FOUNDATION INVESTIGATION AND DESIGN REPORT

REHABILITATION OF HIGHWAY 21
FROM BAYFIELD TO GODERICH, ONTARIO

CULVERT NO. 10 AT STATION 12+138

MINISTRY OF TRANSPORTAION ONTARIO - WEST REGION
PURCHASE ORDER NUMBER 3009-E-0022
GWP 834-93-00

MTO GEOCRES NO. 40P12-27

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TABLE OF CONTENTS

Page

1.0 INTRODUCTION 1
2.0 SITE AND PROJECT DESCRIPTION 3
3.0 GEOLOGY 4
4.0 INVESTIGATION PROCEDURES 4
  4.1 Field Investigation 4
  4.2 Laboratory Tests 5
5.0 SUB-SURFACE CONDITIONS 5
  5.1 Sand and Gravel Fill 6
  5.2 Silty Clay / Silty Sand Fill 6
  5.3 Clayey Silt / Silty Clay 6
  5.4 Groundwater Conditions 7
  5.5 Limited Environmental Investigation 8
6.0 DISCUSSION AND RECOMMENDATIONS 9
  6.1 Comparison of Retaining Wall Options 9
  6.2 Foundations 11
  6.3 Excavation 14
  6.4 Dewatering and Ditch Diversion 14
  6.5 Temporary Shoring 15
  6.6 Outlet Protection 15
  6.7 Soil Corrosivity 15
  6.8 Earthquake Considerations 16
7.0 CLOSURE 17

LIMITATIONS OF REPORT

LIST OF CONSTRUCTION SPECIFICATIONS AND DRAWINGS

DRAWINGS

Drawing No. 1 Culvert Location Plan
Drawing No. 2 Borehole Location Plan
Drawing No. 3 Stratigraphic Cross Sections

APPENDICES

APPENDIX A: Record of Boreholes (BH G26 and BH G27)
APPENDIX B: Laboratory Test Results
APPENDIX C: Site Photographs (Photographs 1 and 2)

1.0 INTRODUCTION

AMEC Environment & 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, 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), Ontario, as shown in Drawing No. 1.

In May 2011, AMEC conducted a foundation investigation comprising 21 boreholes (BH G1 to BH G21) at the locations of eight existing culverts identified for rehabilitation / replacement. The design reports for these culverts have been submitted to MTO separately.

In March 2012, AMEC conducted additional foundation investigations at the locations of 11 additional existing culverts, as shown on Drawing No. 1. The number of boreholes and locations of the boreholes were based on the Highway 21 Culvert Recommendations Table (dated 18 January 2012). The details of the additional culverts investigated, and the boreholes advanced at each location, are summarized in Table 1.1.

Table 1.1 - Culvert Details for Additional Foundation Investigations (March 2012)*

Station	Existing Culvert		Boreholes Drilled	Proposed Work	Foundation Investigation Requirement
	Type	Dimension			
10+267	Concrete Rigid Frame - Open Footing	0.9 x 0.9 x 38.5 m	BH G22 and BH G23	Extend culvert and clean out	Two boreholes for extension
11+691	Concrete Rigid Frame Box	3.75 x 2.30 x 68.4 m	BH G24 and BH G25	Rehabilitate and install RSS to stabilize steep roadway embankment	Foundations for RSS / slopes and protection system to stage the construction
12+138	Concrete Box	1.2 x 1.2 x 24.2 m	BH G26 and BH G27	Rehabilitate inlet, remove outlet precast block wing walls, place gabion wingwalls at east end. Construct CIP wingwalls at west outlet, including scour protection.	Two boreholes at outlet end for retaining wall foundations
13+835	Concrete Box	1.2 x1.2 x 27.05 m	BH G28 and BH G29	Replace south west concrete retaining wall with CIP concrete retaining walls. Construct CIP concrete wingwall at northeast.	Two boreholes (southwest and northeast retaining walls)

Station	Existing Culvert		Boreholes Drilled	Proposed Work	Foundation Investigation Requirement
	Type	Dimension			
15+205	Concrete Arch - Open Footing	7.16 x 3.66 x 29.6 m	BH G30	Rehabilitate and install RSS to stabilize steep roadway embankment. Replace southwest wingwall	Foundations for RSS / slopes (both side of the roadway) and protection system for construction. Protection will be installed approximately 2.5 m from centerline. One borehole for southwest wingwall.
18+380	Rigid Frame Box	3.66 x 1.52 x 21.4 m	BH G31, BH G32, BH G32A, BH G33 and BH G34	Rehabilitate concrete at both ends and soffit and add wingwalls or extend culvert	Boreholes required for a retaining wall between culverts 12-422, and 12-424 on Highway 21 and 12-423 on Cut Line Road , southeast of Intersection. Or lengthening of the culvert. (min. 4 BH for these 3 culverts total)
18+393		3.05 x 0.91 x 15.3 m		Rehabilitate and construct wing walls between this culvert and 12-422/C	
18+409		3.66 x 1.52 x 21.4 m		Rehabilitate and construct wing walls between this culvert and 12-423/C	
18+843	Concrete Frame - Open Footing	1.5 x 1.1 x 24.7 m	BH G35 and BH G36	Rehabilitate ends and replace wingwalls with CIP concrete. Repair culvert interior. Extend inlet end.	Two boreholes (one at each end)
25+232	Concrete Frame - Open Footing	2.9 x 0. 9 x 20.8 m	BH G37	Replace sandbag wingwalls with gabions at west end and CIP concrete retaining wall at east end. Repair outlet concrete. Place scour protection.	One Foundation borehole (east end)
26+521	Concrete Frame - Open Footing	1.8 x 1.2 x 23.5 m	BH G38 and BH G39	Rehabilitate ends and replace sand bag retaining walls with CIP concrete retaining walls	Two Foundation boreholes (one at each end)

* Based on Hwy 21 Culvert Summary Table (dated 13 December 2011), and Hwy 21 Culvert Recommendations Table (dated 18 January 2012).

The purpose of the additional foundation investigation was to obtain information on the subsurface conditions at the additional culvert sites (Table 1.1) by means of boreholes, in-situ tests and laboratory tests on selected soil samples. Based on AMEC's interpretation of the data obtained in the investigation, recommendations are provided on the geotechnical aspects of replacement / rehabilitation / extension of the culverts.

As per the Terms of Reference (TOR) in the Request for Proposal (Purchase Order Number: 3009-E-0022, dated March 2010), separate reports have been prepared - one for each culvert site, except at the intersection of Highway 21 and Cut Line Road, where one report has been prepared for the three culverts located at the intersection.

This report presents the results of foundation investigation together with design discussion and recommendations for the rehabilitation of Culvert No. 10 at Station 12+138.

The factual results of the soil conditions encountered in the boreholes and laboratory tests (without design discussion and recommendations) for the rehabilitation of Culvert No. 10 at Station 12+138 are presented in a separate report titled “Foundation Investigation Report”.

2.0 SITE AND PROJECT DESCRIPTION

The investigated culvert site (at Station 12+138) is located at the existing watercourse (Dogwood Creek) crossing Highway 21, about 60 m south of Bayfield Road, north of Bayfield, Ontario (Drawing No. 1).

At this location, Highway 21 is a two-lane asphaltic concrete paved road with gravel shoulders on both sides with fence, 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 lots. The embankment slopes were covered by tall grasses and other low vegetation at the time of the fieldwork.

As noted in Table 1.1 (Section 1.0), the existing culvert at this location is a 1.2 m wide x 1.2 m high x 24.2 m long concrete box culvert. Preliminary Drawing No. S1 dated April 2012 (Culvert No. 10, Sheet S4) indicates that the height of the existing embankment at the culvert location varies from about 2.5 m to 4.0 m above the surrounding grades, which are at elevations of about 195.0 m east of culvert and 193.5 m west of the culvert.

Currently, there are concrete blocks as outfall at the west end (outlet) of the culvert (Photograph No. 1). As per the design recommendation, the following works are proposed:

- Outlet (west end): Construction of a new retaining wall, removal of the existing concrete block outfall and installation of scour protection.
- Inlet (east end): Construction of a new gabion retaining wall and repair of deteriorated concrete of the box culvert.

At the time of field work, the inlet and outlet ends of the existing culvert were covered with vegetation. Site photographs showing the culvert are presented in Appendix C (Photographs 1 and 2).

