



March 2010

CELEBRATING
50
YEARS
in 2010

FOUNDATION INVESTIGATION AND DESIGN REPORT

**MASKINONGE RIVER TRIBUTARY CULVERT
HIGHWAY 404 EXTENSION FROM QUEENSVILLE
SIDEROAD TO RAVENSHOE ROAD
TOWN OF EAST GWILLIMBURY
MINISTRY OF TRANSPORTATION, ONTARIO
W.P. 2005-07-00**

Submitted to:
AECOM
5080 Commerce Blvd.
Mississauga, ON
L4W 4P2



Image Reference: Google Earth Pro, Image©2010 First Base Solutions, Imagery Date: Mar. 5, 2005

Geocres Number: 31D-495

Report Number: 08-1111-0022D

Distribution:

3 Copies: Ministry of Transportation (Central Region)
1 Copy: Ministry of Transportation (Foundations Section)
2 Copies: AECOM
2 Copies: Golder Associates Ltd.

REPORT



**A world of
capabilities
delivered locally**





Table of Contents

PART A – FOUNDATION INVESTIGATION REPORT

1.0 INTRODUCTION	1
2.0 SITE DESCRIPTION	1
3.0 INVESTIGATION PROCEDURES	1
4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS	2
4.1 Regional Geology	2
4.2 Subsoil Conditions	3
4.2.1 Clayey Silt with Organics / Organic Silt with Clay	3
4.2.2 Sandy Silt and Silt	3
4.2.3 Clayey Silt Till	4
4.2.4 Sand and Gravel	4
4.2.5 Clayey Silt	4
4.2.6 Silty Sand to Sand and Silt	5
4.2.7 Groundwater Conditions	6
5.0 CLOSURE	6

PART B – FOUNDATION DESIGN REPORT

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS	8
6.1 General	8
6.2 Culvert Foundation Options	8
6.3 Strip Footings	9
6.3.1 Geotechnical Resistance	9
6.3.2 Resistance to Lateral Loads	10
6.3.3 Frost Protection	10
6.4 Seismic Site Coefficient	10
6.5 Lateral Earth Pressures	10
6.6 Stability	13
6.6.1 Methodology	13
6.6.2 Parameter Selection	13



6.6.3	Results of Analyses	14
6.6.4	Seismic Stability / Liquefaction Potential	14
6.7	Settlement.....	14
6.7.1	Methodology	15
6.7.2	Parameter Selection	15
6.7.3	Results of Analyses	15
6.8	Design and Construction Considerations	16
6.8.1	Subgrade Preparation and Excavation	16
6.8.2	Control of Groundwater and Surface Water	17
6.8.3	Backfill and Cover / Embankment Fill	17
6.8.4	Erosion Protection	18
7.0	CLOSURE	18

REFERENCES

LIST OF TABLES

Table 1 – Evaluation of Culvert Foundation Alternatives

LIST OF DRAWINGS

Drawing 1 – Borehole Location and Soil Strata

LIST OF FIGURES

Figure 1 – Stability Analysis – High Fill Area at Maskinonge River Tributary Culvert – Station 34+065

Figure 2 – Estimated Settlement Profile – Maskinonge River Tributary Culvert

LIST OF APPENDICES

APPENDIX A RECORD OF BOREHOLES

List of Symbols

List of Abbreviations

Record of Borehole Sheets (C2-1 to C2-6)

APPENDIX B LABORATORY TEST RESULTS

Figure B1 – Grain Size Distribution – Silt

Figure B2 – Plasticity Chart – Clayey Silt Till

Figure B3 – Grain Size Distribution – Clayey Silt

Figure B4 – Plasticity Chart – Clayey Silt (Contains Silty Clay Inter-Layers)

Figure B5-A to B5-D – Oedometer Consolidation Test Results

Figure B6 – Grain Size Distribution – Sand and Silt

APPENDIX C NON-STANDARD SPECIAL PROVISIONS

Working Slab – Item No.



PART A

**FOUNDATION INVESTIGATION REPORT
MASKINONGE RIVER TRIBUTARY CULVERT
HIGHWAY 404 EXTENSION FROM QUEENSVILLE SIDEROAD TO
RAVENSHOE ROAD
TOWN OF EAST GWILLIMBURY
MINISTRY OF TRANSPORTATION, ONTARIO
W.P. 2005-07-00**



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM on behalf of Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the detailed design of the Highway 404-Maskinonge River Tributary culvert structure as part of the Highway 404 Extension project in East Gwillimbury, Ontario.

The terms of reference and scope of work are outlined in MTO's Request for Proposal, dated January 2008. Golder's proposal for foundation engineering services associated with the new culvert at Station 34+023 is contained in Section 6.8 of AECOM's Technical Proposal for this assignment. It is noted that the originally proposed culvert to be located at Station 33+860 for the terrestrial crossing has been deleted from the project and foundation investigation and design services are no longer required as outlined in our letter dated November 27, 2009 and approved by AECOM. The work was carried out in accordance with Golder's Supplementary Specialty Quality Control Plan for foundation engineering services for this project dated August 13, 2008.

2.0 SITE DESCRIPTION

The culvert site is located within a proposed high fill embankment area along the Highway 404 alignment approximately 1 km west of Woodbine Avenue and 1 km south of Holborn Road in the Town of East Gwillimbury in the Region of York (see key plan on Drawing 1) and will extend across the NBL and SBL embankments.

