



**FOUNDATION INVESTIGATION AND DESIGN REPORT**

**for**

**UNNAMED CREEK CULVERT REPLACEMENT**

**SITE NO. 39W-119/C**

**HIGHWAY 11 - STA. 11+917**

**TOWNSHIP OF CLAVET, DISTRICT OF NEW LISKEARD**

**HEARST, ONTARIO**

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

**GWP 5130-13-00**

**WP 5292-14-01**

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.: 118FIR and 119FDR  
GEOCRES No.: 42F-042  
March 6, 2017



**PART A - FOUNDATION INVESTIGATION REPORT**

**for**

**UNNAMED CREEK CULVERT REPLACEMENT**

**SITE NO. 39W-119/C**

**HIGHWAY 11 - STA. 11+917**

**TOWNSHIP OF CLAVET, DISTRICT OF NEW LISKEARD**

**HEARST, ONTARIO**

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

**GWP 5130-13-00**

**WP 5292-14-01**

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.: 118FIR  
GEOCRES No.: 42F-042  
March 6, 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 .....	4
6. SUBSURFACE CONDITIONS .....	4
6.1 Sand and Gravel (Fill) .....	5
6.2 Organic Silt.....	6
6.3 Silt .....	6
6.4 Clayey Silt .....	6
6.5 Silty Clay .....	7
6.6 Sandy Silt to Silty Sand .....	7
7. GROUNDWATER .....	8
8. CHEMICAL TEST RESULTS.....	8
9. CLOSURE.....	9

APPENDIX A – Site Photographs

APPENDIX B – Borehole Location Plan and Soil Strata  
 Explanation of Terms Used in Report  
 Record of Borehole Sheets  
 Grain Size Distribution Curves – Figures 119-GS-1, 119-GS-2 and 119-GS-3  
 Plasticity Charts - Figures – 119-PC-1, 119-PC-2 and 119-PC-3

APPENDIX C – Results of Chemical Corrosivity Tests

**PART A – FOUNDATION INVESTIGATION REPORT**

Unnamed Creek Culvert Replacement

Site No. 39W-119/C

Highway 11 - Sta. 11+917

Township of Clavet, District of New Liskeard

Hearst, Ontario

Assignment No. 5015-E-0009, GWP 5130-13-00, WP 5292-14-01

---

**1. INTRODUCTION**

GHD Limited (GHD) has retained Peto MacCallum Ltd. (PML) on behalf of the Ministry of Transportation of Ontario (MTO) to conduct a foundation investigation for the replacement or rehabilitation of thirteen (13) structures located on Highway 11 and three (3) structures located on Highway 583, near Hearst, Ontario. This foundation investigation report is part of an assignment (Assignment No: 5015-E-0009) to prepare detail designs for replacement or rehabilitation of these 16 structures (15 culverts and Fraser River Bridge). The assignment involves five contracts assigned to be carried out under four different General Work Plans (GWPs).

This report presents the results of the foundation investigation carried out for the replacement of a culvert (MTO Site No. 39W-119/C), located at the crossing of an unnamed creek and Highway 11, about 120 km west of Hearst, Sta. 11+917, in the Township of Clavet, District of New Liskeard.

The purpose of the foundation investigation was to identify the subsurface conditions expected to influence the selection and design of the replacement culvert at the structure location.

**2. SITE DESCRIPTION**

At the culvert location, Highway 11 is a two-lane road and consists of about 3.5 m wide lanes and 2 m wide shoulders, with guiderails on both sides. The highway provides rural arterial road services for the communities in the region. Based on the survey data, the grade of the road at center of the culvert is about El. 202 m. The topography surrounding the culvert is generally flat.

The area near the culvert consisted of dense vegetation with trees of black spruce and thick brush. The slopes on both sides of the road were stable and well vegetated with no sign of distress or cracks.

The creek flows from north to south and empty into Pagwachuan River, located immediately downstream of the culvert. Therefore, the creek flow is largely controlled by the water level in the river. There was only a small amount of water flow in the culvert during the fieldwork.



This culvert includes headwall and wing walls at the outlet that show signs of distress including spalling and scaling of concrete. The sign of deteriorations of the culvert includes staining of the interior walls as well as at the north end of the culvert. There were no major cracks on the vertical walls of the culvert to indicate any distress resulting from differential settlements.

Refer to the Photographs P1 to P4 in Appendix A, for general site and culvert conditions.

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

The fieldwork for the foundation investigation consisted of four (4) boreholes drilled during the period of July 6, 2016 to July 8, 2016, and on July 20, 2016. The boreholes were drilled to depths ranging from 18.3 m to 32 m below the existing grade. Boreholes 16-119-01 and 16-119-02 were drilled on the shoulders of Highway 11 located near the culvert on the west and east approaches. Borehole 16-119-04 was located at the northwest end of culvert, near the toe of the embankment. Access to this borehole location (inlet) was through the heavily wooded area. However, the southeast end of the culvert was not accessible as the slope is dipping directly towards Pagwachuan River, and Borehole 16-119-03 was located at the nearest shoulder of the road.

The location of boreholes in relation to the culvert and their depth are provided in Table 3. In addition, the borehole locations are shown on Drawing 119/C-1.

**Table 3 - Location and Depth of Boreholes**

<b>BOREHOLE NO.</b>	<b>LOCATION</b>	<b>DEPTH (m)</b>	<b>ELEVATION (m)</b>
16-119-01	Southwest Approach, Road Shoulder	21.5	180.4
16-119-02	Northeast Approach, Road Shoulder	20.2	181.6
16-119-03	Southeast Approach, Road Shoulder	32	169.8
16-119-04	NW Culvert End, Near Embankment Toe	18.3	179.1

The boreholes were advanced using a CME 55 track-mounted drilling rig equipped with continuous flight 200 mm diameter hollow stem augers. Attempts were made to obtain rock core from Borehole 16-119-03 and the borehole was advanced to a depth of 32.0 m using NW casing.



Considering the subsoil conditions and type of structure, no further attempt was made and the borehole was terminated at 32.0 m depth. The equipment used for drilling was owned and operated by Landcore Drilling (Landcore) of Chelmsford, Ontario. Landcore is a specialist drilling contractor, and worked under the full time supervision of an experienced PML field technician.

Soil samples were obtained at selected intervals from Boreholes 16-119-01, 16-119-02 and 16-119-04 using a split-spoon sampler in accordance with the Standard Penetration Test (SPT) procedures described in the ASTM D1586. A sample was also taken from Borehole 16-119-03 at a depth of 19.8 m (El. 182.0 m). The drill rig was equipped with 63.5 kg (140 lb) cathead automatic hammer calibrated to fall freely through 760 mm (30 in.).

In addition to SPT, dynamic cone penetration (DCP) tests were conducted to refusal (N = 120 blows) in Boreholes 16-119-01 and 16-119-02, near the termination depths.

Soil samples were visually identified, as they were retrieved and stored in moisture-proof bags.

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 drill cuttings and sealed with a bentonite/cement mixture in accordance with the MTO guidelines and Ministry of Environment (MOE) Reg. 903 for borehole abandonment.

Callon Dietz Inc. of London, Ontario was contracted by PML to carry out the survey of the as-drilled borehole locations and elevations. Co-ordinates were provided in MTM NAD 83 northing and easting. All elevations reported in this report are referred to Geodetic datum.

#### **4. LABORATORY TEST PROCEDURES**

All the soil samples were transported to PML laboratory, located in Toronto for detailed visual examination and laboratory testing. The laboratory tests included the following:

- Natural Moisture Content Determination (36)
- Atterberg Limit Tests (8)
- Grain Size Distribution (5)



Laboratory tests were performed on representative samples of each stratigraphic layers encountered. With the exception of hydrometer test (LS-702), all laboratory tests were conducted in accordance with MTO procedures, which follow American Society for Testing Materials (ASTM) standards.

Chemical tests were carried out on a representative sample by AGAT Laboratories located in Mississauga, Ontario to determine the corrosivity characteristics of soils at the site. These tests included determination of sulphate and chloride contents, pH value and resistivity. The soil sample tested was taken at a depth of 4.8 m (El. 197 m) from Borehole 16-119-04.

All of the laboratory test results are provided on individual Record of Borehole Sheets provided in Appendix B. In addition, results of the grain size distribution test are presented on Figures 119-GS-1, 119-GS-2 and 119-GS-3, and Atterberg limit tests are provided on Figures 119-PC-1, 119-PC-2, and 119-PC-3. Results of chemical tests are presented in Appendix C.

## **5. SITE GEOLOGY**

The site is located within the southern part of the Canadian Shield. Maps published by Ontario Geological Survey suggests that the subsurface conditions at the site consist of glacial till and overlying clay and silt deposits. Locally, the till may contain lenses of clay, silt, sand, gravel, and occasional cobbles and boulders. According to a preliminary report prepared by Evans (1941), on the geology of the Trans-Canada Highway between Longlac and Hearst, the bedrock in the region is composed of pegmatitic granite (granitic-gneiss) with distinct light and dark bands. The granitic-gneiss belongs to the migmatitic metasedimentary-metavolcanic complex of the region.

## **6. 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 provided in Appendix B. The borehole locations and stratigraphic profile sections are shown on Drawing 119/C-1. The boundaries between soil strata have been established at borehole locations only. The boundaries of soil strata between and beyond the boreholes are assumed and it may vary from location to location.

In summary, the subsurface stratigraphy consists of 5.9 m to 7.2 m of granular fill material, which is followed by 200 mm topsoil and 1.10 m thick organic silt. The organic deposits are underlain by



about 2.0 m thick silt. The silt layer is underlain by 6.3 m to 7.5 m of clayey silt, which is followed by silty clay deposit to the depths ranging from 13.7 m (El. 183.7) to 20.4 m (El. 181.5) below the grade of highway shoulders. Silty clay deposit is followed by silty sand layer to the maximum depth of investigation of 32.0 m (El. 169.8) below the existing ground surface. For classification purposes, the soils encountered at this site can be divided into six distinct zones.

- a) Sand and Gravel (Fill)
- b) Organic Silt
- c) Silt
- d) Clayey Silt
- e) Silty Clay
- f) Sandy Silt to Silty Sand

#### **6.1 Sand and Gravel (Fill)**

Fill containing sand and gravel with some silt and trace clay was encountered in boreholes drilled on road shoulders. This fill was brown to dark brown in color, and found to be moist to wet. The thickness of fill was 5.9 m to 7.2 m and extends to El. 196 m to El. 194.6 m. A layer of cobbles of about 0.3 m thick were encountered at the bottom of the sand and gravel fill.

The SPT "N"-values within the sand and gravel fill ranged from 7 to 18 blows/300 mm, indicating a "loose" to "compact" state of soil compactness.

The moisture content of samples from the fill was in the range of 4.9% to 8.7%. The results of grain size analyses completed on samples taken from Boreholes 16-119-01 and 16-119-02 indicated that the fill is composed of 14% - 21% gravel, 62% - 66% sand, 14% - 16% silt and 3% clay. Results of grain size distribution analyses are provided on Figure 119-GS-1 in Appendix B.

