FOUNDATION INVESTIGATION AND DESIGN REPORT MOLLIE RIVER CULVERT REPLACEMENT HIGHWAY 144 TOWNSHIP OF BENNEWEIS DISTRICT OF SUDBURY SITE 46-244 AGREEMENT No.: 5009-E-0061 GWP: 5533-04-00 GEOCRES NO.: 41P-48

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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, Northeastern Region to conduct a geotechnical investigation for a proposed culvert replacement on Highway 144. This work was carried out under Agreement No.: 5009-E-0061 - Geotechnical Retainer - Assignment No.4.

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

2. SITE DESCRIPTION

The site is located on Highway 144, approximately 2.7 km north of Highway 560, in Benneweis Township, District of Sudbury. The structural site number is 46-244.

The existing culvert is a Structural Plate Corrugated Steel Pipe Arch with the dimensions of 7.9 m × 4.9 m × 22.30 m (Figures 2.1 and 2.2). The height of existing embankment is approximately 7.0 m and slope of the embankment is at an approximate slope of 2H:1V (Figure 2.3). The existing culvert allows the flow of Mollie River from west side to east side of Highway 144 (Figure 2.4). Both sides of the highway at this location are moderately wooded (Figure 2.5).

According to the previous geotechnical investigation, the embankment consists of about a 3.0 m thick layer of round boulders (15 to 30 cm) that is underlain by a compact to very dense alluvial medium to coarse grained sand deposit. The photographs were taken during DST drilling activities on October 30, 2010.

Geological information is available from *Northern Ontario Geology Terrain Study Map # 41PSW* published by the Ontario Ministry of Natural Resources for the area. The local terrain for the area has been identified as a esker complex or crevasse filling with sand and gravel material. The topography in the area is mainly of low local relief with the dominant land surface being kettled or pitted terrain and the surface drainage condition being typically dry.

Figure 2.1 Culvert inlet (looking east) (taken on October 30, 2010)

Figure 2.2 Culvert outlet (looking west) (taken on October 30, 2010)

Figure 2.3 East embankment (Looking North) (taken on October 30, 2010)

Figure 2.4 Mollie River (looking west) (taken on October 30, 2010)

Figure 2.5 Vegetation (looking north) (taken on October 30, 2010)

3. INVESTIGATION PROCEDURES AND LABORATORY TESTING

Site work was carried out in the period of six days (October 29, 2010 to November 3, 2010) utilizing a CME 850 drill rig that was operated by Landcore drilling personnel. A total of nine (9) boreholes (including five (5) machine drilled and four (4) hand augered boreholes) were put down at this site.

The boreholes were advanced using wash boring technique. Two boreholes were advanced at the edge of the shoulder on the opposite side of the existing culvert. An additional three boreholes was drilled along the centreline of the highway. One of the three boreholes was advanced within 1.0 m of the edge of the existing culvert and remaining two were drilled at 10 m interval from the centreline of the existing culvert on either side of the pipe. A total of four (4) hand augered boreholes including two (2) hand augered boreholes advanced at each end of the existing culvert (inlet and outlet). The minimum number of boreholes and depths of boreholes were specified by MTO.

Borehole locations and stratigraphic sections are shown on the Borehole Location Plans, (Drawings 1 to 3). Boreholes were put down using solid stem auger and washboring technique except hand auger boreholes that were advanced by a hand operated auger. All boreholes encountered auger refusals at various elevations, which could represent boulders or bedrock. The borehole locations were chosen according to the given specification in assignment order form by MTO.

The borehole locations are referenced to MTO Station numbering system as indicated in the request for quotation. The centre of the existing culvert station was assumed as Station 10+000. The ground surface elevations at the borehole locations were surveyed by DST personnel. Elevations were measured with respect to a MTO benchmark that is located about 19 m east of the embankment and about 48 m north of the existing culvert and 378.86 m above sea level (Drawing 1). Table 3.1 summarizes the detail of borehole locations and depths.

Table 3.1 Detail of borehole locations

Borehole ID	Station	Elevation (m)	Depth (m)	Offset (m)
BH1	10+010	381.6	8.5	2.1 Rt
BH2	10+004	381.4	14.0	2.3 Lt
BH3	9+994.5	381.2	12.5	2.3 Lt
BH4	9+993	381.2	8.4	2.3 Rt
BH5	9+983	381.0	14.9	2.1 Rt
HA1	10+006	376.1	0.2	14.0 Lt
HA2	9+993.5	376.4	0.9	14.0 Lt
HA3	10+008	375.7	0.4	14.4 Rt
HA4	9+992	375.8	0.8	14.4 Rt

The fieldwork was supervised on a full-time basis by DST personnel who located the boreholes in the field, performed sampling and in-situ testing and logged the boreholes. In-situ tests included Standard Penetration Test (SPT). 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.

All boreholes were abandoned using suitable abandonment barrier as described in Ontario Regulation 903 and its amendments. Boreholes BH 1 to BH 5 were sealed with at least 20% solids bentonite slurry sealant and borehole cuttings and covered with cold patch asphalt (at least 0.2 m thick) to surface. Boreholes HA1 to HA4 were sealed with at least 20% solids bentonite slurry sealant and soil to surface.

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, sieve analyses and particle size analyses. A total of forty one (41) moisture contents, nine (9) sieve analyses and one particle size analyse has been done for this assignment. Laboratory test results are presented in the Boreholes Logs (Enclosures 1 to 9), and Plots (Enclosures 10 to 12).

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, consists of asphalt overlying a sand and gravel fill material that is underlain by rockfill overlying a gravel material. Layers with higher silt and sand contents were also encountered within the gravel layer and may be discontinuous. Cobbles and boulders were encountered during the drilling process. Table 4.1 summarizes the elevations and depths of boreholes at auger refusals.

Table 4.1 Depths and elevations of auger refusals

Borehole ID	Depth of auger refusal (m)	Elevation of auger refusal (m)
BH1	8.5	373.1
BH3	12.5	368.7
BH4	8.4	372.8
BH5	14.9	366.1
HA1	0.2	375.9
HA2	0.9	375.5
HA3	0.4	375.3
HA4	0.8	375.0

4.1 Asphalt

Asphaltic concrete was encountered at the top in Boreholes BH 1 to BH 5. The thickness of the asphalt varies between 150 and 200 mm.

4.2 Sand and Gravel Fill

A fill material was identified immediately below the asphalt in Boreholes BH 1 to BH 5 with thicknesses of approximately 0.4, 0.5, 0.5, 0.4 and 0.4 m at depths from 0.2 to 0.6 m (Elev. 381.4 to 381.0 m), 0.15 to 0.6 m (Elev. 381.3 to 380.8 m), 0.15 to 0.6 m (Elev. 381.1 to 380.6 m), 0.2 to 0.6 m

(Elev. 381.0 to 380.6 m) and 0.6 to 4.6 m (Elev. 380.8 to 380.4 m) respectively.

A particle size analysis was conducted on a sample from Borehole BH 1 and the results are shown in following Table 4.2. According the granular gradations, the material identified in the embankment fill can be classified as “Granular A” (SP110S13, Table 2). The moisture content of the tested samples was found to be 1%.

Table 4.2 Summary of fill particle size analysis

Laboratory Results - Particle Size Analysis	
Gravel %	40
Sand %	55
Fines %	5

4.3 Rockfill

Rockfill was identified immediately below the fill (sand and gravel) in Boreholes BH 1 to BH 5 with thicknesses of 2.4, 4.0, 2.5, 4.7 and 4.0 m at depths from 0.6 to 3.0 m (Elev. 381.0 to 378.6 m), 0.6 to 4.6 m (Elev. 380.8 to 376.8 m), 0.6 to 3.1 m (Elev. 380.6 to 378.1), 0.6 to 5.3 m (Elev. 380.6 to 375.9 m) and 0.6 to 4.6 m (Elev. 380.4 to 376.4 m) respectively. Cobbles were identified during the geotechnical investigation within this material. Sand and gravel may also be presented within the rockfill.

4.4 Gravel

Gravel material was identified in Boreholes BH 1, 2, 3, 4, 5, HA1, HA2, HA3 and HA4 at depths of 3.0 m (Elev.378.6 m), 4.6 m (Elev. 376.8 m), 3.1 m (Elev. 378.1 m), 5.3 m (Elev. 375.9 m), 4.6 m (Elev. 376.4 m), 0.1 m (Elev. 376.0 m), 0.1 m (Elev. 376.3 m), 0.1 m (Elev. 375.6 m) and 0.0 m (Elev. 375.8 m). During the drilling process the cobbles and boulders were noted within this layer in the Boreholes BH 1 to BH 5. The thickness of this stratum is not defined for Boreholes BH 1 to BH 4, and HA1 to HA4 as borehole terminus was reached within this stratum. For Borehole BH 5 the thickness of this stratum was found to be 5.4 m.

SPT values vary from 18 to 100+ and indicate the compactness condition varying from compact to very dense, noting that the presence of cobbles and boulders may have inflated these values.

Particle size analyses were conducted on samples from Boreholes BH 1, BH 2, and BH 5, and the results are shown in following Table 4.3. The moisture content of the tested samples was found to vary from 5 to 20%.

Table 4.3 Summary of gravel particle size analyses

Laboratory Results -Particle Size Analyses	
Gravel %	45 to 69
Sand %	25 to 38
Fines %	3 to 8

4.5 Gravel and Sand

Gravel and sand material was encountered in Borehole BH 1 within the gravel layer with a thickness of approximately 0.9 m at a depth from approximately 6.5 to 7.4 m (Elev. 375.1 to 374.2 m).

SPT value of this material was 19 and indicates the compactness condition of compact.

A particle size analysis was conducted on a sample from Borehole BH 1 and the results are shown in following Table 4.4. The moisture content of the tested samples was found to be 8 %.

Table 4.4 Summary of gravel and sand particle size analyses

Laboratory Results - Particle Size Analyses	
Gravel %	45
Sand %	42
Fines %	13

4.6 Silt

A silt layer was identified in BH 3 within the gravel layer with a thickness of approximately 1.5 m at a depth from approximately 10.0 to 11.5 m (Elev. 371.2 to 369.7 m).

SPT value was recorded to be 47 which indicate a compactness condition of dense. A particle size analysis was conducted on a sample from Borehole BH 3 and the results are shown in following Table 4.5. The moisture content of the tested samples was found to be 31%.

Table 4.5 Summary of silt particle size analysis

Laboratory Results - Particle Size Analysis	
Gravel %	0
Sand %	18
Silt %	80
Clay %	2

4.7 Sand

Sand material was encountered in Borehole BH 5 with a thickness of approximately 3.7 m at a depth from 10.0 to 13.7 m (Elev. 371.0 to 367.3 m).

SPT values of this material vary from 19 to 100+ and indicate the compactness condition varying from compact to very dense.

A particle size analysis was conducted on a sample from Borehole BH 5 and the results are shown in following Table 4.6. The moisture content of the tested samples was found to vary from 15 to 23%.

Table 4.6 Summary of sand particle size analyses

Laboratory Results - Particle Size Analyses	
Gravel %	0 to 1
Sand %	64 to 90
Fines %	10 to 35

4.8 Groundwater

During the time of field investigation, the water level at the river was at the elevation of 375.7 m. Since gravel was encountered in the boreholes at this elevation, the groundwater table is expected to be close or slightly above to the elevation of river water level. The groundwater levels can be expected to vary with season and precipitation events.

Table 4.7 Depth of water table at boreholes

Borehole ID	Borehole elevation (m)	Depth of water table below the ground surface (m)	Water table elevation (m)
BH1	381.6	5.9	375.7
BH2	381.4	5.6	375.8
BH3	381.2	5.4	375.8
BH4	381.2	5.5	375.7
BH5	381.0	5.2	375.8
HA1	376.1	Dry	< 375.9
HA2	376.4	0.5	375.9
HA3	375.7	0.0	375.7
HA4	375.8	0.1	375.7

5. MISCELLANEOUS

Site work was carried out between October 29, 2010 to November 3, 2010 utilizing a CME 850 drill rig as well as portable equipment that were both operated by Landcore drilling personnel. Fieldwork was supervised on a full time basis by Steven Prime, P.Eng 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 Loges Paramaguru and Deep Bansal and reviewed by Wesley Saunders, P.Eng and 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 DESCRIPITION

DST Consulting Engineers Inc. (DST) has been retained by the Ministry of Transportation (MTO), Geotechnical Section, Northeastern Region to conduct a geotechnical investigation for a proposed culvert replacement on Highway 144. It is understood that the proposed replacement will involve the placement of a larger opening culvert spanning the existing culvert and the existing culvert will be subsequently removed after new structure has been installed. This proposed culvert replacement is a lager open footing culvert such as Super-Cor steel structure. The roadway protection is required to facilitate the staged construction.

The culvert replacement will be located approximately at same elevation (375.7 m) and location as the existing culvert. The replacement will span the existing culvert. The top of the existing culvert will be subsequently removed after the construction of the new culvert.

The generalized stratigraphy of the existing embankment, based on the conditions encountered in boreholes, consists of asphalt overlying a sand and gravel fill material that is underlain by rockfill overlying a gravel material. Layers with higher silt and sand contents were also encountered and may be discontinuous. Cobbles and boulders were encountered within the gravel materials during the drilling process. The water table is expected to be at the elevation close to the river water level.

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

6.1 Open Footing Culvert

The open footing culvert is referred to a culvert with individual wall foundations on either side of a stream bed or passageway. The terms of reference indicate that the preferred option for the culvert replacement is a larger open footing culvert such as a Super-Cor steel structure supported on spread footings. Generally, three different types of Super-Cor structures are constructed for culverts such as box, arch and round.

The design of the open footing culvert new structure must be in accordance with the Canadian Highway Bridge Design Code CAN/CSA-S6-06 and all relevant Ministry of Transportation specification and guidelines.

6.1.1 Earth Excavation

An open cut operation along the proposed culvert alignment is proposed by MTO for the culvert replacement. This method of construction may result in traffic disturbances and construction of temporary pavement for traffic. Since rock fill within the embankment and cobbles and boulders below the embankment were encountered during field investigation, contractor should be prepared for the excavation and accommodation of these materials during the construction. As a minimum, the procedures should be in accordance with OPSS 902 “Construction Specifications for Excavating and Backfilling-Structures”. If temporary protection systems are required they shall be constructed in accordance with OPSS 539 “Construction Specification for Temporary Protection Systems” and Section 5.1.6 Roadway Protection.

