



FOUNDATION INVESTIGATION AND DESIGN REPORT

**REHABILITATION OF HIGHWAY 21
FROM BAYFIELD TO GODERICH, ONTARIO**

CULVERT NO. 8 AT STATION 11+691

**MINISTRY OF TRANSPORTATION ONTARIO - WEST REGION
PURCHASE ORDER NUMBER 3009-E-0022
WP 834-93-00**

MTO GEOCRES NO. 40P12-25

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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)*

Culvert No.	Station	Existing Culvert		Boreholes Drilled	Proposed Work	Foundation Investigation Requirement
		Type	Dimension			
2	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
8	11+691 (Site No. 12-420/C)	Concrete Rigid Frame Box	3.75 x 2.30 x 68.4 m	BH G24 and BH G25	Rehabilitate and install RSS, if necessary, to stabilize steep roadway embankment	Foundations for RSS / slopes and protection system to stage the construction
10	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
17	13+835	Concrete Box	1.2 x 1.2 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)

Culvert No.	Station	Existing Culvert		Boreholes Drilled	Proposed Work	Foundation Investigation Requirement
		Type	Dimension			
20	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 to stage the construction. Protection will be installed approximately 2.5 m from centerline. One borehole for S/W wingwall.
30	18+380 (Site No. 12-422/C)	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 Culvert No. 30 (12-422/C), and Culvert No. 32 (12-424/C) on Highway 21 and Culvert No. 31 (12-423/C) on Cut Line Road , southeast of Intersection. Or lengthening of the culvert. (min. 4 BH for these 3 culverts total)
31	18+393 (Site No. 12-423/C)		3.05 x 0.91 x 15.3 m		Rehabilitate and construct wing walls between this culvert and Culvert No. 30 (12-422/C)	
32	18+409 (Site No. 12-424/C)		3.66 x 1.52 x 21.4 m		Rehabilitate and construct wing walls between this culvert and Culvert No. 31 (12-423/C)	
34	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)
56	25+232	Concrete Frame - Open Footing	2.9 m 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)
61	26+521	Concrete Frame - Open Footing	1.8 m 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 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 existing Culvert No. 8 at Station 11+691 (Site No. 12-420/C).

The factual results of the soil conditions encountered in the boreholes and laboratory tests (without design discussion and recommendations) for the rehabilitation of existing Culvert No. 8 at Station 11+691 are presented in a separate report titled "Foundation Investigation Report".

2.0 SITE AND PROJECT DESCRIPTION

The investigated culvert site (at Station 11+691) is located at the existing watercourse (Dejong Creek) crossing Highway 21, about 740 m north of Bayfield River Road near 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 with vegetation and trees at the time of the fieldwork.

Based on the Culvert Summary Table provided in Table 1.1 and the Preliminary Drawing No. S1 (Sheet No. ST1), the existing culvert at this location is a combination of Concrete Rigid Frame box and open footing type structures, about 68.4 m long with varying cross-sections. As per the drawing, the culvert is mainly a box structure, with a section (about 5.6 m long) constructed by using open footing structure. The height of the existing embankment is about 11.5 m above the existing grade at the inlet (east side), and about 14.0 m above the existing grade at the outlet (west side), with a slope of about 2H:1V. The design recommendations include rehabilitation of the culvert and installation of Retained Soil System (RSS) walls, if necessary, to stabilize roadway embankment.

Site photographs showing the culvert are presented in Appendix C (Photographs 1 to 4).

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 Highway 21 Culvert Recommendations Table, two (2) boreholes (BH G24 and BH G25) were advanced, each at the shoulder of Highway 21. The as-drilled borehole locations are presented on Drawing No. 2. Each borehole was extended to a depth of about 18.8 m below the existing ground surface, and terminated at an elevation of about 177.5 m in both boreholes (BH G24 and BH G25).

The fieldwork was performed on 12 and 13 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 drilling, sampling and in-situ testing operations were conducted by using hollow-stem augers, using a track-mount drilling rig, owned and operated by Drilltech Drilling Inc. (Newmarket, Ontario) under the full-time supervision of experienced AMEC geotechnical personnel.

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 depths of groundwater, 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.

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.

One selected sample was tested for soil corrosivity potential with respect to concrete and steel, the results of which are discussed in Section 6.7.

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, where applicable, included grain size analysis, Liquid and Plastic Limits, in-situ water content determination, and soil corrosivity analysis. Testing to determine the corrosivity of the soils 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 (30);
- 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 tests are shown in Appendix B.

5.0 SUB-SURFACE CONDITIONS

Based on the investigation results, the soil profile consisted predominantly of surficial sand and gravel fill underlain by fill soils (silty clay / clayey silt / silty sand) overlying native clayey silt / silty clay deposit, which extended to the termination depth of both boreholes (BH G24 and BH G25) at an elevation of about 177.5 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 in Appendix A. Interpolated stratigraphical cross sections at the existing culvert are provided in

Drawing No. 3.

It should be noted that the 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 surface in both boreholes located on the road shoulder. The measured thickness of sand and gravel fill was about 1.4 m in Borehole BH G24, and 0.4 m in BH G25. The sand and gravel fill contained some silt. A pocket of silty clay was encountered in SS 2 in BH G24.

SPT N-values measured in the sand and gravel fill ranged from 10 to 12 blows per 0.3 m. The measured moisture contents in the sand and gravel fill ranged from 4 % to 12 %.

5.2 Silty Clay / Clayey Silt / Silty Sand Fill

Silty clay / clayey silt fill was encountered below the sand and gravel fill in both boreholes. A silty sand fill was interbedded in Borehole BH G24 within the silty clay / clayey fill. The fill soils extended to about 9.1 m below the existing grade (Elevation 187.2 m) in Borehole BH G24, and about 6.1 m (Elevation 190.1 m) in BH G25.

The fill soils were brown / grey in color and contained trace to some sand, and trace gravel, cobbles / boulders and organic matter.

SPT N-values measured in the silty clay / clayey silt / silty sand fill ranged from 5 to 22 blows per 0.3 m. The measured moisture contents in the silty clay / clayey silt / silty sand fill ranged from 13 % to 21 %.

5.3 Clayey Silt / Silty Clay

Native clayey silt / silty clay was encountered below the fill soils in both boreholes, and extended to the termination depth of about 18.8 m in both boreholes (Elevation 177.5 m in both boreholes).

The clayey silt / silty clay was brown/grey in color, and contained trace to some sand, and trace gravel and cobbles / boulders. The SPT 'N' values of the clayey silt / silty clay ranged widely from 11 to 83 blows per 0.3 m, indicating stiff to hard consistency. The measured moisture contents in the clayey silt / silty clay ranged from 12 % 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 G24	SS 10	10.7 - 11.2 (185.5 - 185.0)	1	16	47	36	26	13	13	CL
BH G24	SS 15	18.3 - 18.8 (178.0 - 177.5)	2	9	54	35	25	13	12	CL
BH G25	SS 9	9.1 - 9.6 (187.1 - 186.6)	2	13	50	35	25	13	12	CL
BH G25	SS 14	16.8 - 17.4 (179.4 - 179.0)	1	2	68	29	21	13	8	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. Both boreholes were dry on 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 and water level in Dejong 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 140 ppm, with three samples recording slightly elevated values of 60 ppm and 140 ppm, as shown in the Record of Borehole. The samples recording slightly elevated values did not display any visual evidence of environmental impact. 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, 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. ST1), dated April 2012, for Culvert No. 8 at Station 11+691.

The existing culvert at Station 11+691 is a combination of Concrete Rigid Frame Box and Open Footing type structures, about 68.4 m long with varying cross-sections. The culvert is mainly a box structure, with a section (about 5.6 m long) of open footing structure. The inverts of culvert inlet and outlet are at elevations of about 184.79 m and 182.17 m, respectively. Highway 21 at the culvert location is a two lane paved road with an elevation of 196.3 m.