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 comprises (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 Culvert Recommendations (Table 1.1 in Section 1.0), two (2) boreholes (BH G26 and BH G27) were advanced on the west shoulder of Highway 21 on either side of culvert, each borehole extending to an approximate depth of 9.6 m below the existing grade to elevation 188.0 m in BH G26 and 187.9 m in BH G27. The as-drilled borehole locations are presented on Drawing No. 2.

The fieldwork was performed on 6 March 2012 after acquiring all necessary permits for road occupancy, and obtaining clearance for underground utilities. The ground surfaces at the borehole locations were surveyed with reference to the nearest geodetic benchmark (BM HCP # 102, Sta. 10+449.955, El 197.134).

The boreholes were advanced using solid-stem augers, with a track-mount power-auger drilling rig under the full-time supervision of experienced geotechnical personnel from AMEC. The drilling, sampling and in-situ testing operations were conducted by using a track-mount drill rig owned and operated by Drilltech Drilling Inc., Newmarket, Ontario.

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, wherever encountered, are presented on the Record of Boreholes.

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

One selected sample was tested for soils corrosivity potential with respect to concrete and steel, the result so of which is discussed in Section 6.7.

Upon recovery, all soil samples were screened using a hand-held hydrocarbon surveyor (RKI Eagle), the results of which are presented on the Record of Boreholes.

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, grain size analysis, Liquid and Plastic Limits, in-situ water content determination, and soil corrosivity analysis which was performed by Maxxam Analytics, an accredited CAEL laboratory located in Mississauga, Ontario.

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).

AMEC will retain the soil samples for a period of one year after completion of the project, unless otherwise advised in writing by MTO.

4.2 Laboratory Tests

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

- In-situ water content determination (19);
- Grain size distribution analysis (4);
- Atterberg Limit tests (4); and
- Soil corrosivity (1).

The results of in-situ and laboratory tests are presented in the Record of Boreholes in Appendix A. The grain size distribution curves and plasticity chart, and the results of soil corrosivity test are shown in Appendix B.

5.0 SUB-SURFACE CONDITIONS

The investigation results indicated that the soil profile at the borehole locations consisted predominantly of surficial sand and gravel fill underlain by silty clay / silty sand fill. The fill soils were underlain by native deposit consisting of clayey silt / silty clay extending to the termination depth of the boreholes at elevation of about 188.0 m in both boreholes.

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). Interpolated stratigraphical cross sections showing the existing culvert are provided in Drawing No. 3.

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

5.1 Sand and Gravel Fill

Sand and gravel fill was encountered at the existing grade in both boreholes advanced through the Highway 21 shoulder. The measured thickness of sand and gravel fill was about 400 mm in Borehole BH G26, and 500 mm in BH G27.

Two SPT N-values measured in the sand and gravel fill were 17 and 15 blows per 0.3 m. The measured moisture contents in the sand and gravel fill were 7 % and 10 %

5.2 Silty Clay / Silty Sand Fill

Silty clay fill was encountered below the sand and gravel fill in both boreholes. The silty clay fill extended to about 1.8 m in Borehole BH G26 (Elevation 195.8 m) and about 4.0 m in Borehole BH G27 below the existing grade (Elevation 193.5 m).

The silty clay fill was brown in color and contained trace to some sand, trace gravel and organic matter.

Silty sand fill was encountered below the silty clay fill in Borehole BH G26. The silty sand fill extended to about 2.9 m in Borehole BH G26 below the existing grade (Elevation 194.7 m).

The silty sand fill was brown in color and contained trace clay, gravel and organic matter.

SPT N-values measured in the silty clay / silty sand fill ranged from 7 to 33 blows per 0.3 m. The measured moisture contents in the silty clay / silty sand fill ranged from 13 % to 27 %.

5.3 Clayey Silt / Silty Clay

Native clayey silt / silty clay was encountered below the fill soils and extended to the termination depths of the boreholes at the elevation of about 188.0 m in both boreholes.

The clayey silt / silty clay was grey in color, and contained trace to some sand and trace gravel. The SPT 'N' values of the clayey silt / silty clay ranged from 12 to 37 blows per 0.3 m, indicating a stiff to hard consistency. The measured moisture contents in the clayey silt / silty clay ranged from 16 % to 18 %.

Grain size analyses and Atterberg Limit tests were completed on 4 samples of the clayey silt / silty clay and the results are presented in Table 5.1.

Table 5.1 - Grain Size Distribution Analyses and Atterberg Limit Test Results

(Clayey Silt / Silty Clay)

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 G26	SS 5	3.0 - 3.5 (194.6 - 194.1)	-	1	80	19	22	15	7	CL- ML
	SS 9	9.1 - 9.5 (188.5 - 188.0)	4	15	45	36	26	13	13	CL
BH G27	SS 6	4.6 - 5.1 (192.9 - 192.4)	-	1	63	36	28	15	13	CL
BH G27	SS 8	7.6 - 8.1 (188.8 - 188.3)	2	15	49	34	27	13	14	CL

The grain size distribution curves are presented in Figure No. B 1 and the plasticity chart is presented in Figure No. B 2, in Appendix B.

5.4 Groundwater Conditions

Groundwater conditions in the open boreholes were observed during and on completion of drilling. Groundwater was measured at depths of about 5.0 m below the existing grade (Elevation 192.6 m) in Borehole BH G26, and about 4.0 m below the existing grade (Elevation 193.5 m) in Borehole BH G27. Upon completion of drilling, cave-in was noted in both boreholes to the same depths as the groundwater level.

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 and water level in the creek.

5.5 Limited Environmental Investigation

In accordance with the Terms of Reference and AMEC proposal, soil samples obtained during the geotechnical field drilling program were field screened for evidence of environmental impact. The field screening activities included measuring the combustible organic vapours (COV) in the headspace of samples with a portable hydrocarbon surveyor instrument (RKI Eagle).

No visual or olfactory evidence of environmental impact was observed in the fill and native soil samples recovered from the boreholes. The measured COV concentrations in all soil samples were relatively low, ranging from non-detect to 5 ppm as shown in the Record of Boreholes. The COV results are semi-quantitative at best and are generally used only for relative sample comparison purposes when selecting samples for laboratory analysis. Based on the field screening results, evidence of environmental impact is not suspected.

6.0 DISCUSSION AND RECOMMENDATIONS

In preparation of this report, the following information was considered:

I. Highway 21 Culvert Recommendations Table, dated 18 January 2012.
II. Highway 21 Culvert Summary Table, dated 13 December 2011.
III. AMEC Preliminary Drawing No. S1 (Sheet No. S4), dated April 2012, for Culvert No. 10 at Station 12+138.

Based on the cross-section drawing, the culvert outlet is covered by concrete block outfall. The invert elevations at the inlet and outlet of the culvert are 194.58 m and 194.75 m respectively.

The project comprises the following works:

- Installation of new retaining wall at inlet (east end); and
- Installation of new retaining wall, at outlet (west end) with scour protection after removing the existing concrete block outfall.

Based on the cross-section drawing, the length and height of the new retaining walls will be 3 m and up to 2 m respectively. Cast-in-place concrete or Gravity-type retaining walls or Retained Soil System (RSS) walls are feasible, from the geotechnical viewpoint.

The following sections discuss the geotechnical aspects of feasible new retaining wall types.

6.1 Comparison of Retaining Wall Options

A comparison of the feasible retaining wall structures is provided in Table 6.1.

Table 6.1 - Comparison of Retaining Wall Structure Options

Option	Description	Advantages	Disadvantages	Risks / Consequences	Cost Comparison
Cast-in- place concrete retaining wall	Typically, cantilever, reinforced-concrete, retaining wall.	Durable and low maintenance. Not susceptible to erosion by water flow and ice forces. No specialized contractor is needed. Economical for wall of moderate height	Rigid structure which may show minor cracks. Labour intensive for placing reinforcing bars and formwork. Possible need more time for construction to allow for curing concrete.	Temporary slope excavated into the existing road embankment may have to stand up longer before backfilling.	Medium to high

Option	Description	Advantages	Disadvantages	Risks / Consequences	Cost Comparison
Gravity Type Retaining Wall - Gabion,	Gabions are rectangular steel baskets filled with stone and stacked on one another.	Construction is relatively simple. Flexible type of structure Drain freely.	Gabions are labour-intensive in order to properly place stones inside the gabion baskets. Steel cages may not be stable in long term. Gabion may be subject to erosion by creek water flow and ice forces. Not economical for high walls	Maintenance or replacement may be frequent.	Medium to low
Gravity Type Retaining Wall - Armourstone	Armourstones are large-sized stones, typically up to 1 m wide by 1 m high by 1.5 m long.	Construction is relatively simple. Flexible type of structure. Drain freely. Good resistance to water flow and ice forces. Possibly less installation time.	Source and transportation to site may be high Not economical for high walls		Medium to low

Option	Description	Advantages	Disadvantages	Risks / Consequences	Cost Comparison
Retained Soil System (RSS)	Stone/concrete facade in front of soil mass reinforced with metal strips or geogrids.	Flexible type of structure	RSS requires specialised contractor according to MTO's DSM. Facade material has to be properly selected to prevent erosion by water flow and ice forces. Labour intensive for construction. Reinforcing strips may not be durable.	May require some maintenance	Medium

Considering that the length and height of the new retaining walls at this site, Gravity Type Retaining Wall (e.g. Gabion Wall, Armourstone, etc.) would be suitable at the inlet end, from the geotechnical viewpoint, because of relatively simple construction and flexible structure. However, at the outlet end, due to the grade drop of about 1.5 m immediately below the outlet (refer to Photograph No. 1), the new retaining wall will be founded on a small slope and will have to retain the toe of the road embankment. As such, a cast-in-place concrete retaining wall which provides more resistance to scouring may be desirable.

