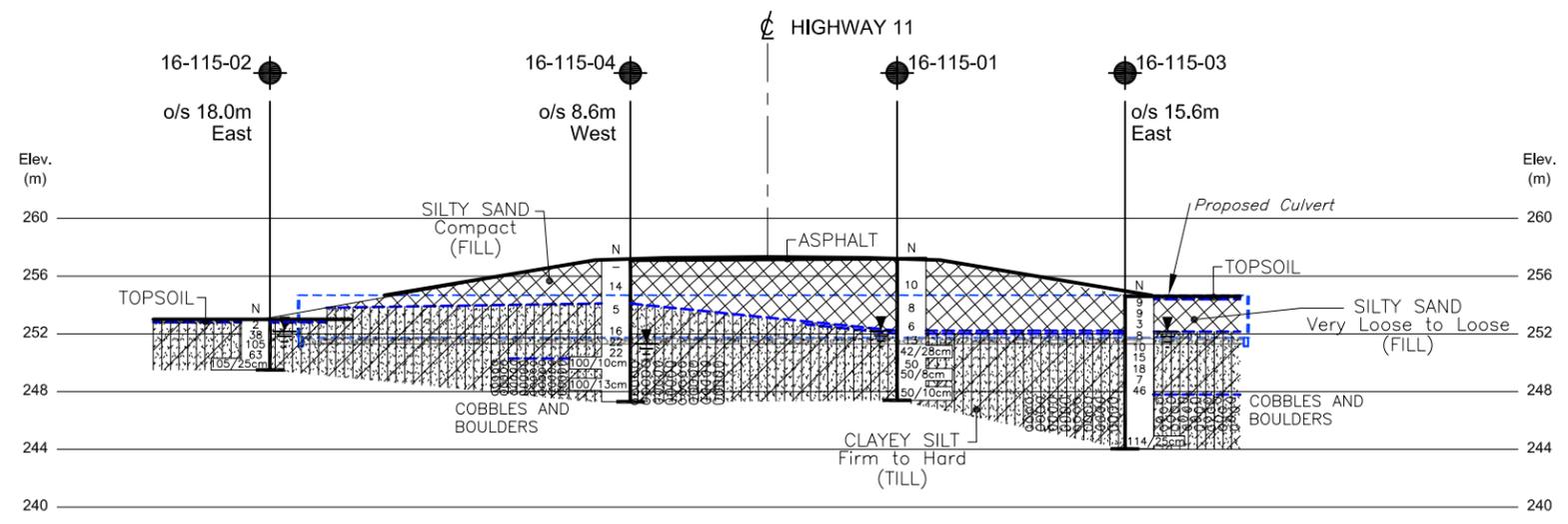
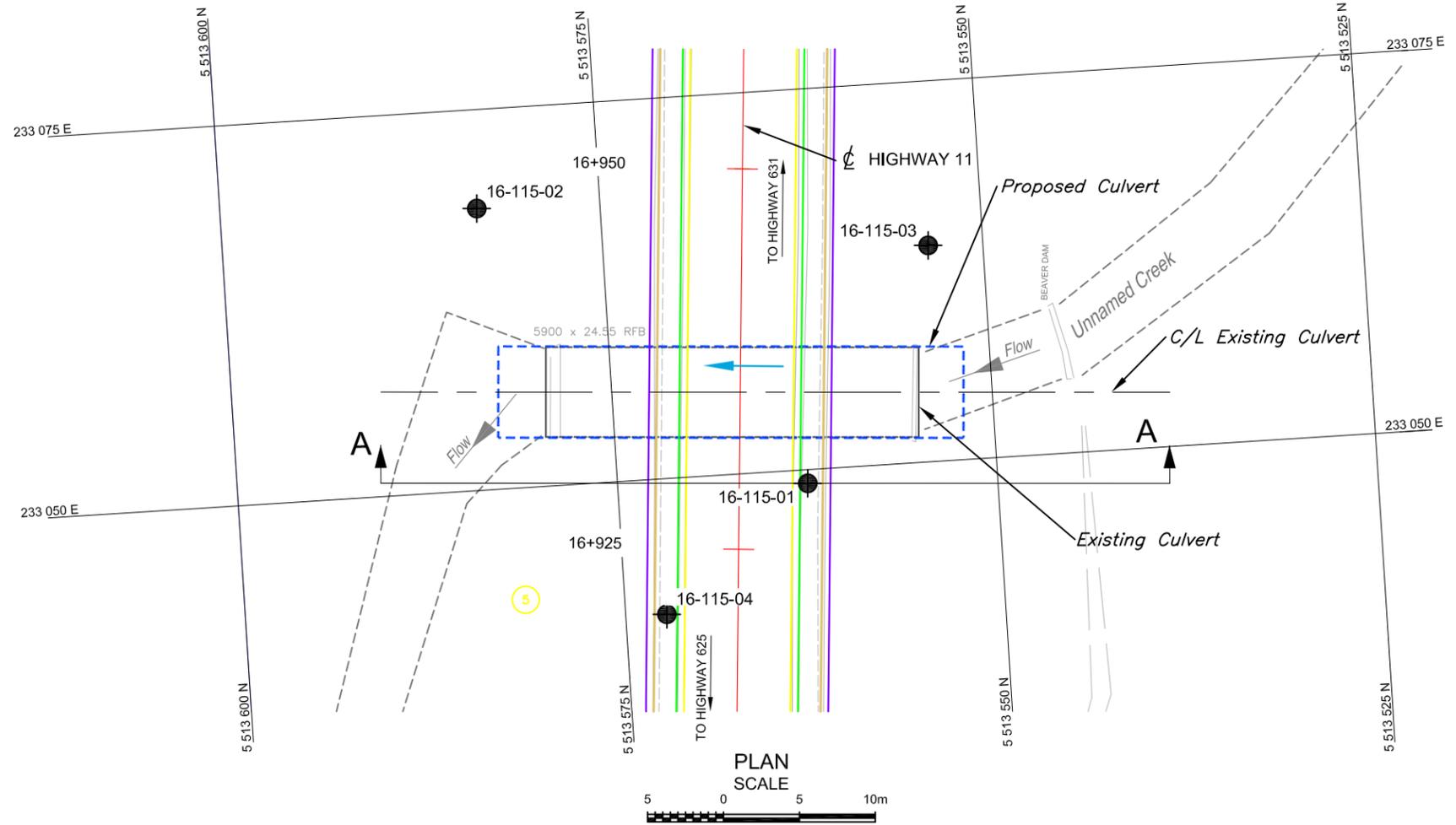
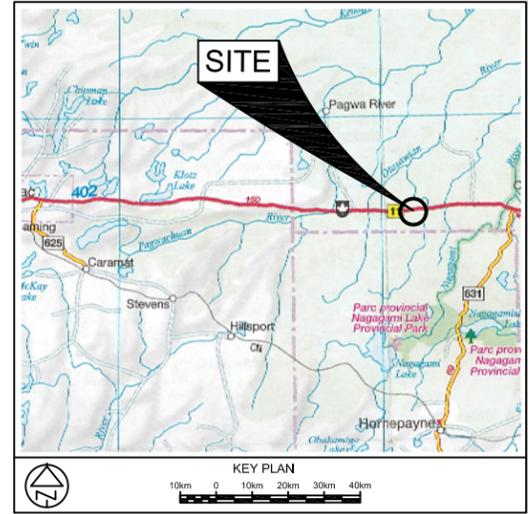
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Chemical Test Results