In addition of the sand and gravel fill, the upper part of the stratigraphy at Borehole 16-119-04 consisted of a clayey silt fill that was found to be dark brown in color, very soft and wet. This material was about 1.7 m thick and contained organics. A laboratory test result on a sample from this fill indicated a moisture content of 30.1%. A layer of 0.3 m thick topsoil was encountered immediately below this fill, and the moisture content of a sample of this topsoil was found to be 40.1%.



## **6.2 Organic Silt**

Black to olive brown colour organic silt was encountered in Borehole 16-119-01, immediately below the sand and gravel fill. The thickness of this deposit was about 1.1 m, extending to El. 194.9 m. The SPT "N"-value was 5 blows/300 mm, indicating firm consistency.

Laboratory test result of a sample of this material indicated a moisture content of 32.3%. The liquid limit of this sample was 46 and the plastic limit was 30, which results in a plasticity index of 16. Based on these values, the material may be classified as organic silt (OH) in the Unified Soil Classification System (USCS). A plasticity chart is provided on Figure 119-PC-1 in Appendix B.

## **6.3 Silt**

A silt layer was encountered at El. 194.9 m in Borehole 16-119-01, at El. 194.6 m in Borehole 16-119-02, and at El. 195.4 m in Borehole 16-119-04. This silt layer contained trace clay and trace sand, and was found to be moist to wet. In BH 16-119-02, it consisted of varying proportions of sand. The thickness of this silt layer was approximately 1.8 m to 2.0 m. SPT "N" value in this layer ranged from 7 to 11 blows/300 mm, indicating loose to compact soil conditions. The moisture content of a sample taken from this silt layer varied from 17.3% to 21.7%.

## **6.4 Clayey Silt**

Clayey silt deposit was encountered in Boreholes 16-119-01, 16-119-02 and 16-119-04, in the range from El. 192.8 m to El. 193.4 m. This clayey silt deposit contained trace sand, and was found to be wet during drilling. The SPT "N"-values ranged from none (Weight of the Hammer) to as high as 11 blows/300 mm, indicating very soft to stiff soil consistency. Thin lenses of silt were encountered within this deposit in all three boreholes. The low SPT blow counts correspond to the locations where silt lenses were encountered. The thickness of this clayey silt deposit varied from 6.3 m in Borehole 16-119-04 to 7.5 m in Borehole 16-119-02.

Laboratory test results indicated that the moisture content of the clayey silt deposit was in the range of 22.3% to 39.2%. The liquid limit ranged from 25 to 27 and the corresponding plastic limits varied between 15 and 19, resulting in plasticity index of 8 to 10. Based on the results of Atterberg limit tests,



the soil may be classified as clay of low plasticity (CL) in the Unified Soil Classification System (USCS).

The plasticity chart is provided on Figure 119-PC-2, in Appendix B.

The grain size analyses carried out on samples taken from Borehole 16-119-04 at a depth of about 8 m (El. 194 m) and from Borehole 16-119-01 at a depth of 15.5 m (El. 186.3 m) indicated 0% gravel, 1% sand, 62% to 84% silt and 15% to 37% clay. The grain size distribution curves and plasticity charts are presented on Figure 119-GS-2, in Appendix B.

### **6.5 Silty Clay**

The clayey silt layer is underlain by a silty clay deposit at a depth varying from 10.3 m (El. 187.1 m) in Borehole 16-119-04 to 16.5 m (El. 185.3 m) in Borehole 16-119-02. This silty clay deposit contained trace sand, and was observed to be wet during drilling. The SPT "N"-values range from none to 4 blows/300 mm, indicating very soft to soft consistency. The silty clay layer was fully penetrated in two boreholes (BH 16-119-02 and BH 16-119-04). The thickness of the deposit was approximately 2.9 m in BH 16-119-02 and approximately 3.4 m in BH 16-119-04.

The moisture content of the silty clay deposit was in the range of 21% to 44.4%, with the lowest values corresponding to those samples containing substantial amount of silt. Atterberg Limit tests performed on samples taken from Borehole 16-119-02 at a depth of 17.1 m (El. 184.7 m) and Borehole 16-119-04 at a depth of 12.6 m (El. 189.4 m) indicated a liquid limit in the range of 47 to 48 and a plastic limit between 19 and 20, resulting in plasticity index of 28. Based on the results of these values, the deposit may be classified as clay of medium plasticity (CI) in the Unified Soil Classification System (USCS). The results are reported on plasticity chart presented on Figure 119-PC-3, in Appendix B.

The grain size analysis of a sample from Borehole 16-119-01 indicates presence of 0% gravel, 1% sand, 21% silt and 78% clay. The grain size distribution curve is given on Figure 119-GS-3, in Appendix B.

### **6.6 Sandy Silt to Silty Sand**

A sandy silt layer was encountered in Borehole 16-119-04 at a depth of 13.7 m (El. 183.7 m), underneath the silty clay deposits. This sandy silt layer contained cobbles and probable boulders



in a matrix of clay and silt. The total thickness of this layer in Borehole 16-119-04 was 3.6 m. The moisture content of a sample from Borehole 16-119-04 was found to be 21%.

A thin layer of sand was encountered in Borehole 16-119-02 at a depth of 19.4 m (El. 182.4 m).

DCP tests were carried out in Boreholes 16-119-01 and 16-119-02 to measure the penetration resistance of soils below the sampling depths. The tests indicated that the penetration index N-values increase from 9 to over 100 in Borehole 16-119-01 and from 48 to 100 in Borehole 16-119-02.

Drilling beyond the depth of 19.8 m (El. 182 m) in Borehole 16-119-03 indicated the presence of silty sand materials with some gravel and trace clay. Obtaining an auger sample at and below the depth of 19.8 m (El. 182 m) in this borehole was found to be difficult, indicating the presence of compact sandy soils with an increasing proportion of cobbles and boulders.

## 7. GROUNDWATER

During drilling, groundwater was encountered in Borehole 16-119-02 at 6.7 m depth (El. 195.1 m). Later at the completion of drilling, the groundwater level in this borehole rose to the depth of 5.5 m (El. 196.3 m). Free water was not noticed in Borehole 16-119-01. In Borehole 16-119-04, high moisture content indicated that the groundwater table is within the upper clayey silt fill.

Generally, because of seasonal fluctuations in precipitations, groundwater levels could be higher or lower and soils could be drier or wetter than what was observed at the site during drilling.

## 8. CHEMICAL TEST RESULTS

A summary of the chemical test results conducted on a clayey silt sample taken at a depth of 4.8 m (El. 197 m) from Borehole 16-119-04 is provided in Table 8. The details of these results and a description of the test method are given in Appendix C.

**TABLE 8 - A SUMMARY OF CORROSIVITY TEST RESULTS**

BOREHOLE NO.	SAMPLE NO.	DEPTH / ELEVATION (m)	SOIL TYPE	SULPHATE (µg/g)	CHLORIDE (µg/g)	pH	RESISTIVITY (Ohm-cm)
16-119-04	SS5	4.9 / 192.5	Clayey Silt	77	3	8.18	5590



## 9. CLOSURE

The drilling work was supervised by Mr. M. Rapsey under the direction of Lulseged Yimam, PhD. P.Eng. The drilling equipment was supplied and operated by LandCore Drilling Ltd., of Chelmsford, Ontario. The laboratory tests were conducted at the PML laboratory in Toronto. Chemical tests were carried out by AGAT Laboratories of Mississauga, Ontario. Surveying of borehole locations was performed by Callon Dietz Inc. of London, Ontario.

This report was prepared by Lulseged Yimam, PhD, P.Eng., and reviewed by 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.



Lulseged Yimam, PhD, P.Eng.  
Senior Engineer, Geotechnical Services



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



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



## **APPENDIX A**

### Site Photographs



**Photograph P1** – View of the Culver Outlet (South Side) and Culvert Interior (July 27, 2016).



**Photograph P2** - Borehole 16-119-04, Northwest Culvert End (July 27, 2016).



**Photograph P3** – Looking North at the Pagwachuan River and the Southeast Road Embankment, (July 27, 16, 2016).



**Photograph P4** – Drilling at the Location of Borehole 16-119-04 (July 8, 2016).



## **APPENDIX B**

Borehole Location Plan and Soil Strata

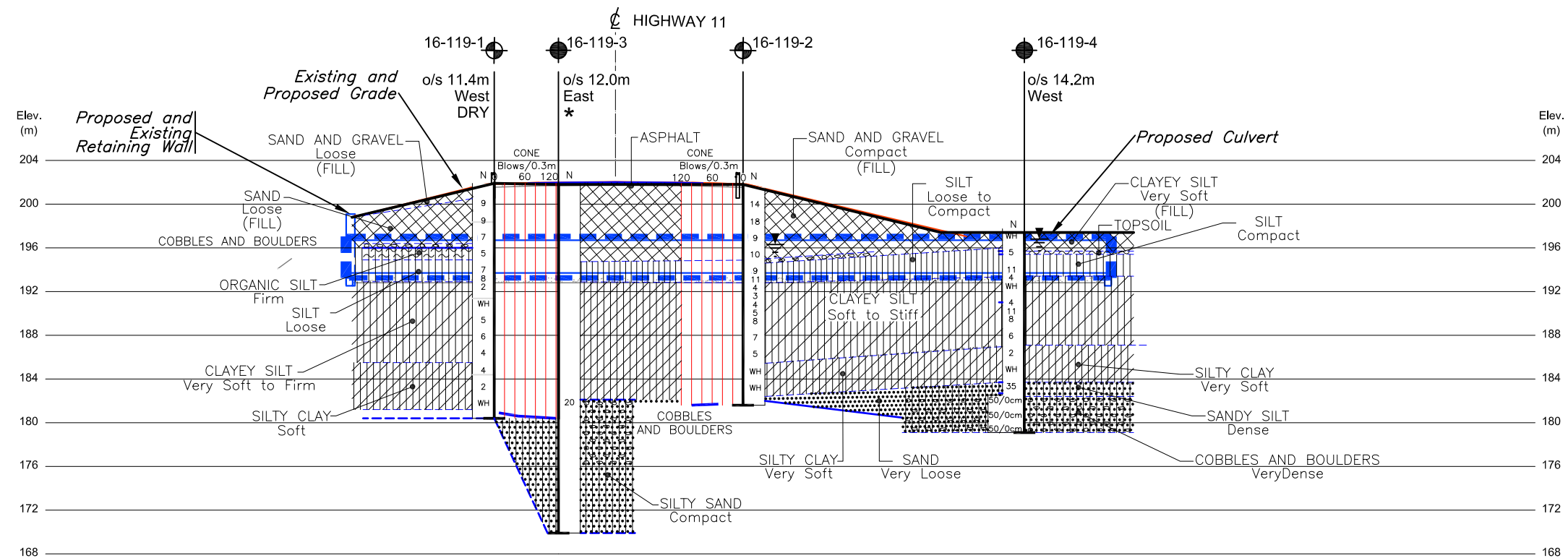
Explanation of Terms Used in Report

Record of Borehole Sheets

Grain Size Distribution Curves – Figures 119-GS-1, 119-GS-2 and 119-GS-3

Plasticity Charts – Figures 119-PC-1, 119-PC-2 and 119-PC-3

SHEET



REVISIONS			
	DATE	BY	DESCRIPTION

HWY No	11	DIST NEW LEASKEARD		
SUBM'D	NA	CHECKED LY	DATE FEB. 23, 2017	SITE 39W-119
DRAWN	NA	CHECKED MV	APPROVED CN	DWG 119/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/0.3m)	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
$\sigma'_{vo}$	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	WTP		WETTER THAN PLASTIC LIMIT	j	kN/m <sup>3</sup>	SEEPAGE FORCE
e	1, %	VOID RATIO						

