



**FOUNDATION INVESTIGATION AND DESIGN REPORT**

**for**

**UNNAMED CREEK CULVERT REPLACEMENT**

**SITE NO. 39W-131/C**

**HIGHWAY 11- STATION 10+961 - McCOIG TOWNSHIP**

**DISTRICT OF NEW LISKEARD, ONTARIO**

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

**GWP 5047-07-00**

**WP 5047-07-01**

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PML Ref.: 16TF013A  
Index No.: 094FIR and 095FDR  
GEOCRES No.: 42F-047  
May 24, 2017



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**PART A - FOUNDATION INVESTIGATION REPORT**

for  
Unnamed Creek Culvert Replacement  
Site No. 39W-131/C  
Highway 11- Station 10+961  
McCoig Township, District of New Liskeard, Ontario  
Assignment No. 5015-E-0009, GWP 5047-07-00, WP 5047-07-01

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**1. INTRODUCTION**

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

This report presents the factual findings obtained from the geotechnical investigation carried out for the proposed replacement of the culvert located on Highway 11, 3.2 km west of Fraser River. The culvert to be replaced is located at the approximate Sta. 10+961, in the Township of McCoig, District of New Liskeard, Ontario.

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

**2. SITE DESCRIPTION**

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

The information provided on the Request for Quotation (RFQ) dated March 2016, indicate that the existing structure is a twin cell timber culvert with a total span of 4.2 m, 1.8 m rise and 26 m long. The fill above the deck is 0.5 m high. This culvert was constructed in 1958 and the roadway accommodates two lanes of vehicular traffic.



The inspection report dated September 25, 2015 indicates that light weathering, light to severe checking and splitting of timber were noted on the east and west side of the culvert barrels. In the case of wearing surface, i.e., on the top of the deck, narrow to medium transverse cracks and light raveling were observed.

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

The PML staff visited the site on August 3, 2016 to mark out the borehole locations. The underground services at the borehole locations were cleared by the respective utility companies. Public and private utility authorities were informed and all the utility clearance documents were obtained before the commencement of drilling work.

The fieldwork was carried out on August 4 and 5, 2016. The location of boreholes in the field were established by PML staff using a portable GPS device. Subsequently, Callon Dietz Inc. of London, Ontario under contract to PML carried out the survey of the borehole locations and elevations, and provided the co-ordinates for locations in MTM NAD 83 northing and easting. PML used the survey data provided by Callon Dietz Inc. for preparation of this report. All elevations reported in this report are referred to Geodetic datum and expressed in meters.

The drilling equipment used was owned and operated by Landcore Drilling of Chelmsford, Ontario, a specialist drilling contractor. The fieldwork was carried out under the full-time supervision of a PML field supervisor. The investigation included advancing four (4) boreholes numbered 16-131-1, 16-131-2, 16-131-3 and 16-131-4 to maximum depths ranging from 4.5 m to 6.3 m (El. 251.4 to El. 247.3). Boreholes 16-131-1 and 16-131-2 were located on the highway shoulders and Boreholes 16-131-3 and 16-131-4 were located near the inlet and outlet of the culvert, respectively. These boreholes were advanced using hollow stem augers powered by a track-mounted drill rig and wash boring. Rock coring was carried out in Boreholes 16-131-3 and 16-131-4 using an NQ size double core barrel. The location of boreholes is shown on the attached Drawing 131/C-1.

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



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

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

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

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

- Natural moisture content determinations (16)
- Grain size distribution analyses (5)
- Atterberg limits (5)

The laboratory tests to determine the index properties were performed in accordance with the MTO test procedures, which follow American Society for Testing Materials (ASTM) test procedures, with the exception of hydrometer test (LS-702). The results of the grain size distribution analyses are presented on Figures 131-GS-1 and 131-GS-2. Results of the Atterberg limit test are provided on Figure PC-131-1. All of the test results are summarized on the attached Record of Borehole sheets.

##### **4.1 Chemical Analysis**

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



## **5. SITE GEOLOGY AND SUBSURFACE CONDITIONS**

### **5.1 Site Geology**

Based on the Quaternary Geology map published in 1991 by the Ontario Ministry of Northern Development and Mines (MNDM), the surface conditions in the project area consist of glacial till composed of undifferentiated, fine grained, predominantly silty clay to silt matrix. The underlying bedrock in the region is Granite-Granodiorite and belongs to the Southern and Superior Province, Paleoproterozoic Intrusive Rocks.

### **5.2 Subsurface Conditions**

The subsurface conditions encountered during the course of the investigation, together with the field and laboratory test results are shown on the Record of Borehole Sheets attached to the report. The borehole locations plan and a stratigraphic profile section are shown on Drawing 131/C-1. The boundaries between soil strata have been established at the borehole locations only. The boundaries of soil strata between and beyond the boreholes are assumed and may vary from location to location.

In general, the subsoil conditions consist of 0.6 m to 3.5 m of silty sand fill below the existing surface which is followed by sandy silt (glacial till) overburden to a depth of 5.0 m below the grade. In the case of boreholes located on the highway shoulders, a 200-mm to 300-mm thick pavement fill consisting of sand and gravel was encountered immediately below the surface. The glacial till deposit is underlain by Granite-Granodiorite bedrock of the Southern and Superior Province. For classification purposes, the soils encountered at this site can be divided into four distinct zones.

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

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

This silty sand fill was encountered in Boreholes 16-131-1 and 16-131-2, immediately below a 200 mm to 300 mm thick pavement fill consisting of sand and gravel. The thickness of this fill under the highway shoulders varies from 2.6 m to 3.5 m and extends to a maximum depth of 3.8 m (El.252.0).



In Borehole 16-131-4, this fill was encountered immediately below the surface and in Borehole 16-131-3, it was encountered immediately below 300 mm of topsoil. The thickness of this fill near the inlet and outlet range from 600 mm to 900 mm. The SPT values in this fill layer vary from 3 blows to 11 blows, indicating loose to compact state of denseness.

The moisture content of this fill material varies from 14.3% to 30.7% with an average value of 19.92%. The result of the sieve analysis test performed on one representative sample from this layer is provided on Figure 131-GS-1. The test result indicate that this deposit consists of 0% gravel, 60% sand, 37% silt and 3% clay.

#### 5.2.2 Topsoil

A 300-mm thick topsoil was encountered in Borehole 16-131-3 immediately below the surface, which extends to El. 253.9. In Borehole 16-131-2, a 200-mm thick topsoil was observed immediately below the silty sand fill at about El. 253.1 and extends to El. 252.9.

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

The silty sand fill is immediately underlain by this sandy silt (glacial till) deposit, which extends to a depth of 5.0 m below the grade and maximum El. 250.3. This glacial till deposit consists of varying proportions of silt and sand. The SPT N values to about El. 252.1 vary from 4 blows to 14 blows, indicating loose to compact denseness. Below El. 252.1, refusal to SPT test was observed, indicating very dense state of compaction. Boreholes 16-131-1 and 16-131-2 were terminated on probable bedrock and the glacial till deposit was fully penetrated in Boreholes 16-131-3 and 16-131-4. The thickness of this till deposit was observed to vary from 1.2 m to 2.4 m.

The moisture content of samples tested from this deposit, varied from 6.3% to 15.4% with an average value of 9.6%. The Atterberg limit test results of four representative samples are presented on Figure 131-PC-1. The test results indicate liquid limit values ranging from 17 to 20, plastic limit values ranging from 12 to 14, and corresponding plasticity index values ranging from 4 to 7. Based on the results of Atterberg limit tests, the soil may be classified as silt of low plasticity (ML) in the Unified Soil Classification System (USCS). The results of the sieve analysis test performed on four representative samples from this layer are provided on Figure 131-GS-2. The test results indicate that this deposit consists of 6% to 10% gravel, 33% to 36% sand, 46% to 52% silt and 8% to 13% clay.





#### 5.2.4 Granite-Granodiorite Bedrock

Presence of bedrock was proven by coring at Boreholes 16-131-3 and 16-131-4 and obtaining 3.0 m long rock cores. The rock coring was terminated at a depth of 6.3 m (El. 247.3) below the existing ground surfaces near the inlet and outlet.

