



FOUNDATION INVESTIGATION AND DESIGN REPORT

for

UNNAMED CREEK CULVERT REPLACEMENT

SITE NO. 39W-118/C

HIGHWAY 11 – STATION 20+420

TOWNSHIP OF CLAVET, DISTRICT OF NEW LISKEARD

HEARST, ONTARIO

ASSIGNMENT NO. 5015-E-0009

GWP 5130-13-00

WP 5309-14-02

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PML Ref.: 16TF013A
Index No.: 114FIR and 115FDR
GEOCRES No.: 42F-043
March 6, 2017



PART A - FOUNDATION INVESTIGATION REPORT

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PART A – FOUNDATION INVESTIGATION REPORT

Unnamed Creek Culvert Replacement

Site No. 39W-118/C

Highway 11 – Station 20+420

Township of Clavet, District of New Liskeard

Hearst, Ontario

Assignment No 5015-E-0009, GWP 5130-13-00, WP 5309-14-02

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 a detail design for replacement or rehabilitation of these 16 structures (15 culverts and the 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-118/C) located at the crossing of an unnamed creek and Highway 11, about 112 km west of Hearst, Sta. 20+420, in the Township of Clavet, District of New Liskeard. A previous investigation carried out by PML at this site is discussed in Section 5 of this report.

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 location of the structure.

2. SITE DESCRIPTION AND PREVIOUS INVESTIGATION

At the culvert location, the highway consists of about 3.5 m wide lanes and 2 m wide shoulders. Highway 11 in this area is a two-lane road and provides rural arterial road services for communities in the region. 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 of the approach embankments were covered with grass and small shrubs.

The embankment slopes are observed to be relatively stable with no sign of distress or cracks.

The unnamed creek is about 3 m wide at the outlet and flows from south to north. During drilling, there were only a small amount of water flowing in the culvert.



The existing culvert is a cast-in-place concrete box structure. The south end of the culvert appeared to be in good condition. However, the north end was showing signs of distress including staining and cracking at several locations. The distress included wide longitudinal and transverse cracks throughout the length of the culvert. It appeared that these cracks were patched with concrete.

Refer to Photographs A1 to A4 in Appendix A, for general conditions of the site and the culvert.

A foundation investigation was carried out previously by PML at the existing culvert location for Philips Planning plus Engineering on behalf of MTO Northern Region and a report was issued in April 1998. This report is available on MTO Geocres (GEOCRES No: 42F-15) under the title:

“Foundation Investigation and Design Report, WP 29-97-00, Highway 11, From the Fraser River Bridge Westerly to the Regional Boundary, 36.3 km, MTO District 53, New Liskeard, GEOCRES No: 42F-15, 1998.”

As a part of the investigation, the field work was conducted in 1997 and consisted of advancing three (3) boreholes at the culvert location. Two of the boreholes were drilled at the north and south ends of the culvert to a depth of 3.6 m and 10.95 m, respectively. The third borehole was located on the shoulder of Highway 11 and drilled to a maximum depth of 5.1 m below the grade. The approximate borehole locations are shown on Drawing 118/C-1.

Based on the borehole data provided in the report, the subsoil conditions immediately below the surface at the culvert location consists of silt with varying proportions of clay, sand and gravel. The silty layer is followed by a glacial till deposit, which is underlain by bedrock.

A copy of the Foundation Investigation part of report (Part A) is provided in Appendix B.

3. FIELD INVESTIGATION PROCEDURES

The fieldwork for the foundation investigation consisted of four (4) boreholes completed during the period of July 8, 2016 to July 11, 2016. The boreholes were drilled to depths in the range of 6.6 m (El. 226.7 m) to 18.5 m (217.5 m) below the existing grade. Boreholes 16-118-01 and 16-118-02 were located on road shoulders, on the west and east approaches. Boreholes 16-118-03 and 16-118-04, were drilled near the southeast and northwest ends of the existing culvert.



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 118/C-1.

Table 3 – Borehole Locations and Depth

BOREHOLE NO.	LOCATION	DEPTH (m)	Elevation (m)	REMARK
16-118-01	West Approach, SW Road Shoulder	15.8	220.2	Competent Soil
16-118-02	East Approach, NE Road Shoulder	18.5	217.5	Terminated on Bedrock
16-118-03	SE Culvert End	13.1	218.6	Terminated on Bedrock
16-118-04	NW Culvert End	6.6	226.7	Terminated on Bedrock

The boreholes were advanced using CME 55 track-mounted drilling rig equipped with continuous flight 200 mm diameter hollow stem augers. Rock coring was carried out using NQ sized core barrel and wash boring within a 75 mm diameter NW casing. The equipment used for drilling was owned and operated by Landcore Drilling (Landcore) of Chelmsford, Ontario, a specialist drilling contractor worked under the full time supervision of an experienced PML field technician.

Soil samples were obtained from all boreholes at selected intervals using a split-spoon sampler in accordance with the Standard Penetration Test (SPT) procedures described in the ASTM D1586. The drill rig was equipped with 63.5 kg (140 lb) cathead automatic hammer calibrated to fall freely through 760 mm (30 in.). In-situ vane tests were carried out using an MTO 'N'-size vane to assess the strength characteristics of cohesive soils in accordance with the procedures outlined in ASTM D2573 (Standard Test Method for Field Vane Shear Test).

Soil samples were visually identified and stored in moisture-proof bags. Rock cores were labeled and placed in core boxes.

The groundwater conditions at the borehole locations were observed during 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 were referred to geodetic datum.

4. LABORATORY TESTING

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 (39)
- Atterberg Limit Tests (8)
- Grain Size Distribution (10)

Laboratory tests were performed on representative samples of each stratigraphic layers encountered. All the laboratory tests were conducted in accordance with MTO procedures, which follow ASTM guidelines, with the exception of hydrometer test (LS-702).

Chemical tests were carried out on a sample by AGAT Laboratories located in Mississauga, Ontario. The tests included the determination of sulphate and chloride contents, pH value and resistivity, and were required to determine the corrosivity characteristics of soils at the site.

All of the laboratory test results are provided on the individual Record of Borehole Sheets provided in Appendix C. In addition, grain size distribution curves are given on Figures 118-GS-1, 118-GS-2, and 118-GS-3, and the results of Atterberg limit tests (Plasticity Chart) is provided on Figure 118-PC-1. Results of chemical tests are presented in Appendix D.

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 C. The borehole locations and stratigraphic profile sections are shown on Drawing 118/C-1. The boundaries between soil strata was established at borehole locations only. The boundaries of soil strata between and beyond the boreholes are assumed and may vary from location to location.

In summary, the subsurface consists of 4.3 m to 4.5 m of granular fill, followed by about 1.0 m thick peat and 0.7 m thick organic silt. These organic materials are underlain by 2.5 m to 9.5 m thick clayey silt deposit, which is underlain by 0.8 m to 3.4 m thick sandy silt layer. Bedrock was encountered below the sandy silt layer in Borehole 16-118-02 located on the east side of culvert and in Boreholes 16-118-03 and 16-118-04 drilled near the inlet and outlet of the culvert. For classification purposes, the soils encountered at the site are classified into the following four zones.

- a) Silty Sand, Some Gravel (Granular Fill)
- b) Peat and Organic Silt
- c) Clayey Silt, Trace Sand, Trace Gravel
- d) Sandy Silt, Trace Clay, Trace Gravel

6.1 Silty Sand, Some Gravel, Trace Clay (Granular Fill)

Granular fill containing sand and gravel with varying proportions of silt was encountered in Boreholes 16-118-01 and 16-118-02 drilled on the road shoulders. The fill was brown to dark brown in color, and has a thickness of 4.3 m to 4.5 m, and extend to El. 231.5 m and El. 231.7 m.

The SPT “N”-values within the sand and gravel fill range from 9 to 22 blows/300 mm, indicating a “loose” to “compact” state of compaction.

The moisture content of samples from the fill was in the range of 9.6% to 14.9%. The result of a grain size analysis performed on representative samples indicated that the silty sand fill is composed of 12% - 14% gravel, 47% - 50% sand, 25% - 33% silt and 8% - 11% clay. Grain size distribution curves are provided on Figure 118-GS-1 in Appendix C.



6.2 Peat and Organic Silt

Dark brown organic silt with pieces of wood was encountered in Borehole 16-119-01 below the granular fill. The thickness of this organic layer was about 0.7 m and extends to El. 230.8 m. The SPT “N”-value was 6 blows/300 mm, indicating firm consistency.

Moisture content determination of a sample of this layer indicates a moisture content of 51.8%.

Approximately 1.0 m thick amorphous peat was encountered in Borehole 16-118-03 immediately beneath the ground surface. This peat was found to be dark brown and wet.

6.3 Clayey Silt, Trace to Some Sand, Trace Gravel

This clayey silt deposit was encountered immediately below the surface in the borehole located near the outlet. The clayey silt deposit in other three boreholes was intercepted immediately below the fill and the organic layers at a depth ranging from El. 231.7 m to El. 230.7 m. This clayey silt deposit was observed to be moist to wet and contain trace sand. The thickness of this brown to grey colour deposit varies from 2.5 m near the outlet to 9.5 m near the inlet.

The SPT “N”-values in this clayey silt vary from “weight of the hammer” to 12 blows/300 mm, indicating very soft to stiff soil consistency. The low blow counts corresponds to the middle part of this deposit where occasional silt seams were intercepted.

In addition, in situ vane shear tests were conducted in Borehole 16-118-03 and the results indicate an undrained shear strength value of 28 kPa.

The moisture content of the clayey silt deposit was observed to vary from 11.5% to as high as 44.3%. The liquid limit of representative samples, with the exception of Sample SS8 from Borehole 16-18-02, ranges from 18 to 30 and the corresponding plastic limit varies from 12 to 19, resulting in a plasticity index of 6 to 11. The liquid limit of Sample SS8 was 44 and the corresponding plastic limit was 19. Based on the results of the Atterberg limit tests, the soil may be classified as clayey silt of low plasticity (CL-ML) in the Unified Soil Classification System (USCS). However, Sample SS8 may be classified as clay of medium plasticity (CI). The plasticity chart is provided on Figure 118-PC-1, in Appendix C.

The grain size analyses performed on samples taken from the clayey silt provided 0% - 1% gravel, 3% - 20% sand, 43% - 78% silt and 16% - 45% clay. However, a sample from a layer of sandy silt



interbedded within the clayey silt resulted in 9% gravel, 32% sand, 43% silt and 16% clay. The grainsize distribution curves are presented on Figure 118-GS-2, in Appendix C.

6.4 Sandy Silt, Trace to Some Clay, Trace to Some Gravel

Sandy silt layer was encountered in all of the boreholes underneath the clayey silt deposits. The depth of this layer where encountered varies from as shallow as 2.5 m (El. 230.8 m) in Borehole 16-118-04 to as deep as 13.5 m (El. 222.5 m) in Borehole 16-118-01. This layer contain some gravel and trace clay, and was observed moist. The thickness of the sandy silt layer where fully penetrated ranges from 1.1 m in Borehole 16-118-04 to 3.8 m in Borehole 16-118-03.

The SPT “N”-values increase with depth from 3 blows/300 mm to 39 blows/300 mm, indicating loose to dense state of soil condition. However, a blow count of 61 blows/300 mm was obtained in Borehole 16-118-02, probably because of a rebound due to an underlying bedrock.