The proposed culvert is located at the bottom of a natural valley where the Maskinonge River Tributary flows from west to east. At the time of the investigation, the valley floor was wet with localized areas of ponded and/or low flowing water. The existing ground surface along the bottom of the valley ranges from about Elevation 251 m to 248 m at the west and east limits of the proposed culvert footprint.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the proposed Hwy 404 - Maskinonge River Tributary culvert was carried out between June 3 and 7, 2009, at which time six boreholes (Borehole C2-1 to C2-6) were advanced at approximately the locations shown on Drawing 1.

The field investigation was carried out using a track-mounted drill rig supplied and operated by Walker Drilling Ltd. of Utopia, Ontario. The boreholes were advanced using 108 mm outside diameter solid stem augers (for Boreholes C2-1 to C2-3, C2-5 and C2-6) and 108 mm inside diameter hollow stem augers (for Borehole C2-4) to depths ranging from 9.4 m to 9.8 m below existing ground surface. Soil samples were obtained at 0.75 m and 1.5 m intervals of depth using 50 mm outside diameter split-spoon samplers driven by a manual cat-head hammer in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586). Select samples of the cohesive soils were obtained using a 76 mm O.D. thin walled Shelby tube. A field vane shear test was conducted in one borehole within the cohesive soils for determination of undrained shear strengths using a MTO standard 'N' size vane.

The groundwater conditions in the open boreholes were observed throughout the drilling operations and piezometers were installed in Boreholes C2-1, C2-3, C2-4 and C2-6 to monitor the groundwater level at the site. The piezometers consist of 50 mm diameter PVC pipe, with a slotted screen sealed at a select depth within the



borehole. The non-instrumented boreholes and the annulus surrounding the piezometer pipe above the sand pack were backfilled to the surface with bentonite pellets in accordance with Ontario Regulation (O.Reg.) 903 as amended by O.Reg. 372/07. The piezometer installation details and water level readings are described on the Record of Borehole sheets in Appendix A.

The field work was supervised on a full-time basis by a member of Golder's engineering staff who arranged for service clearances, supervised the drilling, sampling and in-situ testing operations, logged the boreholes and examined and cared for the soil samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Mississauga for further examination and testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards as appropriate. Classification tests (water content, Atterberg Limits and grain size distribution) and organic content tests were carried out on select soil samples. A consolidation test was performed on a sample of the clayey soil extracted from a Shelby tube taken in Borehole C2-1.

The borehole locations were surveyed in the field by J.D Barnes Ltd. prior to drilling operations. The as-drilled borehole locations (referenced to MTM NAD83 co-ordinate system) and ground surface elevations (referenced to geodetic datum) are summarized below.

Borehole Number	Northing (m)	Easting (m)	Ground Surface Elevation (m)
C2-1	4890050.4	309545.5	251.2
C2-2	4890064.2	309564.0	250.6
C2-3	4890085.8	309582.1	249.9
C2-4	4890107.6	309601.6	249.3
C2-5	4890128.7	309623.7	248.7
C2-6	4890149.3	309640.6	248.0

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The study area for this investigation lies within or near two physiographic regions, delineated in *The Physiography of Southern Ontario*¹ as:

- Simcoe Lowlands; and
- Peterborough Drumlin Field

The surficial soils in the Simcoe Lowlands, to the south and southeast of Lake Simcoe, consist of sands, silts and clays that were deposited within a former glacial lake. It is noted that several areas of drumlinized till break the continuity of the Simcoe Lowlands plain.

¹ Chapman, L.J and Putnam, D.F. 1984. *The Physiography of Southern Ontario, Third Edition*, Ontario Geological Survey Special Volume 2. Accompanied by Map P.2715, Scale 1:600,000.



The surficial soils in the Peterborough Drumlin Field consist of sandy drumlinized till. Some of the drumlins in this area have shallow coverings of silt and fine sand of thickness between about 0.5 m and 2.5 m. "Wave-washed" drumlins, with exposed bouldery surfaces, are also present near the Simcoe Lowlands immediately south and east of Lake Simcoe. Localized deposits of silt, clay and peat are found in the low-lying areas between drumlins.

4.2 Subsoil Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of the in-situ and laboratory tests are given on the Record of Borehole sheets and on the laboratory test plots provided in Appendices A and B, respectively.

The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling, observations of drilling progress and the results of Standard Penetration Tests (SPTs). These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Subsoil conditions will vary between and beyond the borehole locations. The inferred soil stratigraphy based on the results of the boreholes is shown on Drawing 1.

In summary, the subsoil conditions encountered at the site consist of a surficial layer of organic silt with clay to clayey silt with organics, underlain by a stratum of clayey silt containing layers of sand and gravel, silty sand, and sandy silt to silt. A deposit of clayey silt till is present below the surficial deposit of clayey silt with organics in one borehole near the middle of the culvert alignment.

A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Clayey Silt with Organics / Organic Silt with Clay

A 0.7 m to 1.5 m thick surficial layer of clayey silt with organics / organic silt with clay was encountered in Boreholes C2-1 to C2-6. The layer typically contains trace to some sand, trace gravel, rootlets and oxidation staining.

Standard Penetration Test (SPT) 'N' values measured within the clayey silt with organics / organic silt with clay layer range from 1 to 4 blows per 0.3 m of penetration, suggesting a very soft to soft consistency.

A laboratory organic content test performed on a sample of the organic silt with clay layer measured 6.3 percent organics.