The measured recovery of the rock cores ranged between 98% and 100%. The RQD measured from the rock cores retrieved ranged between 94% and 100%. Based on the RQD values, the bedrock may be described as excellent quality. For complete descriptions of the bedrock, refer to rock core description log provided in Appendix B.

#### 5.3 Groundwater

The groundwater level was measured upon completion of drilling and were observed at a depth of 0.56 m (El. 252.5) near the outlet and 2.74 m (El. 253.5) below the existing grade of the road.

The water level in the creek was observed at El. 253.4 during the fieldwork.

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

#### 5.4 Chemical Analysis

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

**Table 5.4-Soil Chemical Analysis Results**

| BOREHOLE NO. | SAMPLE | DEPTH / ELEVATION (m) | SOIL TYPE                 | SULPHATE (µg/g) | CHLORIDE (µg/g) | pH       | RESISTIVITY (Ohm-cm) |
|--------------|--------|-----------------------|---------------------------|-----------------|-----------------|----------|----------------------|
| 16-131-04    | SS-4   | 2.3-2.9 / 251.3-250.7 | Sandy Silt (Glacial Till) | 3               | 44              | 8.6<br>1 | 5590                 |



## 6. CLOSURE

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

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

Yours very truly

Peto MacCallum Ltd.

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AK/MV/CN:az

Part A – Foundation Investigation Report

Unnamed Creek Culvert Replacement, Site No. 39W-131/C, Highway 11, Station 10+961

McCoig Township, District of New Liskeard, Ontario, GWP 5047-07-00, WP 5047-07-01, Index No: 094FIR

PML Ref.: 16TF013A, May 24, 2017

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## **APPENDIX A**

Site Photographs





**Photograph P1:** Looking south-east at the location of Borehole 16-131-4 (August 3, 2016).



**Photograph P2:** Looking south-east at the location of Borehole 16-131-3 (August 3, 2016).





**Photograph P3:** Looking south-west at the culvert inlet (August 3, 2016).



**Photograph P4:** Looking south-east at the culvert outlet (August 3, 2016).

## **APPENDIX B**

Borehole Locations Plan and Soil Strata

Explanation of Terms Used in Report

Record of Borehole Sheets

Results of Grain Size Distribution Analyses – Figures 131-GS-1 and 131-GS-2

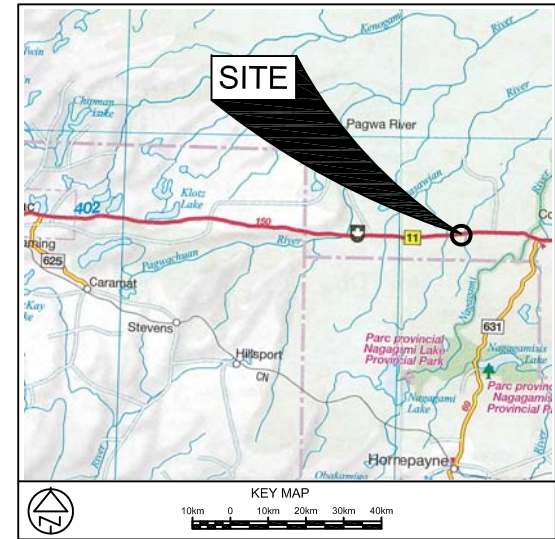
Plasticity Chart – Figures 131- PC -1

Chemical Test Results

Rock Core Photographs

Rock Core Description





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

| BH No     | ELEVATION | NORTHINGS   | EASTINGS  |
|-----------|-----------|-------------|-----------|
| 16-131-01 | 255.8     | 5 514 168.9 | 241 680.9 |
| 16-131-02 | 255.9     | 5 514 181.0 | 241 695.9 |
| 16-131-03 | 254.2     | 5 514 161.4 | 241 690.8 |
| 16-131-04 | 253.6     | 5 514 185.4 | 241 678.3 |

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

| DATE | BY | DESCRIPTION |
|------|----|-------------|
|      |    |             |
|      |    |             |
|      |    |             |
|      |    |             |

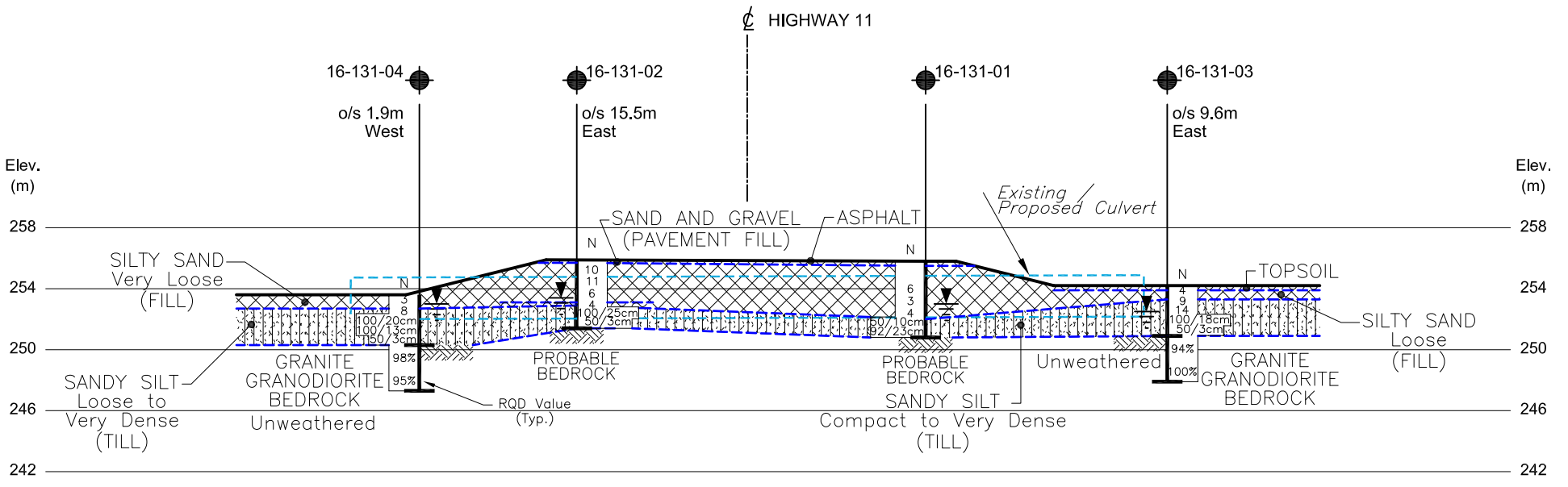
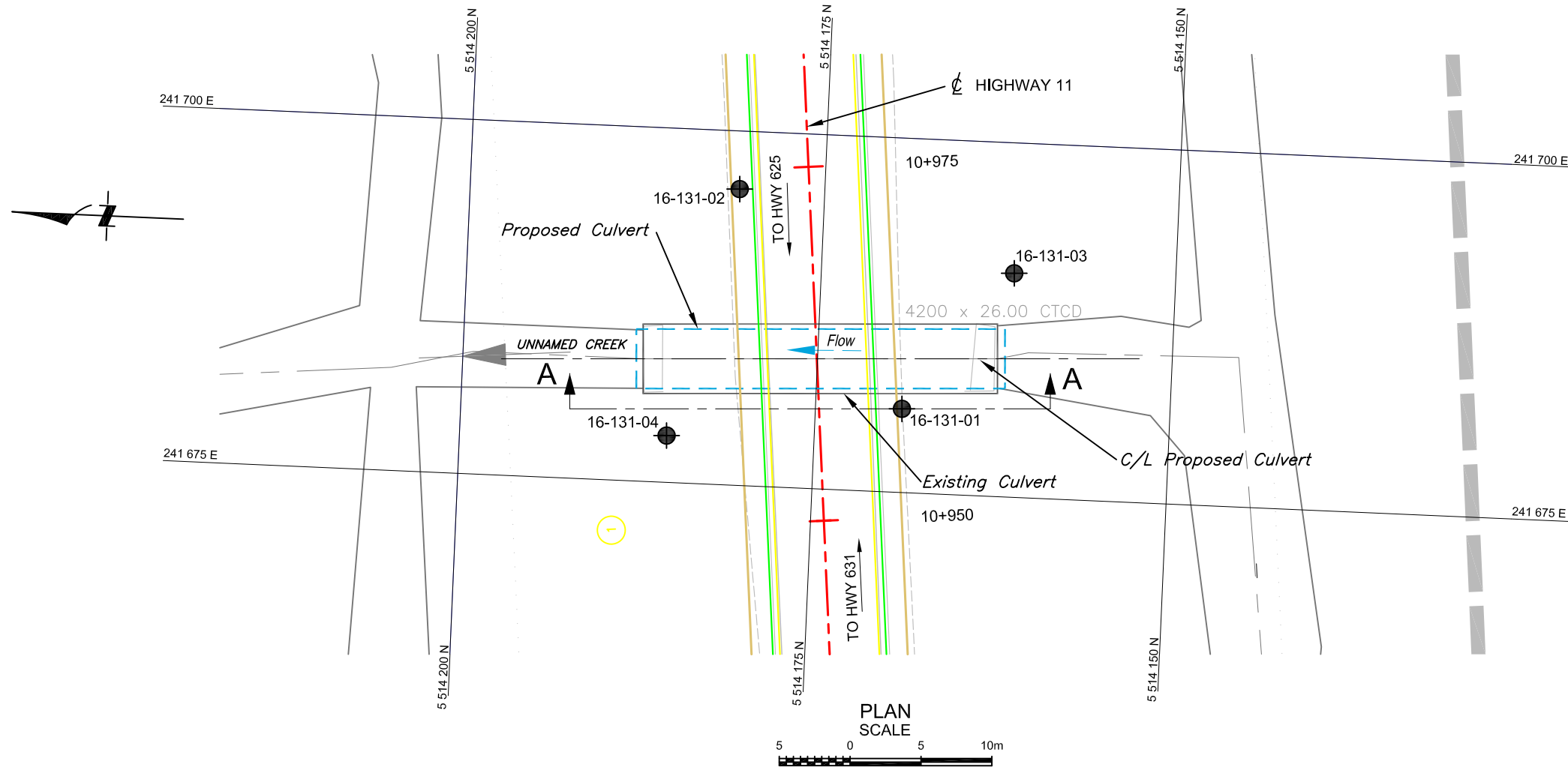
Geocres No. 42F-047