6.1 Embankment Slopes

The borehole investigation results revealed that the soil profile underneath the road embankment consisted of fill soils (silty sand and silty clay/clayey silt) extending to about 9.1 m (Elevation 187.2 m) in BH G24 and 6.1 m (Elevation 190.1 m) in BH G25 below the road surface at the culvert location. The fill soils consisted predominantly of silty clay/clayey silt fill underlying the surficial sand and gravel fill, with an interbedded of silty sand fill encountered in Borehole BH G24. The SPT "N" values varied from 5 to 13 blows per 0.3 m within the silty clay/clayey silt fill, indicating firm to stiff consistency.

The road embankment is approximately about 11.5 m above the surrounding grades at the culvert inlet end (east side of road), and about 14.0 m above the surrounding grades at the outlet end (west side of road). The slope of the existing embankments (both sides of road) is about 2H:1V, which is generally the minimum slope required for embankment slope. Based on the two boreholes drilled, the fill soils were not entirely well compacted as indicated by the relatively-low SPT blow counts. However at the time of the field work, the slope was well vegetated and covered with mature trees, without obvious signs of slope instability. Nevertheless, the paved road surface at the culvert location exhibited wheel track rutting and some cracks parallel to the slope (refer to Photograph No. 4).

Based on the soil conditions encountered within the embankment fill, visual examination of the slopes, and the fact that the existing highway embankment has been in use for many years, the existing embankment should be stable, provided it will not be disturbed. However, it is recommended to inspect and monitor the slopes periodically for any signs of slope movements and stabilization measures be implemented if and when necessary.

If any change to slope geometry is required, or if any excavation is anticipated close to the toe area of the embankments, the slope stability should be assessed in detail prior to carrying out any work.

6.2 Embankment Slope Stabilization

As discussed above, there should be no immediate need for slope stabilization. However, if slope stabilization is required, the slope should be recompacted and/or flattened, which can be achieved with the following options:

- With retaining walls ;
- Without retaining wall, and with culvert extension.

A comparison of the options is provided in Table 6.1.

Table 6.1 - Comparison of Slope Stabilization Options

Option	Description	Advantages	Disadvantages	Risks / Consequences	Cost Comparison
With retaining wall	Retaining wall will be constructed at about 6.1 m to 9.1 m below the existing road surface on native soil. Additional fill placement at the top of the retaining wall.	Will help preserve the environment, because it involves no major tree/vegetation cutting beyond the embankment slope	Excavation over the existing culvert will be required Require lane closure and roadway protection Add more loads to the slope	Increase in stress on the existing culvert foundation May require special permits from the related conservation authority	Medium to high
Without retaining wall and with culvert extension	Will require new fill placement beyond the existing slope toe and additional fill placement over the existing slope Will require extension of culvert	No specialized equipment other than excavation and compaction Minimum excavation of the existing slope	Excavation around the existing culvert inlet and outlet will be required. Will involve cutting and removal of existing trees / vegetation around the culvert ends Existing culvert structure will have to be extended.	Increase in stress on the existing culvert foundation Will disturb the existing environment due to cutting of trees and vegetation May require special permits from the related conservation	High

Option	Description	Advantages	Disadvantages	Risks / Consequences	Cost Comparison
Recompact the existing fill soils to a 2H:1V slope with a 2 m wide bench at 8 m height.	Excavate the existing fill soils and recompact them to standard requirements.	<p>No specialized equipment other than excavation and compaction</p> <p>No need for a large quantity of imported fill.</p> <p>Prevent further settlement of existing fill soils, if still ongoing.</p> <p>Minimize settlement of new fill soil.</p>	<p>To be cost efficient, the road section has to be closed so that recompaction can be carried out without shoring.</p> <p>Will involve cutting and removal of existing trees.</p>	<p>Will disturb the existing environment due to cutting of trees and vegetation</p> <p>May damage the existing culvert structures</p>	Low to medium

The options mentioned have advantages and disadvantages. The slope stabilization option should be reviewed when there is a need for implementation. It should be noted that without recompacting the existing fill soils, further road embankment settlement, if ongoing, is still possible even though slope stabilization measures (if implemented) will prevent slope failure and reduce lateral slope movements.

6.3 Slope Stabilization with Retaining Wall

If the retaining wall option is chosen to stabilize the embankment slope, the following retaining wall types should be considered.

- Cast-in-place Concrete Retaining Wall;
- Gravity Type Retaining Wall (e.g. gabion, armourstone, or similar); and
- Retained Soil System (RSS) Wall.

A comparison of the possible retaining wall structures is provided in Table 6.2.

Table 6.2 - Comparison of Retaining Wall Structure Options

Option	Description	Advantages	Disadvantages	Risks / Consequences	Cost Comparison
Cast-in-place concrete retaining wall	Typically, cantilevered, reinforced-concrete, retaining wall.	Durable and low maintenance. Not susceptible to erosion by water flow and ice forces. No specialized contractor is needed.	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
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 baskets may not be stable in long term. Gabion may be subject to erosion by creek water flow and ice forces.	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		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	<p>RSS requires specialised contractor according to MTO's DSM.</p> <p>Facade material has to be properly selected to prevent erosion by water flow and ice forces.</p> <p>Labour intensive for construction.</p> <p>Reinforcing strips may not be durable.</p>	May require some maintenance	Medium

The type of retaining wall to be selected will depend on the extent of slope stabilization (if required).

6.3.1 Foundations

The investigation indicated that the existing fill is firm to stiff/loose to compact, which is considered to be incompetent to properly support a heavy and rigid retaining wall. It is recommended to place the retaining wall, if required, within native stiff to hard clayey silt / silty clay below the fill soil at or below a depth of about 9.1 m below the existing road level (Elevation 187.2 m) at the east side of the road, and about 6.1 m below existing road level (Elevation 190.1) at the west side of the road.

The geotechnical Ultimate Limit State (ULS) / Serviceability Limit State (SLS) values provided in Table 6.3 should be used for the design of the retaining wall, if required.

Table 6.3 - SLS and ULS Values for Design

Borehole No.	Founding Stratum	Depth below existing grade (m)	Approximate Elevation (m)	Geotechnical Reaction at SLS (kPa)	Factored Geotechnical Resistance at ULS ⁽¹⁾ (kPa)
BH G24	Stiff clayey silt / silty clay	Between 9.3 m and 10.8 m (±)	186.9 m and 185.4 m (±)	150	225
	Hard clayey silt / silty clay	10.8 m (±) and below	185.4 m (±) and below	250	375
BH G25	Stiff clayey silt / silty clay	Between 6.2 m and 7.8 m (±)	190.0 m and 188.4 m (±)	150	225
	Very stiff to hard clayey silt / silty clay	7.8 m (±) and below	188.4 m (±) and below	250	375

Note: ⁽¹⁾ A resistance factor of $\Phi = 0.5$ has been applied to the values provided.

The soil parameters in Table 6.4 may be used for design.

Table 6.4 - Summary of Geotechnical Parameters

Soil Stratum	Bulk Unit Weight of Soil, γ (kN/m ³)	Angle of Friction (degree)	Earth Pressure Coefficient ⁽¹⁾		
			At-rest, K_o	Active, K_a	Passive, K_p^*
Existing cohesive fill (firm)	17	25	0.58	0.40	2.0
Existing cohesive fill (stiff to very stiff)	18	28	0.53	0.35	2.0
Existing granular fill	21	32	0.47	0.30	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. The recommended SLS bearing value is based on a total settlement of up to 25 mm. Detailed foundation analysis will be necessary if accurate values of settlement are required.

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.

The retaining wall should be backfilled with granular soil (OPSS 1010 Granular 'A' or Granular B') and compacted to maximum dry density in conformance to OPSS 501 (Method A).

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

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.

All excavations should be carried out in accordance with the Occupational Health and Safety Act and Regulations for Construction Projects. The excavation and dewatering are discussed in details in Section 6.4.

