



**FOUNDATION INVESTIGATION AND DESIGN REPORT**

**for**

**UNNAMED CREEK CULVERT REPLACEMENT**

**SITE NO. 39W-231/C**

**HIGHWAY 11- STATION 24+441 - KOHLER TOWNSHIP**

**DISTRICT OF NEW LISKEARD, ONTARIO**

**ASSIGNMENT NO. 5015-E-0009**

**GWP 5047-07-00**

**WP 5370-11-03**

PETO MacCALLUM LTD.  
165 CARTWRIGHT AVENUE  
TORONTO, ONTARIO  
M6A 1V5  
Phone: (416) 785-5110  
Fax: (416) 785-5120  
Email: toronto@petomaccallum.com

**Distribution:**

- 3 cc: GHD Ltd. for distribution to MTO  
Project Manager + 1 digital copy (pdf)
- 1 cc: GHD Ltd. for distribution to MTO  
Foundations Section + 1 digital copy (pdf)
- 1 cc: GHD Ltd. + 1 digital copy (pdf)
- 1 cc: PML Toronto
- 1 cc: PML Kitchener

PML Ref.: 16TF013A  
Index No.: 098FIR and 099FDR  
GEOCRES No.: 42F-049  
May 24, 2017



**PART A – FOUNDATION INVESTIGATION REPORT**

**for**

**UNNAMED CREEK CULVERT REPLACEMENT**

**SITE NO. 39W-231/C**

**HIGHWAY 11- STATION 24+441 - KOHLER TOWNSHIP**

**DISTRICT OF NEW LISKEARD, ONTARIO**

**ASSIGNMENT NO. 5015-E-0009**

**GWP 5047-07-00**

**WP 5370-11-03**

PETO MacCALLUM LTD.  
165 CARTWRIGHT AVENUE  
TORONTO, ONTARIO  
M6A 1V5  
Phone: (416) 785-5110  
Fax: (416) 785-5120  
Email: toronto@petomacallum.com

**Distribution:**

- 3 cc: GHD Ltd. for distribution to MTO  
Project Manager + 1 digital copy (pdf)
- 1 cc: GHD Ltd. for distribution to MTO  
Foundations Section + 1 digital copy (pdf)
- 1 cc: GHD Ltd. + 1 digital copy (pdf)
- 1 cc: PML Toronto
- 1 cc: PML Kitchener

PML Ref.: 16TF013A  
Index No.: 098FIR  
GEOCRES No.: 42F-049  
May 24, 2017



## TABLE OF CONTENTS

### PART A - FOUNDATION INVESTIGATION REPORT

1. INTRODUCTION .....	1
2. SITE DESCRIPTION .....	1
3. FIELD INVESTIGATION PROCEDURES .....	2
4. LABORATORY TEST PROCEDURES .....	3
5. SITE GEOLOGY AND SUBSURFACE CONDITIONS .....	4
5.1 Site Geology .....	4
5.2 Subsurface Conditions.....	4
5.2.1 Sandy Silt, Trace Clay, Trace Gravel (Fill) .....	4
5.2.2 Topsoil.....	5
5.2.3 Sandy Silt, Some to Trace Gravel, Trace Clay (Glacial Till) .....	5
5.2.4 Gneiss Bedrock.....	6
5.3 Groundwater .....	6
5.4 Chemical Analysis .....	6
6. CLOSURE .....	7
Appendix A – Site Photographs	
Appendix B – Borehole Locations Plan and Soil Strata at Structure 39W-231/C	
Explanation of Terms Used in Report	
Record of Borehole Sheets	
Results of Grain Size Distribution Analyses – Figures 231-GS-1 and 231-GS-2	
Plasticity Charts – Figures 231-PC-1	
Chemical Test Results	
Rock Core Photograph	
Rock Core Description	

**PART A**  
**FOUNDATION INVESTIGATION REPORT**

for  
Unnamed Creek Culvert Replacement  
Site No. 39W-231/C  
Highway 11- Station 24+441  
Kohler Township, New Liskeard District, Ontario  
Assignment No. 5015-E-0009, GWP 5047-07-00, WP 5370-11-03

---

**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, 27.5 km west of Highway 631. The location of the culvert is at the approximate Sta. 24+441 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 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 are heavily wooded.

The information provided on the Request for Quotation (RFQ) dated March 2016, indicate that the existing structure is a twin cell timber culvert with a total span of 3.5 m, 1.5 m rise and 28 m long. At some point, the culvert was extended on the south side by a 4.0 m long precast concrete box culvert. The fill above the deck is 2.0 m high. This culvert was constructed in 1958 and the roadway accommodates two lanes of vehicular traffic.



The inspection report dated November 20, 2015 indicates that leakage stains through precast units, light scour, light spalling at unsealed lifting holes and exposed corroded rebar were noted on the south side of the culvert barrels. In the case of north side barrels, light to medium rot of north end deck members, minor to moderate crushing of transverse wall timber on all walls, localized to medium rot at soffit timber, light to severe checks and splits were reported. In addition, severe scouring of stream bed at the outlet (north end) was observed.

### **3. FIELD INVESTIGATION PROCEDURES**

The PML staff visited the site on July 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 location of boreholes in the field were established by PML staff using 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 16-231-1, 16-231-2, 16-231-3 and 16-231-4 to maximum depths ranging from 6.3 m to 9.9 m (El. 247.3 to El. 246.4). Boreholes 16-231-1 and 16-231-2 were located on the highway shoulders and Boreholes 16-231-3 and 16-231-4 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 and wash boring. Rock coring was carried out in Borehole 16-231-2 using NQ size double core barrel. Location of boreholes is shown on the attached Drawing 231/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 laboratory owned by PML, located in Toronto. The laboratory testing program included the following:

- Natural moisture content determinations (24)
- Grain size distribution analyses (8)
- Atterberg limits (7)

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 231-GS-1 and 231-GS-2. Results of the Atterberg limit test are provided on Figures PC-231-1 and PC-231-2. All of the test results are summarized on the attached Record of Borehole sheets.

One soil sample from the sandy 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 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 underlying bedrock in the region is Gneiss with interlocking Feldspar, Quartz and Biotite and belongs to the Southern and Superior Province, Paleoproterozoic Intrusive Rocks.

### **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 231/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 2.8 m to 2.9 m of sandy silt fill below the existing surface of highway shoulder, which is followed by sandy silt (glacial till) to the maximum investigation depth of 9.2 m below the grade. In the case of Boreholes 16-231-3 and 16-231-4, a 200-mm to 300-mm thick topsoil was encountered immediately below the surface, which is underlain by sandy silt (glacial till) deposit. In Borehole 16-231-2, the glacial till deposit is underlain by Gneiss Bedrock of the Southern and Superior Province. For classification purposes, the soils encountered at this site can be divided into four distinct zones.