6.2 Foundations

Based on the cross-section drawing, the base of the existing culvert lies at elevations of about 194.4 m and 194.6 m at the inlet and outlet, respectively. The base of the new retaining walls is anticipated to be at or below about 194.0 m. The investigation results for Boreholes BH G26, located on the north side of the culvert, indicated that the competent soil at the founding grade would comprise native very stiff to hard clayey silt / silty clay. However, Borehole BH G27, located on the south side of the culvert, indicated fill soils at the founding level. In Borehole BH G27, competent native soil was located at an elevation of about 193.4 m. If fill soils are encountered at the founding level, the fill soil should be sub-excavated down to competent native soil. The grade can be restored to the proposed founding elevation by backfilling, with lean concrete, which will prevent water from entering and flowing through the backfill.

For the culvert, cut-off walls, if not already present, should be installed to prevent flow below the culvert that could erode base materials.

The geotechnical Ultimate Limit State (ULS)/Serviceability Limit State (SLS) values provided in Table 6.2 should be used for the design of the retaining walls.

Table 6.2 - SLS and ULS Values for Retaining Wall Design

Structure	Borehole No.	Founding Stratum	Depth below Existing Grade (m)	Approximate Elevation (m)	Geotechnical Reaction at SLS (kPa)	Factored Geotechnical Resistance at ULS[(1)], (kPa)
Retaining walls at inlet[(2)] / outlet	BH G26	Very stiff to hard clayey silt / silty clay	2.9 m (±) & below	194.6 m (±) and below	250	325
	BH G27	Stiff to very stiff clayey silt / silty clay	4.5 m (±) & below	193.5 m (±) and below	175	270

Note: [(1)] A resistance factor of Φ = 0.5 has been applied to the values provided.
[(2)] No borehole was drilled at the inlet end of culvert. Recommendations were based on Boreholes BH G26 & BH G27. Field verification is necessary at the time of construction.

The soil parameters in Table 6.3 may be used for design.

Table 6.3 - Summary of Geotechnical Parameters

Soil Stratum	Bulk Unit Weight of Soil, γ (kN/m³)	Angle of Internal Friction (degree)	Earth Pressure Coefficient[(1)]		
			At-rest, K_o	Active, K_a	Passive, K_p
Existing fill	18	28	0.53	0.35	2.0
Clayey silt / silty clay	20	28	0.53	0.35	2.0
Granular A	22	35	0.38	0.27	2.0
Granular B	21	32	0.40	0.30	2.0

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

A frost penetration depth of 1.2 m should be used at this site according to OPSD 3090.101.

The recommended SLS bearing values in Table 6.2 are based on a total settlement of up to 25 mm. Detailed foundation analysis will be necessary if accurate values of settlement are required.

For sliding resistance, an unfactored coefficient of friction of 0.35 should be considered at the base, which includes a resistance factor of 0.8.

The retaining walls should be backfilled with granular soil (OPSS Granular 'A' or Granular 'B' complying OPSS 1010), and compacted as per OPSS 501. Materials for gabion wall, if used, must comply with OPSS 1430 (Material Specification for Gabion Baskets and Mats).

The retaining walls should be provided with a positive drainage system to prevent the build-up of hydrostatic pressure. It is recommended that a non-woven Class II geotextile with an FOS of 75-150 µm (OPSS 1860) be installed between the free draining granular backfill and earth fill / native soils, or immediately behind the wall and underneath the wall, to prevent migration of fines.

If the retained soil system (RSS) wall is selected, the design of the RSS wall should be carried out as per the manufacturer's specifications based on the type of wall selected. Ministry of Transportation's (MTO) RSS Design Guidelines, including the Non Standard Special Provision for RSS (January 2008) included therein, and/or Standard Special Provision to OPSS - SSP 599S23, should be used for the design, supply and construction of the RSS, in addition to any contract requirements and RSS manufacturer's standards.

Excavations for constructing the new retaining walls should be carried out carefully to ensure that the existing foundation of the adjacent culvert and the existing road embankment are not compromised.

Soil subgrade to support the new retaining wall at the culvert inlet end shall be inspected by a geotechnical engineer to verify that the soil subgrade is capable of supporting the new retaining wall according to the design bearing capacity.

Excavation for retaining wall foundations should comply with OPSS 902 (Nov/10) (*Construction Specifications for Excavating and Backfilling* - Structures) should be followed. Backfill should be placed according to OPSS 206 (*Construction Specification for Grading*), and compacted according to OPSS 501 (*Construction Specification for Compacting*). Backfill for the retaining wall should conform to OPSD 3121.150 (*Minimum Granular Backfill Requirement - Walls Retaining*).

Any topsoil, organic soils and other deleterious materials encountered must be removed from the footprint of the foundations. Excavation to replace soft / loose soils should be carried out carefully to ensure that the foundation of existing culvert is not compromised. The exposed subgrade should be verified by proof-rolling (or other acceptable method), and any loose, soft or unstable areas sub-excavated and replaced with competent material. It is recommended that the foundation subgrade should be inspected by a geotechnical engineer.

The excavation and groundwater control are further discussed in Section 6.3 and Section 6.4.

6.3 Excavation

All excavations should be carried out in accordance with the Occupational Health and Safety Act and Regulations for Construction Projects. The soils to be excavated can be classified as follows:

Silty clay / silty sand fill	Type 3
Stiff to hard clayey silt / silty clay	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 and groundwater conditions. The excavation work should comply with OPSS 902 (*Construction Specification for Excavating and backfilling - Structures*). If open cut excavation cannot be carried out due to space restriction, temporary shoring will be required. The temporary shoring is discussed in Section 6.5.

Excavated materials should be stock-piled at least 3 m from the edge of the excavation to avoid the slope instability.

The possibility of encountering cobbles/boulders during construction should be considered.

There may be underground utilities (gas, water, sewer and telephone) within the road embankment which may be exposed during the excavation. All utilities, if present, should be adequately supported or relocated prior to excavation work. Approval should be sought from relevant authorities and utilities companies regarding excavation works around such services.

6.4 Dewatering and Ditch Diversion

Based on the groundwater conditions encountered in Boreholes BH G26 and BH G27 (Section 5.4), the groundwater would likely be at an elevation of about 193.6 m, which is about 1.2 m below the invert elevation of the existing culvert. Excavation may, however, encounter perched water. Groundwater seepage is expected to be slow through the silty clay / clayey silt soils, and could be dewatered using a system of filtered sumps and pumps. High rates of seepage may occur from surface water and dewatering effort could require an increased number of filtered sumps and pumps.

A cofferdam (earth dyke) or similar may be required to prevent water flow from entering the work area and/or reducing the groundwater inflow into the excavation.

Dewatering plans must consider any flows from the highway side drains / ditches that enter into the ditch at the culvert location.

Dewatering and ditch diversion activities should proceed ahead of the excavation operation.

6.5 Temporary Shoring

The temporary shoring of the excavation, if required, should conform to OPSS 539 (*Construction Specification for Temporary Protection Systems*).

The temporary shoring system should be designed to resist the lateral earth, surcharge and hydrostatic pressure which could occur during construction. The design of temporary shoring should be carried out in accordance with the latest edition of Canadian Highway Bridge Design Code CAN/CSA-S6-06 Soil parameters summarized in Table 6.2 may be used for design considerations.

