Peto MacCallum Ltd.
CONSULTING ENGINEERS

FOUNDATION INVESTIGATION AND DESIGN REPORT

for

FORDE CREEK CULVERT REPLACEMENT
SITE NO. 39W-008/C
HIGHWAY 11- STATION 15+158 - STUDHOLM TOWNSHIP
DISTRICT OF NEW LISKEARD, ONTARIO
ASSIGNMENT NO. 5015-E-0009
GWP 5213-05-00
WP 5840-05-01

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PML Ref.: 16TF013A
Index No.: 170FIR and 171FDR
GEOCRES No.: 42F-58
May 7, 2018

Peto MacCallum Ltd.
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PART A - FOUNDATION INVESTIGATION REPORT

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TABLE OF CONTENTS

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Forde Creek Culvert Replacement
Site No. 39W-008/C
Highway 11- Station 15+158
Studholm Township, New Liskeard District, Ontario
Assignment No. 5015-E-0009, GWP 5213-05-00, WP 5840-05-01

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. The revised assignment involves three contracts that were assigned to be carried out under three 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, 6.6 km west of the intersection of Highway 631 and Highway 11. The location of the culvert is at the approximate Sta. 15+158 on Highway 11, in the Township of Studholm, 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 Forde Creek flows from north to south. Generally, the site surrounding the culvert is covered with bushes and grass. The area along the highway on both, north and south sides is heavily wooded.

The information provided on the Request for Quotation (RFQ) dated March 2016 and the information received from the GHD Ltd. dated January 8, 2018, indicate that the existing structure is a corrugated steel pipe ellipse (CSP Ellipse) culvert with a total span of 3.6 m, 2.6 m rise, and 18.8 m long. The fill above the deck is 2.3 m high. This culvert was constructed in 1982 and the roadway accommodates two lanes of vehicular traffic.

The inspection report dated September 25, 2015, indicates that light corrosion of protective coating on the culvert barrels from 200 mm above water line down to invert and build-up of rocks at the inlet were noted. The rock builds up at the inlet may have fallen from the existing rock fill above the crown of the culvert.

3. FIELD INVESTIGATION PROCEDURES

The PML staff visited the site on August 9 and 25, 2016, to mark out the borehole locations. 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 on August 10, 11 and 26, 2016 and 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 (MTM Zone ON-10). PML used the survey data provided by Callon Dietz Inc. for preparation of 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, who is 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 16-008-1,16-008-2, 16-008-3 and 16-008-4 to maximum depths ranging from 6.9 m to 11.1 m (El. 248.3 to El. 247.5). Boreholes 16-008-1 and 16-008-2 were located on the highway shoulders and Boreholes 16-008-3 and 16-008-4 were located at the toe of the embankment near the inlet and outlet of the culvert, respectively. These boreholes were advanced using hollow stem augers and NW casing powered by a track-mounted drill rig. Borehole 16-008-04 was advanced using a tripod and wash boring, and the borehole was extended from 6.1 m to 7.1 m depth by conducting Dynamic Cone Penetration (DCP) test.

Representative soil samples were recovered from the boreholes at 0.75 m intervals to a depth of 7.6 m, using a conventional 51 mm O.D split spoon sampler in accordance with the Standard Penetration Test (SPT) procedure. Below 7.6 m depth, frequency of sampling was increased to 1.5 m intervals. 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 laboratory owned by PML, located in Toronto. The laboratory testing program included the following:

- Natural moisture content determinations (32)
- Grain size distribution analyses (6)
- 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 8-GS-1 and 8-GS-2. Results of the Atterberg limit tests are provided on Figure 8-PC-1. All of the test results are summarized on the attached Record of Borehole sheets.

One soil sample from the sandy silt to 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 provided by AGAT laboratories are presented in Appendix B.

5. SITE GEOLOGY AND SUBSURFACE CONDITIONS

5.1 Site Geology

Based on the Bedrock Geology map (MRD126-REV1, 2011) published by the Ontario Ministry of Northern Development and Mines (MNDM), the culvert site lies within the Superior Province of the Precambrian rock formations. The project area consists mainly of Archean, Metasedimentary (Supercrustal) rocks (specifically, Paragneiss and Migmatite) and Muscavite-Bearing Granite rocks. The Quaternary Geology map published by the MNDM indicates that the surface conditions in the vicinity of the culvert site consist of Glaciomarine deposits; silt and clay, minor sand basins and quiet water deposits.

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 8/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 4.9 m to 5.3 m of gravelly sand (fill) below the existing grade of highway shoulders (Boreholes 16-008-1 and 16-008-2) and 2.0 m to 2.3 m of clayey silt fill near the inlet and outlet. The fill material is followed by sandy silt to silt (glacial till) deposit to the maximum investigation depth of 11.1 m below the grade. In the case of Borehole 16-008-3, 200 mm thick topsoil was encountered immediately below the surface. For classification purposes, the soils encountered at this site can be divided into four distinct zones.

a) Gravelly Sand, Trace Silt (Fill)
b) Topsoil
c) Clayey Silt, Some Sand, Trace Gravel (Fill)
d) Sandy Silt to Silt, Trace Clay, Trace Gravel (Glacial Till)

5.2.1 Gravelly Sand, Trace Silt (Fill)

This gravelly sand fill was encountered in Boreholes 16-008-1 and 16-008-2, immediately below the surface of the highway shoulders. This fill layer ranges in thickness from 4.9 m to 5.3 m and extends to a maximum depth of 5.3 m (El. 253.4) below the existing grade. The SPT values in this fill layer vary from 9 blows to 28 blows, indicating loose to compact state of denseness.

The moisture content of this fill material varies between 4.7% and 24.4%. The result of the sieve analysis test performed on one representative sample from this layer is provided on Figure 8-GS-1. The test result indicates that this deposit consists of 3% gravel, 26% sand, 57% silt and 14% clay sized particles.

5.2.2 Topsoil

Topsoil was encountered only in Borehole 16-008-3, immediately below the surface and the thickness of this layer was observed to be 200 mm. This layer extends to a maximum elevation of 255.0.

5.2.3 Clayey Silt, Some Sand, Trace Gravel (Fill)

This clayey silt fill was encountered in Borehole 16-008-3 below the topsoil and in Borehole 16-008-4, it was encountered immediately below the surface. This fill layer ranges in thickness from 2.0 m to 2.3 m and extends to a maximum depth of 2.5 m (El. 252.7) below the existing ground surface. The SPT values in this fill layer vary from 3 blows to 28 blows, indicating soft to very stiff consistency. The moisture content of this fill material varies between 13.2% and 25.4%.