A small cofferdam (earth dyke) may be required to keep water flows from entering the work area. Dewatering plans must also consider any flows from the road side ditches that enter into the culvert.

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 OPSS 3121.150 (*Minimum Granular Backfill Requirement - Walls Retaining*).

Materials for gabion wall, if used, must comply with OPSS 1430 (Material Specification for Gabion Baskets and Mats).

The new fill placement would increase the stress on the existing culvert foundation. A detailed foundation and settlement analysis may be required once the design details are available in order to estimate the increase in stress to the existing culvert foundations and the corresponding settlement. Further, a slope stability analysis for the proposed retaining should be carryout.

A roadway protection may be required for installation of the retaining wall, if constructed, and is discussed in Section 6.3.3.

6.3.2 Slope Construction

The embankment slope, if reconstructed, should be constructed to proper highway cross-sections using compacted engineered fill as per OPSS 202.010. The construction should be carried out in accordance with OPSS 206 (*Construction Specification for Grading*). Backfill should be placed according to OPSS 206 (*Construction Specification for Grading*), and compacted according to OPSS 501 (*Construction Specification for Compacting*). The selection, placement and compaction of the fill should be carried out under a geotechnical control program.

The fill soils should consist of approved, clean soil earth fill free from topsoil, organic matter etc. The compaction should comply with OPSS 501.

The final slope areas and retained soils behind the retaining walls (if constructed) should be covered with topsoil and seeded in accordance OPSS 802 and OPSS 804, as soon after grading as possible to prevent erosion.

6.3.3 Roadway Protection

Roadway protection may be required during installation of retaining wall (if required) to support the walls of excavation and adjacent traffic lane. The roadway protection scheme designed for performance level 2 system, according to OPSS 539, is recommended to prevent excessive lateral and/ or vertical movement of the existing embankment during construction.

According to OPSS 539, the contractor is responsible for the selection, performance and detailed design of the roadway protection scheme. To meet the performance level 2, the maximum lateral displacement should be limited to 25 mm with maximum allowable angular distortion of 1:200.

A monitoring system should be implemented to check the horizontal and vertical displacements of the roadway surface during construction.

Roadway protection system may comprise sheet piling or soldier piles with lagging. Both systems can be anchored for additional support, if required. Table 6.5 presents a comparison between the two roadway protection systems.

Table 6.5 - Comparison between Sheet Piling and Soldier Piles with Lagging

Option	Description	Advantages	Disadvantages	Risks / Consequences	Cost Comparison
Sheet piles	Closely set piles of timber, steel, etc, driven vertically into the ground in a line to hold back soil and water	Sheet piles are interlocked, therefore, loss of soils will be negligible. Suitable for high water table	May require soil anchors / rakers for lateral support	The surrounding soil may get disturbed during installation of the sheet piles, which may cause failure in unstable slopes	Medium to high
Soldier piles with lagging	Soldier piles (H - steel section) driven first, and horizontal laggings or sheeting placed behind the piles	Can be installed in bored caisson, which significantly reduces disturbance to surrounding soil	May require anchors High risk of soil loss	Excessive settlement may occur due to loss of cohesionless soils under high water table	low to medium

For the existing site condition at the culvert, the soldier piles with lagging may be the preferred roadway protection system. The bottom of the protection system (sheet pile/H-Pile/Caisson) should be extended minimum to an elevation of about 182.0 m. For design purposes, the soil parameters provided in Table 6.3 and 6.4, and the horizontal modulus of Subgrade Reaction (k_s) provided in Table 6.6 may be used for design.

Table 6.6- Horizontal Modulus of Subgrade Reaction

Soil	Horizontal Modulus of Subgrade Reaction (kN/m^3)
Existing fill (below 1.2 m frost penetration depth)	3,000
Stiff to hard, clayey silt / silty clay	30,000 - 35,000

6.4 Slope Stabilization without Retaining Wall and with Culvert Extension

A flatter embankment slope, if required, may be achieved without construction of a retaining wall, if the slope is allowed to extend beyond the existing toe of slope, i.e. the base of the embankment is widened. However, this will necessitate the extension of the culvert. The embankment widening, if chosen, should be constructed with compacted engineered fill at 2H:1V (or flatter) side slopes. The construction should be in accordance with OPSD - 202.010 (Slope Flattening using Surplus Excavated Material on Earth and Rock Embankment), OPSS 501 (Construction Specification for Compacting) and OPSS 206 (Construction Specification for Grading). The selection, placement and compaction of the fill should be carried out under a geotechnical control program

At the time of field work, the areas beyond the existing culvert were covered with trees and tall vegetation. All trees should be cut and removed. All topsoil, organic matters, soft / loose and unsuitable soils should be removed from the footprint of the proposed widening areas. Topsoil should also be stripped from existing slope prior to placement of new embankment fill.

After stripping, the exposed subgrade for new fill should be inspected. Based on the investigation results, native very stiff clayey silt / silty clay is anticipated at the founding grade which should be capable of supporting the new fill loads.

The fill soils to be used for the proposed embankment widening should consist of approved, clean earth and compacted as per OPSS 501.

Provided that the widened embankment is founded on stiff to hard native clayey silt / silty clay soils, and the new fill is properly compacted on the existing embankment side slope, its long-term settlement should not be significant.

A settlement and slope stability analysis should be carried out when the design details are available in order to estimate the increase in stress to the existing culvert foundations and the corresponding settlement.

For the culvert extension, the geotechnical Ultimate Limit State (ULS) / Serviceability Limit State (SLS) values provided in Table 6.3 and geotechnical parameters in Table 6.4 may be used for the design. All other recommendations for retaining wall in sub-section 6.3.1 may be used, as necessary. The excavation and dewatering is provided in Section 6.5.

6.5 Excavation and Dewatering

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:

Fill soils	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. If open cut excavation cannot be carried out due to space restriction, temporary shoring will be required. The temporary shoring is discussed in Section 6.6.

Cobbles and boulders should be expected within the fill and native soils.

Groundwater is not anticipated during excavation work. However, excavation work may encounter the perched groundwater or surface runoff. Seepage is expected to be slow through the silty clay / clayey silt fill, and could be dewatered using a system of sumps and pumps. Higher rates of seepage may occur through the silty sand fill layer encountered in Borehole BH G24. Dewatering effort could require an increased number of sumps and pumps.

6.6 Temporary Shoring

Temporary shoring, if required during excavation work, 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 Canadian Highway Bridge Design Code CN/CSA-S6-06. Soil parameters given in Table 6.4 may be used for design considerations.

6.7 Soil Corrosivity

To determine the soil corrosivity potential with respect to concrete and steel, one soil sample (BH G24 - 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 6.7, while, the Certificate of Analysis is included in Appendix B.

