FOUNDATION INVESTIGATION AND DESIGN REPORT
REHABILITATION OF HIGHWAY 21
FROM BAYFIELD TO GODERICH, ONTARIO

CULVERT REPLACEMENT AT STATION 21+055

MINISTRY OF TRANSPORTATION ONTARIO - WEST REGION
PURCHASE ORDER NUMBER 3009-E-0022
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1.0 INTRODUCTION

AMEC Environment and Infrastructure, a Division of AMEC Americas Limited ("AMEC"), was retained by the Ministry of Transportation Ontario - West Region ("MTO") to provide Detail Design Services for the Rehabilitation of Highway 21, Township of Goderich, Ontario. The project highway is about 20 km long stretching northerly from about 1.85 km south of Bayfield River Bridge (Bayfield) to about 0.17 km north of Huckins Street (Goderich). To provide the required geotechnical information for the Detail Design Services, AMEC conducted a foundation investigation at the locations of eight (8) existing culverts identified for rehabilitation / replacement by the AMEC Design Team. A site plan showing the culvert locations /stations is presented on Drawing No. 1.

The foundation investigation for the culverts comprised advancing a total of 21 boreholes (BH G1 to BH G21) as listed in Table 1.1. Culvert details, as provided by the Design Team, including the stations, type, dimensions and boreholes drilled are summarized in Table 1.1.

Table 1.1- Culvert Details*

Station	Existing Culvert		Boreholes Drilled	Proposed Work	Remark
	Type	Dimension			
10+200 to 10+300	Concrete-open rigid frame	1.80 x 1.20 x 34.3 m	BH G1 to BH G6	Replacement or extension	Two culverts at Jowett's Grove Road Intersection with Hwy 21
	Concrete-open	0.91 x 0.91 x 40.0 m			
10+550	CSP	0.61 m diameter and 24.4 m length	BH G7 and BH G8	Replacement	
10+705	CSP	0.61 m diameter and 24.0 m length	BH G9 and BH G10	Replacement	
11+187	CSP	0.46 m diameter and 24.7 m length	BH G11 and BH G12	Replacement	
11+873	CSP	0.61 m diameter and 21.7 m length	BH G13 and BH G14	Replacement	
12+810	CSP	0.61 m diameter and 19.3 m length	BH G15 and BH G16	Replacement	
21+055	Concrete-open rigid frame	1.82 m x 5.49 m x 23.4 m	BH G17, BH G18 and BH G19	Replacement	
22+826	CSP	0.76 m diameter and 21.4 m length	BH G20 and BH G21	Replacement	

* From Culvert Summary Table provided by AMEC Design Team

The purpose of the foundation investigation was to obtain information on the subsurface conditions at the culvert sites by means of boreholes, in-situ tests and laboratory tests on selected samples. Based on AMEC's interpretation of the data obtained in the investigation, recommendations are provided on the geotechnical aspects of replacement of the culverts.

As per Terms of Reference (TOR) in the Request for Quotation (Purchase Order Number: 3009-E-0022, dated 10 March 2011), separate reports have been prepared for each culvert site. This report presents the results of foundation investigation together with design discussion and recommendations for the culvert at Station 21+055.

The factual results of the soil conditions encountered in the boreholes and laboratory tests for replacement of the culvert at Station 21+055 are presented in a separate report titled "Foundation Investigation Report".

2.0 SITE AND PROJECT DESCRIPTION

The culvert site (at Station 21+055) is located at the existing watercourse (Naftel's Creek) crossing Highway 21, approximately 600 m north of Kitchigami Road, between Bayfield and Goderich, Ontario (Drawing No. 1).

At this location, Highway 21 is a two-lane asphaltic-concrete paved road with gravel shoulders on both sides, and runs on top of an embankment built up above the surrounding grade. The surrounding area is primarily rural in nature, with active agricultural operations and farm houses / vacant lands / wood lot.

Based on the Culvert Summary Table provided, the existing culvert at this location is a concrete-open rigid frame structure (1.82 m x 5.49 m x 24.4 m). Based on drawing provided by MTO (ETR Plate), the fill cover over the culvert is about 3.0 m. AMEC Design Team recommended for the replacement of the existing culvert.

Based on information provided to AMEC, the replacement culvert could be concrete open footing, rectangular or arch, which would be supported by strip footings. No further design information is available at this time of writing this report. It is likely the invert of the replacement culvert would be established at the same level as the existing culvert invert.

Site photographs showing the culvert are presented in Appendix C (Photographs 1 to 3).

3.0 GEOLOGY

Based on Map 2556 (Southern Sheet): 'Quaternary Geology of Ontario' prepared by Ministry of Northern Development and Mines of Ontario (1991), the site is located in an area of transition where the overburden comprise (i) St. Joseph Till (Huron - Georgian Bay lobe) consisting of silt to silty clay matrix, clay content increases southward, clast poor, and (ii) Glaciolacustrine deposits consisting of sand, gravelly sand and gravel; nearshore and beach deposits; and (iii) Glaciolacustrine deposits consisting of silt and clay, minor sand, basin and quiet water deposits.

4.0 INVESTIGATION PROCEDURES

4.1 Field Investigation

In accordance with the Terms of Reference for this investigation, a total of four (4) boreholes (BH G17, BH G17A, BH G18 and BH G19) were advanced at the site. Boreholes BH G17 was drilled adjacent to the culvert inlet, while Borehole BH G18 and BH G19 were drilled on the east and west shoulder respectively. Borehole BH G17A was advanced about 1.5 m from the location of Borehole BH G17 by augering (without sampling) to install a monitoring well for hydrogeological study. The hydrogeological findings are presented in a separate report. The borehole locations are presented on Drawing No. 2.

The fieldwork was performed on 17 May and 18 May 2011 after acquiring all necessary permits for road occupancy, and clearing underground utilities. The ground surfaces at the borehole locations were surveyed with reference to the nearest geodetic benchmark (GBM 0011989U065, Sta. 19+755, El 206.086).

The boreholes were advanced using solid-stem continuous-flight augers, with a track-mounted power-auger drilling rig under the full-time supervision of experienced geotechnical personnel from AMEC. Soil samples were generally taken at 0.76 m intervals for the initial 3 m of the borehole, and 1.5 m thereafter, while performing the Standard Penetration Test (SPT) in accordance with ASTM D1586. This consisted of freely dropping a 63.5 kg (140 lbs.) hammer for a vertical distance of 0.76 m (30 inches) to drive a 51 mm (2 inches) diameter O.D. split-barrel (split spoon) sampler into the ground. The number of blows of the hammer required to drive the sampler into the relatively undisturbed ground by a vertical distance of 0.30 m (12 inches) was recorded as SPT ‘N’ value of the soil which indicated the consistency of cohesive soils or the compactness of non-cohesive soils.

The groundwater conditions were observed in the boreholes during sampling and upon completion of drilling. The groundwater depth measurements are presented on the Record of Boreholes. Two monitoring wells were installed, one each in Borehole BH G17 and Borehole BH G17A for the long term monitoring of groundwater level by the project hydrogeological team (the hydrogeological report is submitted separately). The groundwater levels were measured within the monitoring wells on 14 June and 22 June 2011. The results of groundwater measurements are shown on the Record of Boreholes and summarized in Table 5.3 (Section 5.0).

Upon completion of drilling, the boreholes were backfilled with bentonite in accordance with the general requirements of Ministry of the Environment Regulation 903.

The soil samples were transported to AMEC’s Advanced Soil Laboratory in Scarborough (Toronto) for further examination and laboratory soil testing. The program of laboratory testing included, where applicable, the grain size analysis, Liquid and Plastic Limits, in-situ water content determination, and soil corrosivity analysis.

The results of the in-situ and laboratory tests are presented in the corresponding Record of Boreholes (Appendix A) and Laboratory Test Results (Appendix B).

4.2 Laboratory Tests

All soil samples were subjected to visual identification shown on the Record of Boreholes in Appendix A.

In accordance with the Terms of Reference for this investigation, the following tests were conducted:

- In-situ water content determination (34);
- Grain size distribution analysis (6);
- Atterberg Limit tests (6); and
- Soil Corrosivity (1).

The results of laboratory tests are included on the Record of Boreholes in Appendix A. The grain size distribution curves and Plasticity Chart are shown in Appendix B.

5.0 SUB-SURFACE CONDITIONS

Based on the investigation results, the soil profile consisted predominantly of ground surface cover (topsoil or sand and gravel fill) underlain by fill soils (sandy silt / sand) overlying native deposits (silt and clayey silt) which extended to the termination depths of the boreholes (elevations 191.5 m to 192.5 m ±).

The stratigraphic units and groundwater conditions at the borehole locations are discussed in the following sections. Detailed information is provided in the Record of Boreholes (Appendix A). Stratigraphical cross sections showing the existing culvert is provided in Drawing No. 3.

Soil and groundwater conditions may vary between and beyond the borehole locations.

5.1 Topsoil

Topsoil was encountered at the existing grade in Borehole BH G17 drilled adjacent to the culvert inlet area. The measured thickness of topsoil was about 400 mm. The topsoil consisted primarily of organic matter with some rootlets and soils.

The thickness of topsoil could vary beyond the borehole location.

5.2 Fill Soils

Sand and Gravel Fill

Boreholes BH G18 and BH G19 drilled through the shoulder (east and west) areas of Highway 21 encountered sand and gravel fill at the existing grade. The measured thickness of sand and gravel fill was about 500 mm in Borehole BH G18, and 600 mm in Borehole BH G19.

Two SPT N-values measured within the sand and gravel fill were 30 blows and 36 blows per 0.3 m. The water contents determined within the sand and gravel fill were 5 % and 6 %.

Sandy Silt Fill

Below the topsoil in Borehole BH G17, sandy silt fill was encountered. The sandy silt fill extended to a depth of about 1.4 m below the existing grade.

The sandy silt fill was brown in colour and contained trace gravel, clay and organic matter.

A single SPT N-value measured within the sandy silt fill was 21 blows per 0.3 m. The water content determined within the sandy silt fill was 37 %.

Sand Fill

Underneath the sand and gravel fill, sand fill was encountered in Boreholes BH G18 and BH G19 up to depths of about 6.3 m (Elevation 201.6) and 6.2 m (Elevation 201.5) below the existing grade, respectively.

The sand fill was brown in colour and contained trace to some silt and gravel. Trace organic matter was found in Borehole BH G19.

The SPT N-values measured within the sand fill ranged from 2 blows to 42 blows per 0.3 m. The water contents determined for the sand fill ranged from 8.0 % to 15.0 %.

5.3 Silt

Native silt deposit was encountered below the sandy silt fill in Borehole BH G17; and underneath the sand fill in Boreholes BH G18 and BH G19. The silt extended to depths ranging from 11.3 to 13.0 m below the existing grade.

The silt was grey in color, and contained some to ‘with’ sand, trace clay, sand and cobbles / boulders. The SPT ‘N’ values of the silt were all greater than 50 blows per 0.3 m indicating a very dense compactness condition and possibly trace cobbles/boulders. The measured moisture contents in the silt ranged from 12 % to 16 %.

Grain size analyses were performed on two (2) samples of the silt, and the results are presented in Table 5.1. The silt was non-plastic.

Table 5.1 - Results of Grain Size Analysis

Borehole No.	Sample No.	Depth (Elevation) (m)	Percent Distribution (%)			
			Gravel	Sand	Silt	Clay
BH G18	SS 6	7.6 - 7.7 (200.3 – 200.2)	3	22	68	7
BH G19	SS 8	7.6 - 7.7 (200.1 – 200.0)	2	18	75	5

The grain size distribution curves are presented in Figure No. B 1 in Appendix B.

5.4 Clayey Silt

Clayey silt was encountered below the sandy silt in all boreholes. The clayey silt extended to the termination depths of the boreholes at about 12.3 m to 15.4 m below the existing grade (Elevation 191.5 m to 192.4 m).

The clayey silt was grey in color, and contained trace sand. The SPT 'N' values of the clayey silt were all greater than 50 blows per 0.3 m indicating a hard consistency condition and possibly trace cobbles/boulders. The measured moisture contents in the clayey silt ranged from 13 % to 15 %.

Grain size analyses and Atterberg Limit tests were completed on 3 samples of the clayey silt, and the results are presented in Table 5.2.

Table 5.2 - Grain Size Distribution Analysis and Atterberg Limit Test Results

Borehole No.	Sample No.	Depth (Elevation) (m)	Grain Size Distribution				Atterberg Limit			USCS Modified Group Symbol
			Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Liquid Limit	Plastic Limit	Plasticity Index	
BH G17	SS 11	12.2 - 12.3 (191.6 - 191.5)	0	1	83	16	21	15	6	CL - ML
BH G18	SS 10	13.7-13.8 (194.1 - 194.0)	0	1	85	14	24	16	8	CL
BH G19	SS 12	13.7-13.8 (194.0 - 193.9)	0	1	76	23	24	15	9	CL

The grain size distribution curves are presented in Figure No. B 2, and the plasticity chart is presented in Figure No. B 3, in Appendix B.

