



**FOUNDATION INVESTIGATION AND DESIGN REPORT
ASINN CREEK CULVERT REPLACEMENT
HIGHWAY 599
TOWNSHIP OF SKEY, THUNDER BAY DISTRICT
AGREEMENT NO.: 4014-E-0023
SITE NO.: 48W-314/C
GEOCRES NO. 52G-12
GWP: 6354-14-00**

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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

DST Consulting Engineers Inc. (DST) was retained by MTO under the direction of the prime consultant, Planmac Engineering Inc. (Planmac), to conduct a foundation investigation and provide a foundation design report for the proposed culvert replacement on Highway 599. This work was carried out under Agreement No.: 4014-E-0023. This report addresses the field investigation, laboratory test program, factual report on conditions (Part 1) and recommendations for design and construction for the proposed culvert replacement (Part 2).

This report was initially submitted to Planmac and MTO in March 2017. It is now being re-issued, at the request of MTO under the direction of their prime consultant WSP, to reflect updated project information. WSP has requested revisions to Section 7.4, Staged Construction, the addition of a new section 7.5, Temporary Road Widening, revisions to the fourth paragraph of Section 7.6 to clarify that it includes dewatered excavation slopes, and revised references for dewatering Section 7.10. Furthermore, WSP has requested the deletion of the following sections; precast concrete open footings, corrugated steel plate culverts, retaining walls and recommendations pertaining to advantages and disadvantages of precast concrete open footings and corrugated steel plate culverts.

This revised report supersedes the previous DST March 23, 2017 report.

2. SITE DESCRIPTION

The site is located on Highway 599, approximately 10.7 km North-East of Highway 17 (Latitude 49.4691, Longitude -91.5443), Station 12+464, in the Township of Skey, in the District of Thunder Bay. The Highway runs northeast to southwest across a short drainage channel flowing northwest from Little Sandbar Lake into Sandbar Lake. The drainage channel is broad and flat, being about 100m wide at the culvert location. The existing Asinn Creek occupies a narrow meandering path

within the wider drainage channel. The twin culverts are aligned northwest to southeast and perpendicular to the Highway.

The existing 21.2 m long Corrugated Steel Pipe (CSP) twin culvert is approximately 2.40 m in diameter. The year of construction of the existing culvert is not known with certainty (Figure 2-1 and Figure 2-2). An inspection by others indicates medium corrosion above the waterline and severe corrosion below the waterline. It was also reported that both barrels have deformation under the roadway and debris build up in the north barrel.

Based on the Ontario Structure Inspection Manual (OSIM), the fill thickness at the culvert location is approximately 1.0 m and the height of the embankment is approximately 2.3 m with side slopes of approximately 2H: 1V. There is some erosion of the embankment fill between the culvert barrels at the inlet and outlet areas. This is reportedly due to a lack of protective vegetation cover over the fill material. (Figure 2-2). The wider drainage feature is vegetated with reeds and grasses, while the main channel is open water. The surrounding slopes adjacent to the wider drainage feature are forested.



Figure 2-1: Location of existing culvert at Highway 599 (looking west)



Figure 2-2: Embankment slope condition

3. REGIONAL GEOLOGY

Geological information is available from published *Ontario Geological Survey Map #52GSW* by the *Ontario Ministry of Natural Resources* for the Skey area. The local area landform is identified as outwash plain, valley train. Outwash deposits include plains, fans, deltas, and valley trains of varying sizes, all consisting mainly of sand and gravel. Most outwash sediments were drained from the front of a melting glacier and accumulated in flooded lowlands and valley bottoms. Although most outwash deposits formed in proglacial positions, some accumulated over masses of stagnant glacier ice, resulting in pitted or kettled surfaces. Outwash landscapes that show abandoned channel scars, braid bars or deep kettle holes are commonly coarse in texture (i.e. gravelly and cobbly rather than sandy).

As indicated on the *Bedrock Geology of Ontario West Central Sheet Map 2542*, the soil at the site is underlain by intrusive rocks of Archaen age comprising of massive to foliated granodiorite to granite. Secondary intrusive dyke swarms comprising of Palaeoproterozoic age diabase/dolerite (23b Wabigoon swarm) are indicated to cut across the area trending north west to south east.

4. INVESTIGATION PROCEDURES AND LABORATORY TESTING

Site work was carried out on September 10th to September 11th, 2015 utilizing a CME 750 drill rig equipped for geotechnical drilling and operated by DST. A total of four boreholes were advanced to depths ranging from 12.2 m to 16.3 m. The minimum number and depth of the boreholes was specified by the Ministry of Transportation (MTO).

The borehole locations and stratigraphic sections are shown on the Borehole Location Plan and Drawings 1 and 2 in Appendix C. Borehole 1 was advanced north of the existing culvert at Station 12+471, 3.9 m left of centreline, and advanced to a depth of 14.9 m below existing surface. Borehole 2 was advanced north of the existing culvert at Station 12+474, 12.8 m right of centreline, and advanced to a depth of 12.2 m below existing surface. Borehole 3 was advanced south of the existing culvert at Station 12+456, 6.1 m right of centreline, and advanced to a depth of 16.3 m below existing surface. Borehole 4 was advanced south of the existing culvert at Station 12+458, 5.1 m left of centreline, and advanced to a depth of 14.9 m below surface.

The borehole locations were referenced to the MTO Station numbering system as indicated on the drawings provided by the Ministry. The ground surface elevations at the borehole locations were surveyed by DST personnel and referenced to benchmark 416.142 m N and W in root of 0.30Φ Balsam (N = 5482306.5 m, E = 192860.4 m) as indicated on the drawings provided by the Ministry. Table 4.1 summarizes the details of borehole locations and depths.

All boreholes were abandoned using suitable abandonment barrier as described in Ontario Regulation 903 and its amendments. Augured boreholes were decommissioned by backfilling from the bottom of the hole to the ground surface with bentonite chips.

The fieldwork was supervised on a full-time basis by DST personnel who located the boreholes in the field, arranged for clearance of subsurface utilities, supervised the drilling and in-situ testing operations, retrieved samples, logged the boreholes, and supervised the backfilling of boreholes and reinstatement of drilling locations. Soil samples were obtained from the auger flights and from the split spoon sampler used for the Standard Penetration Test (SPT). The SPT testing was carried out in accordance with the procedures described in ASTM D1586. The number of blows required to drive the sampler 300 mm is known as the standard penetration blow count (N) which provides an indication of the condition or consistency of the soil. The soil samples collected during drilling were identified in the field, placed in labelled containers and transported to DST's geotechnical testing laboratory in Thunder Bay for further analyses.

Classification and index tests were subsequently performed in the laboratory on samples collected from the boreholes to aid in the selection of engineering properties. Laboratory testing included chemical tests, natural moisture contents and particle size analyses on selected soil samples. A total of twenty-seven (27) natural moisture contents, nine (9) grain size particle analyses, five (5) hydrometer tests, one (1) Atterberg limits test and two (2) sets of chemical tests have been carried out for this assignment. Laboratory test results are presented in the Boreholes Logs and graphical plots attached in Appendix D (Enclosures).

Table 4-1 Details of Borehole Locations

Borehole ID	Station	Elevation (m)	Depth (m)	Offset (m)	Completion Details
Borehole 1	12+471	417.2	14.9	3.9 Lt	Borehole backfilled with bentonite chips to ground surface.
Borehole 2	12+474	415.8	12.2	12.8 Rt	Borehole backfilled with bentonite chips to ground surface.
Borehole 3	12+456	417.0	16.3	6.1 Rt	Borehole backfilled with bentonite chips to ground surface.
Borehole 4	12+458	416.9	14.9	5.1 Lt	Borehole backfilled with bentonite chips to ground surface.

5. DESCRIPTION OF SUBSURFACE CONDITIONS

The subsurface conditions presented below are based on the information obtained during power auger drilling and laboratory determination on selected samples.

The generalized stratigraphy of the existing embankment and outside the embankment footprint, based on the conditions encountered in the boreholes consists of the following:

- Embankment fill comprising loose sand and gravel.
- Topsoil encountered at the base of the embankment north of the culverts.
- Underlain by loose to occasionally compact sand (upper layer)
- Which is underlain by a silt layer with trace to some sand, clay and trace gravel.
- Underlying the silt layer is a loose to compact sand (lower layer) is encountered

The soil strata at the culvert location have been summarized in Table 5-1 and detailed descriptions are provided below.

Table 5-1 Summary of soil strata at the culvert location

Layer	Depth (m)	Elevation (m)	Comments
Fill	0.0 to 2.3	417.2 to 414.9	Borehole 1
	0.0 to 2.3	417.0 to 414.7	Borehole 3
	0.0 to 2.3	416.9 to 414.6	Borehole 4
Topsoil	0.0 to 0.20	415.8 to 415.6	Borehole 2
Sand (Upper Layer)	2.3 to 6.7	414.9 to 410.5	Borehole 1
	0.2 to 3.8	415.6 to 412.0	Borehole 2
	2.3 to 3.8	414.7 to 413.2	Borehole 3
	2.3 to 3.8	414.6 to 413.1	Borehole 4
Silt	6.7 to 12.2	410.5 to 405.0	Borehole 1
	3.8 to 12.2	412.0 to 403.6	Borehole 2
	3.8 to 8.8	413.2 to 408.2	Borehole 3
	3.8 to 12.2	413.1 to 404.7	Borehole 4
Sand (Lower Layer)	12.2 to 14.9	405.0 to 402.3	Borehole 1
	8.8 to 16.3	408.2 to 400.7	Borehole 3
	12.2 to 14.9	404.7 to 402.0	Borehole 4

5.1 Fill – Sand and Gravel to Sand

Fill – Sand and Gravel to Sand, some to trace Silt was encountered in Boreholes 1, 3 and 4 with thicknesses of up to 2.3 m (Elev. 417.2 to 414.9 m, Elev. 417.0 to 414.7 m and Elev. 416.9 to 416.1 m). The natural moisture contents of samples tested was found to range between 4 and 26 %. The laboratory test results are summarized in Table 5-2.

Table 5-2 Summary of Particle Size Distribution - Fill - Sand and Gravel to Sand

Laboratory Results – Particle Size Distribution	
Gravel %	1 to 43
Sand %	50 to 88
Fines %	7 to 12

5.2 Topsoil

Topsoil was encountered at surface in Borehole 2 with thicknesses of 0.2 m. It is likely that top soil or other organic soil may also extend outside the area of the embankment fill.

5.3 Sand- Upper Layer

Sand, trace to some Silt, trace Gravel was encountered in all four boreholes, Borehole 1, 2, 3 and 4, at the depth of 2.3 m, 0.2 m, 2.3 m and 2.3 m, with a thickness of 4.4 m (Elev. 414.9 to 410.5 m), 3.6 m (Elev. 415.6 to 412.0 m), 1.5 m (Elev. 414.7 to 413.2 m) and 3.0 m (Elev. 416.1 to 413.1 m) respectively. Organic matter was encountered within this material in Borehole 1, 2, and 3 at depths between 2.3 m to 4.6 m, 0.2 m to 3.8 m and 2.3 m to 3.8 m respectively.

SPT 'N' values vary from 1 to 16, indicating a very loose to compact condition. The natural moisture contents of the sand material vary from 10 to 55 %. The high natural moisture content in the sand layer is an indication of the organic matter encountered within this layer. The laboratory test results are summarized in Table 5-3.

Table 5-3 Summary of Particle Size Distribution - Sand

Laboratory Results – Particle Size Distribution	
Gravel %	0 to 2
Sand %	84 to 93
Fines %	7 to 14

5.4 Silt

Silt, some Sand to Sandy, trace to some Clay was encountered in all four boreholes, Borehole 1, 2, 3 and 4, at the depth of 6.7 m, 3.8 m, 3.8 m and 3.8 m, with a thickness of 5.5 m (Elev. 410.5 to 405.0 m), 8.4 m (Elev. 412.0 to 403.6 m), 5.0 m (Elev. 413.2 to 408.2 m) and 8.4 m (Elev. 413.1 to 404.7 m) respectively. However, the thickness of the silt layer was not proven at Borehole 2 as the borehole was terminated within this layer.