Table 6.7 - Results of Corrosivity Testing

Soil Sample No.	pH	Electrical Conductivity $\mu\text{mho/cm}$	Resistivity (ohms-cm)	Chloride ($\mu\text{g/g}$)	Sulphate ($\mu\text{g/g}$)
BH G24 - SS 4	7.5	771	1300	380	<20

The test results have shown that the sulphate content of the soil is <20 ppm ($\mu\text{g/g}$). 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 $\mu\text{g/g}$) 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 (1300 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 geotechnical considerations of the culvert site at Station 11+691 on Highway 21, near 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,
a Division of AMEC Americas Limited**



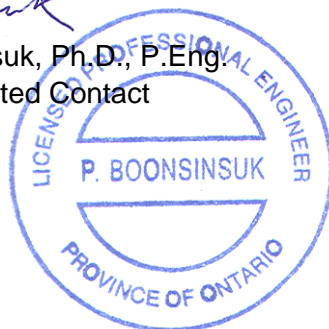
Mohammad Mollah, M.Eng., P.Eng.
Senior Geotechnical Engineer



Shami Malla, P. Eng.
Project Manager



Prapote Boonsinsuk, Ph.D., P.Eng.
Principal Designated Contact



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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 11+ 691 in Highway 21 near 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 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 202.010	Slope Flattening using Surplus Excavated Material on Earth or Rock Embankment
OPSD 203.010	Embankment over Swamp – New Construction
OPSD 203.020	Embankment over Swamp – Existing Slope Excavation to 1H:1V
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

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CLIENT LOGO



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

CHK'D BY:

PB

REV. NO.:

A

PROJECT NO:

TP110076

PROJECTION:

-

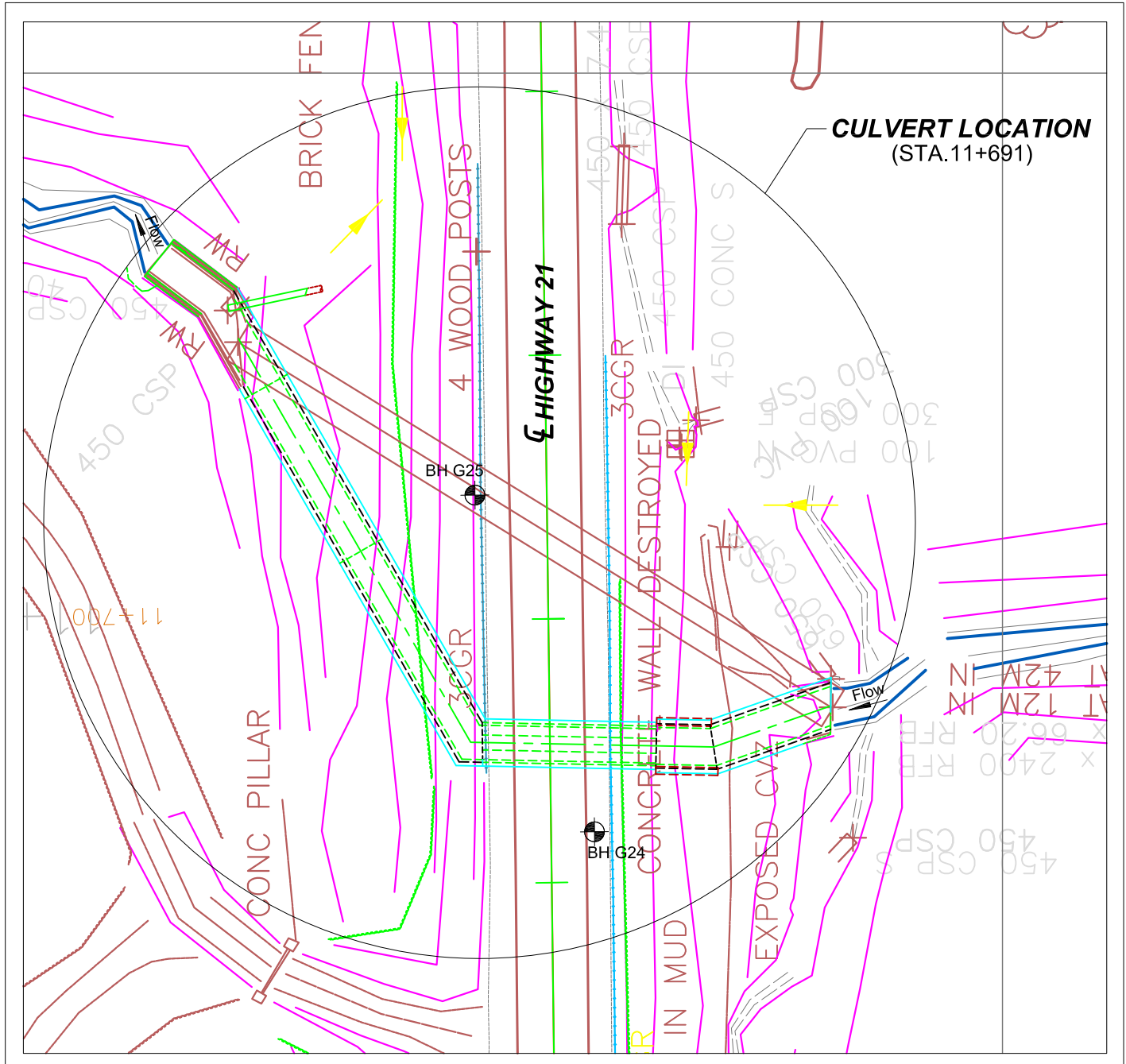
SCALE:

AS SHOWN

DRAWING No.

1

PURCHASE ORDER NUMBER: 3009-E-0022, WP 834-93-00, GEOCRETS No.: 40P12-25



SCALE



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CLIENT LOGO



CLIENT

MINISTRY OF
TRANSPORTATION ONTARIO
WEST REGION

TITLE
BOREHOLE LOCATION PLAN

PROJECT
REHABILITATION OF HIGHWAY 21 - FROM BAYFIELD TO GODERICH
PURCHASE ORDER NUMBER: 3009-E-0022, WP 834-93-00, GEOCREs No.: 40P12-25