| HWY No | SUBM'D | NA | CHECKED | AK | DATE | APR. 03, 2017 | SITE | 39W-131 |
|--------|--------|----|---------|----|------|---------------|------|---------|
|        |        |    |         |    |      |               |      |         |
|        |        |    |         |    |      |               |      |         |
|        |        |    |         |    |      |               |      |         |

DWG 131/C-1



REF GHD Drawing: X-11116826\_39W-131\_Design.dwg undated



PROFILE A - A

SCALE

HORIZONTAL



VERTICAL



NOTES:

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

## EXPLANATION OF TERMS USED IN REPORT

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

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

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

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

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

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

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

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

**JOINTING AND BEDDING:**

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

## ABBREVIATIONS AND SYMBOLS

### FIELD SAMPLING

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

### STRESS AND STRAIN

|                                      |     |                               |
|--------------------------------------|-----|-------------------------------|
| $u_w$                                | kPa | PORE WATER PRESSURE           |
| $u$                                  | 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 16-131-01

1 of 1

METRIC

|        |            |          |                                      |               |      |
|--------|------------|----------|--------------------------------------|---------------|------|
| G.W.P. | 5047-07-00 | LOCATION | Co-ords: 5 514 168.9 N ; 241 680.9 E | ORIGINATED BY | K.D. |
|--------|------------|----------|--------------------------------------|---------------|------|

DIST New Leaskerd BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY A.K.

DATUM Geodetic HWY 11 DATE August 04, 2016 CHECKED BY M.V.

[illegible]

**RECORD OF BOREHOLE No 16-131-02**

1 of 1

**METRIC**

G.W.P. 5047-07-00 LOCATION Co-ords: 5 514 181.0 N ; 241 695.9 E ORIGINATED BY K.D.  
DIST New Leaskerd BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY A.K.  
DATUM Geodetic HWY 11 DATE August 05, 2016 CHECKED BY M.V.

| SOIL PROFILE  |  |            | SAMPLES |      |            | GROUND WATER<br>CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT              |    |    |     |  | PLASTIC<br>LIMIT<br>W <sub>p</sub> | NATURAL<br>MOISTURE<br>CONTENT<br>W | LIQUID<br>LIMIT<br>W <sub>L</sub> | UNIT<br>WEIGHT<br><br>γ<br><br>kN/m³ | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%)<br><br>GR SA SI CL |                   |  |  |
|---------------|--|------------|---------|------|------------|----------------------------|-----------------|--|----|----|-----|--|------------------------------------|-------------------------------------|-----------------------------------|--------------------------------------|--|-------------------|--|--|
| ELEV<br>DEPTH | DESCRIPTION                                    | STRAT PLOT | NUMBER  | TYPE | "N" VALUES |                            |                 | SHEAR STRENGTH kPa                                       |    |    |     |  |                                    |                                     |                                   |                                      |  | WATER CONTENT (%) |  |  |
|               |  |            |         |      |            |                            |                 | ○ UNCONFINED + FIELD VANE<br>● QUICK TRIAXIAL × LAB VANE |    |    |     |  |                                    |                                     |                                   |                                      |  |                   |  |  |
| 255.9         | Ground Surface                                 |            |         |      |            |                            | 20              | 40   | 60 | 80 | 100 |  |                                    |                                     |                                   |                                      |  |                   |  |  |
| 255.7<br>0.2  | Sand and gravel, trace silt<br>(PAVEMENT FILL) |            |         |      |            | ▽*                         |                 |  |    |    |     |  |                                    |                                     |                                   | 0 60 37 3                            |  |                   |  |  |
|               | Silty sand<br>trace clay, trace gravel         |            |         |      |            |                            |                 |  |    |    |     |  |                                    |                                     |                                   |                                      |  |                   |  |  |
|               | Compact Brown Moist<br>to loose                |            | 1       | SS   | 10         |                            |                 |  |    |    |     |  |                                    |                                     |                                   |                                      |  |                   |  |  |
|               | Grey Wet                                       |            | 2       | SS   | 11         |                            |                 |  |    |    |     |  |                                    |                                     |                                   |                                      |  |                   |  |  |
|               | (FILL)   |            | 3       | SS   | 6          |                            |                 |  |    |    |     |  |                                    |                                     |                                   |                                      |  |                   |  |  |
| 253.1<br>2.8  | Topsoil  |            |         |      |            |                            |                 |  |    |    |     |  |                                    |                                     |                                   |                                      |  |                   |  |  |
| 252.9<br>3.0  | Sandy silt<br>trace clay, trace gravel         |            |         |      |            | ▽*                         |                 |  |    |    |     |  |                                    |                                     |                                   |                                      |  |                   |  |  |
|               | Loose Grey Moist                               |            | 4       | SS   | 4          |                            |                 |  |    |    |     |  |                                    |                                     |                                   |                                      |  |                   |  |  |
|               | Very dense<br>(TILL)                           |            | 5       | SS   | 100/25cm   |                            |                 |  |    |    |     |  |                                    |                                     |                                   |                                      |  |                   |  |  |
| 251.4<br>4.5  | End of borehole                                |            |         |      |            |                            |                 |  |    |    |     |  |                                    |                                     |                                   |                                      |  |                   |  |  |
|               | Refusal on probable bedrock                    |            |         |      |            |                            |                 |  |    |    |     |  |                                    |                                     |                                   |                                      |  |                   |  |  |
|               | Sample 6: Sampler bouncing                     |            |         |      |            |                            |                 |  |    |    |     |  |                                    |                                     |                                   |                                      |  |                   |  |  |
|               | * 2016 08 05                                   |            |         |      |            |                            |                 |  |    |    |     |  |                                    |                                     |                                   |                                      |  |                   |  |  |
|               | ▽ Water level observed<br>during drilling      |            |         |      |            |                            |                 |  |    |    |     |  |                                    |                                     |                                   |                                      |  |                   |  |  |