The geotechnical investigation did not show any evidence of organic materials beneath embankment fill except a trace of woods and rootlets in Borehole 5. However, if organic materials are encountered beneath the existing fill, excavations to remove these organics and wood should be completed in accordance with OPSD 203.040.

It is anticipated that the existing groundwater table will be above the invert level. Excavation can be undertaken either dewatering of the excavation or keeping wet without lowering the water table. If excavation is completed in the wet, any sub-excavated materials can be replaced with 19 mm Type I or II clear stone as defined in OPSS 1004.05.02 surrounded with a non-woven geotextile (OPSS 1860.07.05.01 Class II) with a filtration opening size (FOS) less than 135 µm. If excavation is carried out in the dry (with adequate dewatering controls), the material can be replaced with Granular A material meeting SSP 110S13 specifications and compacted to a minimum of 95 % of standard Proctor maximum dry density in accordance with OPSS 501.

6.1.2 Staged Construction

Staged construction has been identified by prime consultant (Genivar) as preferred approach to maintain traffic during the construction of the culvert at this site. The proposed stage construction includes three (3) stages as given in Drawing 4 through 6. Slope stability analyses for the proposed slope geometries have been conducted for all stages and are presented in Section 5.1.4 Embankment Design.

Stage 1 is a temporary lane diversion which involves routing traffic along the existing southbound lane and excavating a portion of the northbound lane at a slope not steeper than 1.5H:1V to allow for the installation of a temporary bridge structure. It is anticipated that excavation in the northbound lane will be predominantly within rock fill materials. Use of temporary concrete barriers will be required.

Stage 2 is a temporary lane diversion which involves routing traffic over the temporary bridge structure to allow for the rehabilitation of the culvert structure and subsequent fill placement for Stage 3. In this configuration, the temporary slope of the granular backfill materials on the eastern embankment will be not steeper than 1.75H:1V and the temporary slope of the granular backfill materials on the western embankment will be 2H:1V. The western embankment will be benched to accommodate the presence of the temporary bridge structure. Use of temporary concrete barriers will be required.

Stage 3 is a temporary lane diversion which involves routing traffic along the widened southbound lane to allow for the removal of the temporary bridge structure and the subsequent completion of fill placement of the completed road structure. Embankment foreslopes should be reinstated as recommended in Section 5.1.11 Embankment Foreslopes.

6.1.3 Foundation Design

The open footing culvert will be located approximately at the same elevation and location as the existing culvert, while maintaining a larger size. The construction of the alternative culvert footings will result in stress changes underneath the foundation of the culvert.

As the proposed culvert is not expected to be heavily loaded and competent subsurface materials were encountered in boreholes, shallow foundations are considered suitable for this site. 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 load resistance factor of 0.5 according to the Canadian Highway Bridge Design Code (CHBDC) CAN/CSA-S6-06 section 6.6.3.6, Table 6.1. The geotechnical resistance was estimated assuming strip footings of variable width at minimum depths of 0.5, 1.0 and 1.5 m which correspond to elevations of 375.4, 374.9 and 374.4 m respectively. Settlement of the structure can be considered negligible due to the marginal change in net loading. Table 6.1 summarizes geotechnical resistance against the width of footing.

Table 6.1 Geotechnical resistances and reactions for strip footings

Elevation of Footing, El. (m)	Width of Footing, B (m)	Ultimate Bearing Capacity, (kPa)	Factored Resistance at ULS, (kPa)	Reaction at SLS, (kPa)
375.4	0.5	250	125	125
	1	280	140	140
	1.5	330	165	165
374.9	0.5	390	195	190
	1	420	210	190
	1.5	465	235	185
374.4	0.5	530	265	180
	1	560	280	180
	1.5	610	305	175

Culvert foundation can be constructed either with dewatering of excavation or without lowering the water in the excavation. If the construction of foundation is carried out at wet, foundation construction can be performed by Tremie concrete placement. In this case, soil below foundation should be carefully prepared to minimize the disturbance.

6.1.4 Embankment Design

Slope stability analyses were carried out with limit equilibrium methods using Geoslope version 2004 software applying Morgenstern and Price methods. Targeted factor of safety for slope stability analyses was 1.3 for permanent condition and 1.2 for temporary condition. As only drained materials are present on site, only drained analyses were performed. Slope stability analyses were performed under the following slope conditions with an embankment height of up to 5.0 m:

- Reinstated embankment with minimum 2H:1V granular fill foreslopes,
- Temporary embankment with 1.5H:1V rock fill foreslopes,
- Temporary embankment with 1.75H:1V granular fill foreslopes

- Temporary embankment with 2H:1V granular fill foreslopes and 2.5 m bench height.

Results indicate that stability will meet or exceed suitable design factors of safety under a drained condition for the evaluated slope configurations and are presented in Table 6.2.

Table 6.2 Summary of stability analyses

Slope Condition	Depth of Water Table below Top of Pavement (m)	Foreslope Gradient	Factor of Safety
Reinstated Embankment with Granular Fill	1.0	2H : 1V	1.3
Temporary Embankment with Rock Fill	1.0	1.5H : 1V	1.3
Temporary Embankment with Granular Fill	1.0	1.75H : 1V	1.2
Temporary Embankment with Granular Fill with 2.5 m bench height	1.0	2H : 1V	1.4

This analyses considered the soil parameters as defined in Table 6.3 and a water table at 1.0 m below the top of pavement in reinstated and temporary embankment conditions respectively.

Excavation of temporary side slopes above the water table that do not support traffic should not be steeper than 1.0H:1.0V, although, flatter slopes may be required depending on construction methods. Temporary rock fill slopes above the water table supporting traffic during the construction stages should not be steeper than 1.5H:1V. Temporary granular slopes above the water table supporting traffic during the construction stages should not be steeper than 1.75H:1V and should be constructed with Granular A or B materials meeting SSP110S13 specifications and compacted to a minimum of 95 % of standard Proctor maximum dry density in accordance with OPSS 501. Design of temporary slopes below the water table will depend on the dewatering method. Embankment foreslopes should be reinstated as indicated in Section 6.1.11 Embankment Foreslopes.

The trench width must be sufficient to permit proper use of compaction equipment suited for the material to be compacted, to reach the degree of compaction required, and to accommodate within the space available as per OPSS 501, “Construction Specification for Compaction”.

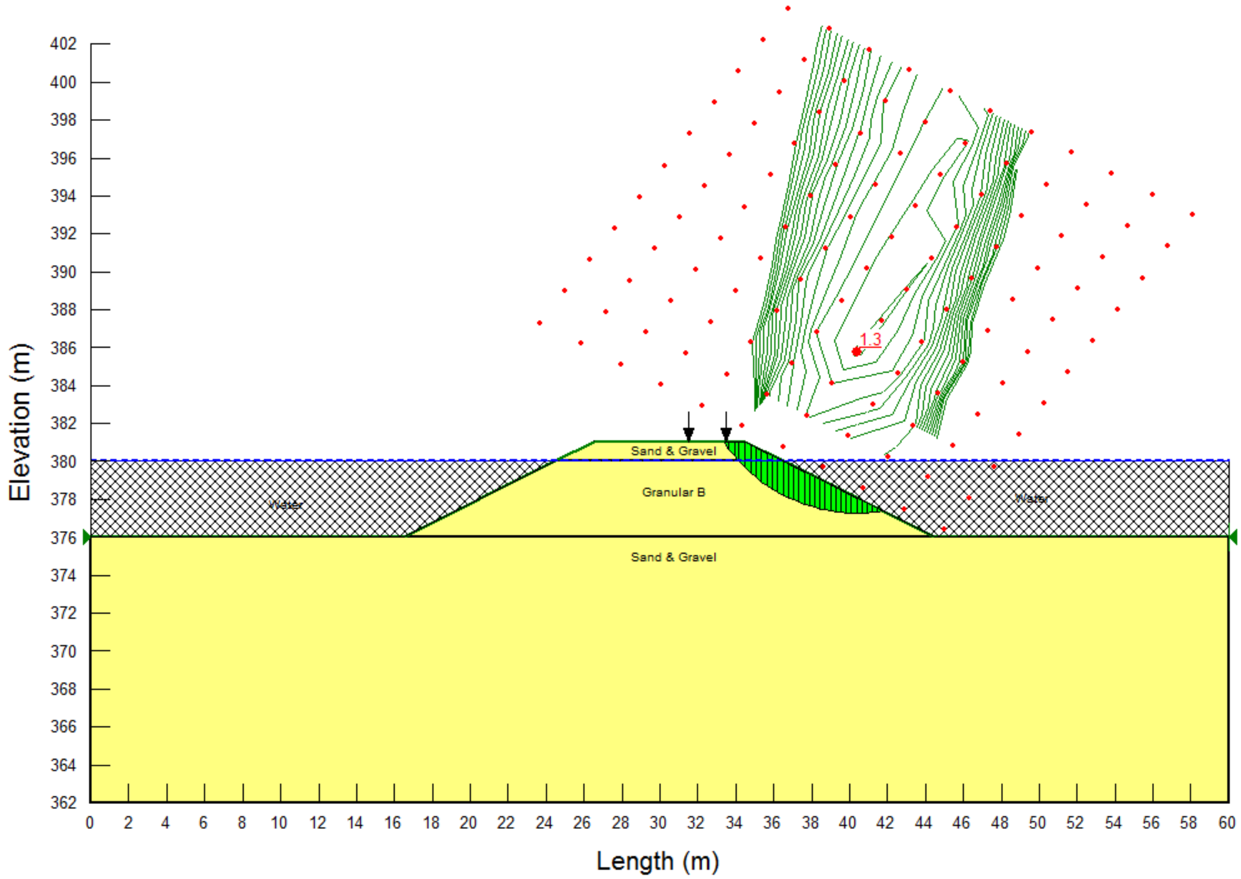

Figure 6.1 Slope stability analysis of reinstated embankment with 2H:1V granular fill foreslopes under drained condition

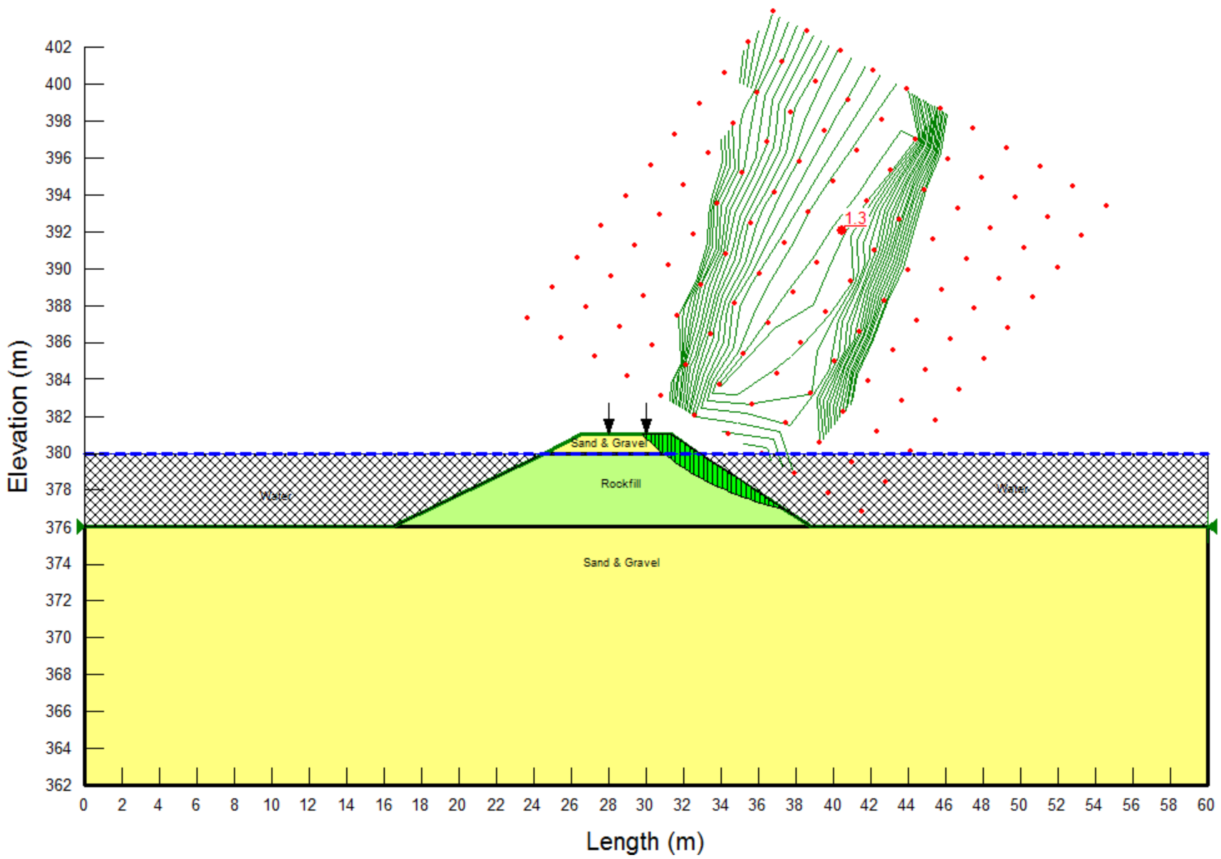

Figure 6.2 Slope stability analysis of temporary embankment with 1.5H:1V rock fill foreslopes under drained condition