LEGEND

- Borehole
- Cone
- Borehole and Cone
- N Blows/0.3m (Std. Pen Test, 475 J/blow)
- CONE Blows/0.3m (60 Cone, 475 J/blow)
- WL at time of investigation July 2016
- WH Penetration due to weight of hammer and rod
- * Water level not established
- Head
- ARTESIAN WATER Encountered
- PIEZOMETER

BH No	ELEVATION	NORTHINGS	EASTINGS
16-115-01	257.2	5 513 562.5	233 049.1
16-115-02	253.0	5 513 583.1	233 068.5
16-115-03	254.6	5 513 553.6	233 064.2
16-115-04	257.1	5 513 572.3	233 041.1

NOTE
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

DATE	BY	DESCRIPTION

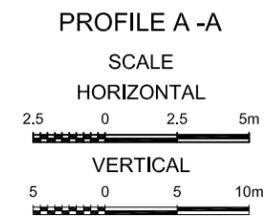
Geocres No. 42F-046					
HWY No	11	CHECKED AK/LY	DATE FEB. 23, 2017	DIST NEW LISKEARD	
SUBM'D	NA	CHECKED MV	APPROVED CN	SITE 39W-115/C	
DRAWN	NA			DWG 115/C-1	



REF GHD Drawing: X-11116826_39W-115_Design.dwg undated

NOTES:

- THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
- THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
- DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.



EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS \bar{N} .

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

COMPOSITION: SECONDARY SOIL COMPONENTS ARE DESCRIBED ON THE BASIS OF PERCENTAGE BY MASS OF THE WHOLE SAMPLE AS FOLLOWS:

PERCENT BY MASS	0-10	10-20	20-30	30-40	>40
	TRACE	SOME	WITH	ADJECTIVE (SILTY)	AND (AND SILT)

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0-12	12-25	25-50	50-100	100-200	>200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0-5	5-10	10-30	30-50	>50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm* IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (R Q D), FOR MODIFIED RECOVERY, IS:

R Q D (%)	0-25	25-50	50-75	75-90	90-100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

JOINTING AND BEDDING:

SPACING	50mm	30-300mm	0.3m-1m	1m-3m	>3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	P H	T W ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	F M	T W ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE
F V	FIELD VANE		

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
l_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_{α}	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_l	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES	n	1, %	POROSITY	e_{max}	1, %	VOID RATIO IN LOOSEST STATE
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES	w	1, %	WATER CONTENT	e_{min}	1, %	VOID RATIO IN DENSEST STATE
ρ_w	kg/m^3	DENSITY OF WATER	S_r	%	DEGREE OF SATURATION	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
γ_w	kN/m^3	UNIT WEIGHT OF WATER	w_L	%	LIQUID LIMIT	D	mm	GRAIN DIAMETER
ρ	kg/m^3	DENSITY OF SOIL	w_p	%	PLASTIC LIMIT	D_n	mm	n PERCENT - DIAMETER
γ	kN/m^3	UNIT WEIGHT OF SOIL	w_s	%	SHRINKAGE LIMIT	C_u	1	UNIFORMITY COEFFICIENT
ρ_d	kg/m^3	DENSITY OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	h	m	HYDRAULIC HEAD OR POTENTIAL
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	q	m^2/s	RATE OF DISCHARGE
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	v	m/s	DISCHARGE VELOCITY
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL	DTPL		DRIER THAN PLASTIC LIMIT	i	1	HYDRAULIC GRADIENT
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL	APL		ABOUT PLASTIC LIMIT	k	m/s	HYDRAULIC CONDUCTIVITY
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL	WTPL		WETTER THAN PLASTIC LIMIT	j	kN/m^2	SEEPAGE FORCE
e	1, %	VOID RATIO						

RECORD OF BOREHOLE No 16-115-01

1 of 1

METRIC

G.W.P. 5130-13-00 LOCATION Co-ords: 5 513 562.5 N ; 233 049.1 E ORIGINATED BY M.R./K.D.
 DIST New Liskeard BOREHOLE TYPE C.F.H.S.A., NW Casing and NQ Coring COMPILED BY A.K.
 DATUM Geodetic HWY 11 DATE July 23, 2016 CHECKED BY M.V.

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20	40	60	80					
											○ UNCONFINED	+ FIELD VANE				
											● QUICK TRIAXIAL	× LAB VANE				
											WATER CONTENT (%)					
											20	40	60			
257.2	Ground Surface															
0.0	Silty sand trace clay, trace gravel Loose to compact Brown Wet															
	(FILL)		1	SS	10											6 54 31 9
			2	SS	8											
			3	SS	6											
252.2	Topsoil															
5.0	Clayey silt with sand and gravel Stiff to hard Grey Damp															
252.0	(TILL)		4	SS	13											
5.2			5	SS	42/28cm											
			6	SS	50											39 34 23 4
			7	SS	50/8cm											
			8	SS	50/10cm											14 33 38 15
247.4	End of borehole															
9.8	Samples 7 & 8: Sampler bouncing															
	* 2016 07 23															
	∇ Water level observed during drilling															
	C.F.H.S.A. denotes Continuous Flight Hollow Stem Augers															

RECORD OF BOREHOLE No 16-115-02

1 of 1

METRIC

G.W.P. 5130-13-00 LOCATION Co-ords: 5 513 583.1 N ; 233 068.5 E ORIGINATED BY K.D.
 DIST New Liskeard BOREHOLE TYPE C.F.H.S.A. and NW Casing COMPILED BY A.K.
 DATUM Geodetic HWY 11 DATE July 25, 2016 CHECKED BY M.V.

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20	40	60	80						100
253.0	Ground Surface																
252.8	Topsoil		1	SS	2												
0.2	Clayey silt with sand and gravel		2	SS	38	▽*											
	Hard Grey Damp (TILL)		3	SS	105												
			4	SS	63												30 26 31 13
			5	SS	105/25cm												
249.5	End of boehole																
3.5																	

* 2016 07 25
 ▽ Water level observed during drilling
 C.F.H.S.A. denotes Continuous Flight Hollow Stem Augers

RECORD OF BOREHOLE No 16-115-03

1 of 1

METRIC

G.W.P. 5130-13-00 LOCATION Co-ords: 5 513 553.6 N ; 233 064.2 E ORIGINATED BY K.D.
 DIST New Liskeard BOREHOLE TYPE C.F.H.S.A., NW Casing and NQ Coring COMPILED BY A.K.
 DATUM Geodetic HWY 11 DATE July 24, 2016 CHECKED BY M.V.