DWN BY:
KW

CHK'D BY:
PB

PROJECTION:
-

DATUM:
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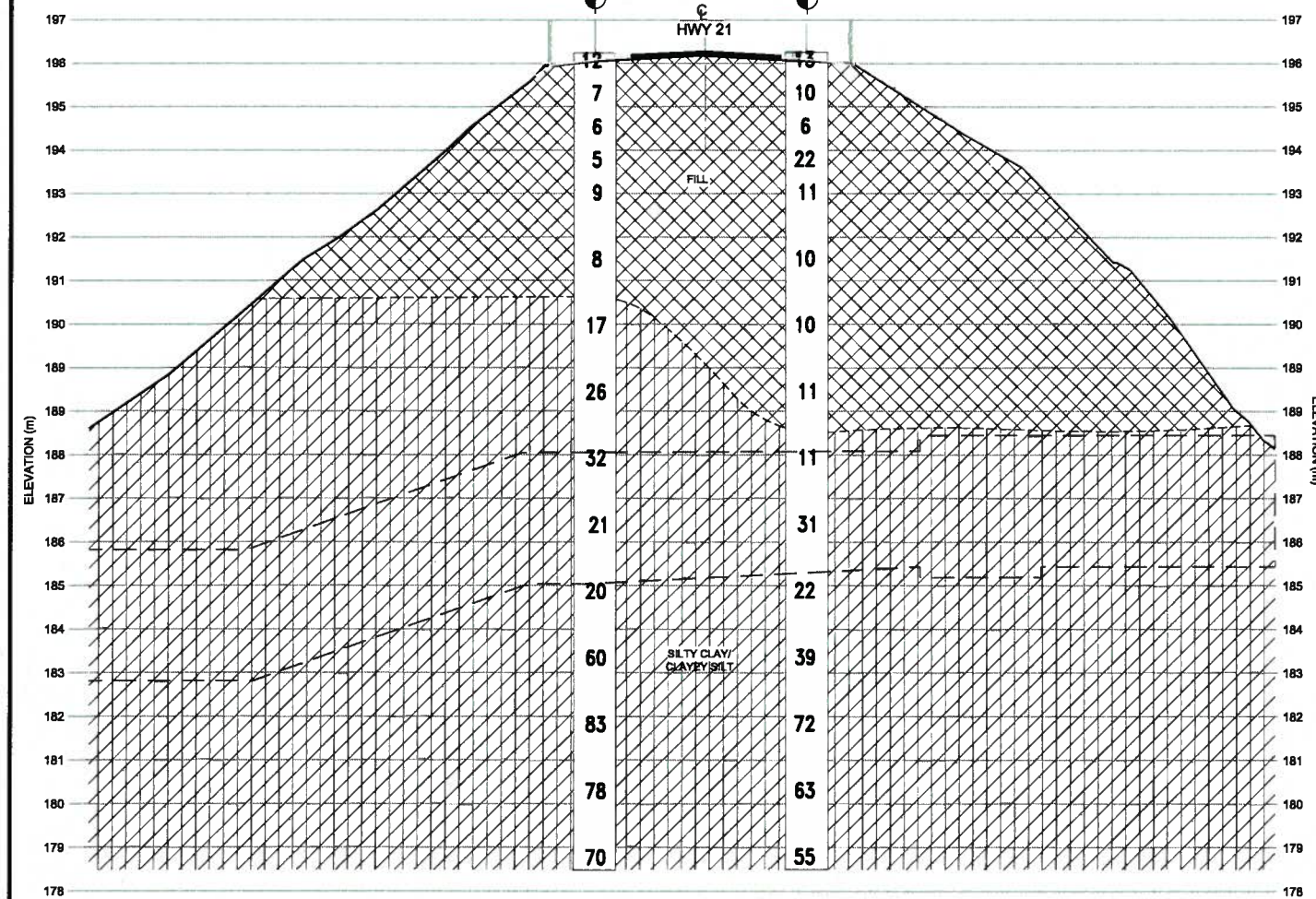
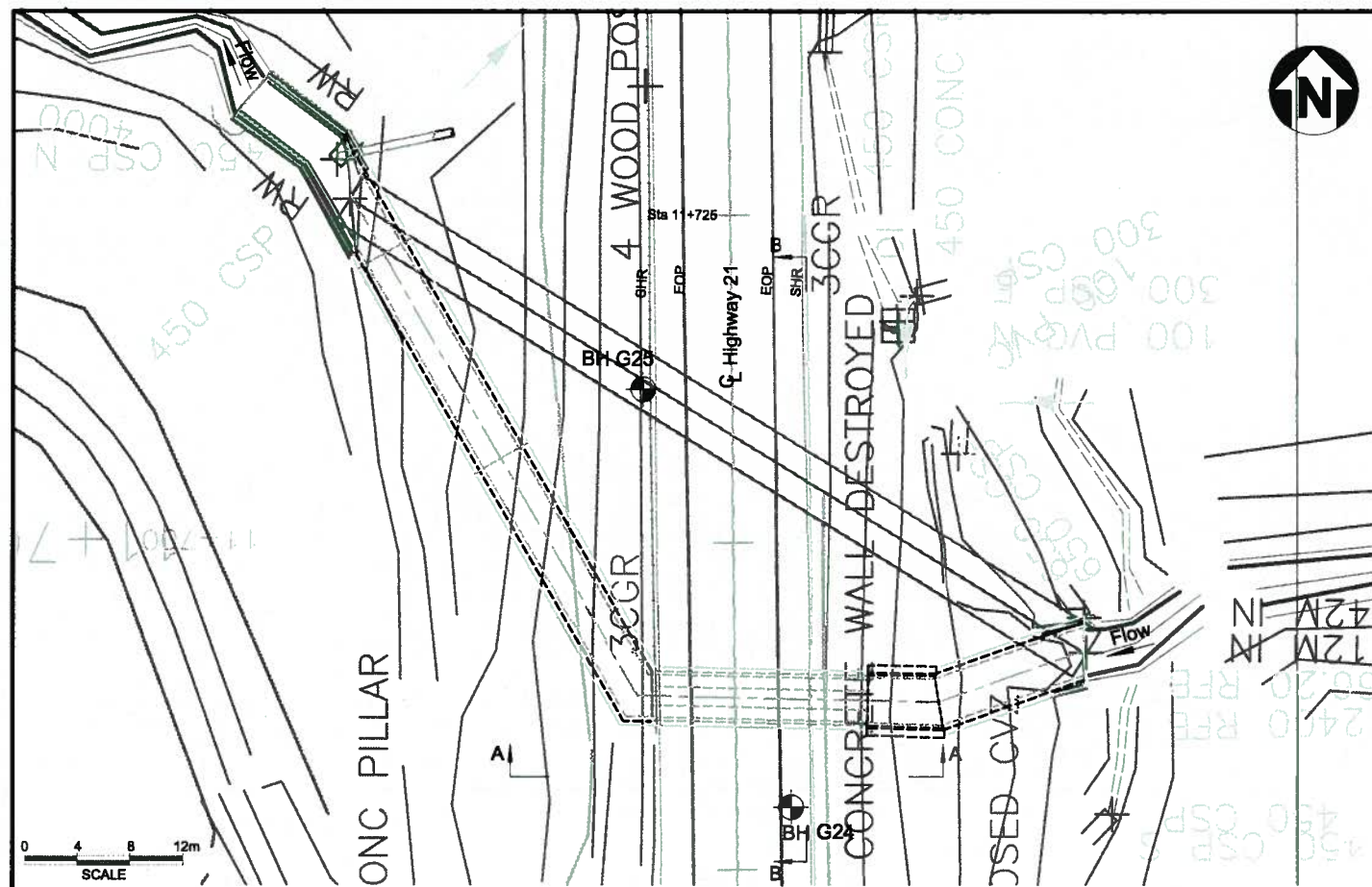
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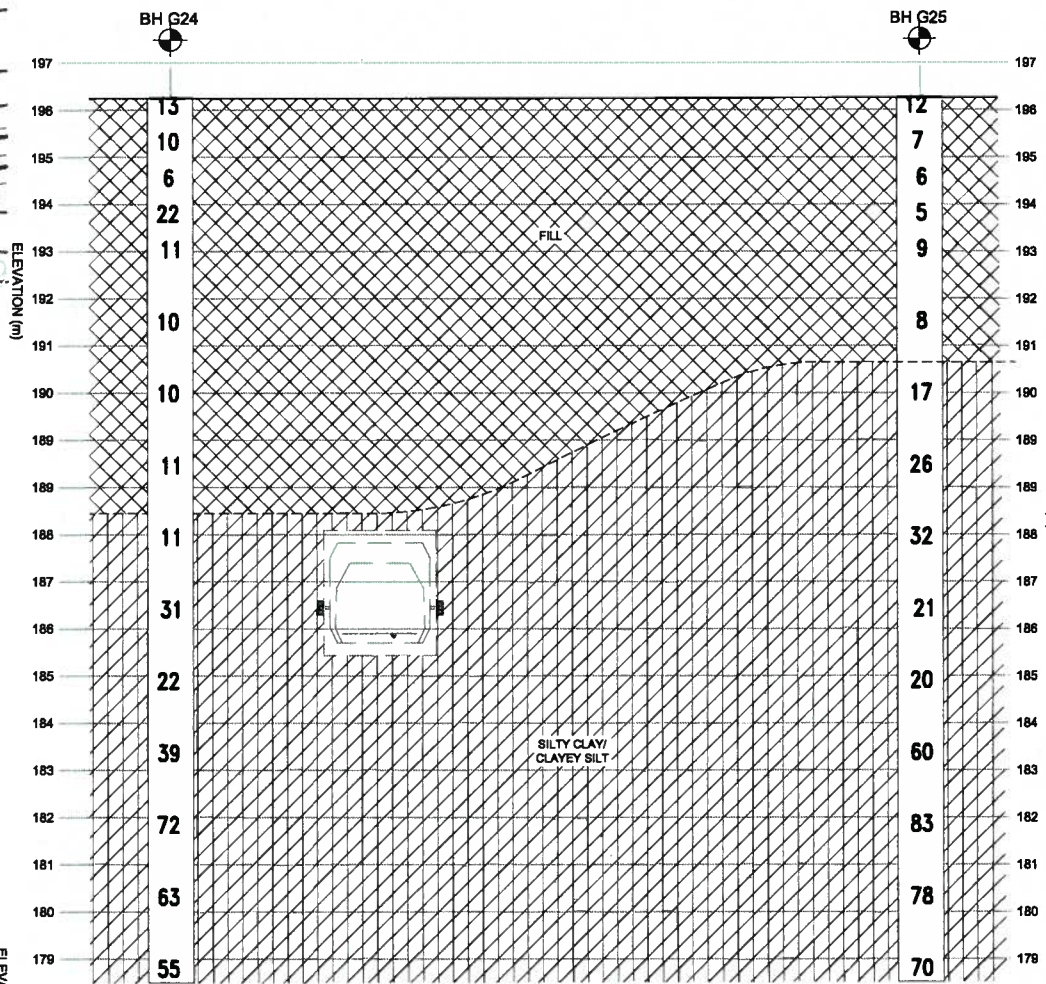
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JANUARY 2013