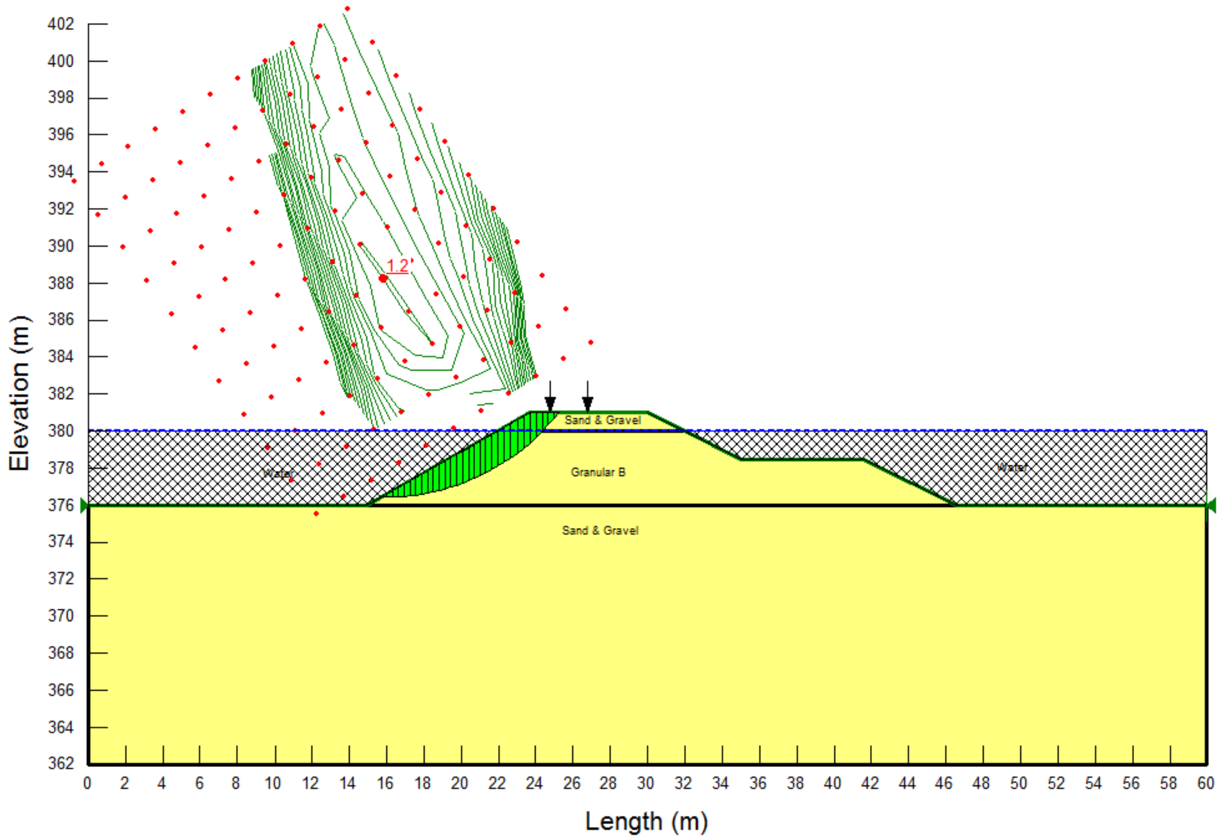

Figure 6.3 Slope stability analysis of temporary embankment with 1.75H:1V granular fill foreslopes under drained condition

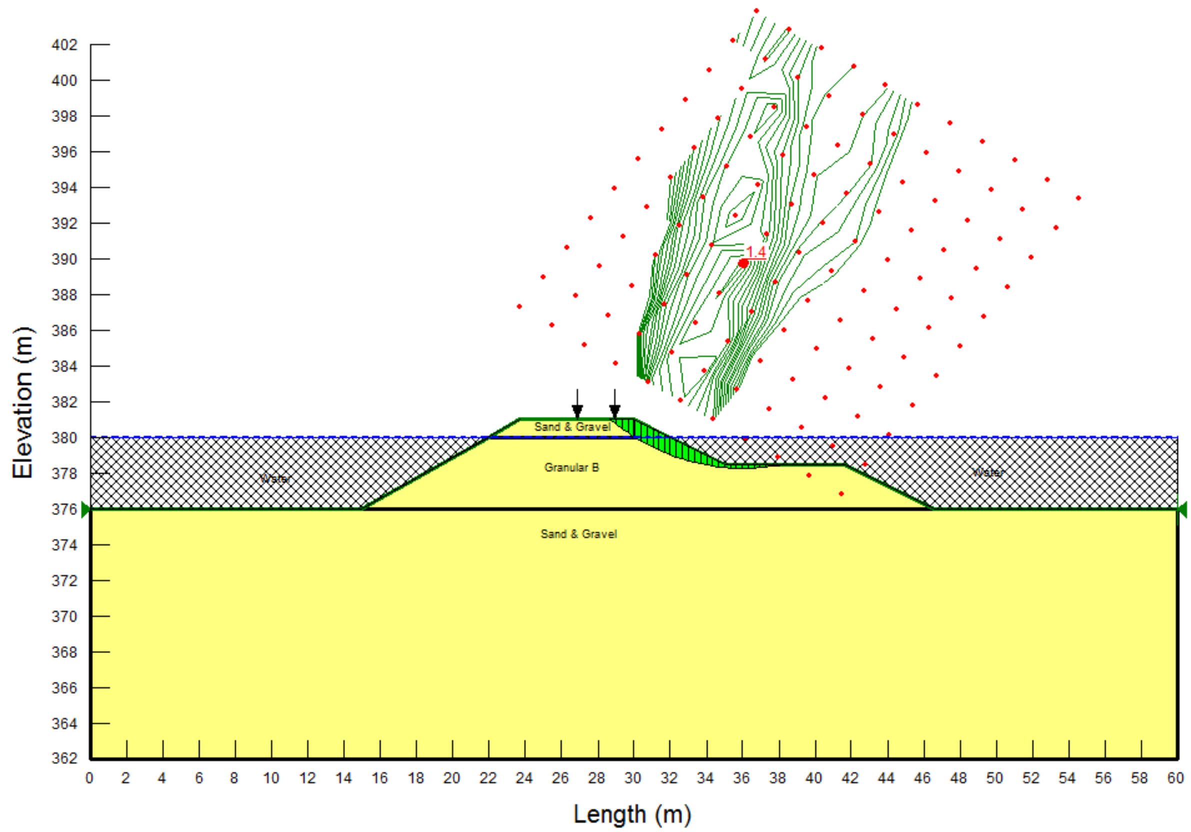

Figure 6.4 Slope stability analysis of temporary embankment with 2H:1V granular fill foreslopes with 2.5 m bench height under drained condition

6.1.5 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 6.3 and assuming linearly variation of stress change with the depth as described in Section 7.8.5.3.2 in Canadian Highway Bridge Design Code. Temporary bracing and shoring may be designed using the typical soil parameters given in Table 6.3, 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 shoring design.

Resistance to lateral forces/sliding resistance between the base slab for the replacement of culvert and subgrade should be calculated in accordance with section 6.7.5 of the CHBDC.

The coefficients for lateral earth pressure can be calculated using equations provided in Table 6.4. Where no significant earth movements are expected, the coefficient K_o should be used.

Table 6.3 Typical soil parameters for existing soils

Soil type	Unit weight (kN/m^3)	Angle of internal friction ϕ (Deg)	Interface friction angle (Concrete-Soil), δ (Deg)
Granular B	21	33	17
Granular A	21	33	17
Rock fill	21	40	-
Gravel to Sand and Gravel	20	33	17
Sand	20	30	16

Table 6.4 Lateral earth pressure coefficients

Earth Pressure Coefficient	Equation*
Active Earth Pressure (K_a)	$\left(\frac{1 - Sin\emptyset}{1 + Sin\emptyset}\right)$
Passive Earth Pressure(K_p)	$\left(\frac{1 + Sin\emptyset}{1 - Sin\emptyset}\right)$
At rest (K_o)	$(1 - Sin\emptyset)$

* Φ is an angle of internal friction

6.1.6 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 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.

Roadway protection is not required for the embankment during the culvert replacement to maintain traffic during the construction. Since rockfill, cobbles and boulders were identified at this site a typical sheet pile system will not be feasible for the site. If roadway protection is required the installation of soldier piles and lagging can be considered to retain one half of roadway embankment for traffic. The design of soldier piles and lagging may be performed using the typical soil parameters given in Table 5.3, but the designer/contractor should verify the appropriate soil parameters for the designs. Alternatively, a detour construction on the highway could be considered which is likely more practical. These systems should be designed by an engineer familiar with these types of designs.

The construction methodology must be in accordance with OPSS 539 “Construction Specification for Temporary Protection Systems” as well as Ministry of Transportation, Ministry of Environment, Ministry of Natural Resources and Department of Fisheries and Oceans guidelines, and also the Occupational Health and Safety Act of Ontario. The contractor’s method and equipment must be suitable for the site conditions and materials used.

6.1.7 Structural Backfill

The backfill for the structure should be designed in accordance the contract documents, Section 7.7.5 of the CHBDC and as specified in OPSS 902 “Construction Specification for Excavation and

Backfilling Structures".

The bottom of the excavation on which the footing is to rest should not be disturbed. In soft conditions, construction of the footing should commence immediately after the final removal of material to the foundation level has been completed.

Excavations for foundation should be extended laterally to at least 0.5 m from the edge of footing. The foundation grade should be filled with Granular "A" material meeting SSP110S13 specifications and compacted to a minimum of 95 % of standard Proctor maximum dry density.

If construction is performed without dewatering, bedding material should consist of 19 mm Type I or II clear stone as defined in OPSS 1004.05.02. If 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 may be required for separation. The clear stone may be placed with a minimum thickness of 50 mm up to the thickness required to reach the desired grade or construct in dry conditions if necessary. No compaction is required of the clear stone.

The extent of the backfill should be selected as given specification in Figure 7.7 in the Canadian Highway Bridge Design Code. The structural backfill should be free of stones exceeding 75 mm in any dimension, debris, organic matter, or frozen materials. Heavy equipment should not be allowed within 1 m of the culvert walls. The backfill material should be separated from the adjacent soil with a non-woven Class II geotextile specified in OPSS 1860. Overfill soils should not be compacted greater than the compaction or equivalent stiffness of soils in the foundation.

6.1.8 Channel Diversion and Dewatering

Since the existing culvert is left in place until the new culvert is constructed, river diversion may not be required for construction. In this case, flow of the river should be completely directed through the existing culvert during the construction. It is important to ensure that a flood in the river does not cause damage to the partly constructed permanent works, to the temporary works or to plant. Floods have a habit of occurring overnight or at weekends and inadequate temporary works can fail with expensive consequences.

If the river has comparatively a small amount of flow (may depend on the season), flow can be directed through existing culvert. In order to prevent back up of water from upstream and downstream, a dyke made of sand bags is sometimes been used as a hydraulic barrier. A suitable sump and pump system, supported by an efficient deep well on wellpoint system, will be required to dewater and stabilize the excavation. A well designed well system with a suitable diameter of well at an appropriate spacing will be required for working under dry condition and to prevent disturbance of the excavation base through sand boiling and hydraulic heave. The variable stratigraphy below the rock fill including silt and silty layers must be considered in the dewatering design. It should be noted that depending on the season, depth of excavation and amount of water flow through the river may vary. The contractor should be prepared to tackle this situation. If flow of the river is high, a cofferdam set up can be considered for the construction. The design of cofferdam may be in accordance with "Foundation Investigation and Design Recommendation for Cofferdam and Dewatering at Mollie River Culvert (MTO GEOCRES NO. 41P-42).

Where dewatering is performed, all dewatering operations should be completed in accordance with OPSS 517 "Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation". If construction is to be completed in the dry 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. In addition, the control of water from the dewatering operation should be accordance with OPSS 518 "Construction Specification for Control of Water from Dewatering Operations".

Water shall be disposed of so as not to be injurious to public health or safety, property, the environment, fisheries, or any part of the work completed or under construction. Dewatering operations shall be directed to a sediment control device or natural attenuation area prior to discharge to watercourses. If a natural attenuation area is used, a minimum 15 m setback shall be maintained from the receiving watercourse. When water is discharged to a watercourse, the water discharged shall be done in a manner that does not cause erosion or other damage to adjacent lands.

Since high volume of dewatering (>50 m^3/day) is expected, Permit To Take Water (PTTW) should be obtained for this construction from Ministry of the Environment. The construction should also be performed accordance to the Ministry of Natural Resources and Department of Fisheries and Oceans guidelines.

6.1.9 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 accordance with OPSD 810.020 “Rip-Rap Treatment for Ditch Inlets” and OPSS 511 and SP511S01 “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 “Rip-Rap treatment for Sewer and Culvert Outlets” and OPSS 511 and SP511S01 “Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting”.

To prevent undermining the bedding of the culvert, cutoff walls should be installed along the entrance and exit end bottom sides of culvert. Cutoff wall should be designed based on velocity of the water flow and the type of soil underneath. The cutoff wall may be installed accordance with “Cutoff Wall for Structural Plate Pipe Arch and Circular CSP” at the inlet and outlet

Considering the permeable nature of the native materials and existing embankment surrounding the culvert installation a clay seal will not be required.

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”.

6.1.10 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.

Given the temperatures during the winter inside the culvert (and particularly given the large size of the culvert), ice is expected to from inside the culvert. At low rate of flow, it is possible that ice may extend to the culvert invert and frost could therefore extend into the soils below the culvert, possibly as deep as 2.2 m. The frost heave may generate additional stresses on the culvert foundation and walls.

Two design approaches are commonly feasible, either 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) or removing the frost susceptible soils within the frost zone. The removal of frost susceptibility material (silt) requires complete removal of materials within the zone of influence extending 2.2 m below foundation level, and laterally 50% of that distance beyond the sides of the culverts (although a two dimensional advanced thermal analysis may indicate somewhat less).

6.1.11 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 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.

6.1.12 Construction Concerns

The main construction issues that need to be addressed with open cut excavation are provisions required for roadway protection, excavation below the water table, dewatering during construction and reinstatement of the embankment fill. These items are important for the successful installation of the new culvert. Particular attention should be paid to maintain the integrity of the existing culvert during the staged method of construction as well as the ability of the chosen construction method to accommodate the presence of rock fill and cobbles within the embankment fill and native materials.

A Quality Verification Engineer shall be required to inspect the condition of the foundation and surrounding soils before installation of bedding and other backfills and ensure the width of trench and trench slope walls are suitable, and ensure compliance with materials placed and compaction methods.

7. REFERENCES

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 Work*s" Spec No. *OPSS* 501, 510, 511, 517, 518, 539, 805, 902.

Municipal and Provincial Common, Volume 3 - Drawings for Roads, Barriers, Drainage, Sanitary Sewers, Watermains and Structures, "*Ontario Provincial Standard for Roads & Public Work*s" Spec No. *OPSD* 203.040, 803.010, 810.010, 810.020, 3090.100.