5.2.4 Sandy Silt to Silt, Trace Clay, Trace Gravel (Glacial Till)

The fill layers are immediately underlain by this sandy silt to silt (glacial till) deposit, which extends to a maximum investigation depth of 11.1 m (El. 247.5). This glacial till deposit consists of varying proportions of silt and sand. The SPT N values at about El. 253.4 to El. 251.8 vary from 4 blows to 30 blows, indicating loose to compact denseness. Below El. 251.8, the SPT values range from 66 blows to refusal, indicating very dense state of compaction. This deposit was not fully penetrated to establish the thickness of this deposit. However, Borehole 16-008-4 was advanced below El. 249.4 by conducting dynamic cone penetration (DCP) test and refusal to dynamic cone penetration was encountered at El. 247.8.

The moisture content of samples tested from this deposit, vary from 7.9% to 12.3% with an average value of 9.8%. The Atterberg limit test results of five representative samples are presented on

Figure 8-PC-1. The test results indicate liquid limit values ranging from 15 to 17, plastic limit values of 12, and corresponding plasticity index values ranging from 3 to 5. Based on the results of Atterberg limit tests, the soil may be classified as silt of low plasticity (ML) in the Unified Soil Classification System (USCS). The results of the sieve analysis test performed on five representative samples from this layer are provided on Figure 8-GS-2. The test result indicates that this deposit consists of 5% to 10% gravel, 32% to 37% sand, 45% to 48% silt and 11% to 13% clay.

5.3 Groundwater

The groundwater level was measured upon completion of drilling and was observed at depths ranging from 2.1 m to 4.9 m (El. 252.8 to El. 253.9), below the existing grade of the road.

The water level in the creek was observed at El. 254.4 during the fieldwork.

Groundwater levels may fluctuate due to the influence of precipitation and seasonal changes. 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 5.4:-Soil Chemical Analysis Results

BOREHOLE NO.	SAMPLE	DEPTH / ELEVATION (m)	SOIL TYPE	SULPHATE (µg/g)	CHLORIDE (µg/g)	pH	RESISTIVITY (Ohm-cm)
16-008-03	SS-7	5.3-5.9 / 249.9-249.3	Sandy Silt to Silt (Glacial Till)	47	7	8.56	5990

6. CLOSURE

Mr. F. Portela and Mr. K. Dally, 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., Principal Consultant, conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

LICENSED PROFESSIONAL ENGINEER
M. VASAVITHASAN
May 07, 2018
PROVINCE OF ONTARIO

Asieh Khadem

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

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Senior Engineer, Geotechnical Services

REGISTERED PROFESSIONAL ENGINEER
C M P Nascimento
May 7, 2018
PROVINCE OF ONTARIO

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

AK/MV/CN:nk-ap

APPENDIX A

Site Photographs

Photograph P1: Looking east from Highway 11 eastbound lane shoulder at the location of Borehole 16-008-1 (August 10, 2016).

Photograph P2: Looking south-west from Highway 11 eastbound lane shoulder at the location of Borehole 16-008-3 (August 10, 2016).

Photograph P3: Looking north-west at the culvert inlet (August 10, 2016).

Photograph P4: Looking south-east at the culvert outlet (August 10, 2016.)

Photograph P5: Looking north-west from the location of Borehole 16-008-4 (August 26, 2016).