The measured water content on two samples of the organic silt with clay layer are 46 and 51 percent.

4.2.2 Sandy Silt and Silt

Layers of sandy silt and silt were encountered below the clayey silt with organics layer in Borehole C2-2 and within and below the clayey silt deposit in Borehole C2-1. The sandy silt and silt layers typically contain trace to some clay and trace gravel. A 0.3 m thick layer of sandy silt was encountered in Borehole C2-1 at a depth of 3.8 m below ground surface (Elevation 247.4 m). A 1.6 m thick upper layer of sandy silt to silt was encountered in Borehole C2-2 at a depth of 0.8 m below ground surface (Elevation 249.8 m). A lower layer of silt was encountered in Boreholes C2-1 and C2-2 at depths of 7.2 m and 6.7 m below ground surface (Elevation



244.0 m), respectively. The silt layer is 2.0 m thick in Borehole C2-2 and Borehole C2-1 penetrated 2.6 m into the layer and was terminated at a depth of 9.8 m below ground surface (Elevation 241.5 m).

The measured SPT 'N' values within the sandy silt and silt layers range from 6 to 116 blows per 0.3 m of penetration, indicating a loose to very dense relative density.

The results of two grain size distribution tests performed on samples of the silt layer are shown on Figure B1.

An Atterberg limits test carried out on a sample of the silt layer in Borehole C2-2 indicates that the material is non-plastic.

The measured water contents on four samples of the silt layer range from 14 to 25 percent.

4.2.3 Clayey Silt Till

A deposit of clayey silt till was encountered below the surficial layer of clayey silt with organics in Borehole C2-3. The till deposit contains some sand, trace gravel and layers of silty sand. The surface of the clayey silt till deposit was encountered at a depth of 0.9 m below ground surface (Elevation 249.0 m) and is 1.4 m thick.

A SPT 'N' value within the clayey silt till deposit is 8 blows per 0.3 m of penetration, suggesting a stiff consistency. A field vane test performed within the clayey silt till deposit exceeded the capacity of the measuring scales (i.e. undrained shear strength greater than 120kPa) indicating a very stiff consistency.

An Atterberg limits test carried out on one sample of the clayey silt till deposit measured a liquid limit of 20 percent, a plastic limit of 14 percent and plasticity index of 6 percent. The results of the Atterberg limits testing are shown on Figure B2 and indicate that the material is a clayey silt of low plasticity.

The measured water content on a sample of the clayey silt till deposit is 19 percent.

4.2.4 Sand and Gravel

A layer of sand and gravel was encountered below the clayey silt till in Borehole C2-3. This layer contains trace clay and silt. The surface of the sand and gravel layer was encountered at a depth on 2.3 m below ground surface (Elevation 247.6 m) and is 1.1 m thick.

A SPT 'N' value within the sand and gravel layer is 27 blows per 0.15 m of penetration, indicating a very dense relative density.

4.2.5 Clayey Silt

A stratum of clayey silt was encountered below the clayey silt with organics / organic silt with clay in Boreholes C2-1 and C2-4 to C2-6, below the sandy silt to silt layer in Borehole C2-2, and below the sand and gravel layer in Borehole C2-3. This stratum typically contains trace to some sand and interlayers of silty clay and silty sand to sand and silt. The surface of the clayey silt stratum was encountered at depths ranging from 0.7 m to 3.4 m below ground surface (Elevation 250.5 m to 246.5 m) and the stratum is 3.2 m to 8.9 m thick. Borehole C2-3 to C2-6 penetrated 6.0 m to 8.9 m into the stratum and were terminated within this stratum at depths ranging from 9.4 m to 9.8 m below ground surface (Elevation 238.2 m to 240.5 m).

The measured SPT 'N' values within the clayey silt stratum range from 4 blows per 0.3 m of penetration to 100 blows per 0.1 m of penetration, suggesting a firm to hard consistency.



The results of two grain size distribution tests performed on samples of the clayey silt stratum are shown on Figure B3.

Atterberg limits testing carried out on eleven samples of the clayey silt stratum measured liquid limits ranging from 18 to 37 percent, plastic limits ranging from 14 to 19 percent and plasticity indices ranging from 3 to 20 percent. The results of the Atterberg limits testing are shown on Figure B4 and indicate that the material is generally a clayey silt of low plasticity. The higher liquid limit values can be attributed to mixing of the silty clay interlayers present within the clayey silt stratum during the Atterberg limits testing.

A laboratory consolidation test was carried out on one specimen of the clayey silt stratum obtained from a Shelby tube sample. The results are shown on Figures B5A to B5D in Appendix B and are summarized below.

Borehole / Sample No.	Sample Depth/Elevation	σ_{vo}' (kPa)	σ_p' (kPa)	$\sigma_p' - \sigma_{vo}'$ (kPa)	OCR	C_c	C_r	e_o	c_v (cm ² /s)
C2-1, Sa#2	0.9 m / 250.3 m	9	200	191	21	0.3	0.04	0.97	7.7×10^{-2}

where: σ_{vo}' is the effective overburden pressure in kPa
 σ_p' is the preconsolidation pressure in kPa
OCR is overconsolidation ratio
 e_o is initial void ratio
 C_c is the compression index
 C_r is the recompression index
 c_v is the coefficient of consolidation (in cm²/s) for a stress range of $9 \text{ kPa} \leq \sigma_v' \leq 160 \text{ kPa}$

The clayey silt sample used for the consolidation test (i.e. from Borehole C2-1, Sa#2) is considered to be over-consolidated. A bulk unit weight of about 18 kN/m³ and a specific gravity of 2.74 was measured on the consolidation test specimen.