Laboratory test results indicate that the moisture content of the sandy silt materials was between 8.5% and 19.3%. Grain size analyses conducted on representative samples indicated 7% - 12% gravel, 30% - 41% sand, 44% - 49% silt and 8% - 14% clay. The results of the grain size distribution analyses are shown on Figure 118-GS-3, in Appendix C.

6.5 Bedrock

The presence of bedrock was proven by coring at Boreholes 16-118-02, 16-118-03 and 16-118-04. During drilling, NQ size rock cores ranging in length from 1.8 m to 3.0 m were obtained from these boreholes. The bedrock elevation varies from El. 229.7 m at the north end of the culvert to as low as El. 220.3 m in Borehole 16-118-02 located on the shoulder near the outlet, indicating a difference in bedrock elevation of 9.4 m within a distance of approximately 8 m. The bedrock in 16-118-03 and 16 118-02 was encountered at El. 220.4 m.

The core samples retrieved from all three boreholes were visually described and logged in the field. In addition, the rock cores were examined in the laboratory by a professional geologist. Generally, the bedrock was described to be granitic or granodioritic gneiss, and shows competent quartz-feldspar layers and alternating mica rich light and dark bands. Measured core recovery ranged from 97% to 100 %, and the RQD was between 50% and 100%. Based on the RQD values, the quality of the bedrock may be described as fair to excellent. Lower RQD values were



obtained for rock cores from Borehole 16-118-02. Pictures of rock cores (Photographs E1 - E3) and a complete description of rock cores is provided in Appendix E.

7. GROUNDWATER

On completion of drilling, the groundwater level was found to be at a depth of 5.2 m (El. 230.8 m) below the existing grade of the road. At the inlet and outlet, the depth to the groundwater ranged from 0.6 m (El. 231.1 m) to 0.8 m (El. 232.5 m) below existing ground surfaces.

The groundwater level may fluctuate due to the influence of precipitation and seasonal changes.

8. CHEMICAL TEST RESULTS

A sample taken at a depth of 5.5 m (El. 229.5) from the clayey silt layer in Borehole 16-118-02 was tested to determine soil corrosivity. A summary of the chemical test results is provided in Table 8. The details of these results and a description of the test method are given in Appendix D.

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)
16-118-02	SS4	5.5 / 229.5	Clayey Silt	7	326	8.01	1600



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 carried out by Callon Dietz Inc. of London, Ontario.

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, MTO Designated Principal Contact, conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.



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



APPENDIX A

Site Photographs



Photograph A1 – Looking at the Outlet (North Side) of the Culvert Structure (July 7, 2016).



Photograph A2 - Drilling set-up at the location of Borehole 16-118-03, South Culvert End. (July 9, 2016).



Photograph A3 – Borehole 16-118-03 and the adjacent Embankment Slope, with thick grass cover at the Inlet in the south and standing water through the Culvert (July 9, 2016).



Photograph A4 – Looking at Borehole 16-118-04 location. (July 11, 2016).



APPENDIX B

Previous Foundation Investigation Report (Part A) of the Unnamed Creek Culvert
(GEOCRES No.: 42F-15)

GEOCRES No. 42F-15DIST. 53 REGION W.P. No. 29-97-00CONT. No. W. O. No. STR. SITE No. HWY. No. 11LOCATION FROM THE FRASER RIVER BRIDGE
WESTERLY TO THE REGIONAL BOUNDARY
36.3KMNo of PAGES -OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.REMARKS:

**FOUNDATION INVESTIGATION AND DESIGN REPORT
W.P. 29-97-00
HIGHWAY 11
FROM THE FRASER RIVER BRIDGE
WESTERLY TO THE REGIONAL BOUNDARY, 36.3 km
MTO DISTRICT 53, NEW LISKEARD**

for

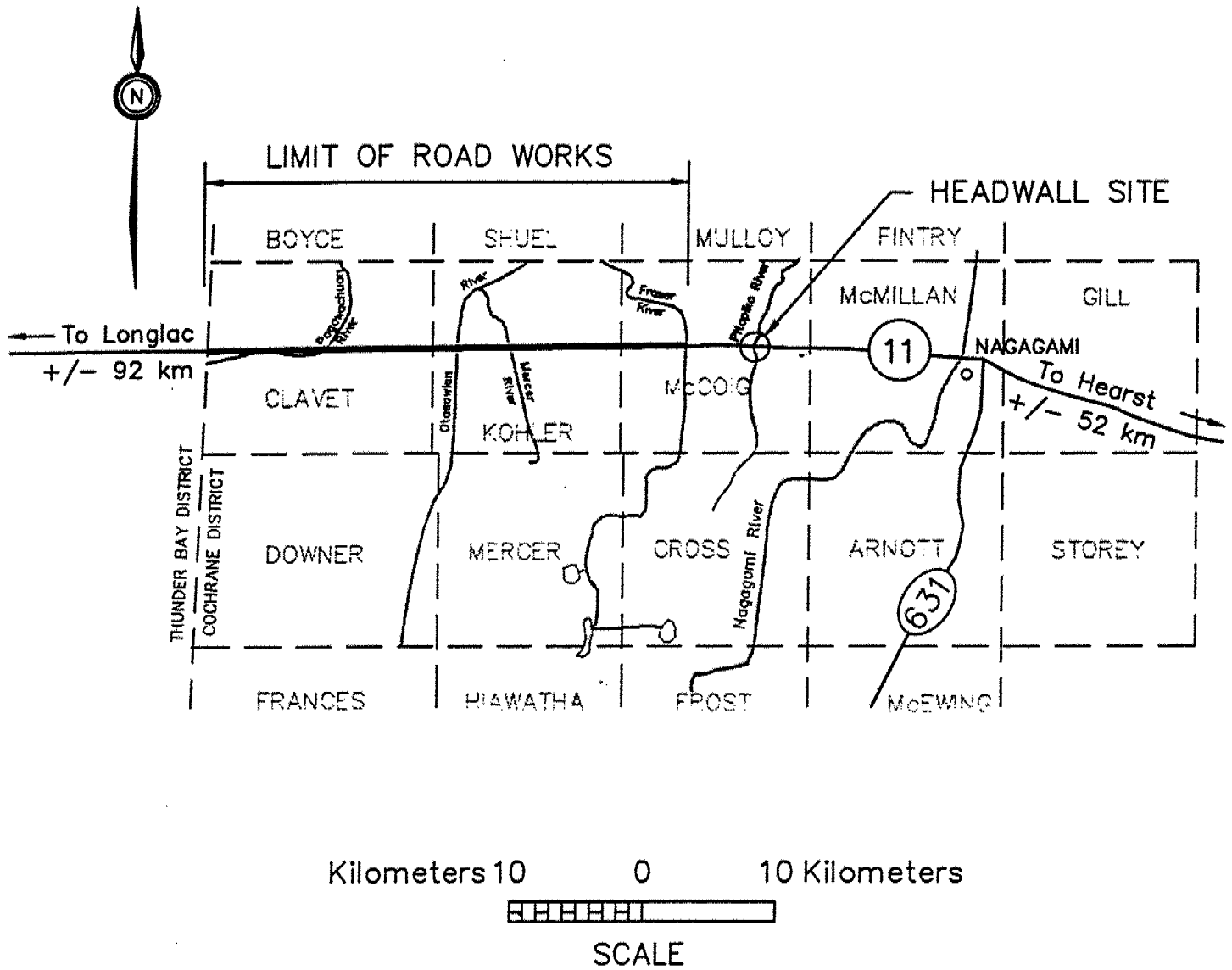
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KEY PLAN
W.P. 29-97-00

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FIGURE 1 TO 6 PARTICLE SIZE DISTRIBUTION CHARTS

LIST OF ABBREVIATIONS

LOG OF BOREHOLE SHEETS

DRAWINGS 1 TO 4 SITE SKETCHES

Peto MacCallum Ltd.

C O N S U L T I N G E N G I N E E R S

FOUNDATION INVESTIGATION AND DESIGN REPORT FOR CULVERT TREATMENTS HIGHWAY 11, FROM THE REGIONAL BOUNDARY WESTERLY TO THE FRASER RIVER BRIDGE, 36.3 km W.P. 29-97-00

1.0 FOUNDATION INVESTIGATION REPORT

1.1 INTRODUCTION

Peto MacCallum Ltd. was retained by Philips Planning and Engineering Limited as part of the Total Project Management (TPM) team to carry out a detailed soils investigation and to prepare a Pavement Design Report and Foundation Investigation and Design Report for Work Project (W.P.) 29-97-00. The Pavement Design Report has been forwarded under separate cover.

The original Terms of Reference identified seven culverts as potentially requiring treatment. Upon review, Philips Planning + Engineering Limited recommended remedial work be carried out at the following four locations:

- 1) 20+420, Township of Clavet - concrete culvert
- 2) 24+441, Township of Kohler - timber culvert
- 3) 13+408, Township of McCoig - corrugated steel pipe (CSP) sideroad culvert
- 4) Pitopiko River, Township of McCoig - twin (CSP) culvert south headwall

1.2 SITE DESCRIPTION

The four foundation investigation locations are located on Highway 11, in the Townships of Clavet, Kohler and McCoig between about 70 and 100 km west of Hearst, Ontario within District 53 - New Liskeard. The work will be carried out as part of Work Project (W.P.) 29-97-00 which extends from the Fraser River Bridge, westerly 36.3 km to the Regional Boundary. Location 4 (Pitopiko River) is located east of the work project limits.

The project is located in the Abitibi Uplands, part of the Canadian Shield physiographic province. The local topography is very flat and is typified by poorly drained sphagnum muskeg and black spruce dominated forest (Smith, S.L., Quaternary Stratigraphic Drilling Transect Timmins to the Moose River Basin, Ontario, Geologic Survey of Canada, 1992). Typical soils comprise Cochrane Till which is described as non-sorted silt and clay tills with granulars, cobbles and boulders. The inorganic soils are typically overlain by varying depths of peat and muck and underlain by relatively hard, primarily igneous bedrock (Sado, E.V., Fullerton, D.S., and Farrand, W.R., Quaternary Geologic Map of the Lake Nipigon 4° x 6° Quadrangle, U.S.A. and Canada, 1994).

1.3 INVESTIGATION PROCEDURES

The field work was carried out inconjunction with the pavement design soils investigation during October and November, 1997. The field work specific to the foundation investigations comprised a total of ten (10) boreholes and four (4) dynamic cone penetration tests advanced to depths of 0.60 to 11.90 m below existing grade.

The boreholes were advanced with a CME 55 track mounted drillrig and a CME 45 truck mounted drillrig equipped with continuous flight hollow and solid stem augers, supplied and operated by specialist drilling contractors. Manual hand augering was also carried out to obtain supplemental surficial organic thicknesses.

Representative samples of the overburden were secured at regular intervals throughout the depth explored. Standard penetration tests were carried out during sampling operations using conventional split spoon equipment. Groundwater observations were made in the boreholes during and following completion of drilling.

The field work was supervised throughout by a member of our engineering staff who directed the drilling and sampling process, prepared the stratigraphic logs, monitored groundwater conditions and cared for the recovered samples. The borehole locations and ground surface elevations were surveyed by Philips Planning + Engineering Limited and are related to the geodetic datum. The borehole at Location 4 (Pitopiko River) was referred to a local temporary benchmark set at 100.00.