Municipal and Provincial Common, Volume 2 - Material Specifications, "*Ontario Provincial Standard for Roads & Public Work*s" Spec No. *OPSS* 1860.

Special Provisions, Ontario Provincial Standards, SSP110S13, SP105S10, SP511S01.

8. 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:

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Junior Project Manager

Reviewed by:

Dr. M W Bo, PhD., P. Eng, P.Geo, Int PE, C.Geol, C. Eng, Eur Geol, Eur Eng
Senior Principal / Director (GeoServices)

Reviewed by:

Wesley Saunders, P. Eng.
Project Manager

A P P E N D I X ‘ A ‘

L I M I T A T I O N S O F R E P O R T

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 a Quality Verification Engineer 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'

EXPLANATION OF TERMS USED IN REPORT

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 Ñ.

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:

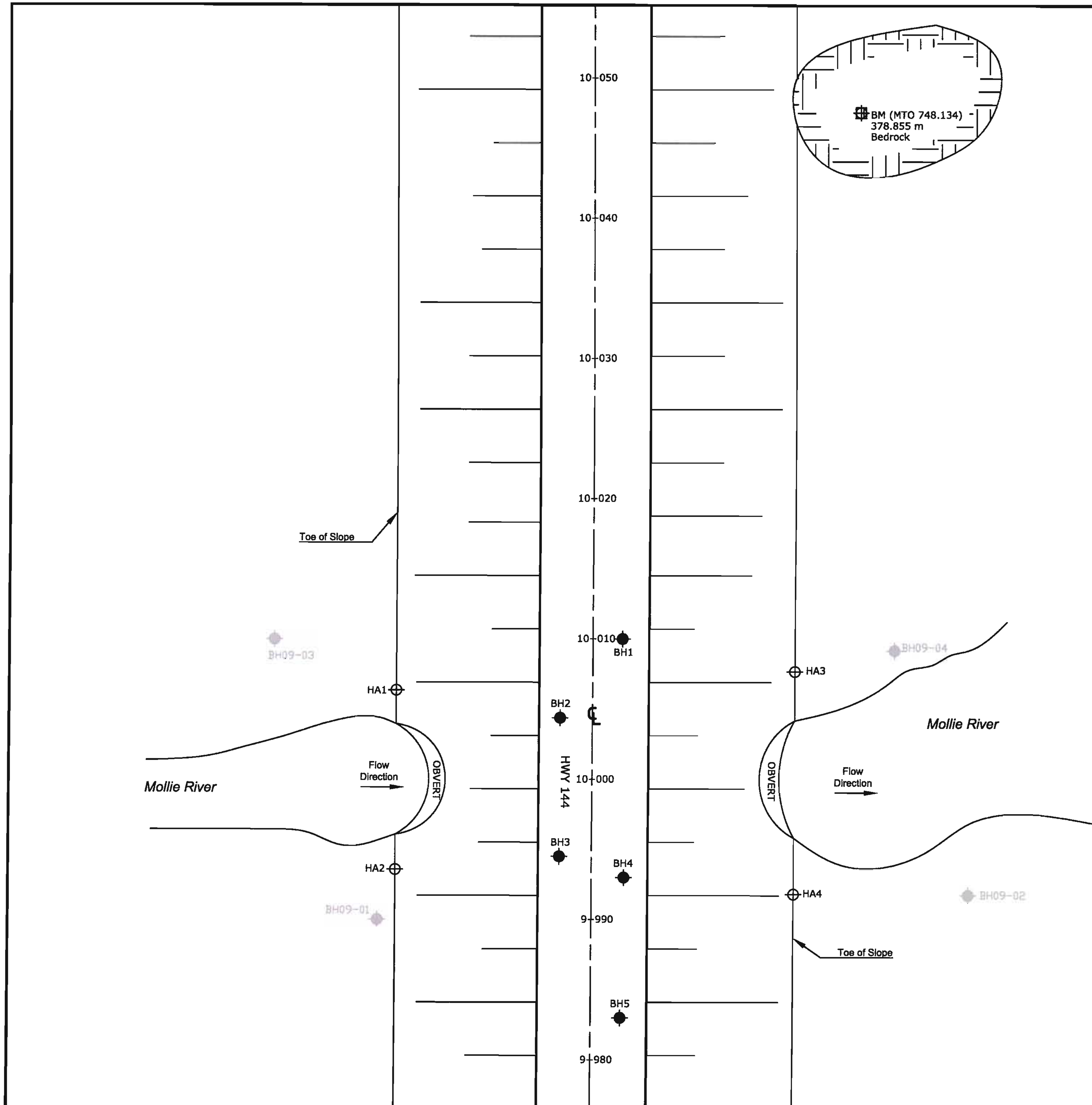
R.Q.D (%)	0 – 25	25 – 50	50 – 75	75 – 90	90 – 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

LEGEND OF RECORDS FOR BOREHOLES: SYMBOLS AND ABBREVATIONS 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.

D R A W I N G S

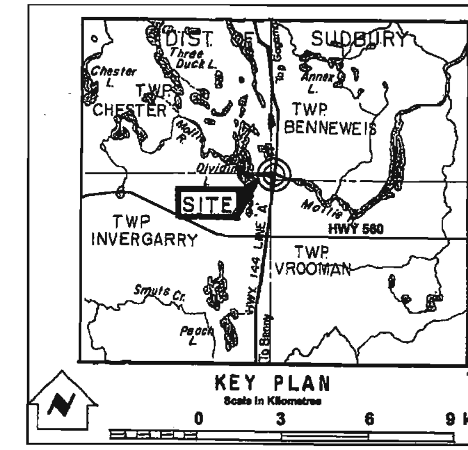


METRIC

AGREEMENT No. 5009-E-0061
CONT No. 2012-5107
GWP No. 5533-04-00
GEOCRES No. 41P-48
SITE: 46-244

HIGHWAY 144
Mollie River Culvert Replacement
BOREHOLE LOCATIONS & SOIL STRATA

SHEET



LEGEND

- Borehole
- Hand Auger
- Borehole with DCPT
- 'N' Blows/0.3m (Std. Pen Test, 475 J/Blow)
- Water level at time of investigation.
- Benchmark

Fill, Organics, Topsoil, Till, Boulders & Cobbles, Sand, Silt, Clay, Sand & Gravel

No.	Elevation	Northing	Easting	Station	Offset
BH10-01	381.56	5260720	436450	10+010	2.1 m RT
BH10-02	381.41	5260712	436448	10+004	2.3 m LT
BH10-03	381.21	5260710	436446	9+994.5	2.3 m LT
BH10-04	381.21	5260703	436449	9+993	2.3 m RT
BH10-05	381.04	5260691	436451	9+983	2.1 m RT
HA10-01	376.07	5260720	436438	10+006	14.0 m LT
HA10-02	376.35	5260707	436435	9+993.5	14.0 m LT
HA10-03	375.71	5260716	436467	10+008	14.4 m RT
HA10-04	375.81	5260699	436463	9+992	14.4 m RT

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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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DRAWING 1

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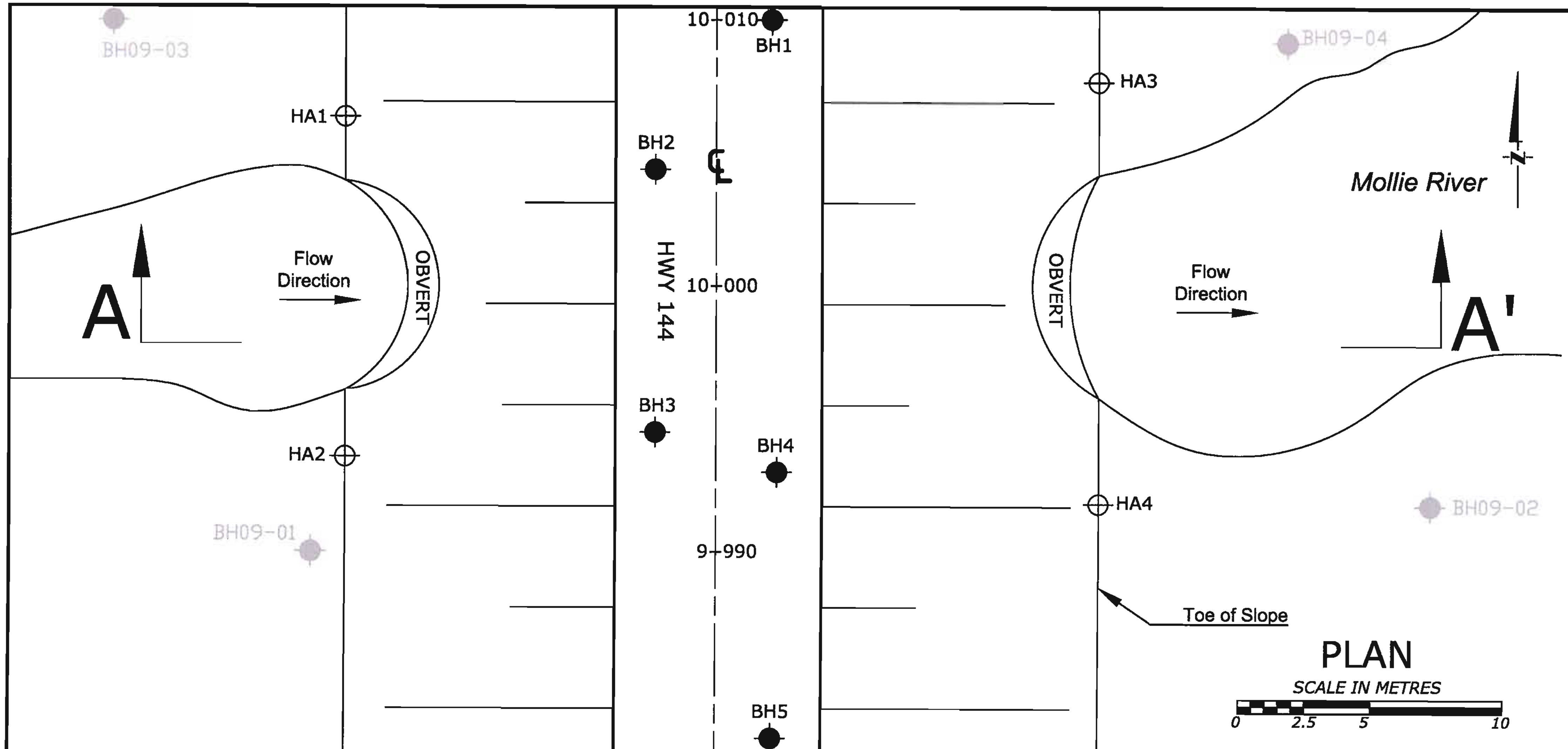
HIGHWAY 144
Mollie River Culvert Replacement
BOREHOLE LOCATIONS & SOIL STRATA

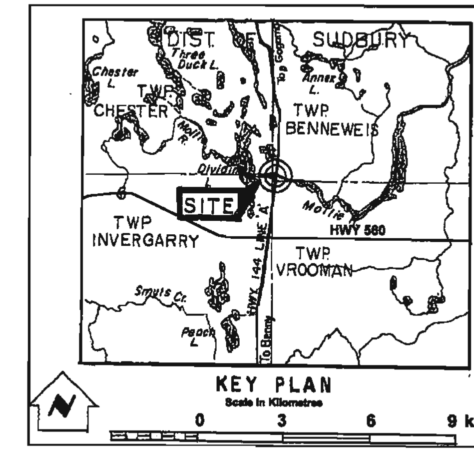
SHEET 11

METRIC



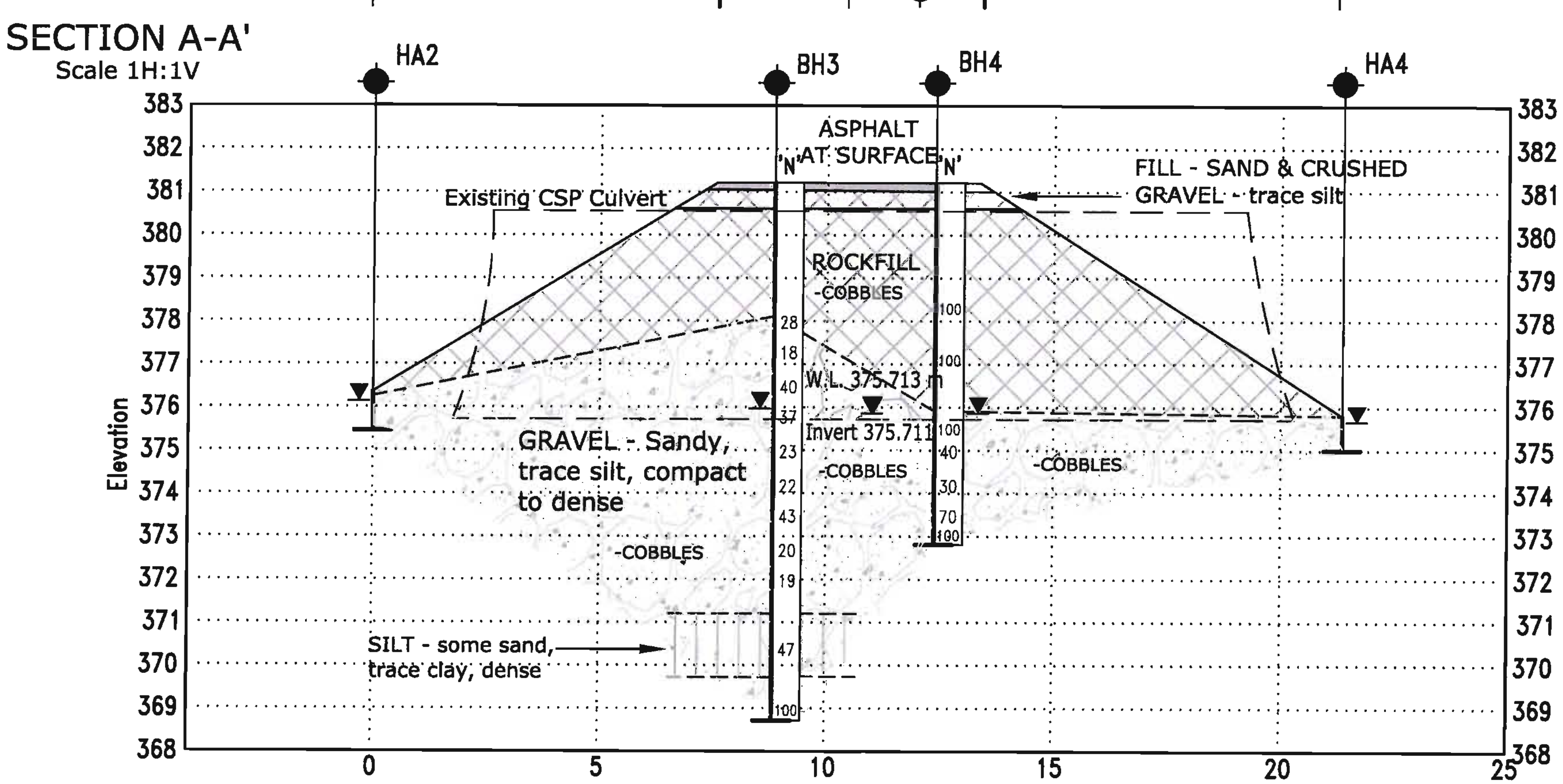
PLAN

SCALE IN METRES 0 2.5 5 10



SECTION A-A'