The measured water contents on samples of the clayey silt stratum range from 19 to 33 percent.

4.2.6 Silty Sand to Sand and Silt

Layers of silty sand to sand and silt were encountered below or within the clayey silt stratum in Boreholes C2-2, C2-4, C2-5 and C2-6. This layer typically contains trace clay and cobbles and boulders were inferred to be present within this layer in Borehole C2-4 as indicated by the grinding of augers as they advanced through the layer. The surface of the silty sand to sand and silt layer was encountered at depths ranging from 5.6 m to 8.0 m below ground surface (Elevation 245.0 m to 240.8 m) and is 1.1 m to 2.3 m thick. Borehole C2-2 penetrated 1.1 m into the lower portion of the silty sand layer and was terminated within this layer at a depth of 9.8 m below ground surface (Elevation 240.9 m).

The measured SPT 'N' values within the silty sand to sand and silt layer range from 66 to 118 blows per 0.3 m of penetration, indicating a very dense relative density.

The results of one grain size distribution test performed on a sample of the sand and silt layer are shown on Figure B9.

The measured water contents on three samples of the silty sand to sand and silt range from 12 to 22 percent.



4.2.7 Groundwater Conditions

Water levels were noted in the open boreholes during and after the drilling operations. Piezometers were installed in Borehole C2-1 sealed within the silt layer, in Borehole C2-3 sealed within the clayey silt till and sand and gravel layers, in Borehole C2-4 sealed within the clayey silt and silty sand layers and in Borehole C2-6 sealed within the silty sand layer. Details of the piezometer installations are shown in the Record of Borehole sheets in Appendix A. The water levels recorded in the boreholes and piezometers are summarized below:

Borehole / Piezometer	Ground Surface Elevation (m)	Depth Below Ground Surface to Water Level (m)	Ground Water Level Elevation (m)	Date	Notes
C2-1	251.2	0.3	250.9	June 12, 2009	Piezometer
C2-2	250.6	0	250.6	June 3, 2009	Open Borehole
C2-3	249.9	0.8	249.1	June 4, 2009	Open Borehole*
C2-4	249.3	1.4	247.9	June 12, 2009	Piezometer
C2-5	248.7	0	248.7	June 3, 2009	Open Borehole
C2-6	248.0	2.8	245.2	June 12, 2009	Piezometer

*A piezometer was installed in this borehole but was destroyed before any water level readings could be taken.

It should be noted that groundwater levels will fluctuate seasonally and are expected to rise during wet periods of the year.

5.0 CLOSURE

The field drilling program was supervised by Mr. Ted Beadle. This Foundation Investigation Report was prepared by Mr. Ted Beadle and reviewed by Mr. Kevin Bentley, P.Eng., a Senior Geotechnical Engineer with Golder. Mr. Jorge M.A. Costa, P.Eng., a Principal of Golder and a Designated MTO Contact for Foundations carried out a quality control review of this report.



FOUNDATION INVESTIGATION AND DESIGN
MASKINONGE RIVER TRIBUTARY CULVERT, WP 2005-07-00

Report Signature Page

GOLDER ASSOCIATES LTD.

Ted Beadle
Geotechnical Group

Jorge M.A. Costa, P.Eng.
Designated MTO Contact, Principal

TB/KJB/JMAC/jl

Kevin J. Bentley, P.Eng.
Senior Geotechnical Engineer

n:\active\2008\1111\08-1111-0022 uma hwy 404 ext. region of york\foundations\report\fidr's\finals\maskinonge culvert\08-1111-0022 rpt final 10mar10 maskinonge river tributary culvert.docx



PART B

**FOUNDATION DESIGN REPORT
MASKINONGE RIVER TRIBUTARY CULVERT
HIGHWAY 404 EXTENSION FROM QUEENSVILLE SIDEROAD TO
RAVENSHOE ROAD
TOWN OF EAST GWILLIMBURY
MINISTRY OF TRANSPORTATION, ONTARIO
W.P. 2005-07-00**



6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides recommendations for the foundation aspects of the proposed culvert structure to allow passage of the Maskinonge River Tributary under the proposed Highway 404 high fill embankment as part of the Highway 404 Extension project. The results of foundation investigation and detail design input for the high fill area where the culvert is located is provided in a separate report. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigation. The discussion and recommendations presented are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to carry out the design of the structure foundations. Where comments are made on construction, they are provided in order to highlight those aspects which could affect the design of the project. Those requiring information on the aspects of construction should make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

Based on the General Arrangement drawing (dated November 2009) provided by AECOM, the proposed culvert located at about Station 34+023 will comprise of a precast concrete structure with associated wingwalls founded on cast-in-place concrete footings. The concrete structure has a span width of 4.9 m and is 130 m long to take into account future widening of the NBL and SBL embankments. The proposed elevation of the highway grade is up to about Elevation 258 m at the roadway level and the crest of the embankment side-slopes is at about Elevation 257 m and 256 m at the west and east sides respectively. The existing ground surface ranges from about Elevation 251 m to 248 m at the west (inlet) and east (outlet) limits of the culvert resulting in a high fill embankment that is up to 8 m high from the crest of the Highway 404 embankment sideslopes (sloped at 2H:1V) to the toe of the embankment fill.