- a) Sandy Silt, Trace Clay, Trace Gravel (Fill)
- b) Topsoil
- c) Sandy Silt, Some to Trace Gravel, Trace Clay (Glacial Till)
- d) Gneiss Bedrock

#### **5.2.1 Sandy Silt, Trace Clay, Trace Gravel (Fill)**

This sandy silt fill was encountered in Boreholes 16-231-1 and 16-231-2 immediately below the surface of the highway shoulders. This fill layer ranges in thickness from 2.8 m to 2.9 m, and extends to a maximum



depth of 2.9 m (El. 253.3) below the existing grade. The SPT values in this fill layer varies from 4 blows to 7 blows, indicating loose state of denseness.

The moisture content of this fill material varies between 9.9% and 18.3%. The Atterberg limit test results of one representative sample is presented on Figure 231-PC-1. The test result indicates liquid limit value of 22, plastic limit value of 16, and corresponding plasticity index value of 6. Based on the result of Atterberg limit test, the soil at the bottom of the fill layer may be classified as clayey silt of low plasticity (CL-ML) in the Unified Soil Classification System (USCS). The result of the sieve analysis test performed on one representative sample from this layer is provided on Figure 231-GS-1. The test result indicate that this deposit consists of 0% gravel, 44% sand, 51% silt and 5% clay.

#### 5.2.2 Topsoil

Topsoil was encountered in Boreholes 16-231-3 and 16-231-4, immediately below the surface and the thickness of this layer was observed to be 200 mm and 300 mm, respectively. This layer extends to maximum elevation of 253.3.

#### 5.2.3 Sandy Silt, Some to Trace Gravel, Trace Clay (Glacial Till)

The topsoil in Boreholes 16-231-3 and 16-231-4, and the sandy silt fill layer in Boreholes 16-231-1 and 16-231-2 are immediately underlain by this sandy silt (glacial till) deposit, which extends to a maximum investigation depth of 9.2 m (El. 247.0). This glacial till deposit consists varying proportions of silt and sand. The SPT N values at about El. 253.6 to El.250.1 vary from 5 blows to 26 blows, indicating loose to compact denseness. Below El. 250.1, the SPT values range from 34 blows to refusal, indicating dense to very dense state of compaction. This deposit was not fully penetrated in three of the boreholes to establish the thickness of this deposit. However, this deposit was fully penetrated in Borehole 16-231-2 and the thickness was observed to be 4.1 m.

The moisture content of samples tested from this deposit, with the exception of SS2 from Borehole 16-231-4, varied from 6.0% to 14.9% with an average value of 10.4%. The Atterberg limit test results of six representative samples are presented on Figure 231-PC-2. The test results indicate liquid limit values ranging from 15 to 22, plastic limit values ranging from 12 to 17, and corresponding plasticity index values ranging from 2 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 seven representative samples from this



layer are provided on Figure 231-GS-2. The test result indicate that this deposit consists of 4% to 15% gravel, 31% to 47% sand, 34% to 54% silt and 4% to 13% clay.

#### 5.2.4 Gneiss Bedrock

Presence of bedrock was proven by coring at Borehole 16-231-2 and obtaining 3.0 m long rock cores. The rock coring was terminated at a depth of 9.9 m (El. 246.3) below the existing grade of the highway shoulder.

The measured recovery of the two rock cores were 98 %. The RQD measured from the rock cores retrieved range between 82% and 98%. Based on the RQD values, the bedrock may be described as good to excellent quality. For complete descriptions of the bedrock, refer to rock core description log provided in Appendix B.

### 5.3 Groundwater

The groundwater level was measured upon completion of drilling and were observed at depths ranging from 2.44 m to 3.96 m (El. 249.6 to El. 252.2), below the existing grade of the road.

The water level in the creek was observed at El. 252.93 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 are summarised 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)
16-231-01	SS-7	6.1-6.7 / 251.1-250.5	Sandy Silt (Glacial Till)	9	11	8.68	8770



## 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 was performed by AGAT Laboratories of Mississauga, Ontario.

This report was prepared by Ms. A. Khadem, M.Sc. Eng., EIT, and Project Supervisor and reviewed by Mr. M. Vasavithasan, M.Sc. 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.

*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

AK/MV/CN:az

Part A – Foundation Investigation Report

Unnamed Creek Culvert Replacement, Site No. 39W-231/C, Highway 11, Station 24+441

Kohler Township, New Liskeard District, Ontario, GWP 5047-07-00, WP 5370-11-03, Index No: 098FIR

PML Ref.: 16TF013A, May 24, 2017

---



## **APPENDIX A**

Site Photographs



**Photograph P1:** Looking west from Highway 11 at the location of Borehole 16-231-1 (July 26, 2016).



**Photograph P2:** Looking south-west from Highway 11 eastbound lane shoulder at the location of Borehole 16-231-3 (July 26, 2016).