Scale 1H:1V



LEGEND

- Borehole
- Hand Auger
- Borehole with DCPT
- 'N' Blows/0.3m (Std. Pen Test, 475 J/Blow)
- Water level at time of investigation.
- Benchmark

Fill, Organics, Topsoil, Till, Gravel, Sand, Silt, Clay, Sand & Gravel

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*Auger Refusal encountered in all boreholes

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DRAWING 2

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GEOCRES No.	41P–48
SITE:	46–244

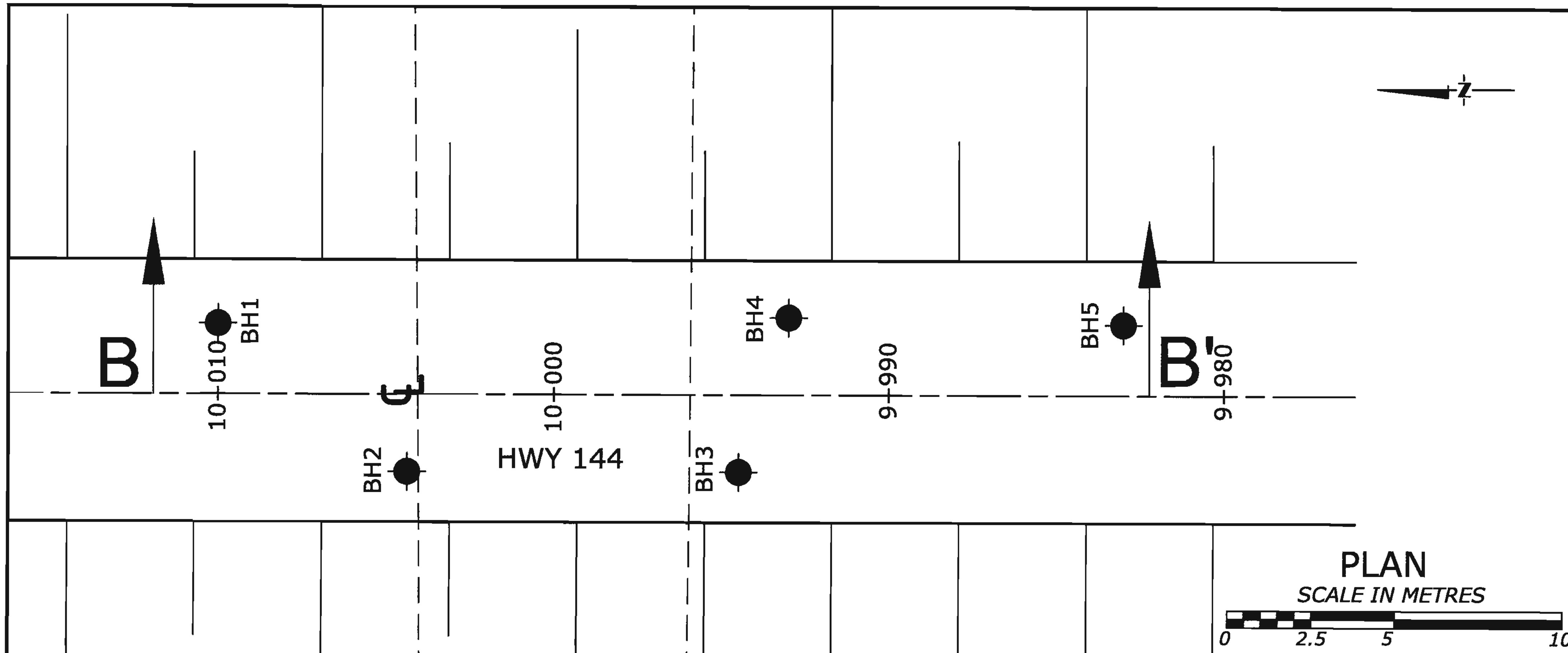
HIGHWAY 144

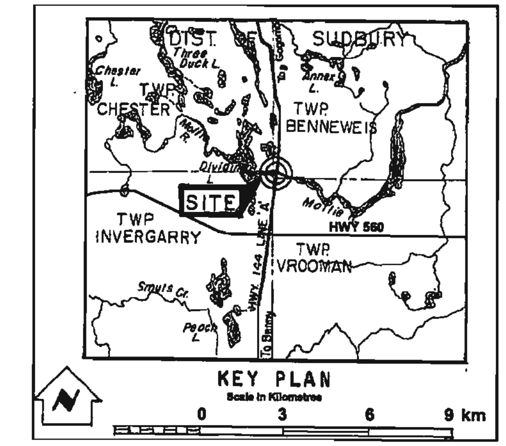
Mollie River Culvert Replacement

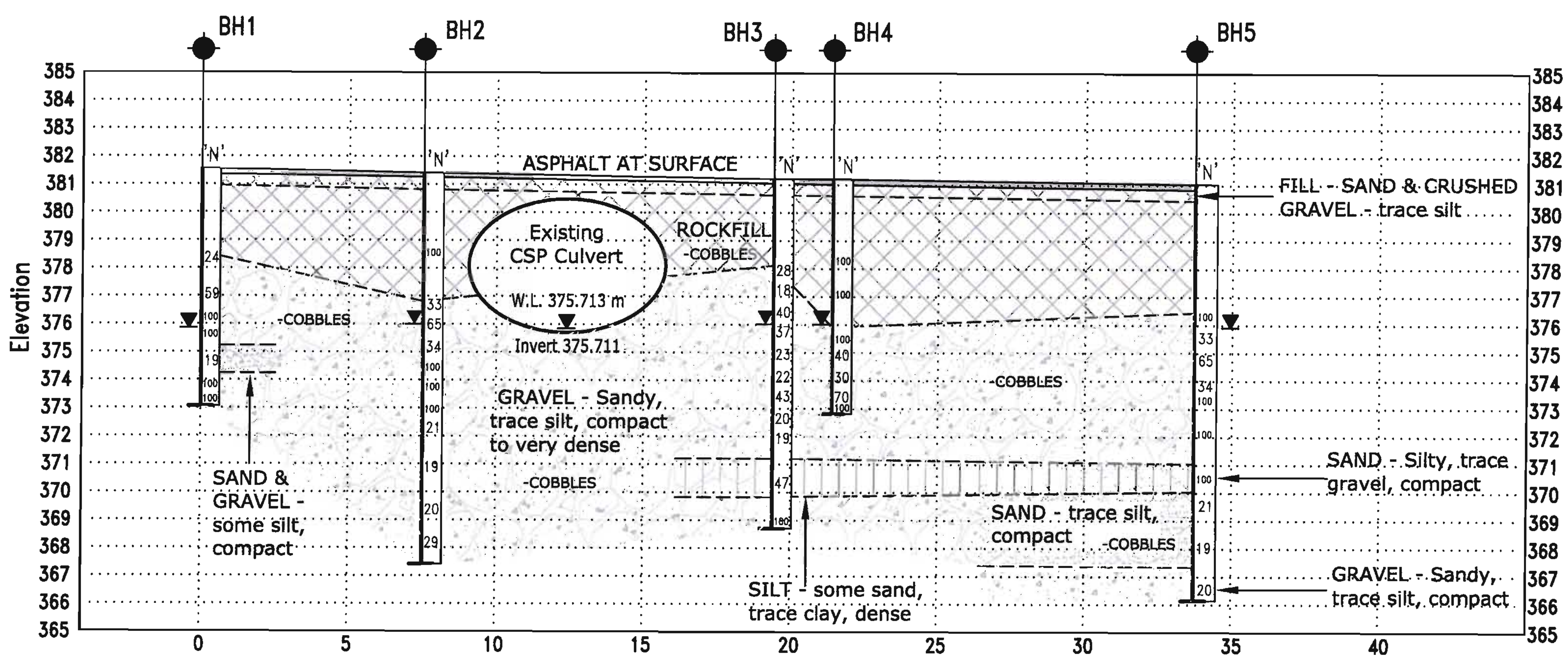
BOREHOLE LOCATIONS & SOIL STRATA

SHEET 12

METRIC







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PROVINCE OF ONTARIO

LEGEND

- Borehole
- Hand Auger
- Borehole with DCPT
- 'N' Blows/0.3m (Std. Pen Test, 475 J/Blow)
- Water level at time of investigation.
- Benchmark
- Fill
- Organics
- Topsoil
- Till
- Gravel
- Sand
- Silt
- Clay
- Sand & Gravel

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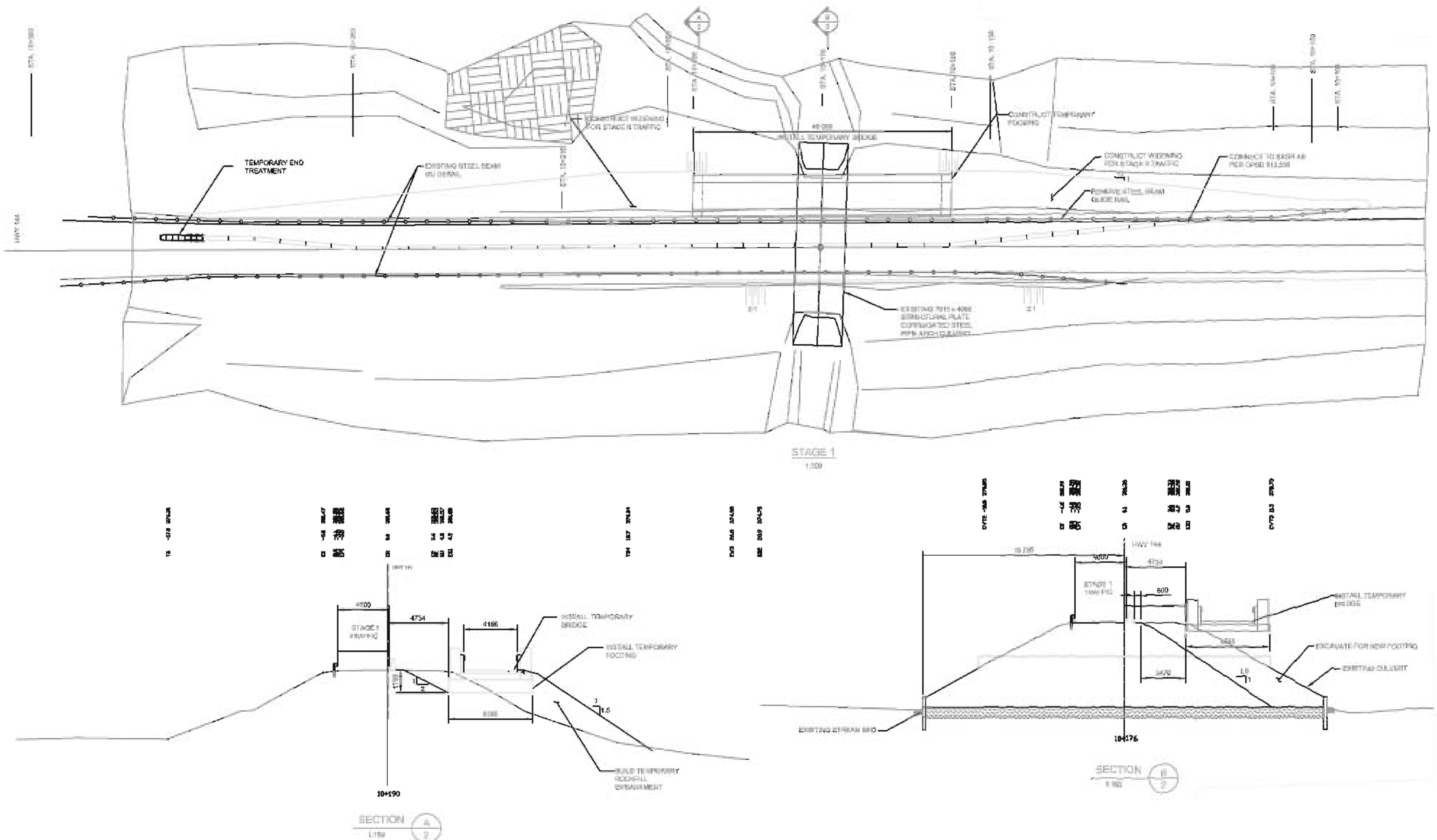
DRAWING 3

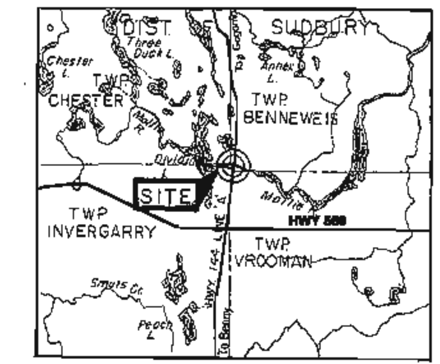
AGREEMENT No. 5009-E-0061
CONT No. 2012-5107
GWP No. 5533-04-00
GEOCRES No. 41P-48
SITE: 46-244

METRIC

HIGHWAY 144
Mollie River Culvert Replacement
STAGE 1

SHEET





KEY PLAN
Scale in Kilometres
0 3 6 9 km

LEGEND

- Borehole
- Hand Auger
- Borehole with DCPT
- 'N' Blows/0.3m (Std. Pen Test, 475 J/Blow)
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DRAWING 4