SPT 'N' values vary from 7 to 18, indicating a loose to compact condition or firm to stiff consistency. The natural moisture contents of the silt material vary from 19 to 40 %. Atterberg Limits test and hydrometer tests were carried out on samples from Boreholes 2, 3 and 4. The results of the Atterberg Limits test indicate that the silt is of low plasticity. Therefore, the silt layer can behave either as cohesionless or cohesive depending on the clay content as shown in the borehole logs. Plasticity charts are presented in Appendix D. The laboratory test results are summarized in Table 5-4 and Table 5-5 below.

Table 5-4 Summary of Particle Size Distribution - Silt

Laboratory Results – Particle Size Distribution	
Gravel %	0 to 2
Sand %	2 to 31
Silt %	69 to 85
Clay %	5 to 29

Table 5-5: Summary of Atterberg Limits - Silt

Laboratory Results – Atterberg Limits	
Liquid Limit %	25
Plastic Limit %	19
Plasticity Index %	6

5.5 Sand- Lower Layer

Sand and silt to some silt, with some Gravel, was encountered in Boreholes 1, 3 and 4, at depths of 12.2 m (Elev. 405.0 m), 8.8 m (Elev. 408.2 m) and 12.2 m (Elev. 404.7 m) respectively. The thickness of the sand layer was not proven as Boreholes 1, 2 and 3 were terminated within this layer.

SPT 'N' values vary from 5 to 33, indicating a loose to compact condition, with one value in the dense category. The natural moisture contents of the sand material vary from 11 to 22 %. The laboratory test results are summarized in Table 5-6.

Table 5-6 Summary of Particle Size Distribution - Sand

Laboratory Results – Particle Size Distribution	
Gravel %	12 to 24
Sand %	46 to 59
Fines %	17 to 42

5.6 Groundwater

Groundwater levels in the boreholes where seepage was noted were measured upon completion of borehole drilling and prior to backfilling of the borehole. This information is included on the Borehole Logs in Appendix D.

At the time of the field investigation groundwater was observed in all four boreholes on completion of drilling (See Table 5-7). The water level of the creek was recorded at an elevation 414.0 m during the field investigation. Therefore, it is assumed that the groundwater table at all borehole locations would be close to or slightly above this level. The interpreted groundwater table at the time of investigation is indicated on the borehole logs.

Given the permeable nature of the stratigraphy at this site, groundwater levels can be expected to vary as the river level varies both seasonally and with local precipitation events.

Table 5-7 Groundwater depth at completion of drilling

Borehole	Groundwater Depth (m)	Groundwater Elev. (m)
Borehole 1	2.1	415.1
Borehole 2	0.7	415.1
Borehole 3	1.9	415.1
Borehole 4	1.8	415.1

5.7 Chemical Test Results

Selected soil samples were submitted to ALS Laboratories Thunder Bay for chemical analyses (pH, sulphate, conductivity, resistivity and Chloride) to assess the potential for corrosion and sulphate attack on buried structures.

The results are presented below in Table 5-8 and 5-9 and discussed in Section 7.15. Copies of the Laboratory Certificate of Analyses are provided in Appendix 'F'.

Table 5-8: Chemical Test Results – Soil Sample

Sample ID	Moisture (%)	Sulphate (mg/kg)	Chloride (mg/kg)	pH	Conductivity (umhos/cm)	Resistivity (ohm - cm)
BH1 at 2.7 m depth	48	131	507	5.43	408	2450

Table 5-9: Chemical Test Results – Water sample

Sample ID	Sulphate (mg/L)	Chloride (mg/L)	pH	Conductivity (umhos/cm)	Resistivity (ohm - cm)
Creek sample	1.43	2.76	7.22	65.6	15244

6. MISCELLANEOUS

Site work was carried out from September 10th to September 11th, 2015 utilizing a CME 750 all-terrain drill rig operated by DST personnel. Fieldwork was supervised on a full-time basis by Mark Menei who located the boreholes in the field, performed sampling, in-situ testing and logged the boreholes. Soil samples retrieved during drilling were identified in the field, placed in labelled containers and transported to DST's laboratory in Thunder Bay for further analysis. Interpretation of the data and preparation of the report was completed by Selorm Danku, Geotechnical Engineer P.Eng., and approved by Mike Fabius, Senior Geotechnical Engineer, P. Eng.

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PART 2: ENGINEERING DISCUSSIONS AND RECOMMENDATIONS

7. GENERAL

This section presents an interpretation of the geotechnical data presented in the factual report and provides geotechnical design recommendations and construction concerns for the proposed culvert replacement.

As discussed in Part I of the report, the generalized stratigraphy of the existing embankment and outside the embankment footprint, based on the conditions encountered in the boreholes consists of the following:

- Embankment fill comprising loose sand and gravel.
- Topsoil encountered at the base of the embankment north of the culverts.
- Underlain by loose to occasionally compact sand (upper layer)
- Which is underlain by a silt layer with trace to some sand, clay and trace gravel.
- Underlying the silt layer, a loose to compact sand (lower layer) is encountered
- At the time of investigation, a groundwater table above creek level, at elevation 415.1.

As the proposed culvert is not expected to be permanently heavily loaded, a shallow foundation is considered suitable for this site. As the cross-sectional area of the proposed new culvert is larger than the existing culvert, the overall effect on the culvert foundation soils can be considered to be negligible.

DST further understands that an open cut excavation will be carried out during replacement of the structure. At this time, 90% detailed design information is available from WSP Final construction drawings should be reviewed by the geotechnical engineer to confirm the design

satisfies the geotechnical recommendations. It is understood that there will be no embankment grade raises or widening as part of the culvert replacement work.

7.1 Replacement Structure

It is understood that only one option, a Twin Box Precast Culvert, is being considered as a replacement structure. There will be no permanent grade raise or widening. The proposed twin precast concrete box culvert is 8.75 m in width by 21.1 m in length (each cell having a hydraulic opening of 4.2 m x 1.8 m).

The design of the replacement structure should be in accordance with the Canadian Highway Bridge Design Code CAN/CSA-S6-14 (CHBDC, 20014) and all relevant Ministry of Transportation specifications and guidelines.

7.2 Foundation Design

The geotechnical resistance was estimated for the ultimate limit state (ULS) and serviceability limit state (SLS). The factored resistance at ULS was calculated by applying a load resistance factor of 0.5 to the ultimate bearing capacity, in accordance with the Bridge Design Code (CHBDC) CAN/CSA-S6-14 Section 6.6. The resistance for the SLS was also calculated in accordance with CHBDC requirements, for a settlement of 25 mm.

The calculated factored geotechnical resistance at ULS and geotechnical reaction at SLS are presented in Tables 7-1, and 7-2 below.

Where unsuitable materials (such as organics) or unstable soils (e.g., as a result of disturbance or softening of the subgrade due to weathering and construction traffic) are encountered, the foundation soils must be removed to suitable undisturbed and compact soils and replaced with Granular A or Granular B Type II material meeting OPSS.PROV 1010 specifications and compacted to a minimum of 98% of Standard Proctor Maximum Dry Density (SPMDD).. A trace of organics was encountered in a few samples of the sand layer. Given that the dead load will not increase and that these materials are mostly below the water table, and based on the information at the borehole locations, there is no need to sub-excavate this material. The foundation soils must be inspected by a geotechnical engineer prior to placement of culvert footings, to confirm conditions are suitable as expected based on the borehole data.

If sub-excavation for frost effects is carried out in the dry (with adequate dewatering controls), the material can be replaced with Granular A or Granular B Type II material meeting OPSS.PROV 1010 specifications and compacted to a minimum of 98% of standard Proctor maximum dry density in accordance with OPSS.PROV 501 "Construction Specification for Compacting". If sub-excavation for frost effects is carried out in the wet (water is maintained at or above adjacent groundwater table), all foundation preparation should be completed in accordance with OPSS 421 "Construction Specification for Pipe Culvert Installation in Open Cut", any specifications provided in the contract documents and as indicated in Section 7.7 Bedding.

A suitable alternative to compacted fill as noted above is 20 mm clear stone with a geotextile (OPSS1004.05.02, Class II) wrap. No compaction is then required. In this case, complete encasement in geotextile is crucial given that the native sands are extremely erodible even from natural groundwater seepage. Any openings through the geotextile or its seams can result in ground loss into the stone with subsequent loss of foundation support after construction.

The lateral extent of all fill supporting foundations should not be less than a distance (from the side of the foundation) equal to the depth of fill below the footing. This applies for the full depth of the fill. For example, a 6 m wide culvert underlain by 0.5 m of engineered fill would require an excavation base 7 m wide plus additional width requirements for access, dewatering equipment and culvert sidefill.

Backfill placement into excavations should commence immediately after the bottom of an excavation is adequately completed. Reducing open excavation time through the use of small stages will reduce the disturbance risk somewhat.

7.2.1 Foundation Design (Twin Box Culvert)

The geotechnical resistance was estimated for the Ultimate Limit State (ULS) and Serviceability Limit State (SLS) for a maximum settlement of 25 mm. The resistance at ULS was calculated by applying a load resistance factor of 0.5 in accordance with the Bridge Design Code (CHBDC) CAN/CSA-S6-14 section 6.6, as shown in Table 7-1 and 7-2.

The geotechnical resistance was estimated assuming a strip footing consisting of a width equal to the width of the twin box culvert (8.75 m) with a length of 21.1 m and a depth of the culvert base equal to 0 m, which is a temporary condition prior to backfill that will be encountered during construction. The culvert can be installed on top of the bedding material placed on undisturbed

native soils. Box culvert founding levels are assumed at 3.1 m depth (Elev. 413.9 m) from the existing ground surface elevation of 417.0 m. The culvert widths and founding depths were based on the updated drawings (modified November 26, 2018) provided by WSP.

Table 7-1: Geotechnical resistances (Concrete Box Culvert) for final condition

Surface Soil Elevation (m)	Invert Elevation (m)	Footing Width (m)	Factored Geotechnical Resistance at ULS (kPa)	Factored Geotechnical Resistance at SLS (kPa)
417.0	413.9	5.5	730	95

Table 7-2: Geotechnical resistances (Concrete Box Culvert) during construction.

Surface Soil Elevation (m)	Invert Elevation (m)	Footing Width (m)	Factored Geotechnical Resistance at ULS (kPa)	Factored Geotechnical Resistance at SLS (kPa)
417.0	413.9	5.5	240	95

The groundwater table was encountered at an approximate elevation of 415.1 m during the field investigation. However, the groundwater table can be expected to fluctuate both with seasonal changes and after local precipitation events. Based on the groundwater level measurements at the time of field drilling, the founding depth of the foundation will be below the groundwater table, and therefore it is expected that dewatering work will be required for the foundation preparation.

7.3 Lateral and Sliding Resistances

The analysis of horizontal and vertical effects of earth loads on the culvert can be performed considering the geotechnical soil parameters provided in Table 7-3 below, and as described in Section 7.6.3.1 of the Canadian Highway Bridge Design Code. Temporary bracing and shoring may be designed using the typical soil parameters given in Table 7-3 and Table 7-4, however the designer/contractor should verify the appropriate soil parameters for the design of a specific bracing and shoring system.

It is recommended that all excavations be either adequately sloped or securely shored and braced to prevent any instability and to provide a safe and stable work area. The design should incorporate the effects of hydrostatic pressure, traffic surcharge and retained sloping earth conditions in the bracing design.

Table 7-3 Typical Soil Parameters for Earth Loads*

Soil type	Unit weight (kN/m ³)	Internal drained friction angle* (Degree)	Interface friction angle** δ (Degree)
Fill Sand and Gravel	22	34	21
Sand	20	32	20
Sandy Silt	18	38	19
Silt	18	29	19

*Friction angle parameters have been estimated from direct shear tests (ASTM D3080)

**Interface between soil and concrete.

Table 7-4 Lateral Earth Pressure Coefficients

Soil type	Active Earth Pressure (K _a)	Passive Earth Pressure, (K _p)	Earth Pressure at Rest, (K ₀)
Equation *	$\left(\frac{1 - \sin\phi}{1 + \sin\phi}\right)$	$\left(\frac{1 + \sin\phi}{1 - \sin\phi}\right)$	$(1 - \sin\phi)$
Fill Sand and Gravel	0.30	3.25	0.47
Sand	0.33	3.00	0.50
Sandy Silt	0.32	3.12	0.48
Silt	0.33	3.00	0.50

* Φ is an angle of internal friction

**The earth pressure coefficients provided here are for the normally consolidated soils condition considering the fully mobilized condition

7.4 Staged Construction

It is understood a four-stage construction method as per WSP's 90% construction drawings will be implemented to complete the culvert replacement as summarised below.