**Photograph P3:** Looking north-west at the culvert inlet (July 26, 2016).



**Photograph P4:** Looking south-west at the culvert outlet (July 26, 2016).



**Photograph P5:** Looking south-east at the culvert outlet (July 26, 2016).



## **APPENDIX B**

Borehole Locations Plan and Soil Strata at Structure 39W-231/C

Explanation of Terms Used in Report

Record of Borehole Sheets

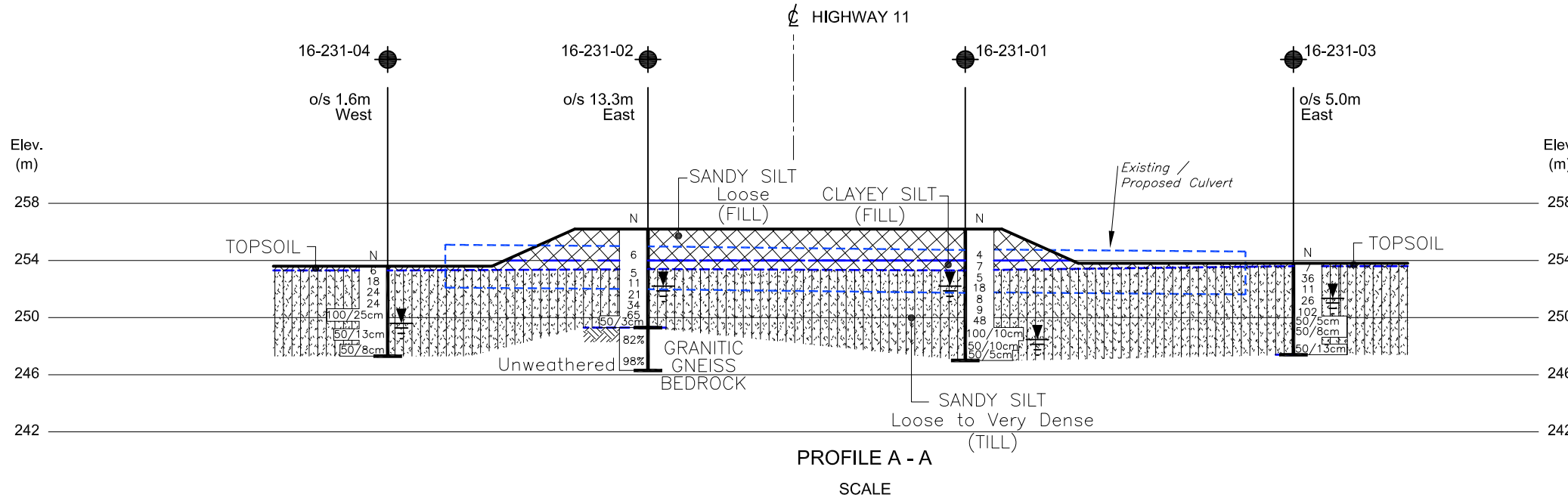
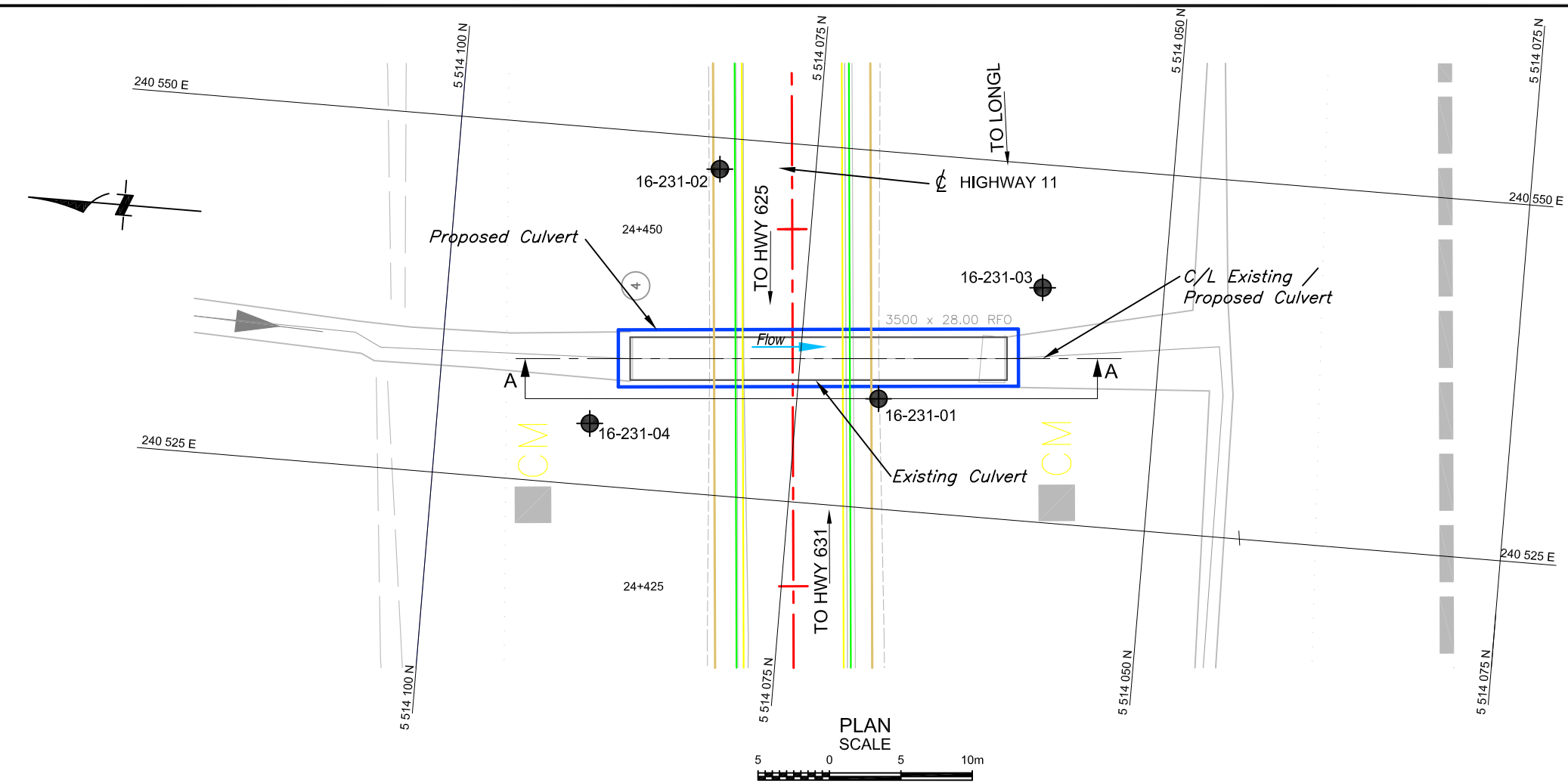
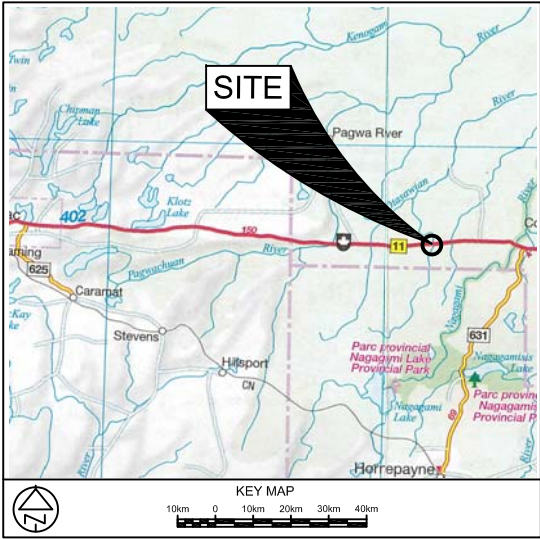
Results of Grain Size Distribution Analyses – Figures 231-GS-1 and 231-GS-2