APPENDIX B

Borehole Locations Plan and Soil Strata at Structure 39W-008/C

Explanation of Terms Used in Report

Record of Borehole Sheets

Results of Grain Size Distribution Analyses – Figures 8-GS-1 and 8-GS-2

Plasticity Chart – Figure 8-PC-1

Chemical Test Results

CONT No GWP No 5213-05-00 WP No 5840-05-01		SHEET
STA. ~15+158 HIGHWAY 11 BOREHOLE LOCATIONS AND SOIL STRATA		

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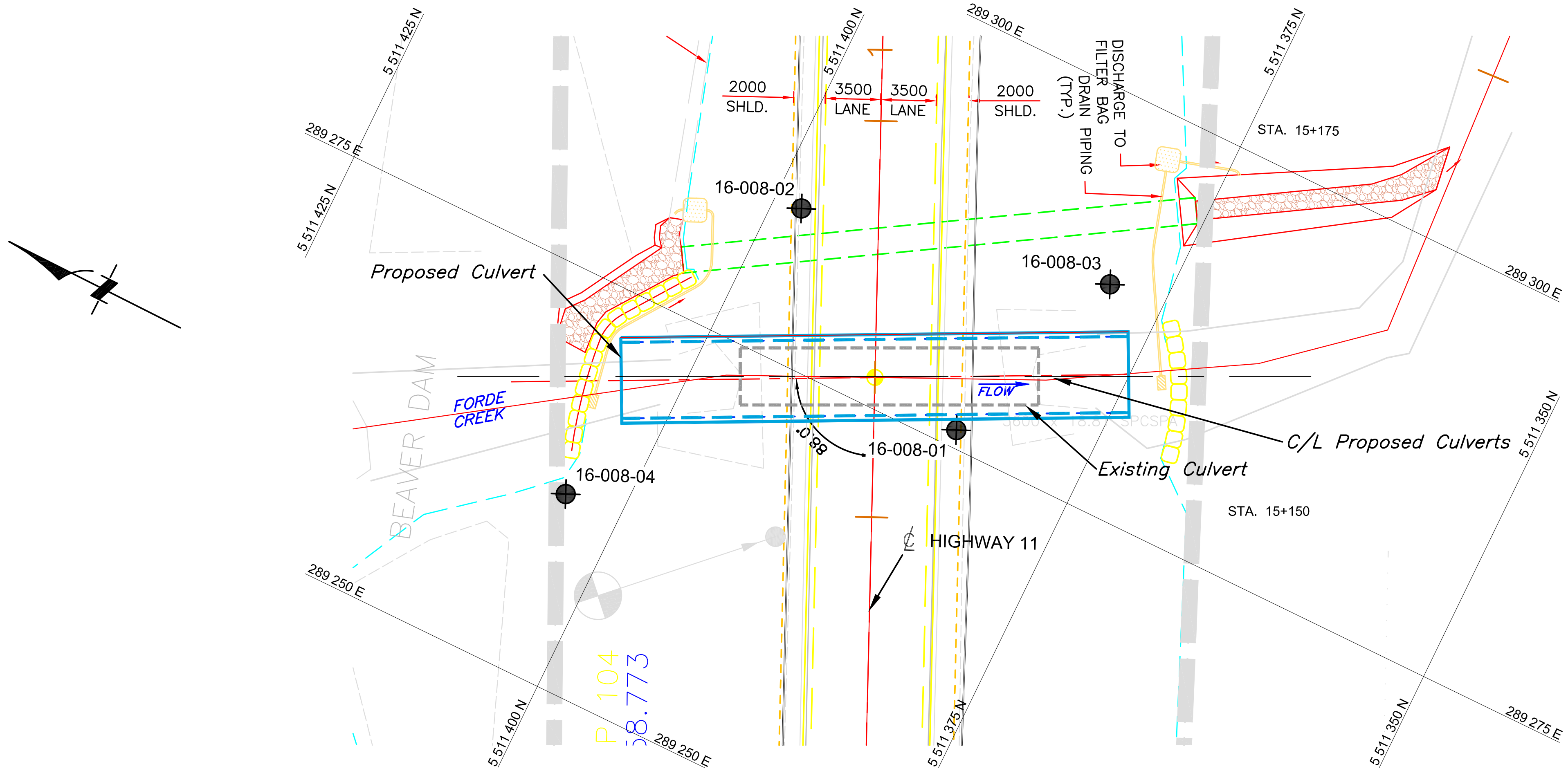
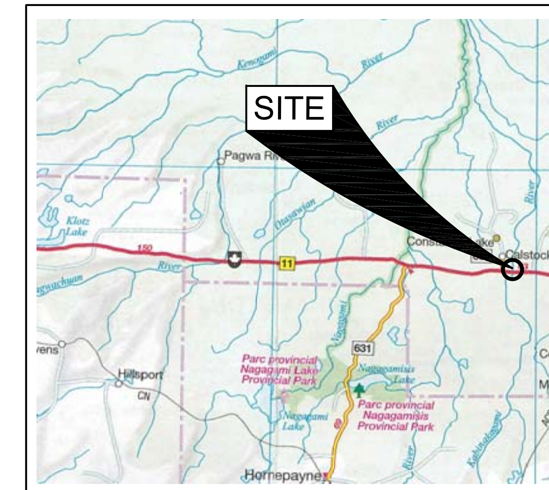


PLAN

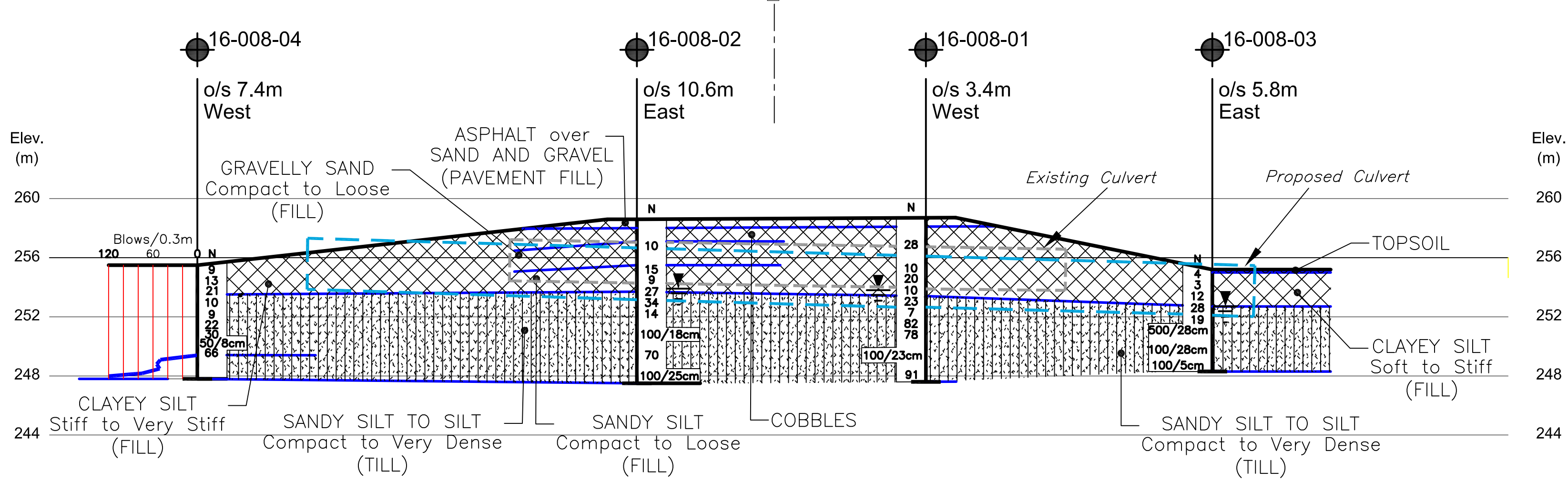
SCALE 5 0 5 10m



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 August 2016
- WH Penetration due to weight of hammer and rod

BH No	ELEVATION	NORTHINGS	EASTINGS
16-008-01	258.7	5 511 383.3	289 276.1
16-008-02	258.6	5 511 398.2	289 284.4
16-008-03	255.2	5 511 378.6	289 288.6
16-008-04	255.5	5 511 403.7	289 261.7



PROFILE A - A

SCALE

HORIZONTAL 2.5 0 2.5 5m

VERTICAL 5 0 5 10m

NOTES:

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

REF GHD Drawing: X-11116826_39W-008_Base.dwg undated

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

REVISIONS DATE	BY	DESCRIPTION

Geocres No. 42F-58

HWY No 11			DIST NEW LISKEARD
SUBM'D NA	CHECKED LY	DATE MAY 7, 2018	SITE 39W-008/C
DRAWN NA	CHECKED MV	APPROVED CN	DWG 008/C-1

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/0.3 m)	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:

RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	*POOR*	*FAIR*	*GOOD*	*EXCELLENT*

JOINTING AND BEDDING:

SPACING	50mm	50 - 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	P 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
r_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_t	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

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

Peto MacCallum Ltd. CONSULTING ENGINEERS

Foundation Design

RECORD OF BOREHOLE No 16-008-01

METRIC

G.W.P. 5213-05-00 LOCATION Co-ords: 5 511 383.3 N ; 289 276.1 E ORIGINATED BY K.D.