6.6 Outlet Protection

Outlet protection treatment in accordance with OPSS 511, OPSS 1004 and OPSD 810.10, or better, should be constructed to prevent erosion adjacent to the culvert as well as scour that could undermine the culvert / retaining wall foundation. A non-woven Class II geotextile with an FS of 75 - 150 µm according to OPSS 1860 should be placed below the rip-rap, if provided, to minimize the potential for erosion of fine particles below the treatment.

6.7 Soil Corrosivity

To determine the soil corrosivity potential with respect to concrete and steel, one soil sample (BH G26 - SS 4) was submitted to Maxxam Analytics Laboratory in Mississauga, and tested for pH, soluble chloride, sulphate, electrical conductivity and resistivity. A summary of the test results are presented in the Table 6.4, while, the Certificate of Analysis is included in Appendix B.

Table 6.4 - Results of Corrosivity Test

Soil Sample No.	pH	Electrical Conductivity µmho/cm	Resistivity (ohm-cm)	Chloride (µg/g)	Sulphate (µg/g)
BH G26 - SS 4	7.4	734	1400	350	54

The test results have shown that the sulphate content of the soil is 54 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 (1400 ohm-cm), the degree of corrosivity should be considered as "severe" 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.

6.8 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, 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 site at Station 12+138 on Highway 21, north of Bayfield, Ontario.

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

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

Sincerely,

AMEC Environment & Infrastructure,
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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.

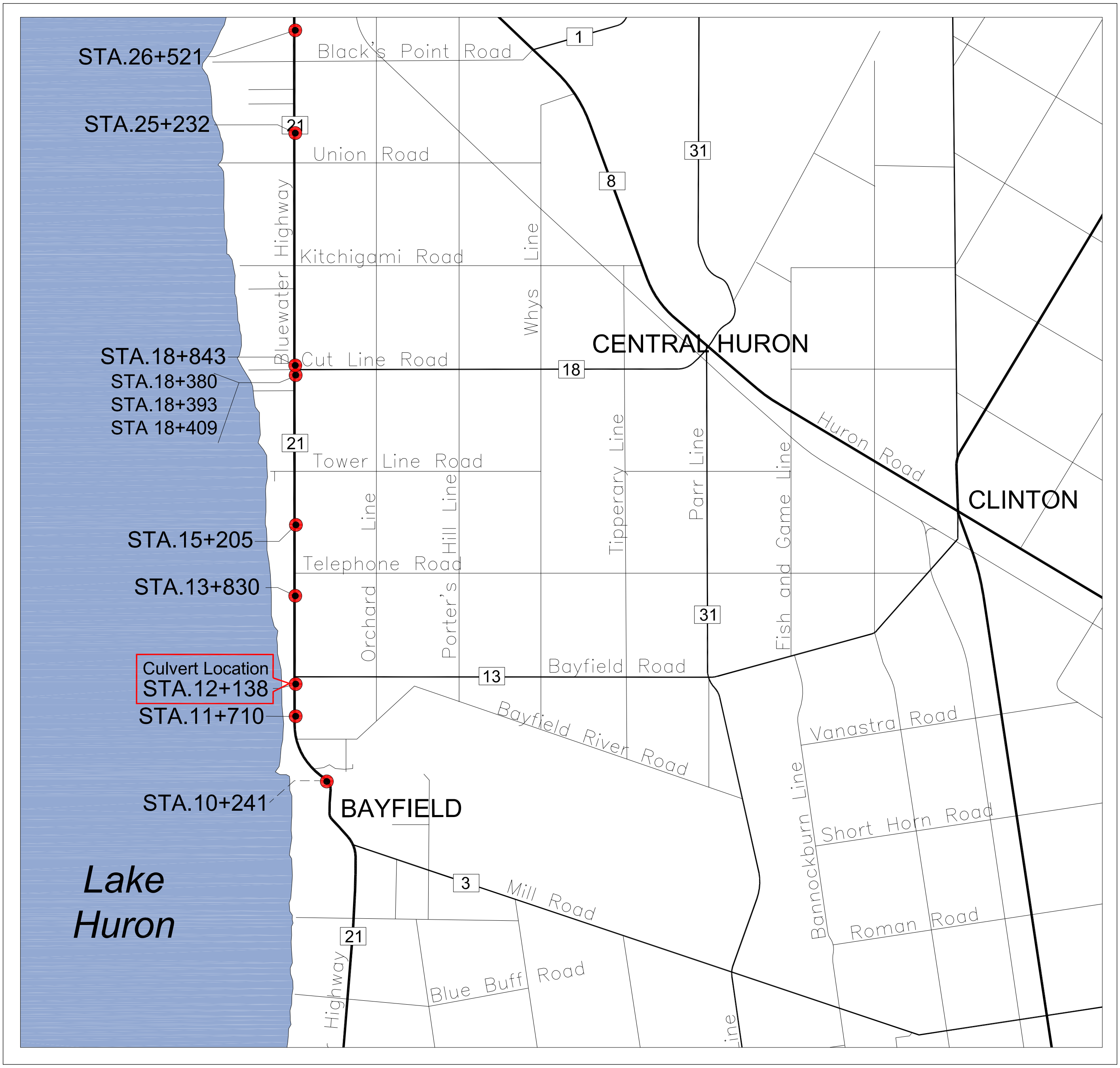
This report was prepared specifically for the culvert at Station 12+138 in Highway 21, north of Bayfield , Ontario, as described in the report. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. AMEC 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 209 (Apr/09)	Construction Specification for Embankments over Swamps and Compressible Soils
OPSS 501 (Nov/10)	Construction Specification for Compacting
OPSS 511 (Apr/11)	Construction Specification for rip-rap, rock protection, and granular sheeting
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
SSP 599S23 (Mar/06)	Special Provision for Materials, Quality Control and Quality Assurance Testing and Acceptance Criteria for Precast Concrete Facing Elements including Panels
Drawings	
OPSD 208.010	Benching of Earth Slopes
OPSD 803.010	Backfill, backfill transition and cover for the concrete culvert
OPSD 810.010	Rip-rap treatment for sewer and culvert outlets
OPSD 3121.150	Minimum granular backfill requirements - walls retaining

