



**FOUNDATION INVESTIGATION AND PRELIMINARY DESIGN REPORT
SITCH CREEK CULVERT # 2 REPLACEMENT
HIGHWAY 595
TOWNSHIP OF GILLIES, THUNDER BAY DISTRICT
AGREEMENT NO.: 6013-E-0021
ASSIGNMENT NO.: 9
SITE NO.: 48W-80C
GEOCRES NO. 52A-195
GWP 6352-14-00**

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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

DST Consulting Engineers Inc. (DST) has been retained by the Ministry of Transportation (MTO), Geotechnical Section, Northwestern Region to conduct a foundation investigation and produce a foundation design report for the proposed culvert replacement on Highway 595. This work was carried out under Agreement No.: 6013-E-0021, Geotechnical Retainer, Assignment No. 4 and Assignment No. 9.

This report addresses the field investigation, laboratory test program, factual report on conditions (Part 1) and recommendations for preliminary design and construction for the proposed culvert replacement (Part 2).

2. SITE DESCRIPTION

The site is located on Highway 595, approximately 0.78 km North of Highway 588 (latitude 48.3017, longitude -89.6992), LHR 62920, offset 0.780, Station 10+775, in the Township of Gillies, in the District of Thunder Bay.

It is understood that the existing 28.0 m long centreline culvert is a Structural Plate Corrugated Steel Pipe (SPCSP) culvert approximately 5.0 m in diameter. The existing culvert (Figure 2.3 and 2.4) has an original date of construction that is unknown and inspection by others indicates there is light corrosion at the water level and slight sag at centreline and ponding within the barrel. The fill thickness above the culvert is approximately 1.0 m and the side slope of the embankment is approximately 2H:1V as noted during visual inspection during field work. The surrounding area is moderately vegetated and wooded (Figure 2.1 and 2.2). Photographs were taken by others (Figures 2.1 to 2.4).

Geological information is available from published *Ontario Geological Survey Map #52ASW* by the *Ontario Ministry of Natural Resources* for the Gillies area. The map indicates that the local area landform is identified as a clayey glaciolacustrine plain. The topography in the area is mainly low local relief; plain with dry drainage conditions.



Figure 2.1 Location of existing culvert at Highway 595 (looking North)



Figure 2.2 Location of existing culvert at Highway 595 (looking South)



Figure 2.3 Culvert inlet (looking West)



Figure 2.4 Culvert outlet (looking East)

3. INVESTIGATION PROCEDURES AND LABORATORY TESTING

Site work was carried out between August 25th and September 9th, 2014 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 5.3 m to 12.8 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 2 to 3. Borehole 1 was advanced North of the existing culvert at Station 10+778, 4.5 m right of centreline, and advanced to a depth of 11.8 m below existing surface. Borehole 2 was advanced South of the existing culvert at Station 10+772, 4.2 m left of centreline, and advanced to a depth of 12.8 m below existing surface. The remaining two boreholes were advanced with portable hand equipment at the inlet and outlet of the existing culvert. Borehole 3 was advanced at the outlet at station 10+777, 18.0 m right of centreline, and advanced to a depth of 5.3 m below existing surface. Borehole 4 was advanced at the inlet at station 10+777, 15.0 m Left of centreline, and advanced to a depth of 6.0 m below existing surface.

The borehole locations are 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 the existing culvert at Station 10+775. A nail in a telephone pole on the north side of the culvert at station 10+796 was assigned as temporary benchmark with elevation of 100.0 m. Table 3.1 summarizes the detail of borehole locations and depths.

All boreholes were abandoned using suitable abandonment barrier as described in Ontario Regulation 903 and its amendments. Boreholes were decommissioned by backfilling to the bottom of the road base with cuttings and bentonite chips. From the bottom of the road base, granular materials were replaced to the bottom of the asphalt and the asphalt was sealed with a cold patch.

The fieldwork was supervised on a full-time basis by DST personnel who located the boreholes in the field, performed sampling, in-situ testing and logged the boreholes. Soil samples were obtained from the auger flights and from the split spoon sampler used for the standard penetration test (SPT). The SPT involves driving a 51 mm diameter thick-walled sampler into the soil under the energy of a 63.5 kg weight falling through 760 mm. The number of blows required to drive the sampler 305 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 laboratory in Thunder Bay for further analysis.

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 tests included moisture contents, particle size analyses and Atterberg limits including plastic limit and liquid limit. A total of thirty nine (39) moisture contents, eight (8) sieve analyses, and one (1) particle size analysis have been carried out for this assignment. Laboratory test results are presented in the Boreholes Logs and graphical plots attached Appendix D (Enclosures).

Table 3.1 Detail of borehole locations

Borehole ID	Station	Elevation (m)	Depth (m)	Offset (m)
BH1	10+778	101.3	11.8	4.5 m Rt
BH2	10+772	101.4	12.8	4.2 m Lt
BH3	10+777	97.9	5.3	18.0 m Rt
BH4	10+777	98.0	6.0	15.0 Lt

4. DESCRIPTION OF SUBSURFACE CONDITIONS

The subsurface conditions are presented based on the information obtained during power auger drilling and hand auger drilling.

The generalized stratigraphy of the existing embankment, based on the conditions encountered in Boreholes 1 and 2, sand layer is overlying a silt layer which is again underlain by a lower sand layer. Asphalt road approximately up to 50 mm thick was noted during field investigation.

Table 4.1 Summary of soil strata at the culvert location

Layer	Depth (m)	Elevation (m)	Comments
Fill Sand	0.0 to 7.3	101.3 to 94.0	
	0.0 to 3.1	101.4 to 98.3	
Silt	7.3 to 8.5	94.0 to 92.8	
	3.1 to 7.6	98.3 to 93.8	
Sand	8.5 to 11.8	92.8 to 89.5	
	7.6 to 12.8	93.8 to 88.6	

4.1 Topsoil

Topsoil was encountered at surface in Boreholes 3 and 4 with a thickness of approximately 0.1 m.

4.2 Fill- Sand

Upper sand layer with trace to some gravel, trace to with silt and cobbles was encountered in Boreholes 1 and 2 with a thickness of 7.3 m (Elev. 101.3 to 94.0 m) and 3.1 m (Elev. 101.4 to 98.3 m) respectively.

SPT 'N' values vary from 7 to 29, indicating a loose to compact condition. The moisture contents of samples tested range from 4 to 13 %. The results of laboratory tests are summarized in Table 4.2.