DIST New Leaskerd BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY N.L.

DATUM Geodetic HWY 11 DATE August 10, 2016 CHECKED BY M.V.

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
258.7	Ground Surface							
0.0	260 mm asphalt over sand and gravel, trace silt (PAVEMENT FILL)							
258.1 / 0.6	Gravelly sand, trace silt; Compact Brown Damp					258		
	occasional cobbles	1	SS	28		257		
		2	SS	10		256, 255		
		3	SS	20				
	(FILL)	4	SS	10	∇ ▼	254		
253.4 / 5.3	Sandy silt to silt trace clay, trace gravel; Loose to compact Grey Moist	5	SS	23		253		
		6	SS	7		252		
	Very dense	7	SS	82		251		
		8	SS	78		250		
		9	SS	100/23cm			H	10 32 45 13
	(TILL)					249, 248		
247.6 / 11.1	End of borehole	10	SS	91				

* 2016 08 10

∇ Water level observed during drilling

▼ Water level measured after drilling

Legend: Dynamic cone penetration resistance plot (20, 40, 60, 80, 100); Shear strength kPa: ○ Unconfined, ● Field vane, ● Quick triaxial, × Lab vane (20, 40, 60, 80, 100); Plastic limit w_P, Natural moisture content w, Liquid limit w_L; Water content (%) 20 40 60; Unit weight γ kN/m³.

●7, ×5: Numbers refer to Sensitivity

20 / 15 — 5 / 10 (%) STRAIN AT FAILURE

ON MTO_VER3 NEW LOGO 16TF013A-4.GPJ ON_MOT.GDT 4/25/18

Peto MacCallum Ltd.
CONSULTING ENGINEERS

Foundation Design

RECORD OF BOREHOLE No 16-008-02

METRIC

G.W.P. 5213-05-00 LOCATION Co-ords: 5 511 398.2 N ; 289 284.4 E ORIGINATED BY K.D.

DIST New Leaskerd BOREHOLE TYPE C.F.H.S.A., NW Casing and Wash Boring COMPILED BY N.L.

DATUM Geodetic HWY 11 DATE August 11, 2016 CHECKED BY M.V.

ELEV DEPTH	DESCRIPTION (SOIL PROFILE)	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
258.6	Ground Surface							
0.0	80mm asphalt over sand and gravel, trace silt (PAVEMENT FILL)							
258.0 / 0.6	occasional cobbles					258		
	Gravelly sand. Compact to loose. Brown. Dry	1	SS	10		257		
						256		
	Sandy silt, trace clay, trace gravel. Moist to wet (FILL)	2	SS	15		255		3 26 57 14
		3	SS	9	∇	254		
253.7 / 4.9	Sandy silt to silt, trace clay, trace gravel. Compact to very dense. Grey. Moist	4	SS	27				
		5	SS	34		253		
		6	SS	14		252		
		7	SS	100/18cm		251	H	5 37 47 11
						250		
		8	SS	70		249		
	(TILL)					248		
247.5 / 11.1	End of borehole	9	SS	100/25cm				

* 2016 08 11

Water level observed during drilling

C.F.H.S.A. denotes Continuous Flight Hollow Stem Augers

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED ● FIELD VANE ● QUICK TRIAXIAL × LAB VANE — 20 40 60 80 100
WATER CONTENT (%): 20 40 60 (w_P, w, w_L)
UNIT WEIGHT γ kN/m³

$●^7$, $×^5$: Numbers refer to Sensitivity

20 / 15 — 5 / 10 (%) STRAIN AT FAILURE

Peto MacCallum Ltd. CONSULTING ENGINEERS

Foundation Design

RECORD OF BOREHOLE No 16-008-03

METRIC

G.W.P. 5213-05-00 LOCATION Co-ords: 5 511 378.6 N ; 289 288.6 E ORIGINATED BY K.D.

DIST New Leaskerd BOREHOLE TYPE C.F.H.S.A., NW Casing and Wash Boring COMPILED BY N.L.

DATUM Geodetic HWY 11 DATE August 10, 2016 CHECKED BY M.V.

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
255.2	Ground Surface							
0.0	Topsoil							
255.0 0.2	Clayey silt some sand, trace gravel wood pieces. Soft to stiff, Grey, Wet (FILL)	1	SS	4		255		
		2	SS	3		254		
		3	SS	12		253		
252.7 2.5	Sandy silt to silt trace clay, trace gravel. Compact, Grey, Moist	4	SS	28	∇			
		5	SS	19		252		
	Very dense (TILL)	6	SS	100/28cm		251	H	7 34 47 12
		7	SS	100/28cm		250	H	
						249		
248.3		8	SS	100/5cm				
6.9	End of borehole							

* 2016 08 11

Water level observed during drilling

C.F.H.S.A. denotes Continuous Flight Hollow Stem Augers

SOIL PROFILE; SAMPLES; STRAT PLOT; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: ○ UNCONFINED, ● FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³

●7, ×5: Numbers refer to Sensitivity   20 / 15 — 5 / 10 (%) STRAIN AT FAILURE

Peto MacCallum Ltd.
CONSULTING ENGINEERS

Foundation Design

RECORD OF BOREHOLE No 16-008-04

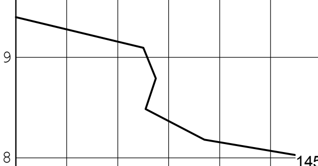
METRIC

G.W.P. 5213-05-00 LOCATION Co-ords: 5 511 403.7 N ; 289 261.7 E ORIGINATED BY F.P.

DIST New Leaskerd BOREHOLE TYPE Tripod, Wash Boring and Cone Penetration COMPILED BY N.L.

DATUM Geodetic HWY 11 DATE August 26, 2016 CHECKED BY M.V.