5.5 Groundwater Conditions

Groundwater conditions in the open boreholes were observed during and on completion of drilling. Groundwater was measured at about 7.6 m below the existing grade (elevation 196.3 m ±) in Borehole BH G17, about 9.9 m (elevation 198.0 m ±) in Borehole BH G18 and about 8.1 m (elevation 199.7 m ±) in Borehole BH G19.

The groundwater levels were also measured in the monitoring wells installed in Boreholes BH G17 and BH G17A on 14 and 22 June 2011. The results of groundwater measurements are shown on the Record of Boreholes and summarized in Table 5.3.

Table 5.3 - Results of Groundwater Measurements

Borehole	Measured Groundwater Level			Remarks
	Date	Depth(m)	Elevation(m)	
BH G17	17 May 2011	7.6 m ±	196.3 m ±	Completion of drilling
	14 June 2011	1.8 m ±	202.1 m ±	In monitoring well
	22 June 2011	2.0 m ±	201.9 m ±	In monitoring well
	16 August 2011	2.3 m ±	201.7 m ±	In monitoring well
	17 May 2012	2.1 m ±	201.8 m ±	In monitoring well
BH G17A	14 June 2011	1.3 m ±	202.6 m ±	In monitoring well
	22 June 2011	1.3 m ±	202.6 m ±	In monitoring well
	16 August 2011	1.5 m ±	202.4 m ±	In monitoring well
	17 May 2012	1.4 m ±	202.5 m ±	In monitoring well
BH G18	18 May 2011	9.9 m ±	198.0 m ±	Completion of drilling
BH G19	17 May 2011	8.1 m ±	199.7 m ±	Completion of drilling

It should be pointed out that the groundwater at the site would fluctuate seasonally and can be expected to be somewhat higher during the spring months and in response to major weather events.

6.0 DISCUSSION AND RECOMMENDATIONS

In preparation of this report, the following drawings were forwarded to AMEC:

- Hwy 21 Culvert Summary Table, dated 3 January 2011.
- A set of MTO Drawings (ETR Plate No. 171-21/9-0 (Plan), 171-21/10-0 (Profile), 171-21/11-0, 171-21/12-0, 171-21/13-0 171-21/24-0, 171-21/25-0, and 171-21/27-0).

Based on the Culvert Summary Table provided by the Design Team, the existing culvert is a concrete - open rigid frame structure (1.82 m by 5.49 m by 24.4 m). The invert elevations of the existing culvert are 202.95 m ± (inlet) and 202.94 m (outlet). Based on the ETR Plate for the area, the fill cover over the culvert is 3.0 m ±. As per recommendation by the AMEC Design Team, the existing culvert would be replaced.

The investigation revealed that the soil profile generally consisted of ground surface cover (topsoil or sand and gravel) underlain by fill soils (sandy silt / sand) overlying native deposits (silt and clayey silt). The groundwater level was encountered at a depth of about 7.6 m (elevation 196.3 m ±) below the existing grade in Borehole BH G17, and about 9.9 m (elevation 198.0 m ±) in Borehole BH G18 and about 8.1 m (elevation 199.7 m ±) in Borehole BH G19. Groundwater levels were encountered in monitoring wells, about three weeks after installation, at elevations of 201.9 m ± in Boreholes BH G17 and 202.6 m ± in Borehole BH G17A. Stratigraphic cross-sections at the culvert location are shown in Drawing No. 3.

Based on the information provided to AMEC, the following culvert types are under consideration for installation at the site:

- Open Footing Rectangular Culvert supported by strip footings, or
- Open Footing Arch Culvert supported by strip footings.

A concrete box type culvert is unlikely to be installed at the site from the growth of fisheries point of view. No more detail design information with regard to the replacement culvert was available at the time of preparation of this report. It may be possible that the replacement culvert would be installed at the same location as or parallel and adjacent to the existing culvert.

The investigation indicated that supporting the rectangular or arch type replacement culvert using strip footing is feasible, although other foundations types, i.e., deep foundations could be considered, if required. Shallow footings should be founded on the competent native silt and clayey silt deposits. It is recommended that practical aspects including traffic protection and temporary detour issues be discussed with experienced contractors prior to construction.

The following discussion and recommendations are based on the aforementioned information and should be revised when details are finalized.

6.1 Comparison of Alternate Foundation Types

Based on the soil conditions encountered in the boreholes drilled for this investigation, the preferred foundation type is a shallow system. A comparison of the possible foundation options is provided in Table 6.1.

Table 6.1 - Comparison of Foundation Types for Culvert Replacement

Foundation	Description	Advantages	Disadvantages	Risks / Consequences	Cost Comparison
Shallow Foundation (Strip Footings)	Strip foundations supported on native competent silt subgrade (e.g. rigid frame open bottom).	Use of standard excavation and construction equipment. No specialist contractor is required. Will require short construction period and minimal disruption to traffic if precast culvert panels are used.	Will require isolated areas, over-excavation of fill below footings and placement of structural fill up to proposed founding elevation. Will require formwork and reinforcing steel installation for footing construction.	Improper installation could result in poor hydraulic flow (low spots) and ponding within the culvert. Unless fills are removed from beneath the complete limits of the structure, differential settlement could result.	Low to Medium
Shallow Foundation (i.e., mat foundation on lean concrete on grade)	Rigid Frame box culvert on lean concrete.	Use of standard excavation and construction equipment. No specialist contractor is required. Will require short construction period and minimal disruption to traffic if precast boxes are used. Requires low design bearing capacity	Will require over-excavation of fill from beneath the complete limits of the culvert, and placement of lean concrete or cohesive structural fill to up to proposed founding elevation. Erosion at inlet or outlet could affect structure.	Improper installation could result in poor hydraulic flow (low spots) and ponding within the culvert. Unless fills are removed from beneath the complete limits of the structure, differential settlement could result.	Low to medium
Deep Foundation	Driven or drilled piles or similar bearing on hard clayey silt, supporting strip foundations (e.g. precast open bottom box or arch culvert).	No over-excavation of fill below proposed founding elevation. Little to no settlement. Erosion at inlet or outlet would have little effect on the structure if piles are monolithically tied to the culvert structure.	Requires specialist contractor (Contractor specializing in pile installation). Requires staging area for piling equipment - larger area of disturbance. Will require longest construction period and disruption to traffic. Will require formwork and reinforcing steel placement for footing construction	Will result in a 'hard' or unyielding spot in the road, possibly resulting in significant differential settlement. Risk of encountering cobbles/boulders, which may complicate pile installation.	High

Based on this comparison of the foundation alternatives, it is recommended that a shallow foundation system be used for open rectangular or arch culvert type.

6.2 Shallow Foundation

The invert level of the proposed replacement culvert is likely to be at an elevation of 203.0 m ± and therefore, shallow footings are likely to extend to at least 201.5 m ±.

The soil profile at the borehole locations indicated that the founding subgrade for the proposed replacement culvert is likely to comprise fill soils (sand) which is unsuitable for supporting the culvert loads. It is recommended the footing grade be extended to competent native deposit (silt). Alternatively, the fill soils should be sub-excavated and replaced with non-shrink concrete fill to place footings at the design grade.

The recommended footing depths, Geotechnical Reaction at Service Limit State (SLS) and Geotechnical Resistance at Ultimate Limit State (ULS) for strip footings for the replacement culvert based on Boreholes BH G17 to BH G19 are given in Table 6.2. If more accurate values are required, detailed foundation analysis should be performed by considering the design footing size, depth and loadings applied.

Table 6.2 - Approximate Footing Depth and SLS and ULS Values

Borehole Number	Foundation Soil Strata	Depth Below Existing Grade (m)	Elevation (m)	Geotechnical Reaction at SLS (kPa)	Factored Geotechnical Resistance at ULS [1] (kPa)
BH G17	Very dense silt	1.5 m (±) and below	202.4 m (±) and below	300	450
BH G18	Very dense silt	6.3 m (±) and below	201.6 m (±) and below	300	450
BH G19	Very dense silt	6.2 m (±) and below	201.5 m (±) and below	300	450

Note: [1] A resistance factor of $\Phi = 0.5$ has been applied to the values provided

The geotechnical resistance at ULS shown on Table 6.2 is applicable for a concentrically loaded spread footing founded on the soil type indicated.

The geotechnical horizontal resistance (against sliding) for spread footings should be designed using a coefficient of friction between concrete and subgrade of 0.35, which includes a resistance factor of 0.8, provided a proper shear key is provided in the footing.

The minimum footing sizes, footing thickness, excavations and other footing requirements should be designed in accordance to the latest edition of the Canadian Highway Bridge Design Code.

The design frost penetration for the general area is 1.2 m. Therefore, a permanent soil cover of 1.2 m or its thermal equivalent is required for frost protection of foundations.

For footings designed and constructed in accordance with the above criteria for SLS, total and differential settlements should be less than 25 mm and 20 mm, respectively.

The culvert footings will have to be protected against scour and erosion by providing rip-rap, vegetative cover, or equivalent. Scour protection should be designed by an experienced engineer.

Dewatering groundwater and the diversion of the creek water from the excavations will be required. It should be noted that during construction, the groundwater level should be lowered by a minimum of 1 m below the footing founding level. Excavation and dewatering, and creek diversion for the construction of the footings are discussed in Section 6.4 and Section 6.5 respectively.

The footing should be inspected and evaluated prior to concreting to confirm that the footings are founded on competent subgrade capable of supporting the recommended design pressure.

Cobbles and boulders should be expected, particularly within the native soils. **The construction contract should include a Nonstandard Special Provision (NSSP) to warn the contractor of the possible presence of cobbles / boulders.**

6.3 Soil Parameters

The soil parameters for design are provided in Table 6.3.

Table 6.3 - Summary of Geotechnical Parameters

Soil Stratum	Bulk Unit Weight of Soil, γ (kN/m^3)	Angle of Internal Friction (degree)	Earth Pressure Coefficient (1)		
			At-rest, K_o	Active, K_a	Passive, K_p
Existing fill	18	30	0.50	0.33	2.0
Existing Granular fill	21	32	0.47	0.30	2.0
Silt	21	30	0.50	0.33	2.0
Clayey silt	20	28	0.53	0.35	2.0
Granular B	21	32	0.47	0.30	2.0
Granular A	22	35	0.43	0.27	2.0

(1) Values based on semi-empirical relations. The K_p (passive condition) values are reduced in order to limit the lateral soil movement that is required to mobilize the passive resistance.

For the design of the culvert walls, at-rest K_0 value should be used, while for temporary shoring system (Section 6.8), K_a value may be used.

6.4 Excavation

All excavation should be carried out as per Occupational Health and Safety Act and Regulations for Construction Projects. The soils to be excavated can be classified as follows:

Sandy silt fill / sand fill	Type 3
Very dense silt / Hard clayey silt	Type 2

Accordingly, a bank slope of 1H:1V is required for excavations in Type 2 and Type 3 soils in accordance with the Occupational Health and Safety Act and Regulations for Construction Projects. For Type 2 soil, a 1.2 m high vertical cut at the bottom of excavation may generally be constructed. A flatter slope may be required depending on the site condition and groundwater level encountered during construction.

Excavated materials should be stockpiled at least 3.0 m from the edge of the excavation to avoid slope instability, subject to confirmation by a geotechnical engineer.

No major excavation difficulties are foreseen in excavating the existing soils, but allowance should be made for boulders and cobbles or other objects in the existing soils. The terms describing the compactness (loose, compact, dense, very dense) or consistency (stiff, very stiff, hard) of soil strata give an indication of the effort needed for excavation. For very dense / hard soils, heavy excavators with rippers or similar may be required.

If open cut cannot be carried out, a temporary shoring system (Section 6.8) may be used to limit the extent of excavations, subject to engineering design and approval.

6.5 Dewatering and Creek Diversion

Excavation within Naftel's Creek would be required for the construction of the culvert foundations and would extend below the existing creek bed. Dewatering would be required. Diversion of creek water from the excavated area by cofferdam or sheet piles or equivalent may be required. Dewatering within the excavated area below the creek bed will likely be required.

Dewatering and creek diversion should commence ahead of excavation operation.

Based on the soil and groundwater conditions at the borehole locations, dewatering within the excavated area could be carried out by a system of sumps and pumps. High water flow rates may be encountered during the course of the construction and the dewatering effort could require an increased number of sumps and pumps or a vacuum system. This should be further evaluated prior to construction via test pit excavation and/or hydrogeological assessment in order to select that the most effective dewatering method.