All samples secured during the investigation were returned to our laboratory for detailed visual examination. The laboratory testing program consisted of natural moisture content determination tests on most recovered samples, six particle size distribution analyses and three atterberg limit tests.

1.4 SUBSURFACE CONDITIONS

We refer to the appended Log of Borehole sheets for details of the drilling work including pavement construction details, soil descriptions, inferred stratigraphy, standard penetration "N" and dynamic cone values, shear strength test results, groundwater observations during and upon completion of drilling, and natural moisture content determination test results. The logs of testholes drilled locally as part of the pavement design investigation have also been included for convenience.

Location 1 - 20+420, Township of Clavet

The culvert at Location 1 is a 3.0 m wide by 1.8 m high rigid frame concrete structure with approximately 3 m of earth cover. Surface water flow through the culvert was negligible at the time of the field work. The culvert is showing signs of distress including lowering of the mid-section of the culvert relative to the ends, and two major breaks at the approximate edge-of-shoulder locations. The distress also includes cracking throughout the length of the culvert, and some deterioration and spalling of the concrete at the ends. Discussions with the MTO Patrol Supervisor indicate that loss of granular material has been experienced from the north road shoulder which may be caused by migration of material through the culvert cracks. It is understood that concrete has been poured into these road shoulder voids in the past.

In general, the subsurface stratigraphy contacted at Location 1 comprised road embankment fills and surficial peat overlying native silt and glacial till deposits.

The road embankment contacted in borehole 101, drilled through the road, comprises the surficial pavement structure over interstratified sand and silt with traces of gravel and clay. The borehole was terminated at 5.10 m depth, near the base of the culvert, upon refusal to auger on wood which may be part of the original culvert form. Borehole 102 located near the edge of the embankment contacted silt with clay. The embankment fills are generally loose to compact based on standard penetration "N" values of 8 to 15 blows per 0.30 m penetration of the split spoon sampler. The embankment soils below the road are typically moist based on moisture contents of 8 to 13% and the soils near the edge of the embankment are wet based on a moisture content of 31%.

Surficial wet black amorphous peat was contacted to 0.60 m depth in borehole 103 located near the south end of the culvert.

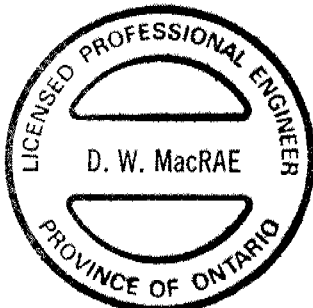
The native inorganic deposits encountered below the road embankment fills and peat consist of silt with varying amounts of clay and traces of sand and gravel. The silt is underlain by glacial tills comprising silty clay and silt with sand, a trace of gravel, and occasional cobbles and boulders. The native deposits range from very loose to loose/soft and become compact with depth based on standard penetration "N" and dynamic cone values in the range of 4 to 12 and shear strengths of 18 to 50 kPa. Moisture contents of 13 to 40% reflected moist/drier than plastic limit (D.T.P.L.) conditions becoming saturated/wetter than plastic limit (W.T.P.L.) with depth. A typical particle size distribution chart for the silt is presented on Figure 1 appended.

Soil colouring and moisture contents indicate that the stabilized groundwater level lies around 3.0 m below the culvert level or 7.5 m below the road grade, at about elevation 229.

2.2 CLOSING

The recommendations contained in this report are based on conditions at the time of the field work. This report was written by Mr. D. MacRae, P.Eng., Project Engineer, was reviewed by Mr. G. Mitchell, M.Eng. P.Eng., Manager, Geotechnical Engineering and was approved by Mr J.B. Dietrich, P.Eng, Managing Director.

Details of the investigation and the recommendations given in this report are considered to be complete. However, should any questions arise, please do not hesitate to contact this office.



PETO MacCALLUM LTD.

A handwritten signature in black ink, appearing to read "D. MacRae", written over a horizontal line.

D. MacRae, P.Eng
Project Engineer

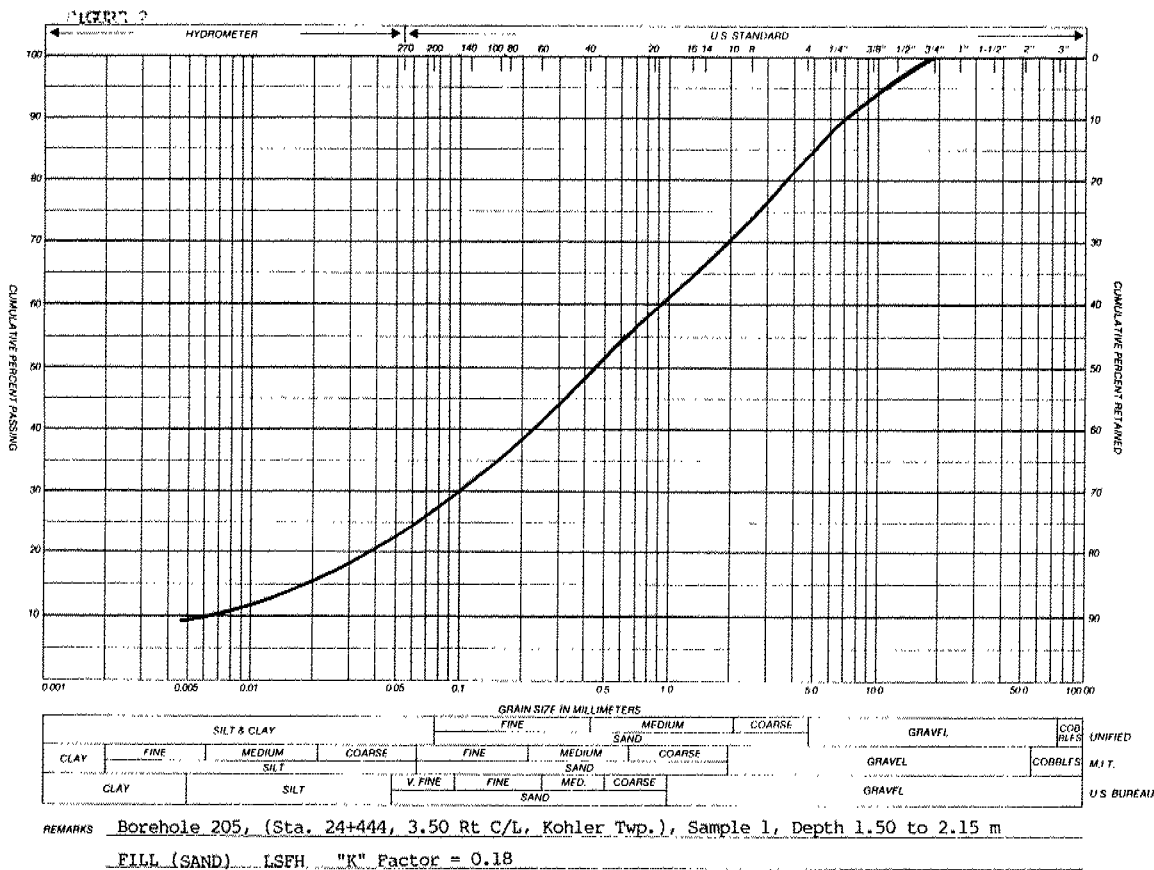
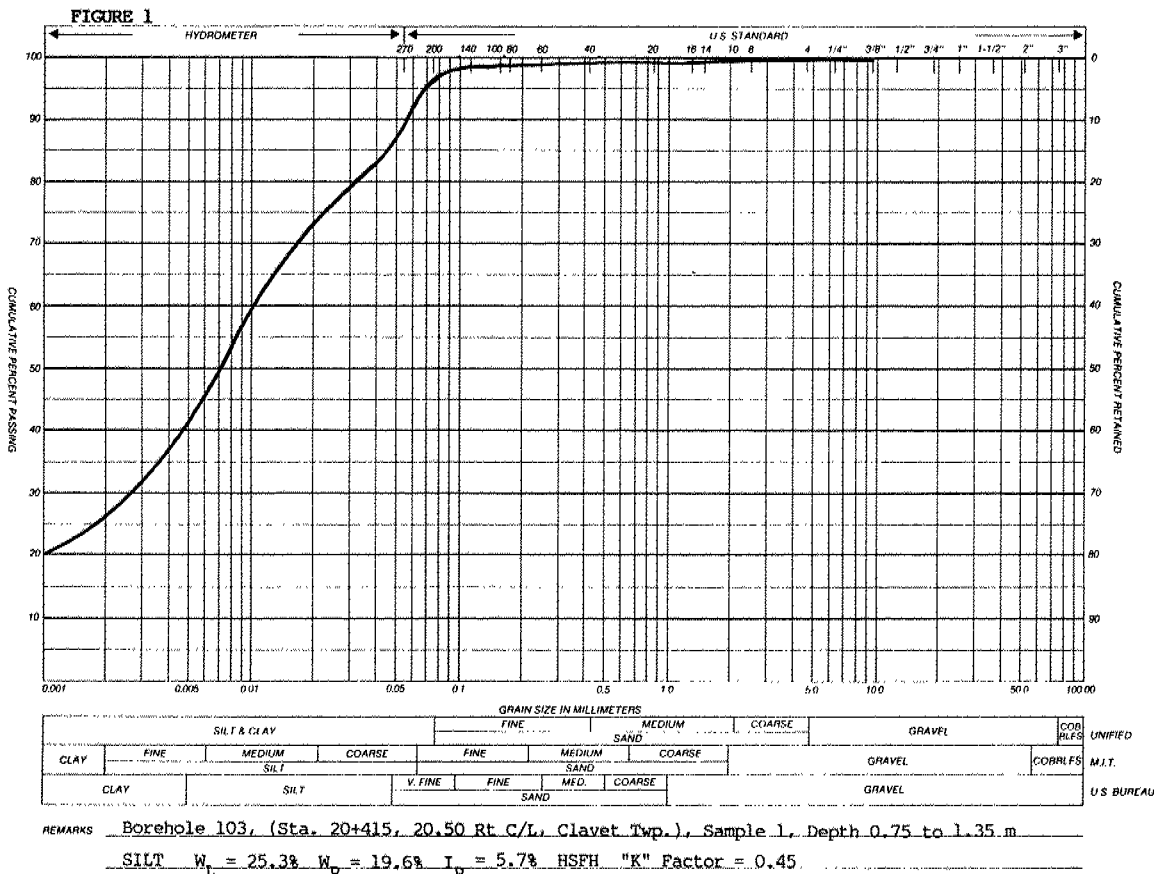
A handwritten signature in black ink, appearing to read "G. Mitchell", written over a horizontal line.

G. Mitchell, M.Eng. P.Eng.
Manager, Geotechnical Engineering

DM/GM:cs

PARTICLE SIZE DISTRIBUTION CHART

OUR PROJECT NO. 97 TF 78



LIST OF ABBREVIATIONS

PENETRATION RESISTANCE

STANDARD PENETRATION RESISTANCE 'N', - THE NUMBER OF BLOWS REQUIRED TO ADVANCE A STANDARD SPLIT SPOON SAMPLER 0.3m INTO THE SUBSOIL. DRIVEN BY MEANS OF A 63.5kg HAMMER FALLING FREELY A DISTANCE OF 0.76m.