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
255.5	Ground Surface										
0.0	Clayey silt, some sand, trace gravel, wood pieces. Stiff to very stiff, Grey, Moist		1	SS	9		255				
			2	SS	13		254				
253.5	(FILL)		3	SS	21	∇					
2.0	Sandy silt to silt, trace clay, trace gravel. Compact, Brown, Moist		4	SS	10		253				
			5	SS	9		252				
			6	SS	22				H		6 37 45 12
			7	SS	30		251				
	Very dense		8	SS	50/8cm		250				
249.4	(TILL)		9	SS	66						6 34 48 12
6.1	End of borehole. Switched to dynamic cone penetration test. Probable sandy silt to silt (TILL)						249				
247.8							248	145			
7.7	End of dynamic cone penetration test							120/5cm			



* 2016 08 26

Water level observed during drilling

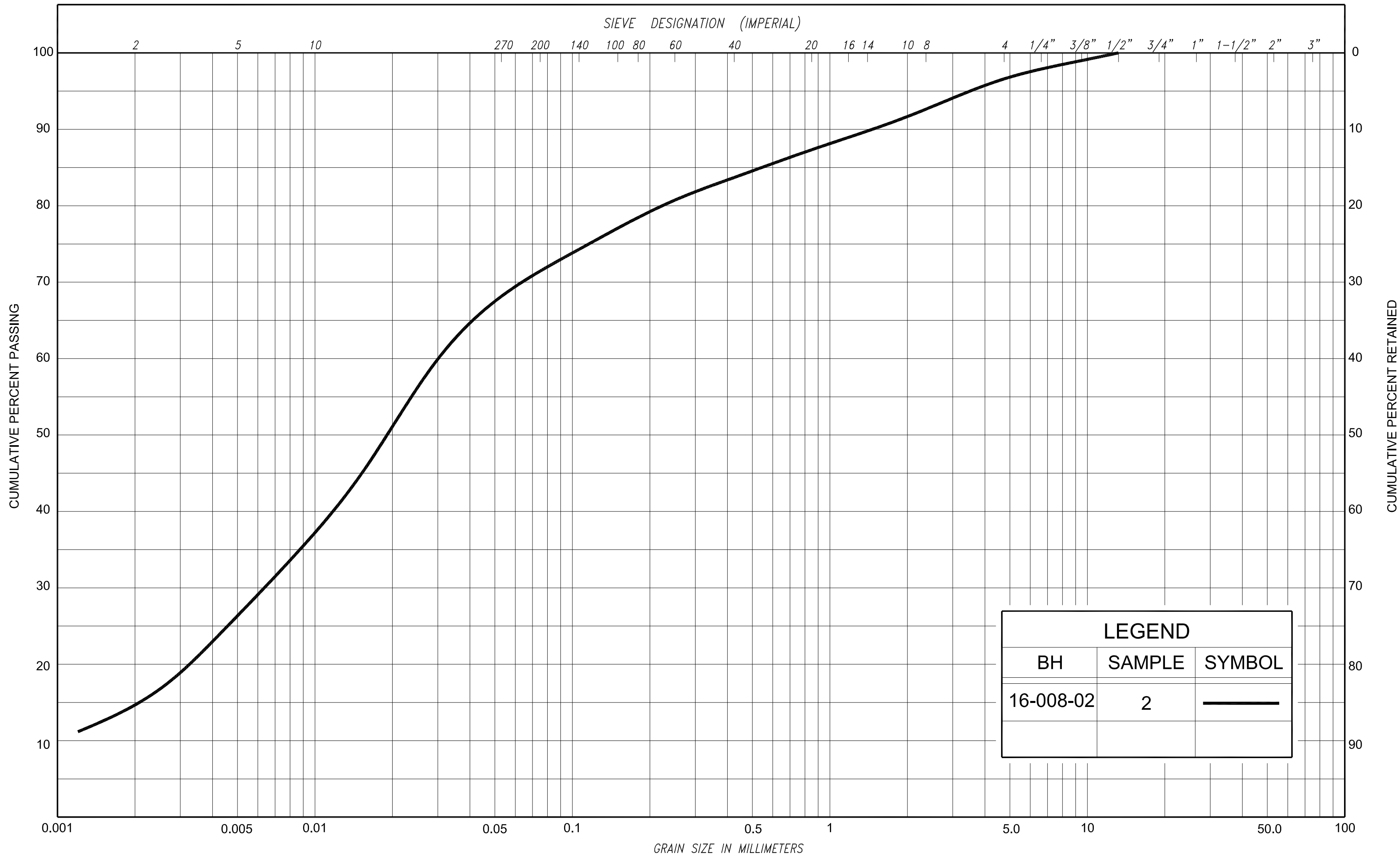
Penetrometer test