Dewatering operations should follow OPSS 518 (Construction Specification for Control of Water from Dewatering Operations) and OPSS 517 (Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation). In particular, the definitions of "Dewatering Operations" as stated in OPSS 518 which include pumping, or vacuum removal of water from excavations should be considered. Furthermore, the specification that "A continuous dewatering operation shall be provided to keep the excavation stable and free of water." stated in OPSS 517 should be implemented.

Groundwater level should be maintained at a minimum of 1 m below the subgrade during footing excavation. **The native soil at this site is fine textured (i.e., silt). If site work is carried out during periods of wet weather, the subgrade will be easily disturbed. Under inclement weather conditions, an adequate granular working surface or lean concrete mud mat would be required to minimize disturbance and protect the integrity of the subgade soils.** Care should also be exercised to minimize disturbance to the final subgrade during excavation. The use of protective skim coat of lean concrete may be warranted where founding surfaces are to be exposed for extended period.

During the construction, temporary runoff controls such as sediment trap, interceptor drain, dyke and / or silt fence should be provided and installed to prevent uncontrolled water / sediment flow into existing water courses. The effluent from dewatering operations should also be filtered or passed through sediment traps to prevent turbidity.

6.6 Backfilling

The replacement culvert excavation should be backfilled as compacted fill. The selection, placement and construction of the fill should be carried under a geotechnical control program. Based on visual and tactile examination of the soil samples, the on-site soils (sandy silt fill / sand fill / silt) may be used for backfilling culvert excavations provided that all organic matter and deleterious materials are removed. Any soft / loose soils identified should be subexcavated and replaced with compacted granular fill. Backfilling should be carried out in accordance with OPSS 206 (*Construction Specification for Grading*) and/or OPSS 422 (*Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut*). Compaction should follow OPSS 501 (*Construction Specification for Compacting*). The backfill material should be free draining material and conform to Group I, as specified OPSS 422.

The reconstruction of the embankment slopes should match the existing slopes and materials, with a maximum slope of 2H:1V.

6.7 Traffic Protection and Temporary Detours

The following alternative scenarios can be considered for construction:

- Scenario 1 - reduced traffic to one-lane using staged open-cut construction, and provide a temporary detour (if required);
- Scenario 2 - reduce traffic to one-lane using traffic protection (sheet piling) with or without temporary detour as required. Sheetpile driving through the very dense silt could be difficult.
- Scenario 3 - close the road entirely to traffic and provide an alternate route and use full open cut method.

It is recommended that practical aspects including traffic protection and temporary detours for the replacement of culvert should be as per contract design.

6.8 Temporary Shoring

Proper shoring in order to support the sides of excavation may be needed for the construction of the replacement culvert, if open excavation cannot be used due to site restriction. The temporary shoring system should be designed to resist the lateral earth, surcharge and hydrostatic pressure which could occur during construction. Bracings should also be installed within the shoring system to minimize movements of the soils.

The design of temporary shoring should be carried out in accordance with Canadian Foundation Engineering Manual, 4th Edition. The soil parameters are provided in Table 6.3 (Section 6.3).

6.9 Soil Corrosivity Testing

One soil sample (BH G17 - SS3) was analysed by Maxxam Analytics Laboratory in Mississauga to determine the soil corrosivity potential with respect to concrete and steel. The Certificate of Analysis is included in Appendix B. A summary of the test results are presented in Table 6.4.

Table 6.4 - Results of Corrosivity Testing

Soil Sample No.	pH	Electrical Conductivity Umho/cm	Resistivity (ohms-cm)	Chloride (µg/g)	Sulphate (µg/g)
BH G17 - SS3	7.9	317	3200	49	120

The test results have shown that the sulphate content of the soil is 120 ppm (µg/g). As per Table 3 “Additional Requirements for concrete subjected to sulphate attack”, Clause 4.1.1.6 of CSA Standards Specification A23.1-09, any soil which has sulphate content below 0.1% (i.e., 1,000 ppm or µg/g) is not considered aggressive with respect to concrete. As such, in accordance with Table 6 of CSA A23.1-09, Type GU (general use) cement can be used for concrete.

Based on the results of soil resistivity of analyzed soil sample, the degree of corrosivity should be considered as “moderate” for exposed metallic structures. This is based on a comparison of the test results to literature reference (J.D. Palmer, Soil Resistivity Measurement and Analysis, Materials Performance, Volume 13, 1974).

A corrosion specialist should be retained, if necessary, to review the test results and provide recommendation for the most effective protection solutions.

6.10 Earthquake Considerations

In conformance with the criteria in Clause 4.4.6.2 in Section 4: Seismic Design of the Canadian Highway Bridge Design Code CAN/CSA-S6-06 (May 2010), the site soil profile is Type I.

7.0 CLOSURE

The sub-soil information contained in this report should be used solely for the purpose of foundation assessment of the Culvert at Station 21+055 on Highway 21, between Bayfield and Goderich, Ontario.

The Limitations of Report is an integral part of this report.

This report was prepared by Mohammad Mollah, M.Eng., P.Eng., and was reviewed by Dr. Prapote Boonsinsuk, Ph.D., P.Eng.

Sincerely,

AMEC Environment & Infrastructure,
a Division of AMEC Americas Limited

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Principal Designated Contact

LICENSED PROFESSIONAL ENGINEER
P. BOONSINSUK
PROVINCE OF ONTARIO

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a Division of AMEC Americas Limited

LIMITATIONS OF REPORT

The conclusions and recommendations given in this report are based on information determined at the testhole locations. The information contained herein in no way reflects on the environmental aspects of the project, unless otherwise stated. Subsurface and groundwater conditions between and beyond the testholes may differ from those encountered at the testhole locations, and conditions may become apparent during construction, which could not be detected or anticipated at the time of the site investigation.

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 the details stated in this report.

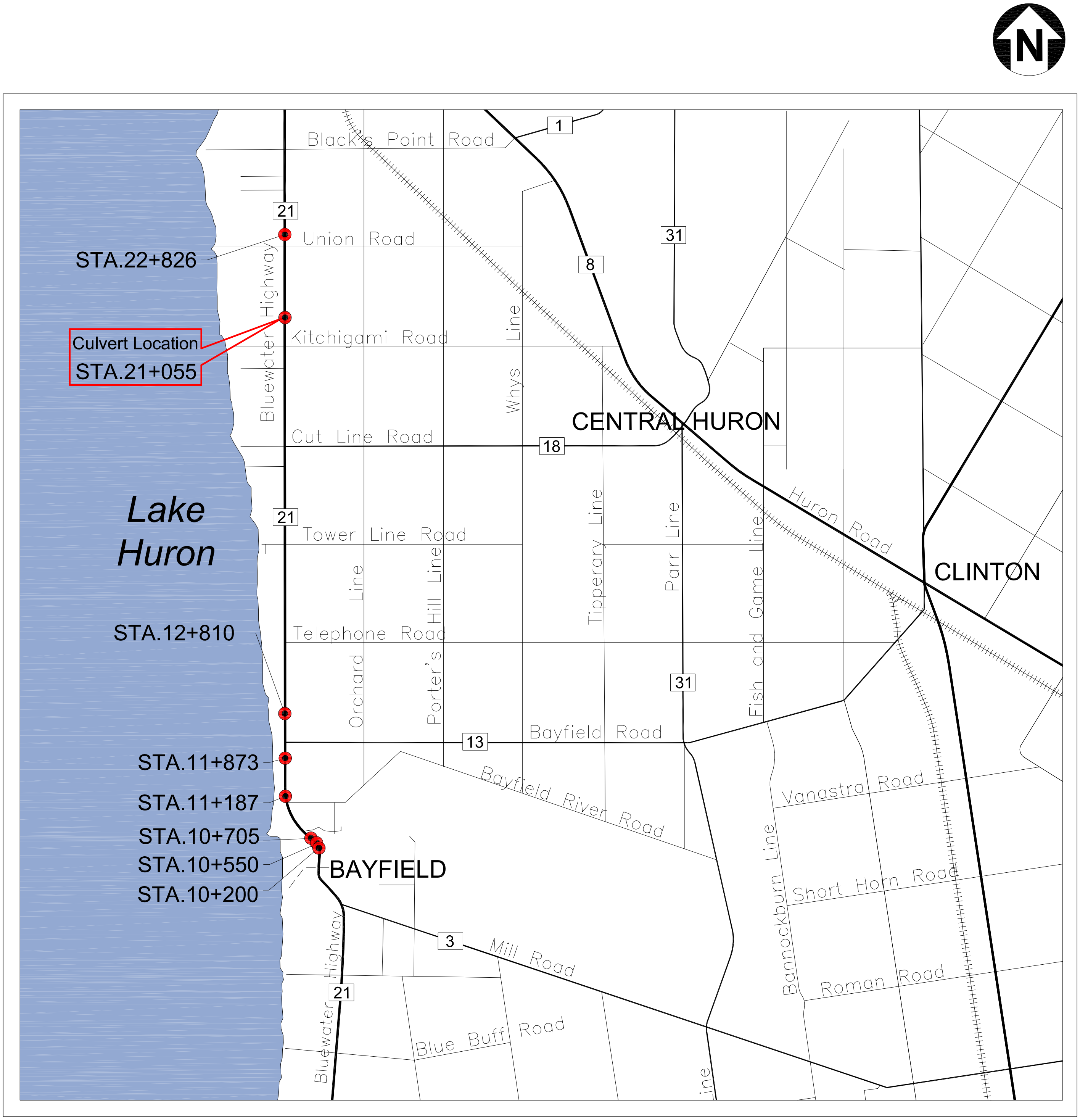
The comments made in this report relating to potential construction problems and possible methods of construction are intended only for the guidance of the designer. The number of testholes may not be sufficient to determine all the factors that may affect construction methods and costs. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusions as to how the subsurface conditions may affect their work. This work has been undertaken in accordance with normally accepted geotechnical engineering practices.

This report was prepared specifically for the culvert at Station 21+055 in Highway 21, Ontario, as described in the report. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. AMEC Environment & Infrastructure, a Division of AMEC Americas Limited, accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

List of Construction Specifications and Drawings

Specification / Drawing	Title
Specifications	
OPSS 180 (Nov/11)	General Specification for the Management and Disposal of Excess Materials
OPSS 206 (Nov/09)	Construction Specification for Grading (Re-issued 2010-11)
OPSS 422 (Apr/04)	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut (Re-issued 2010)
OPSS 501 (Nov/10)	Construction Specification for Compacting
OPSS 511 (Apr/11)	Construction Specification for rip-rap, rock protection, and granular sheeting
OPSS 517 (Nov/10)	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation.
OPSS 518 (Nov/11)	Construction Specification for Control of Water from Dewatering Operations
OPSS 539 (Nov/09)	Construction Specification for temporary protection systems
OPSS 572 (Nov/03)	Construction Specification for Seed and Cover
OPSS 802 (Nov/10)	Construction Specification for Topsoil
OPSS 803 (Nov/10)	Construction Specification for Sodding
OPSS 804 (Nov/10)	Construction Specification for Seed and Cover
OPSS 902 (Nov/10)	Construction Specifications for excavating and Backfilling of structures
OPSS 1004 (Nov/06)	Material Specifications for Aggregates - Miscellaneous
OPSS 1010(Apr/04)	Material Specifications for Aggregates – Base, subbase, select subgrade, and backfill material
OPSS 1860 (Apr/12)	Material Specification for Geotextiles
Drawings	
OPSD 208.010	Benching of Earth Slopes
OPSD 810.010	Rip-rap treatment for sewer and culvert outlets