- Stage 1 - Construct temporary road widening on east side and divert traffic to the east side. Install south cell of the twin precast concrete box culvert. Backfill and reinstate the roadway including widening for the Stage 2.
- Stage 2A – Install temporary roadway protection system. Relocate/install dewatering and control flow system and maintain flow to the north CSP. Divert traffic to the west side. Construct the remaining south cell of the new twin precast concrete box culvert.
- Stage 2B – Relocate/install dewatering and flow control system and divert flow through the newly constructed south cell. Construct the north cell of the new twin precast concrete box culvert. Backfill, reinstate the roadway to final grade, install steel beam guide on the east side

and place pavement structure.

- Stage 3 – Relocate temporary concrete barrier, energy attenuators, install signage and pavement marking. Install temporary roadway protection system. Relocate /install dewatering and flow control system and maintain flow through the newly constructed south cell. Divert traffic to the east side. Construct the remaining north cell of the new twin precast concrete box culvert. Reinstate roadway granular materials and install steel beam guide rail. Remove temporary concrete barriers, energy attenuators. And temporary signals and traffic signs.
- Stage 4 – Remove existing asphalt full depth between stop bars. Place pavement structure and provide final marking and signage. Remove traffic setup and signs.

To maintain traffic lanes during construction, an appropriate roadway protection system should be selected and designed by the contractor in accordance with the recommendations in this report and OPSS 539 “Construction Specification for Temporary Protection Systems”.

7.5 Temporary Road Widening

As discussed in section 7.4 the five-stages (1, 2A, 2A, 3 and 4), construction will incorporate a temporary road widening. Details of the preliminary temporary road widening design have been provided. The stability of the temporary side slopes for the embankment road widening at the maximum anticipated height (2.9 m at Sta. 12+465) were evaluated using the computer program SLOPE/W developed by GeoStudio International Ltd. Based on the Morgenstern and Price method of slices, the static stability was assessed by calculating the factors of safety (FOS) along possible planes of failure in the proposed embankment fill and through the native soil. The groundwater table is modelled at the base of the free-draining temporary fill slope (drained analysis).

Slope stability analyses indicate that the factor of safety for a temporary widened granular fill embankment height of 2.9 m (Elev. 414.0 m) with 2H:1.0V slope is 1.4 (drained condition).

The embankment backfill for the temporary lane widening must be constructed in accordance with OPSS 206 (Embankment construction) and OPSD 208 (Benching of Earth slopes).

7.6 Excavation

Earth excavation will be required adjacent to the existing and replacement structure and will require temporary surface water ditch diversion and temporary support for traffic. This method can more readily accommodate excavation of large boulders, if encountered during excavation.

As a minimum, the procedures should be in accordance with OPSS 902 "Construction Specifications for Excavating and Backfilling-Structures". Where temporary protection systems are required they should be constructed in accordance with OPSS.PROV 539 "Construction Specification for Temporary Protection Systems" and Section 7.7 "Roadway Protection".

The side slopes of the excavations at the maximum anticipated depth (3.7 m) were evaluated based on the method of slices and the Morgenstern and Price method using the computer program SLOPE/W developed by GeoStudio International Ltd. The static stability was assessed by calculating the factors of safety (FOS) along possible planes of failure in the existing embankment fill and through the native soil.

Use of a temporary concrete block barrier wall or cantilever concrete wall or soldier pile wall with lagging will be required if the vertical shoring method is selected. An excavation depth of approximately 3.7 m (Elev. 413.3 m) (for the box culvert) may be required for the staged construction. The stability of the excavation side slopes will be highly dependent on the contractor's methodology and ability to effectively dewater the excavation (See NSSP, Appendix E). The embankment slopes at the inlet and outlet should be not steeper than 2H: 1V. The final embankment slopes should be reinstated as presented in Section 7.14, Embankment Slopes.

For open excavations below the groundwater table, soil dewatering will necessary to lower the groundwater table and maintain stable excavation side slopes. It is recommended that side slopes no steeper than 2.0H: 1V are maintained, assuming the groundwater table directly below the entire excavation is kept below the deepest part of the base level of the excavation. The width of the excavation must be sufficient to accommodate the design culvert, frost protection measures, and at least 1.5 m beyond of the culvert perimeter for placement of the structural backfill zone, or as otherwise required by the culvert design.

The stability of the excavation side slopes will be highly dependent on the contractor's methodology and ability to effectively dewater the soils below the excavation.

7.7 Roadway Protection

Roadway protection for this project should be constructed in accordance with the requirements of the Occupational Health and Safety Act of Ontario (OHSA), O.Reg. 213/91. According to O.Reg. 213/91, s.226, the soils in the area of interest classify as Type 3. Type 3 soils generally are stiff to firm and compact to loose or are previously excavated soil, exhibit signs of surface cracking,

exhibit signs of seepage, if it is dry, may run easily into a conical pile and have a low degree of internal strength. In accordance with O. Reg. 213/91, s.227 (3), if an excavation contains more than one type of soil, the soil should be classified with the highest number as described in section 226. These should be assessed and confirmed in the field as construction progresses.

Since temporary roadway protection is required during the structure replacement, installation of a sheet pile or soldier pile wall may be considered to ensure the stability of the bank and is a feasible option. An appropriate roadway protection system should be selected by the contractor and designed by the contractor's qualified engineer. The temporary roadway protection systems should be constructed in accordance with OPSS 539 "Construction Specification for Temporary Protection Systems". Potential options for the roadway protection system are temporary steel sheet pile walls or using a dewatered open excavation with a temporary side slope of 2.0H:1.0V or less. The advantages and disadvantages of using different road way protection systems are shown in Table 8-1.

The design of a roadway protection system may be performed using the typical soil parameters given in Table 7-3 and Table 7-4, however the designer/contractor should verify the appropriate soil parameters for the designs. Although not encountered at borehole locations, the potential of encountering rock fill, cobbles and boulders exists and therefore, the contractor should be prepared to handle this with the selection of adequate driving or vibratory equipment as well as steel thickness. The construction methodology must be in accordance with all applicable standards and regulations related to the method proposed. The contractor's method and equipment must be suitable for the site conditions and materials used.

7.8 Bedding

The foundation soils, sand and silts in particular, will be very susceptible to disturbance and weakening as a result of over-excavation, traffic, standing water and frost. Any foundation soils that could be disturbed should be protected. The bottom of the excavation on which the culvert or granular pad will rest should not be disturbed. The bedding placement should commence immediately after the final removal of material to the foundation level has been completed, that is, the excavation should not be left open upon reaching the final depth. Construction of precast concrete box culverts should follow the recommendations in OPSS 422 "Precast Concrete Box Culvert".

The bedding for the structure should be in accordance with Section 7.8 of the CHBDC and MTOD 803.021 "Bedding and Backfill for Precast Concrete Box Culvert". The bedding should be a minimum of 0.5 m thick and extend to a minimum width (half of the width of culvert) beyond all sides of the culvert. The bedding material should consist of "Granular A or Granular B Type II" as per Soil Group I in accordance with Table 7.4 of the Canadian Highway Bridge Design Code. The "Granular A or Granular B Type II" should be in accordance to OPSS.PROV 1010. The "Granular A or Granular B Type II" should be placed in layers not exceeding 200 mm in thickness, loose measurement, and each layer compacted to 100% of standard Proctor maximum dry density. The middle one-third of the culvert width of the top bedding layer, having thickness of 75 mm, should be loosely placed.

If construction is performed without dewatering, bedding material should consist of 19 mm Type I or II clear stone as defined in OPSS.PROV 1004.05.02. A non-woven geotextile (OPSS 1860.07.05.01 Class II) with the filtration opening size (FOS) less than 135 µm is required for separation, surrounding all of the stone. No compaction is required of the clear stone.

7.9 Sidefill and Overfill

The material used for culvert sidefill should not contain debris, organic matter, frozen materials, or large stones of a diameter greater than one-half the thickness of the compacted layers being placed or 100 mm, whichever is smaller. Soils should be placed uniformly on each side of the structure in order to prevent lateral displacement. The minimum width of the sidefill should be at least 1.0 m on each side of the culvert for constructability purposes. The sidefill should consist of "Granular A or Granular B Type II" and compacted to 95% of standard Proctor maximum dry density.

Overfill should consist of "Granular A or Granular B Type II" and should be compacted to not greater than the compaction or equivalent stiffness of soils in the sidefill zone and bedding.

Prior to placement of backfill the contractor shall ensure that the joints of the proposed culvert are effectively covered to prevent influx of material from the backfill through the joints with a 600 mm (minimum) wide coverage strip. Non-woven geotextile shall be installed to cover all exterior joints of the culvert, including the top slab. Geotextile shall be free of folds, tears, and wrinkles. The geotextile and the seam requirements at the joints shall be in accordance with OPSS 1860. In addition, joint sealing compounds or preformed gaskets for sealing joints between box culvert units, shall be applied in accordance with the manufacturer's recommendations as per OPSS 422

“Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cut”.

7.10 Flow Control and Dewatering

The culvert should be replaced by diverting the creek channel temporarily adjacent to the new culvert being installed. It is important to ensure that a flood in the channel does not cause damage to the partly constructed permanent works, to the temporary works or to plant. Floods have been known to occur any time, especially overnight or at weekends and inadequate temporary works can fail with expensive consequences.

If the creek has a relatively low flow volume depending on the season, it may be feasible for the creek flow to be directed by staging construction. In order to divert water from upstream and downstream, a dyke made of sand bags has sometimes been used as a hydraulic barrier. However, a sheet pile vertical cut-off wall will provide better control of both surface and groundwater.

Groundwater levels were encountered during the field investigation and these are reported in the section 5.6 of the report and on the borehole logs. Based on groundwater elevation encountered during the field investigation, dewatering work will be required during the proposed culvert replacement work. The proposed excavation depth of 3.7 m (413.5 m elevation) will be below the groundwater levels recorded in Boreholes 1 to 4 (415.1 m elevation).

It should be noted that depending on the season, the amount of water flow through the creek may vary. In addition, the depth of excavation will influence the water volumes that will be required to be managed. The contractor should be prepared to tackle this situation. The contractor should be alerted of the high-water table and surface water, for example through a non-standard special provision (NSSP).

A suitable continuous dewatering operation must be provided to keep the soil below the excavation stable and free of groundwater. The excavation must be monitored daily throughout the duration of excavation until the completion of backfilling to confirm this. The dewatering system must be maintained, and the surrounding area monitored for impacts to items such as, but not limited to, settlement and groundwater usage. The control of water from the dewatering operation should be accordance with OPSS 517 “Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation”, and SSP 517F01. In addition, the dewatering system will require preconstruction surveys and an experienced design engineer’s

approval.

7.11 Erosion Control

Erosion control is essential at inlet and outlet for the successful performance of a culvert. Generally, rip-rap is used to avoid the erosion at inlet and outlet of the culvert. The rip-rap slows down the flow close to the channel bed and prevents culvert failure by the undermining.

To prevent erosion of the surrounding soils at the inlet, rip-rap Treatment should be applied in accordance with OPSD 810.020 “General Rip-Rap Layout for Ditch Inlets” and OPSS 511 “Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting”.

The outlet should be rip-rapped to prevent erosion of the surrounding soils in accordance with OPSD 810.010 “General Rip-Rap Layout for Sewer and Culvert Outlets” and OPSS 511 “Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting”. Rip-Rap material should be complied with OPSS 1004.

To prevent undermining of the bedding, cutoff walls should be installed at both sides of the culvert ends. Cutoff walls should be designed based on velocity of the water flow and the type of soil underneath. Cutoff walls should be extended beyond the whole width and to 1.0 m below the bedding layer as a minimum.

The temporary erosion and sedimentation measures during the construction of culvert should be controlled as described in OPSS 805 “Construction Specification for Temporary Erosion and Sedimentation Control Measures”.