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20	40	60	80						100
											○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE			WATER CONTENT (%)			GR SA SI CL
254.6	Ground Surface																
254.4	Topsoil																
0.2	Silty sand trace clay, trace gravel		1	SS	9												
	Very loose Brown Wet to loose		2	SS	9												
	(FILL)		3	SS	3												
252.2	Clayey silt with sand and gravel		4	SS	8												
2.4	Firm to hard Grey Moist		5	SS	10												
			6	SS	15												
			7	SS	18												
			8	SS	7												
			9	SS	46												
	cobbles and boulders		10	RC NQ	REC 32%											6 32 50 12	
	(TILL)		11	RC NQ	REC 0%												
			12	SS	114/25cm												
244.1	End of borehole																
10.5																	

* 2016 07 24
 ∇ Water level observed during drilling
 C.F.H.S.A. denotes Continuous Flight Hollow Stem Augers

RECORD OF BOREHOLE No 16-115-04

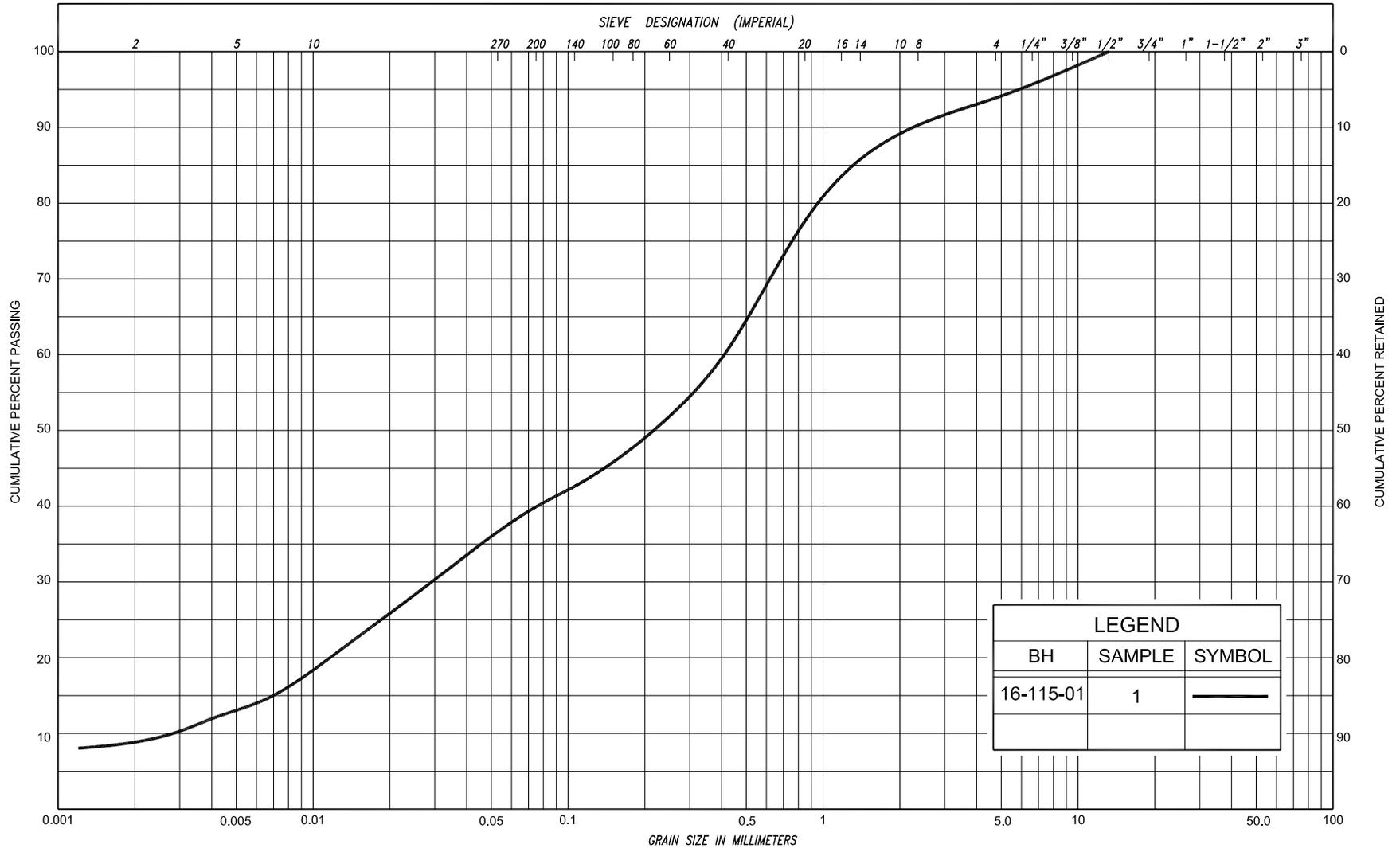
1 of 1

METRIC

G.W.P. 5130-13-00 LOCATION Co-ords: 5 513 572.3 N ; 233 041.1 E ORIGINATED BY K.D.
 DIST New Liskeard BOREHOLE TYPE C.F.H.S.A., NW Casing and NQ Coring COMPILED BY A.K.
 DATUM Geodetic HWY 11 DATE July 25, 2016 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100						20
257.1	Ground Surface																	
0.0	Silty sand trace clay, trace gravel Compact Brown Wet (FILL)			GS	-													
			1	SS	14													
254.1	Clayey silt with sand and gravel Firm to Grey Moist hard		2	SS	5													
			3	SS	16													
			4	SS	22													
			5	SS	22													
			6	SS	100/10cm													
			7	SS	100/13cm													
			8	RC NQ	REC 54%													
247.3	End of borehole																	
9.8																		

* 2016 07 25
 Water level observed during drilling
 C.F.H.S.A. denotes Continuous Flight Hollow Stem Augers