**RECORD OF BOREHOLE No 16-131-03**

1 of 1

**METRIC**

G.W.P. 5047-07-00 LOCATION Co-ords: 5 514 161.4 N ; 241 690.8 E ORIGINATED BY K.D.  
 DIST New Leaskerd BOREHOLE TYPE C.F.H.S.A., NW Casing and Wash Boring COMPILED BY A.K.  
 DATUM Geodetic HWY 11 DATE August 04, 2016 CHECKED BY M.V.

| SOIL PROFILE  |  |            | SAMPLES |          |             | GROUND WATER<br>CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT                      |    |    |     |  | PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT |   |                | UNIT<br>WEIGHT<br><br>γ | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%) |          |                  |    |
|---------------|--|------------|---------|----------|-------------|----------------------------|-----------------|--|----|----|-----|--|---|---|----------------|-------------------------|---|----------|------------------|----|
| ELEV<br>DEPTH | DESCRIPTION  | STRAT PLOT | NUMBER  | TYPE     | "N" VALUES  |                            |                 | SHEAR STRENGTH kPa   |    |    |     |  | w <sub>p</sub>  | w | w <sub>L</sub> |                         | GR  | SA       | SI               | CL |
|               |  |            |         |          |             |                            |                 | ○ UNCONFINED      + FIELD VANE<br>● QUICK TRIAXIAL    × LAB VANE |    |    |     |  |   |   |                |                         |   |          |                  |    |
| 254.2         | Ground Surface   |            |         |          |             |                            | 20              | 40   | 60 | 80 | 100 |  |   |   |                |                         |   |          |                  |    |
| 0.0           | Topsoil  |            | 1       | SS       | 4           | ▽*                         | 254             |  |    |    |     |  |   | ○ |                |                         |   |          | 6   35   47   12 |    |
| 253.9         |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
| 0.3           | Silty sand<br>trace clay, trace gravel<br>rootlets, organics |            |         |          |             |                            |                 |  |    |    |     |  |   |   | ○              |                         |   |          |                  |    |
| 253.3         |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
| 0.9           | Loose      Brown      Wet<br>(FILL)                          |            | 2       | SS       | 9           |                            |                 |  |    |    |     |  |   |   | ○              |                         |   |          |                  |    |
|               | Sandy silt<br>some clay, trace gravel                        |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               | Compact      Grey      Moist                                 |            | 3       | SS       | 14          |                            |                 |  |    |    |     |  |   | ○ |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               | Very dense   |            | 4       | SS       | 100/18cm    |                            |                 |  |    |    |     |  |   | ○ |                |                         |   |          |                  |    |
|               | (TILL)   |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
| 250.9         |  |            | 5       | SS       | 50/3cm      |                            | 251             |  |    |    |     |  |   | ○ |                |                         |   |          |                  |    |
| 3.3           | Granite-Granodiorite bedrock<br>Unweathered                  |            | 6       | RC<br>NQ | REC<br>100% |                            | 250             |  |    |    |     |  |   |   |                |                         |   | RQD 94%  |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            | 7       | RC<br>NQ | REC<br>100% |                            | 249             |  |    |    |     |  |   |   |                |                         |   | RQD 100% |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
| 247.9         | End of borehole  |            |         |          |             |                            | 248             |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
| 6.3           |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |
|               |  |            |         |          |             |                            |                 |  |    |    |     |  |   |   |                |                         |   |          |                  |    |

\* 2016 08 04

▽ Water level observed during drilling

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

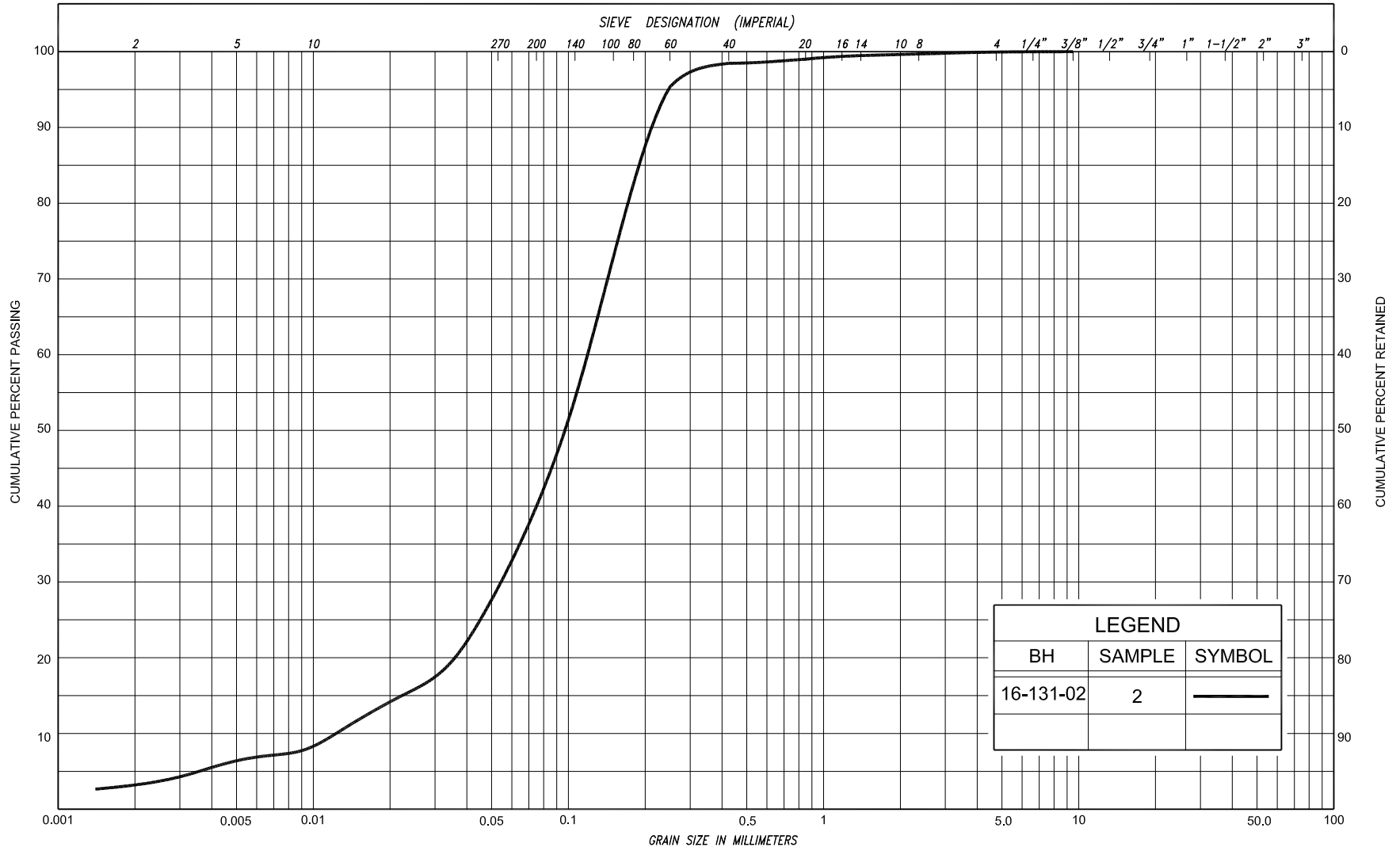
**RECORD OF BOREHOLE No 16-131-04**

1 of 1

**METRIC**

G.W.P. 5047-07-00 LOCATION Co-ords: 5 514 185.4 N ; 241 678.3 E ORIGINATED BY K.D.  
DIST New Leaskerd BOREHOLE TYPE C.F.H.S.A., NW Casing and Wash Boring COMPILED BY A.K.  
DATUM Geodetic HWY 11 DATE August 05, 2016 CHECKED BY M.V.