METRIC

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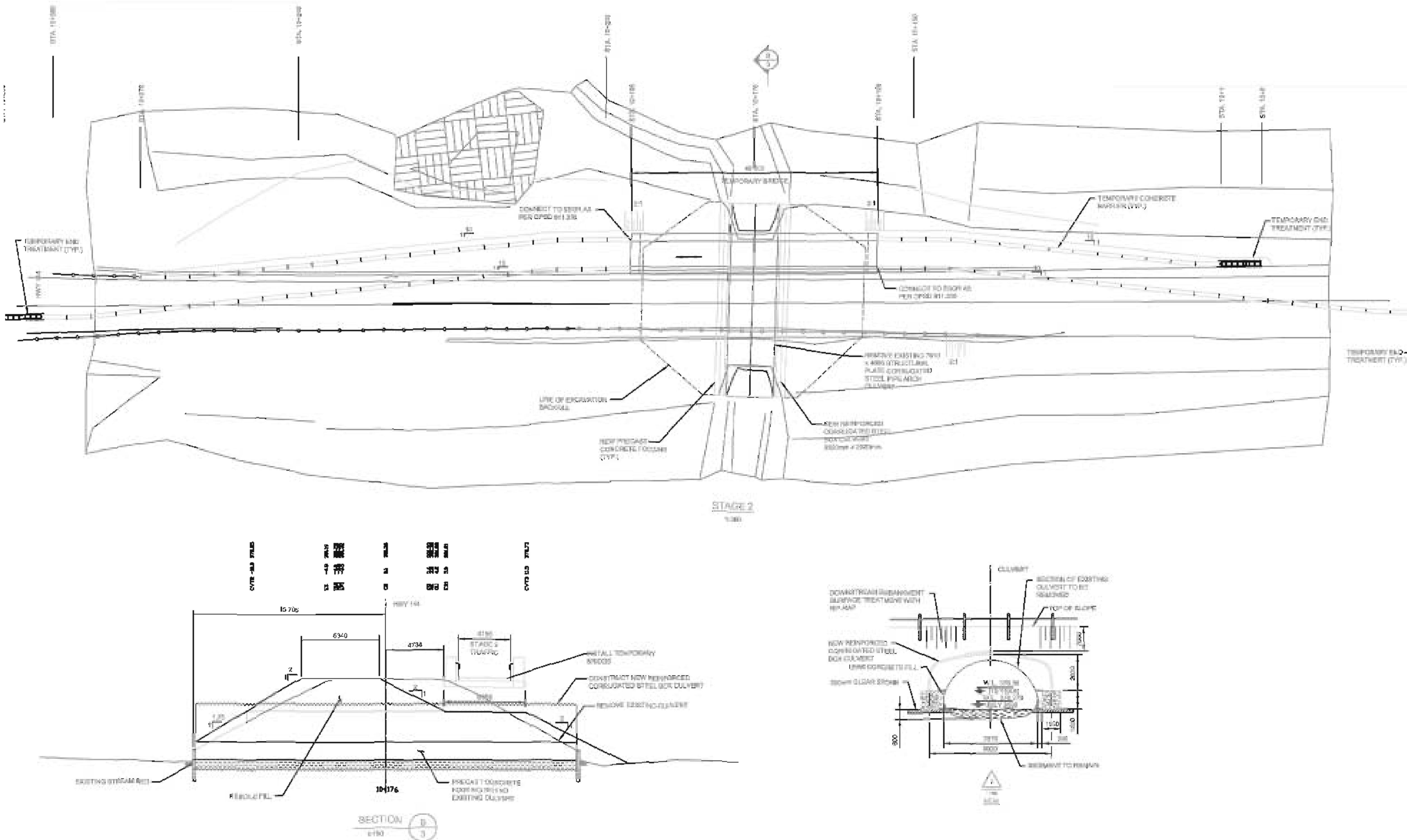
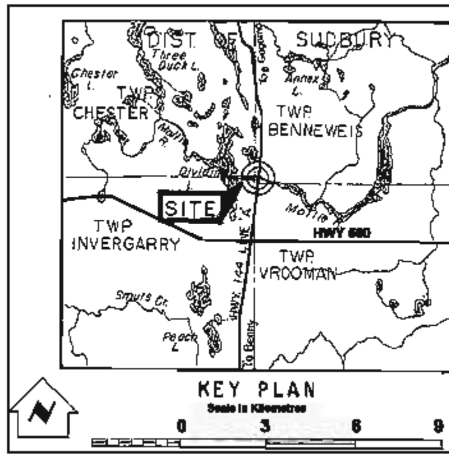
GEOCRES No. 41P-48
SITE: 46-244

HIGHWAY 144
Mollie River Culvert Replacement
STAGE 2

SHEET





LEGEND

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Fill, Organics, Topsoil, Till, Boulders & Cobbles, Sand, Silt, Clay, Sand & Gravel

No.	Elevation	Northing	Easting	Station	Offset
BH10-01	381.05	5269720	435450	10+010	2.1 m RT
BH10-02	381.41	5269712	435448	10+004	2.3 m LT
BH10-03	381.21	5269710	435446	9+994.5	2.3 m LT
BH10-04	381.21	5269703	[illegible]	9+993	2.3 m RT
BH10-05	381.04	5269691	435451	9+983	2.1 m RT
HA10-01	376.07	5269720	435438	10+006	14.0 m LT
HA10-02	376.35	5269707	435435	9+993.5	14.0 m LT
HA10-03	376.71	5269716	435457	10+008	14.4 m RT
HA10-04	376.51	5269699	435463	9+992	14.4 m RT

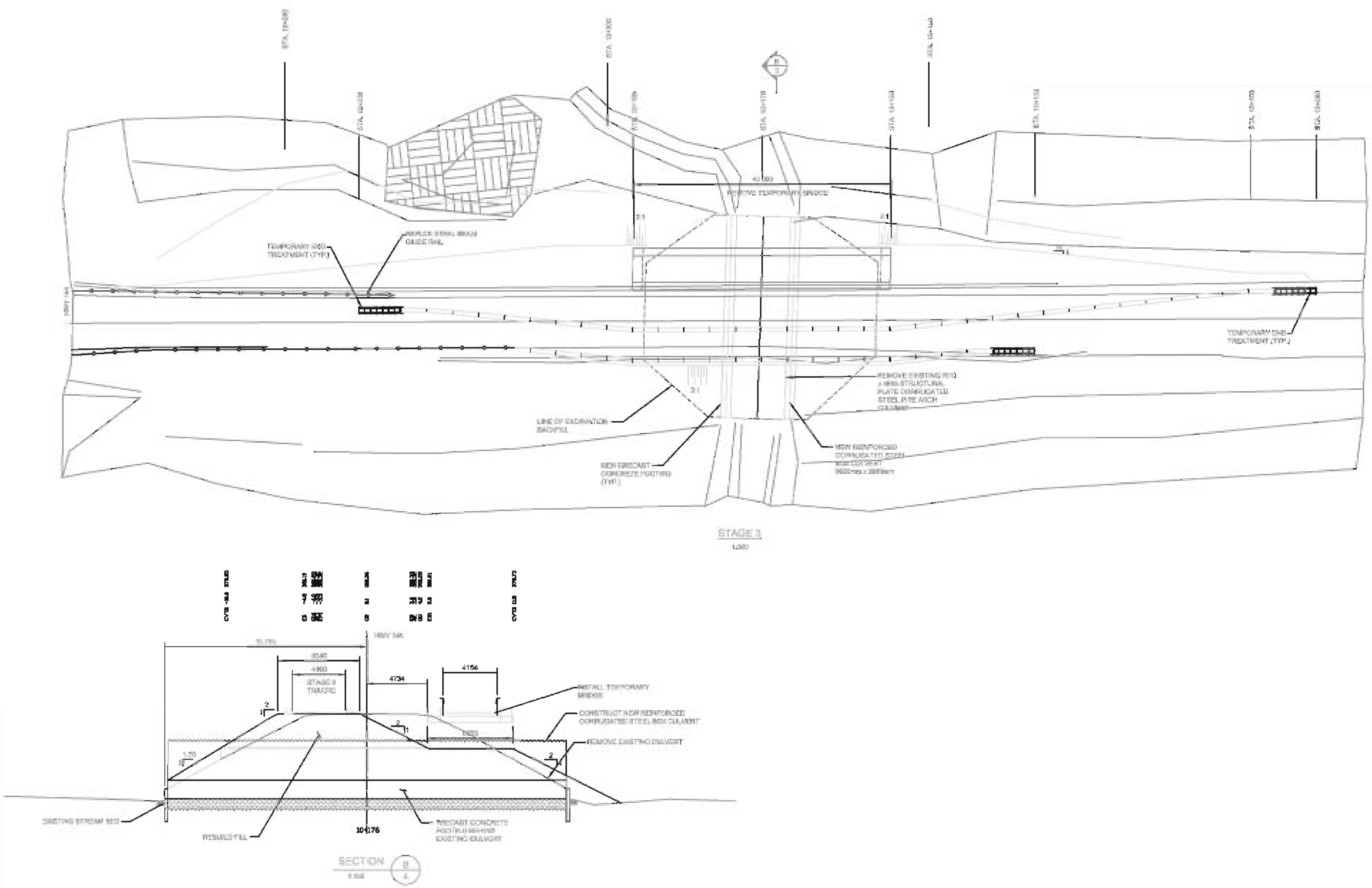
NOTE:
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed by interpolation and may not represent actual conditions.

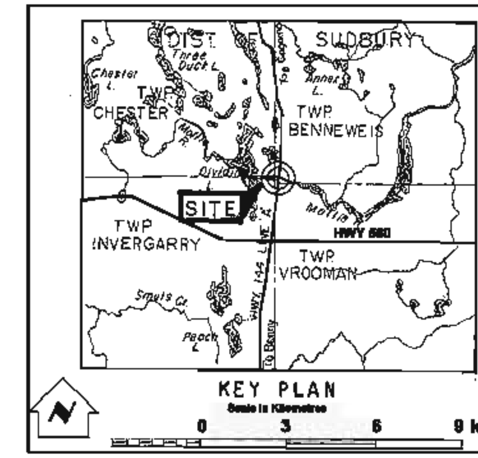
DST consulting engineers
DST Consulting Engineers Inc.
605 Hewitson Street
Thunder Bay, ON P7B 5V5
Ph: (807) 623-2929
Fx: (807) 623-1792
Email: thunderbay@dstgroup.com

DRAWING 5

AGREEMENT No. 5009-E-0061 CONT No. 2012-5107 GWP No. 5533-04-00 GEOCRES No. 41P-48 SITE: 46-244	
HIGHWAY 144 Mollie River Culvert Replacement STAGE 3	SHEET

METRIC





LEGEND

- Borehole
- Hand Auger
- Borehole with DCPT
- 'N' Blows/0.3m (Std. Pen Test, 475 J/Blow)
- Water level at time of investigation.
- Benchmark
- Fill
- Organics
- Topsoil
- Till
- Boulders & Cobbles
- Sand
- Silt
- Clay
- Sand & Gravel

No.	Elevation	Northing	Easting	Station	Offset
BH10-01	381.56	5260720	436460	10+016	2.1 m RT
BH10-02	381.41	5260712	436448	10+004	2.3 m LT
BH10-03	381.21	5260710	436446	9+994.5	2.3 m LT
BH10-04	381.21	5260703	436449	9+993	2.3 m RT
BH10-05	381.04	5260691	436451	9+983	2.1 m RT
HA10-01	376.07	5260720	436438	10+006	14.0 m LT
HA10-02	376.35	5260767	436435	9+993.5	14.0 m LT
HA10-03	376.71	5260716	436457	10+008	14.4 m RT
HA10-04	376.81	5260698	436463	9+992	14.4 m RT

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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DRAWING 6

E N C L O S U R E S

RECORD OF BOREHOLE No BH1

1 OF 1 **METRIC**

W.P. 5533-04-00 LOCATION STA. 10+010, 2.1 m RT (17T 5260720 m N, 436450 m E) ORIGINATED BY SP

DIST ___ HWY 144 BOREHOLE TYPE Solid Stem Auger (100 mm), Washbore (76 mm ID) COMPILED BY ML

DATUM Geodetic DATE 2010 10 30 CHECKED BY MWB

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
381.6	GROUND SURFACE						
381.4 / 0.2	ASPHALT - 200 mm FILL - SAND & CRUSHED GRAVEL - trace silt, brown	AS1	AS			381	40 55 (5)
381.0 / 0.6	ROCKFILL - cobbles					380, 379	Dry cave at 4.9 m on completion. Water level at 375.7 m
378.6 / 3.0	GRAVEL - Sandy, trace silt, brown, compact to very dense - cobbles	SS2	SS	24		378	58 37 (5)
		SS3	SS	59		377	
		SS4	SS	100+		376	SPT 60/150 mm 10/0 mm
		SS5	SS	100+	∇ (375.7)		SPT 25/150 mm 10/0 mm
375.1 / 6.5	SAND & GRAVEL - some silt, brown, compact	SS6	SS	19		375	45 42 (13)
374.2 / 7.4	GRAVEL - Sandy, trace silt, brown, very dense - cobbles	SS7	SS	100+		374	SPT 35/150 mm 14/150 mm 10/0 mm 58 38 (4)
373.1		SS8	SS	100+			SPT 6/150 mm 13/150 mm 10/0 mm
8.5	End of Borehole at 8.5 m Auger Refusal						

Column headings also include: STRAT PLOT; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, □ QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³.