PROJECT NO:
TP110076

DRAWING No.
2



SECTION A-A



SECTION B-B

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

PURCHASE ORDER NUMBER:
3009-E-0022

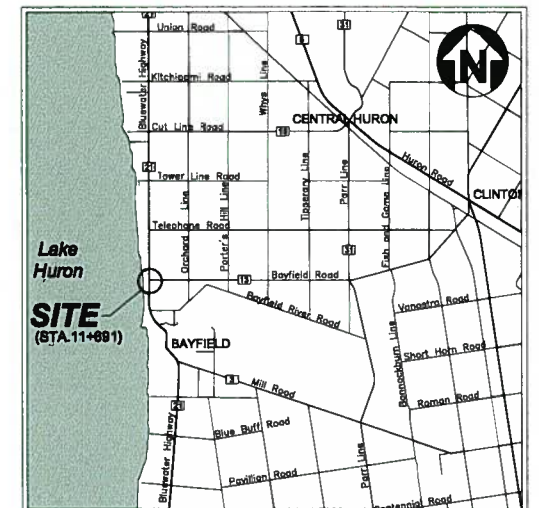
G.W.P. No.
834-93-00

REHABILITATION OF HWY 21 FROM BAYFIELD TO GOODERICH
GEOCRES No.40P12-25
CULVERT AT STA 11+691
STRATIGRAPHIC CROSS SECTION

SHEET
1 OF 1

amec

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KEY PLAN

Approximate Scale
0 2000 4000 6000 8000m

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 G24	4825715	443039	196.3
BH G25	4825747	443029	196.2

NOTES:

- 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.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Borehole without was dry.

SOIL STRATIGRAPHY

- TOPSOIL
- FILL
- SILTY CLAY/CLAYEY SILT



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

AMEC Reference: TP110076

REVISIONS			
DESIGN PB	CHK PB	CODE CHBDC-06	CL 625-ONT
DRAWN KW	CHK HS	SITE 11+691	DWG 3

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 strata, 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	
<u>Cohesionless Soils</u>	<u>SPT N-Value*</u>
Very loose	0 to 5
Loose	5 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	> 50

Consistency of	
<u>Cohesive Soils</u>	<u>Undrained Shear Strength</u>
	<u>kPa</u>
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.

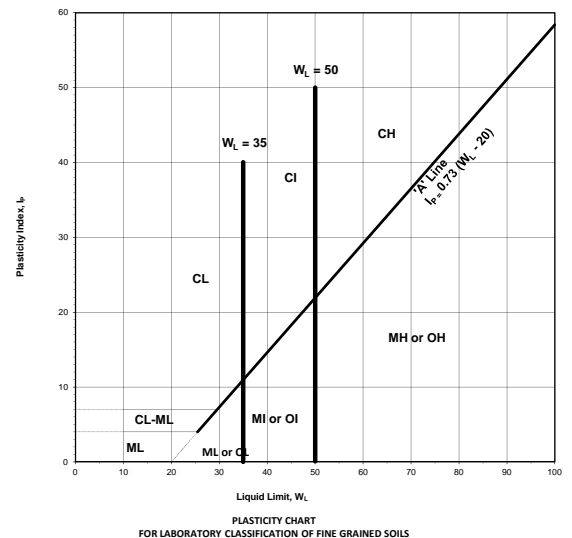
MTC SOIL CLASSIFICATION

Based on MTC Soil Classification Manual



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 PARTICULAR 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 DESCRIPTIVE INFORMATION, & SYMBOL IN PARENTHESIS.	$C_u = \frac{D_{60}}{D_{10}}$ GREATER THAN 4;			
			PREDOMINANTLY ONE SIZE OF A RANGE OF SIZES WITH STONE INTERMEDIATE SIZES MISSING		GP	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES			$C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ BETWEEN 1 AND 3		
		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						
		PLASTIC FINES (FOR IDENTIFICATION PROCEDURES SEE CL BELOW)		SC	CLAYEY SANDS, POORLY GRADED SAND-CLAY MIXTURES						
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT SMALLER THAN 75µm)	IDENTIFICATION PROCEDURE ON FRACTION SMALLER THAN 425µm					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.	$C_u = \frac{D_{60}}{D_{10}}$ GREATER THAN 6;			
	LIQUID LIMIT LESS THAN 35 AND 50	DRY STRENGTH (CRUSHING CHARACTERISTICS)	DILATANCY (REACTION TO SHAKING)	TOUGHNESS (CONSISTENCY NEAR PLASTIC LIMIT)	ML				INORGANIC SILTS & SANDY SILTS OR SLIGHTLY PLASTICITY, ROCK FLOUR	$C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ BETWEEN 1 AND 3	
		NONE	QUICK	NONE	CL			SILTY CLAYS (INORGANIC), GRAVELLY CLAYS, SANDY CLAYS, LEAN CLAYS			
		MEDIUM TO HIGH	NONE TO VERY SLOW	MEDIUM	OL			ORGANIC SILT OF LOW PLASTICITY, ORGANIC SANDY SILTS			
		SLIGHT TO MEDIUM	SLOW	SLIGHT	MI			INORGANIC COMPRESSIBLE FINE SANDY SILT WITH CLAY OF MEDIUM PLASTICITY, CLAYEY SILTS			
	LIQUID LIMIT BETWEEN 35 AND 50	NONE TO SLIGHT	SLOW TO QUICK	SLIGHT	CI			SILTY CLAYS (INORGANIC) OF MEDIUM PLASTICITY	NOT MEETING ALL GRADATION FOR SW		
		HIGH	NONE	MEDIUM TO HIGH	OI			ORGANIC SILTY CLAYS OF MEDIUM PLASTICITY			
		SLIGHT TO MEDIUM	VERY SLOW	SLIGHT	MH			INORGANIC SILTS, HIGHLY COMPRESSIBLE MICACEOUS OR DIATOMEACOUS FINE SANDY SILTS, ELASTIC SILTS			
		SLIGHT TO MEDIUM	SLOW TO NONE	MEDIUM	CH			CLAYS (INORGANIC) OF HIGH PLASTICITY, FAT CLAYS			
	LIQUID LIMIT GREATER THAN 50	HIGH TO VERY HIGH	NONE	HIGH	OH			ORGANIC CLAYS OF HIGH PLASTICITY	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	
		MEDIUM TO HIGH	NONE TO VERY SLOW	SLIGHT TO MEDIUM							
	HIGH ORGANIC SOILS	READILY IDENTIFIED BY COLOUR, ODOUR, SPONGY FEEL & FREQUENTLY BY FIBROUS TEXTURE						Pt	PEAT AND OTHER HIGHLY ORGANIC SOILS	ATTERBERG LIMITS ABOVE A- LINE WITH Ip GREATER THAN 7	