The proposed open footings for the culvert and wingwalls are shown on the GA drawing to range from about Elevation 249.0 m to Elevation 246.3 m at the west and east limits of the culvert, respectively. It is noted that a concrete structure with open footings was recommended as the preferred culvert option in the Preliminary Design Report to convey the 100-year design storm event while maintaining acceptable cross-sectional opening area for terrestrial passage.

6.2 Culvert Foundation Options

The shallow subsoils at the culvert location consist of a surficial layer of clayey silt with organics and organic silt with clay, underlain by layers of sandy silt to silt, clayey silt till, and clayey silt. Surface water was encountered at the ground surface during drilling operations and stabilized groundwater levels measured within three piezometers installed along the culvert alignment ranged from 0.3 m to 2.8 m below ground surface (Elevation 250.9 m to 245.2 m) on June 12, 2009.

Based on the recommendations from the Preliminary Design Report and AECOM, a concrete culvert with open footings has been selected for this site based on hydraulic requirements (footings founded a minimum 2 m below culvert invert level based on scour design requirements) and to provide an acceptable cross-sectional opening for terrestrial passage.

Based on the borehole information, the compact sandy silt to silt and firm to hard clayey silt and clayey silt till located below the surficial layer of clayey silt with organics / organic silt with clay are considered suitable for the



support of the proposed culvert foundations. Both deep and shallow foundations have been considered and advantages, disadvantages, relative costs and risks / consequences for the foundation options are summarized in Table 1. Given that competent founding soils are present at relatively shallow depth (within 2 m below existing ground surface), deep foundations are not considered to be a practical option and will not be discussed further. From a foundations perspective, the preferred option is strip footings to support the precast concrete segments.

6.3 Strip Footings

6.3.1 Geotechnical Resistance

The bottom of the existing valley (i.e. streambed) elevations, recommended level of subexcavation (maximum elevation) required to reach the appropriate founding soils for the culvert and wingwall footing, and founding soil type for the proposed culvert is presented.

Culvert	Culvert Station	Relevant Boreholes	¹Approximate Stream Bed Elevation (m)	Recommended Subexcavation depth / level for proposed footings	Founding Soil Type
Maskinonge River Tributary	34+000	C2-1 to C2-6	251.0 m – u/s 248.0 m – d/s	2 m / 249.0 m – u/s 2 m / 246.0 m – d/s	Stiff to very stiff clayey silt / clayey silt till and compact sandy silt to silt

¹ u/s = upstream, d/s = downstream

For the founding levels noted above, the factored geotechnical axial resistance at Ultimate Limit States (ULS) and the geotechnical resistance at Serviceability Limit States (SLS) for 25 mm of vertical displacement are given below.

Culvert / Wingwall	Proposed Footing Width (m)	Factored Geotechnical Axial Resistance at ULS (kPa)	Geotechnical Resistance at SLS for 25 mm settlement (kPa)
Maskinonge River Tributary	2	350	250

The geotechnical resistances provided assume that the footings are founded on properly prepared, undisturbed soils which for design are assumed to extend to the subexcavation levels provided above.

Given that the groundwater level is higher than the proposed footing founding level, dewatering measures will be required to allow construction of the strip footings in the dry (see Section 6.8.2).

If the concrete for the footing on the native soil cannot be placed immediately after excavation, subgrade preparation and inspection, it is recommended that a working slab be placed to protect the integrity of the bearing stratum. A Non-Standard Special Provision should be included in the Contract Documents for use of a working slab and an example is provided in Appendix C.



6.3.2 Resistance to Lateral Loads

Resistance to lateral forces / sliding resistance between the cast-in-place concrete footings and the undisturbed subgrade soils should be calculated in accordance with Section 6.7.5 of the Canadian Highway Bridge Design Code (CHBDC). The following summarizes the lateral resistance parameters for the various interface materials.

Interface and Loading Condition	Parameter*
Cast-in-Place Concrete on stiff to very stiff clayey silt / clayey silt till: short term loading long term loading	Effective cohesion (c') = 40 kPa Effective friction angle (ϕ') = 28 degrees
Cast-in-Place Concrete on compact sandy silt to silt: short or long term loading	Coefficient of friction ($\tan \delta$) = 0.45

*NAVFAC (1982)

These values represent unfactored values; in accordance with the CHBDC, a factor of 0.8 is to be applied in calculating horizontal resistance.

6.3.3 Frost Protection

All footings should be provided with a minimum 1.5 m soil cover (OPSD 3090.101, Foundation Frost Depths for Southern Ontario) or equivalent thickness of insulation below the footings for frost protection. As a guide, the MTO has adopted an equivalency of 25 mm of rigid polystyrene foam insulation for every 0.3 m reduction in soil cover.

6.4 Seismic Site Coefficient

The peak zonal acceleration ratio is 0.05g for the Town of Bradford, Ontario (CHBDC Table A3.1.1). The Site Coefficient (S) may be taken as 1.2, consistent with Soil Profile Type II in accordance with Section 4.4.6 and Table 4.4 of the CHBDC (2006).

6.5 Lateral Earth Pressures

The lateral earth pressures acting on the culvert walls and associated wing walls / retaining walls will depend on the type and method of placement of the backfill materials, the nature of the soils behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure and the drainage conditions behind the walls. Seismic (earthquake) loading should also be taken into account in the design.