| SOIL PROFILE  |   |            | SAMPLES |          |            | GROUND WATER<br>CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT                      |    |    |     |   | PLASTIC<br>LIMIT<br>W <sub>p</sub> | NATURAL<br>MOISTURE<br>CONTENT<br>W | LIQUID<br>LIMIT<br>W <sub>L</sub> | UNIT<br>WEIGHT<br>γ<br><br>kN/m³ | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%)<br><br>GR SA SI CL |                   |  |  |
|---------------|---|------------|---------|----------|------------|----------------------------|-----------------|--|----|----|-----|---|------------------------------------|-------------------------------------|-----------------------------------|----------------------------------|--|-------------------|--|--|
| ELEV<br>DEPTH | DESCRIPTION   | STRAT PLOT | NUMBER  | TYPE     | "N" VALUES |                            |                 | SHEAR STRENGTH kPa   |    |    |     |   |                                    |                                     |                                   |                                  |  | WATER CONTENT (%) |  |  |
|               |   |            |         |          |            |                            |                 | ○ UNCONFINED      + FIELD VANE<br>● QUICK TRIAXIAL    × LAB VANE |    |    |     |   |                                    |                                     |                                   |                                  |  |                   |  |  |
| 253.6         | Ground Surface  |            |         |          |            |                            | 20              | 40   | 60 | 80 | 100 |   |                                    |                                     |                                   |                                  |  |                   |  |  |
| 0.0           | Silty sand<br>trace clay, trace gravel<br>rootlets            |            | 1       | SS       | 3          | ▽*                         |                 |  |    |    |     |   |                                    |                                     |                                   | 6 33 52 9                        |  |                   |  |  |
| 252.7         | Very loose Black Wet<br>(FILL)                                |            |         |          |            |                            | 253             |  |    |    |     |   |                                    |                                     |                                   |                                  |  |                   |  |  |
| 0.9           | Sandy silt<br>trace clay, trace gravel                        |            | 2       | SS       | 8          |                            | 252             |  |    |    |     |   | ○ H                                |                                     |                                   |                                  |  |                   |  |  |
|               | Loose Grey Moist<br>Very dense                                |            | 3       | SS       | 100/20cm   |                            | 251             |  |    |    |     |   | ○ H                                |                                     |                                   |                                  |  |                   |  |  |
|               | (TILL)  |            | 4       | SS       | 100/13cm   |                            | 250             |  |    |    |     |   | ○                                  |                                     |                                   |                                  |  |                   |  |  |
| 250.3         |   |            | 5       | SS       | 50/3cm     |                            |                 |  |    |    |     | ○ |                                    |                                     |                                   |                                  |  |                   |  |  |
| 3.3           | Granite-Granodiorite bedrock<br>Unweathered                   |            | 6       | RC<br>NQ | REC 100%   |                            | 250             |  |    |    |     |   |                                    |                                     |                                   | RQD 98%                          |  |                   |  |  |
|               |   |            | 7       | RC<br>NQ | REC 98%    |                            | 249             |  |    |    |     |   |                                    |                                     |                                   |                                  |  |                   |  |  |
| 247.3         |   |            |         |          |            |                            | 248             |  |    |    |     |   |                                    |                                     |                                   | RQD 95%                          |  |                   |  |  |
| 6.3           | End of borehole   |            |         |          |            |                            |                 |  |    |    |     |   |                                    |                                     |                                   |                                  |  |                   |  |  |
|               | Samples 4 & 5: Sampler<br>bouncing                            |            |         |          |            |                            |                 |  |    |    |     |   |                                    |                                     |                                   |                                  |  |                   |  |  |
|               | <br><br><br>*    2016   08   05                               |            |         |          |            |                            |                 |  |    |    |     |   |                                    |                                     |                                   |                                  |  |                   |  |  |
|               | ▽    Water level observed<br>during drilling                  |            |         |          |            |                            |                 |  |    |    |     |   |                                    |                                     |                                   |                                  |  |                   |  |  |
|               | C.F.H.S.A. denotes<br>Continuous Flight Hollow<br>Stem Augers |            |         |          |            |                            |                 |  |    |    |     |   |                                    |                                     |                                   |                                  |  |                   |  |  |

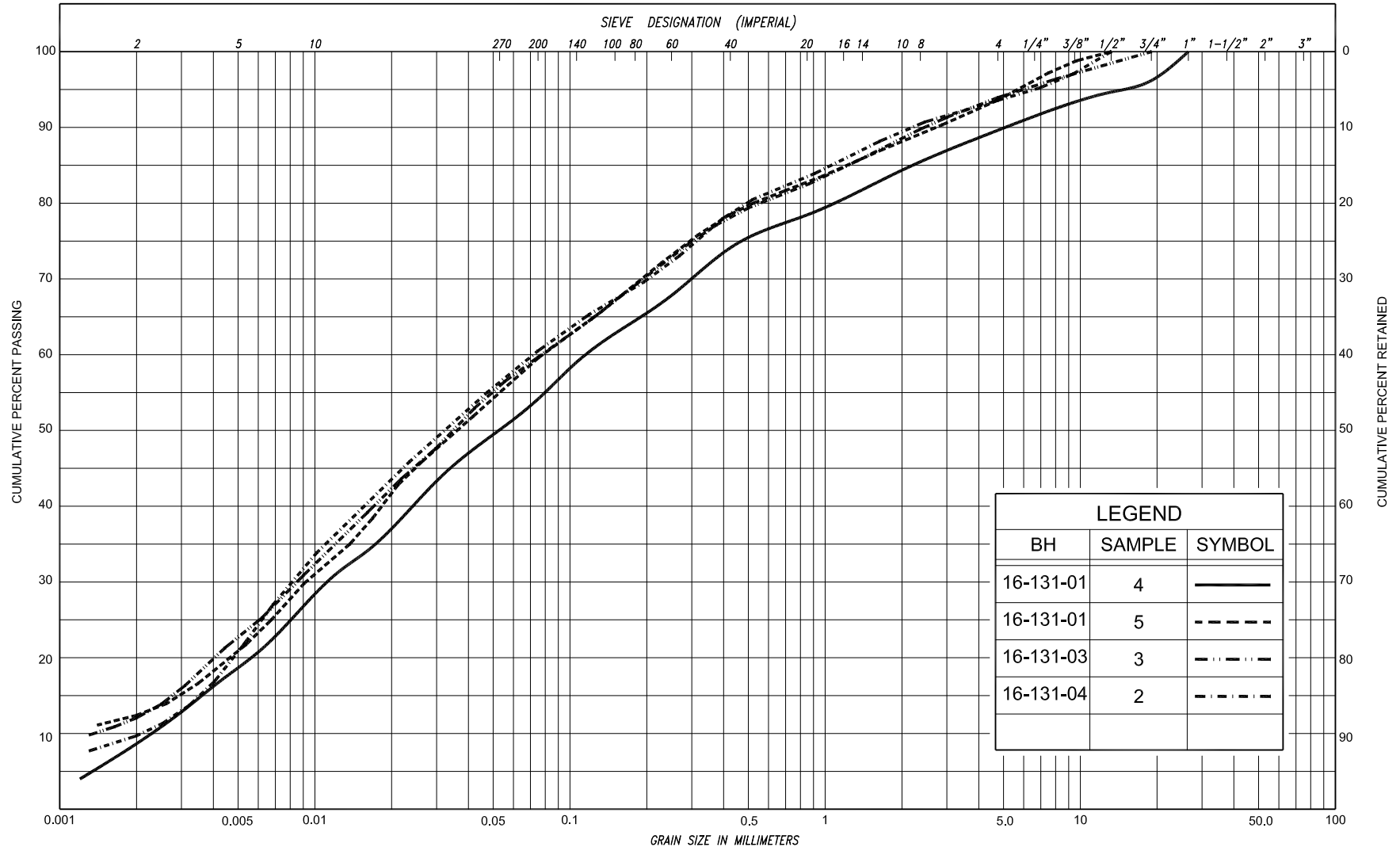


|             |      |  |        |      |        |         |      |        |        |  |        |         |         |  |             |        |
|-------------|------|--|--------|------|--------|---------|------|--------|--------|--|--------|---------|---------|--|-------------|--------|
| SILT & CLAY |      |  |        | 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 SAND, trace clay, trace gravel (FILL)

|         |            |
|---------|------------|
| FIG No. | 131-GS-1   |
| HWY     | 11         |
| G.W.P.  | 5047-07-00 |