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



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	SUSCEPTIBILITY TO SURFICIAL EROSION	SUSCEPTIBILITY TO FROST ACTION	DRAINAGE CHARACTERISTICS
WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	GW	PERVIOUS	EXCELLENT	NEGLECTIBLE	EXCELLENT	MEDIUM	NEGLECTIBLE	NEGLECTIBLE	EXCELLENT
POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	GP	VERY PERVIOUS	GOOD	NEGLECTIBLE	GOOD	MEDIUM	NEGLECTIBLE	NEGLECTIBLE	EXCELLENT
SILTY GRAVELS, POORLY GRADED GRAVEL- SAND-SILT MIXTURES	GM	SEMI-PERVIOUS TO IMPERVIOUS	GOOD	NEGLECTIBLE	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	NEGLECTIBLE TO SLIGHT	PRACTICALLY IMPERVIOUS
WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	SW	PERVIOUS	EXCELLENT	NEGLECTIBLE	EXCELLENT	LOW TO MEDIUM	SLIGHT	NEGLECTIBLE	EXCELLENT
POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	SP	PERVIOUS	GOOD	VERY LOW	FAIR TO GOOD	LOW TO MEDIUM	MODERATE	NEGLECTIBLE 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	NEGLECTIBLE	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 PRACTICALLY
ORGANIC SILTY CLAY OF MEDIUM PLASTICITY	OI	SEMI-PERVIOUS 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 NEGLECTIBLE	NEGLECTIBLE	PRACTICALLY IMPERVIOUS
ORGANIC CLAYS OF HIGH PLASTICITY	OH	IMPERVIOUS	POOR	HIGH	POOR	LOW	MODERATE	NEGLECTIBLE TO SLIGHT	PRACTICALLY IMPERVIOUS
PEAT AND OTHER HIGHLY ORGANIC SOILS	Pt	-	-	-	-	LOW	SEVERE	-	FAIR TO GOOD

RECORD OF BOREHOLE No BH G24

G.W.P. 834-93-00		LOCATION Sta. 11+691, NBL, 5.1m E of Rd C/L, 3.0m S of Culv C/L, E443039 N4825715		1 OF 2		ORIGINATED BY JF	
DIST Goderich HWY 21		BOREHOLE TYPE 200 mm diameter borehole (Hollow Stem)		COMPILED BY SC			
DATUM Geodetic		DATE 12 March 2012 - 12 March 2012		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					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			SOIL VAPOUR READING	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				SHEAR STRENGTH kPa					WATER CONTENT (%)								
									20	40	60	80	100	W _p	W	W _L		GR	SA	SI	CL	
196.3	0.0																					
	brown Sand and Gravel FILL some silt moist		1	SS	13																	
	pocket of silty clay in SS 2		2	SS	10																	
194.9	1.4																					
	brown Silty Clay / Clayey Silt FILL some sand trace gravel and cobbles / boulders		3	SS	6																	
194.1	2.1																					
	grey / brown Silty Sand FILL some clay trace rootlets and asphaltic concrete moist		4	SS	22																	
193.4	2.9																					
	brown / grey Clayey Silt FILL trace to some sand trace gravel		5	SS	11																	
	trace rootlets in SS6		6	SS	10																	
	trace organic matter in SS7		7	SS	10																	
	trace organic matter in SS 8		8	SS	11																	
187.2	9.1																					
	grey CLAYEY SILT / SILTY CLAY trace to some sand trace gravel stiff to hard		9	SS	11																	

Continued Next Page


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

G.W.P. 834-93-00	LOCATION Sta. 11+691, NBL, 5.1m E of Rd C/L, 3.0m S of Culv C/L, E443039 N4825715	ORIGINATED BY JF
DIST Goderich HWY 21	BOREHOLE TYPE 200 mm diameter borehole (Hollow Stem)	COMPILED BY SC
DATUM Geodetic	DATE 12 March 2012 - 12 March 2012	CHECKED BY SM
PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario		JOB NO. TP110076

[illegible]

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

G.W.P. 834-93-00	LOCATION Sta. 11+691, SBL, 5.1m W of Rd C/L, 4.0m N of Culv C/L, E443029 N4825747	ORIGINATED BY JF
DIST Goderich HWY 21	BOREHOLE TYPE 200 mm diameter borehole (Hollow Stem)	COMPILED BY SC
DATUM Geodetic	DATE March 13, 2012 - March 13, 2012	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					PLASTIC LIMIT LIMIT			SOIL VAPOUR READING	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				SHEAR STRENGTH kPa					WATER CONTENT (%)				PPM	GR	SA	SI	CL
									20	40	60	80	100	W _P	W	W _L						
196.2																						
0.0	brown		1	SS	12																	
195.8	Sand and Gravel FILL some silt moist		2	SS	7																	
0.4	brown																					
	Silty Clay FILL some sand trace gravel		3	SS	6																	
	trace organic matter in SS 4		4	SS	5																	
	trace organic matter in SS 5	5	SS	9																		
								</														

Continued Next Page

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

RECORD OF BOREHOLE No. BH G25

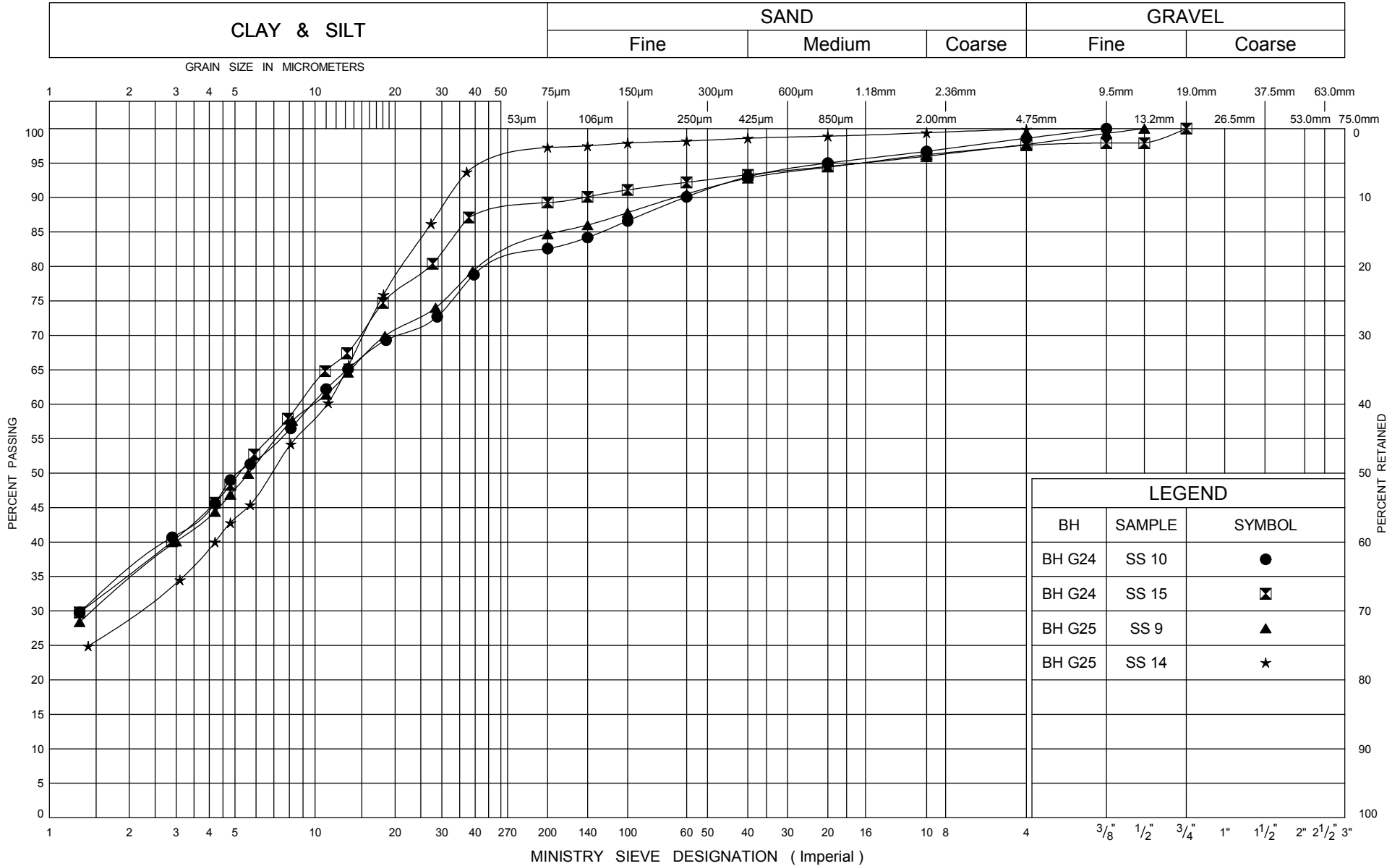
G.W.P. 834-93-00	LOCATION Sta. 11+691, SBL, 5.1m W of Rd C/L, 4.0m N of Culv C/L, E443029 N4825747	2 OF 2	ORIGINATED BY JF
DIST Goderich HWY 21	BOREHOLE TYPE 200 mm diameter borehole (Hollow Stem)	COMPILED BY SC	
DATUM Geodetic	DATE March 13, 2012 - March 13, 2012	CHECKED BY SM	
PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario			JOB NO. TP110076