Table 4.2 Summary of fill sand layer sieve analyses

Laboratory Results - Sieve Analyses	
Gravel %	5 to 18
Sand %	50 to 72
Fines %	8 to 39

4.3 Silt

Silt with trace to some gravel, some sand to sandy was encountered in Boreholes 1, 2, 3 and 4 at a depths of 7.3 m, 3.1 m, 0.1 m, and 0.3 m respectively. The thickness of this stratum for Boreholes 1, 2, and 3 was found to be 1.2 m (Elev. 94 to 92.8 m), 4.5 m (Elev. 98.3 to 93.8 m) and 2.2 m (Elev. 97.8 to 95.6 m) respectively. For Borehole 4 the thickness of this stratum is not defined as borehole terminus was reached at depth of 6.0 m (Elev. 92.0 m) within this stratum.

SPT 'N' values vary from 3 to more than 50, indicating a loose to very dense condition. The moisture contents of samples tested range from 17 to 28 %. The laboratory test results are summarized in following Tables 4.3

Table 4.3 Summary of silt layer sieve analyses

Laboratory Results - Sieve Analyses	
Gravel %	0 to 2
Sand %	18 to 24
Fines %	76 to 82

4.4 Sand

Lower sand layer with trace to some gravel, some silt to silty and cobbles was encountered in Boreholes 1, 2, 3 and 4 at depth of 8.5 m (Elev. 92.8 m), 7.6 m (Elev. 93.8 m) and 2.3 m (Elev. 95.6 m) and 0.1 m (Elev. 97.9 m) respectively. The thickness of this stratum is not defined for borehole 1, 2 and 3 as borehole terminus was reached within this stratum. Auger refusal on possible bedrock was encountered in Borehole 1 and 3 at depth of 11.8 m (Elev. 89.5 m) and 5.3 m (Elev. 92.6 m) respectively. For Borehole 4 the thickness of this stratum was found to be 0.3 m (Elev. 98.0 to 97.7 m).

SPT 'N' values vary from 11 to 42, indicating compact to dense condition. The moisture contents of samples tested range from 10 to 19 %. The results of laboratory tests are summarized

in Table 4.4.

Table 4.4 Summary of sand layer sieve analyses

Laboratory Results - Sieve Analyses	
Gravel %	5 to 14
Sand %	49 to 70
Fines %	16 to 46

4.5 Groundwater

At the time of the field investigation groundwater was observed in Boreholes 1, 2, 3 and 4 and groundwater details are provided in Table 4.5. The groundwater levels can be expected to vary with the season and precipitation events.

Table 4.5 Groundwater depths

Borehole	Groundwater Depth	Groundwater Elevation
Borehole 1	8.5	92.8
Borehole 2	5.8	95.6
Borehole 3	2.2	95.7
Borehole 4	2.4	95.6

5. MISCELLANEOUS

Site work was carried out between August 25th, 2014 and September 9th, 2014 utilizing a CME 750 all-terrain drill rig operated by DST personnel. Fieldwork was supervised on a full time basis by Peter Raynak who located the boreholes in the field, performed sampling, in-situ testing and logged the boreholes. Soil samples collected 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 Deep Bansal, P.Eng and reviewed by Prof. Myint Win Bo, P.Eng a designated principal contact for MTO projects.

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PART 2: ENGINEERING DISCUSSIONS AND RECOMMENDATIONS

6. PROJECT DESCRIPTION

DST Consulting Engineers Inc. has been retained by the Ministry of Transportation (MTO), Northwestern Region, to conduct a foundation investigation and design report for the replacement of the Sitch Creek Culvert # 2 on Highway 595. This work was carried out under Agreement No. 6013-E-0021, Assignment No. 4 and Assignment No. 9, Foundation Investigation and Design Report for the Replacement of Various Culverts.

Existing structure at this location is a 4.8 m in width x 5.0 m in height x 28.0 m in length Structural Plate Corrugated Steel Pipe (SPCSP) culvert with a depth of soil cover of approximately 1.0 m. The culvert was identified with light corrosion at the water level, a slight sag at the centreline and ponding within the barrel. The fill thickness above the culvert is approximately 1.0 m and the side slope of the embankment is approximately 2H: 1V as noted during visual inspection during field work. The culvert replacement is recommended to be of a similar SPCSP culvert.

The generalized stratigraphy of the existing embankment, based on the conditions encountered in boreholes, consists of a sand fill overlying a silt layer that is underlain by a sand layer.

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

6.1 Replacement Structure

The proposed replacement structure at this site is a SPCSP culvert however other culvert types such as concrete box culverts or open footing culverts could also be considered for the culvert replacement.

It is understood that open cut excavation will be used to replace the structure. The design of the replacement structure must be in accordance with the Canadian Highway Bridge Design Code CAN/CSA-S6-06 (CHBDC, 2006) and all relevant Ministry of Transportation specifications and guidelines.

6.1.1 Earth Excavation

Earth excavation will be required adjacent the existing and replacement structure and may 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 shall be constructed in accordance with OPSS.PROV 539 "Construction Specification for Temporary Protection Systems" and Section 6.1.4 Roadway Protection.

when organic materials are encountered during excavation, the excavations to remove these organics and wood should be completed in accordance with OPSS.PROV 209 "Construction Specification for Embankments Over Swamps and Compressible Soils".

Excavation should be 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 and Type 4 if located above and below the water table respectively. 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. Type 4 soils generally are soft to very soft and very loose in consistency, very sensitive and upon disturbance are significantly reduced in natural strength, run easily or flow unless it is completely supported before excavation procedure, have almost no internal strength, are wet or muddy and exerts substantial fluid pressure on its supporting system. In accordance with O. Reg. 213/91, s.227 (3), if an excavation contains more than one type of soil, the soil shall be classified with the highest number as described in section 226.

These should be assessed and confirmed in the field as construction progresses. Open excavation without shoring could be completed provided that the soils are sloped back sufficiently to maintain sidewall stability and protect workers. As per the OHSA O. Reg 213/91, s 234 it is recommended that the excavation side slopes should not be steeper than 1H: 1V for soils Type 1 to 3 and 3H: 1V for soil Type 4. The stability of the excavation side slopes will be highly dependent on the contractor's methodology and ability to effectively dewater the excavation. Bottom width of excavation should be 4 to 6 m wider than maximum width of proposed replacement culvert.

6.1.2 Lateral and Sliding Resistances

The analysis of horizontal and vertical effects of earth loads on the culvert can be performed considering soil parameters given in Table 6.1 and as described in Section 7.6.3.1 in Canadian Highway Bridge Design Code. Temporary bracing and shoring may be designed using the typical soil parameters given in Table 6.1, but the designer/contractor should verify the appropriate soil parameters for the designs of specific bracing and shoring system.