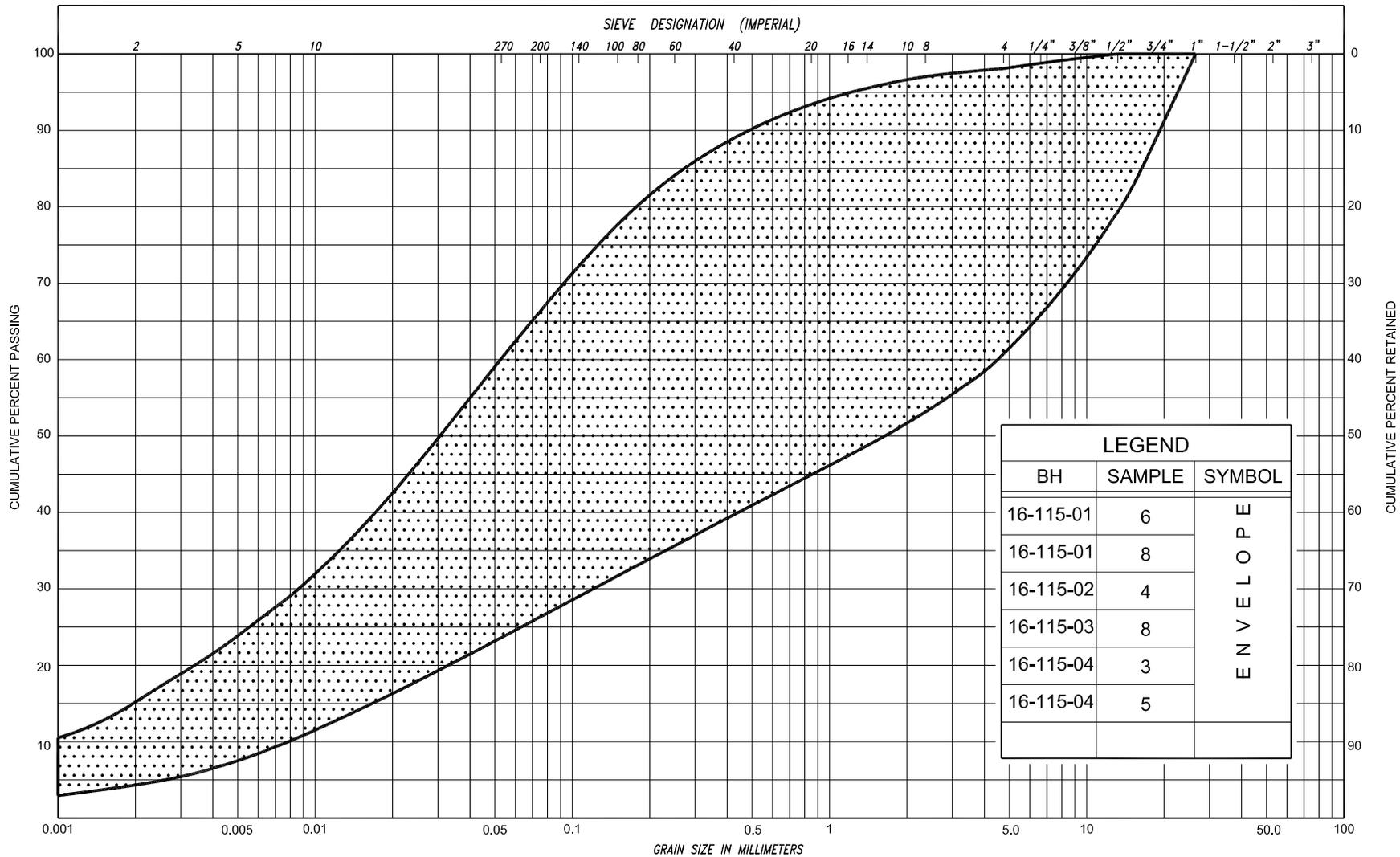
LEGEND		
BH	SAMPLE	SYMBOL
16-115-01	1	—

SILT & CLAY				FINE SAND		MEDIUM SAND		COARSE SAND		GRAVEL		COBBLES	UNIFIED
CLAY	FINE SILT		COARSE SILT	FINE SAND		MEDIUM SAND		COARSE SAND		GRAVEL		COBBLES	M.I.T.
CLAY		SILT		V. FINE SAND	FINE SAND	MED. SAND	COARSE SAND		GRAVEL				U.S. BUREAU



GRAIN SIZE DISTRIBUTION
 SILTY SAND, trace clay, trace gravel
 (FILL)

FIG No.	115-GS-1
HWY	11
G.W.P.	5130-13-00



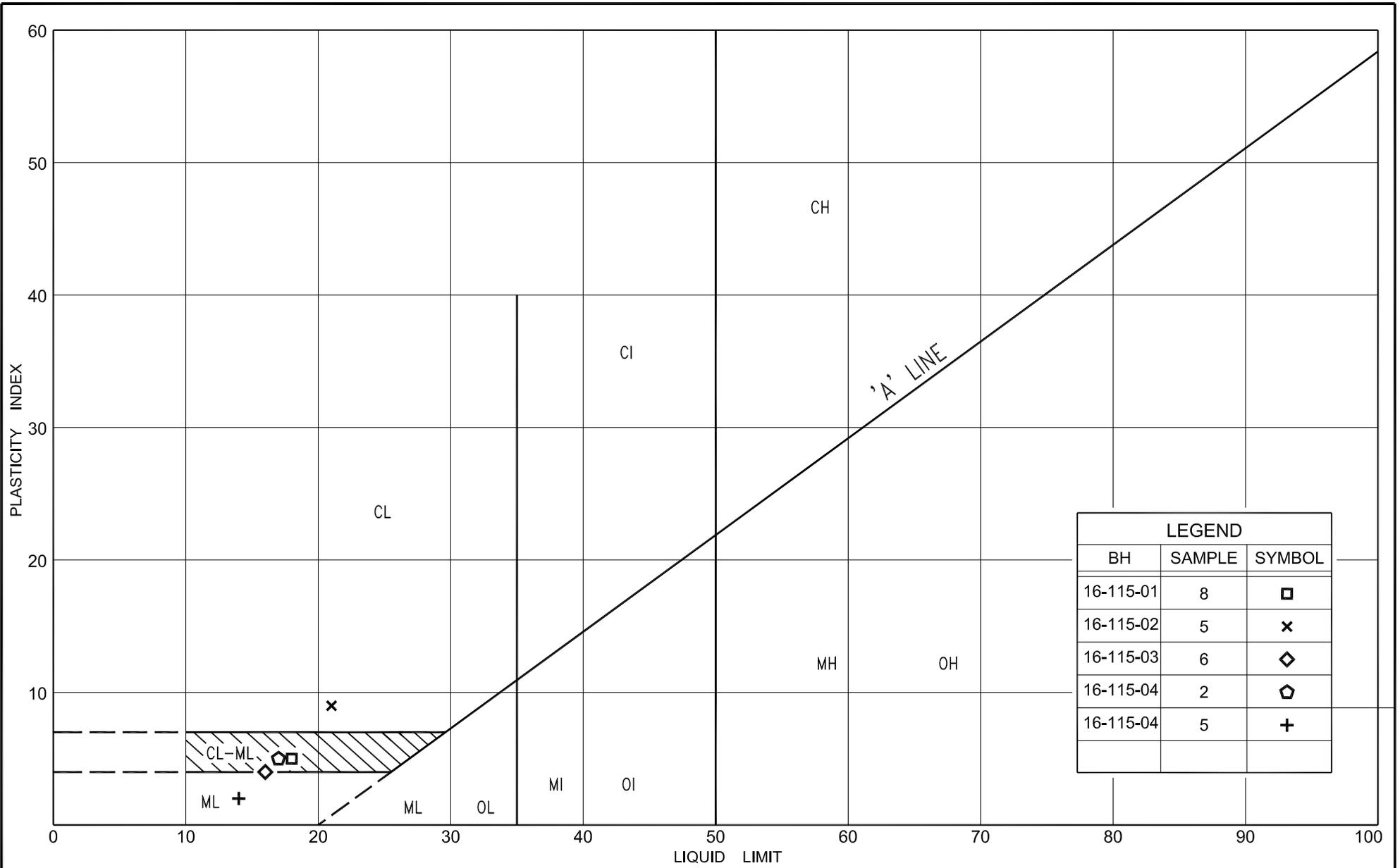
LEGEND		
BH	SAMPLE	SYMBOL
16-115-01	6	E N V E L O P E
16-115-01	8	
16-115-02	4	
16-115-03	8	
16-115-04	3	
16-115-04	5	

SILT & CLAY				FINE SAND		MEDIUM SAND		COARSE SAND		GRAVEL		COBBLES	UNIFIED
CLAY	FINE SILT		COARSE SILT	FINE SAND		MEDIUM SAND		COARSE SAND		GRAVEL		COBBLES	M.I.T.
CLAY		SILT		V. FINE SAND	FINE SAND	MED. SAND	COARSE SAND		GRAVEL				U.S. BUREAU

GRAIN SIZE DISTRIBUTION
CLAYEY SILT, with sand and gravel
(TILL)

FIG No. 115-GS-2
 HWY 11
 G.W.P. 5130-13-00





PLASTICITY CHART
 CLAYEY SILT, with sand and gravel (CL-ML)
 (TILL)

FIG No.	115-PC-1
HWY	11
G.W.P.	5130-13-00



Certificate of Analysis

AGAT WORK ORDER: 16T123966

PROJECT: 16TF013A

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
<http://www.agatlabs.com>

CLIENT NAME: PETO MACCALLUM LIMITED

ATTENTION TO: Lul Yimam

SAMPLING SITE:

SAMPLED BY:

Corrosivity Package

DATE RECEIVED: 2016-08-08

DATE REPORTED: 2016-08-15

Parameter	Unit	SAMPLE DESCRIPTION:		BH16-115-03	BH16-116-02	BH16-231-01
		SAMPLE TYPE:		SS8	SS4	SS7
		DATE SAMPLED:		Soil	Soil	Soil
		G / S	RDL	7/24/2016	7/22/2016	7/26/2016
Sulphide*	%		0.05	<0.05	<0.05	<0.05
Chloride (2:1)	µg/g	2	2	17	95	11
Sulphate (2:1)	µg/g	2	20	4	4	9
pH (2:1)	pH Units		NA	8.16	8.43	8.68
Electrical Conductivity (2:1)	mS/cm		0.005	0.161	0.256	0.114
Resistivity (2:1)	ohm.cm		1	6210	3910	8770
Redox Potential (2:1)	mV		5	246	242	233

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

7757409-7757412 EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil).