Plasticity Chart – Figure 231-PC-1

Chemical Test Results

Rock Core Photograph

Rock Core Description



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

WL at time of investigation July 2016

WH

Penetration due to weight of hammer and rod

\*

Water level not established

Head

Head

ARTESIAN WATER

Encountered

PIEZOMETER

PIEZOMETER

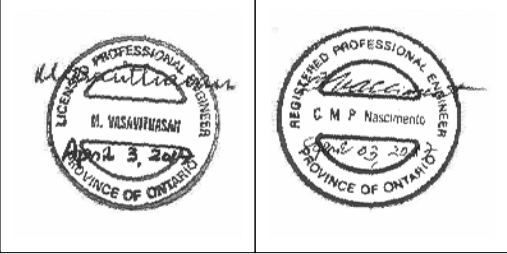
BH No	ELEVATION	NORTHINGS	EASTINGS
16-231-01	256.2	5 514 069.3	240 532.7
16-231-02	256.2	5 514 081.7	240 547.8
16-231-03	253.8	5 514 058.5	240 541.4
16-231-04	253.6	5 514 089.3	240 529.3

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. 042-049					
HWY No	11				DIST NEW LISKEARD
SUBM'D	NA	CHECKED AK	DATE APR. 03, 2017	SITE 39W-231	
DRAWN	NA	CHECKED MV	APPROVED CN	DWG 231/C-1	

- 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	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
$u$	1	PORE PRESSURE RATIO
$\sigma$	kPa	TOTAL NORMAL STRESS
$\sigma'$	kPa	EFFECTIVE NORMAL STRESS
$\tau$	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
$\epsilon$	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
$\mu$	1	COEFFICIENT OF FRICTION

### MECHANICAL PROPERTIES OF SOIL

$m_v$	kPa <sup>-1</sup>	COEFFICIENT OF VOLUME CHANGE
$C_c$	1	COMPRESSION INDEX
$C_s$	1	SWELLING INDEX
$C_\alpha$	1	RATE OF SECONDARY CONSOLIDATION
$c_v$	m <sup>2</sup> /s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
$T_v$	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
$\sigma'_{v0}$	kPa	EFFECTIVE OVERBURDEN PRESSURE
$\sigma'_p$	kPa	PRECONSOLIDATION PRESSURE
$\tau_f$	kPa	SHEAR STRENGTH
$c'$	kPa	EFFECTIVE COHESION INTERCEPT
$\phi'$	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
$c_u$	kPa	APPARENT COHESION INTERCEPT
$\phi_u$	-°	APPARENT ANGLE OF INTERNAL FRICTION
$\tau_R$	kPa	RESIDUAL SHEAR STRENGTH
$\tau_r$	kPa	REMOULDED SHEAR STRENGTH
$S_i$	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

### PHYSICAL PROPERTIES OF SOIL

$\rho_s$	kg/m <sup>3</sup>	DENSITY OF SOLID PARTICLES	n	1, %	POROSITY	$e_{max}$	1, %	VOID RATIO IN LOOSEST STATE
$\gamma_s$	kN/m <sup>3</sup>	UNIT WEIGHT OF SOLID PARTICLES	w	1, %	WATER CONTENT	$e_{min}$	1, %	VOID RATIO IN DENSEST STATE
$\rho_w$	kg/m <sup>3</sup>	DENSITY OF WATER	$S_r$	%	DEGREE OF SATURATION	$I_D$	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
$\gamma_w$	kN/m <sup>3</sup>	UNIT WEIGHT OF WATER	$w_L$	%	LIQUID LIMIT	D	mm	GRAIN DIAMETER
$\rho$	kg/m <sup>3</sup>	DENSITY OF SOIL	$w_p$	%	PLASTIC LIMIT	$D_n$	mm	n PERCENT - DIAMETER
$\gamma$	kN/m <sup>3</sup>	UNIT WEIGHT OF SOIL	$w_s$	%	SHRINKAGE LIMIT	$C_u$	1	UNIFORMITY COEFFICIENT
$\rho_d$	kg/m <sup>3</sup>	DENSITY OF DRY SOIL	$I_p$	%	PLASTICITY INDEX = $w_L - w_p$	h	m	HYDRAULIC HEAD OR POTENTIAL
$\gamma_d$	kN/m <sup>3</sup>	UNIT WEIGHT OF DRY SOIL	$I_L$	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	q	m <sup>3</sup> /s	RATE OF DISCHARGE
$\rho_{sat}$	kg/m <sup>3</sup>	DENSITY OF SATURATED SOIL	$I_C$	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	v	m/s	DISCHARGE VELOCITY
$\gamma_{sat}$	kN/m <sup>3</sup>	UNIT WEIGHT OF SATURATED SOIL	DTPL		DRIER THAN PLASTIC LIMIT	i	1	HYDRAULIC GRADIENT
$\rho'$	kg/m <sup>3</sup>	DENSITY OF SUBMERGED SOIL	APL		ABOUT PLASTIC LIMIT	k	m/s	HYDRAULIC CONDUCTIVITY
$\gamma'$	kN/m <sup>3</sup>	UNIT WEIGHT OF SUBMERGED SOIL	WTPL		WETTER THAN PLASTIC LIMIT	j	kN/m <sup>3</sup>	SEEPAGE FORCE
e	1, %	VOID RATIO						

**RECORD OF BOREHOLE No 16-231-01**

1 of 1

**METRIC**

G.W.P. 5047-07-00 LOCATION Co-ords: 5 514 069.3 N ; 240 532.7 E ORIGINATED BY K.D.  
DIST New Liskeard BOREHOLE TYPE Hollow Stem Augers, NW Casing and Wash Boring COMPILED BY A.K.  
DATUM Geodetic HWY 11 DATE July 26, 2016 CHECKED BY M.V.






SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED      + FIELD VANE										○		
								● QUICK TRIAXIAL      × LAB VANE												
256.2	Ground Surface						20	40	60	80	100									
0.0	Sandy silt trace clay, trace gravel  Loose      Brown      Wet  (FILL)																			
	clayey silt		1	SS	4								○							
			2	SS	7								○							
253.3	Sandy silt some gravel, trace clay sand seams  Loose to      Brown      Moist compact		3	SS	5								○							
2.9			4	SS	18								○			15 47 34 4				
			5	SS	8								○							
			6	SS	9								○							
	Dense to very dense		7	SS	48								○			15 42 39 4				
			8	SS	100/10cm								○							
	(TILL)		9	SS	50/10cm								○							
247.0	End of borehole		10	SS	50/5cm															
9.2	Samples 9 & 10: Sampler bouncing																			
	          *      2016    07    26  ▽      Water level observed during drilling																			