NR = NO RECOVERY +³, ×³: Numbers refer to Sensitivity O³% STRAIN AT FAILURE

RECORD OF BOREHOLE No BH2

1 OF 1 **METRIC**

W.P. 5533-04-00 LOCATION STA. 10+004, 2.3 m LT (17T 5260712 m N, 436448 m E) ORIGINATED BY SP

DIST HWY 144 BOREHOLE TYPE Solid Stem Auger (100 mm), Washbore (76 mm ID) COMPILED BY ML

DATUM Geodetic DATE 2010 11 01 CHECKED BY MWB

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
381.4	GROUND SURFACE						
381.3 / 0.2	ASPHALT - 150 mm						Dry cave at 6.4 m on completion. Water level at 375.8 m
	FILL - SAND & GRAVEL - trace silt, brown	AS1	AS			381	
380.8 / 0.6	ROCKFILL - cobbles					380	
						379	
		SS2	SS	100+		378	SPT 100/150 mm
376.8 / 4.6	GRAVEL - Sandy, trace silt, brown/grey, compact to very dense - cobbles	SS3	SS	33		377	
		SS4	SS	65	∇	376	
		SS5	SS	34		375	
		SS6	SS	100+		374	59 33 (8) SPT 30/150 mm 10/0 mm
		SS7	SS	100+			SPT 26/150 mm 10/0 mm
		SS8	SS	100+		373	SPT 10/0 mm
	- - - - - brown	SS9	SS	21		372	
		SS10	SS	19		371	
						370	
		SS11	SS	20		369	
		SS12	SS	29		368	63 34 (3)
367.4 / 14.0	End of Borehole at 14.0 m						

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, □ QUICK TRIAXIAL, × LAB VANE: 20 40 60 80 100

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L — WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m³

NR = NO RECOVERY $+^3, \times^3$: Numbers refer to Sensitivity O 3% STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No BH3

METRIC

W.P. 5533-04-00 LOCATION STA. 9+994.5, 2.3 m LT (17T 5260710 m N, 436446 m E) ORIGINATED BY SP

DIST HWY 144 BOREHOLE TYPE Solid Stem Auger (100 mm), Washbore (76 mm ID) COMPILED BY ML

DATUM Geodetic DATE 2010 11 03 CHECKED BY MWB

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
381.2	GROUND SURFACE					
381.1 / 0.2	ASPHALT - 150 mm					Dry cave at 3.7 m on completion. Water level at 375.8 m
	FILL - SAND & CRUSHED GRAVEL - trace silt, brown	AS1	AS			
380.6 / 0.6	ROCKFILL - cobbles					
378.1 / 3.1	GRAVEL - Sandy, trace silt, brown, compact to dense - cobbles	SS2	SS	28		
		SS3	SS	18		
		SS4	SS	40		
		SS5	SS	37	∇ (375.8)	
		SS6	SS	23		
		SS7	SS	22		
		SS8	SS	43		
		SS9	SS	20		
		SS10	SS	19		
371.2 / 10.0	SILT - some sand, trace clay, grey, dense - cobbles	SS11	SS	47		0 18 80 2
369.7 / 11.5	GRAVEL - Sandy, trace silt, brown/grey, very dense - cobbles and boulders	SS12	SS	100+		SPT 17/150 mm 30/150 mm 10/0 mm
368.7 / 12.5	End of Borehole at 12.5 m Auger Refusal					

Chart columns: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, □ QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³. Elevation scale 381 to 369.

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

ON_MOT GS-TB-012437 - MTO HWY 144 - MOLLIE RIVER.GPJ DST_MIN.GDT 4/5/12

RECORD OF BOREHOLE No BH4

METRIC

W.P. 5533-04-00 LOCATION STA. 9+993, 2.3 m RT (17T 5260703 m N, 436449 m E) ORIGINATED BY SP

DIST HWY 144 BOREHOLE TYPE Solid Stem Auger (100 mm), Washbore (76 mm ID) COMPILED BY ML

DATUM Geodetic DATE 2010 10 28 CHECKED BY MWB

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
381.2	GROUND SURFACE					
381.0 0.2	ASPHALT - 200 mm					Dry cave at 2.1 m on completion. Water level at 375.7 m
380.6 0.6	FILL - SAND & CRUSHED GRAVEL - trace silt, brown	AS1	AS			
	ROCKFILL - cobbles	SS2	SS	100+		SPT 10/0 mm
		SS3	SS	100+		SPT 100/76 mm 10/0 mm
375.9 5.3	GRAVEL - Sandy, trace silt, brown, dense to very dense - cobbles and boulders				∇ (375.7)	
		SS4	SS	100+		SPT 10/0 mm
		SS5	SS	40		
		SS6	SS	30		
		SS7	SS	70		
372.8 8.4	End of Borehole at 8.4 m Auger Refusal	SS8	SS	100+		SPT 10/0 mm

Elevation scale: 381, 380, 379, 378, 377, 376, 375, 374, 373

Plot headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, □ QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20, 40, 60; UNIT WEIGHT γ kN/m³

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

RECORD OF BOREHOLE No BH5

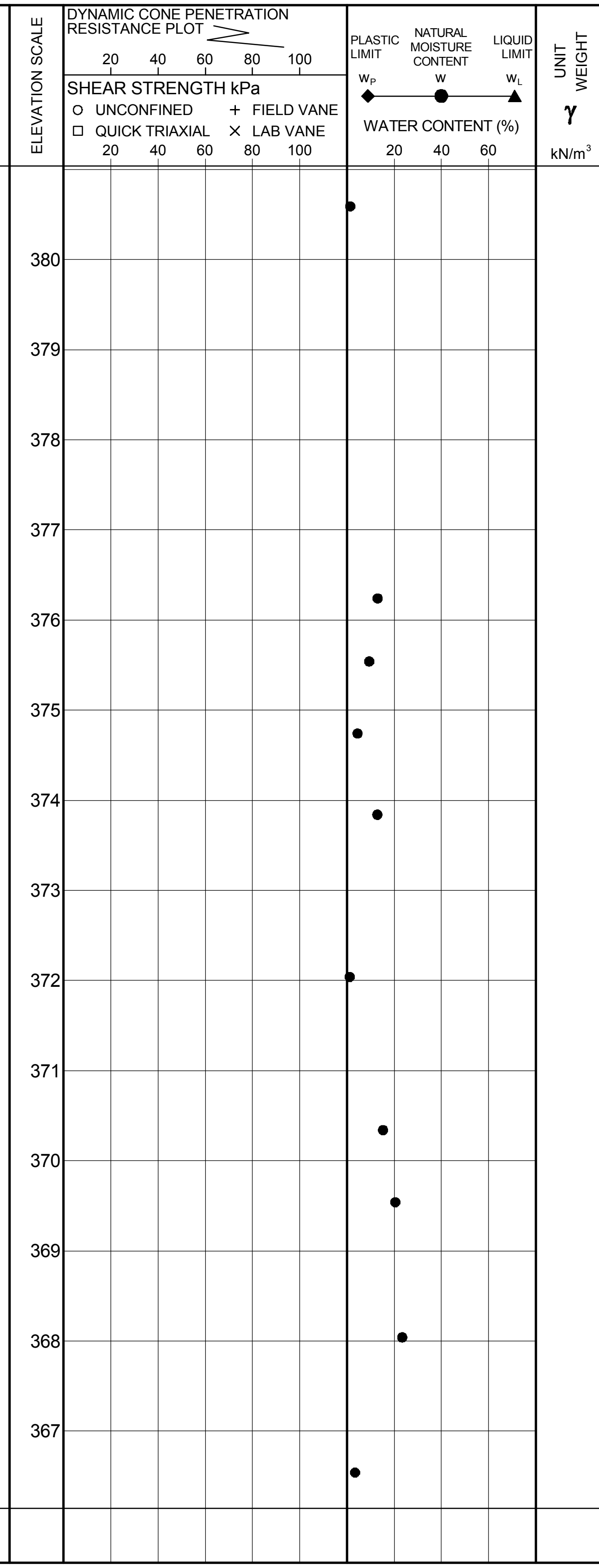
METRIC

W.P. 5533-04-00 LOCATION STA. 9+983, 2.1 m RT (17T 5260691 m N, 436451 m E) ORIGINATED BY SP

DIST HWY 144 BOREHOLE TYPE Solid Stem Auger (100 mm), Washbore (76 mm ID) COMPILED BY ML

DATUM Geodetic DATE 2010 10 29 CHECKED BY MWB

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
381.0	GROUND SURFACE					
380.8 / 0.2	ASPHALT - 200 mm					Dry cave at 2.1 m on completion. Water level at 375.8 m
380.4 / 0.6	FILL - SAND & CRUSHED GRAVEL - brown	AS1	AS			
	ROCKFILL					
376.4 / 4.6	GRAVEL - Sandy, trace silt, brown, compact to very dense - cobbles and boulders - - - - - trace wood and rootlets - - - -	SS2	SS	37	∇ (375.8)	69 25 (6)
		SS3	SS	43		
		SS4	SS	52		
		SS5	SS	21		
		SS6	SS	24		
		SS7	SS	36		
371.0 / 10.0	SAND - Silty, trace gravel, grey/brown, compact	SS8	SS	14		1 64 (35)
370.0 / 11.0	SAND - trace silt, grey/brown, compact	SS9	SS	21		0 90 (10)
		SS10	SS	19		
367.3 / 13.7	GRAVEL - Sandy, trace silt, compact - cobbles	SS11	SS	20		
366.1 / 14.9	End of Borehole at 14.9 m Auger Refusal					



NR = NO RECOVERY $+^3, \times^3$: Numbers refer to Sensitivity O 3% STRAIN AT FAILURE

ON_MOT GS-TB-012437 - MTO HWY 144 - MOLLIE RIVER.GPJ DST_MIN.GDT 4/5/12

RECORD OF BOREHOLE No HA1

METRIC

W.P. 5533-04-00 LOCATION STA. 10+006, 14.0 m LT (17T 5260720 m N, 436438 m E) ORIGINATED BY SP

DIST HWY 144 BOREHOLE TYPE Hand Auger COMPILED BY ML

DATUM Geodetic DATE 2010 11 01 CHECKED BY MWB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, □ QUICK TRIAXIAL, × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
376.1	GROUND SURFACE										
376.0 / 0.1	ORGANICS		AS1	AS							
375.9 / 0.2	GRAVEL - Sandy, trace organics and silt, brown - cobbles		AS2	AS							
	End of Borehole at 0.2 m Auger Refusal										

NR = NO RECOVERY

$+^3, \times^3$: Numbers refer to Sensitivity

O $^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No HA2

METRIC

W.P. 5533-04-00 LOCATION STA. 9+993.5, 14.0 m LT (17T 5260707 m N, 436435 m E) ORIGINATED BY SP

DIST ____ HWY 144 BOREHOLE TYPE Hand Auger COMPILED BY ML

DATUM Geodetic DATE 2010 11 01 CHECKED BY MWB

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
376.4	GROUND SURFACE						
376.3 0.1	ORGANICS	AS1	AS				Water level at 375.9 m
	GRAVEL - Sandy, trace organics and silt, brown - cobbles				∇	376	
		AS2	AS				
375.5 0.9	End of Borehole at 0.9 m Auger Refusal						

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE □ QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

NR = NO RECOVERY $+^3, \times^3$: Numbers refer to Sensitivity ○ $^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No HA3

1 OF 1 **METRIC**

W.P. 5533-04-00 LOCATION STA. 10+008, 14.4 m RT (17T 5260716 m N, 436467 m E) ORIGINATED BY SP

DIST HWY 144 BOREHOLE TYPE Hand Auger COMPILED BY ML

DATUM Geodetic DATE 2010 11 01 CHECKED BY MWB

ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, □ QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
375.7	GROUND SURFACE					▽					
375.7 / 0.1	ORGANICS										Water level at 375.7 m
375.3 / 0.4	GRAVEL - Sandy, trace organics and silt, brown - cobbles		AS1	AS			375		● (~20)		
	End of Borehole at 0.4 m Auger Refusal										

NR = NO RECOVERY

+ 3, × 3: Numbers refer to Sensitivity

O 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No HA4

1 OF 1 **METRIC**

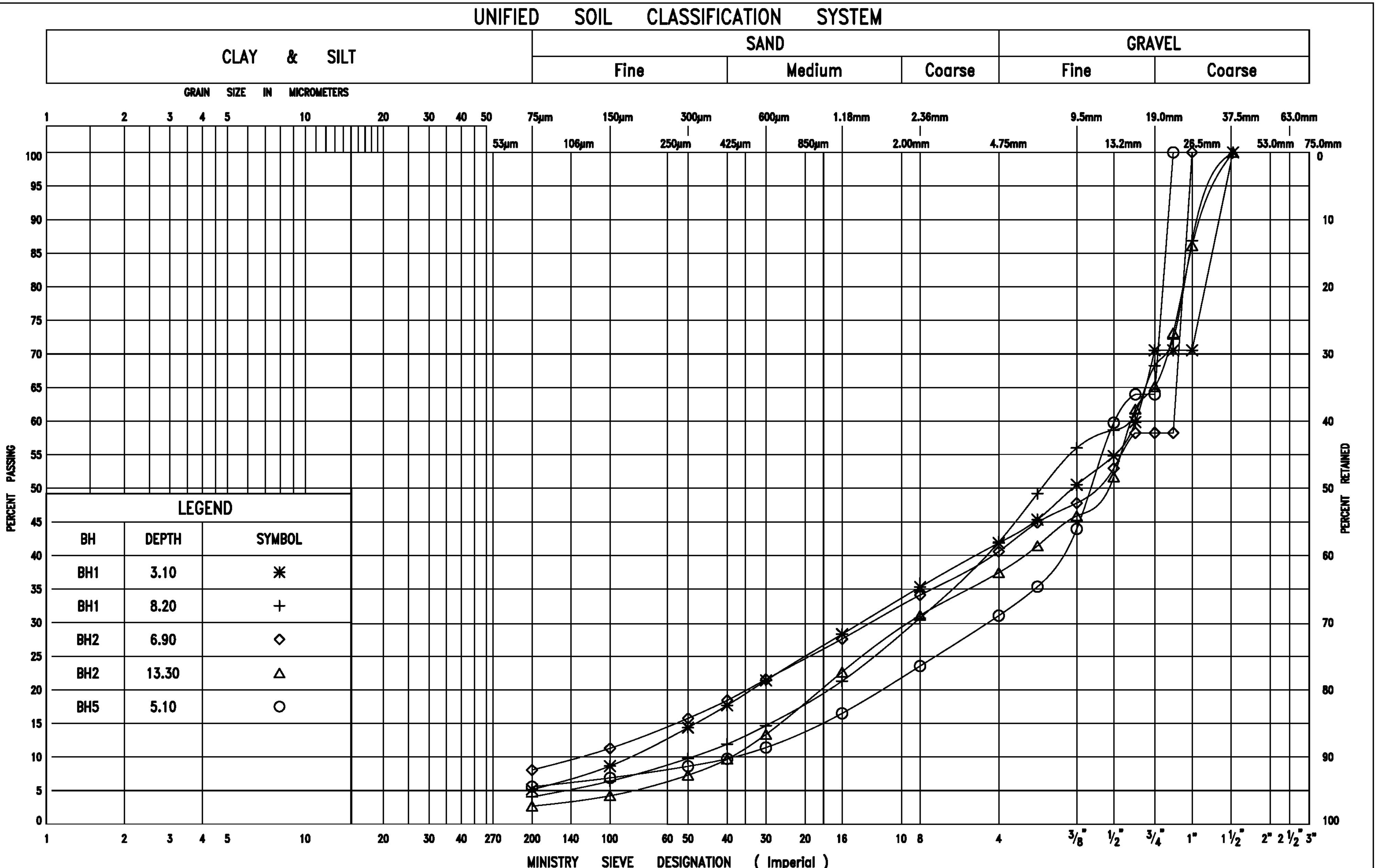
W.P. 5533-04-00 LOCATION STA. 9+992, 14.4 m RT (17T 5260699 m N, 436463 m E) ORIGINATED BY SP