It is recommended that all excavations be either adequately sloped or securely shored and braced to prevent earth caving 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 6.1 Typical soil parameters for earth loads

Soil type	Top Elevation (m)	Unit weight (kN/m ³)	Internal friction angle (Deg)	Soil/Steel Interface friction angle δ (Deg)
Granular A ^{&}	-	20	35	14
Sand Fill	101.3 to 97.9	21	30	14
Silt	94.0 to 97.7	19	30	14
Sand	92.8 to 95.6	20	32	14

[&] Please note that parameters of Granular A are dependent on the degree of compaction, mineralogy, angularity of the soil particles and therefore could vary from the listed values

Table 6.2 Lateral Earth Pressure Coefficients

Earth Pressure Coefficient	Equation*	Granular A [#]	Sand Fill [#]	Silt [#]	Sand [#]
Active Earth Pressure (K _a)	$\left(\frac{1 - \sin\phi}{1 + \sin\phi}\right)$	0.27	0.33	0.33	0.30
Passive Earth Pressure(K _p)	$\left(\frac{1 + \sin\phi}{1 - \sin\phi}\right)$	3.68	3.0	3.0	3.2
At rest (K _o)	$(1 - \sin\phi)$	0.42	0.50	0.50	0.47

* ϕ is an angle of internal friction

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

For over consolidated (OC) soils the earth pressure coefficient at rest condition should be corrected using a following relationship

$$K_{o(OC)} = K_{o(NC)} * (OCR)^{0.5}$$

Where

K_{o(oc)}= Earth pressure coefficient over consolidated soils

K_{o(Nc)}= Earth pressure coefficient normally consolidated soils

OCR= Over consolidation Ratio

The following table provides a coefficient of friction for various soils with steel that may be used in the assessment of sliding resistances.

Table 6.3 Coefficient of friction for sliding resistance

Soils	Coefficient of Friction
Granular A , Sand Fill	0.25
Sand	0.25
Silt	0.25

6.1.3 Foundation Design

The culvert will be located at approximately the same vertical and horizontal alignment of the existing structure. As the proposed culvert is not expected to be heavily loaded, a shallow foundation is considered suitable for this site. As the cross sectional area of the replacement structure is to be the same or larger than the existing, the overall effect on the culvert foundation

soils will be a small decrease in stress at the base of the culvert. The culvert should be installed to a minimum depth of 5.4 m (Elev. 96.0 m) below top of pavement and bedding material placed on undisturbed native silt or sandy soils.

Where unsuitable or unstable soils are encountered; the foundation soils must be removed to a firm or hard soils and replaced to the foundation grade. If sub-excavation for frost effects is carried out in the dry (with adequate dewatering controls), the material can be replaced with Granular A material meeting OPSS.PROV 1010 specifications and compacted to a minimum of 95 % 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 6.1.6 Bedding.

The settlement of foundation is expected to be not more than 25 mm due to no change in loading conditions to the site. Since considerable settlements are unlikely to occur, no camber is recommended at this site.

6.1.4 Roadway Protection

Since some temporary roadway protection is required during the structure replacement, installation of a sheet piles with necessary support may be considered to ensure the stability of the bank and is a feasible option. Alternatively, the use of gabion wall or soldier piles with lagging installed as the excavation progresses may also be considered. Soldier piles, properly designed, will be more capable of accommodating the presence of cobbles if encountered within the embankment fill. As the potential of encountering cobbles exists, the contractor should be prepared to handle this with the selection of adequate driving or vibratory equipment as well as steel thickness. The use of gabion wall will require widening of road embankment at the location of culvert replacement with temporary culvert extension. Alternatively a detour during construction may be considered which will allow full replacement of culvert at same time.

The design of roadway protection may be performed using the typical soil parameters given in Table 6.1, but the designer/contractor should verify the appropriate soil parameters for the designs.

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.

6.1.5 Bedding

The foundation soils, silts in particular, will be very susceptible to disturbance and weakening as a result of traffic, standing water and frost. Any foundation soils that could be disturbed shall be protected and therefore use of working mat during construction is recommended. The bottom of the excavation on which the culvert or granular pad is to rest shall not be disturbed. The bedding placement should commence immediately after the final removal of material to the foundation level has been completed.

The bedding for the structure should be designed in accordance with Section 7.6 of the CHBDC. The bedding shall be a minimum of 200 mm 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" as per Soil Group I in accordance with Table 7.4 of the Canadian Highway Bridge Design Code. The "Granular A" shall be in accordance to OPSS.PROV 1010. The "Granular A" should be placed in layers not exceeding 200 mm in thickness, loose measurement, and each layer compacted to a minimum of 95 % of standard Proctor maximum dry density. The middle one-third of the culvert width of the top bedding layer, having minimum thickness of 75 mm, shall be loosely placed and uncompacted.

Where 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. Since fine materials are present beneath the clear stone a non-woven geotextile (OPSS 1860.07.05.01 Class II) with the filtration opening size (FOS) less than 135 µm will be required for separation. No compaction is required of the clear stone.

6.1.6 Sidfill and Overfill

The material used for culvert sidfill 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 shall be deposited uniformly on each side of the structure in order to prevent lateral displacement. The minimum width of the sidfill should be at least half of the culvert width in each side. The sidfill should consist of Granular A" and compacted to 95% of

standard Proctor maximum dry density.

Overfill should consist of “Granular A” and should be compacted to not greater than the compaction or equivalent stiffness of soils in the sidefill zone and bedding. Due to presence of silt soils underneath the sand fill it is recommended that the backfill materials should be separated from the adjacent soil with a non-woven Class II geotextile, with a filtration opening size of between 50 to 100 µm, specified in OPSS 1860 “Material Specifications for Geotextiles”.

6.1.7 Dewatering

During construction In order to prevent back up of 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. A suitable sump and pump system, possibly supported by an efficient well-point system, will be required to dewater and stabilize the excavation. A well designed well-point system with a suitable diameter of well point at an appropriate spacing will perform better for working under dry condition and to prevent disturbance of the excavation base through sand boiling and hydraulic heave. It should be noted that depending on the season, depth of excavation and amount of water flow through the creek may vary. 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 continuous dewatering operation must be provided to keep the excavation stable and free of water. 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 518 “Construction Specification for Control of Water from Dewatering Operations”.

6.1.8 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 shall be applied in accordance with OPSD 810.020 “Rip-Rap Treatment for Ditch Inlets” and OPSS 511 “Construction

Specification for Rip-Rap, Rock Protection, and Granular Sheeting”.