The following recommendations are made concerning the design of the culvert walls. It should be noted that these design recommendations and parameters assume level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- Select, free draining granular fill meeting the specifications of SP110S13 (Aggregates) Granular 'A' or Granular 'B' Type II but with less than 5 percent passing the 200 sieve should be used as backfill behind the walls. Transverse drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements with respect to sub drains and frost



taper should be in accordance with OPSD 3101.150 (Walls – Abutment, Backfill) and OPSD 3121.150 (Walls – Retaining, Backfill).

- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the culvert walls, in accordance with *CHBDC* Section 6.9.3 and Figure 6.6. Compaction equipment should be used in accordance with Special Provision 105S10 (Compaction). Other surcharge loadings should be accounted for in the design as required.
- The granular fill may be placed either in a zone with the width equal to at least 1.5 m behind the back of the walls (Case I on Figure C6.20(a) of the *Commentary* to the *CHBDC*), or within the wedge shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the footing (see Case II on Figure C6.20(b) of the *Commentary* to the *CHBDC*).
- For Case I, the pressures are based on the proposed embankment fill materials and the existing native soils and the following parameters (unfactored) may be used assuming the use of granular earth fill such as Select Subgrade Material (SSM) for embankment construction:

	Earth Fill (Granular Material)
Soil unit weight:	21 kN/m ³
Coefficients of static lateral earth pressure:	
Active, K_a	0.31
At rest, K_o	0.47

- For Case II, the pressures are based on the granular fill as placed, and the following parameters (unfactored) may be assumed:

	Granular 'A'	Granular 'B' Type II
Soil unit weight:	22 kN/m ³	21 kN/m ³
Coefficients of static lateral earth pressure:		
Active, K_a	0.27	0.27
At rest, K_o	0.43	0.43

If the wall support and culvert structure allow lateral yielding, active earth pressures may be used in the geotechnical design of the structure. If the culvert structure does not allow lateral yielding, at-rest earth pressures should be assumed for geotechnical design. The movement required to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure for design, should be calculated in accordance with Section C6.9.1 and Table C6.6 of the *Commentary* to the *CHBDC*.

A restrained structure is typically a concrete box culvert or a rigid frame culvert structure where the rotational and/or horizontal movement is not sufficient to mobilize the active pressure condition. For this condition, an at-rest pressure plus any compaction surcharge should be included in the design of the structure.



Seismic (earthquake) loading must also be taken into account in the design in accordance with Section 4.6 of the *CHBDC*. In this regard, the following should be included in the assessment of lateral earth pressures:

- Seismic loading will result in increased lateral earth pressures acting on the culvert walls and/or retaining walls. The walls should be designed to withstand the combined lateral loading for the appropriate static pressure conditions given above, plus the earthquake-induced dynamic earth pressure. According to Table C4.2 of the *Commentary* to the *CHBDC*, this site is located in Seismic Zone 1. The site specific zonal acceleration ratio for Bradford is 0.05. For the thickness and competent overburden soils encountered at this site, an amplification factor of the ground motion is recommended for design (i.e. Site Coefficient, $S=1.2$). As such, the recommended ground surface acceleration will increase to 0.06g. The seismic lateral earth pressure coefficients given below have been derived based on a design zonal acceleration ratio of $A = 0.06$.
- In accordance with Sections 4.6.4 and C.4.6.4 of the *CHBDC* and its *Commentary*, for structures which allow lateral yielding, the horizontal seismic coefficient, k_h , used in the calculation of the seismic active pressure coefficient, is taken as 0.5 times the zonal acceleration ratio (i.e. $k_h = 0.03$). For structures that do not allow lateral yielding, k_h is taken as 1.5 times the zonal acceleration ratio (i.e. $k_h = 0.09$). The seismic active earth pressure coefficient is also dependent on the vertical component of the earthquake acceleration, k_v . Three discrete values of vertical acceleration are typically selected for analysis, corresponding to $k_v = +2/3 k_h$, $k_v = 0$, and $k_v = 2/3 k_h$.
- The following seismic active pressure coefficients (K_{AE}) for the two cases (Case I and Case II) may be used in design. These coefficients reflect the maximum K_{AE} obtained using the k_h and three values of k_v as described above. It should be noted that these seismic earth pressure coefficients assume that the back of the wall is vertical and the ground surface behind the wall is flat.

SEISMIC ACTIVE PRESSURE COEFFICIENTS, K_{AE}

	Case A	Case B	
	Earth Fill (Granular Material)	Granular 'A'	Granular 'B' Type II
Yielding wall	0.32	0.26	0.26
Non-yielding wall	0.37	0.30	0.30

Note : These *CHBDC* seismic K_{AE} values include the effect of wall friction ($\delta=\Phi'/2$) and are less than the static values of K_a and K_o reported above for the very low zonal acceleration ratio for this site.

- The above K_{AE} values for yielding walls are applicable provided that the wall can move up to 250A (mm), where A is the design zonal acceleration ratio of 0.06. This corresponds to displacements of up to 15 mm at this site.
- The earthquake-induced dynamic pressure distribution, which is to be added to the static earth pressure distribution, is a linear distribution with maximum pressure at the top of the wall and minimum pressure at its toe (i.e. an inverted triangular pressure distribution). The total pressure distribution (static plus seismic) may be determined as follows:



$$P = K \gamma' d + (K_{AE} - K) \gamma' H$$

Where	K	is either the static active earth pressure coefficient (K_a) or the static at rest earth pressure coefficient (K_o);
	K_{AE}	is the seismic active earth pressure coefficient;
	γ'	is the effective unit weight of the soil (kN/m^3) <ul style="list-style-type: none">• taken as soil unit weights given above for fill materials• taken as 21 kN/m^3 for the native materials
	d	is the depth below the top of the wall (m); and
	H	is the height of the wall above the toe (m).