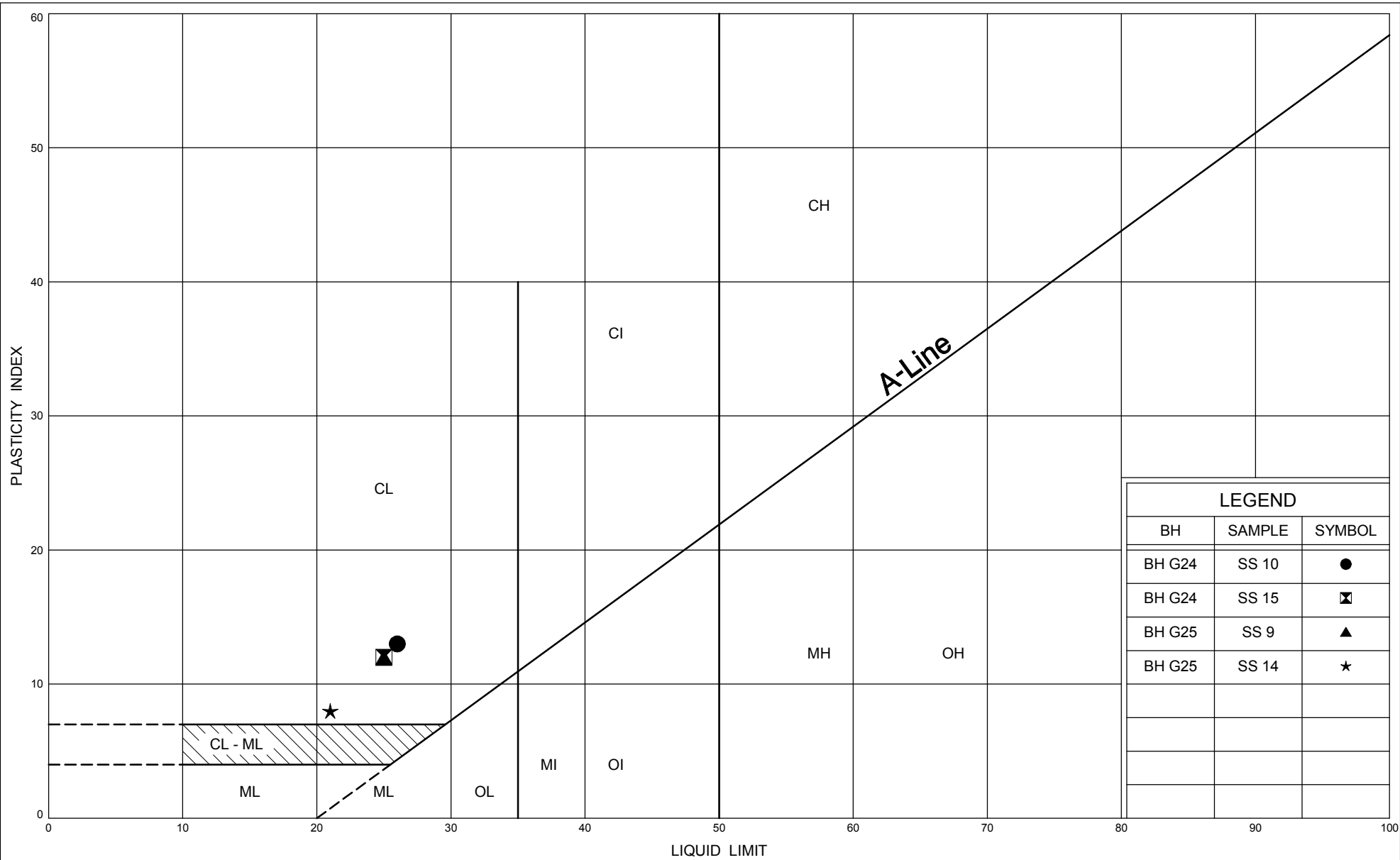
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DEPTH m	ELEVATION SCALE m	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			SOIL VAPOUR READING	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				SHEAR STRENGTH kPa					WATER CONTENT (%)								
					○ UNCONFINED + FIELD VANE					Wp W WL												
					● QUICK TRIAXIAL x LAB VANE																	
					20 40 60 80 100					20 40 60												
177.5 18.8	grey CLAYEY SILT / SILTY CLAY trace to some sand trace gravel very stiff to hard						186															
			10	SS	21		185												0			
							184							17					0			
							183															
			12	SS	60		182							13					0			
							181							13					0			
							180															
			14	SS	78		179							14					0	1 2 68 29		
							178															
	trace cobbles / boulders in SS15		15	SS	70							15					0					
	End of Borehole																					
	Groundwater level on 13 March 2012 : dry																					

APPENDIX B

LABORATORY TEST RESULTS

UNIFIED SOIL CLASSIFICATION SYSTEM





LEGEND		
BH	SAMPLE	SYMBOL
BH G24	SS 10	●
BH G24	SS 15	⊠
BH G25	SS 9	▲
BH G25	SS 14	★

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

Attention: Shami Mala
AMEC Environment & Infrastructure
Scarborough
104 Crockford Blvd
Scarborough, 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 CaCl ₂ EXTRACT	8	2012/03/22	2012/03/22	CAM SOP-00413	SM 4500H+ B
pH CaCl ₂ 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

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

AMEC Environment & Infrastructure
Client Project #: TP110076.05

-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

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

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

AMEC Environment & Infrastructure
Client Project #: TP110076.05

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

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

AMEC Environment & Infrastructure
Client Project #: TP110076.05

Test Summary

Maxxam ID MV6500
Sample ID G30-SS2
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

Maxxam ID MV6501
Sample ID G37-SS2
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		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
Sample ID G38-SS2
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		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

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

AMEC Environment & Infrastructure
Client Project #: TP110076.05

Test Summary

Maxxam ID MV6502 Dup
Sample ID G38-SS2
Matrix Soil

Collected 2012/03/16
Shipped
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

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

AMEC Environment & Infrastructure
Client Project #: TP110076.05

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

QC Batch	Parameter	Date	Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
			% 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 (SO ₄)	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.

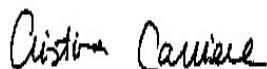
(1) - Matrix Spike Parent ID [MV6502-01]

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

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).

A handwritten signature in black ink, reading "Cristina Carriere".

CRISTINA CARRIERE, Scientific Services

=====

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.

APPENDIX C

SITE PHOTOGRAPHS

**HIGHWAY 21, GODERICH, ONTARIO
(CULVERT NO. 8 AT Sta. 11 + 691)**



PHOTOGRAPH NO. 1

Looking towards the existing culvert inlet and slope above the culvert.



PHOTOGRAPH NO. 2

Looking towards the existing culvert outlet area and the slope of the outlet.

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PHOTOGRAPH NO. 3

View of the spillway
downstream of the outlet.



PHOTOGRAPH NO. 4

View of the road and
shoulder above the culvert.