7.12 Frost Protection

In accordance with OPSD 3090.100 “Foundation Frost Depths for Northern Ontario”, the frost penetration at this location is about 2.1 m. Frost susceptible soils should not be used adjacent to the culvert wall within the depth of frost penetration from both the road surface and the culvert walls.

The soils under the culvert are highly frost susceptible (capable of forming thick ice lenses with the associated pressures and heave).

During winter season, ice may form inside the culvert and a low flow rate may assist the ice formation. It is expected that ice may extend to the culvert invert and frost could therefore extend

into the soils below the culverts, possibly as deep as 2.1 m. The frost heave may generate additional stresses on the culvert foundation and walls.

As the frost penetration extends below the invert level of the culvert, the frost protection should be in accordance with OPSD 803.030 and 803.031 "Frost Treatment - Pipe Culverts, Frost Penetration Line below Bedding Grade" and "Frost Treatment - Pipe Culverts, Frost Penetration Line between Top of the Pipe and Bedding Grade".

Three design approaches are commonly applied; designing the culvert with enough strength and rigidity to tolerate these pressures (recognizing that the maximum differential pressures and movements as a result of frost lensing cannot be accurately quantified); removing the frost susceptible soils within the frost zone; or providing adequate insulation to reduce frost penetration.

If sub-excavation for frost effects is carried out in the dry (with adequate dewatering controls), the material can be replaced with Granular B Type 1 material compacted to 95% of standard Proctor maximum dry density. If the excavation is in the wet (water is maintained at or above adjacent groundwater table) then the material should be rockfill or clear stone surrounded by geotextile, without the need for compaction. Depending on the structural design of the culvert, partial sub-excavation (less than 2.0 m) may also be considered to reduce differential stresses associated with frost; however, the exact pressures and movements cannot be accurately quantified.

Acceptable insulation to prevent frost penetration would be 115 mm thick Dow Styrofoam Highload 40 Insulation or an equivalent material with a compressive strength of approximately 275 kPa or greater. It is recommended that the insulation be placed beneath the structure and extend 2.44 m beyond the faces of the buried structure.

7.13 Embankment Foreslopes

Existing culvert foreslopes are approximately 2H: 1V on both the west and east embankments. The foreslopes should be reinstated with a slope not steeper than 2H: 1V if being constructed with compacted granular materials. The foreslopes may be reinstated with a slope not steeper than 1.5H: 1V if being constructed with rock fill. The minimum thickness of the rock fill must be 2 m to achieve an adequate FOS for the reinstated rock fill embankment.

7.14 Construction Concerns

The main construction issues that need to be addressed for this site are design and implementation of an effective soil dewatering system, removal of cover/embankment materials, staged removal of the existing culvert, provisions required for temporary roadway protection, diversion of the channel, excavation below the water table and reinstatement of the embankment fill. These items are important for the successful installation of the new culvert.

As discussed above, the contractor should be aware of the potential subsurface conditions at each phase of the culvert replacement work, especially the requirement for an effective soil dewatering method, and for proper shoring design and installation.

A Geotechnical Engineer should inspect the condition of the foundation and surrounding soils before installation of bedding and other backfills, ensure the width of trench and trench wall slopes are suitable, and ensure compliance with material placements and compaction methods.

7.15 Chemical Testing

The results of the analytical test conducted on water and soil samples at the site location have been presented in Table 5-8 and 5-9 and also included in Appendix F. The suite of the parameters tested is intended to allow the design engineer to assess the requirements for the appropriate type of cement to be used in construction and the need for corrosion protection of steel reinforcing elements.

The analytical results of the soil samples were compared with applicable Canadian Standards Association (CSA) standards as shown in Table 7-5 below

The chemical sulphate content analyses for representative soil and water sample tested indicate a sulphate concentration of 131 mg/kg (0.0131 %) and 1.43 mg/L (0.000143 %) in soil and water respectively. The results were compared with Canadian Standards Association (CSA) Standards A23.1 for sulphate attack potential on concrete structures and possess a “negligible” risk for sulphate attack on concrete material and accordingly, conventional GU or MS Portland cement may be used in the construction of the proposed concrete elements.

The pH value for the soil and water samples was reported to be 5.43 and 7.22, indicating a durable condition against corrosion in the water, however a corrosive condition in the soil. These results were evaluated using Table C1 of Building Research Establishment (BRE) Digest 363 (SD1 -

2005). The pH is greater than 5.5 in the water and less than 5.5 in the soil indicating the concrete will be exposed to acid attack in the soil. The chloride content of the selected soil sample was also compared with the threshold level and present negligible concrete corrosion potential. Resistivity and conductivity was found to be 2450 and 15244 ohm-cm and 408 and 65.6 umhos / cm respectively for the samples analysed from BH1 and the creek water.

Table 7-5: Additional requirements for concrete subjected to Sulphate Attack

Class of Exposure	Degree of Exposure	Water soluble Sulphate in soil sample (%)	Cement Grade to be used
S-1	Very Severe	> 2.0	HS or HSb
S-2	Severe	0.20 – 2.0	HS or HSb
S-3	Moderate	0.10 – 0.20	MS, MSb, LH, HS, or HSb

* Information from Table 3 of CSA Standards A23.1-04

8. CLOSURE

The subsurface information and design recommendations presented above must be reviewed at the time of detail design to determine if additional geotechnical investigation is required.

Table 8-1 summarizes the advantages and disadvantages of the use of a concrete or steel sheet pile wall and a temporary cut slope.

Table 8-1 Advantages and Disadvantages of Roadway Protection Methods

Roadway Protection Option	Advantages	Disadvantages
Steel sheet pile wall	<ul style="list-style-type: none"> • Relatively non-permeable. • Increased erosion control capacity. • Ease of installation when working below ground water table. • Can design with a suitable factor of safety. • Suitable stratum for pile toe embedment exists (compact to dense sand with silt) between approximate elevations 408m and 404m. 	<ul style="list-style-type: none"> • Difficult driving through any boulders, cobbles, concrete • High installation cost. • Special construction equipment and design required.
Temporary Cut Slope with 2.0H:1V side slopes	<ul style="list-style-type: none"> • Does not require specialized equipment. • Low construction cost. • Can achieve suitable factor of safety when soil below excavation is fully drained. 	<ul style="list-style-type: none"> • Excavation area is considerably larger • Gravity drainage to a suitable level can be very slow. • Soil loss from internal erosion may require control. • Permeable soils will need extensive dewatering. Dewatering can be challenging. • Increased surface erosion due to exposed material. • Lower factor of safety while waiting for gravity drainage and with increasing excavation depth. • Soils exposed in temporary cut will likely require some form of surface protection during the works.

9. REFERENCES

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- Discussion on Proc. Paper 1732 (Wu, 1958), Proc. ASCE, Vol. 85, No. SM3 (67-79). Kenney, T. C. (1959)
- Municipal and Provincial Common, Volume 1 - General & Construction Specifications, "*Ontario Provincial Standard for Roads & Public Works*" Spec No. OPSS 422, 511, 517, 518, 805, 902.
- Municipal and Provincial Common, Volume 2 - Material Specifications, "*Ontario Provincial Standard for Roads & Public Works*" Spec No. OPSS 1860.
- Municipal and Provincial Common, Volume 3 - Drawings for Roads, Barriers, Drainage, Sanitary Sewers, Watermains and Structures, "*Ontario Provincial Standard for Roads & Public Works*" Spec No. OPSD 203.040, 803.010, 803.030, 803.031, 810.010, 810.020, 3090.100.
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- Provincial-Orientated, Volume 6 - Material Specifications, "*Ontario Provincial Standard for Roads & Public Works*" Spec No. OPSS.PROV 1004, 1010.
- Soil Mechanics in Engineering Practice. Third Edition. Terzaghi, Karl; Peck, Ralph B.; and Mesri, Gholamreza
- The Surveys and Design Office, Highway Engineering Division, Ministry of Transportation, 1990, Pavement Design and Rehabilitation Manual.

10. LIMITATIONS OF REPORT

A description of limitations which are inherent in carrying out site investigation studies is given in Appendix 'A', and this forms an integral part of this report.

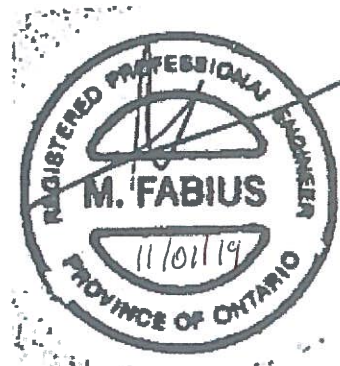
For DST CONSULTING ENGINEERS INC.

Prepared by:

Approved by:



Selorm Danku, P.Eng.
Geotechnical Engineer



Mike Fabius, P.Eng.
Senior Geotechnical Engineer

APPENDIX 'A'
LIMITATIONS OF REPORT

LIMITATIONS OF REPORT

GEOTECHNICAL STUDIES

The data, conclusions and recommendations which are presented in this report, and the quality thereof, are based on a scope of work authorized by the Client. Note that no scope of work, no matter how exhaustive, can identify all conditions below ground. Subsurface and groundwater conditions between and beyond the testholes may differ from those encountered at the specific locations tested, and conditions may become apparent during construction which were not detected and could not be anticipated at the time of the site investigation. Conditions can also change with time. It is recommended practice that DST Consulting Engineers be retained during construction to confirm that the subsurface conditions throughout the site do not deviate materially from those encountered in the testholes. The benchmark and elevations used in this report are primarily to establish relative elevation differences between the testhole locations and should not be used for other purposes, such as grading, excavation, planning, development, etc.

The design recommendations given in this report are applicable only to the project described in the text and then only if constructed substantially in accordance with details stated in this report. Since all details of the design may not be known, we recommend that we be retained during the final stage to verify that the design is consistent with our recommendations, and that assumptions made in our analysis are valid.

Unless otherwise noted, the information contained herein in no way reflects on environmental aspects of either the site or the subsurface conditions.

The comments given in this report on potential construction problems and possible methods are intended only for the guidance of the designer. The number of testholes may not be sufficient to determine all the factors that may affect construction methods and costs, e.g. the thickness of surficial topsoil or fill layers may vary markedly and unpredictably. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusion as to how the subsurface conditions may affect their work.

Any results from an analytical laboratory or other subcontractor reported herein have been carried out by others, and DST Consulting Engineers Inc. cannot warranty their accuracy. Similarly, DST cannot warranty the accuracy of information supplied by the client.

Appendix B

DESCRIPTION OF TERMS

EXPLANATION OF TERMS USED IN REPORT

SPT 'N' VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE OF THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51 mm O.D. SPLIT BARREL SAMPLES TO PENETRATE 0.3 m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5 kg, FALLING FREELY A DISTANCE OF 0.76 m. FOR PENETRATION OF LESS THAN 0.3 m 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 (DCPT): CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51 mm 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 0.3 m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS

TEXTURAL CLASSIFICATION OF SOILS

BOULDERS	COBBLES	GRAVEL	SAND	SILT	CLAY
GREATER THAN 200 mm	75 TO 200 mm	4.75 TO 75 mm	0.075 TO 4.75 mm	0.002 TO 0.075 mm	LESS THAN 0.002 mm

COARSE GRAIN SOIL DESCRIPTION (50% GREATER THAN 0.075 mm)

TERMINOLOGY	TRACE OR OCCASIONAL	SOME	WITH	ADJECTIVE (e.g. SILTY OR SANDY)	AND (e.g. SAND AND SILT)
	LESS THAN 10%	10 TO 20%	20 TO 30%	30 TO 40%	40 TO 60%

CONSISTENCY*: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (C_u) AND SPT 'N' VALUES AS FOLLOWS

C_u (kPa)	0 – 12	12 – 25	25 – 50	50 - 100	100 - 200	> 200
N (BLOWS / 0.3 m)	<2	2 - 4	4 - 8	8 - 15	15 - 30	>30
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

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

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

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


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

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100 mm+ IN LENGTH EXPRESSED AS A PERCENTAGE OF THE LENGTH OF THE CORING RUN.