DRAWINGS



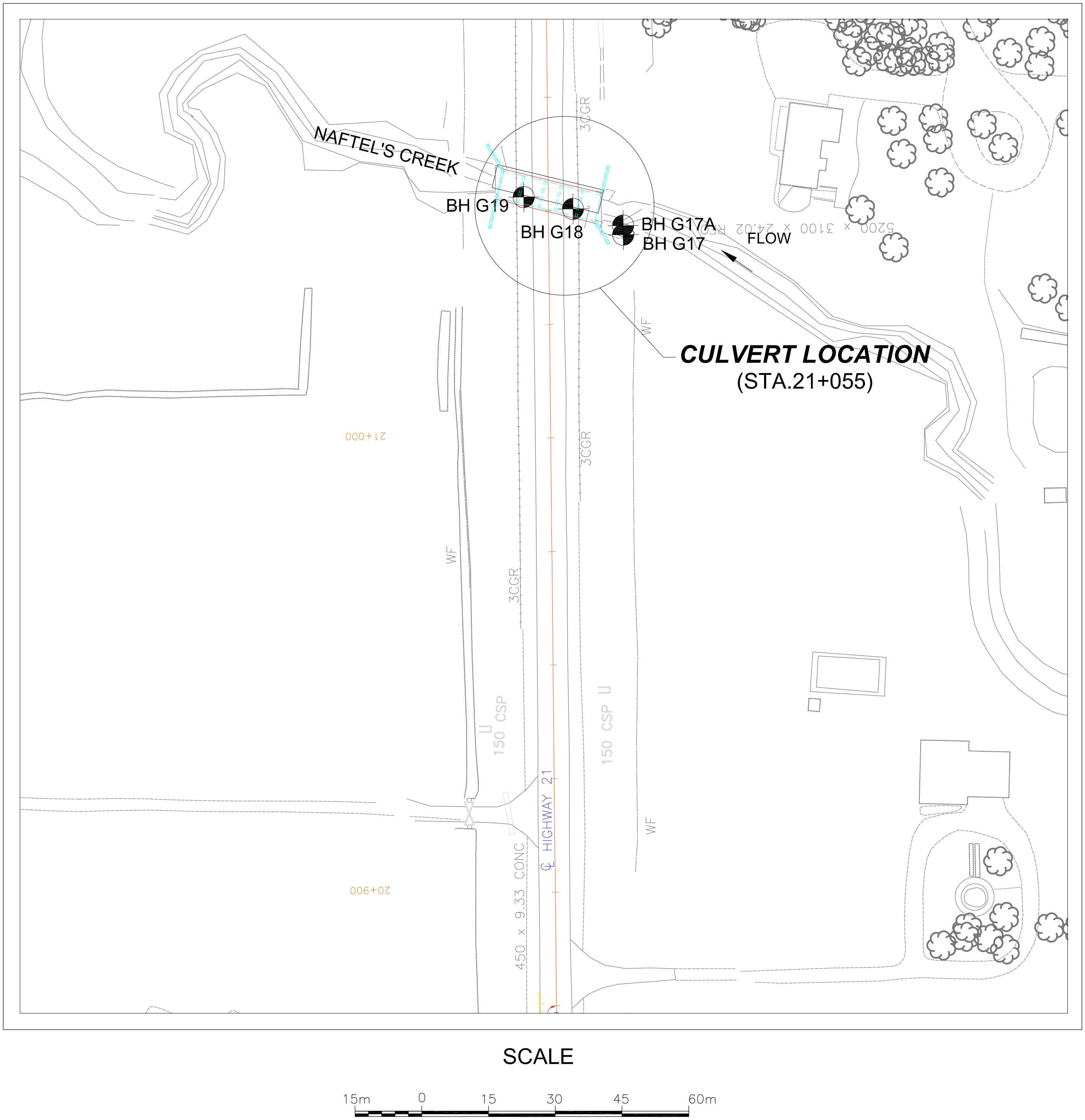
SCALE

1500m 0 1500 3000 4500 6000m

LEGEND

● CULVERT LOCATION

AMEC Environment & Infrastructure, a Division of AMEC Americas Limited	amec	CLIENT LOGO Ontario	CLIENT MINISTRY OF TRANSPORTATION ONTARIO WEST REGION	
TITLE CULVERT LOCATION PLAN		DWN BY: KW	DATUM: -	DATE: JANUARY 2013
PROJECT REHABILITATION OF HIGHWAY 21 - FROM BAYFIELD TO GODERICH, ONTARIO PURCHASE ORDER NUMBER: 3009-E-0022, WP 834-93-00, GEOCRES No.: 40P12-29		CHK'D BY: PB	REV. NO.: A	PROJECT NO: TP110076
		PROJECTION: -	SCALE: AS SHOWN	DRAWING No. 1



AMEC Environment & Infrastructure, a Division of AMEC Americas Limited	amec	CLIENT LOGO Ontario	CLIENT MINISTRY OF TRANSPORTATION ONTARIO WEST REGION	
TITLE BOREHOLE LOCATION PLAN		DWN BY: KW	DATUM: -	DATE: JANUARY2013
PROJECT REHABILITATION OF HIGHWAY 21 - FROM BAYFIELD TO GODERICH		CHK'D BY: PB	REV. NO.: A	PROJECT NO: TP110076
PURCHASE ORDER NUMBER: 3009-E-0022, WP 834-93-00, GEOCRES No.: 40P12-29		PROJECTION: -	SCALE: AS SHOWN	DRAWING No. 2

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

PURCHASE ORDER NUMBER:	
3009-E-0022	
G.W.P. No. 834-93-00	
REHABILITATION OF HWY 21 FROM BAYFIELD TO GODERICH GEOCRES No.40P12-29 **CULVERT AT STA 21+055** STRATIGRAPHIC CROSS SECTION	**SHEET 1 OF 1**

amec

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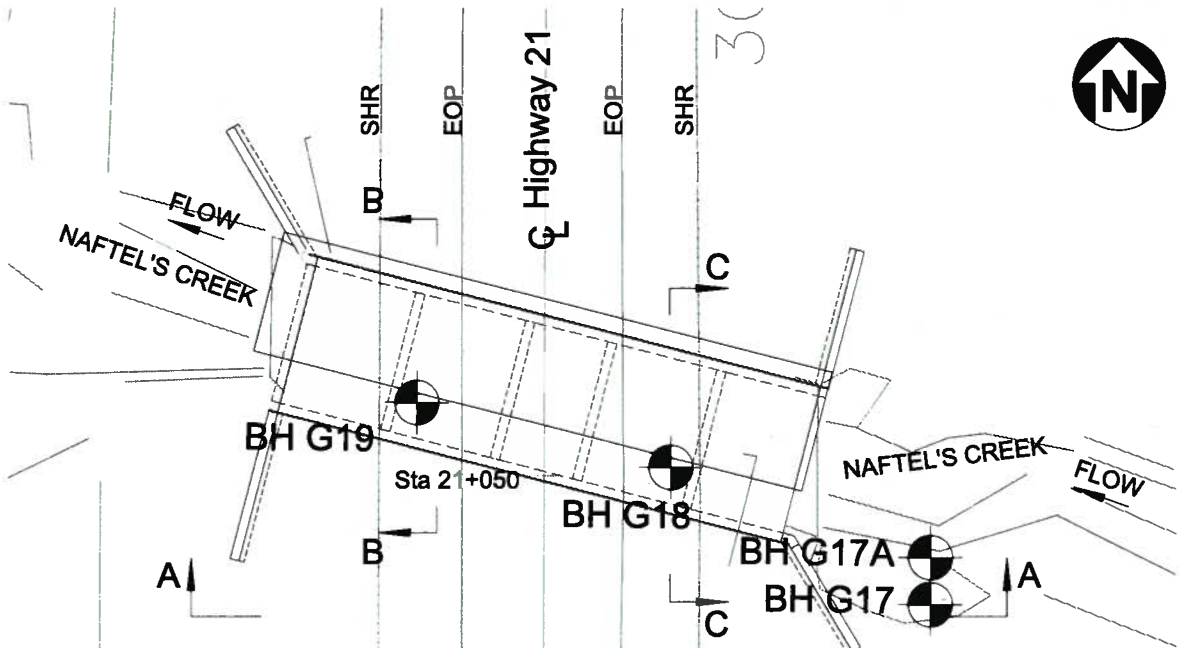
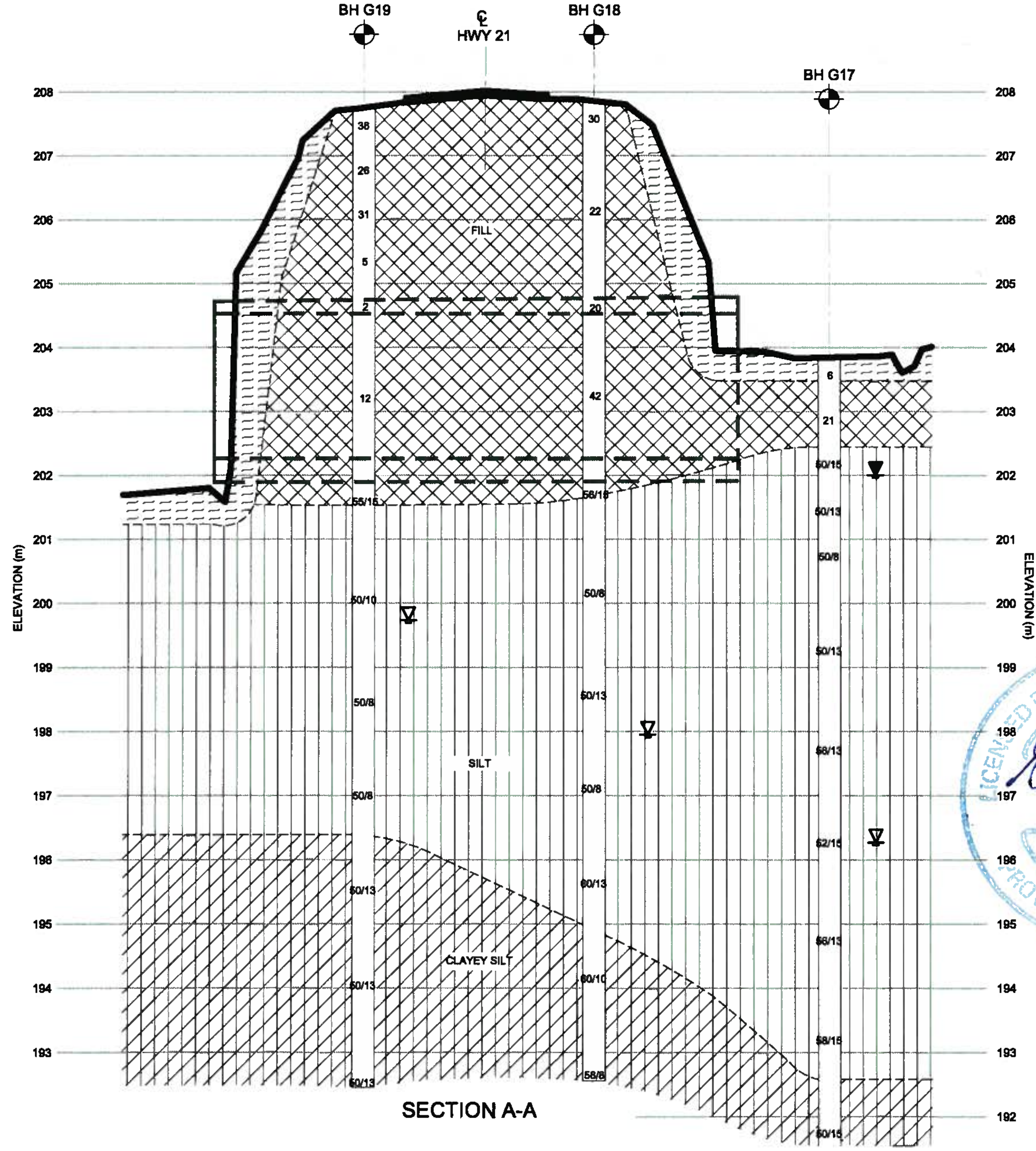
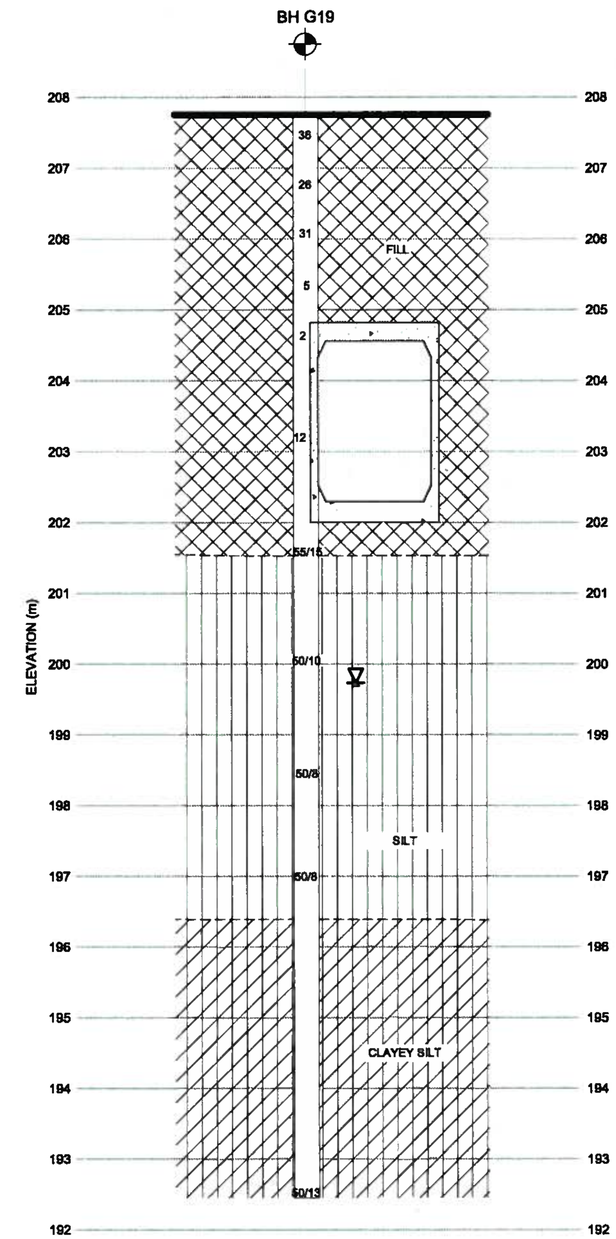