Shear strength legend: ○ UNCONFINED; ● QUICK TRIAXIAL; ● FIELD VANE; × LAB VANE

Water content legend: PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L

●7, ×5 : Numbers refer to Sensitivity

20 / 15 —○— 5 / 10 (%) STRAIN AT FAILURE



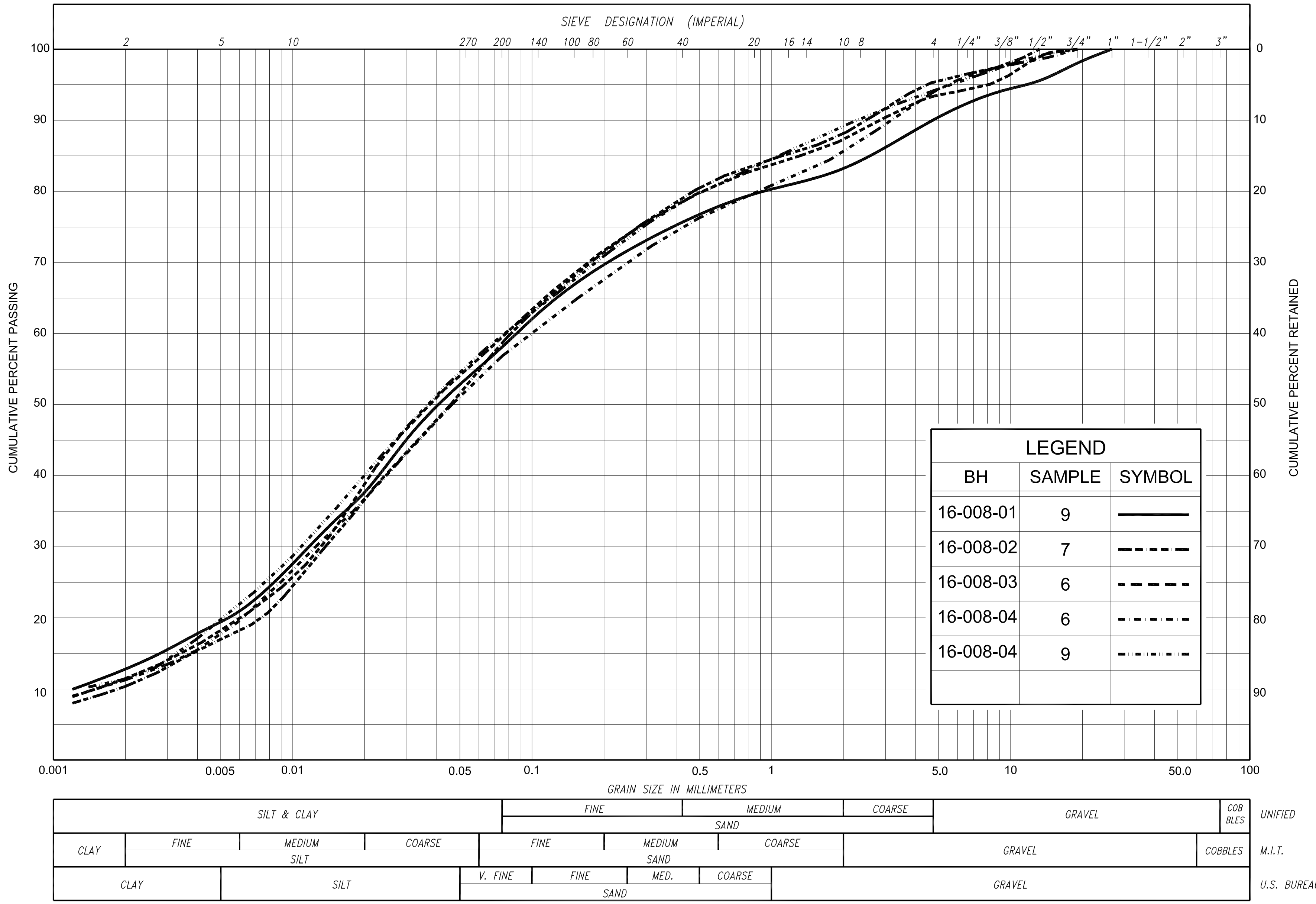
SILT & CLAY				SAND: FINE	SAND: MEDIUM	SAND: COARSE	GRAVEL	COBBLES	UNIFIED
CLAY	SILT: FINE	SILT: MEDIUM	SILT: COARSE	SAND: FINE	SAND: MEDIUM	SAND: COARSE	GRAVEL	COBBLES	M.I.T.
CLAY	SILT		SAND: V. FINE	SAND: FINE	SAND: MED.	SAND: COARSE	GRAVEL		U.S. BUREAU

Ontario

GRAIN SIZE DISTRIBUTION

SANDY SILT, trace clay, trace gravel
(FILL)

FIG No.	008-GS-1
HWY	11
G.W.P.	5213-05-00

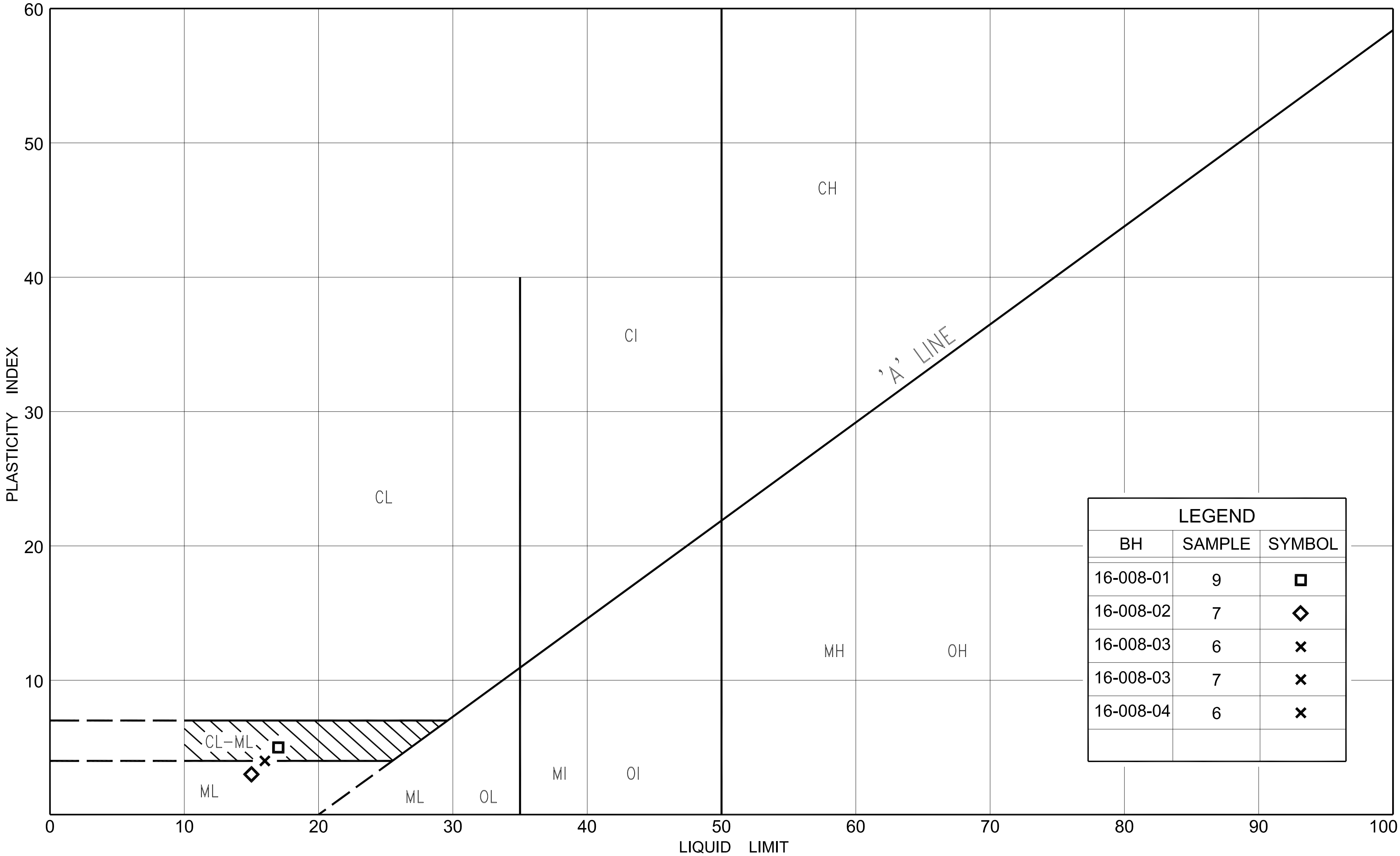


Ontario

GRAIN SIZE DISTRIBUTION

SANDY SILT TO SILT, trace clay, trace gravel
(TILL)