**RECORD OF BOREHOLE No 16-231-02**

1 of 1

**METRIC**

G.W.P. 5047-07-00 LOCATION Co-ords: 5 514 081.7 N ; 240 547.8 E ORIGINATED BY K.D.  
DIST New Liskeard BOREHOLE TYPE Hollow Stem Augers and NW Casing COMPILED BY A.K.  
DATUM Geodetic HWY 11 DATE July 27, 2016 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED      + FIELD VANE										○		
								● QUICK TRIAXIAL      × LAB VANE												
256.2	Ground Surface						20	40	60	80	100									
0.0	Sandy silt trace clay, trace gravel  Loose      Brown  (FILL)						256													
							255													
			1	SS	6		254													
253.4	Sandy silt some gravel, trace clay  Loose to      Brown      Moist compact																			
2.8			2	SS	5		253							H						
			3	SS	11		252													
			4	SS	21		251													
			5	SS	34		250							H						
			6	SS	65		249													
			7	SS	50/3cm		248													
			249.3	Granitic Gneiss bedrock Unweathered		8	RC NQ	REC 98%	247											
			9	RC NQ	REC 98%															
			246.3	End of borehole																
9.9	Sample 7: Sampler bouncing																			
	<div>*      2016   07   27</div> <div>      Water level observed during drilling</div>																			

**RECORD OF BOREHOLE No 16-231-03**

1 of 1

**METRIC**

G.W.P. 5047-07-00 LOCATION Co-ords: 5 514 058.5 N ; 240 541.4 E ORIGINATED BY K.D.  
DIST New Liskeard BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY A.K.  
DATUM Geodetic HWY 11 DATE July 26, 2016 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED      + FIELD VANE										○		
								● QUICK TRIAXIAL      × LAB VANE												
253.8	Ground Surface						20	40	60	80	100									
253.6	Topsoil																			
0.2	Sandy silt trace clay, trace gravel  Loose to Grey Wet compact		1	SS	7	▽*							○				9 31 54 6			
			2	SS	36								○							
			3	SS	11								⦶							
			4	SS	26								○							
			5	SS	102								○							
			6	SS	50/5cm								⦶							
			7	SS	50/8cm								○							
			8	SS	50/13cm									○						
247.4	(TILL)															4 39 51 6				
6.4	End of borehole																			
	Samples 6, 7 & 8: Sampler bouncing																			
	  *    2016   07   26																			
	▽    Water level observed during drilling																			

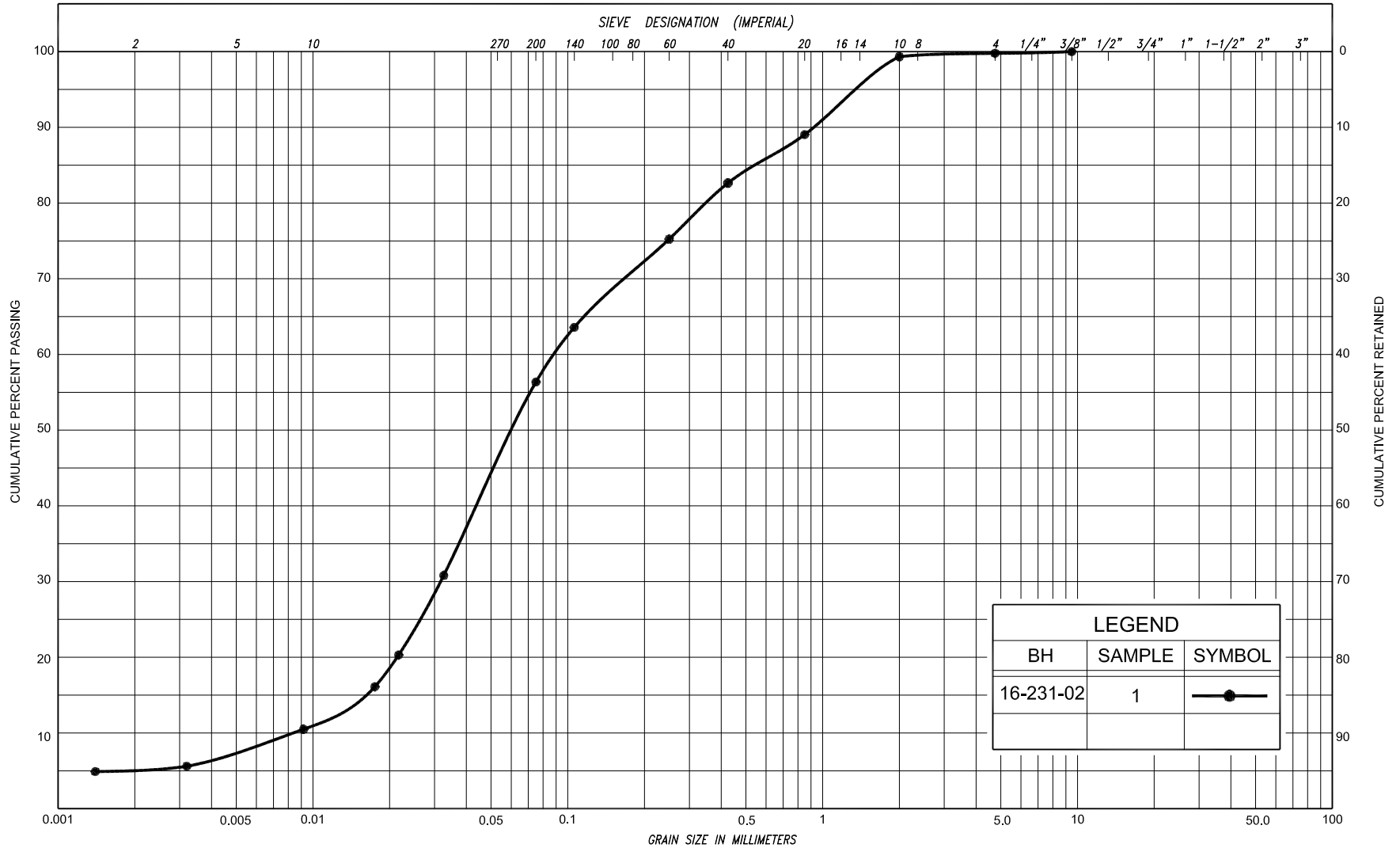
**RECORD OF BOREHOLE No 16-231-04**

1 of 1

**METRIC**

G.W.P. 5047-07-00 LOCATION Co-ords: 5 514 089.3 N ; 240 529.3 E ORIGINATED BY K.D.  
DIST New Liskeard BOREHOLE TYPE Hollow Stem Augers and NW Casing COMPILED BY A.K.  
DATUM Geodetic HWY 11 DATE July 27, 2016 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED + FIELD VANE									
								● QUICK TRIAXIAL × LAB VANE									
					WATER CONTENT (%)												
253.6	Ground Surface						20	40	60	80	100						
0.0	Topsoil		1	SS	6								○				
253.3	Sandy silt some to trace clay some ro trace gravel																
0.3	Loose to Brown Wet compact		2	SS	18								○				
			3	SS	24								○			6 40 47 7	
			4	SS	24								○				
	Very dense		5	SS	100/25cm								○				
			6	SS	50/13cm								○			11 34 42 13	
	(TILL)																
247.3	End of borehole		7	SS	50/8cm								○				
6.3	Samples 6 & 7: Sampler bouncing																