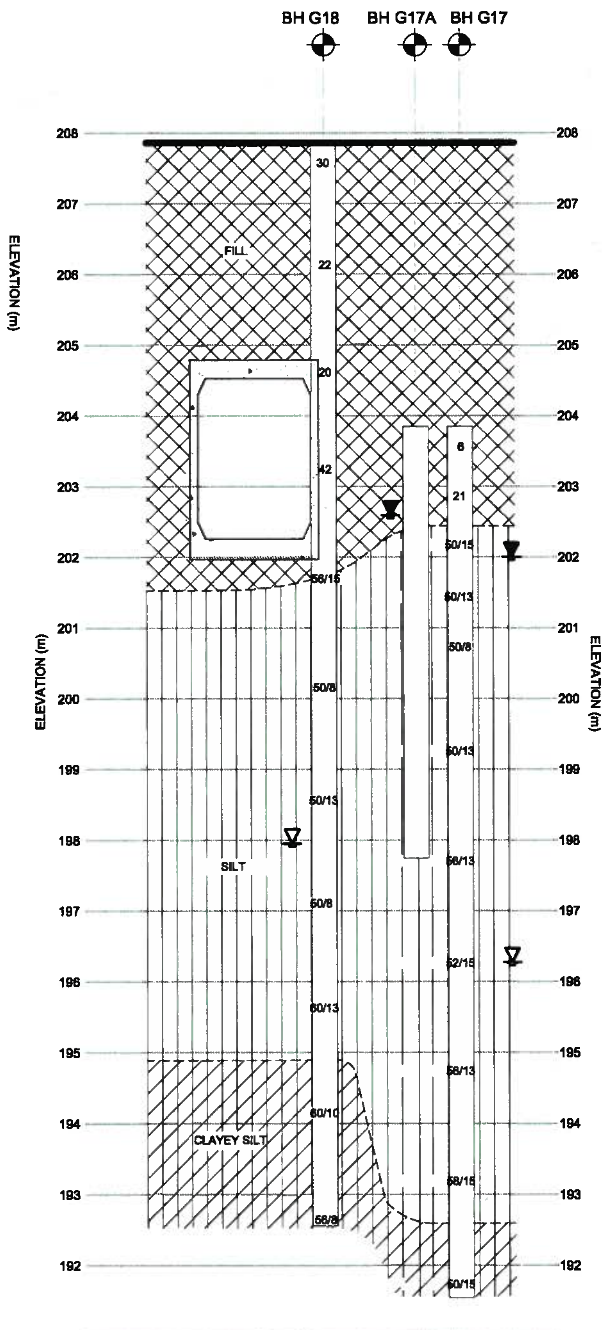
PLAN



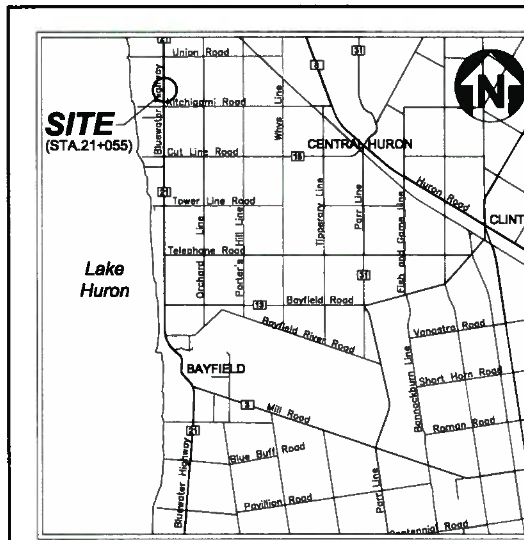
SECTION A-A



SECTION B-B



SECTION C-C



KEY PLAN

2000m 0 2000 4000 6000 8000m

Approximate Scale

LICENSED PROFESSIONAL ENGINEER S. MALLA 100025829 11 Mar '13 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER P. BOONSINSUK 11 Mar '13 PROVINCE OF ONTARIO

SOIL STRATIGRAPHY

- TOPSOIL
- FILL
- CLAYEY SILT
- SILT

SCALE: 0 4 8 12m HOR; 0 1 2 3m VER

LEGEND

- BOREHOLE LOCATION
- GROUNDWATER LEVEL AT TIME OF INVESTIGATION
- GROUNDWATER LEVEL IN MONITORING WELL
- EOP EDGE OF PAVEMENT
- SHR SHOULDER ROUND

DESCRIPTION	UTM COORDINATES NORTHING	UTM COORDINATES EASTING	ELEVATION (m)
BH G17	4835074	443127	203.85
BH G18	4835073	443116	207.86
BH G19	4835080	443105	207.75

NOTES:
1. The boundaries between soil strata have been established only at borehole locations. Between boreholes, the boundaries are assumed from geological evidence and may be subject to considerable error.
2. This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
3. Borehole without ⊻ ▼ was dry.

REVISIONS					
DESIGN PB	CHK PB	CODE CHBDC-06	CL 625-ONT	DATE JAN. 2013	
DRAWN KW	CHK HS	SITE 21+055		DWG 3	

P:\GEOProjects\2011\TP-Burlington\TP110076-HWY 21105-Foundation\Drawings...\TB112041 - Washburn Drain.DWG

APPENDIX A

RECORD OF BOREHOLES

EXPLANATION OF BOREHOLE LOG

This form describes some of the information provided on the borehole logs, which is based primarily on examination of the recovered samples, and the results of the field and laboratory tests. Additional description of the soil/rock encountered is given in the accompanying geotechnical report.

GENERAL INFORMATION

Project details, borehole number, location coordinates and type of drilling equipment used are given at the top of the borehole log.

SOIL LITHOLOGY

Elevation and Depth

This column gives the elevation and depth of inferred geologic layers. The elevation is referred to the datum shown in the Description column.

Lithology Plot

This column presents a graphic depiction of the soil and rock stratigraphy encountered within the borehole.

Description

This column gives a description of the soil stratums, based on visual and tactile examination of the samples augmented with field and laboratory test results. Each stratum is described according to the *MTC Soil Classification Manual*.

The compactness condition of cohesionless soils (SPT) and the consistency of cohesive soils (undrained shear strength) are defined as follows *(Ref. MTC Soil Classification Manual)*:

Compactness of Cohesionless Soils	SPT N-Value*
Very loose	0 to 5
Loose	5 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	> 50

Consistency of Cohesive Soils	Undrained Shear Strength kPa
Very soft	0 to 12
Soft	12 to 25
Firm	25 to 50
Stiff	50 to 100
Very stiff	100 to 200
Hard	Over 200

* For penetration of less than 0.3 m, N-values are indicated as the number of blows for the penetration achieved (e.g. 50/25: 50 blows for 25 centimeter penetration).

Soil Sampling

Sample types are abbreviated as follows:

SS	Split Spoon	TW	Thin Wall Open (Pushed)	RC	Rock Core	GS	Grab Sample
AS	Auger Sample	TP	Thin Wall Piston (Pushed)	WS	Washed Sample	AR	Air Return Sample

Additional information provided in this section includes sample numbering, sample recovery and numerical testing results.

Field and Laboratory Testing

Results of field testing (e.g., SPT, pocket penetrometer, and vane testing) and laboratory testing (e.g., natural moisture content, and limits) executed on the recovered samples are plotted in this section.

Instrumentation Installation

Instrumentation installations (monitoring wells, piezometers, inclinometers, etc.) are plotted in this section. Water levels, if measured during fieldwork, are also plotted. These water levels may or may not be representative of the static groundwater level depending on the nature of soil stratum where the piezometer tips are located, the time elapsed from installation to reading and other applicable factors.

Comments

This column is used to describe non-standard situations or notes of interest.

MTC SOIL CLASSIFICATION
Based on MTC Soil Classification Manual

Ontario

MAJOR DIVISION				GROUP SYMBOL	TYPICAL DESCRIPTION	INFORMATION REQUIRED FOR DESCRIBING SOILS	LABORATORY CLASSIFICATION CRITERIA	
COARSE GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 75µm)	GRAVELS MORE THAN HALF THE COARSE FRACTION LARGER THAN 4.75mm	CLEAN GRAVELS (LITTLE OR NO FINES)	WIDE RANGE IN GRAIN SIZE & SUBSTANTIAL AMOUNTS OF ALL INTERMEDIATE PARTICAL SIZE	GW	WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	GIVE TYPE, NAME, IF NECESSARY, INDICATE APPROX % OF SAND & GRAVEL ; MAX SIZE; ANGULARITY, SURFACE CONDITION, & HARDNESSOF THE COARSE GRAINS, LOCAL OR GEOLOGICAL NAME & OTHER PERTINENT DESCRICTIVE INFORMATION, & SYMBOL IN PARENTHESIS.	$C_u = \frac{D_{60}}{D_{10}}$ GREATER THAN 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ BETWEEN 1 AND 3	
			PREDOMINANTLY ONE SIZE OF A RANGE OF SIZES WITH STONE INTERMEDIATE SIZES MISSING	GP	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES			
		GRAVEL WITH FINES (APPLICABLE AMOUNT OF FINES)	NON PLASTIC FINES (FOR IDENTIFICATION PROCEDURES SEE ML BELOW)	GM	SILTY GRAVELS, POORLY GRADED GRAVEL-SAND- SILT MIXTURES			
			PLASTIC FINES (FOR IDENTIFICATION PROCEDURES SEE CL BELOW)	GC	CLAYEY GRAVELS, POORLY GRADED GRAVEL-SAND-CLAY MIXTURES			
	SANDS MORE THAN HALF THE COARSE FRACTION SMALLER THAN 4.75mm	CLEAN SANDS (LITTLE OR NO FINES)	WIDE RANGE IN GRAIN SIZE & SUBSTANTIAL AMOUNT OF ALL INTERMEDIATE PARTICLE SIZES	SW	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	FOR UNDISTURBED SOILS ADD INFORMATION ON STRATIFICATION, DEGREE OF COMPACTNESS, CEMENTATION, MOISTURE CONDITION & DRAINAGE CHARACTERISTICS	NOT MEETING ALL GRADATION REQUIREMENTS FOR GW	
			PREDOMINANTLY ONE SIZE OR A RANGE OF SIZES WITH SOME INTERMEDIATE SIZE MISSING	SP	POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES			
		SANDS WITH FINES (APPLICABLE AMOUNT OF FINES)	NON PLASTIC FINES (FOR IDENTIFICATION PROCEDURES SEE ML BELOW)	SM	SILTY SANDS, POORLY GRADED SAND-SILT MIXTURES		ATTERBERG LIMITS BELOW A-LINE OR Ip LESS THAN 4	ABOVE A-LINE WITH Ip BETWEEN 4 AND 7 ARE BORDERLINE CASES REQUIRING USE OF DUAL SYMBOLS
			PLASTIC FINES (FOR IDENTIFICATION PROCEDURES SEE CL BELOW)	SC	CLAYEY SANDS, POORLY GRADED SAND-CLAY MIXTURES		ATTERBERG LIMITS ABOVE A- LINE WITH Ip GREATER THAN 7	

USE GRAIN SIZE CURVE IN IDENTIFYING THE FACTORS AS GIVEN UNDER FIELD IDENTIFICATION

DETERMINE PERCENTAGE OF GRAVEL & SAND FROM GRAIN SIZE CURVE. DEPENDING ON PERCENTAGE OF FINES (FRACTION SMALLER THAN 75 µm) COARSE GRAINED SOILS ARE CLASSIFIED AS FOLLOWS:

LESS THAN 5%	GW, GP, SW, SP
MORE THAN 12%	GM, GC, SM, SC
5% TO 12%	BORDER LINE CASES REQUIRE USE OF DUAL SYMBOL.

FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT SMALLER THAN 75µm) — SILT AND CLAYS

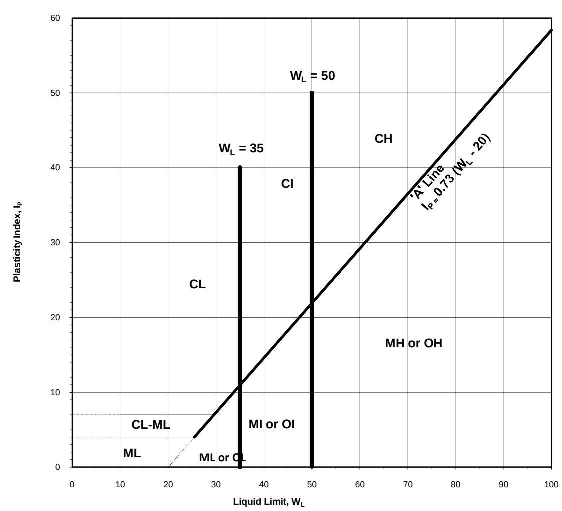
IDENTIFICATION PROCEDURE ON FRACTION SMALLER THAN 425µm

	DRY STRENGTH (CRUSHING CHARACTERISTICS)	DILATANCY (REACTION TO SHAKING)	TOUGHNESS (CONSISTENCY NEAR PLASTIC LIMIT)	GROUP SYMBOL	TYPICAL DESCRIPTION	INFORMATION REQUIRED FOR DESCRIBING SOILS	LABORATORY CLASSIFICATION CRITERIA	
LIQUID LIMIT LESS THAN 35	NONE	QUICK	NONE	ML	INORGANIC SILTS & SANDY SILTS OR SLIGHTLY PLASTICITY, ROCK FLOUR	GIVE TYPE, NAME, IF NECESSARY, INDICATE DEGREE AND CHARACTER OF PLASTICITY, AMOUNT AND MAXIMUM SIZE OF COURSE GRAINS, COLOUR IN WET CONDITION, ODOUR, IF ANY, LOCAL OR GEOLOGIC NAME & OTHER PERTINENT DESCRICTIVE INFORMATION & SYMBOL IN PARENTHESIS.	$C_u = \frac{D_{60}}{D_{10}}$ GREATER THAN 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ BETWEEN 1 AND 3	
	MEDIUM TO HIGH	NONE TO VERY SLOW	MEDIUM	CL	SILTY CLAYS (INORGANIC), GRAVELLY CLAYS, SANDY CLAYS, LEAN CLAYS			
	SLIGHT TO MEDIUM	SLOW	SLIGHT	OL	ORGANIC SILT OF LOW PLASTICITY, ORGANIC SANDY SILTS			
LIQUID LIMIT BETWEEN 35 AND 50	NONE TO SLIGHT	SLOW TO QUICK	SLIGHT	MI	INORGANIC COMPRESSIBLE FINE SANDY SILT WITH CLAY OF MEDIUM PLASTICIT, CLAYEY SILTS			
	HIGH	NONE	MEDIUM TO HIGH	CI	SILTY CLAYS (INORGANIC) OF MEDIUM PLASTICITY		NOT MEETING ALL GRADATION FOR SW	
	SLIGHT TO MEDIUM	VERY SLOW	SLIGHT	OI	ORGANIC SILTY CLAYS OF MEDIUM PLASTICITY	FOR UNDISTURBED SOILS AND INFORMATION ON STRUCTURE, STRATIFICATION, CONSISTANCY IN UNDISTURBED AND REMOLDED STATES, MOISTURE & DRAINAGE CONDITION.		
LIQUID LIMIT GREATER THAN 50	SLIGHT TO MEDIUM	SLOW TO NONE	MEDIUM	MH	INORGANIC SILTS, HIGHLY COMPRESSIBLE MICACEOUS OR DIATOMECACOUS FINE SANDY SILTS, ELASTIC SILTS		ATTERBERG LIMITS BELOW A- LINE OR Ip LESS THAN 4	ABOVE A-LINE WITH Ip BETWEEN 4 AND 7 ARE BORDERLINE CASES REQUIRING USE OF DUAL SYMBOLS
	HIGH TO VERY HIGH	NONE	HIGH	CH	CLAYS (INORGANIC) OF HIGH PLASTICITY, FAT CLAYS			
	MEDIUM TO HIGH	NONE TO VERY SLOW	SLIGHT TO MEDIUM	OH	ORGANIC CLAYS OF HIGH PLASTICITY		ATTERBERG LIMITS ABOVE A- LINE WITH Ip GREATER THAN 7	
HIGH ORGANIC SOILS	READILY IDENTIFIED BY COLOUR, ODOUR, SPONGY FEEL & FREQUENTLY BY FIBROUS TEXTURE			Pt	PEAT AND OTHER HIGHLY ORGANIC SOILS			

FRACTION		U.S STANDARD SIEVE SIZE		DEFINING RANGES OF PERCENTAGE BY WEIGHT OF MINOR COMPONENTS	
		PASSING	RETAINED	PERCENT	DESCRIPTOR
GRAVEL	COARSE	75 mm	26.5 mm		
	FINE	26.5 mm	4.75 mm	40-50	AND
SAND	COARSE	4.75 mm	2.00 mm	30-40	Y/EY
	MEDIUM	2.00 mm	425 µm	20-30	WITH
	FINE	425 µm	75 µm	10-20	SOME
FINES (SILT OR CLAY BASED ON PLASTICITY)		75 µm		1-10	TRACE

OVERSIZED MATERIAL

ROUNDED OR SUBROUNDED	NOT ROUNDED
ROUNDED OR SUBROUNDED: COBBLES 75 mm TO 200 mm BOULDERS > 200 mm	NOT ROUNDED: ROCK FRAGMENTS > 75 mm ROCKS > 0.76 CUBIC METRE IN VOLUME



PLASTICITY CHART
FOR LABORATORY CLASSIFICATION OF FINE GRAINED SOILS

BOUNDARY CLASSIFICATION: BOUNDARY CLASSIFICATION: SOILS POSSESSING CHARACTERISTICS OF TWO GROUPS ARE DESIGNATED BY COMBINATIONS OF GROUP SYMBOLS FOE EXAMPLE GW-GC WELL GRADED GRAVEL-SAND MIXTURE WITH CLAY BINDER

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AMEC Earth & Environmental,
a Division of AMEC American

www.amec.com

MTC SOIL CLASSIFICATION MANUAL

ENGINEERING PROPERTIES OF SOIL

TYPICAL NAMES OF SOIL GROUPS	GROUP SYMBOLS	PERMEABILITY WHEN COMPACTED	STRENGTH WHEN COMPACTED	COMPRESSIBILITY WHEN COMPACTED	WORKABILITY AS A CONSTRUCTION MATERIAL	SCOUR RESISTANCE	SUSCEPTIBI LIIY TO SURFICIAL EROSION	SUSCEPTIBILI TY TO FROST ACTION	DRAINAGE CHARACTERISTICS
WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	GW	PERVIOUS	EXCELLENT	NEGLIGIBLE	EXCELLENT	MEDIUM	NEGLIGIBLE	NEGLIGIBLE	EXCELLENT
POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	GP	VERY PERVI0US	GOOD	NEGLIGIBLE	GOOD	MEDIUM	NEGLIGIBLE	NEGLIGIBLE	EXCELLENT
SILTY GRAVELS, POORLY GRADED GRAVEL- SAND-SILT MIXTURES	GM	SEMI-PERVIOUS TO IMPERVIOUS	GOOD	NEGLIGIBLE	GOOD	LOW TO MEDIUM	SLIGHT	SLIGHT	FAIR TO SEMI IMPERVIOUS
CLAYEY GRAVELS, POORLY GRADED GRAVEL-SAND-CLAY MIXTURES	GC	IMPERVIOUS	GOOD TO FAIR	VERY LOW	GOOD	MEDIUM	SLIGHT	NEGLIGIBLE TO SLIGHT	PRACTICALLY IMPERVIOUS
WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	SW	PERVIOUS	EXCELLENT	NEGLIGIBLE	EXCELLENT	LOW TO MEDIUM	SLIGHT	NEGLIGIBLE	EXCELLENT
POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	SP	PERVIOUS	GOOD	VERY LOW	FAIR TO GOOD	LOW TO MEDIUM	MODERATE	NEGLIGIBLE TO SLIGHT	EXCELLENT
SILTY SANDS, POORLY GRADED SAND-SILT MIXTURES	SM	SEMI-PERVIOUS TO IMPERVIOUS	GOOD	LOW	FAIR	LOW	MODERATE	SLIGHT TO MODERATE	FAIR TO SEMI IMPERVIOUS IMPERVIOUS
CLAYEY SANDS, POORLY GRADED SAND WITH SOME CLAY MIXTURES	SC	IMPERVIOUS	GOOD TO FAIR	LOW	GOOD	VERY LOW TO LOW	MODERATE TO SLIGHT	NEGLIGIBLE	PRACTICALLY IMPERVIOUS
INORGANIC SILTS AND SANDY SILTS OF SLIGHT PLASTICITY, ROCK FLOUR	ML	SEMI-PERVIOUS TO IMPERVIOUS	FAIR	MEDIUM	FAIR	VERY LOW	SEVERE	SEVERE	FAIR TO POOR
INORGANIC CLAYEY SILTS OF LOW PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, LEAN CLAYS	CL	IMPERVIOUS	FAIR	MEDIUM	GOOD TO FAIR	LOW TO MEDIUM	SLIGHT TO MODERATE	MODERATE TO SEVERE	PRACTICALLY IMPERVIOUS
ORGANIC SILTS OF LOW PLASTICITY	OL	SEMI-PERVIOUS TO IMPERVIOUS	POOR	MEDIUM	FAIR TO POOR	VERY LOW TO LOW	SEVERE	SEVERE	POOR
INORGANIC COMPRESSIBLE SILTS OF MEDIUM PLASTICITY	MI	SEMI-PERVIOUS TO IMPERVIOUS	FAIR	MEDIUM TO HIGH	FAIR TO POOR	LOW	MODERATE	MODERATE TO SEVERE	FAIR TO POOR
INORGANIC SILTY CLAYS OF MEDIUM PLASTICITY	CI	IMPERVIOUS	FAIR TO POOR	HIGH	FAIR	LOW TO MEDIUM	SLIGHT	MODERATE TO SEVERE	SEMI IMPERVIOUS TO PRACTICALL Y
ORGANIC SILTY CLAY OF MEDIUM PLASTICITY	OI	SEMI-PERVI0US TO IMPERVIOUS	POOR	HIGH	POOR	VERY LOW TO LOW	SEVERE	MODERATE TO SEVERE	POOR TO PRACTICALLY IMPERVIOUS
INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS	MH	SEMI-PERVIOUS TO IMPERVIOUS	FAIR TO POOR	HIGH	POOR	VERY LOW	MEDIUM	SEVERE	POOR
INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS	CH	IMPERVIOUS	POOR	HIGH	FAIR TO POOR	LOW TO MEDIUM	SLIGHT TO NEGLIGIBLE	NEGLIGIBLE	PRACT I.CALL Y IMPERVIOUS
ORGANIC CLAYS OF HIGH PLASTICITY	OH	IMPERVIOUS	POOR	HIGH	POOR	LOW	MODERATE	NEGLIGIBLE TO SLIGHT	PRACTICALLY IMPERVIOUS
PEAT AND OTHER HIGHLY ORGANIC SOILS	Pt	-	-	-	-	LOW	SEVERE	-	FAIR TO GOOD

Ontario

RECORD OF BOREHOLE No. BH G17

G.W.P. 834-93-00 | LOCATION Sta: 21+055, 4.0 m S of Culvert, 16.4 m Rt of CL of Rd, E 443127; N 4835074 | ORIGINATED BY JF

DIST Goderich HWY 21 | BOREHOLE TYPE 150 mm diameter borehole (Solid Stem) | COMPILED BY SAL

DATUM Geodetic | DATE 17 May 2011 - 17 May 2011 | CHECKED BY SM

PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario | JOB NO. TP110076

ELEV DEPTH (m)	DESCRIPTION	NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
203.9 / 0.0	**about 400 mm TOPSOIL**	1	SS	6	16	
203.5 / 0.4	brown **Sandy Silt FILL** trace gravel and clay trace organic matter moist	2	SS	21	37	
202.5 / 1.4	light grey **SILT** some to with sand, trace clay and gravel, trace cobbles/boulders very dense moist to wet	3	SS	50/15	14	
		4	SS	50/13	15	
		5	SS	50/8	15	
		6	SS	50/13	15	
		7	SS	56/15	14	
		8	SS	52/15	14	

Column headings: SOIL PROFILE; SAMPLES; STRAT PLOT; GROUND WATER CONDITIONS; DEPTH m; ELEVATION SCALE m; 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; SOIL VAPOUR READING PPM; GR SA SI CL

Elevation scale: 203, 202, 201, 200, 199, 198, 197, 196, 195. Depth scale: 1, 2, 3, 4, 5, 6, 7, 8.