DYNAMIC PENETRATION RESISTANCE: - THE NUMBER OF BLOWS REQUIRED TO ADVANCE A 51mm, 60 DEGREE CONE, FITTED TO THE END OF DRILL RODS. 0.3m INTO THE SUBSOIL. THE DRIVING ENERGY BEING 475J PER BLOW.

DESCRIPTION OF SOIL

THE CONSISTENCY OF COHESIVE SOILS AND THE RELATIVE DENSITY OR DENSENESS OF COHESIONLESS SOILS ARE DESCRIBED IN THE FOLLOWING TERMS:-

<u>CONSISTENCY</u>	<u>'N' BLOWS/0.3m</u>	<u>c kPa</u>	<u>DENSENESS</u>	<u>'N' BLOWS/0.3m</u>
VERY SOFT	0 - 2	0 - 12	VERY LOOSE	0 - 4
SOFT	2 - 4	12 - 25	LOOSE	4 - 10
FIRM	4 - 8	25 - 50	COMPACT	10 - 30
STIFF	8 - 15	50 - 100	DENSE	30 - 50
VERY STIFF	15 - 30	100 - 200	VERY DENSE	> 50
HARD	> 30	> 200		
W.T.P.L.	WETTER THAN PLASTIC LIMIT		D.T.P.L.	DRIER THAN PLASTIC LIMIT
	A.P.L.		ABOUT PLASTIC LIMIT	

TYPE OF SAMPLE

S.S.	SPLIT SPOON	T.W.	THINWALL OPEN
W.S.	WASHED SAMPLE	T.P.	THINWALL PISTON
S.B.	SCRAPER BUCKET SAMPLE	O.S.	OESTERBERG SAMPLE
A.S.	AUGER SAMPLE	F.S.	FOIL SAMPLE
C.S.	CHUNK SAMPLE	R.C.	ROCK CORE
S.T.	SLOTTED TUBE SAMPLE		
	P.H.	SAMPLE ADVANCED HYDRAULICALLY	
	P.M.	SAMPLE ADVANCED MANUALLY	

SOIL TESTS

Qu	UNCONFINED COMPRESSION	L.V.	LABORATORY VANE
Q	UNDRAINED TRIAXIAL	F.V.	FIELD VANE
Qcu	CONSOLIDATED UNDRAINED TRIAXIAL	C	CONSOLIDATION
Qd	DRAINED TRIAXIAL		

GEOTECHNICAL SURVEY DATA	
W.P. 29-97-00	
SURVEY DATE	TYPE OF SURVEY
October, November, 1997	Peto MacCallum Ltd. Power Auger, Power Excavator, Hand Auger
<p>NOTES</p> <ol style="list-style-type: none">1. Conditions and pavement depths apply only to the date of survey.2. The boundaries between the strata have been established only at core/borehole locations. Between cores/boreholes the boundaries are assumed and may be subject to error.3. Soils are described according to the MTO Soils Classification System.4. Pavement core locations were established using random numbers.5. Abbreviations for boring and test data conform to OPSD 100.06.6. Dimensions are in metres and/or millimetres unless otherwise shown. Stations in kilometres + metres.7. In the logs of testholes, the abbreviation D+/- represents the difference in ground surface elevation of points offset from the C/L. Geodetic elevations are provided where available.	

LOG OF BOREHOLE NO. 101 & 102

PROJECT W.P. 29-97-00, Highway 11

OUR PROJECT NO. 97 TF 78

LOCATION From Fraser River Bridge, Westerly to the Regional Boundary, 36.3 km

BORING DATE 1997 11 02


ENGINEER G. Mitchell

BORING METHOD Continuous Flight Hollow Stem Augers

TECHNICIAN B. Squire

SOIL PROFILE				SAMPLES				SHEAR STRENGTH C_u		LIQUID LIMIT W_L PLASTIC LIMIT W_p WATER CONTENT W W_p W W_L WATER CONTENT % 10 20 30			GROUND WATER OBSERVATIONS AND REMARKS		
DEPTH in METRES	DESCRIPTION	LEGEND	ELEVATION	NUMBER	TYPE	BLOWS/0.3m N - VALUES	DYNAMIC CONE PENETRATION * STANDARD PENETRATION TEST *								
							BLOWS/0.3M 20 40 60 80								
BOREHOLE 101 Sta. 20+417, 3.60 m Lt C/L, Clavet Twp. GROUND ELEVATION 236.02															
0.47	70 mm of asphaltic concrete over 400 mm of crushed gravel, granular, moist		235	1	SS	15	15						Upon completion of drilling and removal of augers, borehole caved at 4.30 m with no free water.		
1.50	FILL: Brown fine to medium sand trace silt, trace gravel, moist becoming light brown silt, trace sand, trace gravel, trace organics, moist		234	2	SS	8	8								
2.20	becoming brown fine to medium sand, trace silt, trace gravel, moist		233	3	SS	10	10								
3.00			233	4	SS	10	10								
3.70			232												
4.50	becoming light brown silt, trace clay, trace sand, moist		232												
5.10	wood		231	5	SS	11	11								
BOREHOLE TERMINATED AT 5.10 m DUE TO REFUSAL TO AUGER ON WOOD															

NOTES:

CHECKED BY: 

LOG OF BOREHOLE NO. 103 (Sta. 20+415, 20.50 Rt C/L, Clavet Twp.)

PROJECT W.P. 29-97-00, Highway 11

OUR PROJECT NO. 97 TF 78

LOCATION From Fraser River Bridge, Westerly to the Regional Boundary, 36.3 km

BORING DATE 1997 11 2 & 3

ENGINEER G. Mitchell

BORING METHOD Continuous Flight Solid Stem Augers

TECHNICIAN B. Squire

SOIL PROFILE				SAMPLES			SHEAR STRENGTH C_u (kPa) ▲		LIQUID LIMIT W_L		PLASTIC LIMIT W_P		GROUND WATER OBSERVATIONS AND REMARKS		
DEPTH METRES	DESCRIPTION	LEGEND	ELEVATION	NUMBER	TYPE	BLOWS/0.3m N - VALUES	50	100	150	200	WATER CONTENT				
							DYNAMIC CONE PENETRATION * STANDARD PENETRATION TEST *				Wp			W	
							BLOWS/0.3M				Wp			W	
	GROUND ELEVATION 231.74						20	40	60	80	10	20	30		
0.60	PEAT: Black amorphous peat, wet		231												
1.40	SILT: Very loose to loose grey silt with clay, trace sand and gravel, moist		230	1	SS	4									
2.20	becoming loose to compact mottled light brown and grey silt, trace clay, trace gravel, moist		229	2	SS	6									
3.00	becoming layered with dark brown clayey silt, D.T.P.L. to W.T.P.L.		228	3	SS	4									
			228	4	SS	8									
4.5	SILTY CLAY: Soft to very stiff light grey silty clay, trace sand and gravel, occasional cobbles, W.T.P.L. (till)		227	5	SS										
			226												
6.0			225	6	SS										
			225												
7.50			224	7	SS										
	SILT: Compact to very dense light grey silt with sand, trace clay, occasional cobbles and boulders, saturated (till)		223												
9.0			222	8	SS	8									
			221	9	SS										
10.95	BOREHOLE TERMINATED AT 10.95 m DUE TO REFUSAL TO AUGER ON PROBABLE BEDROCK														
12.0															

20/100 mm (bouncing)

Upon completion of augering and removal of augers, free water at 0.15 m (surficial water).

NOTES:

- ▲ Undrained shear strength determined from pocket penetrometer test
 ■ Undrained shear strength determined from vane shear test
 □ Remoulded shear strength determined from vane shear test
 S = Sensitivity = Undrained shear strength/Remoulded shear strength

CHECKED BY

W.P. 29-97-00, HIGHWAY 11
FROM FRASER RIVER BRIDGE,
WESTERLY TO THE REGIONAL BOUNDARY, 36.3 KM
TOWNSHIP OF CLAVET

20+395 3.40 Lt C/L D -100 (El. 236.22)
Culvert @ 20+420

0 - 200 Asph
200 - 300 Cr Gr Moist
w @ 250 = 5.9%
300 - 2.50 Br F-Med Sa W Si Tr Gr Moist

20+400 7.00 Rt C/L D -450

0 - 050 Br Med Sa Tps W Gr Moist
050 - 200 Br Med Sa W Gr Tr Si Moist
200 - 450 Lt Br F Sa W Si Moist

20+400 15.50 Rt C/L D -4.25

0 - 075 Br Med Sa Tps W Gr Moist
075 - 200 Br Med Sa W Si Moist
200 - 550 Lt Br F Sa W Si Moist
Wet @ 300

20+407 3.70 Lt C/L D -080 (El. 236.11)
Culvert @ 20+420

0 - 100 Asph
100 - 200 Cr Gr Moist
200 - 1.20 Br F-Med Sa W Si Tr Gr Moist
1.20 - 1.80 Br Si W Sa Tr Gr Moist
1.80 - 2.50 Br F Sa Tr Si & Gr Moist

20+432 3.40 Lt C/L D -070 (El. 236.03)
Culvert @ 20+420

0 - 240 Asph
240 - 340 Cr Gr Moist
340 - 1.20 Br F-Med Sa W Si Tr Gr Moist
1.20 - 1.80 Br Si W Sa Tr Gr Moist
1.80 - 2.50 Br F Sa Tr Si & Gr Moist

20+445 3.30 Lt C/L D -080 (El. 236.02)
Culvert @ 20+420

0 - 310 Asph
310 - 380 Cr Gr Moist
380 - 1.65 Br F-Med Sa W Si Tr Gr Moist
1.65 - 2.50 Br Si W Sa Tr Gr Moist
w @ 2.05 = 8.1%

SITE SKETCH LOCATION 1

20+400

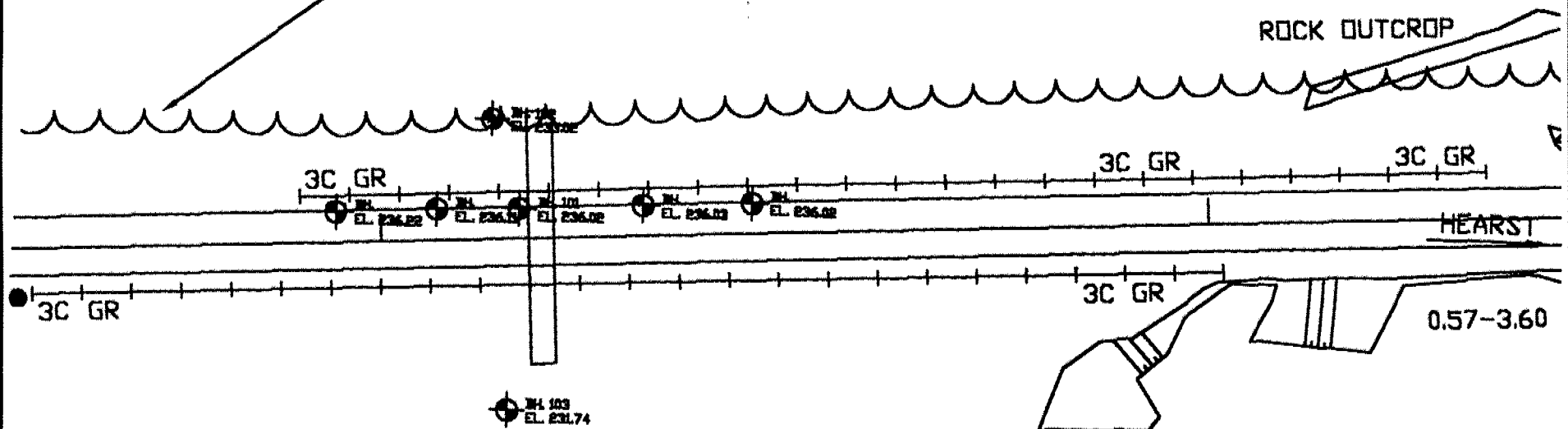
3.05 x 1.83 x 30.6m
Concrete Culvert
Rigid Frame Box Type