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

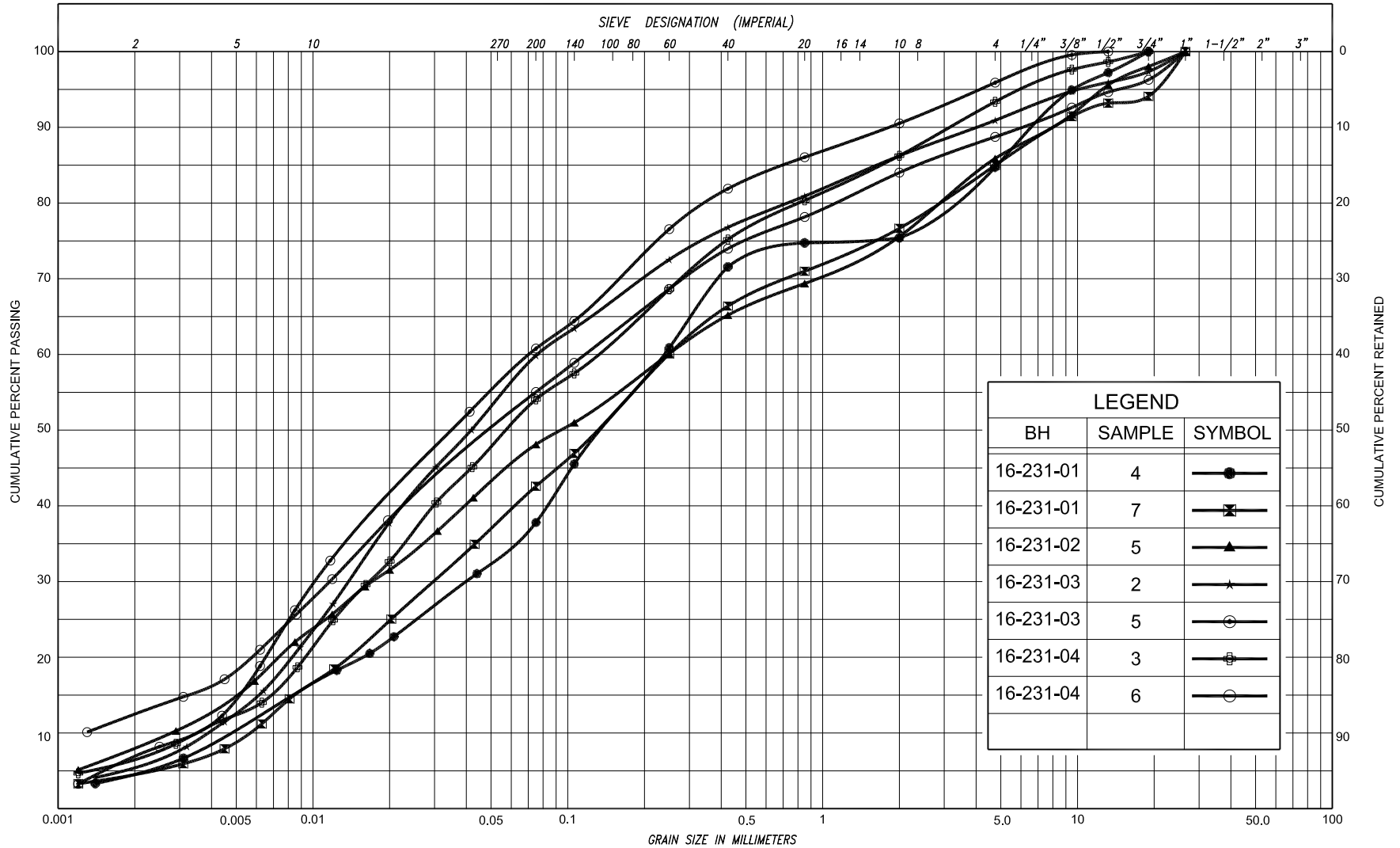


# GRAIN SIZE DISTRIBUTION SANDY SILT, trace clay (FILL)

FIG No. 231-GS-1

HWY 11

G.W.P. 5047-07-00

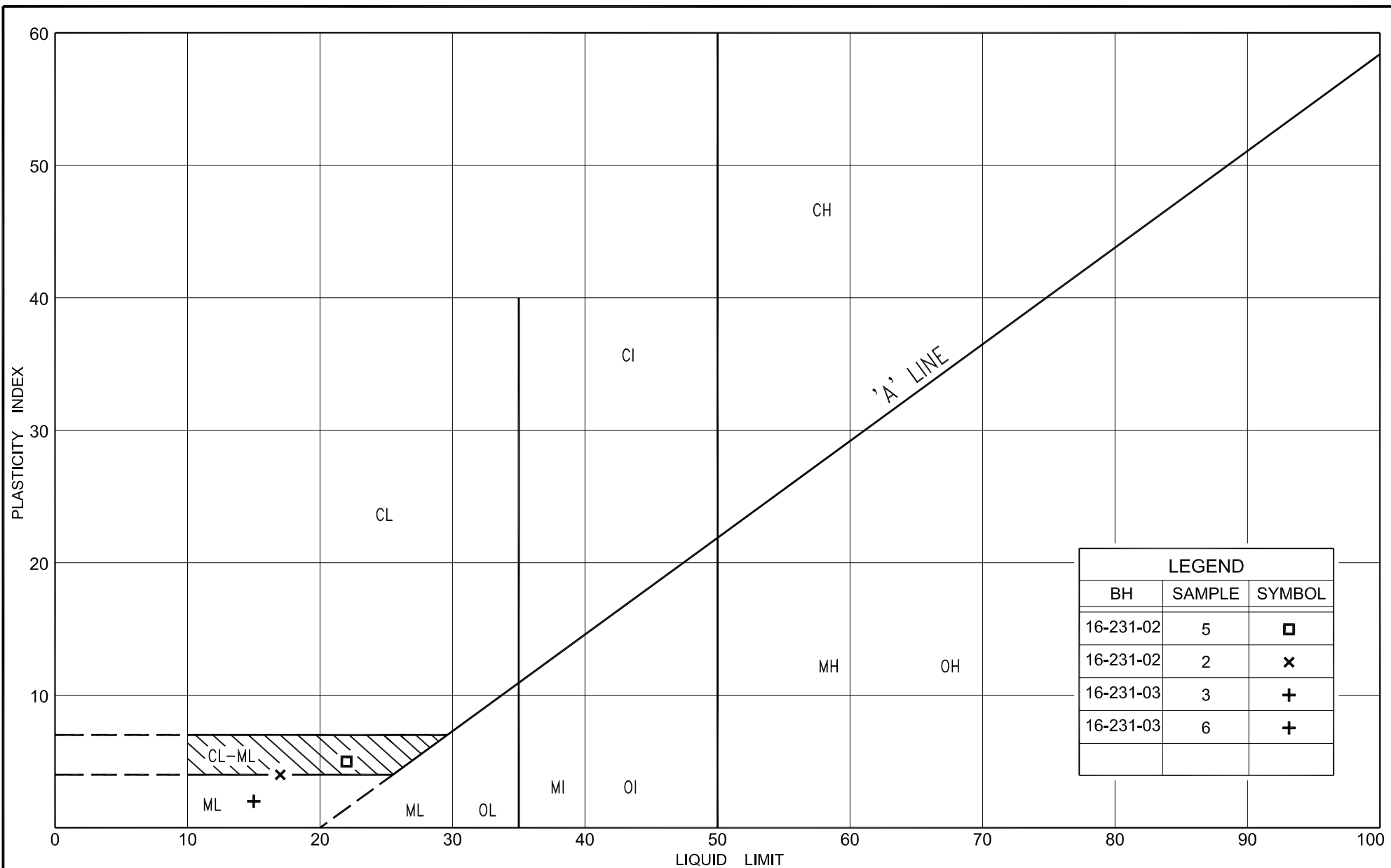


SILT & CLAY				FINE		MEDIUM		COARSE	GRAVEL			COBBLES	UNIFIED	
				SAND										
CLAY	FINE		MEDIUM	COARSE	FINE		MEDIUM	COARSE		GRAVEL			COBBLES	M.I.T.
	SILT													
CLAY		SILT			V. FINE	FINE	MED.	COARSE	GRAVEL					U.S. BUREAU
				SAND										



# **GRAIN SIZE DISTRIBUTION** SANDY SILT, trace to some clay, trace to some gravel (TILL)

FIG No. 231-GS-2  
 HWY 11  
 G.W.P. 5047-07-00



**PLASTICITY CHART**  
 SANDY SILT, trace clay, trace gravel (ML)  
 (TILL)

FIG No. 231-PC-1  
 HWY 11  
 G.W.P. 5047-07-00



**AGAT** Laboratories

## 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

		BH16-115-03		BH16-116-02	BH16-231-01
SAMPLE DESCRIPTION:		SS8		SS4	SS7
SAMPLE TYPE:		Soil		Soil	Soil
DATE SAMPLED:		7/24/2016		7/22/2016	7/26/2016
Parameter	Unit	G / S	RDL	7757409	7757411
Sulphide*	%	0.05	<0.05	<0.05	<0.05
Chloride (2:1)	µg/g	2	17	95	11
Sulphate (2:1)	µg/g	2	20	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				REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD	Method Blank	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:





## Time Markers

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

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
<b>Soil Analysis</b>			
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 A – Foundation Investigation Report

Unnamed Creek Culvert Replacement, Site No. 39W-231/C, Highway 11, Station 24+441

Kohler Township, New Liskeard District, Ontario, GWP 5047-07-00, WP 5370-11-03, Index No: 098FIR

PML Ref.: 16TF013A, May 24, 2017



**Photograph R1:** Rock cores at Borehole 16-231-02 (March 21, 2017).



### ROCK CORE DESCRIPTION

<u>Borehole No</u>	<u>Core Run</u>	<u>Depth (m)</u>	<u>% CR</u>	<u>% RQD</u>	<u>Description</u>
16-231-02	1	6.9 – 8.4	98	82	<b>GNEISS:</b>  Medium grey to dark grey, minor grey and dark grey bands, medium to coarse grained, interlocking feldspar and quartz, with biotite, medium hard (geological and knife test-IRS-4), slightly weathered to unweathered, moderately fractured, dipping and vertical joints, rough, undulating, unfilled.
	2	8.4 – 9.9	98	98	

**CR\*** - Core Recovery  
**RQD\*** - Rock Quality Designation

Logged by: S. Siddiqi, P.Geo.  
 Reviewed by: Mark Vasavithasan