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

To prevent undermining of the bedding, cutoff walls shall be installed along the entrance and exit end bottom sides of culvert. Cutoff walls should be designed based on velocity of the water flow and the type of soil underneath.

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

6.1.9 Frost Protection

In accordance with OPSD 3090.100 “Foundation Frost Depths for Northern Ontario”, the frost penetration at this location is about 2.2 m. The frost susceptible soils shall not be used adjacent to the culvert wall within the depth of frost penetration from the road surface. 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 2.2 m. The frost heave may generate additional stresses on the culvert foundation and walls.

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. As the frost penetration is extended 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 Pipe and Bedding Grade”.

Where 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 2.2 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 125 mm Dow Styrofoam Highload 40 Insulation or an equivalent material with a compressive strength of approximately 275 kPa or greater. For a region that has a freezing index greater than 1500 Celsius Degree-Days it is recommended that the insulation be placed beneath the structure and extend 2.44 m from the face of the buried structure.

6.1.10 Embankment Foreslopes

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

6.1.11 Construction Concerns

The main construction issues that need to be addressed for this site are 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.

A Quality Verification Engineer shall be required to inspect the condition of the foundation and surrounding soils before installation of fill materials and ensure the width of excavation and excavation slope walls are suitable, and ensure compliance with materials placed and compaction methods as well as a sheet pile installation.

7. CLOSURE

Based on the information collected from field investigation, parameters interpreted from laboratory test results, groundwater monitoring data and information provided by the client, the proposed replacement structure at this site is recommended to be a Structural Plate Corrugated Steel Pipe culvert. Table 7.1 below summarizes the advantages and disadvantages of the use of sheet pile, soldier pile and gabion walls for roadway protection. Since it is a temporary roadway protection, the sheet pile system with necessary support is considered to be a recommended option however design of roadway protection is the responsibility of the contractor as per the contract drawings.

Table 7.1 Advantages and disadvantages of various roadway protection methods

Roadway Protection Option	Advantages	Disadvantages
Sheet Pile	<ul style="list-style-type: none"> • Relatively non permeable • Increased erosion control capacity 	<ul style="list-style-type: none"> • Lightweight material may encounter difficult driving through cobbles • Higher installation cost • Specialized construction and design required
Soldier Pile	<ul style="list-style-type: none"> • Heavier gauge materials may be better to be able to accommodate presence of cobbles • Lower cost 	<ul style="list-style-type: none"> • Permeable • Potential for erosion of retained materials • longer installation time
Gabion Wall	<ul style="list-style-type: none"> • Ease of Installation • Lower cost • Presence of cobbles and boulders is not an issue 	<ul style="list-style-type: none"> • Permeable • Potential for erosion of retained materials

8. REFERENCES

Canadian Foundation Engineering Manual. 2006. Fourth Edition, Canadian Geotechnical Society.
Canadian Highway Bridge Design Code. 2006, CAN/CSA-S6-06, A National Standard of Canada,
Canadian standards Association.

Municipal and Provincial Common, Volume 1 - General & Construction Specifications, "*Ontario
Provincial Standard for Roads & Public Works*" Spec No. OPSS 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.

Provincial-Orientated, Volume 5 - MTO General Conditions of Contract and General & Construction
Specifications, "*Ontario Provincial Standard for Roads & Public Works*" Spec No.
OPSS.PROV 209, 501, 510, 539.

Provincial-Orientated, Volume 6 - Material Specifications, "*Ontario Provincial Standard for Roads &
Public Works*" Spec No. OPSS.PROV 1004, 1010.

The Surveys and Design Office, Highway Engineering Division, Ministry of Transportation, 1990,
Pavement Design and Rehabilitation Manual.

9. 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:

Reviewed by:



Deep Bansal, P. Eng
Geotechnical Engineer

A handwritten signature in blue ink, appearing to read "Bernardo Villegas".

Bernardo Villegas, M.Sc
Manager / Sector Head

Reviewed By:



Dr. M W Bo, PhD., P. Eng, P.Geo, Int PE,
C.Geol, C. Eng, Eur Geol, Eur Eng
Senior Vice President / Senior Principal

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

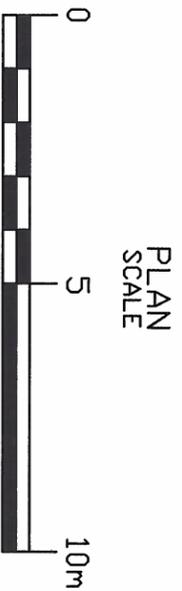
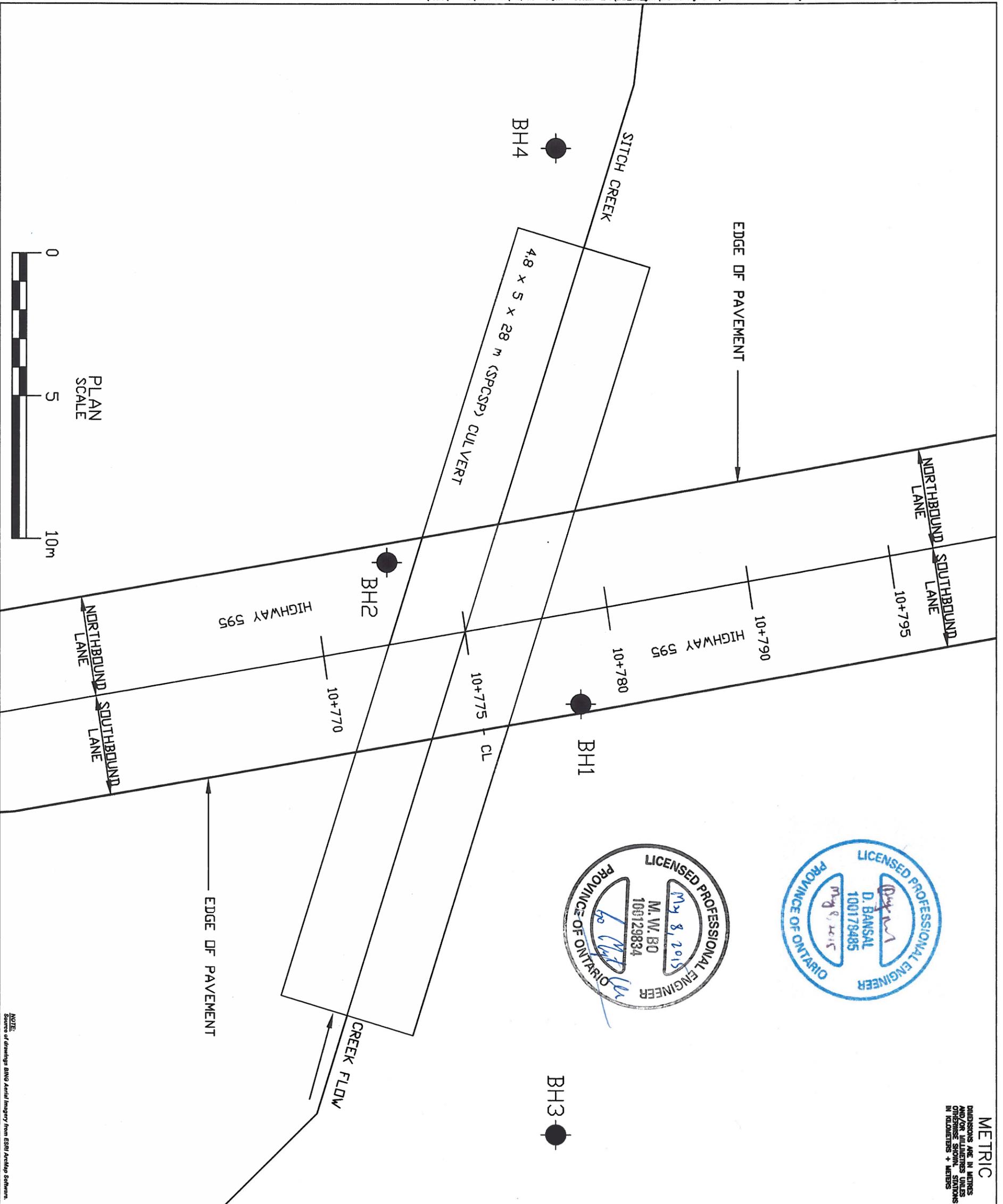
LEGEND OF RECORDS FOR BOREHOLES: SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE

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

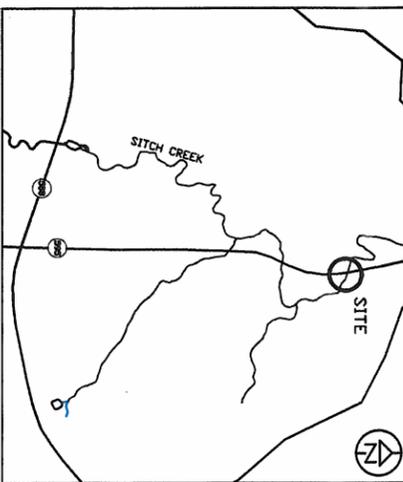
DRAWINGS



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



CONT	No	No
GWP	No 6352-14-00	
SITE	No 48W-80/C	
	GEOCRECS No 52A-195	
	CULVERT REPLACEMENT SITICH CREEK CULVERT	
	STA 10+770 TO STA	10+790
	Survey	Revised
	SHEET	

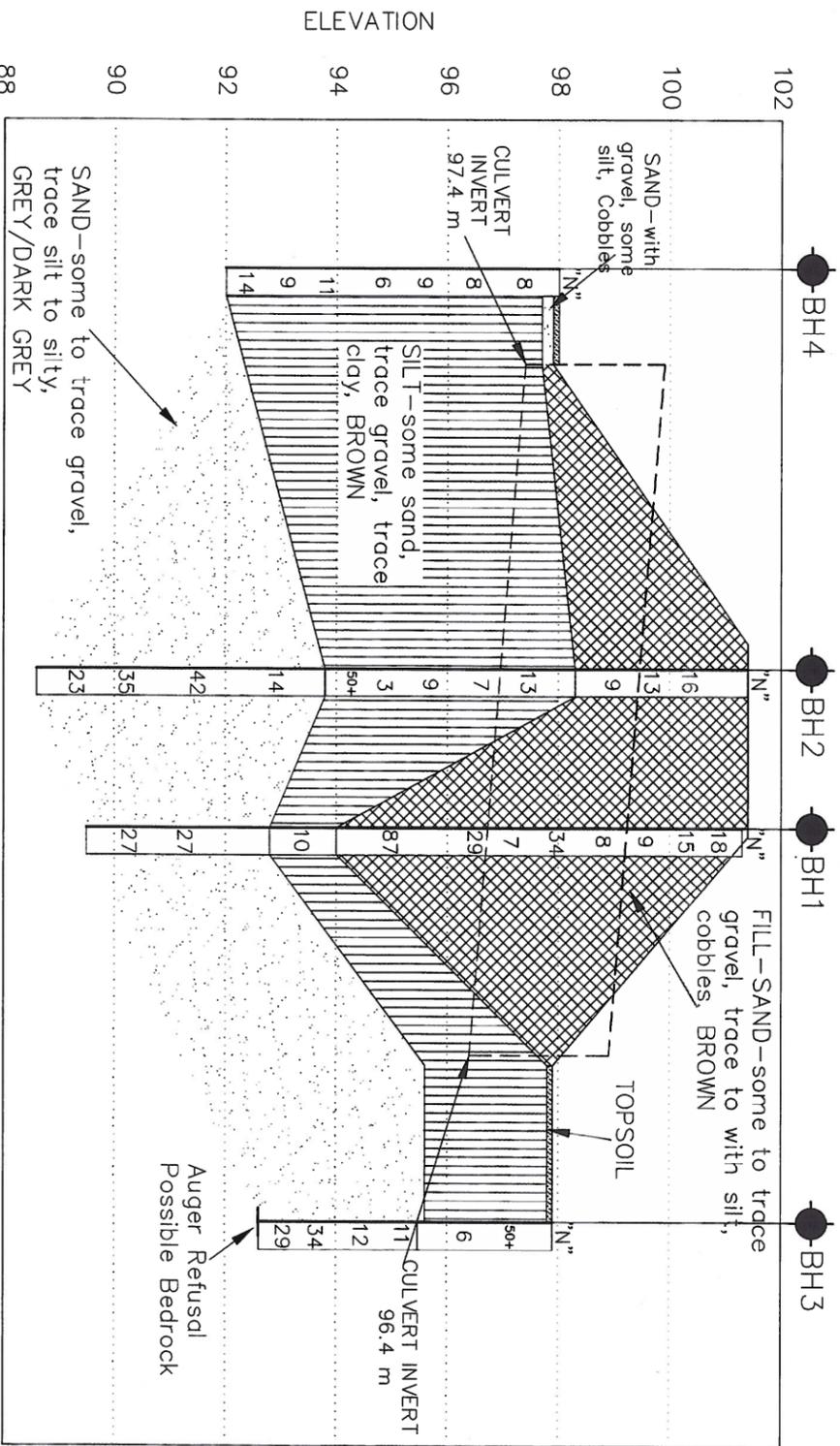
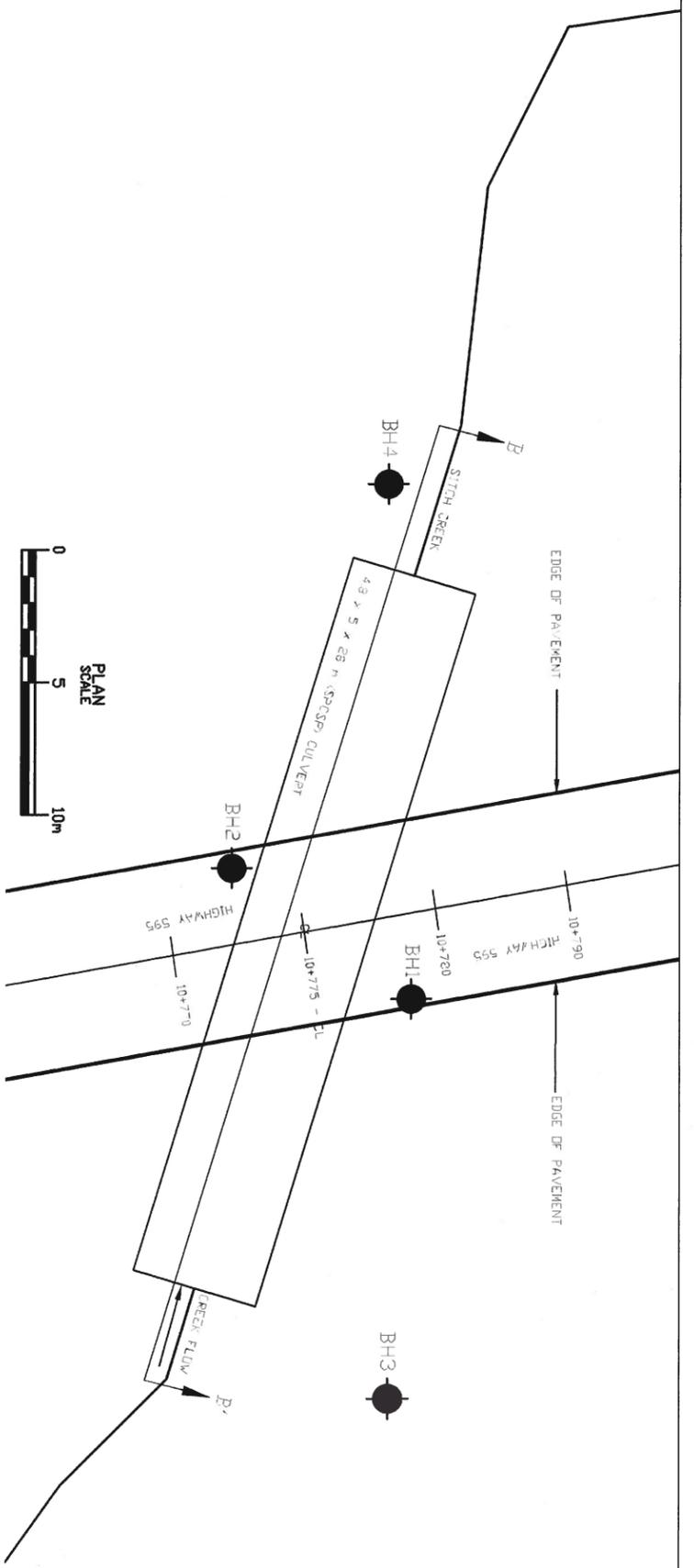