20+500



BM

ROCK OUTCROP



Peto MacCallum Ltd.
CONSULTING ENGINEERS

DATE	SCALE	PML REF.	DRAWING NO.
APRIL, 1998	N.T.S	97 TF 78	1



APPENDIX C

Borehole Location Plan and Soil Strata

Explanation of Terms used in Report

Record of Borehole Sheets

Grain Size Distribution Curves – Figures 118-GS-1, 118-GS-2 and 118-GS-3

Plasticity Charts – Figure 118-PC-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
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa ⁻¹	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
c_v	m ² /s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{v0}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_i	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

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

RECORD OF BOREHOLE No 16-118-01

1 of 2

METRIC

G.W.P. 5130-13-00 LOCATION Co-ords: 5 514 380.0 N ; 218 977.7 E ORIGINATED BY M.R.
DIST New Liskeard BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY L.Y.
DATUM Geodetic HWY 11 DATE July 08 and 09, 2016 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	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 (%)												
236.0	Ground Surface						20	40	60	80	100						
0.0	Silty sand some gravel, trace clay asphalt fragments																
	Compact Brown to Moist dark brown																
	(FILL)																
231.5	Organic silt, wood pieces																
4.5	Firm Dark Wet brown		3	SS	6	▽*											
230.7	Clayey silt some sand, trace gravel		4	SS	7												
5.3	Firm to Brown Moist very soft																
			5	SS	7												
			6	SS	9												
			7	SS	7												
			8	SS	WH**												
			9	SS	1												
			10	SS	7												
			11	SS	5												
222.5	Sandy silt trace to some clay trace to some gravel																
13.5	Compact Grey Moist to dense		12	SS	29												
	Cont'd																

Cont'd

RECORD OF BOREHOLE No 16-118-01

2 of 2

METRIC

G.W.P.	5130-13-00	LOCATION	Co-ords: 5 514 380.0 N ; 218 977.7 E	ORIGINATED BY	M.R.
DIST	New Liskeard	BOREHOLE TYPE	Continuous Flight Hollow Stem Augers	COMPILED BY	L.Y.
DATUM	Geodetic HWY 11	DATE	July 08 and 09, 2016	CHECKED BY	M.V.

[illegible]

RECORD OF BOREHOLE No 16-118-02

1 of 2

METRIC

G.W.P. 5130-13-00 LOCATION Co-ords: 5 514 394.0 N ; 218 986.1 E ORIGINATED BY M.R.
DIST New Liskeard BOREHOLE TYPE C.F.H.S.A., Wash Boring and NQ Diamond Coring COMPILED BY L.Y.
DATUM Geodetic HWY 11 DATE July 10, 2016 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS *	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20 40 60 80 100									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
236.0	Ground Surface																
0.0	Silty sand some gravel, trace clay																
	Brown to Moist dark brown																
			1	SS	16								○			12 47 33 8	
			2	SS	9												
	(FILL)																
231.7																	
4.3	Clayey silt, trace sand																
	Stiff Brown Moist to firm to wet		3	SS	12								○			0 3 78 19	
			4	SS	8								○				
			5	SS	7								○				
			6	SS	3								○				
	Sandy silt some clay, trace gravel																
	Loose Brown Wet		7	SS	4											9 32 43 16	
			8	SS	WH**								○	—			
			9	SS	6								○				
			10	SS	3								○				
			11	SS	10												
223.7																	
12.3	Sandy silt trace to some clay trace to some gravel		12	SS	20								○			12 34 45 9	
	Compact to Grey Moist very dense to wet																
			13	SS	23								○				
													</				

Cont'd

RECORD OF BOREHOLE No 16-118-02

2 of 2

METRIC

G.W.P. 5130-13-00 LOCATION Co-ords: 5 514 394.0 N ; 218 986.1 E ORIGINATED BY M.R.
DIST New Liskeard BOREHOLE TYPE C.F.H.S.A., Wash Boring and NQ Diamond Coring COMPILED BY L.Y.
DATUM Geodetic HWY 11 DATE July 10, 2016 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER * CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT						PLASTIC LIMIT NATURAL MOISTURE LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						w _p	w	w _L		GR	SA	SI	CL
								<div><div></div><div></div><div></div><div></div><div></div></div> <div>○ UNCONFINED + FIELD VANE</div> <div>● QUICK TRIAXIAL × LAB VANE</div>													
221.0								20	40	60	80	100									
220.3			14	SS	61																
15.7	Granitic Gneiss bedrock Unweathered Good to fair quality		15	RC NQ	REC 100%		220												RQD	80%	
			16	RC NQ	REC 97%		219												RQD	50%	
217.5							218														
18.5	End of borehole																				
	<div>* Borehole charged with drilling water</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>																				

RECORD OF BOREHOLE No 16-118-03

1 of 1

METRIC

G.W.P. 5130-13-00 LOCATION Co-ords: 5 514 366.3 N ; 218 984.8 E ORIGINATED BY M.R.
DIST New Liskeard BOREHOLE TYPE C.F.H.S.A., Wash Boring and NQ Diamond Coring COMPILED BY L.Y.
DATUM Geodetic HWY 11 DATE July 09, 2016 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS *	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ 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												
231.7	Ground Surface						20	40	60	80	100									
0.0	Peat, amorphous		1	SS	1	▽*														
	Dark brown																			
230.7	Clayey silt, trace sand silt lenses	2	SS	2																
1.0	Firm to stiff Brown to grey Moist	3	SS	2																
		4	SS	6																
		5	SS	7																
		6	SS	4																
		7	TW	-																
		8	SS	2																
224.2	Sandy silt trace to some clay trace to some gravel		9	SS	3															
7.5	Compact Grey Moist																			
			10	SS	11															

* Borehole charged with
drilling water

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

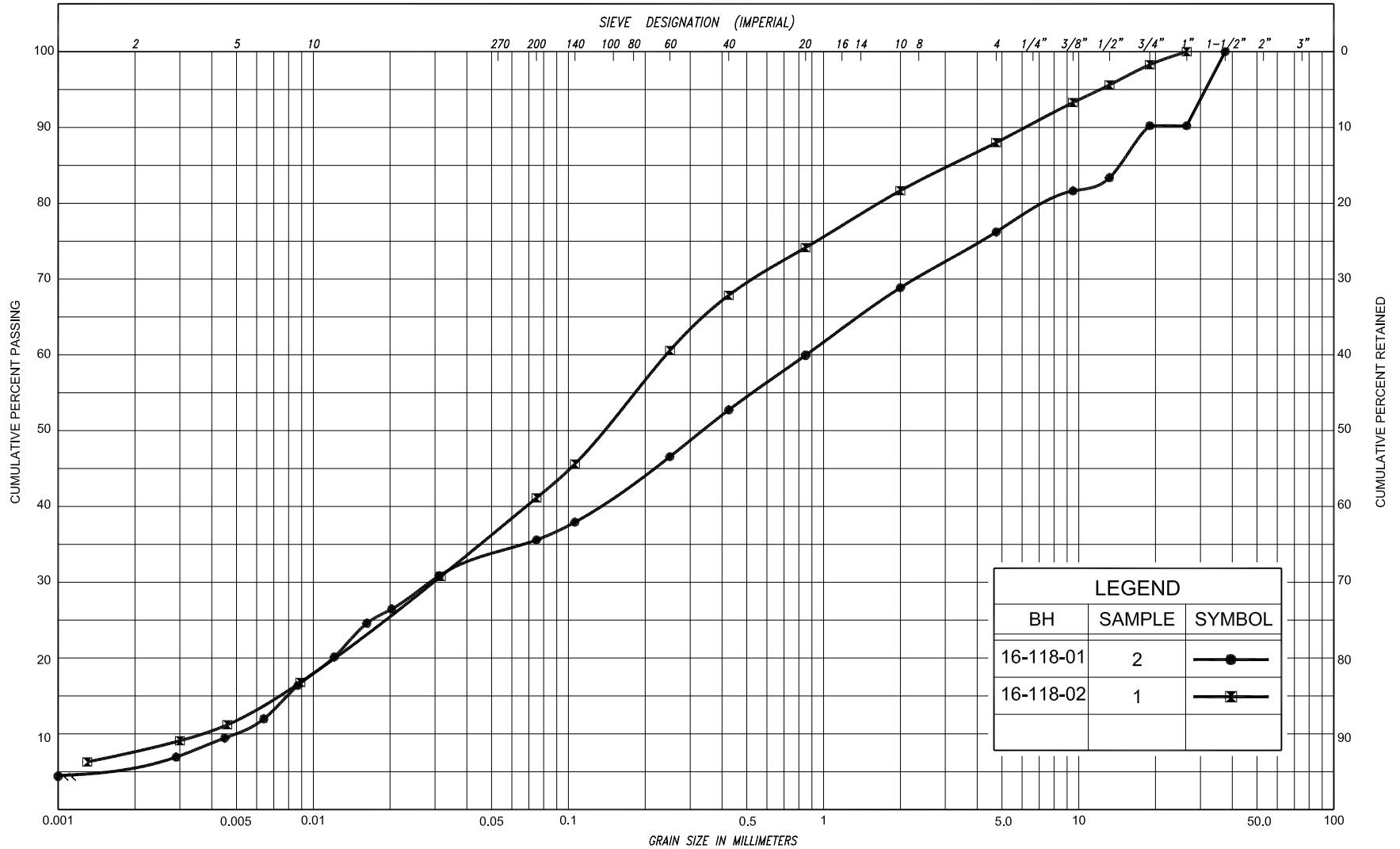
RECORD OF BOREHOLE No 16-118-04

1 of 1

METRIC

G.W.P. 5130-13-00 LOCATION Co-ords: 5 514 403.2 N ; 218 975.4 E ORIGINATED BY M.R.
DIST New Liskeard BOREHOLE TYPE C.F.H.S.A., Wash Boring and NQ Diamond Coring COMPILED BY L.Y.
DATUM Geodetic HWY 11 DATE July 11, 2016 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20 40 60 80 100									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
20 40 60 80 100					WATER CONTENT (%)												
233.3	Ground Surface																
0.0	Clayey silt, trace sand		1	SS	9	▽*	233										
	Firm to Mottled Moist stiff grey/brown		2	SS	10		232										
			3	SS	11												
							231										
230.8			4	SS	9												
2.5	Sandy silt trace to some clay trace to some gravel																
	Loose Grey Moist		5	SS	4		230										
229.7	Granitic Gneiss bedrock																
3.6	Unweathered		6	RC NQ	REC 100%		229									RQD 97%	
	Excellent quality						228										
			7	RC NQ	REC 100%		227									RQD 97%	
226.7	End of borehole																
6.6																	
																</	