**RECORD OF BOREHOLE No 16-119-01**

1 of 2

**METRIC**

G.W.P. 5130-13-00 LOCATION Co-ords: 5 514 304.7 N ; 210 608.8 E ORIGINATED BY M.R.  
DIST New Liskeard BOREHOLE TYPE C.F.H.S.A. and Dynamic Cone Penetration Test COMPILED BY L.Y.  
DATUM Geodetic HWY 11 DATE July 06, 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										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE										○		
								● QUICK TRIAXIAL × LAB VANE												
201.9	Ground Surface						20	40	60	80	100									
0.0	Sand and gravel some silt, trace clay Loose    Brown    Moist Styrofoam pieces						201													
	Fine to medium sand Grey		1	SS	9		200						○							
							199													
	(FILL)		2	SS	9		198						○			21 62 14 3				
							197													
	cobbles		3	SS	7		196													
196.0	Organic silt						195													
5.9	Loose    Black to Moist mottled olive brown		4	SS	5		194							○						
194.9	Silt trace sand, trace clay						193													
7.0	Loose    Brown    Moist to grey    to wet		5	SS	7		192													
			6	SS	8		191							○						
192.9	Clayey silt, trace sand						190													
9.0	Very soft Grey    Wet to firm		7	SS	2		189													
			8	SS	WH**		188							○						
			9	SS	5		187													
			10	SS	6															
186.9	Cont'd																			

**RECORD OF BOREHOLE No 16-119-01**

2 of 2

**METRIC**

G.W.P. 5130-13-00 LOCATION Co-ords: 5 514 304.7 N ; 210 608.8 E ORIGINATED BY M.R.  
DIST New Liskeard BOREHOLE TYPE C.F.H.S.A. and Dynamic Cone Penetration Test COMPILED BY L.Y.  
DATUM Geodetic HWY 11 DATE July 06, 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												
186.9							20	40	60	80	100									
15.0	Clayey silt, trace sand																			
	Very soft Grey Wet to firm (Cont'd.)		11	SS	4															
185.5																				
16.4	Silty clay, trace sand																			
	Soft to Grey Wet very soft		12	SS	4															
			13	SS	2															
			14	SS	WH															
181.2	End of borehole																			
20.7																				
180.4	End of dynamic cone penetration test																			
21.5																				

# RECORD OF BOREHOLE No 16-119-02

1 of 2

## METRIC

G.W.P.	5130-13-00	LOCATION	Co-ords: 5 514 315.8 N ; 210 620.7 E	ORIGINATED BY	M.R.
DIST	New Liskeard	BOREHOLE TYPE	C.F.H.S.A. and Dynamic Cone Penetration Test	COMPILED BY	L.Y.
DATUM	Geodetic HWY 11	DATE	July 07, 2016	CHECKED BY	M.V.

[illegible]

**RECORD OF BOREHOLE No 16-119-02**

2 of 2

**METRIC**

G.W.P. 5130-13-00 LOCATION Co-ords: 5 514 315.8 N ; 210 620.7 E ORIGINATED BY M.R.  
DIST New Liskeard BOREHOLE TYPE C.F.H.S.A. and Dynamic Cone Penetration Test COMPILED BY L.Y.  
DATUM Geodetic HWY 11 DATE July 07, 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		
								20	40	60	80	100						20	40	60
186.8																				
15.0	Clayey silt, trace sand																			
	Very soft Grey Wet (Cont'd.)		13	SS	5								o			0 1 62 37				
185.3							186													
16.5	Silty clay, trace sand																			
	Very soft Grey Wet		14	SS	WH**		185						o							
							184													
			15	SS	WH		183						o							
182.4																				
19.4	Silty sand																			
182.0	Very loose Grey Wet						182													
19.8	End of borehole																			
181.6																				
20.2	End of dynamic cone penetration test																			
<div>* 07 07 2016</div> <div>▽ Water level observed during drilling</div> <div>▼ Water level measured after drilling</div> <div>WH** denotes penetration due to weight of rods and hammer</div> <div>NOTE: Sand heave after sample SS-15</div> <div>C.F.H.S.A. denotes Continuous Flight Hollow Stem Augers</div>																				

**RECORD OF BOREHOLE No 16-119-03**

1 of 3

**METRIC**

G.W.P. 5130-13-00 LOCATION Co-ords: 5 514 307.1 N ; 210 632.4 E ORIGINATED BY M.R.  
DIST New Liskeard BOREHOLE TYPE NW Casing + Wash Boring + NQ Coring COMPILED BY L.Y.  
DATUM Geodetic HWY 11 DATE July 19 and 20, 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												
201.8	Ground Surface						20	40	60	80	100	20	40	60						
0.0	Probable sand and gravel some silt  Compact      Brown to Damp to loose      dark brown   																			

# RECORD OF BOREHOLE No 16-119-03

2 of 3

METRIC

G.W.P.	5130-13-00	LOCATION	Co-ords: 5 514 307.1 N ; 210 632.4 E	ORIGINATED BY	M.R.
--------	------------	----------	--------------------------------------	---------------	------

DIST New Liskeard BOREHOLE TYPE NW Casing + Wash Boring + NQ Coring COMPILED BY L.Y.

DATUM Geodetic HWY 11 DATE July 19 and 20, 2016 CHECKED BY M.V.

[illegible]

# RECORD OF BOREHOLE No 16-119-03

3 of 3

**METRIC**

G.W.P.	5130-13-00	LOCATION	Co-ords: 5 514 307.1 N ; 210 632.4 E	ORIGINATED BY	M.R.
DIST	New Liskeard	BOREHOLE TYPE	NW Casing + Wash Boring + NQ Coring	COMPILED BY	L.Y.
DATUM	Geodetic	HWY	11	DATE	July 19 and 20, 2016
				CHECKED BY	M.V.

[illegible]

**RECORD OF BOREHOLE No 16-119-04**

1 of 2

**METRIC**

G.W.P. 5130-13-00 LOCATION Co-ords: 5 514 329.0 N ; 210 607.0 E ORIGINATED BY M.R.  
DIST New Liskeard BOREHOLE TYPE C.F.H.S.A. and Wash Boring COMPILED BY L.Y.  
DATUM Geodetic HWY 11 DATE July 07 and 08, 2016 CHECKED BY M.V.

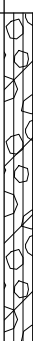
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)			
								○ UNCONFINED	+ FIELD VANE							● QUICK TRIAXIAL	× LAB VANE	
197.4	Ground Surface						20	40	60	80	100							
0.0	Clayey silt, organics		1	SS	WH**	▽*	197						○					
	Very soft Dark brown Wet (FILL)																	
195.7	Topsoil		2	SS	5		196						○					
1.7																		
195.4	Silt, trace clay						195											
2.0	Compact Brown to grey Wet		3	SS	11		194						○					
193.4	Clayey silt, trace sand		4	SS	4		193						○					
4.0	Very soft Grey Wet to soft		5	SS	WH		192						○					
			7	SS	4		191						○					
	Stiff to firm		8	SS	11		190						○					
			9	SS	8		189											
			10	SS	6		188						○					
187.1	Silty clay, trace sand						187											
10.3	Very soft Grey Wet		11	SS	2		186						○					
			12	SS	WH		185						○					
183.7	Sandy silt, trace clay						184											
13.7	Dense Grey Wet		13	SS	35		183						○					
182.4	Sand and gravel layer Cont'd																	