THE **ROCK QUALITY DESIGNATION (R.Q.D)** FOR MODIFIED RECOVERY IS:

R.Q.D (%)	0 – 25	25 – 50	50 – 75	75 – 90	90 – 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

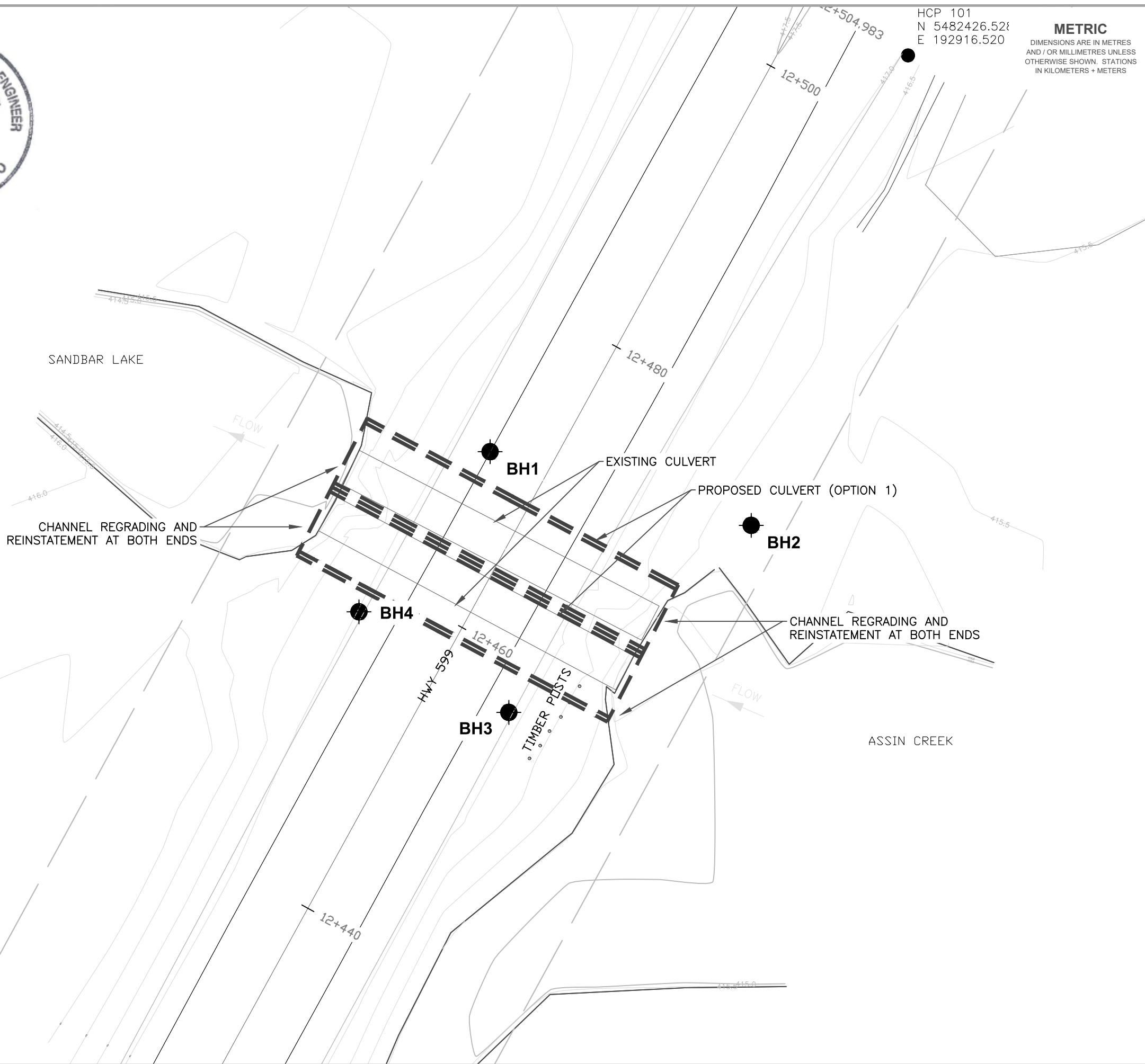
LEGEND OF RECORDS FOR BOREHOLES: SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE

SS	SPLIT SPOON SAMPLE	WS	WASH SAMPLE
TW	THIN WALL SHELBY TUBE SAMPLE	AS	AUGER (GRAB) SAMPLE
PH	SAMPLER ADVANCED BY HYDRAULIC PRESSURE	TP	THIN WALL PISTON SAMPLE
WH	SAMPLER ADVANCED BY SELF STATIC WEIGHT	PM	SAMPLER ADVANCED BY MANUAL PRESSURE
SC	SOIL CORE	RC	ROCK CORE
	WATER LEVEL	$SENSITIVITY = \frac{UNDISTURBED\ SHEAR\ STRENGTH}{REMOLDED\ SHEAR\ STRENGTH}$	

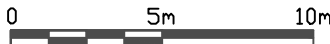
*HIERARCHY OF SOIL STRENGTH PREDICTION: **1)** LABORATORY TRIAXIAL TESTING. **2)** FIELD INSITU VANE TESTING. **3)** LABORATORY VANE TESTING. **4)** SPT VALUES. **5)** POCKET PENETROMETER.

Appendix C

DRAWINGS



PLAN MAP
Scale 1:250



HCP 101
N 5482426.528
E 192916.520

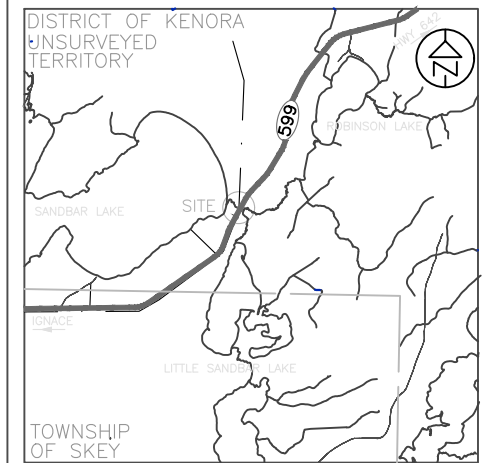
METRIC
DIMENSIONS ARE IN METRES
AND / OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETERS + METERS

AG No 4014-E-0023
WP No 6354-14-00
SITE No 48C-0314/C0
GEOCREs No 52G-12



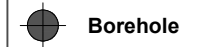
**CULVERT
REPLACEMENT ASSIN
CREEK CULVERT**
STA 12+422 TO STA 12+500
Survey 13-06 Revised

**SHEET
1**



KEY PLAN
1.0 km 0 1.0 km

LEGEND



No.	Elev. (m)	MTM Zone 16		Survey	
		North (m)	East (m)	Station	Offset
BH1	417.2	5482275	410311	12+471	3.9 m LT
BH2	415.8	5482272	410325	12+474	12.8 m RT
BH3	417.0	5482258	410312	12+456	6.1 m LT
BH4	416.9	5482262	410304	12+458	5.1 m RT

REV	DATE	ISSUE	DRAWN BY	CHECKED	APPROVAL
1	21-Sep-15	DRAFT	MD	BV	MWB
2	2-Feb-16	DRAFT	EM	SD	MK
3	16-May-16	DRAFT	EM	PDS	MK
4	01-Mar-17	DRAFT	LA	BV	MF
5	25-Oct-18	DRAFT	CS	SD	BV

NOTE:
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed by interpolation and may not represent actual conditions.

DST Consulting Engineers Inc.
605 Hewitson Street
Thunder Bay, ON P7B 5V5
Ph: (807) 623-2929
Fx: (807) 623-1792
Email: thunderbay@dstgroup.com



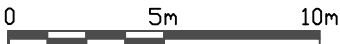
SANDBAR LAKE

CHANNEL REGRADING AND
REINSTATEMENT AT BOTH ENDS



PLAN MAP

Scale 1:250



CHANNEL REGRADING AND
REINSTATEMENT AT BOTH ENDS

BH4

BH3

BH1

BH2

EXISTING CULVERT

PROPOSED CULVERT (OPTION 1)

LINE C

TIMBER PULPS

ASSIN CREEK

METRIC

DIMENSIONS ARE IN METRES
AND / OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETERS + METERS



AG No 4014-E-0023
WP No 6354-14-00
SITE No 48C-0314/C0
GEOCREs No 52G-12

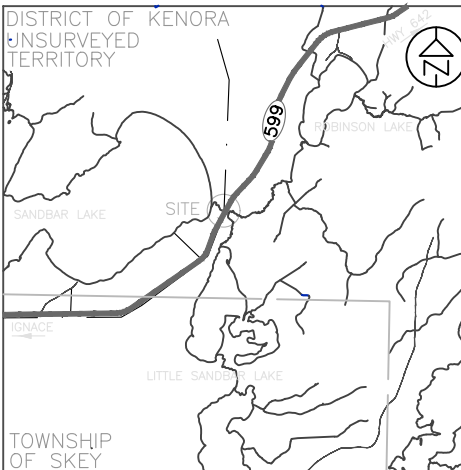
CULVERT
REPLACEMENT ASSIN
CREEK CULVERT

STA 12+422 TO STA 12+500

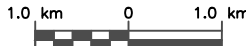
Survey 13-06 Revised

BOREHOLE LOCATIONS
AND SOIL STRATA

SHEET
2



KEY PLAN



LEGEND



Borehole



SPT (BLOWS/300 mm)



Water level at completion of drilling



Fill



Organics



Topsoil



Till



Bedrock



Sand



Silt



Clay



Sand & Gravel



Boulders

No.	Elev. (m)	MTM Zone 16		Survey	
		North (m)	East (m)	Station	Offset
BH1	417.2	5482275	410311	12+471	3.9 m LT
BH2	415.8	5482272	410325	12+474	12.8 m RT
BH3	417.0	5482258	410312	12+456	6.1 m LT
BH4	416.9	5482262	410304	12+458	5.1 m RT

REV	DATE	ISSUE	DRAWN BY	CHECKED	APPROVAL
1	21-Sep-15	DRAFT	MD	BV	MWB
2	2-Feb-16	DRAFT	EM	SD	MK
3	8-May-16	DRAFT	EM	POS	MK
4	13-Oct-16	DRAFT	EM	SD	MK
5	8-Dec-16	DRAFT	RW	POS	MK
6	1-Mar-17	DRAFT	RW	BV	MF
7	25-Oct-18	DRAFT	CS	SD	BV

NOTE:
The boundaries between soil strata have been established only at
borehole locations. Between boreholes the boundaries are assumed
by interpolation and may not represent actual conditions.