Certified By:

Amanjot Bhela



Quality Assurance

CLIENT NAME: PETO MACCALLUM LIMITED
 PROJECT: 16TF013A
 SAMPLING SITE:

AGAT WORK ORDER: 16T123966
 ATTENTION TO: Lui Yimam
 SAMPLED BY:

Soil Analysis

RPT Date: Aug 15, 2016			DUPLICATE				Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD	Measured Value		Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits		
								Lower	Upper		Lower	Upper		Lower	Upper	

Corrosivity Package

Sulphide*	7757409	7747409	< 0.05	< 0.05	NA	< 0.05	100%	80%	120%						
Chloride (2:1)	7757412	7757412	11	11	0.0%	< 2	93%	80%	120%	100%	80%	120%	103%	70%	130%
Sulphate (2:1)	7757412	7757412	9	9	NA	< 2	99%	80%	120%	102%	80%	120%	104%	70%	130%
pH (2:1)	7557412	7757412	8.68	8.70	0.2%	NA	101%	90%	110%	NA			NA		
Electrical Conductivity (2:1)	7757412	7757412	0.114	0.114	0.0%	< 0.005	99%	90%	110%	NA			NA		
Redox Potential (2:1)	7757412	7757412	233	232	0.4%	< 5	103%	70%	130%	NA			NA		

Comments: NA signifies Not Applicable.

Duplicate Qualifier: As the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

Certified By: _____

Amanjot Bhela



Time Markers

AGAT WORK ORDER: 16T123966

PROJECT: 16TF013A

5835 COOPERS AVENUE
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CANADA L4Z 1Y2
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<http://www.agatlabs.com>

CLIENT NAME: PETO MACCALLUM LIMITED

ATTENTION TO: Lul Yimam

Sample ID	Sample Description	Sample Type	Date Sampled	Date Received
7757409	BH16-115-03 SS8	Soil	24-JUL-2016	08-AUG-2016

Corrosivity Package

Parameter	Date Prepared	Date Analyzed	Initials
Sulphide*	12-AUG-2016	12-AUG-2016	MI
Chloride (2:1)	12-AUG-2016	12-AUG-2016	JC
Sulphate (2:1)	12-AUG-2016	12-AUG-2016	JC
pH (2:1)	12-AUG-2016	12-AUG-2016	MM
Electrical Conductivity (2:1)	12-AUG-2016	12-AUG-2016	AR
Resistivity (2:1)	12-AUG-2016	12-AUG-2016	SYS
Redox Potential (2:1)			AR

7757411	BH16-116-02 SS4	Soil	22-JUL-2016	08-AUG-2016
---------	-----------------	------	-------------	-------------

Corrosivity Package

Parameter	Date Prepared	Date Analyzed	Initials
Sulphide*	12-AUG-2016	12-AUG-2016	MI
Chloride (2:1)	12-AUG-2016	12-AUG-2016	JC
Sulphate (2:1)	12-AUG-2016	12-AUG-2016	JC
pH (2:1)	12-AUG-2016	12-AUG-2016	MM
Electrical Conductivity (2:1)	12-AUG-2016	12-AUG-2016	AR
Resistivity (2:1)	12-AUG-2016	12-AUG-2016	SYS
Redox Potential (2:1)			AR

7757412	BH16-231-01 SS7	Soil	26-JUL-2016	08-AUG-2016
---------	-----------------	------	-------------	-------------

Corrosivity Package

Parameter	Date Prepared	Date Analyzed	Initials
Sulphide*	12-AUG-2016	12-AUG-2016	MI
Chloride (2:1)	12-AUG-2016	12-AUG-2016	JC
Sulphate (2:1)	12-AUG-2016	12-AUG-2016	JC
pH (2:1)	12-AUG-2016	12-AUG-2016	MM
Electrical Conductivity (2:1)	12-AUG-2016	12-AUG-2016	AR
Resistivity (2:1)	12-AUG-2016	12-AUG-2016	SYS
Redox Potential (2:1)			AR

Method Summary

CLIENT NAME: PETO MACCALLUM LIMITED
AGAT WORK ORDER: 16T123966
PROJECT: 16TF013A
ATTENTION TO: Lui Yimam
SAMPLING SITE:
SAMPLED BY:

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
Sulphide*	MIN-200-12025	ASTM E1915-09	GRAVIMETRIC
Chloride (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
Sulphate (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
pH (2:1)	INOR 93-6031	MSA part 3 & SM 4500-H+ B	PH METER
Electrical Conductivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B	EC METER
Resistivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B,SSA #5 Part 3	CALCULATION
Redox Potential (2:1)		McKeague 4.12 & SM 2510 B	REDOX POTENTIAL ELECTRODE



PART B –FOUNDATION DESIGN REPORT

for

UNNAMED CREEK CULVERT REPLACEMENT

SITE NO. 39W-115/C

HIGHWAY 11- STATION 16+935 - KOHLER TOWNSHIP

DISTRICT OF NEW LISKEARD, ONTARIO

ASSIGNMENT NO. 5015-E-0009

GWP 5130-13-00

WP 5130-13-01

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PML Ref.: 16TF013A
Index No.: 103FDR
GEOCRES No.: 42F-046
March 6, 2017



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Appendix C – General Arrangement

Appendix D – List of Standard Specifications Relevant to Report
Non-Standard Special Provisions (NSSP)

PART B FOUNDATION DESIGN REPORT

for
Unnamed Creek Culvert Replacement
Site No. 39W-115/C
Highway 11- Station 16+935
Kohler Township, New Liskeard District, Ontario
Assignment No. 5015-E-0009, GWP 5130-13-00, WP 5130-13-01

7. INTRODUCTION

This foundation investigation and design report with the interpretation and recommendations are intended for the use of GHD Ltd. (GHD) on behalf of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The design-build contractor must make their own interpretation based on the factual data in Part A of the report. Where comments are made on construction, they are provided only to highlight those aspects, which could affect the design of the project. Contractors must make their own interpretation of the factual information provided in Part A of the report, as it may affect equipment selection, proposed construction methods, and scheduling.

8. PROJECT DESCRIPTION

8.1 General

This report provides foundation design recommendations based on interpretation of the geotechnical data presented in the factual report (Part A). This report is to assist the design team in the selection of a suitable type of foundation for the replacement of the culvert located on Highway 11, 35.2 km west of the intersection of Highway 631, and Highway 11 (Sta. 16+935) in the Township of Kohler, District of New Liskeard.

The discussions and recommendations presented in this report are based on the preliminary information received by PML and the factual data obtained during the geotechnical investigation carried out by PML.