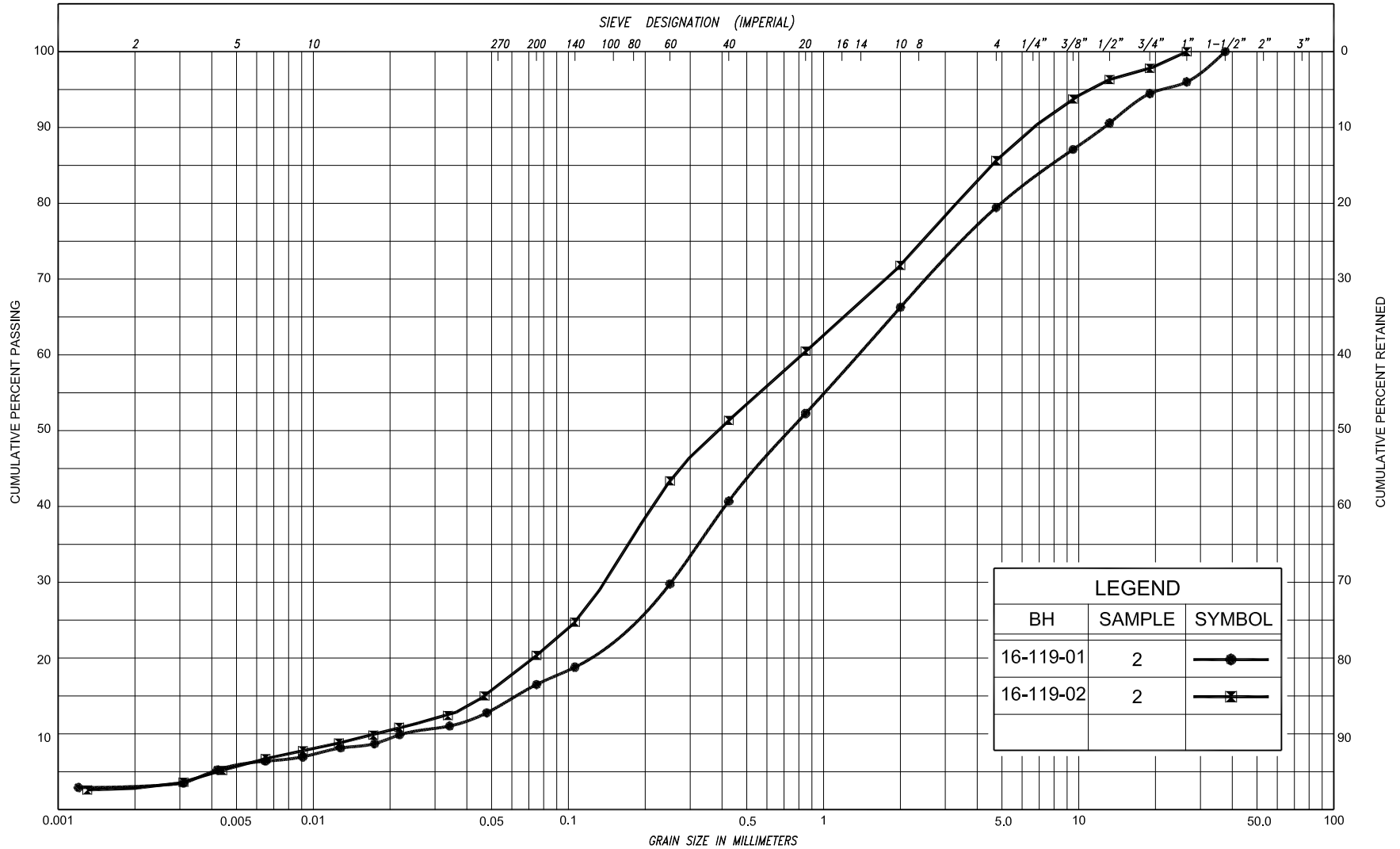
**RECORD OF BOREHOLE No 16-119-04**

2 of 2

**METRIC**

G.W.P. 5130-13-00 LOCATION Co-ords: 5 514 329.0 N ; 210 607.0 E ORIGINATED BY M.R.  
DIST New Liskeard BOREHOLE TYPE C.F.H.S.A. and Wash Boring COMPILED BY L.Y.  
DATUM Geodetic HWY 11 DATE July 07 and 08, 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												
182.4							20	40	60	80	100									
15.0	Cobbles and boulders in sandy silt matrix		14	SS	50/0cm		182													
	Very dense Grey      Moist																			
							181													
			15	SS	50/0cm		180													
179.1																				
18.3	End of borehole		16	SS	50/0cm															
	<div>*      2016   07   07</div> <div>▽      Water level observed          during drilling</div> <div>WH**    denotes penetration          due to weight of rods          and hammer</div> <div>C.F.H.S.A.    denotes Continuous Flight Hollow Stem Augers</div>																			

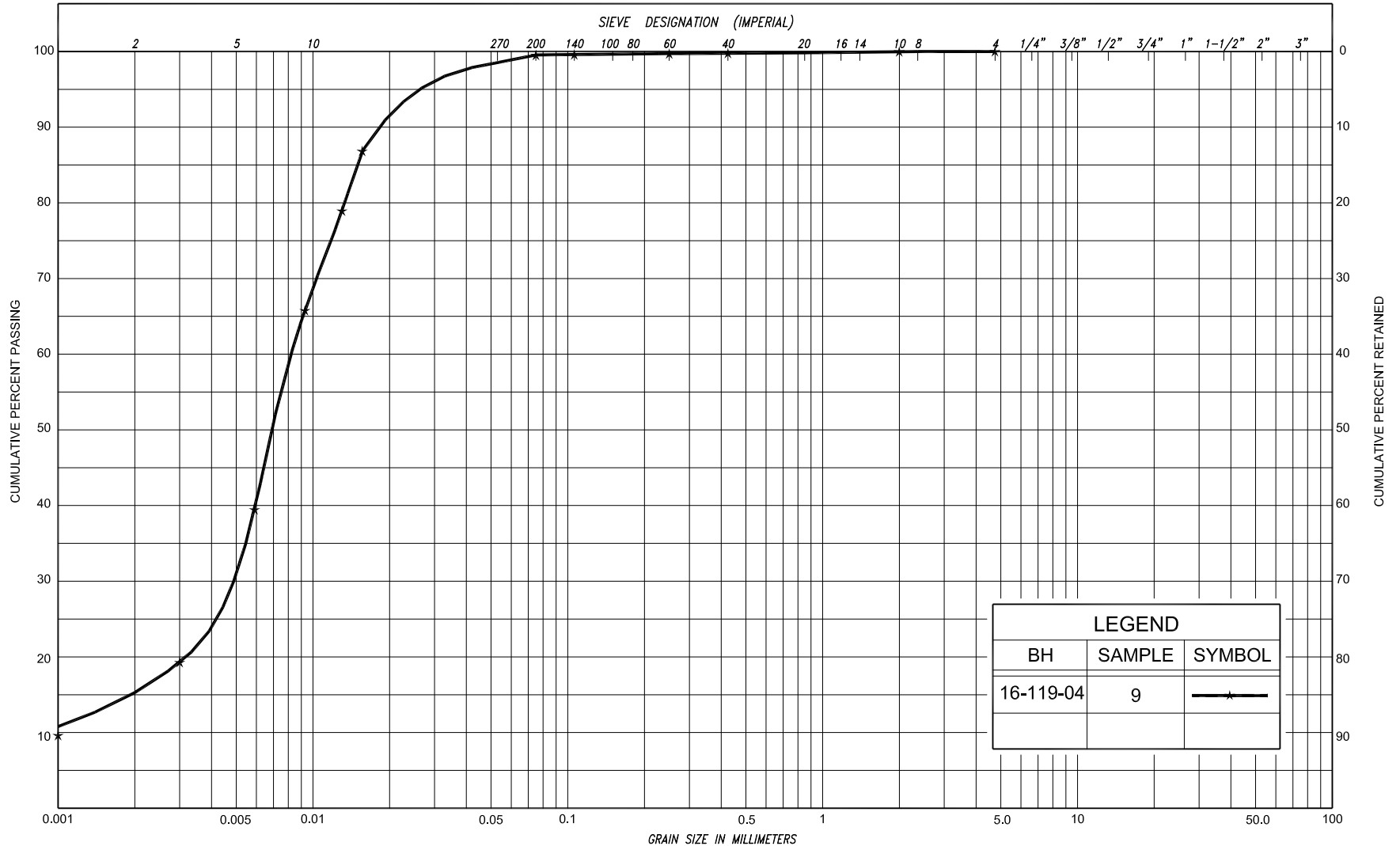


SILT & CLAY				FINE		MEDIUM		COARSE	GRAVEL			COBBLES	UNIFIED						
				SAND															
CLAY	FINE		MEDIUM		COARSE		FINE		MEDIUM		COARSE		GRAVEL		COBBLES	M.I.T.			
	SILT																		
CLAY			SILT			V. FINE		FINE		MED.		COARSE		GRAVEL					U.S. BUREAU
						SAND													



# GRAIN SIZE DISTRIBUTION SAND AND GRAVEL, some silt, trace clay (FILL)

FIG No. 119-GS-1  
HWY 11  
G.W.P. 5130-13-00



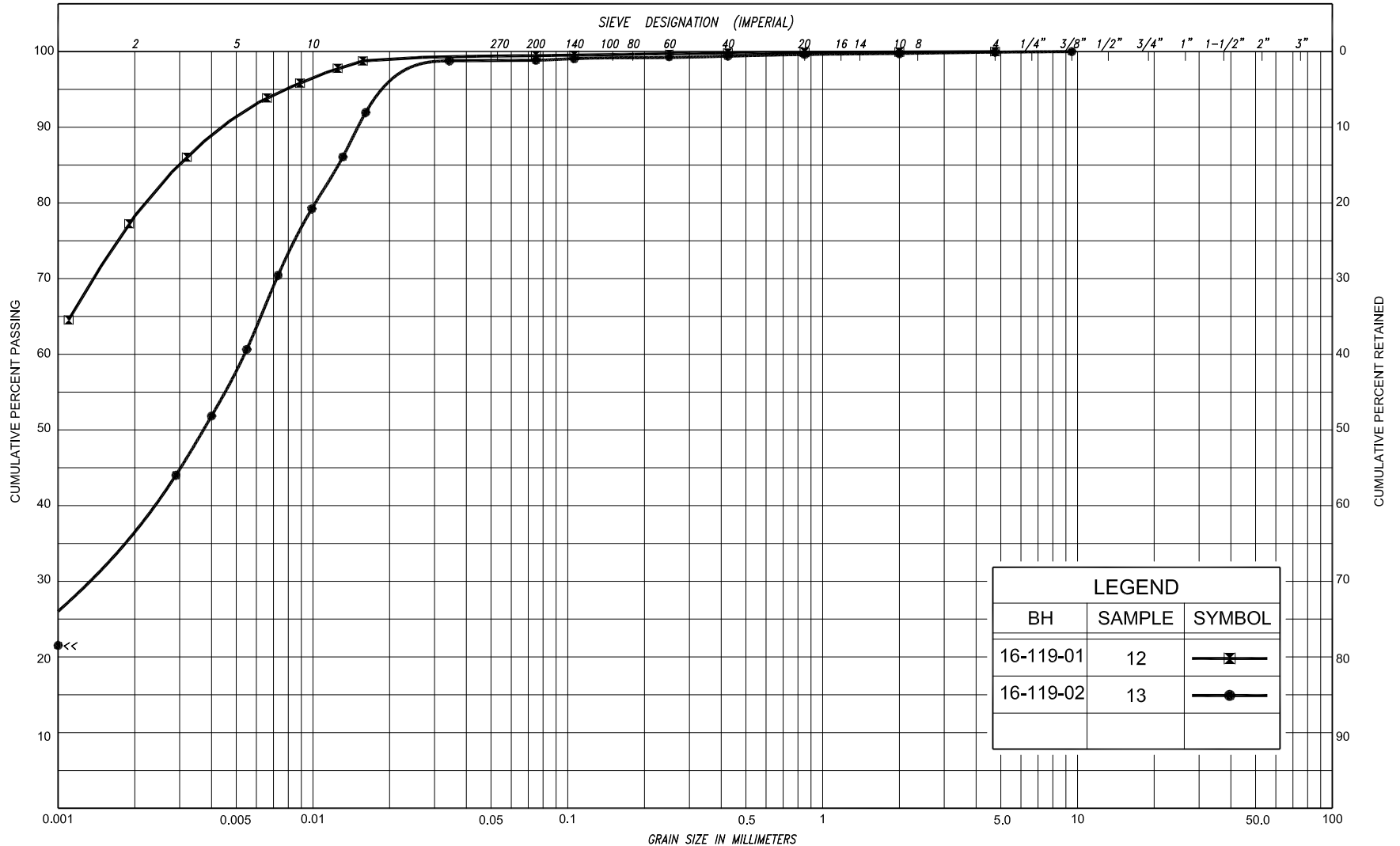
LEGEND		
BH	SAMPLE	SYMBOL
16-119-04	9	— *