DIST ____ HWY 144 BOREHOLE TYPE Hand Auger COMPILED BY ML

DATUM Geodetic DATE 2010 11 01 CHECKED BY MWB

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, □ QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
375.8	GROUND SURFACE										
	GRAVEL - Sandy, trace organics and silt, brown - cobbles					∇					Water level at 375.7 m
375.0 0.8	End of Borehole at 0.8 m Auger Refusal						375				

NR = NO RECOVERY $+^3, \times^3$: Numbers refer to Sensitivity   O $^{3\%}$ STRAIN AT FAILURE



BH	DEPTH	SYMBOL
BH1	3.10	✳
BH1	8.20	+
BH2	6.90	◇
BH2	13.30	△
BH5	5.10	○

GRAIN SIZE DISTRIBUTION
GRAVEL

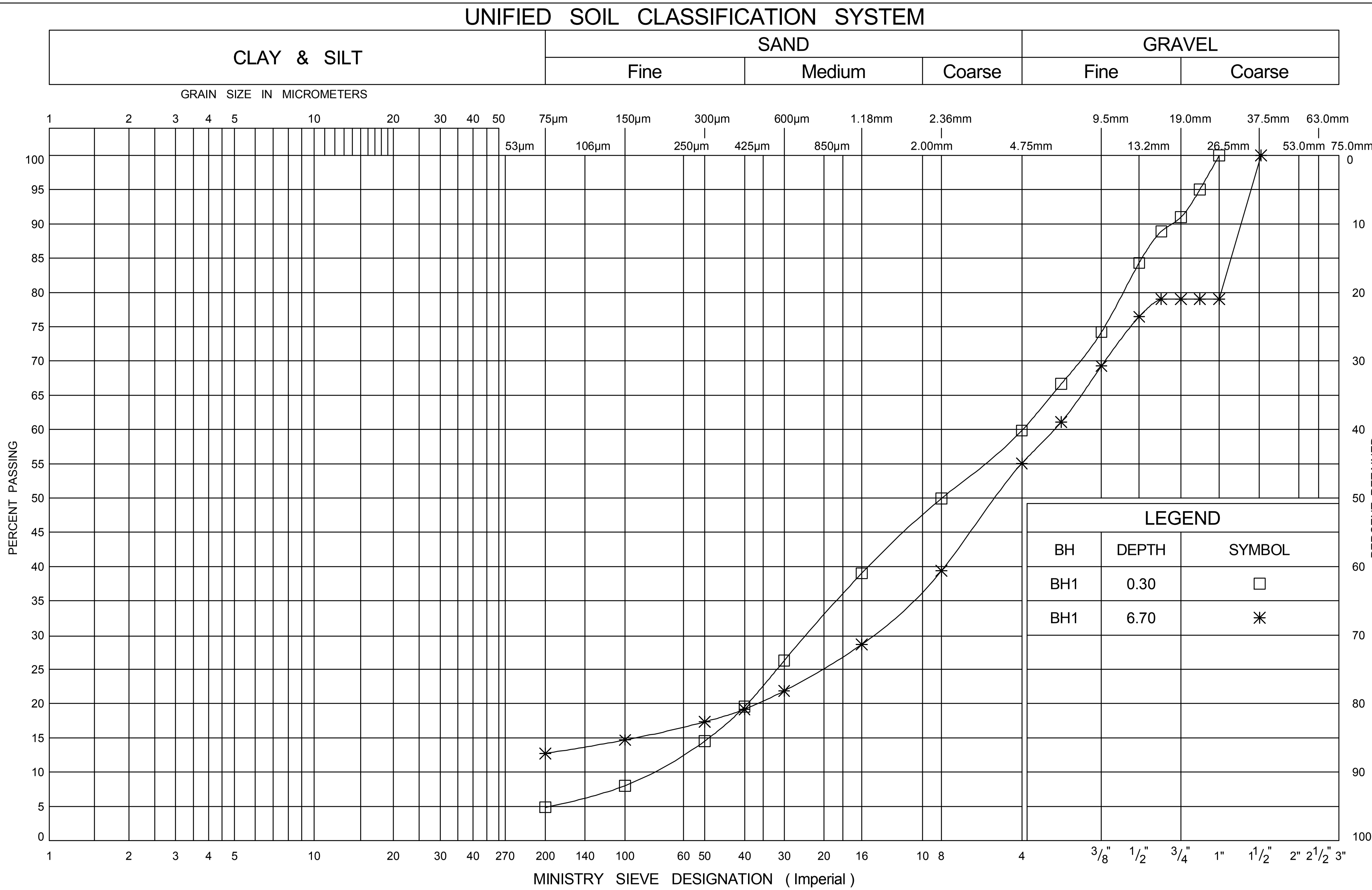
ENCLOSURE 10

W P 5009-E-0061 #4

HIGHWAY 144

Ontario

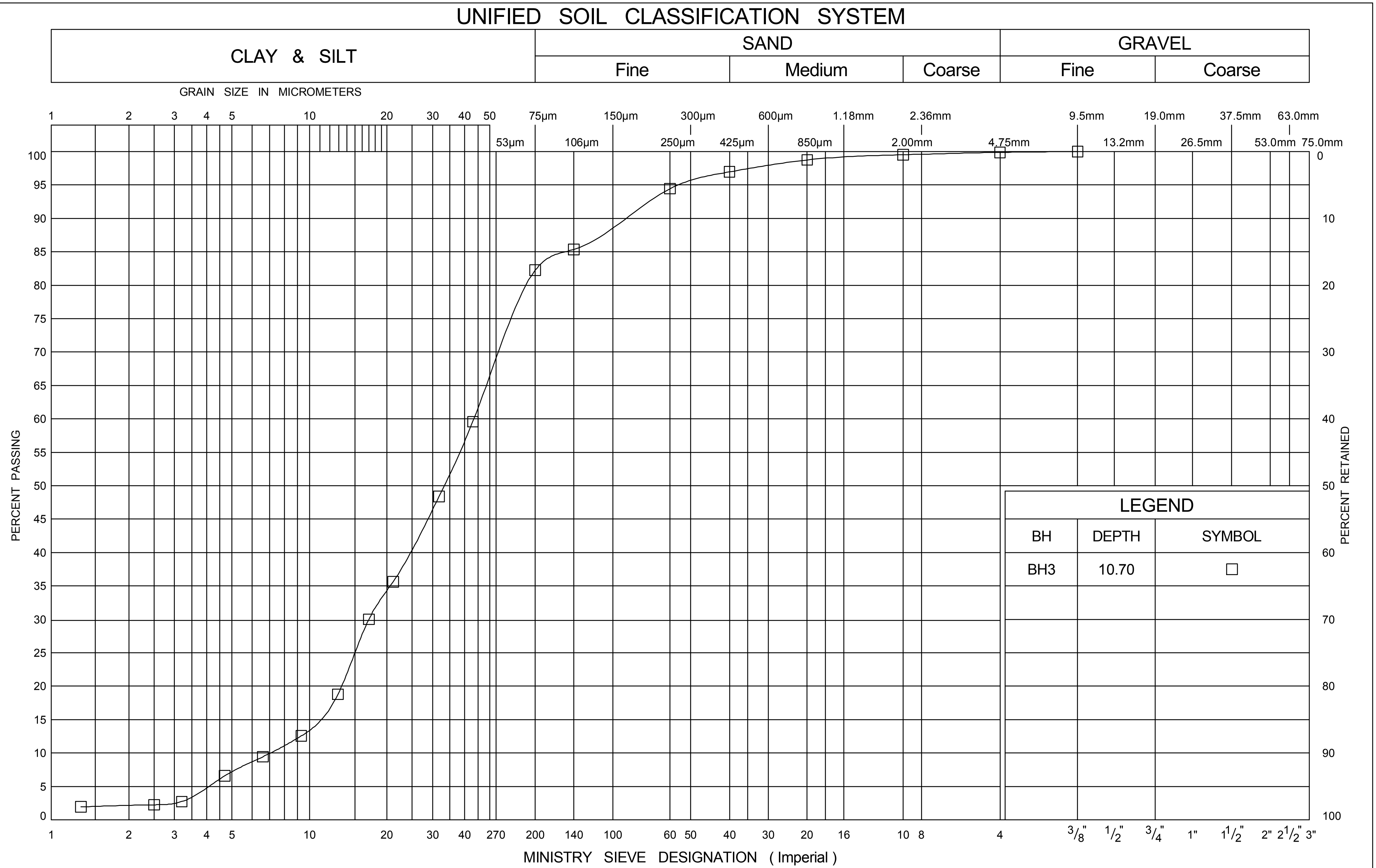
ONTARIO MOT GRAIN SIZE GS-TB-012437 - MTO HWY 144 - MOLLIE RIVER.GPJ DST_MIN.GDT 26/11/10



GRAIN SIZE DISTRIBUTION
SAND & GRAVEL

Ministry of Transportation Ontario	ENCLOSURE 11
	W P 5533-04-00
	HIGHWAY 144

ONTARIO MOT GRAIN SIZE GS-TB-012437 - MTO HWY 144 - MOLLIE RIVER.GPJ DST_MIN.GDT 4/5/12



GRAIN SIZE DISTRIBUTION

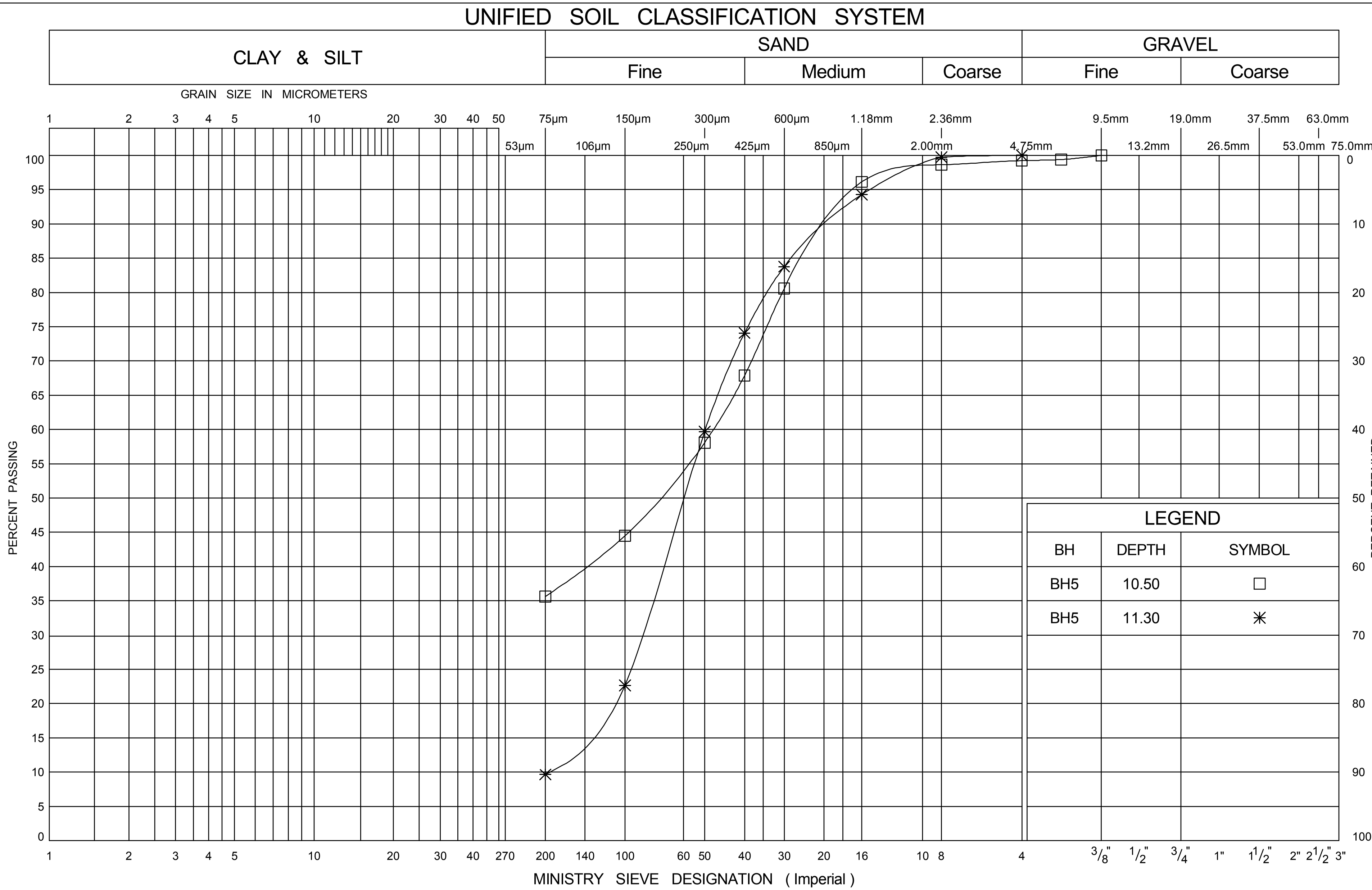
SILT - some sand

ENCLOSURE 12

W P 5009-E-0061 #4

HIGHWAY 144

Ontario



GRAIN SIZE DISTRIBUTION
SAND

ENCLOSURE 13

W P 5009-E-0061 #4

HIGHWAY 144

Ontario