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

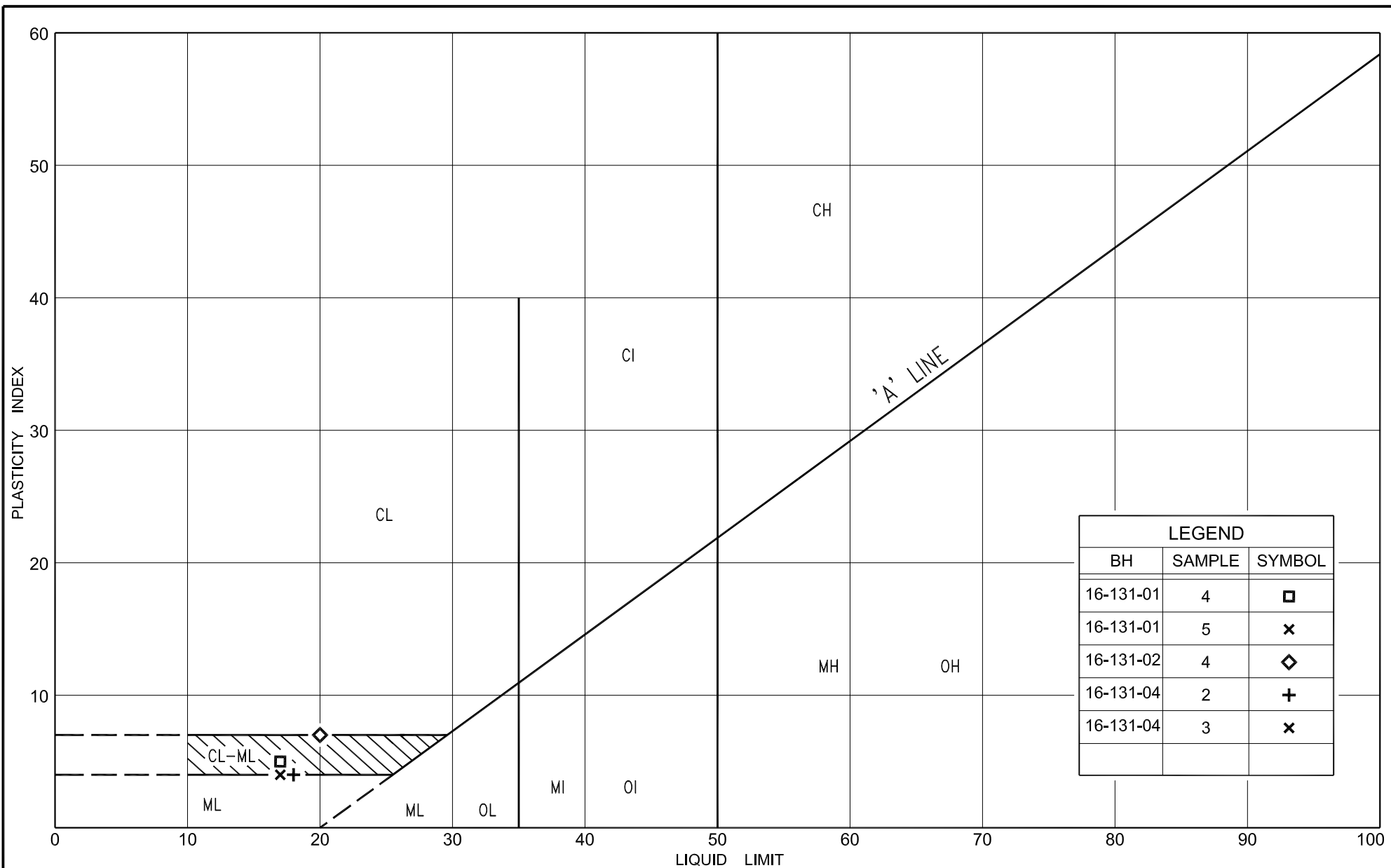


# GRAIN SIZE DISTRIBUTION SANDY SILT, trace to some clay, trace gravel (TILL)

FIG No. 131-GS-2

HWY 11

G.W.P. 5047-07-00



**PLASTICITY CHART**  
 SANDY SILT, trace to some clay, trace gravel (CL-ML)  
 (TILL)

FIG No. 131-PC-1

HWY 11

G.W.P. 5047-07-00



**AGAT** Laboratories

## Certificate of Analysis

AGAT WORK ORDER: 16T131831

PROJECT: 16TF013A

5835 COOPERS AVENUE  
MISSISSAUGA, ONTARIO  
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<http://www.agatlabs.com>

CLIENT NAME: PETO MACCALLUM LIMITED

SAMPLING SITE:

ATTENTION TO: Lul Yimam

SAMPLED BY: Kyle Daly

### Corrosivity Package

DATE RECEIVED: 2016-08-29

DATE REPORTED: 2016-09-07

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

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

**7813058-7813068** EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil).

Certified By:

*Amanjot Bhela*



## Quality Assurance

CLIENT NAME: PETO MACCALLUM LIMITED

PROJECT: 16TF013A

SAMPLING SITE:

AGAT WORK ORDER: 16T131831

ATTENTION TO: Lui Yimam

SAMPLED BY: Kyle Daly

### Soil Analysis

| RPT Date: Sep 07, 2016 |       |           | DUPLICATE |        |     | Method Blank | REFERENCE MATERIAL |                   | METHOD BLANK SPIKE |          | MATRIX SPIKE      |       |
|------------------------|-------|-----------|-----------|--------|-----|--------------|--------------------|-------------------|--------------------|----------|-------------------|-------|
| PARAMETER              | Batch | Sample Id | Dup #1    | Dup #2 | RPD |              | Measured Value     | Acceptable Limits |                    | Recovery | Acceptable Limits |       |
|                        |       |           |           |        |     |              |                    | Lower             | Upper              |          | Lower             | Upper |

#### Corrosivity Package

|                               |         |         |       |       |      |         |      |     |      |      |     |      |      |     |      |
|-------------------------------|---------|---------|-------|-------|------|---------|------|-----|------|------|-----|------|------|-----|------|
| Chloride (2:1)                | 7813068 | 7813068 | 559   | 551   | 1.4% | < 2     | 91%  | 80% | 120% | 102% | 80% | 120% | 104% | 70% | 130% |
| Sulphate (2:1)                | 7813068 | 7813068 | 14    | 14    | 0.0% | < 2     | 96%  | 80% | 120% | 102% | 80% | 120% | 101% | 70% | 130% |
| pH (2:1)                      | 7813068 | 7813068 | 8.37  | 8.29  | 1.0% | NA      | 101% | 90% | 110% | NA   |     |      | NA   |     |      |
| Electrical Conductivity (2:1) | 7813068 | 7813068 | 0.986 | 0.986 | 0.0% | < 0.005 | 100% | 90% | 110% | NA   |     |      | NA   |     |      |
| Redox Potential (2:1)         | 7813068 | 7813068 | 254   | 254   | 0.0% | < 5     | 103% | 70% | 130% | NA   |     |      | NA   |     |      |

Comments: NA signifies Not Applicable.