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



# GRAIN SIZE DISTRIBUTION CLAYEY SILT, trace sand

FIG No.	119-GS-2
HWY	11
G.W.P.	5130-13-00



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

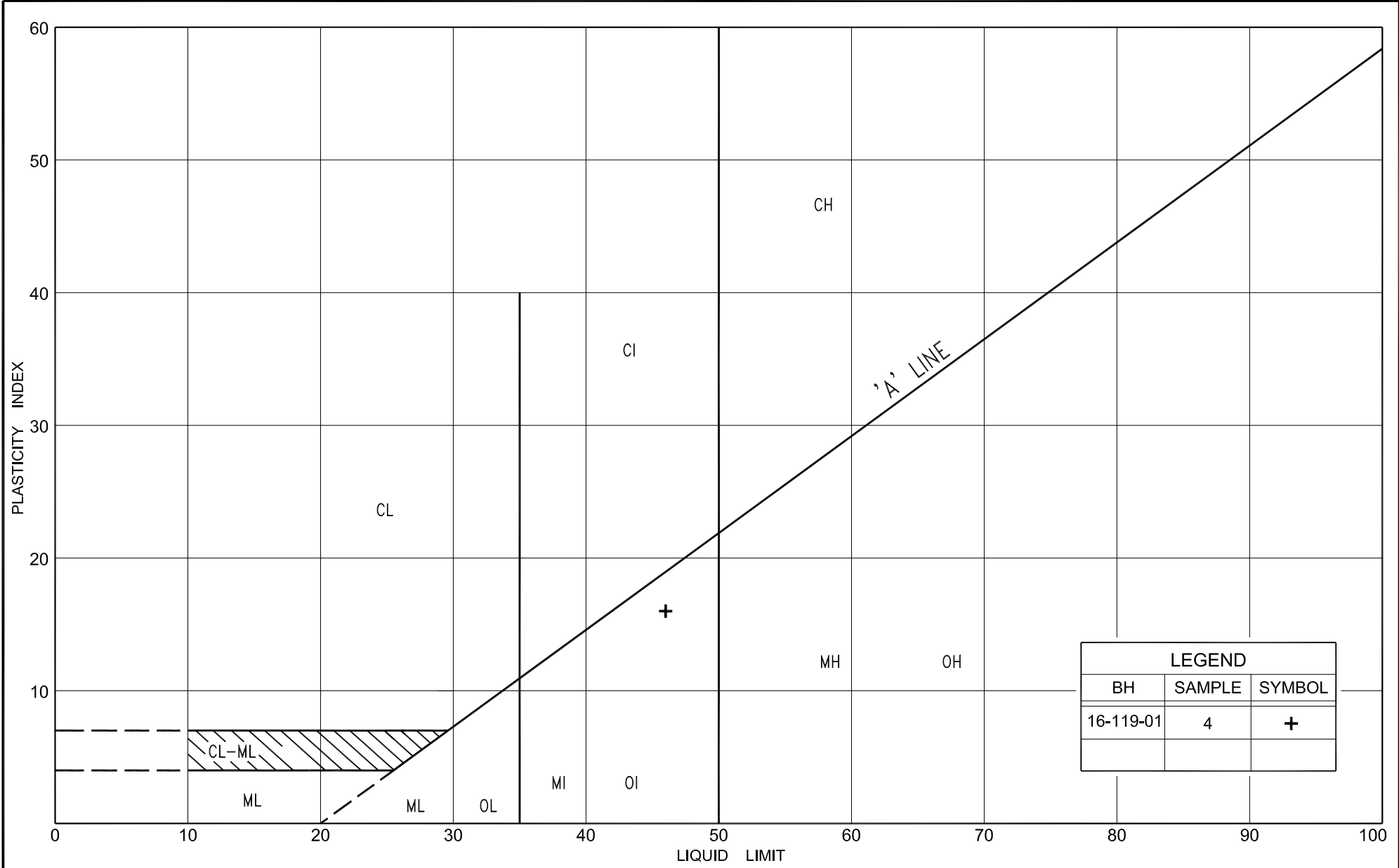


# GRAIN SIZE DISTRIBUTION SILTY CLAY, trace sand

FIG No. 119-GS-3

HWY 11

G.W.P. 5130-13-00

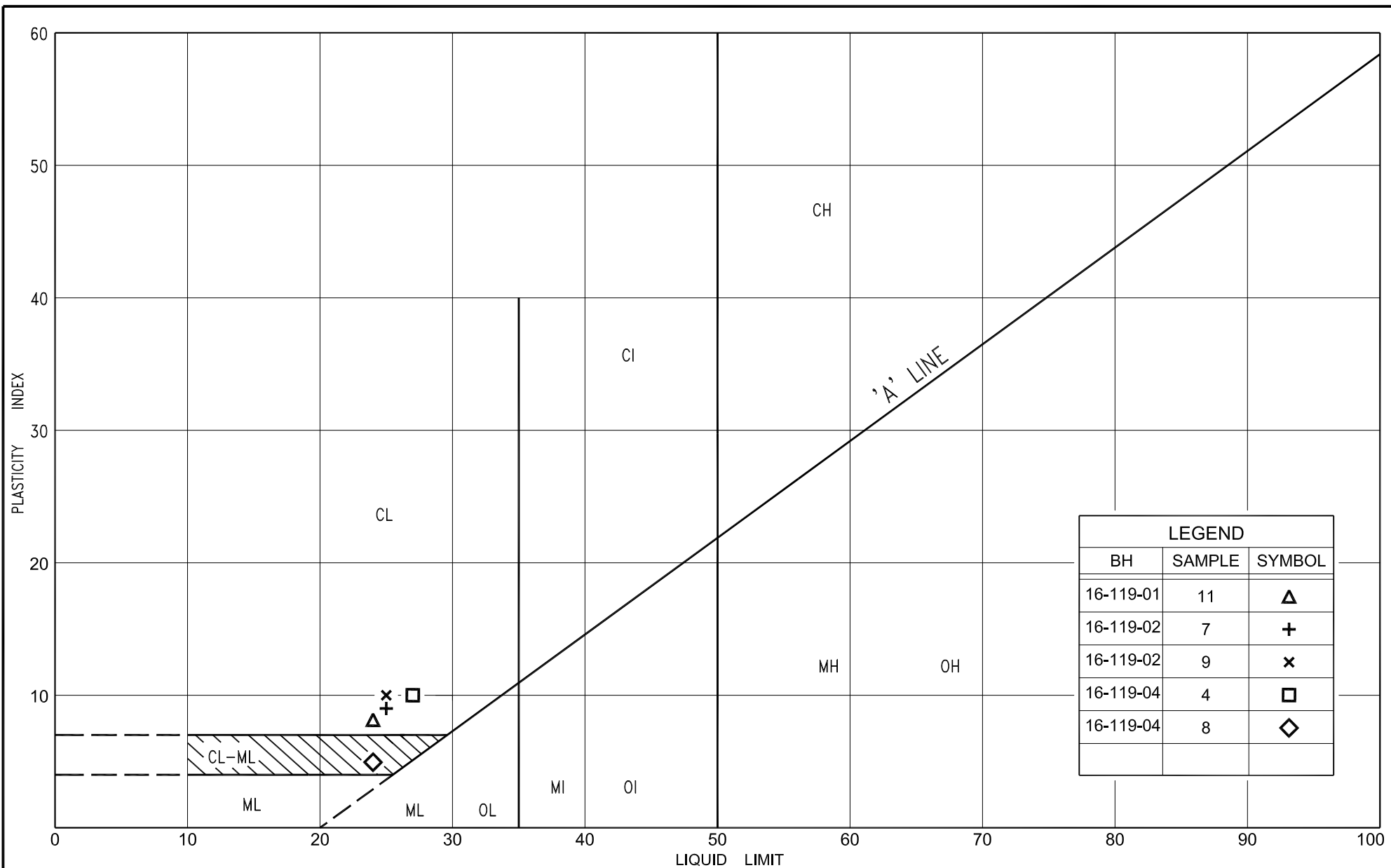


# PLASTICITY CHART ORGANIC SILT (OI)

FIG No. 119-PC-1

HWY 11

G.W.P. 5130-13-00

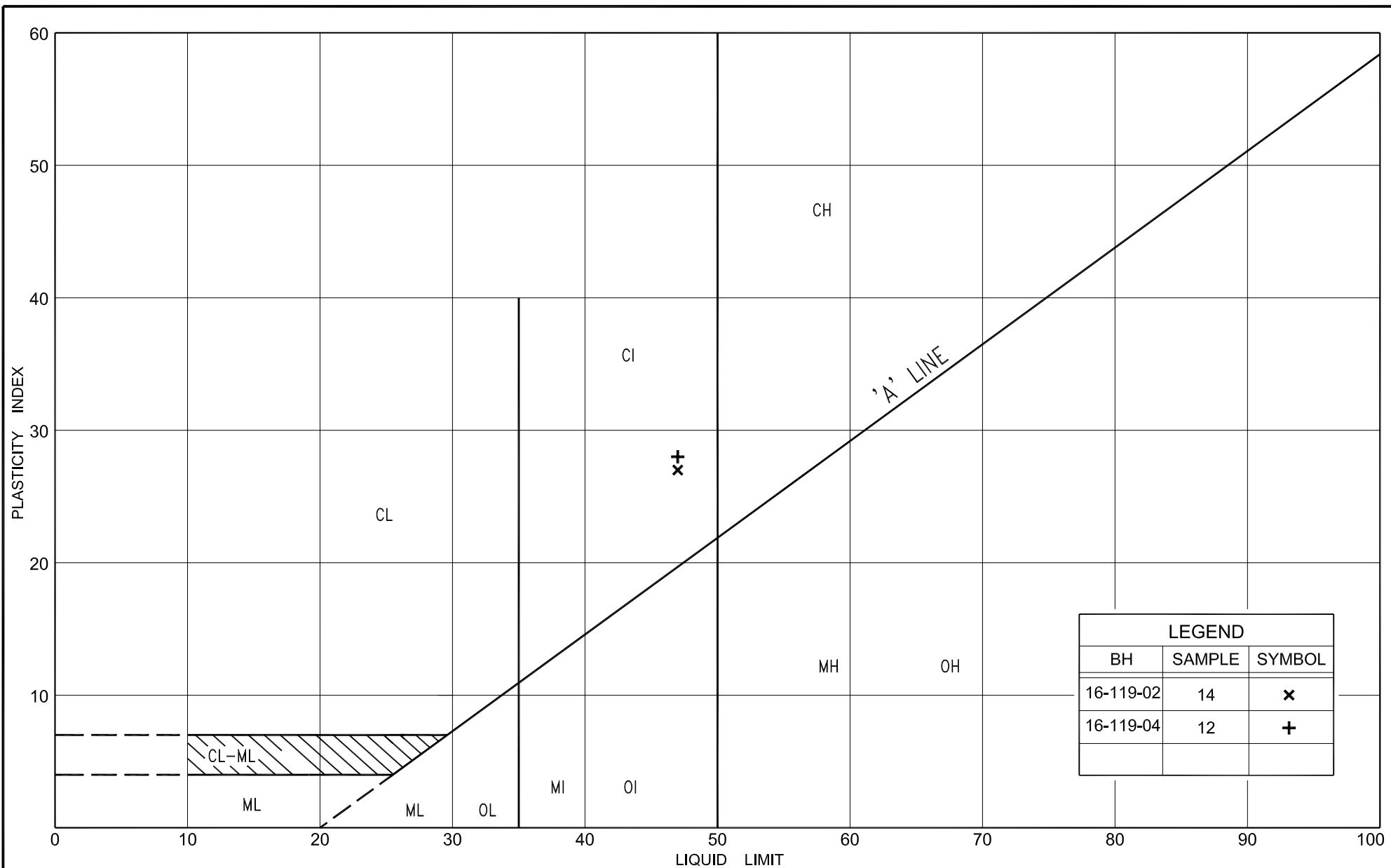


**PLASTICITY CHART**  
CLAYEY SILT, trace sand (CL / CL-ML)

FIG No. 119-PC-2

HWY 11

G.W.P. 5130-13-00



# PLASTICITY CHART SILTY CLAY, trace sand (CI)

FIG No. 119-PC-3

HWY 11

G.W.P. 5130-13-00



## **APPENDIX C**

### Results of Chemical Corrosivity Tests



**AGAT** Laboratories

## Certificate of Analysis

AGAT WORK ORDER: 16T119380

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: 2016-07-25

DATE REPORTED: 2016-08-03

				BH16-117-03	BH16-118-02	BH16-119-01	BH16-119-04
SAMPLE DESCRIPTION:				SS7	SS4	SS10	SS5
SAMPLE TYPE:				Soil	Soil	Soil	Soil
DATE SAMPLED:				7/13/2016	7/10/2016	7/6/2016	6/7/2016
Parameter	Unit	G / S	RDL	7729948	7729949	7729950	7729951
Sulphide*	%		0.05	<0.05	<0.05	<0.05	<0.05
Chloride (2:1)	µg/g		2	16	326	3	7
Sulphate (2:1)	µg/g		2	27	7	77	26
pH (2:1)	pH Units		NA	8.18	8.01	8.18	8.18
Electrical Conductivity (2:1)	mS/cm		0.005	0.174	0.625	0.179	0.154
Resistivity (2:1)	ohm.cm		1	5750	1600	5590	6490
Redox Potential (2:1)	mV		5	265	279	259	262

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

**7729948-7729951** 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:

*Sofra Pehlyora*

## Quality Assurance

CLIENT NAME: PETO MACCALLUM LIMITED

PROJECT: 16TF013A

SAMPLING SITE:

AGAT WORK ORDER: 16T119380

ATTENTION TO: Lul Yimam

SAMPLED BY:

### Soil Analysis

RPT Date: Aug 03, 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*	7229948	7229948	< 0.05	< 0.05	NA	< 0.05	105%	80%	120%	NA			NA		
Chloride (2:1)	7730302		273	272	0.4%	< 2	96%	80%	120%	104%	80%	120%	106%	70%	130%
Sulphate (2:1)	7730302		77	78	1.3%	< 2	94%	80%	120%	105%	80%	120%	106%	70%	130%
pH (2:1)	7736650		8.20	8.21	0.1%	NA	101%	90%	110%	NA			NA		
Electrical Conductivity (2:1)	7736650		0.231	0.231	0.0%	< 0.005	99%	90%	110%	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:



## Method Summary

CLIENT NAME: PETO MACCALLUM LIMITED

AGAT WORK ORDER: 16T119380

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 B – FOUNDATION DESIGN REPORT**

**for**

**UNNAMED CREEK CULVERT REPLACEMENT**

**SITE NO. 39W-119/C**

**HIGHWAY 11 - STA. 11+917**

**TOWNSHIP OF CLAVET, DISTRICT OF NEW LISKEARD**

**HEARST, ONTARIO**

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

**GWP 5130-13-00**

**WP 5292-14-01**

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.: 119FDR  
GEOCRES No.: 42F-042  
March 6, 2017



## TABLE OF CONTENTS

### PART B– FOUNDATION DESIGN REPORT

10. INTRODUCTION .....	10
11. PROJECT DESCRIPTION .....	10
11.1 General .....	10
11.2 Existing Culvert.....	10
11.3 Proposed Culvert .....	11
11.4 Foundation Conditions.....	12
12. CULVERT REPLACEMENT OPTIONS .....	12
12.1 Option 1: Precast Concrete Box Culvert .....	14
12.2 Option 2: Cast-In-Place Reinforced Concrete Box Culvert .....	14
12.3 Option 3: Three-Sided Open Footing Precast Concrete Culvert.....	14
12.4 Recommendations for Preferred Option.....	15
12.5 Headwall and Wing Walls.....	15
13. BACKFILL AND COVER MATERIAL.....	17
14. LATERAL EARTH PRESSURE .....	17
15. APPROACH EMBANKMENT .....	18
16. FOUNDATION FROST DEPTH .....	19
17. SEISMIC CONSIDERATIONS .....	19
18. CONSTRUCTION CONSIDERATIONS.....	19
18.1 Staged Construction .....	19
18.2 Excavation .....	20
18.3 Subgrade Preparation.....	20
18.4 Groundwater Control .....	21
19. EROSION CONTROL .....	22
20. SOIL CORROSIVITY.....	23
21. CLOSURE .....	24

APPENDIX D – General Arrangement Drawing

APPENDIX E – List of Ontario Provincial Standard Documents Relevant to the Report and Non-Standard Specific Provision (NSSP)

**PART B – FOUNDATION DESIGN REPORT**

Unnamed Creek Culvert Replacement

Site No. 39W-119/C

Highway 11 – Sta. 11+917

Township of Clavet, District of New Liskeard

Hearst, Ontario

Assignment No 5015-E-0009, GWP 5130-13-00, WP 5292-14-01

---

**10. INTRODUCTION**

This report provides foundation design recommendations based on the interpretation of the geotechnical data presented in the foundation investigation report (Part A) to assist the design team in selecting a suitable type of foundation for the culvert replacement at the crossing of Highway 11 and an unnamed Creek near Sta. 11+917, in the Township of Clavet, District of New Liskeard.

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

**11. PROJECT DESCRIPTION**

**11.1 General**

The discussions and recommendations presented in this report are based on the General Arrangement (GA) drawing provided by GHD and the factual data obtained from the geotechnical investigation carried out by PML. The GA drawing is provided in Appendix D.