DRAWINGS

DRAWING NO. 1	CULVERT LOCATION PLAN
DRAWING NO. 2	BOREHOLE LOCATION PLAN
DRAWING NO. 3	STRATIGRAPHIC CROSS SECTIONS



SCALE

1500m 0 1500 3000 4500 6000m

LEGEND

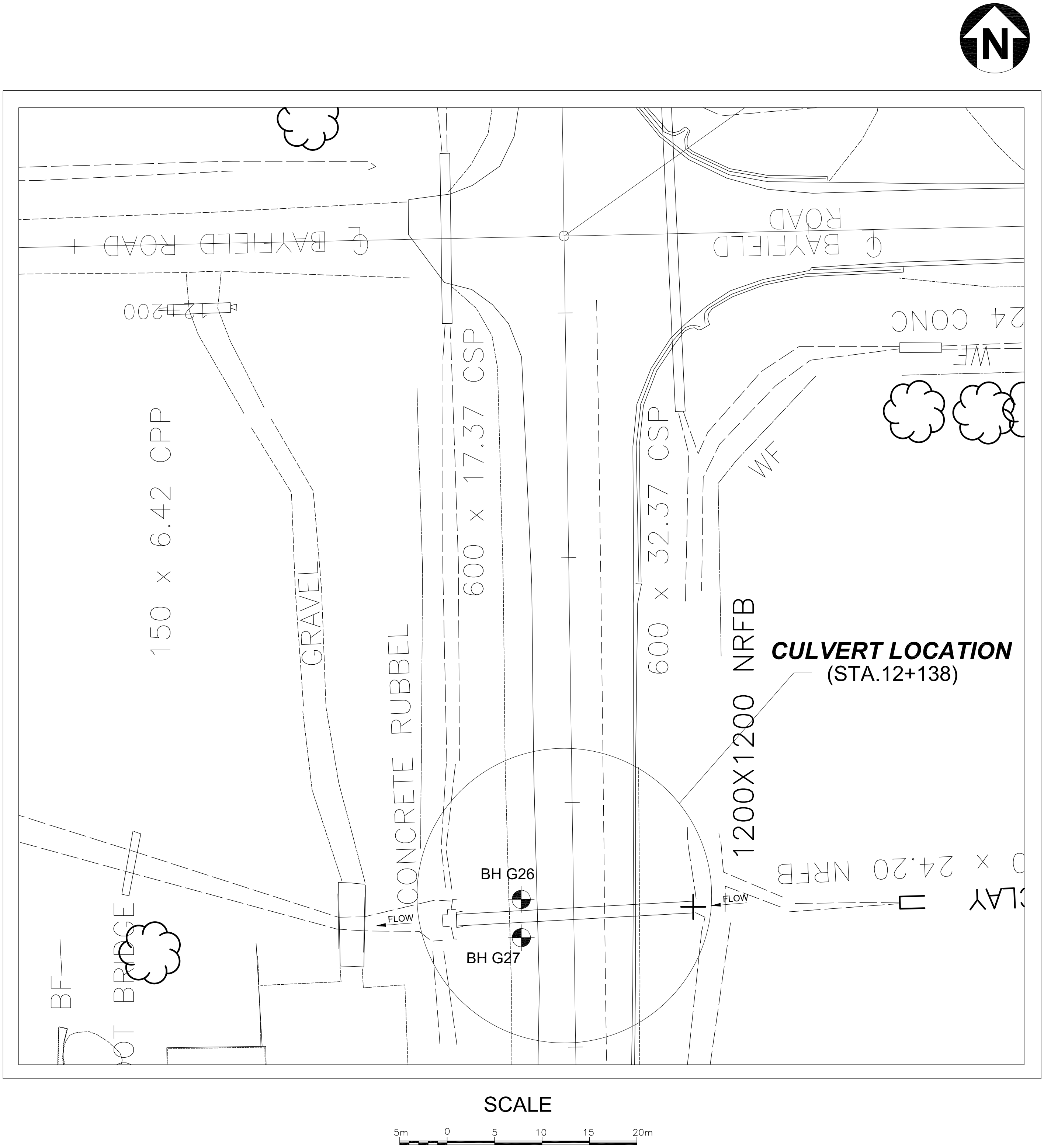
CULVERT LOCATION

AMEC Environment & Infrastructure, a Division of AMEC Americas Limited

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.: 40P12-27	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	BOROHOLE LOCATION PLAN	DWN BY: KW	DATUM: -	DATE: JANUARY 2013
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.: 40P12-27	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.40P12-27 **CULVERT AT STA 12+138** STRATIGRAPHIC CROSS SECTION	**SHEET 1 OF 1**

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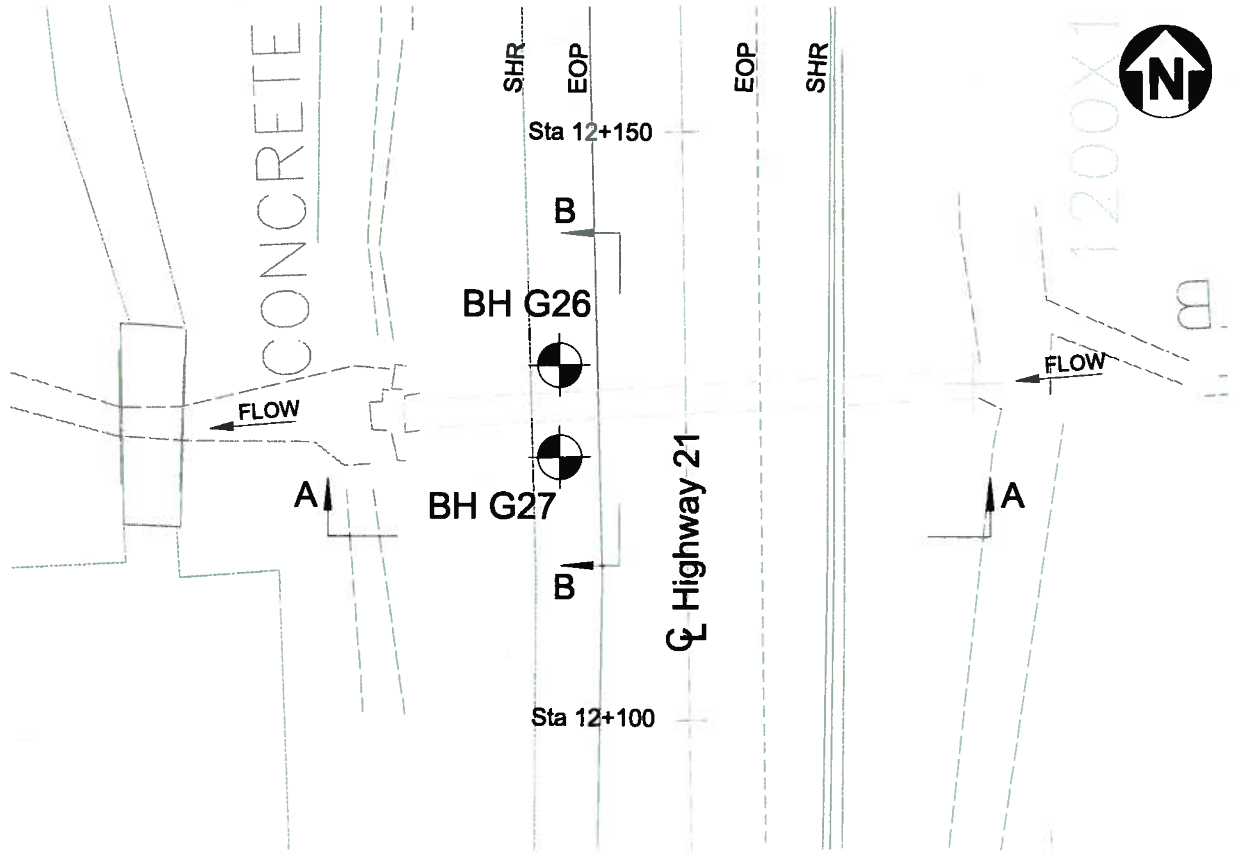
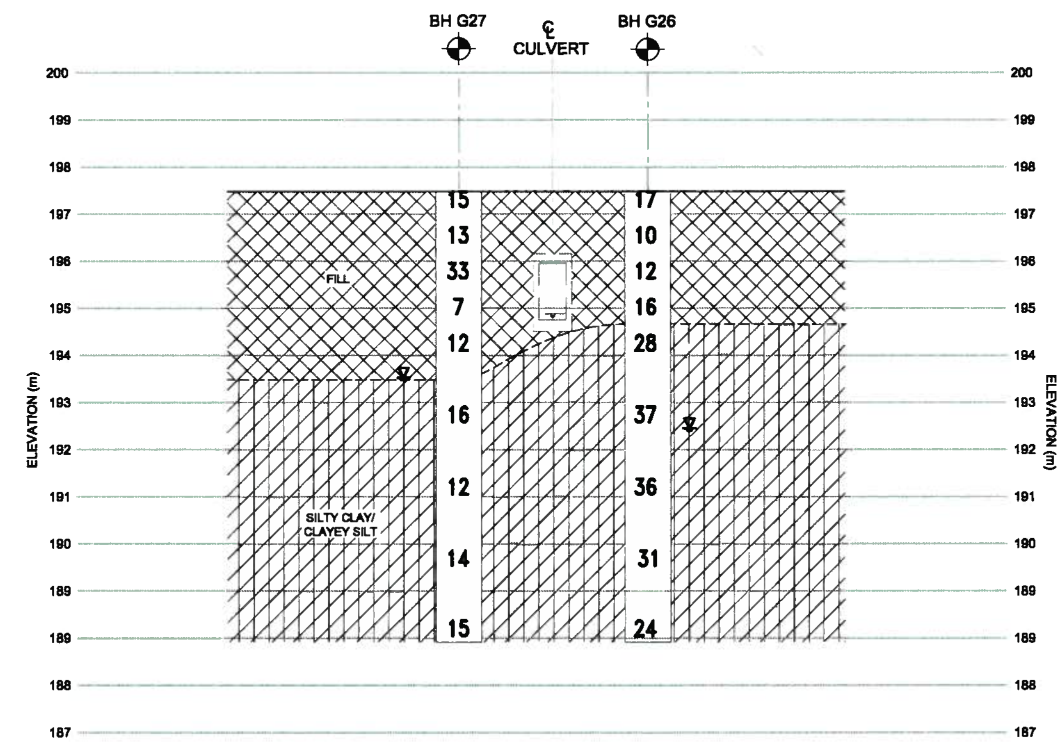