FIG No.	008-GS-2
HWY	11
G.W.P.	5213-05-00



Ontario

PLASTICITY CHART

SANDY SILT TO SILT, trace clay, trace gravel (ML)
(TILL)

FIG No.	008-PC-1
HWY	11
G.W.P.	5213-05-00

Certificate of Analysis

AGAT Laboratories

AGAT WORK ORDER: 16T131831
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:Kyle Daly

Corrosivity Package

DATE RECEIVED: 2016-08-29
DATE REPORTED: 2016-09-07

				BH16-004-02	BH16-008-03	BH16-112-04	BH16-131-04	BH16-133-02
			SAMPLE DESCRIPTION:	SS7	SS7	SS4A	SS4	SS3
			SAMPLE TYPE:	Soil	Soil	Soil	Soil	Soil
			DATE SAMPLED:	8/29/2016	8/29/2016	8/29/2016	8/29/2016	8/29/2016
Parameter	**Unit**	**G / S**	**RDL**	**7813058**	**7813065**	**7813066**	**7813067**	**7813068**
Chloride (2:1)	µg/g		2	16	7	159	44	559
Sulphate (2:1)	µg/g		2	62	47	43	3	14
pH (2:1)	pH Units		NA	8.44	8.56	8.07	8.61	8.37
Electrical Conductivity (2:1)	mS/cm		0.005	0.216	0.167	0.441	0.179	0.986
Resistivity (2:1)	ohm.cm		1	4630	5990	2270	5590	1010
Redox Potential (2:1)	mV		5	258	249	261	243	254

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

7813058-7813068 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

5835 COOPERS AVENUE
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Quality Assurance

CLIENT NAME: PETO MACCALLUM LIMITED | **AGAT WORK ORDER: 16T131831**
PROJECT: 16TF013A | **ATTENTION TO: Lul Yimam**
SAMPLING SITE: | **SAMPLED BY:Kyle Daly**

Soil Analysis

RPT Date: Sep 07, 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															
Chloride (2:1)	7813068	7813068	559	551	1.4%	< 2	91%	80%	120%	102%	80%	120%	104%	70%	130%
Sulphate (2:1)	7813068	7813068	14	14	0.0%	< 2	96%	80%	120%	102%	80%	120%	101%	70%	130%
pH (2:1)	7813068	7813068	8.37	8.29	1.0%	NA	101%	90%	110%	NA			NA		
Electrical Conductivity (2:1)	7813068	7813068	0.986	0.986	0.0%	< 0.005	100%	90%	110%	NA			NA		
Redox Potential (2:1)	7813068	7813068	254	254	0.0%	< 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

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Method Summary

CLIENT NAME: PETO MACCALLUM LIMITED **AGAT WORK ORDER: 16T131831**

PROJECT: 16TF013A **ATTENTION TO: Lul Yimam**

SAMPLING SITE: **SAMPLED BY:Kyle Daly**

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
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

Peto MacCallum Ltd.
CONSULTING ENGINEERS

PART B –FOUNDATION DESIGN REPORT

for

FORDE CREEK CULVERT REPLACEMENT
SITE NO. 39W-008/C
HIGHWAY 11- STATION 15+158 - STUDHOLM TOWNSHIP
DISTRICT OF NEW LISKEARD, ONTARIO
ASSIGNMENT NO. 5015-E-0009
GWP 5213-05-00
WP 5840-05-01

PETO MacCALLUM LTD.
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Distribution:
3 cc: GHD for distribution to MTO
Project Manager + 1 digital copy (pdf)
1 cc: GHD for distribution to MTO
Foundations Section + 1 digital copy (pdf)
1 cc: GHD + 1 digital copy (pdf)
1 cc: PML Toronto
1 cc: PML Kitchener

PML Ref.: 16TF013A
Index No.: 171FDR
GEOCRES No.: 42F-58
May 7, 2018

TABLE OF CONTENTS

PART B - FOUNDATION DESIGN REPORT

PART B - FOUNDATION DESIGN REPORT
Forde Creek Culvert Replacement
Site No. 39W-008/C
Highway 11- Station 15+158
Studholm Township, New Liskeard District, Ontario
Assignment No. 5015-E-0009, GWP 5213-05-00, WP 5840-05-01

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 contractor. The contractors 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, 6.6 km west of the intersection of Highway 631 and Highway 11 (Sta. 15+158) in the Township of Studholm, District of New Liskeard.

The discussions and recommendations presented in this report are based on the information received by PML on January 8, 2018 and the factual data obtained during the geotechnical investigation carried out by PML.

8.2 Existing Culvert

The existing structure is a corrugated steel pipe ellipse (CSP Ellipse) culvert with a total span of 3.6 m, 2.6 m rise and 18.8 m long. The structure supports 2.3 m high fill above the deck. Based on the information provided by GHD, the invert of the existing culvert at the centerline of Highway 11 is at approximate El. 253.9 and the embankment above the creek bed is approximately 5.0 m high.

This culvert was constructed in 1982 and the road accommodates two lanes of vehicular traffic. the inspection carried out on 25 September 2015, indicates that light corrosion of protective coating 0.2 m above water line down to invert and build-up of rocks at inlet, were noted on the culvert barrels. In the case of Wearing surface (Asphalt) at top of the structure, narrow crack down centreline of roadway was observed.

The foundation details of the existing culvert are not available. However, considering the width of the culvert and the fill height above the deck, the load imposed by the exiting culvert at the founding level may not exceed 165 to 180 KN per meter length of the culvert.

8.3 Proposed Culvert

Based on the information provided by GHD Ltd. Dated January 8, 2018, it is proposed to replace the existing culvert with a 32.0 m long precast concrete box culvert with an opening size of 4.8 m span and 2.4 m rise, along the same vertical and horizontal alignments of the existing CSP Ellipse culvert.