The list of Ontario Provincial Standard Specifications (OPSSs) and Ontario Provincial Standard Drawings (OPSDs) cited in this report is provided in Appendix E.

**11.2 Existing Culvert**

The existing culvert is a 3.04 m wide, 3.65 m high and 28.0 m long cast-in-place (CIP) concrete box structure with a fill height of 3.0 m above the deck. Based on field measurements, the existing embankment above the creek bed is approximately 7.9 m high. The embankment slopes on both



sides of the culvert are well vegetated with brush and trees, and the embankments appeared to be in good condition with no sign of sloughing or erosion on slopes.

Based on the Request for Quotation (RFQ), it is understood that the existing CIP culvert was constructed in 1942 and has no record of rehabilitation.

The highway accommodates two lanes of vehicular traffic, one on each side of the road. According to the Preliminary Structural Assessment Report prepared by WSP (MTO 5013-E-0052), the condition of the existing culvert is fair. However, the south end of the culvert shows spalling and deterioration of concrete and scaling. The existing culvert includes a headwall and wing walls at the outlet (south end). There is no headwall, wing walls, or rip-rap at the inlet.

The headwall and the wing walls show signs of distress in the form of visible cracks including spalling of concrete and scaling. The sign of deteriorations includes staining of the interior walls as well as at the north end of the culvert. The absence of wide cracks on vertical interior walls and top slab suggest that the effect of settlement on the existing culvert was relatively minor. Considering the size of the culvert and the height of the fill above the deck, the service loading from the existing structure may be expected to be in the range of 75 kPa to 100 kPa at the founding level.

### **11.3 Proposed Culvert**

Based on the GA drawing, it is understood that the existing structure will be replaced by a single cell precast concrete box culvert, with a span of 4.2 m and height of 3.0 m. The culvert replacement will not involve a grade raise or widening of the road. The height of the embankment above the top of the box culvert at the centerline of the highway will be 5.0 m, and the finished grade of the highway will remain at approximately El. 202 m. The proposed culvert will extend to the north and will generally be 35 m long. It will involve no change in the vertical and horizontal alignments. In addition, the invert of the existing culvert at both the inlet and outlet will be at El. 193.7 m. Details of the proposed culvert are shown on the GA drawing provided in Appendix D.

It is understood that the existing headwall and wing walls at the outlet (south end) will also be replaced along with the culvert. Based on the GA drawing, the replacement headwall will be about 7 m long and flanked by wing walls extending to an approximate distance of 10.0 m from the external faces of the culvert to maintain the slope of the embankment at 2H:1V. The wing walls are expected to be located along the same alignment (180°) as the headwall.



It is understood that no detour is planned to divert the traffic and the construction of the replacement precast concrete box 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. This will require a properly designed roadway protection system along the centerline of the road.

#### **11.4 Foundation Conditions**

In summary, the subsurface at the proposed culvert location generally consists of 5.9 m to 7.2 m thick sand and gravel fill, followed by 1.8 m to 2.0 m loose to compact silt. This silt layer is underlain by 6.3 m to 7.5 m thick, soft to firm clayey silt deposit, which extends to about El. 185.3 m.

The clayey silt deposit is followed by a silty clay layer that varies in thickness from 2.9 m to 3.4 m in the area where this layer was fully penetrated. The silty clay layer is underlain by silty sand to sandy silt to the maximum depth of investigation of 20.4 m (El. 181.5 m) below the existing grade.

The water level in the unnamed creek was observed at El. 194.2 m in July, 2016 and is provided on the GA drawing. The groundwater level at the site is expected to be influenced by the flow conditions in the unnamed creek and the adjacent Pagwachuan River.

#### **12. CULVERT REPLACEMENT OPTIONS**

The feasibility of the following three options for replacing the existing culvert along the same vertical and horizontal alignments are discussed in this report.

- Precast concrete box culvert
- Cast-in-place (CIP) concrete box culvert
- Three sided open footing precast concrete culvert

A discussion on these options are provided below in the order of preference. A comparison of the technical advantages and disadvantages for the replacement culvert are provided in Table 12.