8.2 Existing Culvert

The existing structure is a 5.6 m span, 2.0 m rise and 23 m long cast-in-place concrete box culvert. The structure supports a fill height of 2.5 m above the deck. Based on the preliminary GA drawing provided by GHD, dated January 2017, the invert of the existing culvert at the centerline of Highway 11 is at approximate El. 251.82 and the embankment above the creek bed is approximately 5.0 m high.

This culvert was constructed in 1958 and the road accommodates two lanes of vehicular traffic. This structure has no record of rehabilitation. Based on the inspection carried out on 16 June 2015, severe disintegration in the barrel at the North end was observed. In addition, active leakage through stained cracks on barrel walls and wide longitudinal cracks on the soffit were observed. The structure has been in service for more than fifty years and further settlements may not be expected. Considering the width of the culvert and the fill height above the deck, it is estimated that the load imposed by the existing culvert at the founding level may not exceed 75 kPa to 85 kPa.

8.3 Proposed Culvert

Based on the preliminary information provided by GHD Ltd., it is proposed to replace the existing culvert with a 33.0 m long precast concrete box culvert with an opening size of 6.0 m span and 2.0 m rise, along the same vertical and horizontal alignments.

The preliminary structural information provided by GHD indicates that the proposed invert of the replacement box culvert slopes down from about El. 251.97 at the inlet to El. 251.66 at the outlet. The founding levels of the subgrade at the inlet and outlet are proposed to be at El. 251.19 and El. 250.88, respectively allowing for 780 mm of the thickness of the culvert box and granular base materials. It is proposed to construct the replacement culvert along the same vertical and horizontal alignments and the grade of the road at the culvert location will be maintained at the existing elevation of El. 256.76, which will result in fill height including the pavement structure of 2.5 m above the deck of the culvert.

There is no local detour planned to divert the traffic and the construction of the replacement culvert will be carried out in two stages by allowing the traffic to use one side of the highway with the aid of a temporary traffic signal. A properly designed temporary roadway protection along the centerline of the road will be required.



8.4 Structure Foundation

In general, the subsoil conditions consist of 2.2 m to 5.0 m silty sand fill below the existing surface which is followed by clayey silt with sand and gravel (glacial till) to a maximum investigation depth of 10.5 m below the grade. The groundwater level was observed between El. 251.3 and El. 252.2 during the fieldwork. The water level in the creek was observed at El. 252.8 during the fieldwork.

The feasibility of the following three options are discussed for replacing the existing culvert along the same vertical and horizontal alignments:

- Replacement with a precast concrete box culvert,
- Replacement with a cast-in-place concrete box culvert, and
- Replacement with an open footing concrete culvert.

Considering the subsoil conditions, the recommendations for the replacement culvert are provided below in the order of preference. A comparison of the technical advantages and disadvantages for the replacement culvert are presented in table 8-4.

8.4.1 Option 1: Precast Concrete Box Culvert

Based on the structural information available, it is assumed that the precast box culvert will be placed at about El. 251.04±. The subsoil conditions below the proposed founding level are capable of supporting precast concrete box culvert. Bedding for the precast concrete box culvert should be in accordance with OPSS 422.07.08, and may consist of 300 mm thick granular material, including the 75-mm leveling course required by OPSS 422.07.07. Bedding should be as specified in OPSS 422.05.13, and should also be placed in accordance with OPSS 422.07.07.

As required by the Canadian Highway Bridge Design (CHBDC 2014), cut-off walls at both ends of the culvert shall be provided. The design of cut-off wall shall meet the requirements of clauses 1.9.5.6 and 1.9.11.6.5 of CHBDC 2014, to protect against scour or undermining. Cut-off walls shall be in accordance with OPSD 812.010 or made of precast concrete with similar dimensions to prevent piping/washout of granular bedding with provision to protect the clayey silt till subgrade material below invert.



Table 8-4 - Comparison of Alternate Culvert Options

Option 1: Precast Concrete Box Culvert	Option 2: Cast-In-Place Concrete Box Culvert	Option 3: Three-Sided Precast Open Culvert
<p>Advantages:</p> <ol style="list-style-type: none"> 1. High degree of quality and uniformity, design flexibility, superior strength, and durability 2. Reduced weather dependency during installation 3. Reduced impact on traffic interruption 4. Ease of construction and installation in wet conditions is possible 5. The joints provide flexibility to accommodate differential settlement 	<p>Advantages:</p> <ol style="list-style-type: none"> 1. Reduces uneven settlement 2. Reduces water leakage and deterioration of culvert 3. Ability to withstand differential settlements 4. Longer life span of the structure 5. Degradation of subgrade can be avoided by placing lean concrete 	<p>Advantages:</p> <ol style="list-style-type: none"> 1. High degree of quality and uniformity, design flexibility, superior strength, and durability 2. Generally allows for natural streambed to remain intact 3. Less accumulation of sediments in the upstream of channel 4. Reduced weather dependency during installation 6. Ease of construction and installation in wet conditions is possible 7. Adequate geotechnical resistance available at founding level
<p>Disadvantages:</p> <ol style="list-style-type: none"> 1. Natural stream bed will not remain intact 2. Cause sediment accumulation in the upstream of the channel 3. Possibility for degradation of subgrade 	<p>Disadvantages:</p> <ol style="list-style-type: none"> 1. Natural stream bed will not remain intact 2. Cause sediments accumulation in the upstream of the channel 3. Weather dependent during construction 4. Major dewatering scheme is required to construct the floor slab under 1 m high water 	<p>Disadvantages:</p> <ol style="list-style-type: none"> 1. Probability of uneven or differential settlements are possible 2. Limited ability to withstand differential settlements
<p>Cost of Construction: Total Cost \$ 14,000/m</p>	<p>Cost of Construction: Total Cost \$ 15,000/m</p>	<p>Cost of Construction: Total Cost \$ 14,500/m</p>
<p>Recommended</p>	<p>Technically Feasible but Not Recommended</p>	<p>Technically Feasible but Not Recommended</p>

Considering the dimensions of the proposed precast concrete box culvert, the clayey silt till layer at the founding level, and the groundwater level, a factored geotechnical resistance at ULS of 250 kPa and at SLS of 180 kPa are recommended for design.

The grade of Highway 11 is expected to be maintained at the existing elevation consequently, the fill height above the deck is not expected to exceed 2.5 m. Therefore, there will be no additional load on the culvert to induce settlement. The geotechnical resistance of 180 kPa recommended at SLS is higher than the load of 85 kPa from the existing culvert. Therefore, the net increase in load from the



replacement culvert will have a negligible effect to cause settlement. Continuing post-construction settlements to cause any differential settlements will not be a concern.

The removal of the existing foundation may cause disturbance to the founding surface of the proposed replacement culvert. In addition, the clayey silt with sand and gravel (till) at the founding level may be susceptible to disturbance from construction traffic and any ponded water. To limit the degradation of the founding soil, it is recommended that the granular bedding be placed on the subgrade within four hours after preparation, inspection, and approval of the founding subgrade.

8.4.2 Option 2: Cast-in-Place Reinforced Concrete Box Culvert

The cast-in-place concrete culverts typically consist of heavier sections compared precast concrete box culverts. Construction under 1.0 m of ground water will impose greater difficulties for construction in dry conditions.