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

Certified By:





## Method Summary

CLIENT NAME: PETO MACCALLUM LIMITED

AGAT WORK ORDER: 16T131831

PROJECT: 16TF013A

ATTENTION TO: Lui Yimam

SAMPLING SITE:

SAMPLED BY: Kyle Daly

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

Part A – Foundation Investigation Report

Unnamed Creek Culvert Replacement, Site No. 39W-131/C, Highway 11, Station 10+961

McCoig Township, District of New Liskeard, Ontario, GWP 5047-07-00, WP 5047-07-01, Index No: 094FIR,

PML Ref.: 16TF013A, May 24, 2017

---



**Photograph R1:** Rock cores at Borehole 16-131-03 (March 21, 2017).

Part A – Foundation Investigation Report

Unnamed Creek Culvert Replacement, Site No. 39W-131/C, Highway 11, Station 10+961

McCoig Township, District of New Liskeard, Ontario, GWP 5047-07-00, WP 5047-07-01, Index No: 094FIR,

PML Ref.: 16TF013A, May 24, 2017

---



**Photograph R2:** Rock cores at Borehole 16-131-04 (March 21, 2017).



## ROCK CORE DESCRIPTION

| BOREHOLE NO. | CORE RUN | DEPTH (M) | % CR | % RQD | DESCRIPTION  |
|--------------|----------|-----------|------|-------|--|
| 16-131-03    | 1        | 3.3 – 4.8 | 100  | 94    | <b>GRANITE-GRANODIORITE:</b><br><br>Light grey to medium grey, medium grey strong, granular well developed grains, dense, coarse grained, hard, unweathered, very sparsely fractured to fractured, undulating, no fillings, rough. |
|              | 2        | 4.8 – 6.3 | 100  | 100   |  |
| 16-131-04    | 1        | 3.3 – 4.7 | 100  | 98    |  |
|              | 2        | 4.7 – 6.3 | 98   | 95    |  |

**CR\*** - Core Recovery

**RQD\*** - Rock Quality Designation

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



**PART B – FOUNDATION DESIGN REPORT**

**for**

**UNNAMED CREEK CULVERT REPLACEMENT**

**SITE NO. 39W-131/C**

**HIGHWAY 11- STATION 10+961 - McCOIG TOWNSHIP**

**DISTRICT OF NEW LISKEARD, ONTARIO**

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

**GWP 5047-07-00**

**WP 5047-07-01**

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**Distribution:**

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- 1 cc: PML Kitchener

PML Ref.: 16TF013A  
Index No.: 095FDR  
GEOCRES No.: 42F-047  
May 24, 2017



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

**PART B - FOUNDATION DESIGN REPORT**

for  
Unnamed Creek Culvert Replacement  
Site No. 39W-131/C  
Highway 11- Station 10+961  
McCoig Township, District of New Liskeard, Ontario  
Assignment No. 5015-E-0009, GWP 5047-07-00, WP 5047-07-01

---

**7. INTRODUCTION**

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

**8. PROJECT DESCRIPTION**

**8.1 General**

This report provides foundation design recommendations based on interpretation of the geotechnical data presented in the factual report (Part A). This report is to assist the design team in the selection of a suitable type of foundation for the replacement of the culvert located on Highway 11, 3.2 km west of Fraser River (Sta. 10+961) in the Township of McCoig, District of New Liskeard.

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

**8.2 Existing Culvert**

The existing structure is a twin cell timber culvert with a total span of 4.2 m, 1.8 m rise and 26 m long. The structure supports 0.5 m high fill above the deck. Based on the information provided by GHD, the invert of the existing culvert at the centerline of Highway 11 is at approximate El. 252.45 and the embankment above the creek bed is approximately 2.9 m high.





This culvert was constructed in 1958 and the road accommodates two lanes of vehicular traffic. Based on the inspection carried out on 25 September, 2015, light weathering, light to severe checking and splitting of timber were noted on the east and west side of the culvert barrels. Narrow to medium transverse cracks and light raveling were also observed on the wearing surface.

The foundation details of the existing timber culvert are not available. However, considering the width of the culvert and the fill height above the deck, the load imposed by the existing culvert at the founding level may not exceed 55 to 65 kN per meter length of the culvert.

### **8.3 Proposed Culvert**

It is proposed to replace the existing culvert with a 27.0 m long precast concrete box culvert with an opening size of 6.0 m span and 2.0 m rise, along the same vertical and horizontal alignments.

The structural information provided by GHD indicates that the proposed invert of the replacement box culvert slopes down from about El. 252.53 at the inlet to El. 252.37 at the outlet. The founding levels of the subgrade at the inlet and outlet are proposed to be at El. 251.86 and El. 251.70, respectively. It is proposed to construct the replacement culvert along the same vertical and horizontal alignments and the grade of the road at the culvert location will be maintained at the existing elevation of El. 255.4, which will result in a fill height including the pavement structure of 0.5 m above the deck of the culvert.

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

### **8.4 Structure Foundation**

In summary, the subsoil conditions consist of 0.6 m to 3.5 m of silty sand fill below the existing surface, which is followed by sandy silt (glacial till) overburden to a depth of 5.0 m below the grade. In the case of boreholes located on the highway shoulders, a 200-mm to 300-mm thick pavement fill consisting of sand and gravel was encountered immediately below the surface. The glacial till deposit is underlain by Granite-Granodiorite bedrock of the Southern and Superior Province. The groundwater level was



observed between El. 252.5 and El. 253.5 in the boreholes during the fieldwork. The water level in the creek was observed at El. 253.4 during the fieldwork.

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

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

Considering the subsoil conditions, the recommendations for the replacement culvert are provided below in the order of preference. A comparison of the technical advantages and disadvantages for the replacement culvert are presented in Table 8.4.



**Table 8.4 - Comparison of Alternate Culvert Options**

| <b>OPTION 1: PRECAST CONCRETE BOX CULVERT</b>   | <b>OPTION 2: CAST IN-PLACE CONCRETE BOX CULVERT</b>  | <b>OPTION 3: THREE-SIDED PRECAST OR CAST-IN-PLACE OPEN CULVERT</b>  |
|---|--|---|
| <p>Advantages:</p> <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. The joints provide flexibility to accommodate differential settlement</li> </ol> | <p>Advantages:</p> <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> | <p>Advantages:</p> <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>6. Ease of construction and installation in wet conditions is possible</li> <li>7. Adequate geotechnical resistance available at founding level</li> </ol> |
| <p>Disadvantages:</p> <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>   | <p>Disadvantages:</p> <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 1.5 m high water</li> </ol>    | <p>Disadvantages:</p> <ol style="list-style-type: none"> <li>1. Uneven or differential settlements are possible</li> <li>2. Limited ability to withstand differential settlements</li> <li>3. Silty soil below the invert level is susceptible to scour</li> <li>4. Foundation on the bedrock requires extensive dewatering</li> </ol>  |
| <p>Cost of Construction:<br/>Total Cost \$ 14,000/m</p>   | <p>Cost of Construction:<br/>Total Cost \$ 15,000/m</p>  | <p>Cost of Construction:<br/>Total Cost \$ 14,500/m</p>   |
| <b>Recommended</b>  | <b>Technically Feasible but Not Recommended</b>  | <b>Technically Not Feasible; Not Recommended</b>  |



#### 8.4.1 Option 1: Precast Concrete Box Culvert

Based on the structural information available, it is assumed that the precast concrete box culvert will be placed at about El. 251.78±. The subsoil conditions below the proposed founding level is capable of supporting precast concrete box culvert. Bedding for the precast concrete box culvert should be in accordance with OPSS 422.07.08, and may consist of 300 mm thick granular material, including the 75 mm leveling course required by OPSS 422. Bedding should be as specified in OPSS 422.05.13, and should also be placed in accordance with OPSS 422.07.07.

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

For the design of the proposed precast concrete box culvert placed below about El. 251.7, a factored geotechnical resistance of 250 kPa at ULS and 180 kPa at SLS may be utilized. A total settlement of about 20 mm under the geotechnical resistance at SLS may be expected and majority of the settlements are expected to take place upon completion of construction.

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

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

The subsoil conditions below the proposed founding level of the culvert are capable of adequately supporting the cast-in-place concrete box culvert. However, the existing silty soil below the proposed founding surface will require a cut-off wall to prevent scour or washout. Further, construction under 1.5 m of ground water will impose greater difficulties for construction in dry conditions.



If this option is considered, a dewatering scheme should be used to provide a working platform for formwork and placing of concrete. In this case, the box culvert may be placed at about El. 251.78 and designed using a geotechnical resistance of 250 kPa at ULS and 180 kPa at SLS. Same as in option 1, the total settlement is not expected to exceed 20 mm and the associated differential settlement will be within about 15 mm.

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

#### 8.4.3 Option 3: Three-Sided Precast Concrete or Cast-In-Place Open Culvert

It is considered that three-sided open culvert could be placed opened footings. It is noted that the very dense sandy silt (glacial till) encountered below the proposed founding level of the replacement culvert is susceptible for scour. Section C1.9.11.1 of the Canadian Highway Bridge Design Code commentary (CHBDC 2014) suggests avoiding the replacement of open footings on soil materials that are susceptible to scour. Although the bedrock/probable bedrock at this site is within 1.0 m to 2.1 m of the invert level, excavation into the overlying very dense sandy silt (glacial till) would require extensive dewatering to obtain the referred dry condition to place the precast concrete footing on the bedrock. For these reasons, this option is not recommended.