**Table 12 - 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> <ol style="list-style-type: none"> <li>1. High degree of quality and uniformity, design flexibility, superior strength and durability</li> <li>2. Reduced weather dependency during installation</li> <li>3. Reduced impact on traffic interruption;</li> <li>4. Ease of construction and installation in wet conditions is possible</li> <li>5. Better at accommodating differential settlements than cast-in-place culverts</li> </ol>	<b>Advantages:</b> <ol style="list-style-type: none"> <li>1. Reduces uneven settlement</li> <li>2. Reduces water leakage and deterioration of culvert</li> <li>3. Ability to withstand differential settlements;</li> <li>4. Longer life span of the structure</li> <li>5. Degradation of subgrade can be avoided by placing lean concrete</li> </ol>	<b>Advantages:</b> <ol style="list-style-type: none"> <li>1. High degree of quality and uniformity, design flexibility, superior strength and durability</li> <li>2. Generally allows for natural streambed to remain intact;</li> <li>3. Less accumulation of sediments in the upstream of channel</li> <li>4. Reduced weather dependency during installation</li> <li>5. Ease of construction and installation in wet conditions is possible</li> </ol>
<b>Disadvantages:</b> <ol style="list-style-type: none"> <li>1. Natural stream bed will not remain intact;</li> <li>2. Cause sediment accumulation in the upstream of the channel;</li> <li>3. Possibility for degradation of subgrade.</li> </ol>	<b>Disadvantages:</b> <ol style="list-style-type: none"> <li>1. Natural stream bed will not remain intact;</li> <li>2. Cause sediments accumulation in the upstream of the channel;</li> <li>3. Weather dependent during construction;</li> <li>4. Major dewatering scheme is required to construct the floor slab under 1 m high water.</li> </ol>	<b>Disadvantages:</b> <ol style="list-style-type: none"> <li>1. Subsoil conditions at shallow depths are not favourable to support the culvert on strip footings;</li> <li>2. Probability of uneven or differential settlements is high;</li> <li>3. Limited ability to withstand differential settlements.</li> </ol>
<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 and Not Recommended</b>



### **12.1 Option 1: Precast Concrete Box Culvert**

Based on the comparison provided in Table 12, the use of precast concrete box culvert placed at an elevation below the invert level of the existing structure (El. 194 m), founded on the loose to compact silt deposit is feasible and recommended for replacement structure. Recommendations for the design of the preferred option are provided in Section 12.4.

### **12.2 Option 2: Cast-In-Place Reinforced Concrete Box Culvert**

As in the case of the existing structure, the loose to compact silt layer underlain by soft to stiff clayey silt deposit is capable of providing adequate geotechnical resistance to support a cast-in place (CIP) reinforced concrete box culvert. The existing silt layer below the proposed founding surface will require a cut-off wall to prevent washout or undermining of subgrade.

However, if this option is considered, construction under about 3.0 m of groundwater will impose difficulties, and a dewatering scheme shall be used to provide a working platform for form work and placing concrete. The CIP concrete box culvert may be designed using a geotechnical resistance of 175 kPa at factored Ultimate Limit State (ULS) and 125 kPa at Serviceability Limit State (SLS) if the structure is founded on the undisturbed silt layer. The dewatering to construct the culvert in dry conditions will be a major concern and because of this problem, this option is not preferred.

### **12.3 Option 3: Three-Sided Open Footing Precast Concrete Culvert**

The silt encountered below the proposed founding level of the replacement culvert is susceptible to scour. Section C1.9.11.1 of the CHBDC, 2014 suggests avoiding the use of open footing on material susceptible to scour. Further, the subsoil conditions at the proposed founding level is not favourable to provide adequate geotechnical resistance to support the culvert on strip footings. If three-sided precast concrete culvert is preferred, then the use of deep foundation (piles) founded in the compact to very dense sand and gravel layer below approximately El. 180 m should be considered.



## **12.4 Recommendations for Preferred Option**

The preliminary GA drawing indicates that the proposed precast concrete box culvert will be placed at an elevation of about 193.7 m. The bedding for the culvert is expected to be placed on loose to compact silt to sandy silt layer, which is capable of providing adequate geotechnical resistance.

The option of using a precast concrete box culvert will require at least 75 mm of levelling course to meet the requirement of OPSS 422.07.08 and a bedding material as specified in OPSS 422.05.13.

The bedding should be placed in accordance with Section 422.07.07 of OPSS 422.

As required by Clauses 1.9.5.6 and 1.9.11.6.5 of the Canadian Highway Bridge Design Code (CHBDC, 2014), cut-off walls should be provided at both ends of the proposed culvert replacement. Cut-off walls should be in accordance with OPSD 812.010 or made of precast concrete with similar dimensions to prevent washout of granular bedding with provision to protect the material below invert. The cut-off walls should be extended to a minimum of 1.2 m below the invert elevation.

Considering the dimensions of the proposed precast concrete box culvert, the silt layer at the founding level, and the groundwater level, a factored geotechnical resistance at ULS of 175 kPa and at SLS of 125 kPa are recommended for design. Generally, no net increase in the load conditions is expected to induce settlement if these values are used for design.

The removal of the existing foundation may cause disturbance to the founding surface of the proposed culvert. In addition, the silt layer at the founding level will be susceptible to disturbance from construction traffic and any ponded water. In order 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 footing subgrade.

## **12.5 Headwall and Wing Walls**

Considering the height of the fill to be retained, it is recommended that the headwall and wing walls should be cast-in-place (CIP) concrete structures. The wing walls should be founded at least 500 mm below the elevation of the creek bed. Because of the order of loading expected at the foundation, including the load imposed by the fill and the subsoil conditions, a spread footing is



recommended to support the CIP concrete structure. A spread footing should be placed at about El. 193.5 m or deeper and may be designed assuming the geotechnical resistances given below.

Factored Geotechnical Bearing Resistance at ULS = 175 kPa

Geotechnical Bearing Resistance at SLS = 125 kPa

The factored geotechnical resistance at ULS is based on a factor of 0.5 as recommended in the Canadian Highway Bridge Design Code (CHBDC 2014). The grade of Highway 11 is expected to be maintained at the same elevation and there will be no additional fill from the embankment.

The subgrade is susceptible to disturbance from construction traffic and any ponded water. In order to limit the degradation of the founding soil, it is recommended that a concrete working slab (lean concrete) be placed on the subgrade within four hours after preparation, inspection and approval of the footing subgrade. This requirement should be addressed by a note on structural drawings.

The subsoil conditions at the founding level may be considered yielding, and active earth pressure conditions may be assumed for calculation of earth pressure against the wing walls. On the other hand, sufficient movement of the headwall may not be feasible and “at rest” conditions may be assumed for the computation of earth pressure. Adequate drainage should be provided behind the headwall and wing walls to prevent the build-up of hydrostatic pressure. The sub-drain should be installed as per OPSD 3504 and should be provided with positive drainage.

Based on the GA drawing, it is understood that reinforced soil system (RSS) is under consideration for headwall and wing walls instead of cast-in-place concrete retaining walls. However, RSS wall is a proprietary product, and a designated source list is maintained by MTO. Considering the potential for scour and undermining at the site, the supplier of the product should be consulted to assess the suitability of using RSS wall adjoining a river with a fluctuating flow regime.

The RSS wall may be founded at about El. 193.5 m, and designed using the geotechnical resistances provided for the CIP concrete structures. Based on the conditions of the existing headwall and wing walls, no major global stability problems are expected for RSS wall founded on the silt deposit. However, this should be verified after the details of the RSS wall are known.



Gabion walls may be considered as an alternate option for the headwall and wing walls. The construction of the wall should follow the procedures provided in OPSS 512. For gabion structures exceeding 2 m in height, including the embedment depth, the MTO RSS process should be followed. At the structure location, the gabion walls may be placed at El. 193.5 m and the walls may be designed using the geotechnical resistances provided for CIP concrete structures.

### **13. BACKFILL AND COVER MATERIAL**

OPSS Granular 'A' or 'B' Type II materials should be utilized for granular backfill and carried out in accordance with the requirements specified in the OPSS 902. The backfill material should be placed according to the procedures described in OPSS 422.07.11, and in layers not exceeding 200 mm in thickness before compaction. Backfill immediately below the roadway should be compacted in accordance with OPSS 501. The type of compaction equipment and the compaction procedure should also be based on OPSS 501. Backfill should be placed simultaneously behind both sides of the new 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. In addition, restrictions on compaction near the culvert should be as specified in OPSS 902.07.06.02.

Cover material required at the site shall meet the requirements of Group I or Group II specified in OPSS 422.05.14, and placed in accordance with OPSS 422.07.12.

### **14. LATERAL EARTH PRESSURE**

The earth pressure for concrete structures should be computed as per Clause 6.12.2 (b) of Canadian Highway Bridge Design Code (CHBDC, 2014). Sufficient movement of the structure wall may not be permitted for all of the options discussed above and "at rest" conditions may be assumed to compute earth pressure. Further, 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 by 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 design water level (kN/m<sup>3</sup>)  
 $\gamma'$  = Unit weight of submerged backfill ( $\gamma - \gamma_w$ ) material below design 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 above design water level (m)  
 $h_2$  = Depth below design water level (m)  
 $q$  = Surcharge load (kPa)  
 $C_p$  = Compaction pressure, kPa (refer to Clause 6.12.3 of CHBDC, 2014)  
 $C_s$  = Earth pressure from seismic events, kPa (refer to Clause 4.6.5 of CHBDC, 2014)

Granular 'A' or 'B' should be utilized as backfill material and carried out according to OPSS 902. Table 14 provided the recommended earth pressure coefficients for granular backfill.

**Table 14 - Earth Pressure Coefficients**

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

## 15. APPROACH EMBANKMENT

Based on field measurements, the height of the existing approach fill is approximately 7.9 m above the creek bed. As stated above, there will be no increase in the profile grade of the highway. Based on the GA drawing, there will also be no significant change in the slope of the embankment.

The assessment of the existing slope during site investigation indicated the embankment is performing well with no signs of instability, such as cracking or ravelling. Hence no major instability problems are anticipated for the replacement embankment constructed with 2H:1V side slopes.

The embankment fill may consist of suitable earth or granular fill, preferably Granular B Type II below the water level. Any soft area as well as organic deposits exist at the base of the



embankment should be removed before placing the fill. Rip-rap should be provided on both the upstream and downstream sides of the creek to protect the toe of the embankment and the creek bed near the culvert from erosion. 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.

## **16. 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 any granular backfill should be constructed in accordance with OPSD 3101.150.

## **17. 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.

## **18. CONSTRUCTION CONSIDERATIONS**

### **18.1 Staged Construction**

Generally, a roadway protection (shoring) system will be required to remove the existing culvert and install the replacement structure while maintaining the traffic on Highway 11. The subsoil encountered at the site should be favourable for driving sheet piles to construct a shoring system. Alternatively, shoring system consisting of soldier piles and timber lagging may be considered. However, it should this type of shoring will be very costly for culvert construction.

Temporary roadway protection shall be designed and constructed according to OPSS 539 to meet a Performance Level of 2. The contractor shall be responsible for the detail design of the roadway protection system, including the type and method of installation. The soil parameters given in Table 18.1 are recommended for the design of the roadway protection system.



**Table 18.1 – Soil Parameters**

ELEVATION (m)		SOIL TYPE	Soil Parameters		
FROM	TO		FRICTION ANGLE ( $\phi^\circ$ )	UNIT WEIGHT ( $\gamma$ ) kN/m <sup>3</sup>	C <sub>u</sub> , (kPa)
201.9	194.6	Sand and Gravel Fill	30	20	-
194.6	192.8	Silt, Trace Clay, Trace Sand	26	18	-
192.8	185.3	Clayey Silt, Trace Sand	-	18	50

## **18.2 Excavation**

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA) and MTO Regulations for Construction Projects. The protection system for excavations should follow OPSS 539, Construction Specification for Temporary Protection Systems, and OPSS 902, Construction Specifications for Excavating and Backfilling – Structures.