If this option is considered, a dewatering scheme shall be used to provide working platform for formwork and placing of concrete. In this case, the footing of box culvert may be placed at about El. 251.04 and designed using a geotechnical resistance of 250 kPa at ULS and 180 kPa at SLS. Similar to Option 1, a net increase in load from the cast-in-place concrete box culvert is negligible to cause noticeable settlement.

The removal of the existing foundation may cause disturbance to the founding surface of the proposed culvert. In addition, the till deposit at the founding level will be susceptible to disturbance from construction traffic and any ponded water. To limit the degradation of the founding soil, it is recommended that 100 mm thick concrete working slab (lean concrete) be placed on the subgrade within four hours after preparation, inspection, and approval of the foundation subgrade. The dewatering to construct the cast-in-place culvert in dry condition will be costly and impose greater difficulties. In view of the construction dewatering difficulties, this option is not preferred.

8.4.3 Option 3: Three-Sided Open Precast Concrete Culvert on Strip Footing

The glacial till deposit at the invert level is not susceptible to scour and capable of providing adequate geotechnical resistance to support the culver on strip footings. The strip footings may be designed assuming a geotechnical resistance of 250 kPa at ULS and 180 kPa at SLS. A total settlement of 20 mm may be expected under the recommended geotechnical resistance of 180 kPa.



Similar to Option 2, it is recommended that 100 mm thick concrete working slab (lean concrete) be placed on the subgrade within four hours after preparation, inspection, and approval of the foundation subgrade. The dewatering to construct the strip footing for the culvert in dry condition will be costly and impose greater difficulties. In view of the construction dewatering difficulties, this option is also not preferred.

8.4.4 Recommended Option for Culvert Replacement

From a geotechnical perspective and based on the subsurface conditions, precast concrete box culvert placed at about El 251.04 is the preferred option for the replacement of the existing culvert.

Options 2 and 3 are technically feasible but as outlined previously, considering the construction difficulties, the cost of dewatering 1.0 m high groundwater, and technical reasons, they are not recommended.

8.4.5 Lateral Earth Pressure

Earth pressure for the concrete structure should be computed as per the Clause 6.12.2 (b) of Canadian Highway Bridge Design Code (CHBDC, 2014). The earth pressure calculation should include maximum water level expected in the creek. The lateral earth and water pressure, p (kPa), may be computed using the equivalent fluid pressures presented in Section 6.12 of the CHBDC 2014 or employing the following equation assuming a triangular pressure distribution.

$$P = K (\gamma h_1 + \gamma' h_2 + q) + \gamma_w h_2 + C_p + C_s$$

- Where, P = lateral earth pressure (kPa)
 K = lateral earth pressure coefficient
 γ = unit weight of backfill material above water level (kN/m³)
 γ' = unit weight of submerged backfill ($\gamma - \gamma_w$) material below water level (kN/m³)
 γ_w = unit weight of water (9.8 kN/m³)
 h_1 = depth below final grade (m), above design water level
 h_2 = depth below design water level (m)
 q = surcharge load (kPa)
 C_p = compaction pressure (refer to clause 6.12.3 of CHBDC 2014)
 C_s = earth pressure induced by seismic events, kPa (refer to clause 4.6.5 of CHBDC 2014)
- Where \emptyset = angle of internal friction of retained soil (35° for Granular A or 30° for Granular B Type II)
 δ = angle of friction between soil and wall (24° for Granular A or B Type II)



The seismic site coefficient for the conditions at this site is provided in Section 10 of this report. Granular ‘A’ or ‘B’ should be utilized as backfill material and should be carried out in accordance with the requirements specified in the OPSS 902. The following parameters are recommended for the granular backfill:

Table 8.4.5: Recommended Geotechnical Parameters

GEOTECHNICAL PARAMETER	GRANULAR A	GRANULAR B TYPE II
Angle of Internal Friction, degrees	35°	30°
Unit Weight, kN/m ³	22.5	21.5
Coefficient of Active Earth Pressure (K_a)	0.27	0.33
Coefficient of Earth Pressure at Rest (K_o)	0.43	0.5
Coefficient of Passive Earth Pressure (K_p)	3.69	3

Sufficient movement of the structure wall should not be permitted for all three options and “at rest” conditions may be assumed for the calculation of earth pressure.

Backfill shall be placed simultaneously behind both sides of the culvert, maintaining the height of backfill approximately the same. At no time should the difference in backfill elevation from one side to the other be greater than 500 mm.

8.5 Approach Embankment

The height of the existing approach fill is approximately 5.0 m above the creek bed. PML understands that there will be no increase in the profile grade of the road and it will be maintained at El. 256.76. No major instability problems are anticipated for the excavated section of the embankment to be reconstructed with similar side slope as the existing. Considering the high-water level, the fill should consist of well compacted granular material, preferably Granular B Type II. Any spongy or soft area observed within the base of the embankment should be removed before placing the fill.

Rip-rap should be provided on the upstream and downstream sides of the creek to protect the toe of the embankments and to prevent erosion of creek bed in the proximity of the culvert. Rip-rap shall be in accordance with OPSD 810.010 and provided to a minimum height of 1.0 m above the high flood level expected in the creek.



9. FOUNDATION FROST DEPTH

In accordance with OPSD 3090.101, a minimum of 2.6 m earth cover is required to protect against the frost penetration in the area where the site is located.

Frost tapers within the granular backfill should be constructed in accordance with OPSD 3101.150. The frost penetration depth, f , is measured from the top of the final grade to the box of the structure or bottom of the footing.

10. SEISMIC CONSIDERATIONS

The Spectral and Peak Ground Accelerations ($S_a(0.2)$ and PGA) for the project site, based on the Town of Hearst, Ontario, and for the 2% in 50-year probability of exceedance, is 0.060 and 0.035, respectively (National Building Code of Canada, 2015). The Reference Peak Ground Acceleration (PGA_{ref}) based on these $S_a(0.2)$ and PGA values is 0.028. The soil at the site for seismic design purposes is classified as Type D in accordance with Clause 4.4.3.2 of CHBDC, 2014.

10.1 Cover and Backfill

Backfill materials shall meet the requirements of Group I, or Group II specified in OPSS 422.05.14, and placed according to the procedures described in Section 422.07.11. It shall be placed in layers not exceeding 200 mm in thickness before compaction and compacted in accordance with OPSS 501. Backfill on each side of the box culvert shall be completed simultaneously and at no time, the levels on each side of the culvert exceed more than 400 mm. Restrictions on compaction near the culvert shall be as specified in OPSS 902.07.06.02.

The cover material shall meet the requirements of OPSS 422.05.14 and placed in accordance with OPSS 422.07.12.

11. CONSTRUCTION CONSIDERATIONS

11.1 Staged Construction

The construction of the culvert replacement is expected to be carried out in two stages. As described in Section 8.3, staged construction with a roadway protection system will be required to remove the existing culvert and to install the new culvert while maintaining traffic on Highway 11. Surface water



should be diverted away from open excavations and all excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA) and MTO Regulations for Construction Projects.

The subsoil including cobbles and boulders encountered at this site is not favorable for driving sheet piles to design and construct a shoring system to maintain traffic on Highway 11. The cobbles encountered below El. 249.1 may cause difficulties to drive the sheet piles to adequate depth of embedment. The use of soldier piles and timber laggings supported by anchors or struts may have to be considered to construct temporary shoring systems. The soldier piles may have to be lowered in pre-augured holes and filled with non-shrinkable grout to support the excavation with timber laggings. However, this type of shoring systems will be very costly to use for a culvert construction. The Non-Standard Special Provision (NSSP) provided in Appendix D shall be included in the contract document to alert the contractor.