**PART B – FOUNDATION DESIGN REPORT**

**for**

**UNNAMED CREEK CULVERT REPLACEMENT**

**SITE NO. 39W-231/C**

**HIGHWAY 11- STATION 24+441 - KOHLER TOWNSHIP**

**DISTRICT OF NEW LISKEARD, ONTARIO**

**ASSIGNMENT NO. 5015-E-0009**

**GWP 5047-07-00**

**WP 5370-11-03**

PETO MacCALLUM LTD.  
165 CARTWRIGHT AVENUE  
TORONTO, ONTARIO  
M6A 1V5  
Phone: (416) 785-5110  
Fax: (416) 785-5120  
Email: [toronto@petomaccallum.com](mailto:toronto@petomaccallum.com)

**Distribution:**

- 3 cc: GHD Ltd. for distribution to MTO  
Project Manager + 1 digital copy (pdf)
- 1 cc: GHD Ltd. for distribution to MTO  
Foundations Section + 1 digital copy (pdf)
- 1 cc: GHD Ltd. + 1 digital copy (pdf)
- 1 cc: PML Toronto
- 1 cc: PML Kitchener

PML Ref.: 16TF013A  
Index No.: 099FDR  
GEOCRES No.: 42F-049  
May 24, 2017



## TABLE OF CONTENTS

### PART B - FOUNDATION DESIGN REPORT

7. INTRODUCTION.....	8
8. PROJECT DESCRIPTION.....	8
8.1 General.....	8
8.2 Existing Culvert .....	9
8.3 Proposed Culvert.....	9
8.4 Structure Foundation.....	10
8.4.1 Option 1: Precast Concrete Box Culvert .....	10
8.4.2 Option 2: Cast-in-Place Reinforced Concrete Box Culvert.....	12
8.4.3 Option 3: Three Sided Open Precast Concrete Culvert on Strip Footing .....	13
8.4.4 Recommended Option for Culvert Replacement .....	13
8.4.5 Lateral Earth Pressure.....	13
8.5 Approach Embankment.....	14
9. FOUNDATION FROST DEPTH.....	15
10. SEISMIC CONSIDERATIONS.....	15
10.1 Cover and Backfill .....	15
11. CONSTRUCTION CONSIDERATIONS .....	16
11.1 Staged Construction.....	16
11.2 Excavation .....	17
12. GROUNDWATER CONTROL .....	17
13. TEMPORARY WORKS.....	18
14. SOIL CORROSION.....	18
15. CLOSURE .....	20

Appendix C – 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-231/C  
Highway 11- Station 24+441  
Kohler Township, New Liskeard District, Ontario  
Assignment No. 5015-E-0009, GWP 5047-07-00, WP 5370-11-03

---

**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, 27.5 km west of the intersection of Highway 631 and Highway 11 (Sta. 24+441) 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 twin cell timber culvert with a total span of 3.5 m, 1.5 m rise and a total of 28 m long. At some point, the culvert was extended by adding a 4.0 m long by 3.5 m wide precast concrete box culvert. The structure supports 2.0 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. 256.2 and the embankment above the creek bed is approximately 4.0 m high.