Continued Next Page

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

Ontario

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RECORD OF BOREHOLE No. BH G17

G.W.P. 834-93-00	LOCATION Sta: 21+055, 4.0 m S of Culvert, 16.4 m Rt of CL of Rd, E 443127; N 4835074	ORIGINATED BY	JF
DIST Goderich HWY 21	BOREHOLE TYPE 150 mm diameter borehole (Solid Stem)	COMPILED BY	SAL
DATUM Geodetic	DATE 17 May 2011 - 17 May 2011	CHECKED BY	SM
PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario		JOB NO.	TP110076

SOIL PROFILE | SAMPLES | GROUND WATER CONDITIONS | DEPTH (m) | ELEVATION SCALE (m) | 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) | SOIL VAPOUR READING (PPM) | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	GR	SA	SI	CL
			9	SS	56/13	14				
			10	SS	58/15	15				
192.6 11.3	grey **CLAYEY SILT** trace sand, trace cobbles/boulders hard									
191.5 12.3			11	SS	50/15	13	0	1	83	16

Depth scale: 10, 11, 12 m; Elevation scale: 194, 193, 192 m

End of Borehole

Monitoring well details:
- 50 mm diameter PVC pipe:
- concrete: 0.0 - 0.3 m
- bentonite plug: 0.3 - 10.4 m
- sand pack 10.4 - 10.7m
- slotted pipe: 10.7 - 12.2 m
- sand pack: 12.2 - 12.3 m
- protective casing: 0.9 m above ground

Groundwater level on
16 May 2011 was 7.6 m depth
22 June 2011 was 2.0 m depth

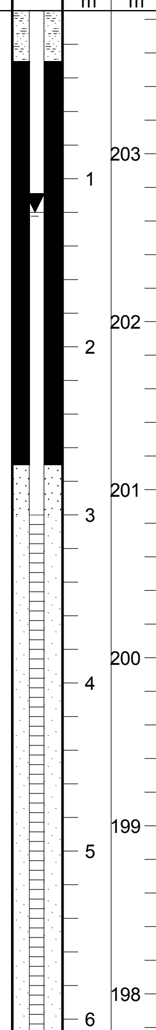
+3, ×3: Numbers refer to Sensitivity ○3% STRAIN AT FAILURE

Ontario

RECORD OF BOREHOLE No. BH G17A

G.W.P. 834-93-00	LOCATION Sta: 21+055, 4.0 m S of Culvert, 16.4 m Rt of CL of Rd, E 443127; N 4835074	ORIGINATED BY JF
DIST Goderich HWY 21	BOREHOLE TYPE 150 mm diameter borehole (Solid Stem)	COMPILED BY SAL
DATUM Geodetic	DATE 17 May 2011 - 17 May 2011	CHECKED BY SM
PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario		JOB NO. TP110076

ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	DEPTH m	ELEVATION SCALE m	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT; WATER CONTENT (%)	SOIL VAPOUR READING PPM	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
203.9 0.0	Augered down to 6.1 m for installation of well. No samples were taken nor SPT recorded.											
197.8 6.1	**End of Borehole**											



Monitoring well details:
- 50 mm diameter PVC pipe:
- concrete: 0.0 - 0.3 m
- bentonite plug: 0.3 - 2.7 m
- sand pack 2.7 - 3.0 m
- slotted pipe: 3.0 - 6.1 m
- protective casing: 0.9 m above ground.

Groundwater level on 22 June 2011 was 1.3 m depth

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

Ontario

RECORD OF BOREHOLE No. BH G18

G.W.P. 834-93-00	LOCATION Sta: 21+055, 3.0 m S of Culvert, 5.4 m Rt of CL of Rd, E 443116; N 4835073	ORIGINATED BY JF
DIST Goderich HWY 21	BOREHOLE TYPE 150 mm diameter borehole (Solid Stem)	COMPILED BY SAL
DATUM Geodetic	DATE 18 May 2011 - 18 May 2011	CHECKED BY SM
PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario		JOB NO. TP110076

ELEV DEPTH (m)	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE (m)	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
207.9 / 0.0	**Sand and Gravel FILL** trace silt moist	1	SS	30		6	
207.4 / 0.5	brown **Sand FILL** some silt, trace to some gravel				207		
		2	SS	22	206	8	
		3	SS	20	205	11	
					204		
		4	SS	42	203	12	
					202		
201.6 / 6.3	grey **SILT** some to with sand, trace clay and gravel very dense moist to wet	5	SS	56/15		11	
					201		
		6	SS	50/8		15	3 22 68 7
					200		
					199		

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; DEPTH m; ELEVATION SCALE m; 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; SOIL VAPOUR READING PPM.

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity ○ $^{3\%}$ STRAIN AT FAILURE

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RECORD OF BOREHOLE No. BH G18

G.W.P. 834-93-00 LOCATION Sta: 21+055, 3.0 m S of Culvert, 5.4 m Rt of CL of Rd, E 443116; N 4835073 ORIGINATED BY JF

DIST Goderich HWY 21 BOREHOLE TYPE 150 mm diameter borehole (Solid Stem) COMPILED BY SAL

DATUM Geodetic DATE 18 May 2011 - 18 May 2011 CHECKED BY SM

PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario JOB NO. TP110076

ELEV DEPTH (m)	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE (m)	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
		7	SS	50/13			14	
					▽ (9.9 m)	198		
		8	SS	50/8			13	
						197		
						196		
		9	SS	60/13			16	
						195		
194.9 13.0	grey **CLAYEY SILT** trace sand hard							
		10	SS	60/10			15	0 1 85 14
						194		
						193		
		11	SS	56/8			14	
192.6 15.3	**End of Borehole** Groundwater level on 18 May 2011 was 9.9 m depth							

Depth scale (m): 10, 11, 12, 13, 14, 15

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

Ontario

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RECORD OF BOREHOLE No. BH G19

G.W.P. 834-93-00 | LOCATION Sta: 21+055, 3.0 m S of Culvert, 5.4 m Lt of CL of Rd, E 443105; N 4835080 | ORIGINATED BY JF

DIST Goderich HWY 21 | BOREHOLE TYPE 150 mm diameter borehole (Solid Stem) | COMPILED BY SAL

DATUM Geodetic | DATE 17 May 2011 - 17 May 2011 | CHECKED BY SM

PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario | JOB NO. TP110076

ELEV DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	GR	SA	SI	CL
207.8 / 0.0	brown **Sand and Gravel FILL** some silt moist	1	SS	36		5				
207.2 / 0.6	brown **Sand FILL** trace to some silt and gravel	2	SS	26		10				
		3	SS	31		9				
	pocket of organic matter in SS4	4	SS	5		13				
	mixed with organic matter in SS5	5	SS	2		15				
	trace organic matter in SS6	6	SS	12		14				
201.5 / 6.2	grey **SILT** some to with sand, trace clay very dense moist to wet; trace cobbles / boulders	7	SS	55/15		15				
		8	SS	50/10	▽ (approx. 8.0 m)	15	2	18	75	5

Column headings also printed on the log: STRAT PLOT; DEPTH (m); ELEVATION SCALE (m); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (20, 40, 60, 80, 100): ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (20, 40, 60); SOIL VAPOUR READING (PPM); REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8 m. Elevation scale: 207, 206, 205, 204, 203, 202, 201, 200, 199 m.

Continued Next Page

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

Ontario

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RECORD OF BOREHOLE No. BH G19

G.W.P. 834-93-00 | LOCATION Sta: 21+055, 3.0 m S of Culvert, 5.4 m Lt of CL of Rd, E 443105; N 4835080 | ORIGINATED BY JF

DIST Goderich HWY 21 | BOREHOLE TYPE 150 mm diameter borehole (Solid Stem) | COMPILED BY SAL

DATUM Geodetic | DATE 17 May 2011 - 17 May 2011 | CHECKED BY SM

PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario | JOB NO. TP110076

ELEV DEPTH (m)	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	DEPTH m	ELEVATION SCALE m	WATER CONTENT (%)	SOIL VAPOUR READING PPM	GR	SA	SI	CL
		9	SS	50/8				12					
	trace cobbles / boulders					10	198						
		10	SS	50/8			197	15					
	trace cobbles / boulders					11							
196.3 11.4	grey **CLAYEY SILT** trace sand hard					12	196						
		11	SS	50/13				14					
						13	195						
		12	SS	50/13		14	194	14		0	1	76	23
						15	193						
192.4		13	SS	50/13				13					
15.4	**End of Borehole** Groundwater level on 17 May 2011 was 8.1 m depth												

+3, ×3: Numbers refer to Sensitivity

○3% STRAIN AT FAILURE

Dynamic Cone Penetration Resistance Plot: 20 40 60 80 100

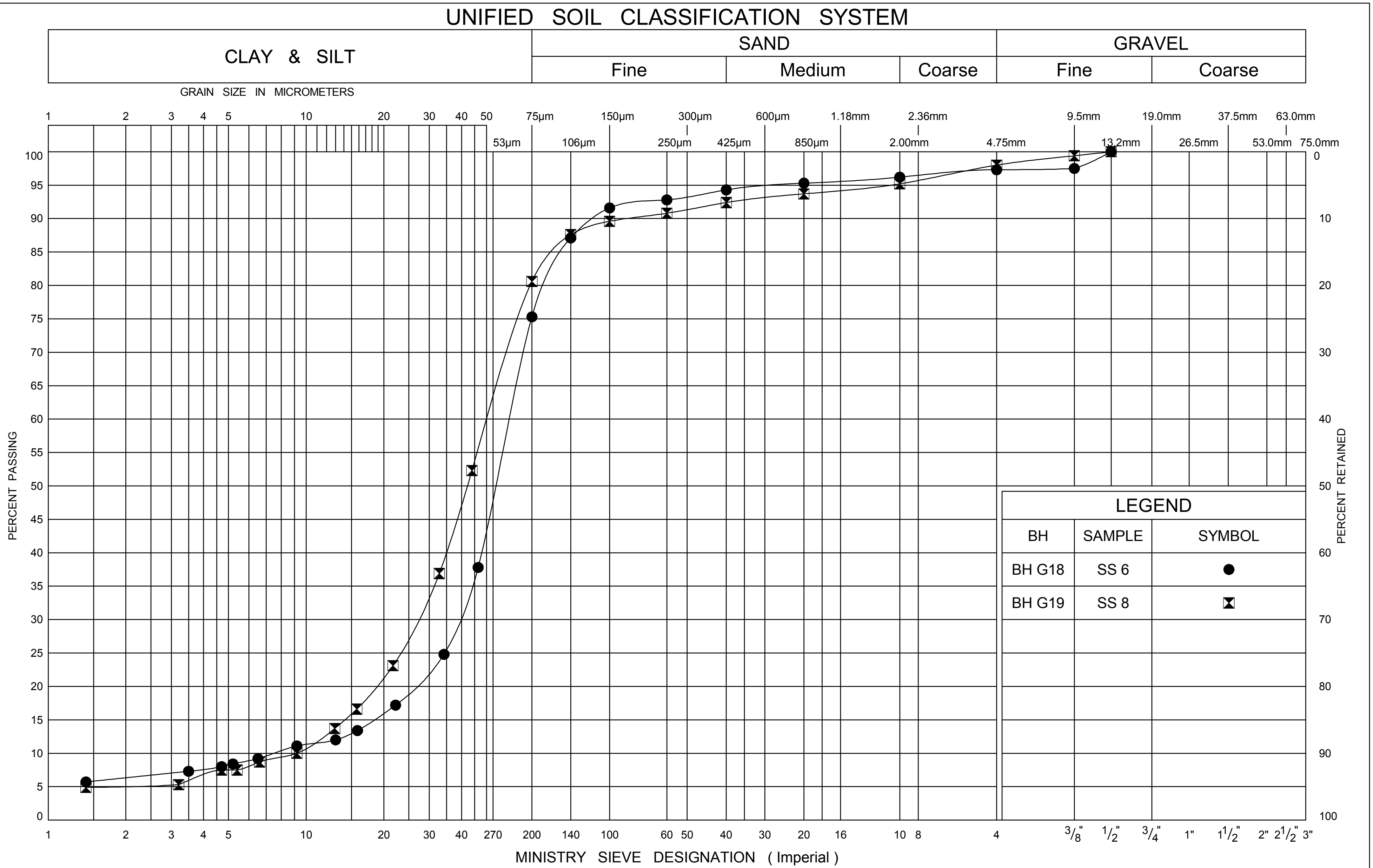
Shear Strength kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

Plastic Limit W_P — Natural Moisture Content W — Liquid Limit W_L; Water Content (%) 20 40 60

Remarks & Grain Size Distribution (%)