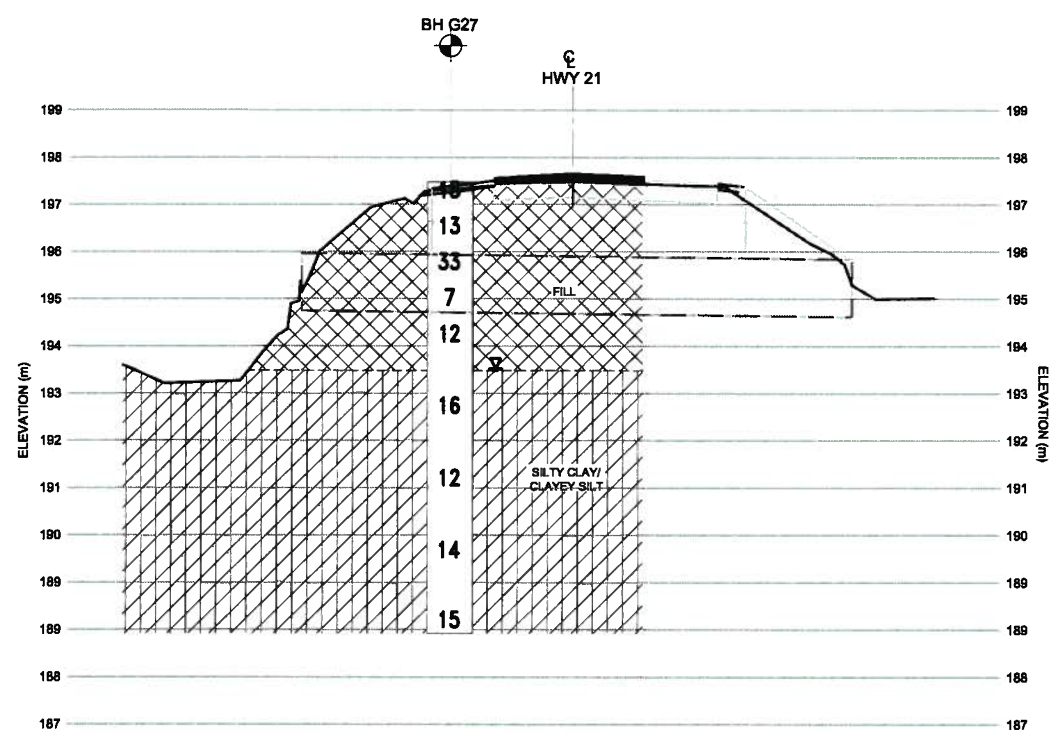
PLAN

KEY PLAN

2000m 0 2000 4000 6000 8000m
Approximate Scale



SECTION B-B



SECTION A-A

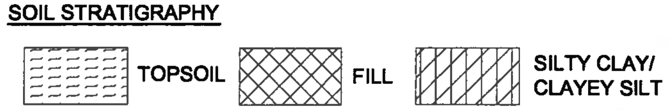
LEGEND

⊕	BOREHOLE LOCATION
⊻	GROUND WATER LEVEL AT TIME OF INVESTIGATION
EOP	EDGE OF PAVEMENT
SHR	SHOULDER ROUND

DESCRIPTION	UTM COORDINATES		ELEVATION (m)
	NORTHING	EASTING	
BH G26	4826179	443031	199.1
BH G27	4826169	443031	197.5

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.

SOIL STRATIGRAPHY



0 2 4 6m HOR
0 1 2 3m VER
SCALE

AMEC Reference: TP110076

DESIGN PB	CHK PB	CODE CHBDC-06	CL 625-ONT	DATE JAN. 2013
DRAWN KW	CHK HS	SITE 12+138		DWG 3

P:\GEOProjects\2011\TP-Burlington\TP110076-HWY 21\05-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

Coarse-grained soils (more than half by weight larger than 75µm)

MAJOR DIVISION			GROUP SYMBOL	TYPICAL DESCRIPTION	INFORMATION REQUIRED FOR DESCRIBING SOILS	LABORATORY CLASSIFICATION CRITERIA
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		NOT MEETING ALL GRADATION REQUIREMENTS FOR GW
	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		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)	GC	CLAYEY GRAVELS, POORLY GRADED GRAVEL-SAND-CLAY MIXTURES		ATTERBERG LIMITS ABOVE A- LINE WITH Ip GREATER THAN 7
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	$C_u = \frac{D_{60}}{D_{10}}$ GREATER THAN 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ BETWEEN 1 AND 3
		PREDOMINANTLY ONE SIZE OR A RANGE OF SIZES WITH SOME INTERMEDIATE SIZE MISSING	SP	POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES		NOT MEETING ALL GRADATION FOR SW
	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

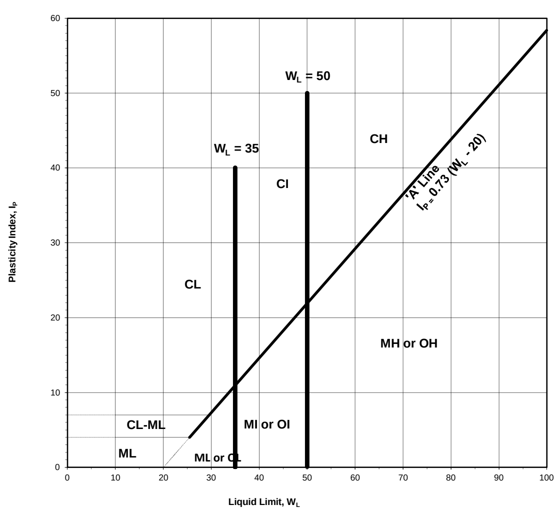
	DRY STRENGTH (CRUSHING CHARACTERISTICS)	DILATANCY (REACTION TO SHAKING)	TOUGHNESS (CONSISTENCY NEAR PLASTIC LIMIT)	GROUP SYMBOL	TYPICAL DESCRIPTION	INFORMATION REQUIRED FOR DESCRIBING SOILS
LIQUID LIMIT LESS THAN 35	NONE	QUICK	NONE	ML	INORGANIC SILTS & SANDY SILTS OR SLIGHTLY PLASTICITY, ROCK FLOUR	GIVE 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.
	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	
	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	
	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	
HIGH ORGANIC SOILS	READILY IDENTIFIED BY COLOUR, ODOUR, SPONGY FEEL & FREQUENTLY BY FIBROUS TEXTURE			Pt	PEAT AND OTHER HIGHLY ORGANIC SOILS	

Fractions

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	40-50	AND
	FINE	26.5 mm / 4.75 mm	30-40	Y/EY
SAND	COARSE	4.75 mm / 2.00 mm	20-30	WITH
	MEDIUM	2.00 mm / 425 µm	10-20	SOME
	FINE	425 µm / 75 µm	1-10	TRACE
FINES (SILT OR CLAY BASED ON PLASTICITY)		75 µm /		

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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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

amec

RECORD OF BOREHOLE No BH G26

G.W.P. 834-93-00	LOCATION Sta.12+138, SBL, 5.1m E of Rd C/L, 2.6m N of Culv C/L, E443031 N4826179	ORIGINATED BY	JF
DIST Goderich HWY 21	BOREHOLE TYPE 150 mm diameter borehole (Solid Stem)	COMPILED BY	DA
DATUM Geodetic	DATE 6 March 2012 - 6 March 2012	CHECKED BY	SM
PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario		JOB NO.	TP110076

ELEV DEPTH (m)	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	DEPTH (m)	WATER CONTENT (%)	SOIL VAPOUR READING (PPM)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
197.6 / 0.0	brown **Sand and Gravel FILL** some silt moist	1	SS	17			7	0	
197.2 / 0.4	brown **Silty Clay FILL** trace to some sand moist	2	SS	10			16	0	
195.8 / 1.8	brown **Silty Sand FILL** trace clay and gravel moist trace organic matter in SS4	3	SS	12			16	0	
		4	SS	16			19, 15	0	
194.7 / 2.9	grey **CLAYEY SILT / SILTY CLAY** trace to some sand trace gravel very stiff to hard mainly silt in SS 5	5	SS	28			18	0	- 1 80 19
		6	SS	37	∇ (approx. 5.0 m)		17	0	
		7	SS	36			16	0	
		8	SS	31			17	0	
		9	SS	24			17	0	4 15 45 36
188.0 / 9.6	**End of Borehole** Cave-in depth on 6 March 2012 was 5.0 m.								

Column headings: STRAT PLOT; ELEVATION SCALE (m) 197–188; 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.