This culvert was constructed in 1958 and the road accommodates two lanes of vehicular traffic. Based on the inspection carried out on 16 June, 2015, leakage stains through precast units, light scour, light spalling of concrete at unsealed lifting holes and exposed corroded rebar were noted on the precast concrete box culvert that was added at a later date. In the case of barrels of the timber culvert on the north side, light to medium rot of deck members, minor to moderate crushing of transverse wall timber on all walls, localized to medium rot at soffit timber, light to severe checks and splits were observed. In addition, severe scouring of stream bed at the outlet (north end) was observed.

The foundation details of the existing timber culvert are not available. However, considering the width of the culvert and the fill height above the deck, the load imposed by the existing culvert at the founding level may not exceed 150 to 165 kN per meter length of the culvert. However, the pressure imposed by the existing precast concrete box culvert on the south side may not exceed 60 kPa to 70 kPa.

## **8.3 Proposed Culvert**

Based on the preliminary information provided by GHD Ltd., it is proposed to replace the existing culvert with a 30.0 m long precast concrete box culvert with an opening size of 4.0 m span and 1.5 m rise, along the same vertical and horizontal alignments.

The structural information provided by GHD indicates that the proposed invert of the replacement box culvert slopes down from about El. 252.42 at the inlet to El. 251.94 at the outlet. The founding levels of the subgrade at the inlet and outlet are proposed to be at El. 251.81 and El. 251.33, respectively. 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. 256.2, which will result in fill height including the pavement structure of 2.25 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 2.8 m to 2.9 m of sandy silt fill below the existing surface of highway shoulders, which is followed by sandy silt (glacial till) to the maximum investigation depth of 9.2 m below the grade. In the case of boreholes located near the inlet and outlet, 200-mm to 300-mm thick topsoil was encountered immediately below the surface, which is underlain by till layer. In Borehole 16-231-2, the till deposit is underlain by Gneiss Bedrock at about El. 249.3. The groundwater level was observed between El. 249.6 and El. 252.2 during the fieldwork. The water level in the creek was observed at El. 252.9 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. 251.57±. The subsoil conditions below the proposed founding level is 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. 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 sandy silt till subgrade material below invert.

**Table 8-4 - Comparison of Alternate Culvert Options**

<b>Option 1: Precast Concrete Box Culvert</b>	<b>Option 2: Cast In-Place Concrete Box Culvert</b>	<b>Option 3: Three-Sided Precast Open Culvert</b>
<b>Advantages:</b> 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	<b>Advantages:</b> 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	<b>Advantages:</b> 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
<b>Disadvantages:</b> 1. Natural stream bed will not remain intact 2. Cause sediment accumulation in the upstream of the channel 3. Possibility for degradation of subgrade	<b>Disadvantages:</b> 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	<b>Disadvantages:</b> 1. Probability of uneven or differential settlements are possible 2. Limited ability to withstand differential settlements 3. Silty soil below the invert level is susceptible to scour
<b>Cost of Construction:</b> Total Cost \$ 14,000/m	<b>Cost of Construction:</b> Total Cost \$ 15,000/m	<b>Cost of Construction:</b> Total Cost \$ 14,500/m
<b>Recommended</b>	<b>Technically Feasible but Not Recommended</b>	<b>Technically Not Feasible; Not Recommended</b>



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 20 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 (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 silty soil below the proposed founding surface will require a cut-off wall to prevent scour or washout. Further, 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. 251.57 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 (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 soil materials that are susceptible to scour. For these reason, this option is 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 251.57 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, cost of dewatering 1.0 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  
 $\gamma$  = unit weight of backfill material above assumed water level (kN/m<sup>3</sup>)  
 $\gamma'$  = unit weight of submerged backfill ( $\gamma - \gamma_w$ ) material below assumed water level (kN/m<sup>3</sup>)  
 $\gamma_w$  = unit weight of water (9.8 kN/m<sup>3</sup>)  
 $h_1$  = 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)



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 and GRANULAR B TYPE II
Angle of Internal Friction, degrees	35°
Unit Weight, kN/m <sup>3</sup>	22.5
Coefficient of Active Earth Pressure ( $K_a$ )	0.27
Coefficient of Earth Pressure at Rest ( $K_o$ )	0.43
Coefficient of Passive Earth Pressure ( $K_p$ )	3.69

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 4.0 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. 256.2. No major instability problems are anticipated for the excavated section of embankment to be reconstructed with similar side slope as the existing.

The embankment fill may consist of well-compacted, suitable earth or granular fill. The fill below water table 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 ( $S_a$  (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 exceeds 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 favourable 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. 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 the 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 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 ( $\phi^\circ$ )	UNIT WEIGHT(Y) $\text{kN/m}^3$	$C_u, \text{kN/m}^2$
256.2	253.3	Sandy Silt Fill	30	18	0
253.3	250.1	Loose to Compact Sandy Silt Till	28	19	0
250.1	247.0	Dense to Very Dense Sandy 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 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. 241.0 and El. 243.3, 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  $\mu\text{m}$ . 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 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 9  $\mu\text{g/g}$  (0.0009%) reported in Table 5-1 for the sandy 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, potential for sulphate attack will be mild or relatively low. The chloride content of 95 ppm or 0.0011% (11  $\mu\text{g/g}$ ) reported in Appendix B is significantly lower than the concentration value of 250 ppm (0.025%) that generally leads to corrosive environment for buried metals. Potential for corrosive environment at this site is relatively low.



Electrical resistivity less than 2000 ohm-cm generally leads to highly corrosive environment for steel elements in contact with soil. The resistivity value of 8770 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 8.68 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. A. Khadem, M.Sc. Eng., EIT., Project Supervisor, and reviewed by Mr. M. Vasavithasan, M.Sc. 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.

*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

AK/MV/CN:az



## **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
OPSS 518	Construction Specification for Control of Water from Dewatering Operations
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



## **NON-STANDARD SPECIAL PROVISIONS (NSSP)**

### **NSSP 1 – 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 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 a cofferdam consisting of damming of the creek and diversion of the flow by pumping through temporary conduits for staging of construction will likely be required at this site.

### **NSSP 2 – 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 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 3 – 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.