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605 Hewitson Street
Thunder Bay, ON P7B 5V5
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DRAWING 2

Appendix D
ENCLOSURES

RECORD OF BOREHOLE No BH1

1 OF 1

METRIC

W.P. GWP 6354-14-00 LOCATION ASINN CREEK ORIGINATED BY MM
 DIST MTO HWY 599 BOREHOLE TYPE HOLLOW STEM AUGER - 80 mm ID / SOLID STEM AUGER COMPILED BY SA
 DATUM Geodetic DATE 2015 09 11 CHECKED BY SD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
417.2	GROUND SURFACE													
	FILL - SAND, SOME SILT, TRACE GRAVEL LOOSE BROWN		AS1	AS			417							
			SS2	SS	9		416							
			SS3	SS	8									
414.9							415							1 87 (12)
2.3	SAND, SOME SILT, TRACE GRAVEL LOOSE TO COMPACT BROWN TO GREY ORGANIC MATTER AT 2.3 m to 4.6 m		SS4	SS	8									Water level taken at 2.1 m at end of drilling
			SS5	SS	6		414							
			SS6	SS	8		413							2 84 (14)
			SS7	SS	8		412							
							411							
410.5			SS8	SS	10		410							
6.7	SANDY SILT, TRACE GRAVEL LOOSE GREY						409							
			SS9	SS	8		408							
			SS10	SS	10		407							
407.0							406							
10.2	SILT, SOME SAND LOOSE GREY		SS11	SS	9		405							
			SS12	SS	7		404							0 15 (85)
405.0							403							
12.2	SAND, TRACE SILT LOOSE GREY		SS13	SS	5									
			SS14	SS	8									
402.3														
14.9	END OF BOREHOLE AT 14.9 m													

ONL_MOT-HIGH VANES AC-BH LOGS.GPJ DATA TEMPLATE.GDT 13/5/16

+³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No BH2

1 OF 1

METRIC

W.P. GWP 6354-14-00 LOCATION ASINN CREEK ORIGINATED BY MM
 DIST MTO HWY 599 BOREHOLE TYPE HOLLOW STEM AUGER - 80 mm ID / SOLID STEM AUGER COMPILED BY SA
 DATUM Geodetic DATE 2015 09 10 CHECKED BY SD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								20	40	60	80					
415.8	GROUND SURFACE															
415.6	TOPSOIL															
0.2	SAND, TRACE SILT VERY LOOSE TO COMPACT BROWN TO GREY		AS1	AS			415									Water level taken at 0.7 m at end of drilling
			SS2	SS	1											
	ORGANIC		SS3	SS	11		414									
			SS4	SS	5		413									
			SS5	SS	7		412									
412.0							412									
3.8	SANDY SILT LOOSE TO COMPACT GREY		SS6	SS	9		411									0 31 (69)
			SS7	SS	12		410									
			SS8	SS	10		409									
409.1							408									
6.7	SILT, SOME CLAY, TRACE SAND FIRM TO STIFF GREY						407									0 5 76 19
	LOW PLASTICITY		SS9	SS	7		406									
			SS10	SS	12		405									
			SS11	SS	13		404									
	TRACE CLAY															
403.6			SS12	SS	15											2 20 73 5
12.2	END OF BOREHOLE AT 12.2 m															

ONL_MOT-HIGH VANES AC-BH LOGS.GPJ DATA TEMPLATE.GDT 13/5/16








+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No BH3

1 OF 1

METRIC

W.P. GWP 6354-14-00 LOCATION ASINN CREEK ORIGINATED BY MM
 DIST MTO HWY 599 BOREHOLE TYPE SOLID STEM AUGER COMPILED BY SA
 DATUM Geodetic DATE 2015 09 10 CHECKED BY SD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
								20 40 60 80 100							
417.0	GROUND SURFACE														
	FILL - SAND AND GRAVEL, TRACE SILT LOOSE BROWN TO GREY		AS1	AS			416								43 50 (7)
			SS2	SS	9		415								0 88 (12) Water level taken at 1.9 m at end of drilling
			SS3	SS	9		414								
414.7	SAND, TRACE SILT COMPACT GREY ORGANIC MATTER AT 23 m to 3.8 m		SS4	SS	10		413								
SS5			SS	16	412									0 12 80 8	
413.2	SILT, SOME SAND, TRACE TO SOME CLAY COMPACT GREY						411								
			SS6	SS	10		410								
							409								
			SS7	SS	14		408								12 46 (42)
							407								
			SS8	SS	15		406								
408.2	SILT AND SAND, SOME GRAVEL COMPACT TO DENSE GREY						405								
			SS9	SS	14		404								
							403								
			SS10	SS	18		402								
						401								24 59 (17)	
			SS11	SS											
	SAND WITH GRAVEL, SOME SILT DENSE GREY														
			SS12	SS	26										
			SS13	SS	33										
400.7	END OF BOREHOLE AT 16.3 m														
			SS14	SS	24										
			SS15	SS	27										
16.3															

ONL MOT-HIGH VANES AC-BH LOGS.GPJ DATA TEMPLATE.GDT 13/5/16

+³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No BH4

1 OF 1

METRIC

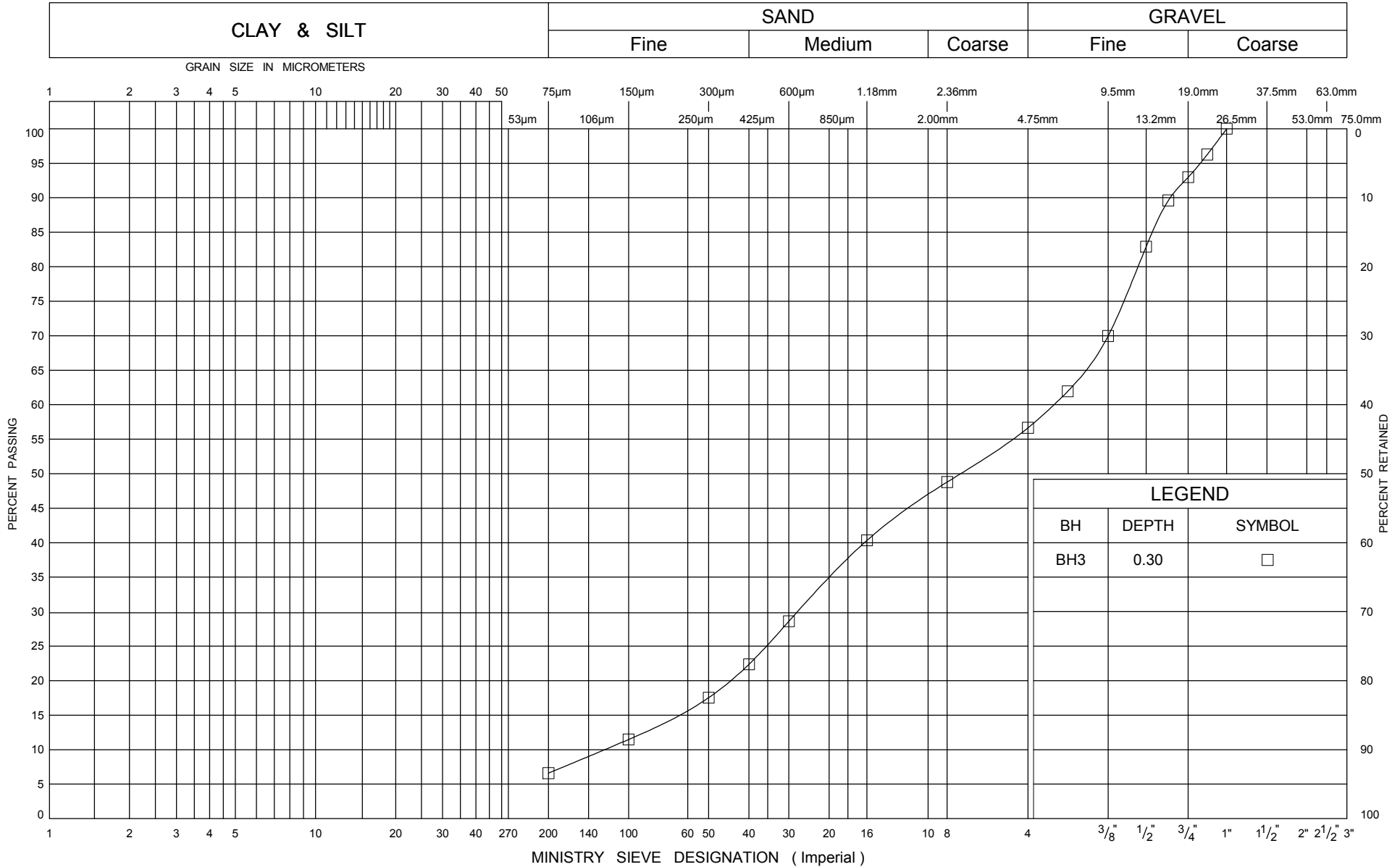
W.P. GWP 6354-14-00 LOCATION ASINN CREEK ORIGINATED BY MM
 DIST MTO HWY 599 BOREHOLE TYPE HOLLOW STEM AUGER - 80 mm ID / SOLID STEM AUGER COMPILED BY SA
 DATUM Geodetic DATE 2015 09 10 CHECKED BY SD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
416.9	GROUND SURFACE													
	FILL - SAND AND GRAVEL		AS1	AS										
416.1							416							
0.8	SAND, TRACE SILT LOOSE BROWN TO GREY		SS2	SS	6		415							
			SS3	SS	7									
			SS4	SS	6		414							
	ORGANIC (WOOD FRAGMENTS)		SS5	SS	6									
413.1							413							
3.8	SILT, SOME SAND, TRACE CLAY LOOSE TO COMPACT BROWN TO GREY		SS6	SS	8									
			SS7	SS	9		412							
							411							
			SS8	SS	13		410							
			SS9	SS	15		409							
							408							
			SS10	SS	18									
							407							
406.7														
10.2	SILT WITH CLAY, TRACE SAND STIFF TO VERY STIFF GREY		SS11	SS	14		406							
			SS12	SS	19		405							
404.7														
12.2	SAND, TRACE SILT COMPACT GREY		SS13	SS	25		404							
							403							
			SS14	SS	25									
402.0							402							
14.9	END OF BOREHOLE AT 14.9 m													

ONL_MOT-HIGH VANES AC-BH LOGS.GPJ DATA TEMPLATE.GDT 13/5/16

+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
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Ontario