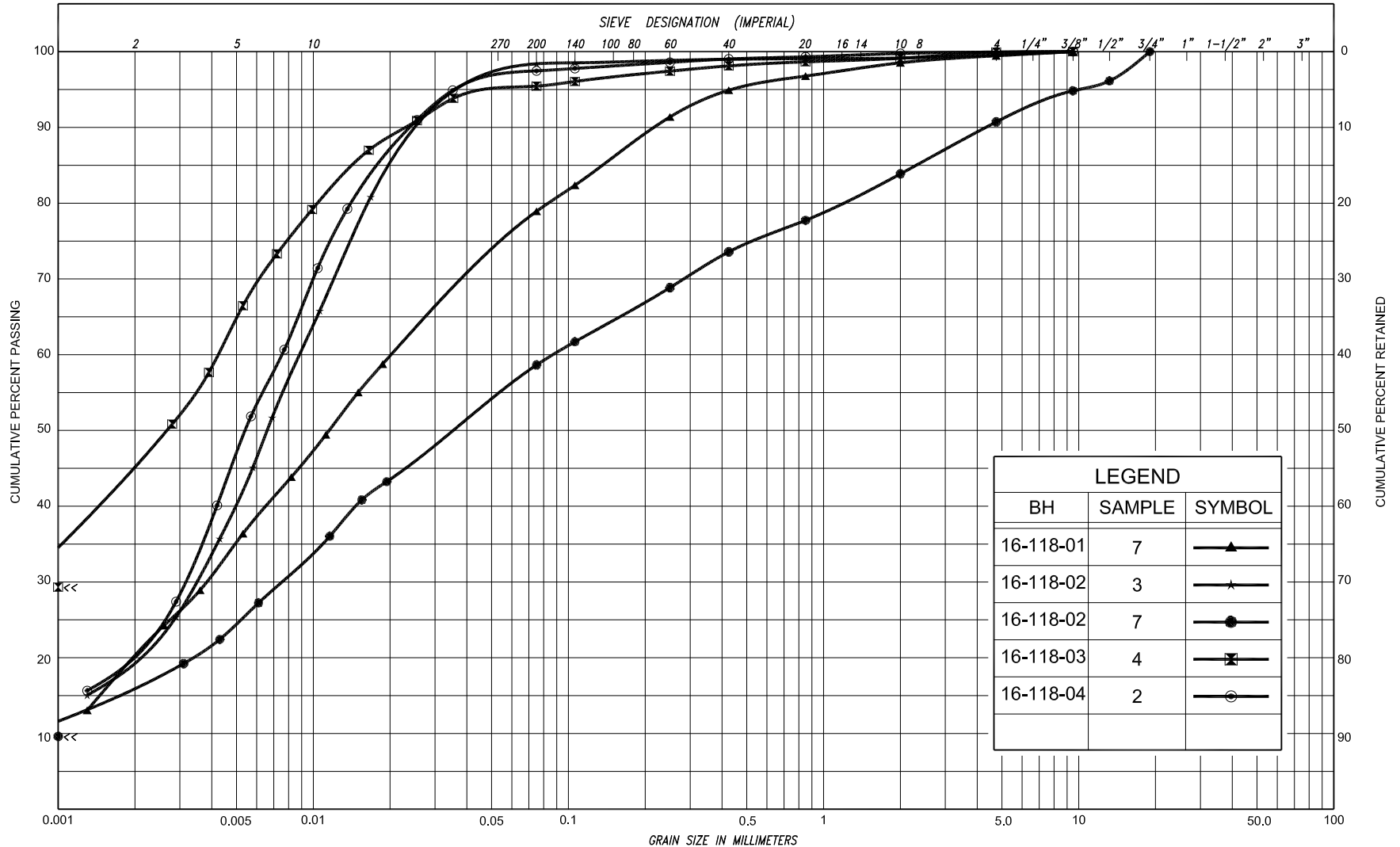
LEGEND		
BH	SAMPLE	SYMBOL
16-118-01	2	—●—
16-118-02	1	—■—

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 SILTY SAND, some gravel, trace clay (FILL)

FIG No. 118-GS-1
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																			
CLAY		SILT		V. FINE	FINE	MED.	COARSE	GRAVEL								U.S. BUREAU				
				SAND																

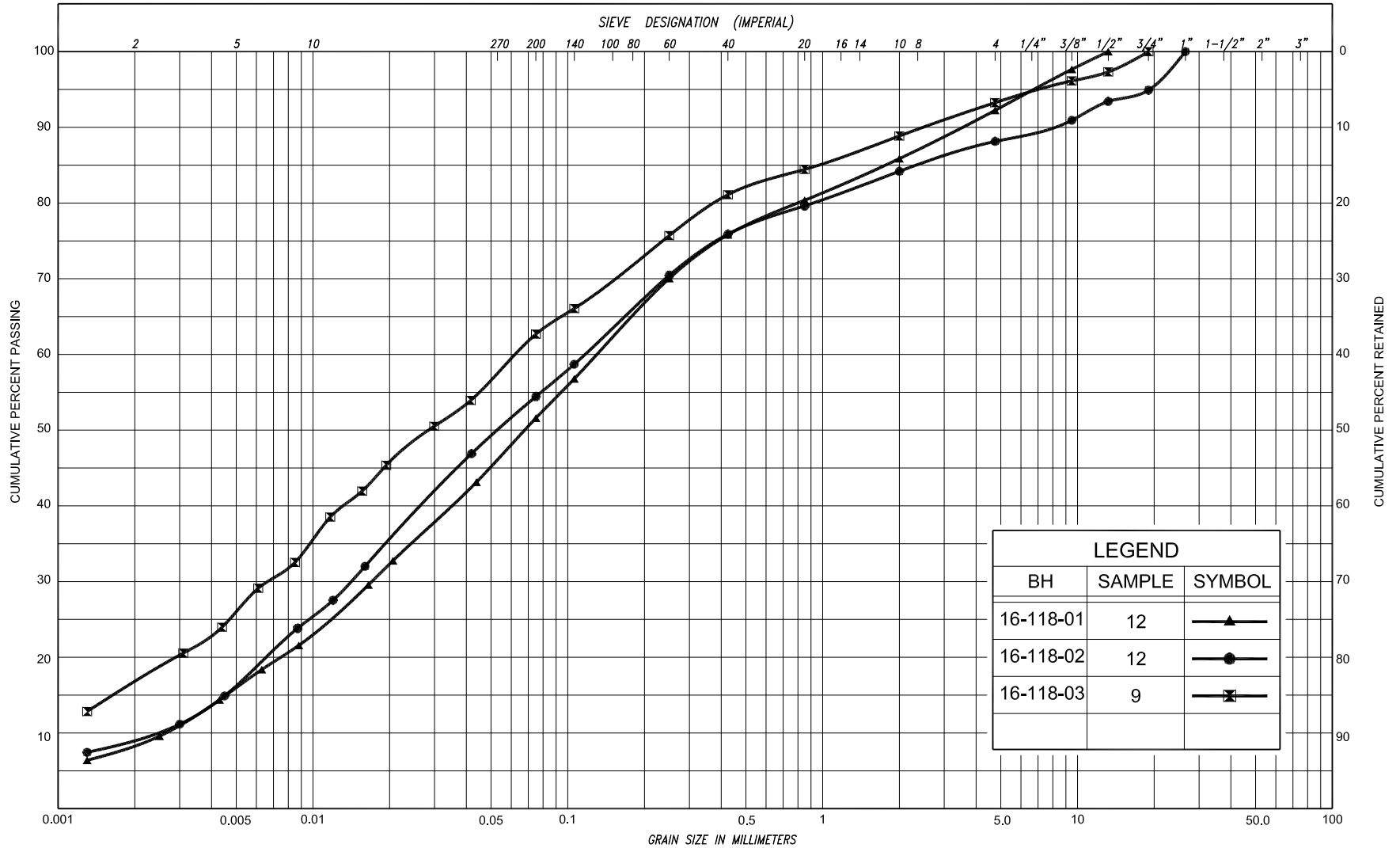


GRAIN SIZE DISTRIBUTION CLAYEY SILT, trace to some sand, trace gravel (CL)

FIG No. 118-GS-2

HWY 11

G.W.P. 5130-13-00



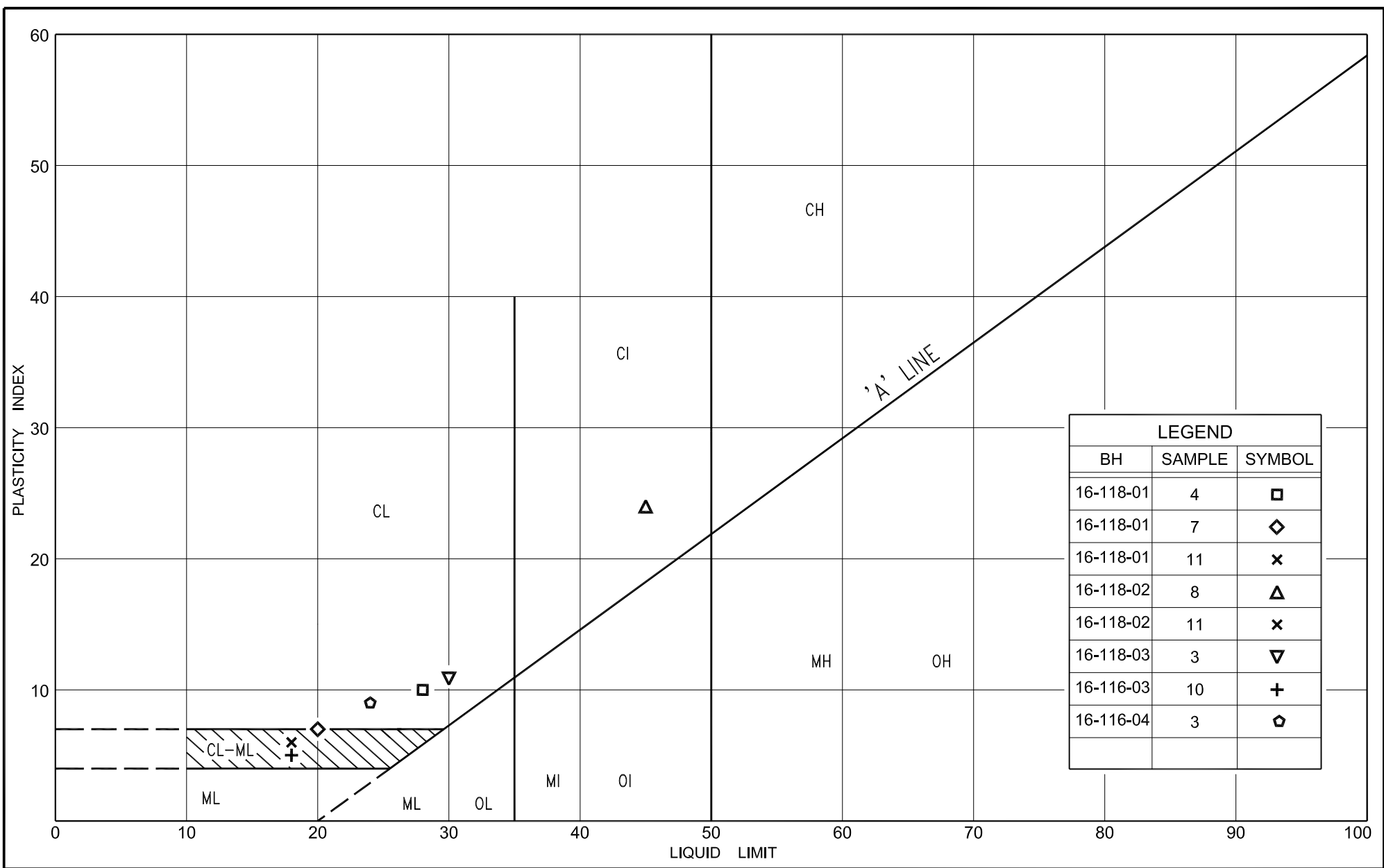
SILT & CLAY				FINE		MEDIUM		COARSE	GRAVEL			COBBLES	UNIFIED		
				SAND											
CLAY	FINE		MEDIUM	COARSE	FINE		MEDIUM	COARSE		GRAVEL			COBBLES	M.I.T.	
	SILT				SAND										
CLAY		SILT			V. FINE	FINE	MED.	COARSE	GRAVEL					U.S. BUREAU	
SAND															



GRAIN SIZE DISTRIBUTION

SANDY SILT, trace to some clay, trace to some gravel

FIG No. 118-GS-3
 HWY 11
 G.W.P. 5130-13-00



PLASTICITY CHART

CLAYEY SILT, trace sand, trace gravel (CL-ML / CL / CI)

FIG No. 118-PC-1

HWY 11

G.W.P. 5130-13-00



APPENDIX D

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: Lul Yimam

SAMPLING SITE:

SAMPLED BY:

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



APPENDIX E

Rock Core Photographs

Rock Core Description



Photograph E1 - Rock Core from Borehole 16-118-02 (July 10, 2016).