No.	Elevation	Northing	Easting	Station	Offset
BH1	101.3	5353250 m N	289797 m E	10+778	4.5 m RT
BH2	101.4	5353249 m N	289792 m E	10+772	4.2 m LT
BH3	97.9	5353250 m N	289818 m E	10+777	18.0 m RT
BH4	98.0	5353257 m N	289779 m E	10+777	15.0 m LT

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

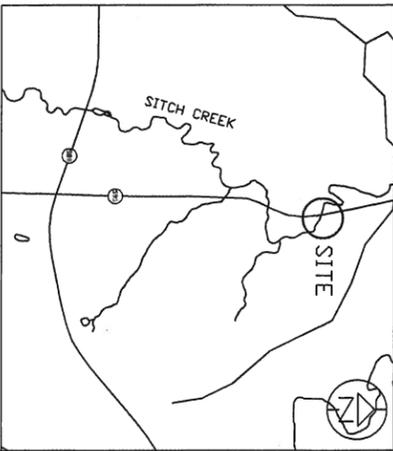
DST
DST Consulting Engineers Inc.
605 Hewitson Street
Thunder Bay, ON P7B 5V5
Ph: (807) 623-2929
Fax: (807) 623-1792
Email: thunderbay@dstgroup.com

NOTE:
Source of drainage data Aerial Imagery from ESRI ArcMap Software.



METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SPECIFIED
IN MILLIMETRES + METERS

NOTE:
Source of drawings BMG Aerial Imagery from ESRI ArcMap Software.



CONT No	No	
GWP	No 6352-14-00	
SITE	No 48W-80/C	
GEOGRES	No 52A-195	
CULVERT REPLACEMENT		SHEET
SITCH CREEK CULVERT		
STA	10+770 TO STA 10+790	
Survey	Revised	

LEGEND

- ◆ Borehole
- Blows/0.3m (Std. Pen Test, 475 J/Blow)
- ▼ Water level at time of investigation.
- Fill
- Organics
- Topsoil
- Till
- Bedrock
- Sand
- Silt
- Clay
- Sand & Gravel
- Boulders



No.	Elevation	Northing	Easting	Station	Offset
BH1	101.3	5353250 m N	239797 m E	18+778	4.5 m RT
BH2	101.4	5353249 m N	239792 m E	18+772	4.2 m LT
BH3	97.9	5353250 m N	239818 m E	19+777	18.0 m RT
BH4	98.0	5353257 m N	239779 m E	19+777	15.0 m LT

NOTE:
The boundaries between soil strata have been established only at boreholes shown and no other soil boundaries are assumed by interpolation and may not represent actual conditions.