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

Ontario

amec

RECORD OF BOREHOLE No. BH G27

G.W.P. 834-93-00 — LOCATION Sta.12+138, SBL, 5.1m W of Rd C/L, E443031 N4826169 — ORIGINATED BY JF

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

DATUM Geodetic — DATE March 6, 2012 - March 6, 2012 — CHECKED BY SM

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

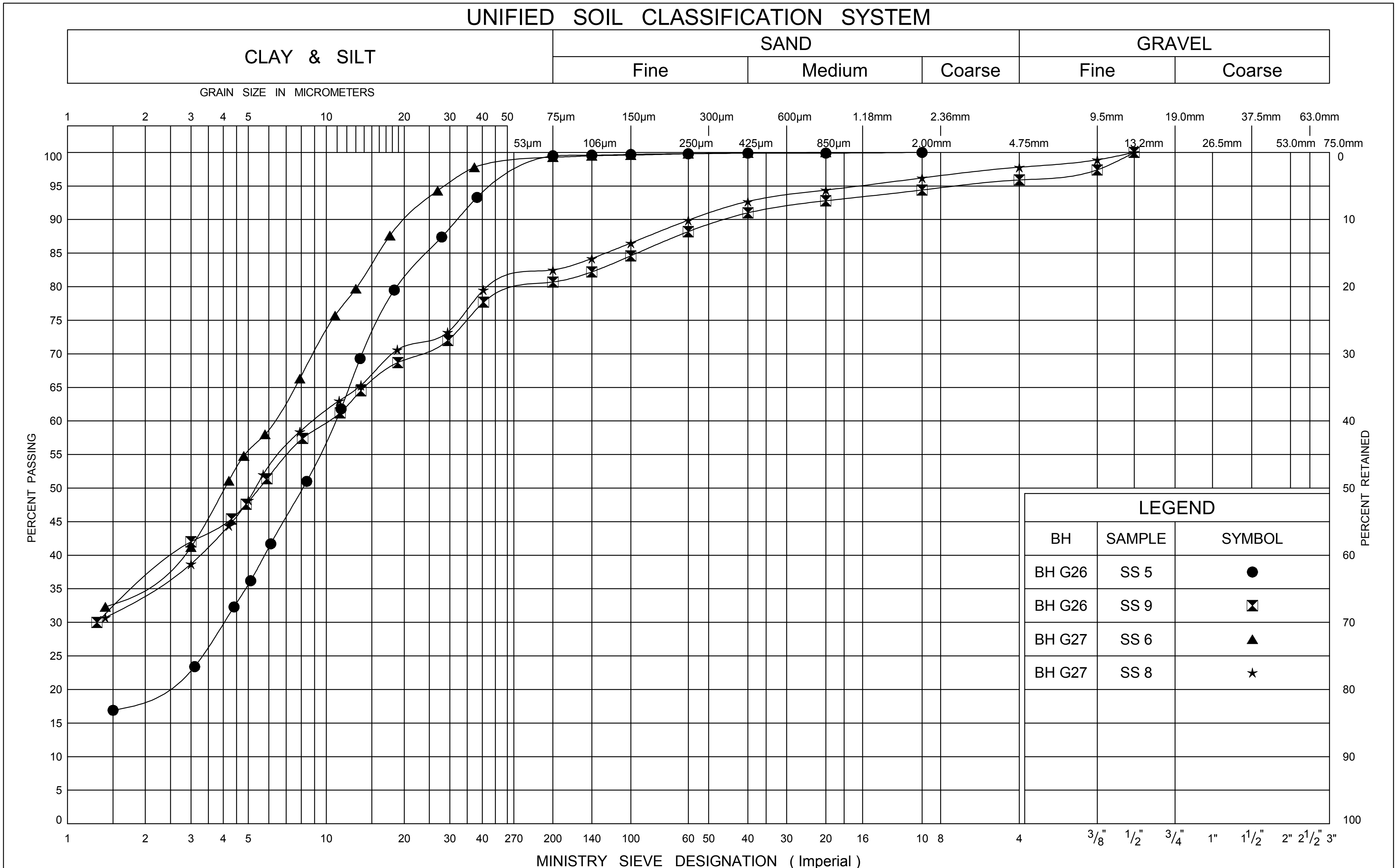
ELEV DEPTH (m)	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	SOIL VAPOUR READING (PPM)	GR	SA	SI	CL
197.5 0.0	brown **Sand and Gravel FILL** some silt moist	1	SS	15		10	0				
197.0 0.5	brown **Silty Clay FILL** trace sand and gravel	2	SS	13		14	0				
	sandy silt pocket in SS3	3	SS	33		10	0				
	some organic matter in SS 4	4	SS	7		27	5				
	pocket of sandy silt in SS 5	5	SS	12		19	5				
193.5 4.0	grey **CLAYEY SILT / SILTY CLAY** trace to some sand, trace gravel stiff to very stiff				▽ (approx. 3.9 m)						
		6	SS	16		19	0	-	1	63	36
		7	SS	12		17	0				
		8	SS	14		16	0	2	15	49	34
		9	SS	15		18	0				
187.9 9.6	**End of Borehole** Cave-in depth on 6 March 2012 was 4.0 m.										

Column headings: SOIL PROFILE; SAMPLES; STRAT PLOT; 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); REMARKS & GRAIN SIZE DISTRIBUTION (%).

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

APPENDIX B

LABORATORY TEST RESULTS



Ministry of Transportation

Ontario

GRAIN SIZE DISTRIBUTION

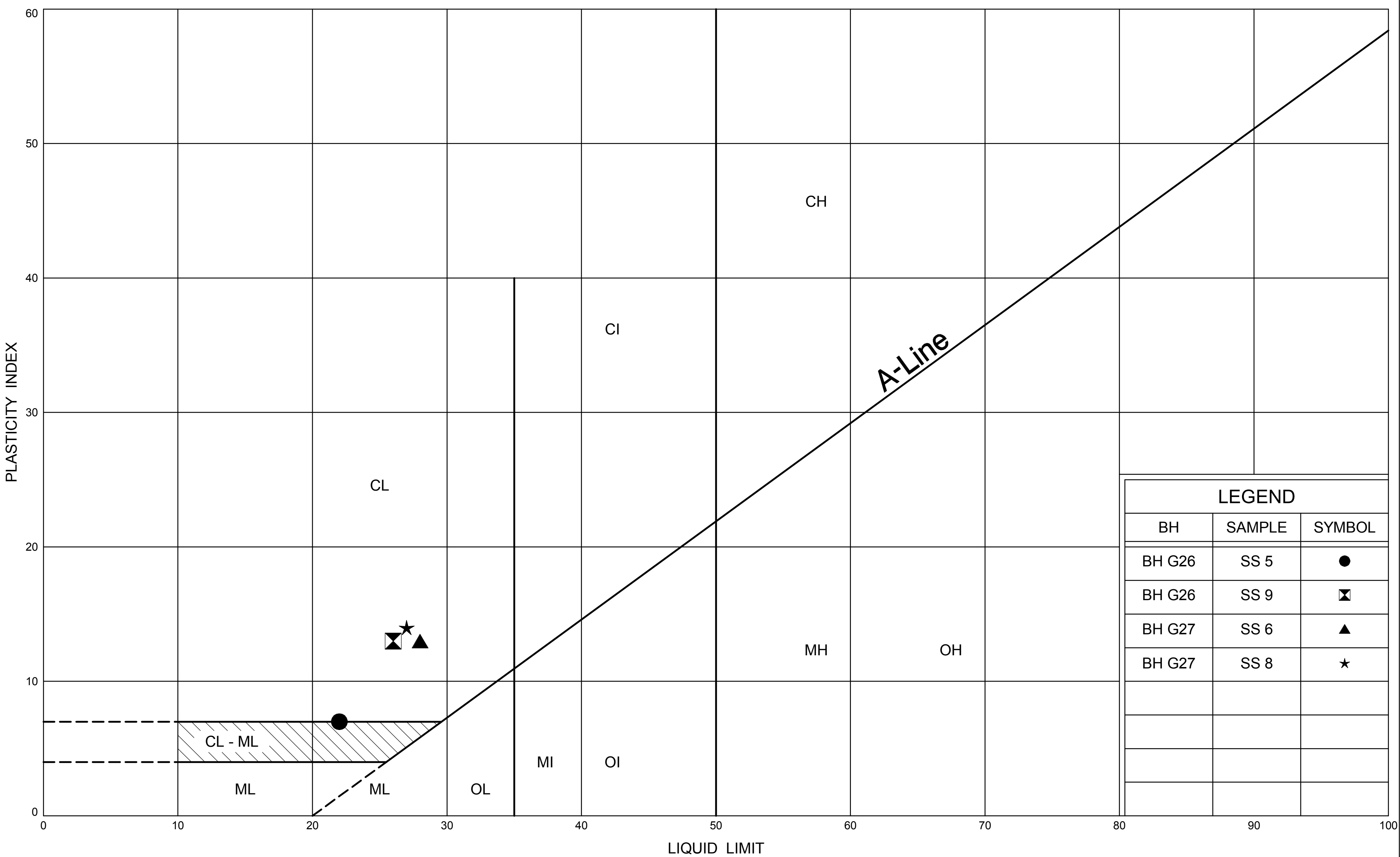
CLAYEY SILT / SILTY CLAY

Figure No. B 1

G.W.P. 834-93-00

Culvert at Sta. 12+138, Hwy 21, Bayfield to Goderich

ONTARIO MOT GRAIN SIZE TP110076-5-3 MTO.GPJ ONTARIO MOT.GDT 11/06/12



ONTARIO MOT PLASTICITY CHART TP110076-5-3 MTO.GPJ ONTARIO MOT.GDT 11/06/12

Ministry of Transportation Ontario	PLASTICITY CHART CLAYEY SILT / SILTY CLAY	Figure No. B 2 G.W.P. 834-93-00 Culvert at Sta. 12+138, Hwy 21, Bayfield to Goderich