Photograph E2 - Rock Core from Borehole 16-118-03 (July 09, 2016).



Appendix E, Rock Core Photographs, Page 3 of 3



ROCK CORE DESCRIPTION

BOREHOLE NO.	CORE RUN	DEPTH (m)	% CR	% RQD	DESCRIPTION
16-118-02	1	15.8 – 17	100	80	META-GRANITE - GRANODIORITE (Foliated to Gniess): Greensih grey to grey bands, medium to coarse grained, hard (geological hammar and knife test), unweathered to slightly or moderately weathered, unfractured to very sparsely fractured, undulating, smooth to rough, no infillings. Intact Rock Strength (IRS): R5 (very strong).
	2	17 – 18.6	97	50	-Highly weathered and fractured from 15.8 m to 16.0 m, 17.3 m to 17.5 m. Note: Vertical open fractures seen on Run 2 possibly due to mechanical damage induced by drilling/coring.. Visual Petrography: Quartz, Feldspar, Mica and Green Hornblend.
16-118-03	1	11.3 – 12.2	100	100	META-GRANITE - GRANODIORITE: Grey to dark grey, pinkish grey, medium grained to very coarse grained bands, very coarse (randomly oriented streaks of color), hard, unweathered to slightly weathered, undulating, closely spaced, smooth to rough fracture surface, fresh, no infillings. IRS: R5 (very strong).
	2	12.2 – 13.1	100	100	Visual Petrography: Quartz, Feldspar, Mica, Biotite.
16-118-04	1	3.5 – 5.2	100	97	GRANITE - GRANODIORITE: Grey to pinkish grey with occasional white to grey coarse grained bands, hard, fresh or unweathered to slightly weathered, undulating, rough fractures with no infillings. IRS: R5 (very strong).
	2	5.2 – 6.6	100	97	Visual Petrography: Quartz, Feldspar, Muscovite.

Logged by: Shahid Siddiqi, P.Geo

Reviewed by: Lulseged Yimam, PhD, P.Eng



PART B - FOUNDATION DESIGN REPORT

for

UNNAMED CREEK CULVERT REPLACEMENT

SITE NO. 39W-118/C

HIGHWAY 11 – STATION 20+420

TOWNSHIP OF CLAVET, DISTRICT OF NEW LISKEARD

HEARST, ONTARIO

ASSIGNMENT NO. 5015-E-0009

GWP 5130-13-00

WP 5309-14-02

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- 1 cc: PML Toronto
- 1 cc: PML Kitchener

PML Ref.: 16TF013A
Index No.: 115FDR
GEOCRES No.: 42F-043
March 6, 2017



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 Non- Standard Specific Provision

PART B – FOUNDATION DESIGN REPORT

Unnamed Creek Culvert Replacement

Site No. 39W-118/C

Highway 11 – Station 20+420

Township of Clavet, District of New Liskeard

Hearst, Ontario

Assignment No 5015-E-0009, GWP 5130-13-00, WP 5309-14-02

10. INTRODUCTION

This foundation design report with the interpretations 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 structure. 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

This report provides foundation design recommendations based on interpretation of the geotechnical data presented in the foundation investigation report to assist the design team in the selection of a suitable type of foundation for the culvert replacement at the unnamed creek located near Sta. 20+420 in the Township of Clavet, District of New Liskeard.

The discussions and recommendations 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, dated January 2017, is provided in Appendix F.

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

11.2 Existing Culvert

The existing culvert is a 3 m wide, 1.83 m high and 37 m long cast-in-place (CIP) concrete box structure with a fill height of 3 m above the deck.

Based on the Request for Quotation (RFQ), the culvert was constructed in 1942, and was probably lengthened with sections of precast concrete box culverts at a later date.



The highway accommodates two lanes of vehicular traffic. The condition of the existing culvert near the inlet (south end) was relatively good, with no signs of concrete deterioration or distress. However, the north end of the culvert shows cracking and staining at several locations. The walls and the soffit exhibit diagonal and transverse cracks, which appeared to be patched over.

11.3 Proposed Culvert

The RFQ does not provide guidelines or options for the replacement culvert. Based on the GA drawing provided by GHD, it is understood that the existing structure will be replaced by a single cell precast concrete box culvert, with a span of 3.0 m and height of 1.8 m. The length of the proposed culvert will be 44 m, about 5 m longer than the existing structure. The length will be extended almost equally, both on the north and south culvert ends. The culvert replacement will not involve grade raise or road widening, and the finished grade of the highway will remain at about El. 236.0 m. The height of the fill above the culvert will be 3.0 m. The invert elevation of the culvert at inlet and outlet will be El. 230.93 m and El. 230.91 m, respectively. Details of the proposed culvert are shown on the GA drawing provided in Appendix F.

11.4 Foundation Conditions

In summary, the subsurface at the culvert location consists of 4.3 m to 4.5 m thick silty sand fill followed by 2.5 m to 9.5 m thick, firm to stiff clayey silt deposit. The clayey silt deposit is underlain by a 0.8 m to 3.4 m thick, compact to dense sandy silt layer. The sandy silt layer is underlain by granitic- granodiorite gneiss bedrock at elevations varying steeply from El. 229.7 m (Borehole 16-118-04) at the northwest end (outlet) of the culvert to El. 220.3 m (borehole 16-118-02) at the northeast shoulder.

The foundation investigation report previously prepared by PML in 1998 and provided in Appendix B, also indicated the presence of a bedrock at depths in the range of 3.6 m (El. 229.5 m) at the north end of the culvert to 10.95 m (El. 220.9 m) at the south end.

The groundwater level during fieldwork was observed between El. 230.8 m and El. 232.5 m, and is expected to be influenced by the flow of the unnamed creek.



12. CULVERT REPLACEMENT OPTIONS

The RFQ does not specify or provide guidelines for the options to be evaluated for the replacement culvert. However, the feasibility of the following three options are discussed for replacing the existing culvert along the same vertical and horizontal alignments:

- 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.

The presence of bedrock at shallow depth at the north end of the culvert may lead to uneven settlements as well as cause difficulties to construct the required structures for dewatering and removal of existing culvert. For this reason, it is recommended that the road be re-aligned towards the south end of the culvert, where the bedrock is relatively deep.

12.1 Option 1: Precast Concrete Box Culvert

Based on the GA drawing provided in Appendix F, it is assumed that precast concrete box culvert is the preferred option to replace the existing structure.

As outlined in Table 12, and considering the subsurface condition at the structure location, the use of precast concrete box culvert placed at a level below the invert level (El. 231 m) of the existing structure, founded on the firm to stiff clayey silt, is the preferred option for the replacement culvert. Foundation design parameters and recommendations are provided in Section 12.4.

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

For a CIP concrete box culvert founded on the firm to stiff clayey silt, the structure may be designed using a factored geotechnical resistance of 175 kPa at Ultimate Limit State (ULS) and 125 kPa at Serviceability Limit State (SLS). During construction, the removal of the existing foundation may cause disturbance to the founding surface. In addition, the clayey silt layer at the founding level will be susceptible to disturbance from construction traffic and any ponded or



flowing water. To limit degradation, it is recommended to construct a concrete working slab (lean concrete) on the subgrade within four hours after its preparation, inspection and approval.

Table 12 - Comparison of Alternate Culvert Options

OPTION 1: PRECAST CONCRETE BOX CULVERT	OPTION 2: CAST IN-PLACE CONCRETE BOX CULVERT	OPTION 3: THREE-SIDED PRECAST OPEN CULVERT
Advantages: <ol style="list-style-type: none"> 1. High degree of quality and uniformity, design flexibility, superior strength and durability; 2. Reduced weather dependency during installation; 3. Reduced impact on traffic interruption; 4. Ease of construction and installation in wet conditions is possible. 5. Ability to accommodate differential settlements. 	Advantages: <ol style="list-style-type: none"> 1. Reduces uneven settlement; 2. Reduces water leakage and deterioration of culvert; 3. Ability to withstand differential settlements; 4. Longer life span of the structure; 5. Degradation of subgrade can be avoided by placing lean concrete. 	Advantages: <ol style="list-style-type: none"> 1. High degree of quality and uniformity, design flexibility, superior strength and durability; 2. Generally allows for natural streambed to remain intact; 3. Less accumulation of sediments in the upstream of channel; 4. Reduced weather dependency during installation; 5. Ease of construction and installation in wet conditions is possible.
Disadvantages: <ol style="list-style-type: none"> 1. Natural stream bed will not remain intact; 2. Cause sediment accumulation in the upstream of the channel; 3. Possibility for degradation of subgrade. 	Disadvantages: <ol style="list-style-type: none"> 1. Natural stream bed will not remain intact; 2. Cause sediments accumulation in the upstream of the channel; 3. Weather dependent during construction; 4. Major dewatering scheme is required to construct the floor slab under 1 m high water. 	Disadvantages: <ol style="list-style-type: none"> 1. Subsoil conditions at shallow depths are not favourable to support the culvert on strip footings; 2. Probability of uneven or differential settlements is high; 3. Limited ability to withstand differential settlements.
Cost of Construction: Total Cost \$ 14,000/m	Cost of Construction: Total Cost \$ 15,000/m	Cost of Construction: Total Cost \$ 14,500/m
Recommended	Technically Feasible but Not Recommended	Technically Not Feasible and Not Recommended



However, based on the performance of the existing culvert and the cracks and distresses on the interior walls, it is assumed that the variable foundation condition at the site may not be suitable for the construction of a CIP concrete box culvert. Further, if this option is considered, construction under about 3.0 m high groundwater will impose difficulties, and a dewatering scheme will be required to provide a working platform for formwork and concrete placement. Generally, the dewatering requirement to construct the CIP box culvert in dry conditions will be a major concern. In view of these anticipated construction difficulties, this option is not recommended.