6.6 Stability

6.6.1 Methodology

Limit equilibrium slope stability analyses were performed using the commercially available software program "Slide", produced by Rocscience Inc., employing the Morgenstern-Price method of analysis to check that a minimum Factor of Safety of 1.5 is achieved for global stability (CFEM, 2006) of the proposed embankment height and wingwall geometry under static conditions along the culvert alignment. This minimum Factor of Safety is considered appropriate for the embankment / retaining wall system at the culvert site considering the design requirements and the available field and laboratory testing data.

6.6.2 Parameter Selection

For the cohesionless soils, effective stress parameters were employed in the embankment stability analyses assuming drained conditions. Undrained conditions were modelled for the cohesive soils. The soil parameters were estimated from empirical correlations proposed by Kulhawy and Mayne (1990) and the CHBDC (2006) using the results of in situ Standard Penetration Tests (SPT), visual classification and the results of laboratory testing. The earth fill embankment geometry assumes side slopes no steeper than 2 horizontal: 1 vertical (2H:1V) perpendicular to the proposed highway alignment. The piezometric conditions used in the analyses are based on the highest groundwater levels noted during drilling or measured in the piezometer installations.

The simplified soil stratigraphy and the associated strengths and unit weights assigned for the different soil types along the culvert alignment are presented below.



Location	Soil Layer	Bulk Unit Weight (kN/m ³)	Undrained Shear Strength (kPa)	Cohesion (c') (kPa)	Effective Friction Angle (degrees)
Maskinonge River Tributary Culvert (Station 34+023)	Clayey Silt with Organics / Organic Silt with Clay	15	10	-	-
	Earth Fill Embankment	21	-	0	32
	Firm to Stiff Clayey Silt	19	40	-	-
	Stiff to Very Stiff Clayey Silt Till / Compact Sandy Silt to Silt / Dense to Very Dense Sand and Gravel	21	100	5	32
	Very Stiff to Hard Clayey Silt	21	200	-	-

6.6.3 Results of Analyses

The stability analyses performed along the culvert alignment indicate that after the completion of construction, the embankment will have a Factor of Safety of 1.5 or greater for deep seated, global failure surfaces that would impact the operation of the roadway, culvert or wingwalls. An example result of the analysis performed along the culvert alignment and wingwall at Station 34+065 is shown on Figure 1.

The analyses assume that all surficial clayey silt with organics and organic silt have been removed from the proposed new culvert and embankment footprint and the new embankment fill is properly placed and compacted as per SP206S03.

6.6.4 Seismic Stability / Liquefaction Potential

Pseudo-static methods of embankment stability analysis indicate that a yield acceleration of about 0.23g results in a Factor of Safety against side slope instability of 1.0. Based on the yield acceleration and the correlation proposed by Makdisi and Seed (1978), it is estimated that very little additional deformation (i.e. less than about 5 mm) of the embankment would result under the design earthquake event.

The liquefaction potential of the soils below the culvert foundations under seismic loading has been considered using the empirical method outlined in Section C.4.6.2 of the *CHBDC Commentary*, which correlates the cyclic resistance ratio (CRR) of the soils with their normalised penetration resistance and fines content. Based on this assessment and assuming a ground surface acceleration of 0.06g, the subsoils are not considered liquefiable for an earthquake magnitude of 7.0.

6.7 Settlement

The proposed concrete culvert is located in a proposed fill embankment area up to about 8 m high adjacent to the culvert and up to about 6 m high directly overlying the culvert. The culvert footings are to be founded 2 m below existing ground surface and below the surficial organic silt with clay and clayey silt with organics layers. It



is assumed the existing ground surface (i.e. natural streambed) will be re-instated to carry the surface water flow through the culvert after construction of the footings is complete.

6.7.1 Methodology

Analyses were performed using the commercially available software program “Settle3D” produced by Rocscience Inc. and hand calculations to estimate the settlement of the culvert foundations from the proposed high fill embankment. A bulk unit weight of 21 kN/m^3 was employed for the proposed embankment fill and cover above the culvert in calculating the embankment loading on the culvert foundation subsoils.

6.7.2 Parameter Selection

Static settlement analyses were carried out for the foundation soils using the following parameters based on field and laboratory test data and accepted correlations as proposed by Kulhawy and Mayne (1990):

Location	Soil Layer	Depth below ground surface (m)	Bulk Unit Weight (kN/m^3)	Estimated Deformation Properties
Maskinonge River Tributary Culvert Alignment (Station 34+023)	Clayey Silt with Organics / Organic Silt	0 – 1	15	n/a
	Firm to Stiff Clayey Silt	1 – 2	19	$e_o = 0.97$, $C_c = 0.3$, $C_r = 0.04$, $\text{OCR} > 1$
	Stiff to Very Stiff Clayey Silt Till / Compact Sandy Silt to Silt / Dense to Very Dense Sand and Gravel	2 – 3	21	$E' = 50 \text{ MPa}$
	Very Stiff to Hard Clayey Silt	3 - 9	21	$E' = 50 \text{ MPa}$

n/a = not applicable to culvert foundation analysis assuming that footings are founded 2 m below existing ground surface and below the surficial clayey silt with organics and organic silt layers.