APPENDIX B

LABORATORY TEST RESULTS



Ministry of Transportation

Ontario

GRAIN SIZE DISTRIBUTION

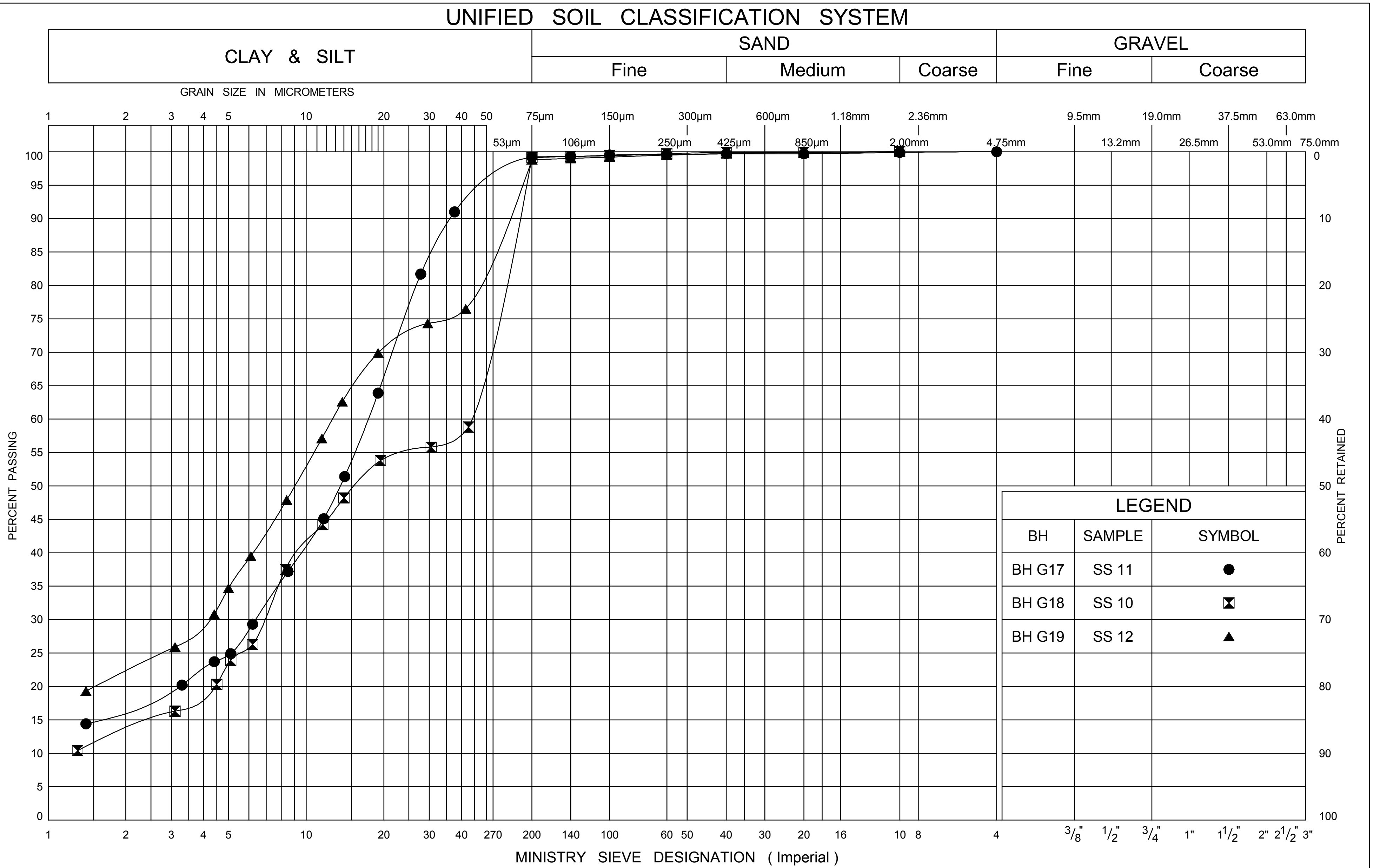
Silt

Figure No. B1

G.W.P. 834-93-00

Culvert at Sta. 21+055, Hwy 21, Bayfield to Goderich

ONTARIO MOT GRAIN SIZE TP110076-5-2 MTO.GPJ ONTARIO MOT.GDT 03/01/13



ONTARIO MOT GRAIN SIZE TP110076-5-2 MTO.GPJ ONTARIO MOT.GDT 03/01/13

Ministry of Transportation
Ontario

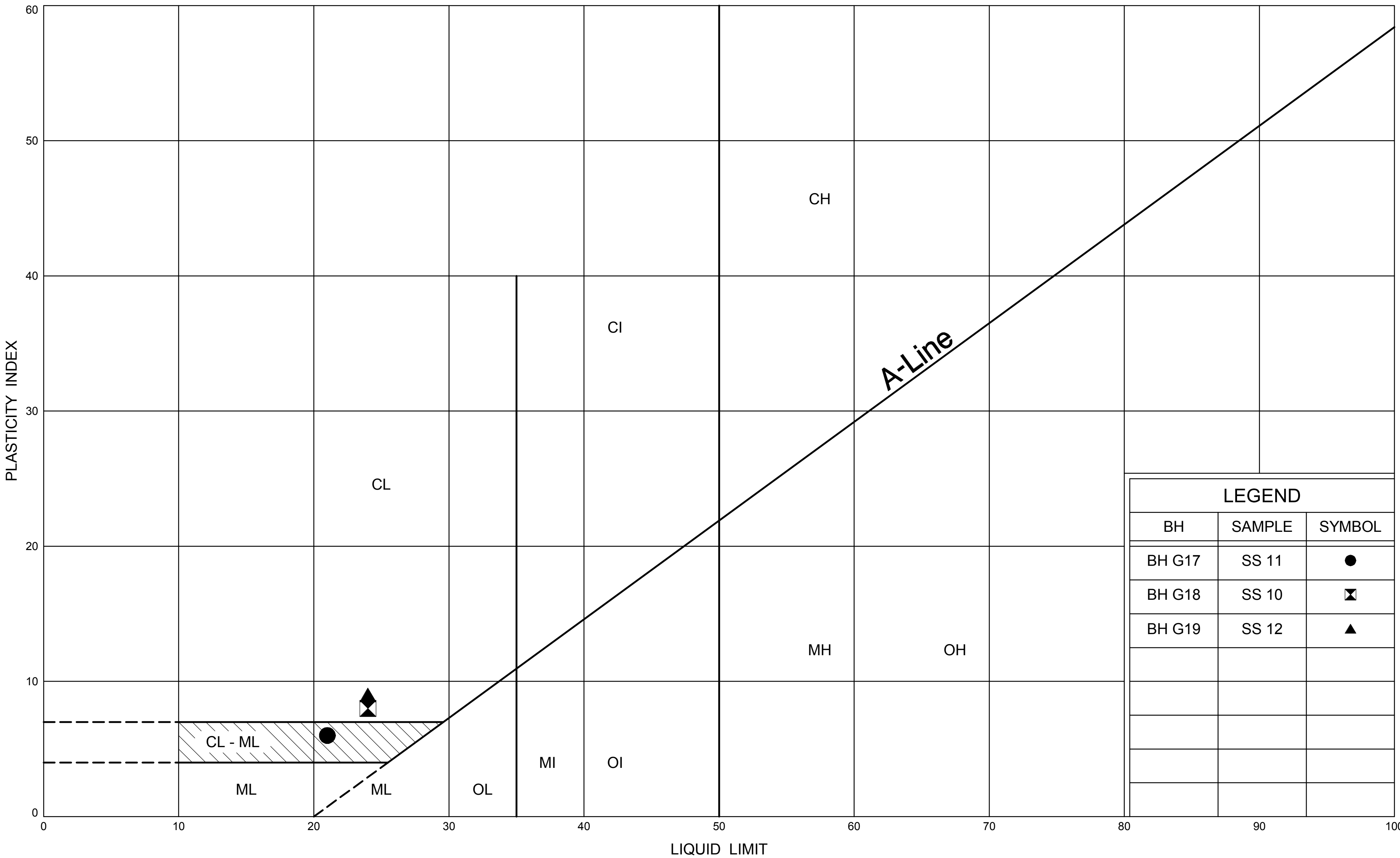
GRAIN SIZE DISTRIBUTION

Clayey Silt

Figure No. B2

G.W.P. 834-93-00

Culvert at Sta. 21+055, Hwy 21, Bayfield to Goderich



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PLASTICITY CHART

Clayey Silt

Figure No. B3

G.W.P. 834-93-00

Culvert at Sta. 21+055, Hwy 21, Bayfield to Goderich

Your Project #: TP110076.5
Site: HWY21 (7 CULVERTS)
Your C.O.C. #: 32091

Attention: Shami Malla
AMEC Earth & Environmental Ltd
Scarborough
104 Crockford Blvd
Sacroborough, ON
CANADA M1R3C3

Report Date: 2011/06/06

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B175937
Received: 2011/05/27, 17:25

Sample Matrix: Soil
Samples Received: 7

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Method Reference
Chloride (20:1 extract)	4	N/A	2011/06/02	CAM SOP-00463	
Chloride (20:1 extract)	3	N/A	2011/06/04	CAM SOP-00463	
Conductivity	7	N/A	2011/06/02	CAM SOP-00414	APHA 2510
pH CaCl2 EXTRACT	6	2011/06/02	2011/06/02	CAM SOP-00413	SM 4500 H
pH CaCl2 EXTRACT	1	2011/06/03	2011/06/03	CAM SOP-00413	SM 4500 H
Resistivity of Soil	7	2011/05/30	2011/06/02	CAM SOP-00414	APHA 2510
Sulphate (20:1 Extract)	7	N/A	2011/06/04	CAM SOP-00464	EPA 375.4

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.
* Results relate only to the items tested.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

GINA BAYBAYAN,
Email: GBAYBAYAN@maxxam.ca
Phone# (905) 817-5766

==
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Total cover pages: 1

Maxxam Job #: B175937
Report Date: 2011/06/06

AMEC Earth & Environmental Ltd
Client Project #: TP110076.5
Project name: HWY21 (7 CULVERTS)

RESULTS OF ANALYSES OF SOIL

Maxxam ID		JQ4509	JQ4510	JQ4511		JQ4512		JQ4513		JQ4514		
Sampling Date		2011/05/16	2011/05/16	2011/05/16		2011/05/16		2011/05/18		2011/05/17		
	Units	**BH G7 / SS2**	**BH G10 / SS4**	**BH G12 / SS4**	**QC Batch**	**BH G13 / SS2**	**QC Batch**	**BH G15 / SS2**	**QC Batch**	**BH G17 / SS3**	**RDL**	**QC Batch**
Calculated Parameters												
Resistivity	ohm-cm	2600	530	1100	2502843	3200	2502843	6000	2502843	3200		2502843
Inorganics												
Soluble (20:1) Chloride (Cl)	ug/g	140	970	470	2508305	120	2506767	<20	2506767	49	20	2506767
Conductivity	umho/cm	389	1870	951	2506690	316	2506690	166	2506690	317	2	2506690
Available (CaCl2) pH	pH	7.61	7.50	7.60	2506893	7.81	2506893	7.61	2508147	7.93		2506893
Soluble (20:1) Sulphate (SO4)	ug/g	<20	<20	<20	2508307	<20	2506764	<20	2506764	120	20	2506764

Maxxam ID		JQ4515		
Sampling Date		2011/05/17		
	Units	**BH G21 / SS2**	**RDL**	**QC Batch**
Calculated Parameters				
Resistivity	ohm-cm	1900		2502843
Inorganics				
Soluble (20:1) Chloride (Cl)	ug/g	270	20	2506767
Conductivity	umho/cm	532	2	2506690
Available (CaCl2) pH	pH	7.74		2506893
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	2506764

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

Package 1	20.3°C

Each temperature is the average of up to three cooler temperatures taken at receipt

GENERAL COMMENTS

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

AMEC Earth & Environmental Ltd
Client Project #: TP110076.5
Project name: HWY21 (7 CULVERTS)

Maxxam Job #: B175937
Report Date: 2011/06/06

QUALITY ASSURANCE REPORT

			Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	Units	Value (%)	QC Limits	% Recovery	QC Limits
2506690	Conductivity	2011/06/02					<2	umho/cm	2.4	35	103	75 - 125
2506764	Soluble (20:1) Sulphate (SO4)	2011/06/04	102	75 - 125	97	85 - 115	<20	ug/g	NC	35		
2506767	Soluble (20:1) Chloride (Cl)	2011/06/02	109	75 - 125	98	85 - 115	<20	ug/g	NC	35		
2508305	Soluble (20:1) Chloride (Cl)	2011/06/04	95	75 - 125	103	85 - 115	<20	ug/g	5.0	35		
2508307	Soluble (20:1) Sulphate (SO4)	2011/06/04	111	75 - 125	95	85 - 115	<20	ug/g	NC	35		

N/A = Not Applicable
RPD = Relative Percent Difference
Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.
Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.
QC Standard: A blank matrix to which a known amount of the analyte has been added. Used to evaluate analyte recovery.
Spiked Blank: A blank matrix to which a known amount of the analyte has been added. Used to evaluate analyte recovery.
Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.
NC (RPD): The RPD was not calculated. The level of analyte detected in the parent sample and its duplicate was not sufficiently significant to permit a reliable calculation.

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

Validation Signature Page

Maxxam Job #: B175937

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Cristina Carriere

CRISTINA CARRIERE, Scientific Services

==

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APPENDIX C

SITE PHOTOGRAPHS

Photograph No. 1: View of existing culvert inlet.

Photograph No. 2: View inside the culvert.

Photograph No. 3: View embankment at existing culvert oulet.