Your Project #: TP110076.05
Your C.O.C. #: 27188503, 271885-03-01

Attention: Shami Mala
AMEC Environment & Infrastructure
Scarborough
104 Crockford Blvd
Sacroborough, ON
CANADA M1R3C3

Report Date: 2012/03/23

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B238403
Received: 2012/03/19, 12:10

Sample Matrix: Soil
Samples Received: 9

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Method Reference
Chloride (20:1 extract)	9	N/A	2012/03/23	CAM SOP-00463	EPA 325.2
Conductivity	9	N/A	2012/03/23	CAM SOP-00414	APHA 2510
pH CaCl2 EXTRACT	8	2012/03/22	2012/03/22	CAM SOP-00413	SM 4500H+ B
pH CaCl2 EXTRACT	1	2012/03/22	2012/03/23	CAM SOP-00413	SM 4500H+ B
Resistivity of Soil	9	2012/03/19	2012/03/23	CAM SOP-00414	APHA 2510
Sulphate (20:1 Extract)	9	N/A	2012/03/23	CAM SOP-00464	EPA 375.4

Remarks:

Maxxam Analytics has performed all analytical testing herein in accordance with ISO 17025 and the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act. All methodologies comply with this document and are validated for use in the laboratory. The methods and techniques employed in this analysis conform to the performance criteria (detection limits, accuracy and precision) as outlined in the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act. Reporting results to two significant figures at the RDL is to permit statistical evaluation and is not intended to be an indication of analytical precision.

The CWS PHC methods employed by Maxxam conform to all prescribed elements of the reference method and performance based elements have been validated. All modifications have been validated and proven equivalent following the 'Alberta Environment Draft Addenda to the CWS-PHC, Appendix 6, Validation of Alternate Methods'. Documentation is available upon request. Maxxam has made the following improvements to the CWS-PHC reference benchmark method: (i) Headspace for F1; and, (ii) Mechanical extraction for F2-F4. Note: F4G cannot be added to the C6 to C50 hydrocarbons. The extraction date for samples field preserved with methanol for F1 and Volatile Organic Compounds is considered to be the date sampled.

Maxxam Analytics is accredited by SCC (Lab ID 97) for all specific parameters as required by Ontario Regulation 153/04. Maxxam Analytics is limited in liability to the actual cost of analysis unless otherwise agreed in writing. There is no other warranty expressed or implied. Samples will be retained at Maxxam Analytics for three weeks from receipt of data or as per contract.

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

../2

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

==

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Total cover pages: 2

Maxxam Job #: B238403
Report Date: 2012/03/23

AMEC Environment & Infrastructure
Client Project #: TP110076.05

RESULTS OF ANALYSES OF SOIL

Maxxam ID		MV6494	MV6495	MV6496	MV6497	MV6498		
Sampling Date		2012/03/13 10:00	2012/03/13 10:00	2012/03/13 10:10	2012/03/13 10:10	2012/03/13 09:50		
	Units	**G22-SS6**	**G26-SS4**	**G28-SS2**	**G31-SS2**	**G35-SS1B**	**RDL**	**QC Batch**
Calculated Parameters								
Resistivity	ohm-cm	3400	1400	970	1700	3400		2793995
Inorganics								
Soluble (20:1) Chloride (Cl)	ug/g	90	350	550	290	90	20	2799578
Conductivity	umho/cm	292	734	1030	598	290	2	2799683
Available (CaCl2) pH	pH	7.64	7.41	7.71	7.72	7.71		2798076
Soluble (20:1) Sulphate (SO4)	ug/g	25	54	<20	<20	20	20	2799579

Maxxam ID		MV6499	MV6500		MV6501		MV6502		
Sampling Date		2012/03/16 14:30	2012/03/16 14:40		2012/03/16 15:50		2012/03/16 14:50		
	Units	**G24-SS4**	**G30-SS2**	**QC Batch**	**G37-SS2**	**QC Batch**	**G38-SS2**	**RDL**	**QC Batch**
Calculated Parameters									
Resistivity	ohm-cm	1300	800	2793995	1300	2793995	1100		2793995
Inorganics									
Soluble (20:1) Chloride (Cl)	ug/g	380	640	2799578	350	2799578	450	20	2799578
Conductivity	umho/cm	771	1250	2799683	785	2799683	949	2	2799683
Available (CaCl2) pH	pH	7.47	7.82	2798076	8.05	2799276	7.35		2798048
Soluble (20:1) Sulphate (SO4)	ug/g	<20	<20	2799579	<20	2799579	<20	20	2799579

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

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Maxxam Job #: B238403
Report Date: 2012/03/23

AMEC Environment & Infrastructure
Client Project #: TP110076.05

Test Summary

Maxxam ID MV6494
Sample ID G22-SS6
Matrix Soil

Collected 2012/03/13
Shipped
Received 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798076	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

Maxxam ID MV6495
Sample ID G26-SS4
Matrix Soil

Collected 2012/03/13
Shipped
Received 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798076	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

Maxxam ID MV6496
Sample ID G28-SS2
Matrix Soil

Collected 2012/03/13
Shipped
Received 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798076	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

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Test Summary

Maxxam ID MV6497
Sample ID G31-SS2
Matrix Soil

Collected 2012/03/13
Shipped
Received 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798076	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

Maxxam ID MV6498
Sample ID G35-SS1B
Matrix Soil

Collected 2012/03/13
Shipped
Received 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798076	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

Maxxam ID MV6499
Sample ID G24-SS4
Matrix Soil

Collected 2012/03/16
Shipped
Received 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798076	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

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Test Summary

Maxxam ID MV6500 **Collected** 2012/03/16
Sample ID G30-SS2 **Shipped**
Matrix Soil **Received** 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798076	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

Maxxam ID MV6501 **Collected** 2012/03/16
Sample ID G37-SS2 **Shipped**
Matrix Soil **Received** 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2799276	2012/03/22	2012/03/23	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

Maxxam ID MV6502 **Collected** 2012/03/16
Sample ID G38-SS2 **Shipped**
Matrix Soil **Received** 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798048	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

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Test Summary

Maxxam ID	MV6502 Dup	**Collected**	2012/03/16
Sample ID	G38-SS2	**Shipped**	
Matrix	Soil	**Received**	2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

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Package 1	10.7°C

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

GENERAL COMMENTS

Maxxam Job #: B238403
Report Date: 2012/03/23

AMEC Environment & Infrastructure
Client Project #: TP110076.05

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
2799578	Soluble (20:1) Chloride (Cl)	2012/03/23	107	75 - 125	106	75 - 125	<20	ug/g	NC	35		
2799579	Soluble (20:1) Sulphate (SO4)	2012/03/23	114 (1)	75 - 125	104	85 - 115	<20	ug/g	NC (2)	35		
2799683	Conductivity	2012/03/23					<2	umho/cm	0.1	35	99	75 - 125

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.

(1) - Matrix Spike Parent ID [MV6502-01]

(2) - Duplicate Parent ID [MV6502-01]

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Validation Signature Page

Maxxam Job #: B238403

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

HIGHWAY 21, GODERICH, ONTARIO
(CULVERT AT Sta. 12 + 138)

PHOTOGRAPH NO. 1

Looking towards the existing culvert outlet.

PHOTOGRAPH NO. 2

View of the slope over the outlet.