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DRAWING 2

Appendix D
ENCLOSURES

RECORD OF BOREHOLE No BH1

1 OF 1

METRIC

W.P. 6013-E-0021 LOCATION Stich Creek #2 STA 10+778 RT 4.5 m ORIGINATED BY PR
 DIST Thunder Bay HWY 595 BOREHOLE TYPE Hollow Stem Auger 80 mm COMPILED BY DB
 DATUM Local DATE 2014 08 25 CHECKED BY DM

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa							
						20	40	60	80	100	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L		
						O UNCONFINED + FIELD VANE □ QUICK TRIAXIAL X LAB VANE				WATER CONTENT (%)					
						50	100	150	200	250	20	40	60		
101.3	GROUND SURFACE														
	FILL-SAND-some to trace gravel, trace to with silt, cobbles, BROWN, LOOSE TO VERY DENSE		AS1	AS											
			SS2	SS	18										
			SS3	SS	15										
			SS4	SS	9										
			SS5	SS	8										
			SS6	SS	34										
			SS7	SS	7										
			SS8	SS	29										
			SS9	SS	87										
	-concrete at tip														
94.0	SILT-some sand, trace gravel, BROWN, COMPACT														
7.3			SS10	SS	10										
92.8	SAND-some gravel, trace to with silt, GREY, COMPACT														
8.5			SS11	SS	27										
			SS12	SS	27										
89.5	END OF BOREHOLE Auger Refusal Possible Bedrock														
11.8															

ON_MOT-HIGH VANES GS-TB-019502 STICH CREEK 2.GPJ_DST_MIN.GDT 11/24/14

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

RECORD OF BOREHOLE No BH2

1 OF 1

METRIC

W.P. 6013-E-0021 LOCATION Stich Creek #2 STA 10+772 LT 4.2 m ORIGINATED BY PR
 DIST Thunder Bay HWY 595 BOREHOLE TYPE Hollow Stem Auger 80 mm COMPILED BY DB
 DATUM Local DATE 2014 08 26 CHECKED BY DM

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	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
						20	40	60	80	100	20	40	60		GR SA SI CL	
101.4	GROUND SURFACE															
	FILL-SAND-some gravel, some silt, cobbles, BROWN, LOOSE TO COMPACT		AS1	AS												18 69 (13)
			SS2	SS	16											
			SS3	SS	13											
			SS4	SS	9											
98.3																
3.1	SILT-some sand, trace gravel, trace clay, BROWN, VERY LOOSE TO VERY DENSE		SS5	SS	13											2 18 73 7
			SS6	SS	7											
			SS7	SS	9											
			SS8	SS	3											
	-cobbles		SS9	SS	50+											
93.8																
7.6	SAND-some gravel, some silt, cobbles, DARK GREY, COMPACT TO DENSE		SS10	SS	14											14 70 (16)
			SS11	SS	42											
			SS12	SS	35											
			SS13	SS	23											
88.6																
12.8	END OF BOREHOLE															

ONL_MDT_CS-TB-019502_STICH_CREEK_2.GPJ DST_MIN.GDT 3/20/15

NR = NO RECOVERY +³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No BH3

1 OF 1

METRIC

W.P. 6013-E-0021 LOCATION Stich Creek #2 STA 10+777 RT 18.0 m ORIGINATED BY PR
 DIST Thunder Bay HWY 595 BOREHOLE TYPE Hollow Stem Auger 80 mm COMPILED BY DB
 DATUM Local DATE 2014 09 09 CHECKED BY DM

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa						
						20	40	60	80	100	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	
						50	100	150	200	250	WATER CONTENT (%)			
97.9	GROUND SURFACE													
97.8 / 0.1	TOPSOIL SILT-trace gravel, trace clay, cobbles, BROWN, LOOSE TO VERY DENSE		AS1	AS										
			SS2	SS	50+									
			SS3	SS	6									
95.6														
2.3	SAND-silty, trace gravel, DARK GREY, COMPACT TO DENSE		SS4	SS	11									
			SS5	SS	12									5 49 (46)
			SS6	SS	34									
			SS7	SS	29									
92.6														
5.3	END OF BOREHOLE Auger Refusal on Possible Bedrock													

ON_MOT-HIGH VANES GS-TB-019502 STICH CREEK 2.GPJ_DST_MIN.GDT 11/24/14

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

RECORD OF BOREHOLE No BH4

1 OF 1

METRIC

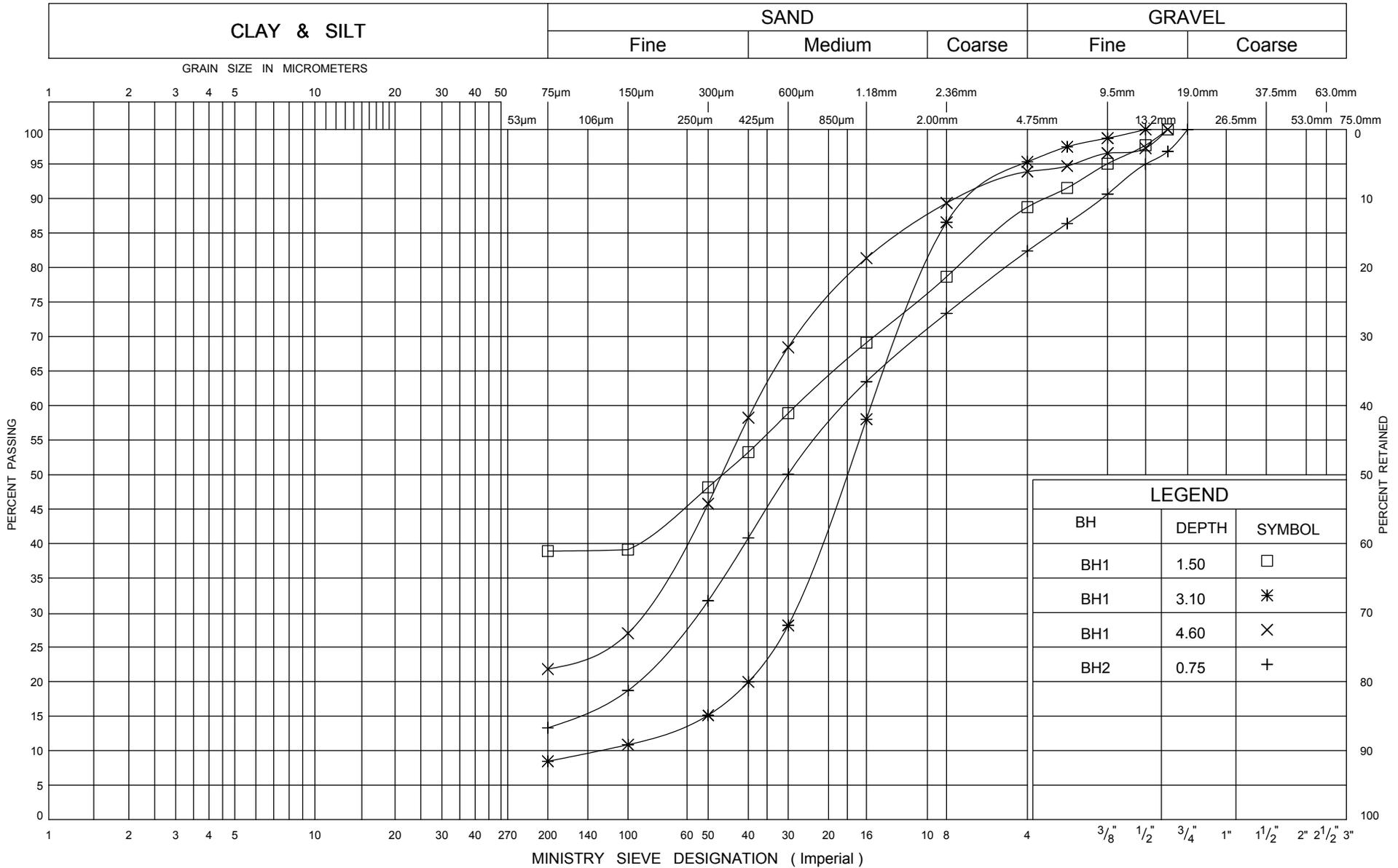
W.P. 6013-E-0021 LOCATION Stich Creek #2 STA 10+777 LT 15.0 m ORIGINATED BY PR
 DIST Thunder Bay HWY 595 BOREHOLE TYPE Hollow Stem Auger 80 mm COMPILED BY DB
 DATUM Local DATE 2014 09 09 CHECKED BY DM