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

The subsoil conditions at the proposed founding level is not favourable to provide adequate geotechnical resistance to support three sided precast concrete culvert on strip footings. Instead, piles or micro piles installed into the bedrock at variable depths may be required. For this reason, this option is not recommended.

12.4 Recommendation for Preferred Option

The GA drawing indicates that the proposed precast concrete box culvert will be placed at about El. 230.9 m. If the culvert is to be placed at El. 230.9 m, organic silt and peat may need to be sub-excavated in some places and replaced with Granular B Type II material.

Generally, the bedding for the culvert is expected to be placed on firm to stiff clayey silt layer, which is capable of providing adequate geotechnical resistance. The option of using a precast 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 the OPSS 422.05.13. Bedding may consist of 300 mm thick granular material, and should also be placed in accordance with OPSS 422.07.07.

As required by Clauses 1.9.5.6 and 1.9.11.6.5 of the Canadian Highway Bridge Design Code (CHBDC, 2014) and as shown in the GA drawing, cut-off walls should be provided at both ends of the proposed precast concrete box culvert. Cut-off walls shall be in accordance with OPSS 812.010 or made of precast concrete with similar dimensions to prevent washout of granular bedding. The cut-off wall 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 firm to stiff clayey 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.

However, the presence of a shallow bedrock at the northwest end of the culvert may create a variable foundation condition that could lead to differential settlement. The culvert may be relocated towards the south end and the road at this location may be realigned, in order to mitigate the impact of differential settlement. Alternatively, the clayey silt may be removed to about El. 226.0 m and replaced with lean concrete or granular materials and the culvert be placed at the proposed elevation of El. 231.2 m to provide a uniform foundation condition.

The removal of the existing foundation may cause disturbance to the founding surface of the proposed culvert. In addition, the clayey 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 founding subgrade.

13. BACKFILL AND COVER MATERIAL

OPSS Granular 'A' or 'B' should be utilized as granular backfill material and carried out in accordance with 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 be in accordance with OPSS 501. Backfill should 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. In addition, restrictions on compaction near the culvert shall 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 the 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 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

γ = Unit weight of backfill material above design water level (kN/m³)

γ' = Unit weight of submerged backfill ($\gamma - \gamma_w$) material below design water level

(kN/m³) γ_w = Unit weight of water (9.8 kN/m³)

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, kN/m ³	22.5	21.5
Coefficient of Active Earth Pressure (K_a)	0.27	0.33
Coefficient of Earth Pressure at Rest (K_o)	0.43	0.5
Coefficient of Passive Earth Pressure (K_p)	3.69	3.0

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.



15. APPROACH EMBANKMENT

The height of the existing approach fill is about 4.8 m above the creek bed. As indicated before, there will be no increase in the profile grade of the highway or widening of embankment. No major instability problems are anticipated for the 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 spongy or soft area as well as organic deposits 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 based on 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, 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. At the site, the presence of shallow bedrock at the northwest end of the culvert may not be favourable for driving sheet piles to construct a shoring system. Hence, the use of soldier piles and timber laggings



supported by anchors may have to be considered to construct temporary shoring system. However, this type of shoring system will not be economical to use for a culvert construction.

Temporary shoring or roadway protection system shall be designed and constructed to meet a Performance Level of 2 according to OPSS 539. The soil parameters given in Table 18.1 may be used for the design of the roadway protection system. The culvert may be relocated towards the south end and the road at this location may be realigned, in order to mitigate the impact due to differential settlement, if relocating the culvert towards the south end is not considered.

Table 18.1 – Soil Parameters

ELEVATION (m)		SOIL TYPE	SOIL PARAMETERS		
FROM	TO		FRICTION ANGLE (ϕ°)	UNIT WEIGHT (γ) kN/m ³	C _u , kPa
236	231.7	Silty Sand Fill	30	20	-
231.7	221.2	Clayey Silt	-	18	50

PML understands that the construction of the replacement culvert will be carried out in stages by allowing the traffic to use one side of the highway with the aid of a temporary traffic signal. Based on the information provided by GHD, the staging is proposed to be carried out by temporarily lowering the grade of one side of the highway on a short term basis while allowing the traffic on the other side. If additional stages are required, the flow of traffic will be switched again while further excavation and grade lowering is carried out. The grade lowering will require providing a stable slope for the fill remaining on the side of the highway carrying the traffic. A properly designed temporary roadway protection will be required if a stable slope cannot be provided.

A stable slope should be maintained for excavation through the fill if a staging scheme by grade lowering is considered for transferring the traffic during the removal of the existing structure and installation of the replacement culvert. It is stated that the contractor is responsible for detail design of temporary works. A slope of 2H:1V is considered stable for the embankment fill at the structure location. Where the new embankment fill is replaced with OPSS 1010 Granular B Type II material, the temporary inner slopes between raising road sections may be completed at 1.5H:1V. Alternatively, a temporary slope of 1H:1V may be achieved using a geogrid reinforcement.



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 may be carried out using conventional excavation equipment. All excavated surfaces should be kept free of frost and water during the period of construction. Runoff shall be directed away from open excavations and should not be allowed to flow into the excavation. 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 Groundwater Control

The groundwater level at the site was observed to be between El.232.5 m and El.230.8 m and the excavation to the suggested founding level of El. 230.5 m may have to be carried out under 2 m high water. 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. A cofferdam consisting of sheet piles may be utilised for excavation and dewatering on the south side of the highway where bedrock was encountered at deeper depths. 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 the sumps located along the periphery of the cofferdam. If restrictions are imposed on placing a clay puddle in the creek, construction should be carried out under the prevailing water level. In this case, the backfill material shall consist of Granular B Type II containing particle sizes not finer than 75 µm.



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 H, 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

Large scale erosion was not observed during site investigation. But, the embankment slopes on both sides of the highway were exposed for sheet and rill erosion due to the absence of vegetation cover. Protective measures might, therefore, be required for the new culvert. 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 culvert replacement.

Further, inlet and outlet protection in accordance with OPSS 511 (Construction Specification for Rip-Rap, Rock Protection and Granular Sheeting), 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 obtained for the clayey silt sample is 7 µg/g or 0.0008%. According to Clause 4.1.1.6 of the Canadian Standards Association (CSA) standard A23.1-14, soluble sulphate concentrations less than 1000 µg/g or 0.1% generally indicate a low degree of sulphate attack when concrete is in contact with soil or groundwater.

However, the chloride content provided in Table 8 suggests the presence of a moderately corrosive environment for buried metal or reinforcing steel. For non-corrosive environment, it is generally recognised that chloride concentrations should be below 250 ppm. Further, the resistivity value provided in Table 8 is less than 2000 ohm-cm, and this also indicates that a moderately corrosive environment should be expected for steel in contact with soil.

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

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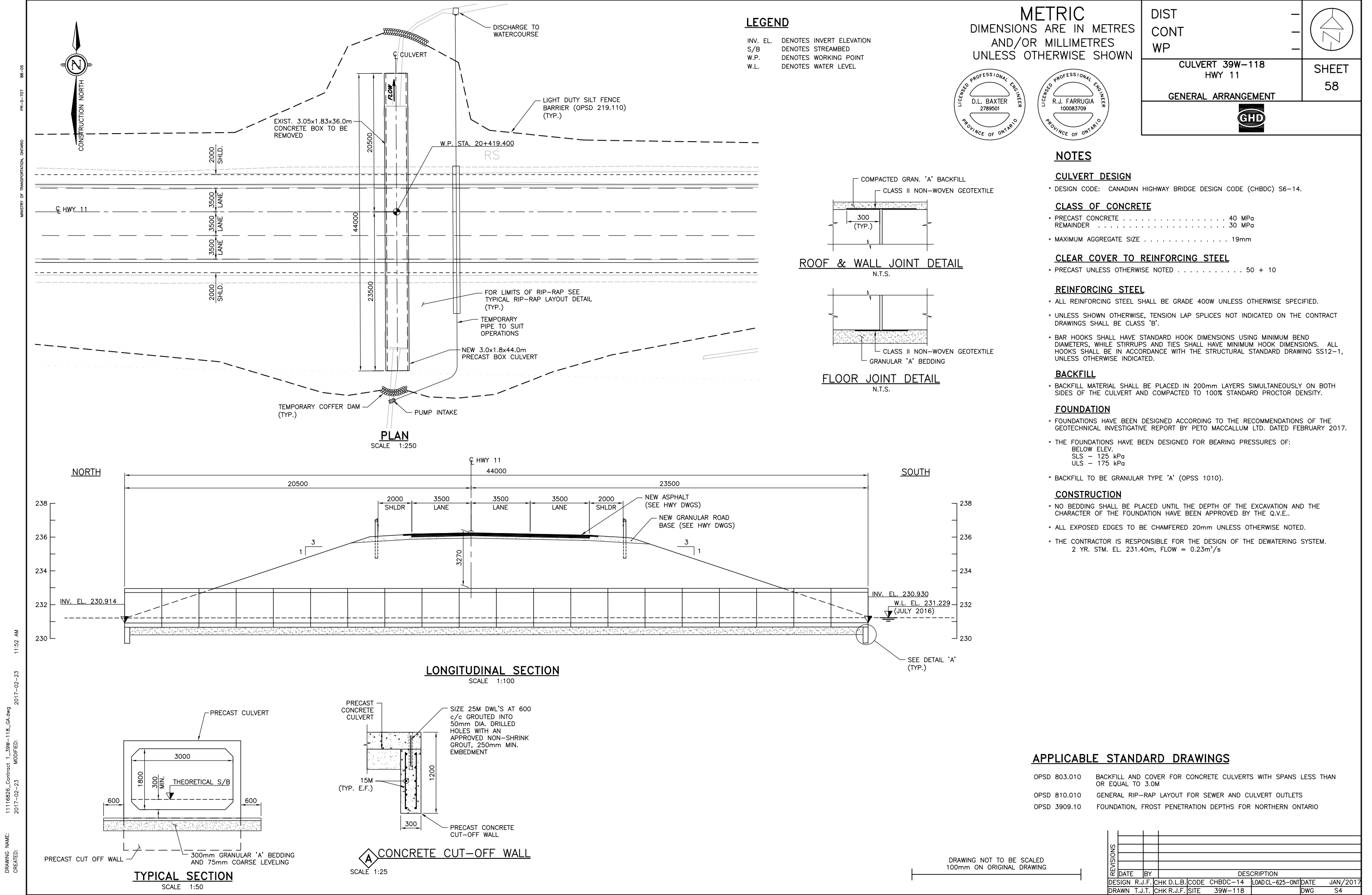
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APPENDIX F

General Arrangement Drawing





APPENDIX G

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



LIST OF STANDARD SPECIFICATIONS RELEVANT TO THE REPORT

DOCUMENT	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
OPSS 501	Construction Specification for Compacting
OPSS 902	Excavation and Backfilling of Structures
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 1010	Material Specification for Aggregates - Base, Subbase, Select Subgrade, And Backfill Material
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.Prov 1004	Material Specification for Aggregates – Miscellaneous
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 – Surface Water Control and Dewatering (Addition to OPSS 518)

The contractor shall take measures for necessary surface water diversions and drainage and 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.

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 soils at the site require careful design of excavation and fill slope geometries and shoring schemes including slope and excavation protection for the removal of the existing culvert. 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. The contractor is responsible for designing excavation and slope geometries, as well as temporary roadway protection 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 may cause excessive settlements.