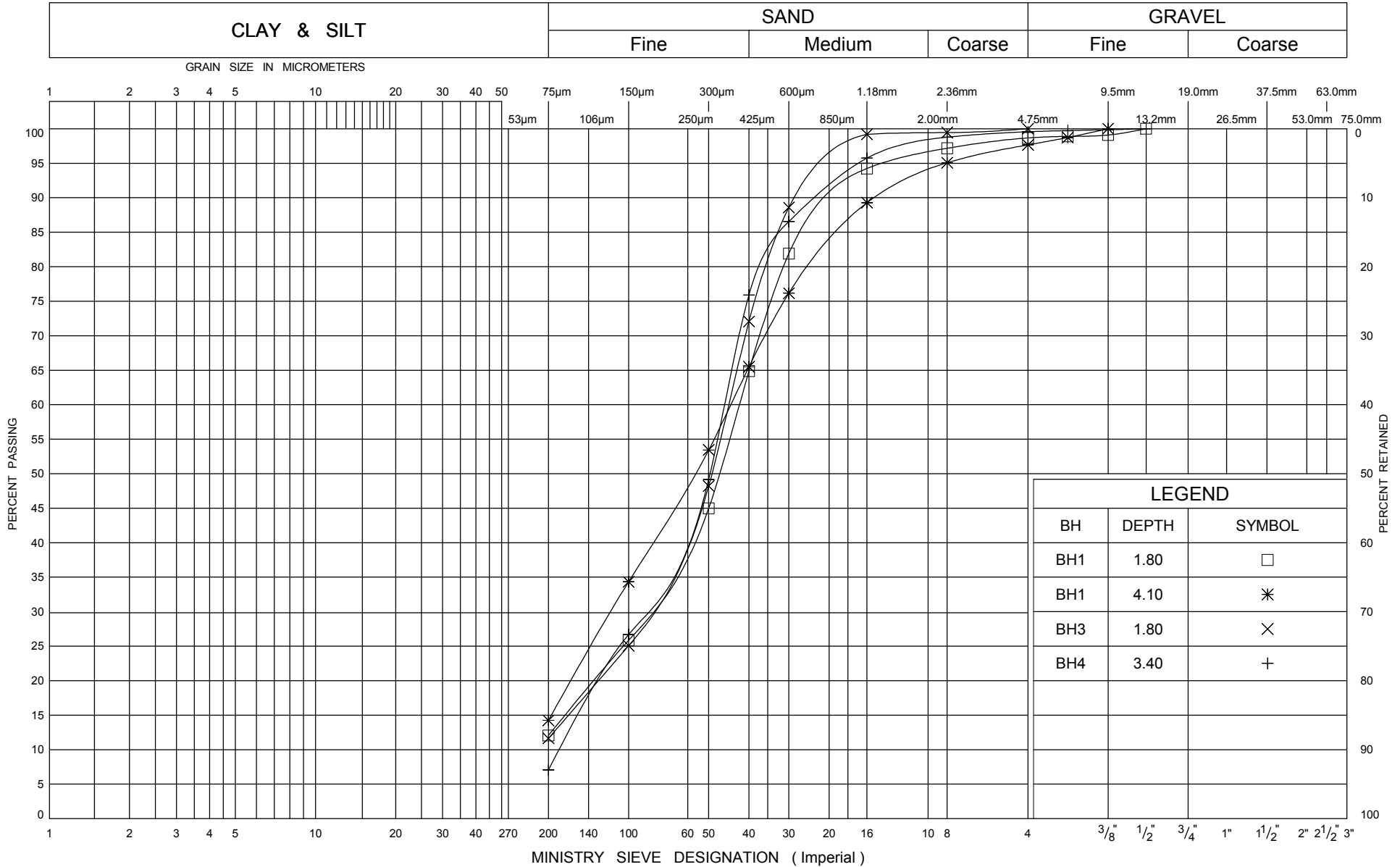
**GRAIN SIZE DISTRIBUTION
SOIL DESCRIPTION
FILL - SAND AND GRAVEL**

ENCLOSURE 5

DST REF. # GS-TB-020407

ASINN CREEK CULVERT

UNIFIED SOIL CLASSIFICATION SYSTEM



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GRAIN SIZE DISTRIBUTION
SOIL DESCRIPTION
SAND - UPPER LAYER

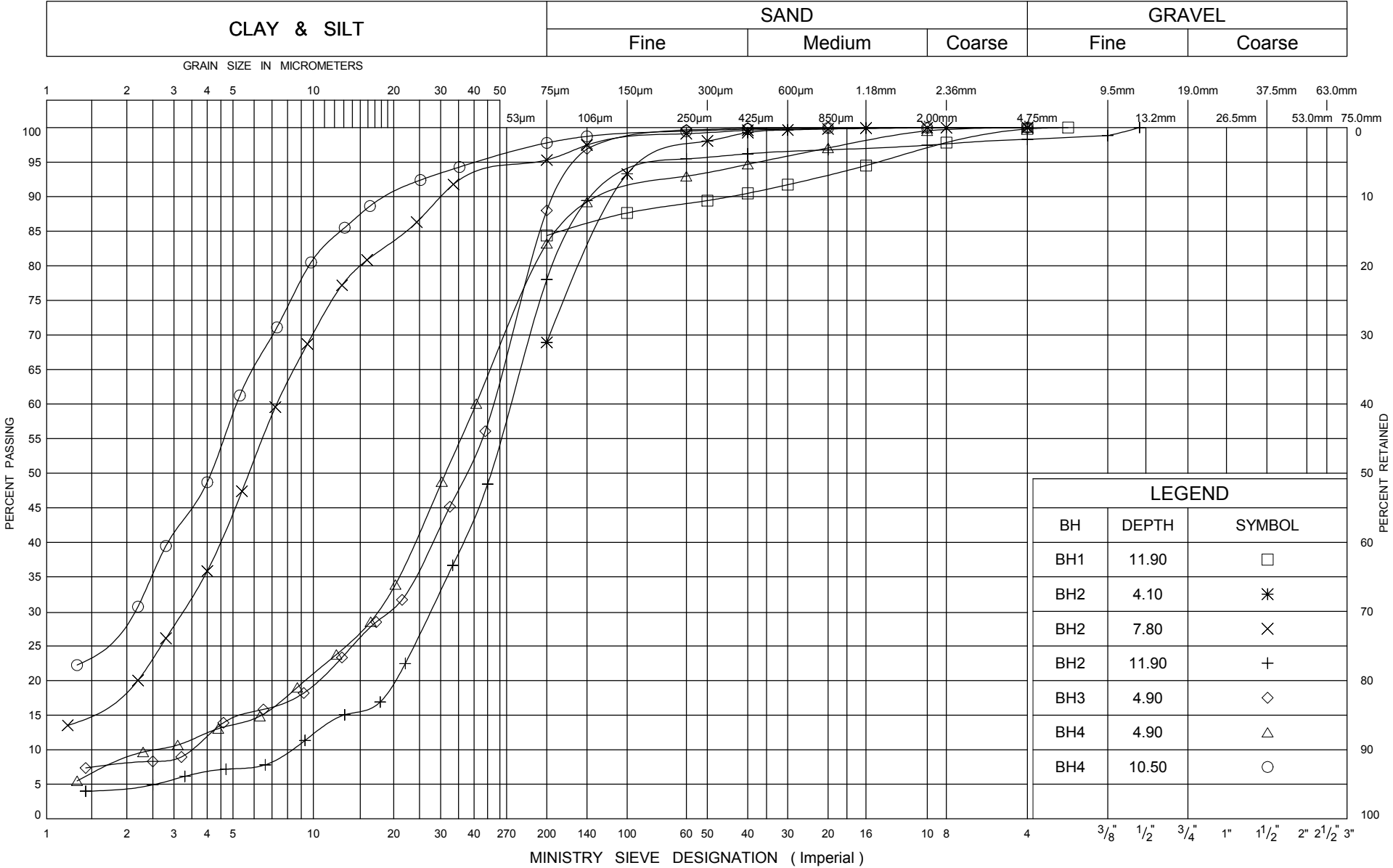
ENCLOSURE 6

DST REF. # GS-TB-020407

ASINN CREEK CULVERT

ONTARIO MOT GRAIN SIZE GS-TB-020407 ASINN CREEK - BH LOGS.GPJ DATA TEMPLATE.GDT 29/1/16

UNIFIED SOIL CLASSIFICATION SYSTEM

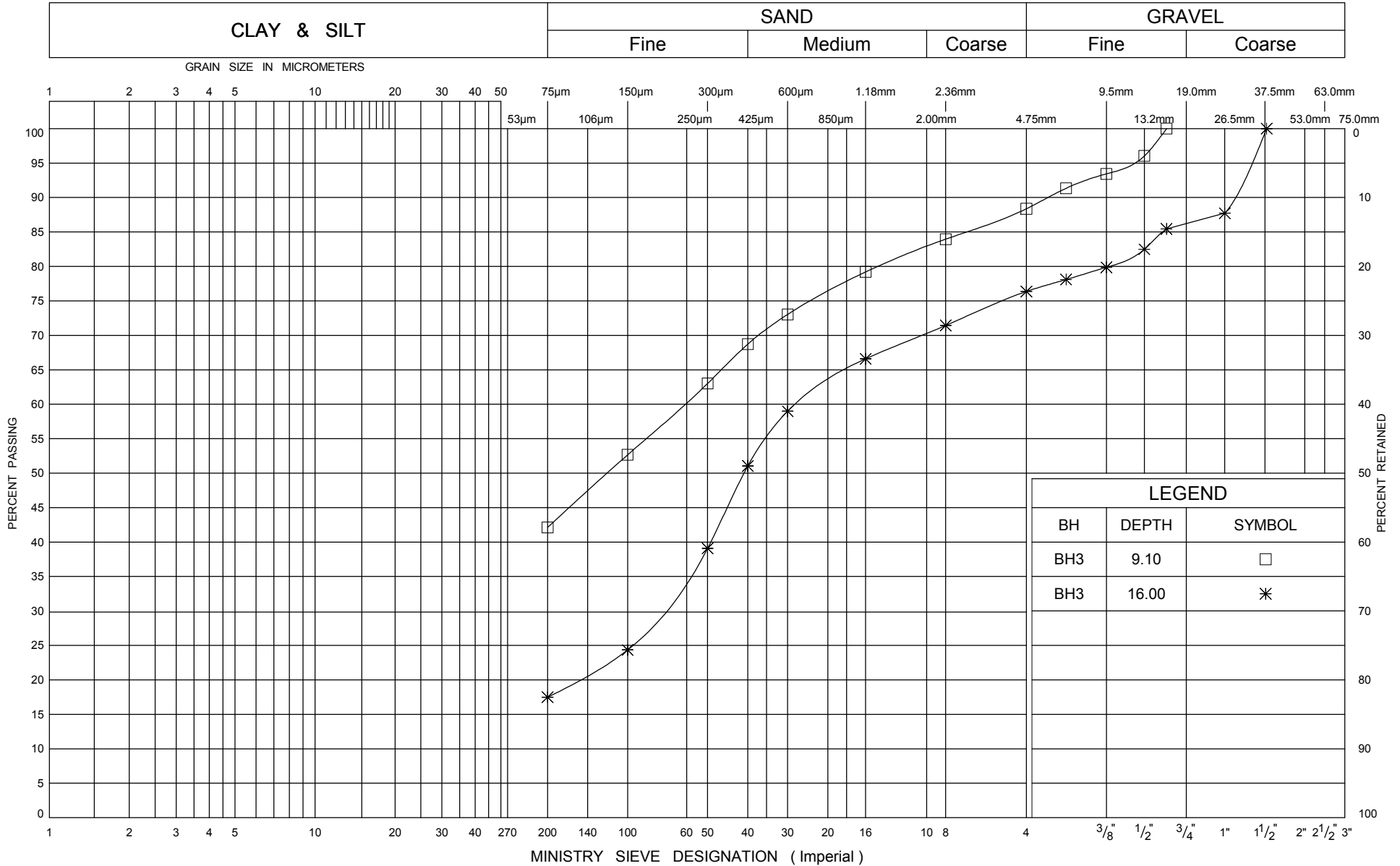


Ministry of
Transportation
Ontario

GRAIN SIZE DISTRIBUTION
SOIL DESCRIPTION
SILT

ENCLOSURE 7
DST REF. # GS-TB-020407
ASINN CREEK CULVERT

UNIFIED SOIL CLASSIFICATION SYSTEM



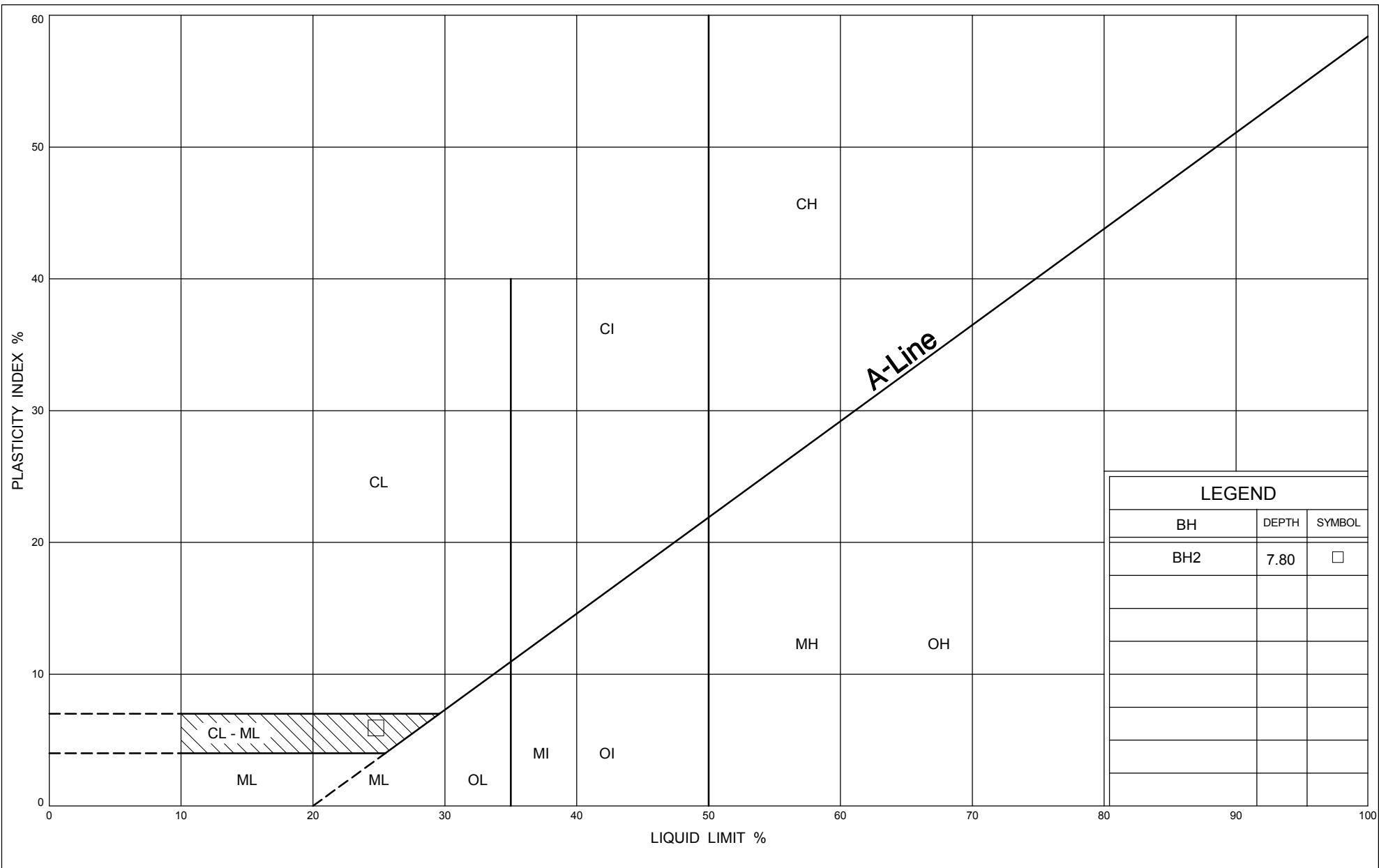
Ministry of
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GRAIN SIZE DISTRIBUTION
SOIL DESCRIPTION
SAND - LOWER LAYER

ENCLOSURE 8

DST REF. # GS-TB-020407

ASINN CREEK CULVERT



LEGEND		
BH	DEPTH	SYMBOL
BH2	7.80	□



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Ontario

PLASTICITY CHART SILT

ENCLOSURE 9

DST REF. # GS-TB-020407

ASINN CREEK CULVERT

Appendix E

**NON-STANDARD SPECIAL
PROVISION**

GROUNDWATER - Item No. 1

Non-Standard Special Provision

This special provision covers the groundwater level.