Alternatively, a two-lane detour or a single lane detour with temporary traffic signals and a creek bypass system may be utilized to maintain the traffic on the highway. If this option is considered, an additional foundation investigation may be required.

Temporary roadway protection shall be designed and constructed in accordance with OPSS 539 (Temporary Protection Systems). To meet a minimum Performance Level of 2, the detail design of the temporary roadway protection system should be carried out by the contractor. The following soil parameters are recommended for the design of the roadway protection system.

Table 11.1 Soil Parameters

ELEVATION		SOIL TYPE	SOIL PARAMETERS		
FROM	TO		FRICTION ANGLE (ϕ°)	UNIT WEIGHT (γ) KN/m ³	C _u , KN/m ²
257.2	252.2	Silty Sand Fill	30	18	0
254.1	244.1	Clayey Silt Till	0	11*	100

* Submerged unit weight



11.2 Excavation

The roadway should be protected by a properly designed protection system when space limitation exists. The protection system for excavations should be in accordance with OPSS 539, Construction Specification for Temporary Protection Systems, and OPSS 902, Construction Specifications for Excavating and Backfilling–Structures. Excavated material shall not be stockpiled in the areas immediately adjacent to the top of the excavation slopes.

Based on the record of boreholes, the excavations for the construction of replacement culvert will be advanced through existing fill material underlain by native till deposits. For OSHA classification purposes, the fill materials should be classified as Type 3 soils and clayey silt till should be classified as Type 2 soils. For excavations through multiple soil types, the side slope geometry is governed by the soil with the highest number designation.

12. GROUNDWATER CONTROL

The groundwater level was encountered between El. 251.3 and El. 252.2, and the excavation to the founding level will have to be carried out under 1.0 m high water level. The groundwater level should be lowered to a minimum of 0.5 m below the proposed founding levels to allow for construction in-the-dry and to place bedding materials.

For construction in-the-dry, the creek will have to be temporarily diverted and a cofferdam may be required due to the relatively pervious nature of the subsoil. A cofferdam consisting of sheet piles may not be feasible for excavation and dewatering at this site. Alternatively, a cofferdam consisting of sand bags and clay puddle may be constructed by damming the upstream and downstream of the culvert. Dewatering may be carried out from sumps located along the interior periphery of the cofferdam. If restrictions are imposed on placing clay puddle in the creek, the culvert replacement may have to be constructed under the prevailing water level.

If the construction is carried out under water, the backfill material shall consist of Granular B Type II containing particle sizes not finer than 75 μm . However, Granular B Type II may be used if the construction is carried out in-the-dry, and the replacement fill shall be placed in layers not exceeding 200 mm in thickness before compaction and compacted in accordance with OPSS 501.

Groundwater levels are subject to seasonal fluctuations and precipitation patterns.



13. TEMPORARY WORKS

The contractor shall be responsible for the selection, performance and detailed design of the dewatering system including the cofferdam. The dewatering system should be designed to conform to the requirement of OPSS 517 (Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation) and OPSS 518 (Construction Specification for Control of Water from Dewatering Operations) in addition to the requirements of NSSP provided in Appendix D.

14. SOIL CORROSION

One sample from the till deposit was tested for soil corrosively and potential exposure of concrete to sulphate attack. A summary of the chemical test results is provided in Appendix B of this report. The sulphate concentration of 20 µg/g (0.0020%) reported in Table 5-1 for the clayey silt till soil is far too low compared to the value of 0.1% suggested in Canadian Standard A23.1-14 to have any effect on buried concrete structures. Therefore, the potential for sulphate attack will be mild or relatively low. The chloride content of 17 ppm or 0.0017% (17 µg/g) reported in Appendix B is significantly lower than the concentration value of 250 ppm (0.025%) that generally leads to the corrosive environment for buried metals. Potential for the corrosive environment at this site is relatively low.

Electrical resistivity less than 2000 ohm-cm generally leads to the highly corrosive environment for steel elements in contact with soil. The resistivity value of 6210 ohm-cm reported is significantly higher than 2000 and suggests a moderately or non-corrosive environment at this site for steel elements. However, the reported pH value of 8.16 is slightly higher than the value of 5.5 that generally leads to corrosion.

Generally, no sulphate attack is expected from selected backfill materials. However, it may be advisable to test backfill material for corrosion potential if the material is imported from unknown sources.



15. CLOSURE

This Foundation Investigation and Design Report was prepared by Ms. Asieh Khadem, M.Sc. Eng., EIT., Project Supervisor, and reviewed by Mr. Mark Vasavithasan, MSc. Eng., P.Eng. Senior Engineer, Geotechnical Services. Mr. C.M.P. Nascimento, P.Eng., Project Manager and MTO Designated Principal Contact, conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

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APPENDIX C

General Arrangement



APPENDIX D

List of Standard Specifications Relevant to Report
Non-Standard Special Provisions (NSSP)



LIST OF STANDARD SPECIFICATIONS RELEVANT TO REPORT

DOCUMENT	TITLE
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS 902	Excavation and Backfilling of Structures
OPSS 501	Construction Specification for Compacting
OPSD 810-010	General Rip-Rap Layout Sewer and Culvert Outlets
OPSD 3090.101	Foundation, Frost Penetration depths for Southern Ontario
OPSS 539	Temporary Protection Systems
OPSS 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS 518	Construction Specification for Control of Water from Dewatering Operations



NON-STANDARD SPECIAL PROVISIONS (NSSP)

NSSP 1 – Installation of Shoring for Roadway Protection and Excavation (Addition to OPSS 539)

The Contractor is advised that cobbles and/or boulders may be encountered during the installation of sheet piles for shoring or during the excavation of the embankment. The Contractor shall select and use the appropriate methods and equipment to account for obstructions from cobbles, during the installation of sheet piles or excavations.

NSSP 2 – Surface Water Control and Dewatering (Addition to OPSS 518)

The Contractor shall take necessary measures for diversion of surface water and drainage, and to lower the prevailing groundwater level to a minimum of 0.5 m below the base of the excavations to allow for construction work within the overburden in-the-dry.

The subsoil conditions encountered at this site are relatively pervious in nature. The Contractor shall be responsible for designing and implementing measures for surface water control and dewatering. The dewatering design and the implementation shall prevent unsafe conditions, such as sloughing, base heave, or boiling under unbalanced hydrostatic conditions. The contractor is also advised that damming of the creek and diversion of the flow by pumping through temporary conduits for the staging of construction will likely be required at this site.

NSSP 3 – Excavation and Slope Stability (Addition to OPSS 902 and OPSS)

The contractor is advised that the subsoils at this site require careful design for excavation including fill slope geometries and shoring schemes for the removal of part of the existing cast-in-place concrete culvert and to maintain the stability of the culvert that will be left in place for diversion of traffic. The contractor is also advised to restrict the stockpiling of material and the placement of heavy equipment near the crest of the slope, in order to prevent slope instabilities. The contractor shall be responsible for carrying out slope stability analyses and design of excavation to determine stable slope geometries, temporary roadway protection schemes, and shoring schemes required for their operations.



NSSP 4 – Settlement Management (Addition to OPSS 902)

The contractor is advised that their design and construction methods should minimize additional loading in excess of existing loads on the soil at the founding level. Increases in loading in excess of existing levels will cause settlements that may be excessive and may exceed the tolerable limit.