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	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES			20	40	60	80	100						50	100	150
98.0	GROUND SURFACE																		
98.0/0.0	TOPSOIL	AS1	AS																
97.7/0.3	SAND-with gravel, some silt, cobbles	SS2	SS	8															
	SILT-with sand to sandy, trace clay, cobbles, BROWN/ DARK GREY, LOOSE TO COMPACT	SS3	SS	8															
		SS4	SS	9															
		SS5	SS	6															
		SS6	SS	11															
		SS7	SS	9															
		SS8	SS	14															
92.0	END OF BOREHOLE																		
6.0																			

ON_MOT-HIGH VANES GS-TB-019502 STICH CREEK 2.GPJ_DST_MIN.GDT 11/24/14

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

UNIFIED SOIL CLASSIFICATION SYSTEM



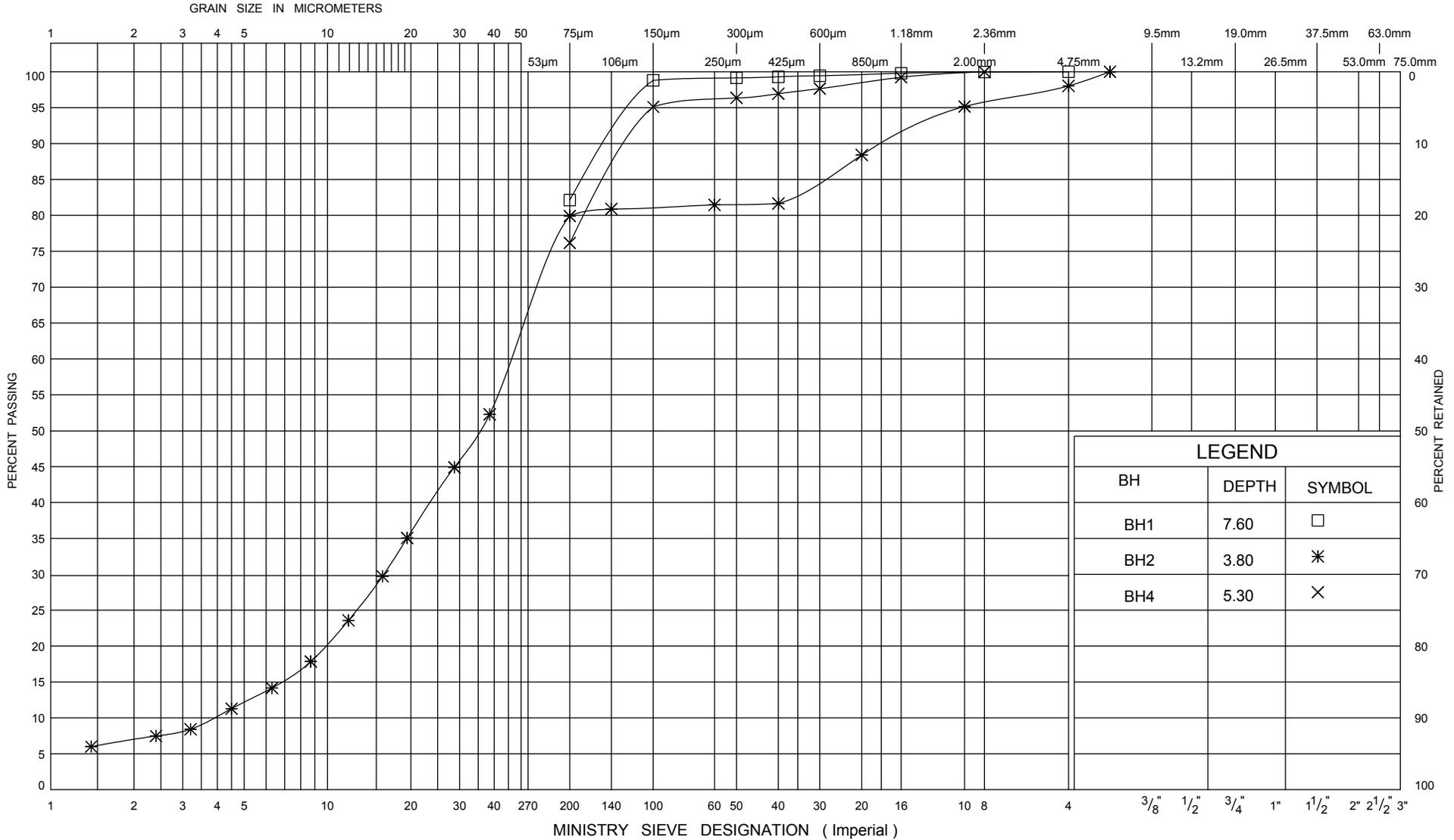
GRAIN SIZE DISTRIBUTION FILL-SAND

ENCLOSURE 5
W P 6013-E-0021
HWY 595



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



GRAIN SIZE DISTRIBUTION SILT

ENCLOSURE 7
W P 6013-E-0021
HWY 595



Ministry of
Transportation
Ontario