The preliminary structural information provided by GHD indicates that the proposed invert of the replacement box culvert slopes down from about El. 254.0 at the inlet to El. 253.46 at the outlet. The founding levels of the subgrade at the inlet and outlet are proposed to be at El. 253.40 and El. 252.86, respectively allowing for 300 mm thick concrete floor and approximately 300 mm of granular bedding materials. The replacement culvert is expected to be constructed 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. 258.8, which will result in a fill height of 2.67 m, including the pavement structure, 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 4.9 m to 5.3 m of gravelly sand (fill) below the existing grade of highway shoulders (Boreholes 16-008-1 and 16-008-2) and 2.0 m to 2.3 m of clayey silt fill in near the inlet and outlet. The fill material is followed by sandy silt to silt (glacial till) to the maximum investigation depth of 11.1 m below the grade. In the case of Borehole 16-008-3, 200 mm thick topsoil was encountered immediately below the surface. The water level in the creek was observed at El. 254.4 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 concrete box culvert will be placed at about El. 253.13±. The subsoil conditions below the proposed founding level are capable of supporting precast concrete box culvert. The option of a precast concrete box culvert will require at least 75 mm of leveling course meeting the requirement of OPSS 422.07.08 and bedding material should be from Group 1 or Group II of Table 1, as specified in OPSS 422.05.13. The bedding for the replacement culvert should be placed in accordance with Section 422.07.07 of OPSS 422.

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 sandy silt to silt till subgrade material below invert. For the design of the proposed precast concrete box culvert, a factored geotechnical resistance of 250 kPa at ULS and 180 kPa resistance at SLS may be utilized. A total settlement of 25 mm under the geotechnical resistance at SLS may be expected and majority of the settlements are expected to take place upon completion of construction.

The removal of the existing foundation may cause disturbance to the founding surface of the proposed replacement culvert. In addition, the sandy silt to silt (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 subsoil conditions below the proposed founding level of the culvert are capable of adequately supporting the cast-in-place concrete box culvert. However, the existing sandy silt to silt soil below the proposed founding surface will require a cut-off wall to prevent scour or washout. Further, construction under 1.3 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. 253.13 and designed using a geotechnical resistance of 250 kPa at ULS and 180 kPa at SLS. Same as in option 1, the total settlement is not expected to exceed 20 mm and the associated differential settlement will be within about 15 mm.

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 loose to very dense sandy silt to silt (glacial till) encountered below the proposed founding level of the replacement culvert is susceptible for scour. Section C1.9.11.1 of the Canadian Highway Bridge Design Code commentary (CHBDC 2014) suggests avoiding placing open footings on soils that are susceptible to scour. For these reason, this option is not recommended.

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**
Advantages: 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	Advantages: 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	Advantages: 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
Disadvantages: 1. Natural stream bed will not remain intact 2. Cause sediment accumulation in the upstream of the channel 3. Possibility for degradation of subgrade	Disadvantages: 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 1.3 m high water	Disadvantages: 1. Probability of uneven or differential settlements are possible 2. Limited ability to withstand differential settlements 3. Sandy silt to silt soil below the invert level is susceptible to scour
Cost of Construction: Total Cost $ 15,500/m	Cost of Construction: Total Cost $ 16,500/m	Cost of Construction: Total Cost $ 16,000/m
Recommended	**Technically Feasible but Not Recommended**	**Technically Not Feasible; Not Recommended**

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 253.13 is the preferred option for the replacement of the existing culvert.

Options 2 is technically feasible but not recommended considering the construction difficulties. Option 3 is technically not feasible. As outlined previously, considering the construction difficulties, the cost of dewatering 1.3 m high groundwater, and technical reasons, Options 2 and 3 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 assumed water level (kN/m^3)
γ' = unit weight of submerged backfill (γ - γ_w) material below assumed water level (kN/m^3)
γ_w = unit weight of water (9.8 kN/m^3)
h_1 = depth below final grade (m), above assumed water level
h_2 = depth below assumed 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 $Ø$ = angle of internal friction of retained soil
δ = angle of friction between soil and wall

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	OPSS GRANULAR A	OPSS GRANULAR B TYPE II and III
Angle of Internal Friction, degrees	35°	30°
Unit Weight, kN/m^3	22.5 ± 0.5	21.5 ± 0.5
Coefficient of Active Earth Pressure (K_a)	0.27	0.33
Coefficient of Earth Pressure at Rest (K_o)	0.43	0.50
Coefficient of Passive Earth Pressure (K_p)	3.69	3.00

Sufficient movement of the structure wall may 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 400 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 widening or increase in the profile grade of the road and it will be maintained at El. 258.8. 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 3090.100, 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 (Sa (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 (PGAref) based on these Sa (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.

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 dense to very dense glacial till 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 very dense glacial till encountered below El. 251.9 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 (Ø°)	UNIT WEIGHT(ϒ) KN/m^3	C_U, KN/m^2
258.7	253.4	Gravelly sand (Fill)	30	18	0
253.4	247.5	Loose to very dense Sandy silt to silt (Till)	32	21	0

Note: Submerged unit weight should be used below water level

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 OHSA classification purposes, the fill materials should be classified as Type 3 soils and the sandy silt to 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. 252.8 and El. 253.9, and the excavation to the founding level will have to be carried out under 1.3 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 NSSP FOUN0003 (Amendment to OPSS 902), in addition to the requirements of NSSP provided in Appendix D.

14. SOIL CORROSION

One sample from the till deposit was tested for soil corrosivity 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 47 µg/g (0.0047%) reported in Table 5-1 for the sandy silt to silt till 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 0.0007% (7 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. The 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 5990 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 8.56 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., Principal Consultant, conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

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APPENDIX C

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 501	Construction Specification for Compacting
OPSS 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
NSSP FOUN0003	Dewatering Structure Excavations (Amendment to OPSS 902)
OPSS 539	Temporary Protection Systems
OPSS 902	Excavation and Backfilling of Structures
OPSD 810-010	General Rip-Rap Layout Sewer and Culvert Outlets
OPSD 812.010	Cut Off Wall for Structural Plate Pipe Arch and Circular Csp
OPSD 3090.100	Foundation, Frost Penetration depths for Northern Ontario
OPSD 3101.150	Walls Abutment, Backfill Minimum Granular Requirement

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 517 and NSSP FOUN0003)

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 or on the surface of bedrock in-the-dry, whichever is applicable.

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.