It should be noted that depending on the season, the amount of water flow through the creek may vary. The groundwater level at the site may also be subject to seasonal variations. The contractor should be prepared for this situation. The contractor should be aware of the high water table, the potential for surface water fluctuations. The contractor should take this into account when selecting an excavation method, and any subsequent dewatering methods.

Appendix F

**CHEMICAL TEST
RESULTS**



DST Thunder Bay
ATTN: Selorm Danku
DST Consulting Engineers Inc.
1120 Premier Way , Suite 200
Thunder Bay ON P7B 0A3

Date Received: 01-DEC-15
Report Date: 10-DEC-15 07:58 (MT)
Version: FINAL

Client Phone: 807-345-3620

Certificate of Analysis

Lab Work Order #: L1708995
Project P.O. #: NOT SUBMITTED
Job Reference:
C of C Numbers:
Legal Site Desc:

Rikki Thomson
Account Manager

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ADDRESS: 1081 Barton Street, Thunder Bay, ON P7B 5N3 Canada | Phone: +1 807 623 6463 | Fax: +1 807 623 7598
ALS CANADA LTD Part of the ALS Group A Campbell Brothers Limited Company

Sample Details/Parameters		Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L1708995-1	ASINM CREEK							
Sampled By:	Client on 01-DEC-15 @ 00:01							
Matrix:	Soil							
Physical Tests								
Conductivity		408		4.0	umhos/cm	07-DEC-15	07-DEC-15	R3325981
% Moisture		48.0		0.10	%	04-DEC-15	05-DEC-15	R3325347
pH		5.43		0.10	pH units		07-DEC-15	R3326423
Resistivity		2450		100	ohm cm	07-DEC-15	07-DEC-15	R3325976
Leachable Anions & Nutrients								
Chloride		507		20	mg/kg	04-DEC-15	08-DEC-15	R3327616
Anions and Nutrients								
Sulphate		131		20	mg/kg	04-DEC-15	08-DEC-15	R3327616

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
CL-WT	Soil	Chloride in Soil	EPA 300.0
EC-WT	Soil	Conductivity (EC)	EPA 9050A
A representative subsample is tumbled with de-ionized (DI) water. The ratio of water to soil is 2:1 v/w. After tumbling the sample is then analyzed by a conductivity meter.			
MOISTURE-WT	Soil	% Moisture	Gravimetric: Oven Dried
PH-WT	Soil	pH	MOEE E3137A
Soil samples are mixed in the deionized water and the supernatant is analyzed directly by the pH meter.			
RESISTIVITY-WT	Soil	Resistivity	MOECC E3138
Resistivity on a soil is a 2:1 extraction of DI water to soil. Sample is tumbled for 30 min. Conductivity of the extraction is taken and the inverse is calculated for resistivity.			
SO4-WT	Soil	Sulphate	EPA 300.0

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
WT	ALS ENVIRONMENTAL - WATERLOO, ONTARIO, CANADA

Chain of Custody Numbers:

GLOSSARY OF REPORT TERMS

Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.

mg/kg - milligrams per kilogram based on dry weight of sample

mg/kg wwwt - milligrams per kilogram based on wet weight of sample

mg/kg lwt - milligrams per kilogram based on lipid weight of sample

mg/L - unit of concentration based on volume, parts per million.

< - Less than.

D.L. - The reporting limit.

N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.

UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.

Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Workorder: L1708995

Report Date: 10-DEC-15

Page 1 of 2

Client: DST Thunder Bay
DST Consulting Engineers Inc. 1120 Premier Way , Suite 200
Thunder Bay ON P7B 0A3

Contact: Selorm Danku

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
CL-WT								
Soil								
Batch R3327616								
WG2226771-3	CRM	AN-CRM-WT						
Chloride			102.9		%		70-130	08-DEC-15
WG2226771-2	LCS							
Chloride			95.9		%		70-130	08-DEC-15
WG2226771-1	MB							
Chloride			<20		mg/kg		20	08-DEC-15
EC-WT								
Soil								
Batch R3325981								
WG2227671-1	MB							
Conductivity			<4.0		umhos/cm		4	07-DEC-15
MOISTURE-WT								
Soil								
Batch R3325347								
WG2226652-2	LCS							
% Moisture			95.5		%		90-110	05-DEC-15
WG2226652-1	MB							
% Moisture			<0.10		%		0.1	05-DEC-15
PH-WT								
Soil								
Batch R3326423								
WG2228014-1	LCS							
pH			6.99		pH units		6.7-7.3	07-DEC-15
SO4-WT								
Soil								
Batch R3327616								
WG2226771-3	CRM	AN-CRM-WT						
Sulphate			110.5		%		60-140	08-DEC-15
WG2226771-2	LCS							
Sulphate			96.2		%		70-130	08-DEC-15
WG2226771-1	MB							
Sulphate			<20		mg/kg		20	08-DEC-15

Quality Control Report

Workorder: L1708995

Report Date: 10-DEC-15

Page 2 of 2

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Hold Time Exceedances:

All test results reported with this submission were conducted within ALS recommended hold times.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.



DST Thunder Bay
ATTN: Bernie Villegas
DST Consulting Engineers Inc.
605 Hewitson street
Thunder Bay ON P7B 5V5

Date Received: 19-OCT-15
Report Date: 21-OCT-15 10:30 (MT)
Version: FINAL

Client Phone: 807-626-1310

Certificate of Analysis

Lab Work Order #: L1689521
Project P.O. #: NOT SUBMITTED
Job Reference: GS-TB-020407
C of C Numbers:
Legal Site Desc:

Rikki Thomson
Account Manager

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ALS CANADA LTD Part of the ALS Group A Campbell Brothers Limited Company

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters		Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L1689521-1 LOW RIVER - 48W-6C Sampled By: CLIENT on 15-OCT-15 @ 14:05 Matrix: WATER Physical Tests Conductivity (EC) pH Anions and Nutrients Chloride (Cl) Sulfate (SO4)								
		46.6		3.0	uS/cm		19-OCT-15	R3292437
		7.37		0.10	pH		19-OCT-15	R3292437
		0.47		0.10	mg/L		20-OCT-15	R3293233
		0.77		0.30	mg/L		20-OCT-15	R3293233
L1689521-2 WIGGLE CREEK -48W-312C Sampled By: CLIENT on 15-OCT-15 @ 15:30 Matrix: WATER Physical Tests Conductivity (EC) pH Anions and Nutrients Chloride (Cl) Sulfate (SO4)								
		42.0		3.0	uS/cm		19-OCT-15	R3292437
		7.11		0.10	pH		19-OCT-15	R3292437
		0.91		0.10	mg/L		20-OCT-15	R3293233
		1.13		0.30	mg/L		20-OCT-15	R3293233
L1689521-3 SAVANT LAKE - 48W-313C Sampled By: CLIENT on 15-OCT-15 @ 16:10 Matrix: WATER Physical Tests Conductivity (EC) pH Anions and Nutrients Chloride (Cl) Sulfate (SO4)								
		52.3		3.0	uS/cm		19-OCT-15	R3292437
		6.98		0.10	pH		19-OCT-15	R3292437
		2.25		0.10	mg/L		20-OCT-15	R3293233
		0.51		0.30	mg/L		20-OCT-15	R3293233
L1689521-4 GRAYSTONE LAKE -48W-189C Sampled By: CLIENT on 15-OCT-15 @ 17:13 Matrix: WATER Physical Tests Conductivity (EC) pH Anions and Nutrients Chloride (Cl) Sulfate (SO4)								
		31.1		3.0	uS/cm		19-OCT-15	R3292437
		7.14		0.10	pH		19-OCT-15	R3292437
		0.13		0.10	mg/L		20-OCT-15	R3293233
		1.21		0.30	mg/L		20-OCT-15	R3293233
L1689521-5 ASINN CREEK-48W-314C Sampled By: CLIENT on 15-OCT-15 @ 10:05 Matrix: WATER Physical Tests Conductivity (EC) pH Anions and Nutrients Chloride (Cl) Sulfate (SO4)								
		65.6		3.0	uS/cm		19-OCT-15	R3292437
		7.22		0.10	pH		19-OCT-15	R3292437
		2.76		0.10	mg/L		20-OCT-15	R3293233
		1.43		0.30	mg/L		20-OCT-15	R3293233

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Method Blank	Chloride (Cl)	B	L1689521-1, -2, -3, -4, -5
Matrix Spike	Chloride (Cl)	MS-B	L1689521-1, -2, -3, -4, -5

Sample Parameter Qualifier key listed:

Qualifier	Description
B	Method Blank exceeds ALS DQO. All associated sample results are at least 5 times greater than blank levels and are considered reliable.
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
CL-L-IC-N-TB	Water	Chloride in Water by IC (Low Level)	EPA 300.1 (mod)
Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.			
EC-TITR-TB	Water	Conductivity	APHA 2510 B
This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.			
PH-TITR-TB	Water	pH	APHA 4500-H
This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode			
SO4-IC-N-TB	Water	Sulfate in Water by IC	EPA 300.1 (mod)
Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.			

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
TB	ALS ENVIRONMENTAL - THUNDER BAY, ONTARIO, CANADA

Chain of Custody Numbers:

GLOSSARY OF REPORT TERMS

Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.

mg/kg - milligrams per kilogram based on dry weight of sample
mg/kg ww - milligrams per kilogram based on wet weight of sample
mg/kg lwt - milligrams per kilogram based on lipid weight of sample
mg/L - unit of concentration based on volume, parts per million.
< - Less than.

D.L. - The reporting limit.
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

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Client: DST Thunder Bay
DST Consulting Engineers Inc. 605 Hewitson street
Thunder Bay ON P7B 5V5

Contact: Bernie Villegas

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
CL-L-IC-N-TB		Water						
Batch	R3293233							
WG2196265-6	LCS							
Chloride (Cl)			99.7		%		90-110	20-OCT-15
WG2196265-5	MB							
Chloride (Cl)			<0.10		mg/L		0.1	20-OCT-15
EC-TITR-TB		Water						
Batch	R3292437							
WG2195669-2	LCS							
Conductivity (EC)			97.8		%		90-110	19-OCT-15
WG2195669-1	MB							
Conductivity (EC)			<3.0		uS/cm		3	19-OCT-15
PH-TITR-TB		Water						
Batch	R3292437							
WG2195669-2	LCS							
pH			6.02		pH		5.9-6.1	19-OCT-15
SO4-IC-N-TB		Water						
Batch	R3293233							
WG2196265-6	LCS							
Sulfate (SO4)			98.7		%		90-110	20-OCT-15
WG2196265-5	MB							
Sulfate (SO4)			<0.30		mg/L		0.3	20-OCT-15

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Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
B	Method Blank exceeds ALS DQO. All associated sample results are at least 5 times greater than blank levels and are considered reliable.

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Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
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Legend & Qualifier Definitions:

EHTR-FM: Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR: Exceeded ALS recommended hold time prior to sample receipt.
EHTL: Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT: Exceeded ALS recommended hold time prior to analysis.
Rec. HT: ALS recommended hold time (see units).

Notes*:

Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L1689521 were received on 19-OCT-15 09:25.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.