#### 8.4.4 Recommended Option for Culvert Replacement

From a geotechnical perspective and based on the subsurface conditions, precast concrete box culvert placed at about El 251.78 is the preferred option for the replacement of the existing culvert.

Options 2 and 3 are technically feasible but not preferred considering the construction difficulties and cost of dewatering 1.5 m high groundwater.



#### 8.4.5 Lateral Earth Pressure

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

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

Where,  $P$  = lateral earth pressure (kPa)  
 $K$  = lateral earth pressure coefficient  
 $\gamma$  = unit weight of backfill material above assumed water level (kN/m<sup>3</sup>)  
 $\gamma'$  = unit weight of submerged backfill ( $\gamma - \gamma_w$ ) material below assumed water level (kN/m<sup>3</sup>)  
 $\gamma_w$  = unit weight of water (9.8 kN/m<sup>3</sup>)  
 $h_1$  = depth below final grade (m), above assumed water level  
 $h_2$  = depth below assumed water level (m)  
 $q$  = surcharge load (kPa)  
 $C_p$  = compaction pressure (refer to clause 6.12.3 of CHBDC 2014)  
 $C_s$  = earth pressure induced by seismic events, kPa (refer to clause 4.6.5 of CHBDC 2014)

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

**Table 8.4.5: Recommended Geotechnical Parameters**

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



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

Backfill shall be placed simultaneously behind both sides of the culvert, maintaining the height of backfill approximately the same. At no time, should the difference in backfill elevation from one side to the other be greater than 400 mm.

### **8.5 Approach Embankment**

The height of the existing approach fill is approximately 3.0 m above the creek bed. PML understands that there will be no increase in the profile grade of the road and it will be maintained at El. 255.4. No major instability problems are anticipated for the excavated section of embankment to be reconstructed with similar side slope as the existing.

The embankment fill may consist of well-compacted, suitable earth or granular fill. The fill below water table should consist of well compacted granular material, preferably Granular B Type II. Any spongy or soft area observed within the base of the embankment should be removed before placing the fill.

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

### **9. FOUNDATION FROST DEPTH**

In accordance with OPSD 3090.100, a minimum of 2.6 m earth cover is required to protect against the frost penetration in the area where the site is located.

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

### **10. SEISMIC CONSIDERATIONS**

The Spectral and Peak Ground Accelerations ( $S_a$  (0.2) and PGA) for the project site, based on the Town of Hearst, Ontario, and for the 2% in 50-year probability of exceedance, is 0.060 and 0.035,



respectively (National Building Code of Canada, 2015). The Reference Peak Ground Acceleration (PGA<sub>ref</sub>) 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 C in accordance with Clause 4.4.3.2 of CHBDC, 2014.

### **10.1 Cover and Backfill**

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

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

## **11. CONSTRUCTION CONSIDERATIONS**

### **11.1 Staged Construction**

The construction of the culvert replacement is expected to be carried out in two stages. As described in Section 8.3, staged construction with a roadway protection system will be required to remove the existing culvert and to install the new culvert while maintaining traffic on Highway 11. Surface water should be diverted away from open excavations and all excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA) and MTO Regulations for Construction Projects.

The very dense glacial till encountered below El. 252.1 and shallow bedrock encountered at this site are not favourable for driving sheet piles to adequate depth of embedment. To construct a shoring system to maintain traffic on Highway 11, the use of soldier piles and timber laggings supported by anchors or struts may have to be considered to construct temporary shoring systems. The soldier piles may have to be lowered in pre-augured holes and filled with non-shrinkable grout to support the excavation with timber lagging. However, this type of shoring system will be very costly to use for a culvert construction. The Non-Standard Special Provision (NSSP) provided in the Appendix D shall be included in the contract document to alert the contractor.





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

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

**Table 11.1 Soil Parameters**

| ELEVATION |       | SOIL TYPE                           | SOIL PARAMETERS                    |   |                      |
|-----------|-------|-------------------------------------|------------------------------------|---|----------------------|
| FROM      | TO    |                                     | FRICTION<br>ANGLE ( $\phi^\circ$ ) | UNIT<br>WEIGHT( $\gamma$ )<br>kN/m <sup>3</sup> | C <sub>u</sub> , kPa |
| 255.9     | 252.5 | Silty Sand Fill                     | 30                                 | 18  | 0                    |
| 252.5     | 251.8 | Loose to Compact Sandy<br>Silt Till | 28                                 | 19  | 0                    |
| 251.8     | 250.3 | Very Dense Sandy Silt<br>Till       | 32                                 | 21  | 0                    |

Note: Submerged unit weight should be used below water level

## 11.2 Excavation

Excavation should be carried out in accordance with OPSS 902, Construction Specifications for Excavating and Backfilling–Structures. Excavated material shall not be stockpiled in the areas immediately adjacent to the top of the excavation slopes.

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



## **12. GROUNDWATER CONTROL**

The groundwater level was encountered between El. 252.5 and El. 253.5, and the excavation to the founding level will have to be carried out under 1.5 m high water level. The groundwater level should be lowered to a minimum of 0.5 m below the proposed founding levels to allow for construction in-the-dry and to place bedding materials.

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

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

Groundwater levels are subject to seasonal fluctuations and precipitation patterns.

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



### **13. SOIL CORROSION**

One sample from the till deposit was tested for soil corrosivity and potential exposure of concrete to sulphate attack. A summary of the chemical test results is provided in Appendix B of this report. The sulphate concentration of 3 µg/g (0.0003%) reported in Table 5-1 for the sandy silt till is far too low compared to the value of 0.1% suggested in Canadian Standard A23.1-14 to have any effect on buried concrete structures. Therefore, potential for sulphate attack will be mild or relatively low. The chloride content of 44 ppm or 0.0044% (44 µg/g) reported in Appendix B is significantly lower than the concentration value of 250 ppm (0.025%) that generally leads to corrosive environment for buried metals. Potential for corrosive environment at this site is relatively low.

Electrical resistivity less than 2000 ohm-cm generally leads to highly corrosive environment for steel elements in contact with soil. The resistivity value of 5590 ohm-cm reported is significantly higher than 2000 ohm-cm and suggests a moderately or non-corrosive environment at this site for steel elements. However, the reported pH value of 8.61 is slightly higher than the value of 5.5 that generally leads to corrosion.

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



#### 14. CLOSURE

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

Yours very truly

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## **APPENDIX C**

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



## LIST OF STANDARD SPECIFICATIONS RELEVANT TO REPORT

| DOCUMENT      | TITLE   |
|---------------|---|
| OPSS 422      | Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut  |
| OPSS 501      | Construction Specification for Compacting   |
| OPSS 517      | Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation |
| OPSS 518      | Construction Specification for Control of Water from Dewatering Operations                          |
| OPSS 539      | Temporary Protection Systems  |
| OPSS 902      | Excavation and Backfilling of Structures  |
| OPSD 810-010  | General Rip-Rap Layout Sewer and Culvert Outlets  |
| OPSD 812.010  | Cut Off Wall for Structural Plate Pipe Arch and Circular Csp  |
| OPSD 3090.100 | Foundation, Frost Penetration depths for Northern Ontario   |
| OPSD 3101.150 | Walls, Abutment, Backfill, Minimum Granular Requirement   |



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

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

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

The fill and sandy silt till expected within the depth of excavation consist of significant amount of sand and are relatively pervious. The presence of some clay means the permeability of these soils varies from low to medium depending on the percentage of fines. Generally, in view of the relatively pervious subsoil conditions, the dewatering design and the implementation should prevent unsafe conditions, such as sloughing and boiling under unbalanced groundwater conditions. In addition to 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 – Excavation and Slope Stability (Addition to OPSS 902 and OPSS)**

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

### **NSSP 3 – Settlement Management (Addition to OPSS 902)**

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