Excavation of the soils at the structure location should be feasible using conventional excavation equipment. All excavated surfaces should be kept free of frost and water during the period of construction. Runoff should be directed away from open excavations and should not be allowed to flow across slope faces. Excavated material shall not be stockpiled on top of the excavation.

Based on the record of boreholes, the excavations for the construction of replacement culvert will be advanced through existing embankment fill material. For OHSA classification purposes, the fill materials should be classified as Type 3 soils. Below groundwater table, Type 3 soils and fill material should be classified as Type 4 soils. For excavations through multiple soil types, the side slope geometry is governed by the soil with the highest number designation.

## **18.3 Subgrade Preparation**

Preparation of the subgrade for construction of the culvert should be carried out in accordance with OPSS 902 (Excavation and Backfilling of Structures).

For the precast box culvert, it is recommended to provide a 300 mm thick granular bedding below the culvert. The bedding should comprise Granular A or Granular B Type II material, satisfying the specification given in OPSS.PROV 1010 (Material Specification for Aggregates - Base, Subbase,



Select Subgrade, and Backfill), compacted to 95% of the ASTM D-698, Standard Proctor Maximum Dry Density (SPMDD) in conformance to OPSS 501 (Construction Specification for Compacting).

Alternatively, 19 mm diameter clear stone can be utilized for granular bedding and levelling course provided that this material is wrapped with filter fabric to prevent migration of fines from the native soil and ultimately potential failure of the culvert. Clear stone should satisfy the specifications in OPSS.PROV 1004 (Material Specification for Miscellaneous Aggregates) meeting the physical properties and gradation requirements of 19 mm Type 2 Clear Stone and placed in accordance with

OPSS 501 (Construction Specification for Compacting).

The silt layer that will be exposed at the founding subgrade level of the proposed precast box culvert, is expected to be susceptible to degradation if it is under water. In order to limit the effect of this problem, it is recommended that bedding material is placed on the subgrade within four hours after preparation, inspection and approval of the subgrade, and dewatering.

Levelling course and granular bedding can be placed below the water level if the material is sufficiently self-compacting or by overbuilding above the water level and then compacting and trimming to the bedding level. The extent if overbuilding could be as high as 1 m.

The bedding material should be separated from the underlying ground (native material) by a geosynthetic filter fabric. The filter fabric should conform to OPSS 1860 (Material Specification for Geotextiles) and comprise a Class II non-woven geotextile with a filtration opening size (FOS) of 105 to 210  $\mu\text{m}$ . The filter fabric should be placed beneath the bedding and extend to each side of the subgrade and to the top of the bedding and/or granular cover material.

#### **18.4 Groundwater Control**

As stated in the Foundation Investigation Report, the groundwater level at the site varied between El.196.8 m and El.196.3 m and the excavation to the founding level may have to be carried out under 3 m high water level. Groundwater levels are subject to seasonal fluctuations and precipitation patterns. 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.



The creek may have to be temporarily diverted and a cofferdam may be required to maintain a dry work environment. A cofferdam consisting of sheet pile walls may be utilised for excavation and dewatering. 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 by pumping from the sumps located along the 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  $\mu\text{m}$ . Construction in-the-wet can be done by excavating without dewatering, overbuilding the levelling course/bedding and compacting, then trimming to the required top of bedding elevation.

For the construction in the dry, the contractor should be responsible for 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 these standard specifications,

Non-Standard Specific Provisions (NSSP) provided in Appendix E, should also be followed.

In accordance with the Ontario Water Resources Act, the Water Taking and Transfer Regulation 387/04, a Permit to Take Water (PTTW) from the Ministry of Environment is required if the dewatering discharge is greater than 50,000 L/day. The expected daily flows at the culvert location should be assessed to determine if this permit will be necessary. It may be prudent to obtain the PTTW to avoid delays should the PTTW become necessary during construction.

## **19. EROSION CONTROL**

Generally, the measures provided in the OPSD 800 series (inlet/outlet treatment, headwalls, cut-off walls etc.) need to be considered to prevent the effect of erosion after the culvert is replaced.

Further, inlet and outlet protection in accordance with OPSS 511 (Construction Specification for Rip-Rap, Rock Protection and Granular Sheet piling), OPSS. PROV 1004 (Material Specification for Aggregates) and OPSD 810.010 (General Rip-Rap Layout Sewer and Culvert Outlets) is recommended to prevent erosion adjacent to the culvert as well as scour.



Clay seals at the inlet shall be in conformance with OPSS 1205 (Material Specification for Clay Seal) and extend over the area defined under rock protection.

Where embankments are composed of earth, they should be covered with topsoil or suitable excess earth material from swamps or muskeg areas and seeded in accordance with OPSS 802 (Construction Specification for Topsoil) and OPSS 804 (Construction Specification for Topsoil) as soon as grading is completed to prevent erosion and material degradation.

## **20. SOIL CORROSIVITY**

A sample of the clayey silt was tested for soil corrosivity and potential exposure of concrete to sulphate attack. A summary of the chemical test results are provided in Table 8 of Part A of this report. As shown in this table, the sulphate content is relatively low (77 µg/g or 0.008%), and this value suggests that sulphate resistant cement may not be required for the installation of the new culvert. According to Clause 4.1.1.6 of the Canadian Standards Association (CSA) standard A23.1-14, soluble sulphate concentrations less than 0.1% (1000 µg/g) generally indicate a low degree of sulphate attack when concrete is in contact with soil or groundwater. In Table 8, the resistivity value is also relatively high, indicating a non-corrosive environment to buried steel. In addition, the chloride content is low and the pH is within the normal range expected for soil pH.

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



## 21. CLOSURE

This report was prepared by Lulseged Yimam, PhD. P.Eng., and reviewed by M. Vasavithasan, M.Sc., 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.



Lulseged Yimam, PhD, P.Eng.  
Senior Engineer, Geotechnical Services



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



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

LY/MK/CN:mk-nk

Part B- Foundation Design Report

Unnamed Creek Culvert Replacement, Site No. 39W-119/C, Highway 11 - Sta. 11+917

Township of Clavet, Hearst, Ontario, GWP 5130-13-00, WP 5292-14-01, Index No. 119FDR

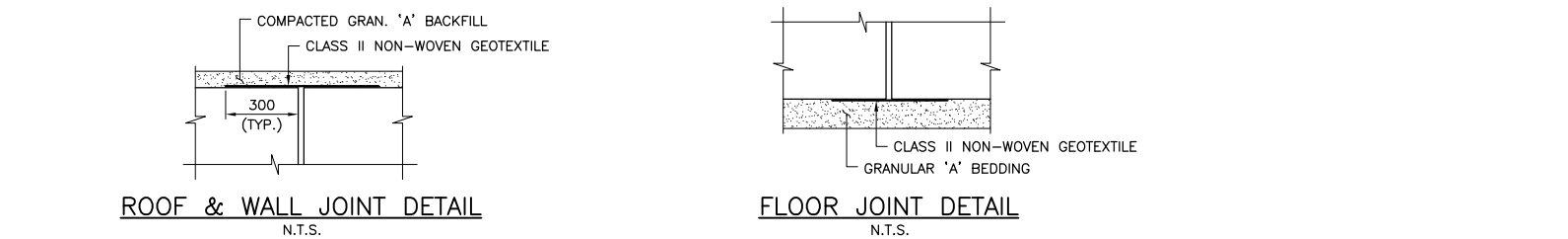
PML Ref.: 16TF013A, December 20, 2016

---



## **APPENDIX D**

### General Arrangement Drawing



DRAWING NOT TO BE SCALED  
100mm ON ORIGINAL DRAWING

REVISIONS									
	DATE	BY		DESCRIPTION					
	DESIGN	R.J.F.	CHK D.L.B.	CODE	CHBDC-14	LOAD CL-625-ONT	DATE	JAN/2017	
	DRAWN	C.O.H.	CHK R.J.F.	SITE	39W-119	DWG	S5		



## **APPENDIX E**

List of Ontario Provincial Standard Documents Relevant to the Report  
Non-Standard Specific Provision (NSSP)



### LIST OF STANDARD SPECIFICATIONS RELEVANT TO THE REPORT

DOCUMENTS	TITLE
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSD 812.010	Cut off wall for Structural Plate Pipe Arch and Circular CSP
OPSD 3504	Granular Backfill Requirements for Retaining Walls
OPSS 512	Construction Specification for Installation of Gabions
OPSS 902	Excavation and Backfilling for Structures
OPSS 501	Construction Specification for Compacting
OPSD 810.010	General Rip-Rap Layout Sewer and Culvert Outlets
OPSD 3090.100	Foundation Frost Depth for Northern Ontario
OPSD 3101.150	Walls, Abutment, Backfill Minimum Granular Requirement
OPSS 539	Construction Specification For Temporary Protection Systems
OPSS.PROV 1010	Material Specification for Aggregates - Base, Subbase, Select Subgrade, And Backfill Material
OPSS.PROV 1004	Material Specification for Miscellaneous Aggregates
OPSS 1860	Material Specification for Geotextiles
OPSS 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS 518	Construction Specification for Control of Water from Dewatering Operations
OPSD 800 Series	Inlet/outlet Treatment, Headwalls, cut-off walls, etc.
OPSS 511	Construction Specification for Rip-Rap, Rock Protection and Granular Sheeting
OPSS 1205	Material Specification for Clay Seal
OPSS 802	Construction Specification for Topsoil
OPSS 804	Construction Specification for Seed and Cover



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

### **NSSP 1 – Surface Water Control and Dewatering (Addition to OPSS 518)**

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

In view of the relatively pervious subsoil conditions encountered at this site, the dewatering design and the implementation should prevent unsafe conditions, such as sloughing and boiling under unbalanced groundwater conditions. Although the Contractor shall be responsible for designing and implementing measures for surface water control and dewatering, the Contractor is also advised that damming of the drain and diversion of the flow by pumping through temporary conduits for construction staging will likely be required at this site.

### **NSSP 2 – Installation of Shoring of Roadway Protection (Addition to OPSS 539)**

The Contractor is advised that cobbles and/or boulders may be encountered during the installation of shoring elements. The Contractor shall select and use the appropriate methods for shoring installation and excavations to account for such possible obstructions.

### **NSSP 3 – Excavations and Slope Stability (Addition to OPSS 902 and OPSS 539)**

The Contractor is advised that the weak subsoils at the site require careful design of excavation and fill slope geometries and shoring schemes including slope and excavation protection for the removal of one barrel of the existing CSP culvert to maintain the stability of the CSP culvert that will be left in place for water diversion. The Contractor is also advised to restrict the stockpiling of material and the placement of heavy equipment near slope crests in order to prevent slope instabilities. The analyses and discussions in the Foundation Design Report are provided for conceptual illustration of the issue. The Contractor is responsible for carrying out slope stability analyses and design of excavation and slope geometries and temporary roadway protection schemes and shoring schemes required for their operations.

### **NSSP 4 – Settlement Management (Addition to OPSS 902)**

The contractor is advised that their design and construction should minimize additional loading on foundation soil over existing levels as increases in loading over existing levels will cause related settlements that may be excessive.