6.7.3 Results of Analyses

Based on the results of the settlement analyses, the maximum total settlements are comprised of immediate settlement (i.e. settlement during or shortly after construction) due mainly to the compression of the cohesionless soil layers and primary consolidation settlement (i.e. time-dependant settlement after construction) of the cohesive soil layers.

Figure 2 shows the estimated settlement profile along the bottom of the proposed culvert strip footings. The total settlement is estimated to be about 60 mm consisting of about 35 mm immediate settlement and 25 mm consolidation settlement. The majority (up to 90%) of the primary consolidation settlement within the overconsolidated clayey silt deposit containing sandy silt to silt interlayers is anticipated to occur within the first month after completion of construction.

It is important to note that the maximum settlement predicted at the ground surface (after stripping of all topsoil / organics) directly adjacent to the culvert foundations (i.e. High Fill Area 1 in the Deep Cut / High Fill Areas Foundation Investigation and Design Report under separate cover) is up to 100 mm and a comparison of the settlements at the culvert footing vs. the ground surface adjacent to the culvert is summarized below.



Location	Total Estimated Settlement (mm)	Initial Settlement Component (mm)	Primary Consolidation Settlement Component (mm)
Bottom of Culvert Footings	60	35	25
Ground Surface adjacent to Culvert (High Fill Area 1)	100	50	50 ¹

¹ consolidation settlement can be reduced to less than 25 mm if a 3-month preload period is provided or if the near surface clayey silt (up to 1.5 m thick) is subexcavated.

The majority (up to 90%) of the primary consolidation settlement within the cohesive subsoils under the footprint of the high fill embankment, including adjacent to the culvert is expected to occur within the first 3 months after completion of construction of the embankments. Therefore, a preloading period of at least 3 months is required prior to levelling and paving operations to induce the majority of settlements and reduce differential settlements along the sides of the culvert which could manifest to the surface of the highway embankment. It is recommended that the preload period of 3 months be scheduled into the Contract. In addition, it is recommended that the upper 1.5 m of the surficial clayey silt be subexcavated and backfilled (see Section 6.8.3) to a minimum distance of 2 m beyond the outer plan limits of the culvert footings to avoid creating a differential settlement contact line immediately adjacent to the culvert.

Alternatives to reduce post-construction settlements and preloading times for the foundation soils under the footprint of the high fill embankment including adjacent to the culvert are provided in the Deep Cut / High Fill Areas Foundation Investigation and Design Report and consist of preloading (as described above) or subexcavating the upper 1.5 m of the surficial clayey silt. Subexcavation of the surficial clayey silt from within the limits of the high fill embankment could also be considered in order to reduce the risk (magnitude) of differential settlements and provide a smooth transition along the length of the high fill embankment and between the embankment fill and the fill over the culvert.

Based on a manufacturer's (CON/SPAN Bridge Systems) Installation Handbook (dated 2000), the top of the footings on which a CON/SPAN structure is placed should not undergo differential settlement (or vary in elevation) more than 6 mm per 3 m length (1/4-inch per 10 feet). Based on the predicted settlement profile, the manufacturer's recommended settlement tolerance is satisfied. If an alternative concrete culvert system is used, the settlement tolerance recommended by the manufacturer must be satisfied.

6.8 Design and Construction Considerations

6.8.1 Subgrade Preparation and Excavation

Based on the borehole results, the excavation up to 2 m below ground surface as part of the foundation excavations for the culvert footings and wingwalls will extend through the surficial clayey silt with organics / organic silt, sandy silt to silt, clayey silt till, and clayey silt soils.

For temporary excavations made within the upper 2 m below ground surface, the soils are considered to be Type 3 according to the Occupational Health and Safety Act and Regulation for Construction Projects (OHSA). As such, temporary excavations in Type 3 soils should be carried out with walls sloped no steeper than 1H:1V provided groundwater is allowed sufficient time to drain and surface water is diverted around the excavation.



All excavations must be carried out in accordance with the latest edition of the OHSA.

6.8.2 Control of Groundwater and Surface Water

Surface water was encountered at the ground surface during drilling operations and stabilized groundwater levels measured within three piezometers installed along the culvert alignment ranged from 0.3 m to 2.8 m below ground surface (Elevation 250.9 m to 245.2 m) on June 12, 2009.

Groundwater control will be required at the culvert location, as the foundation excavations are expected to extend below the groundwater level at the culvert site. Where the excavation will be advanced through existing cohesive soils (i.e. no excavation through water-bearing granular soils), seepage into the excavation should be adequately controlled by pumping from properly filtered sumps. Where the excavation will be advanced through or into water-bearing cohesionless soils, appropriate dewatering of the water-bearing granular soil deposits will be required to maintain the water level below the founding level for the culvert during construction. Specifically, the sandy silt to silt soils present in Borehole C2-2 and clayey silt till soils underlain by saturated sand and gravel in Borehole C2-3 are susceptible to "loosening" and/or basal heave due to unbalanced water pressures and dewatering measures will be required.

Based on the grain size distributions of the sandy silt to silt soils and presence of granular interlayers within the clayey silt till and clayey silt deposits, it is considered that water will drain freely from the sides and bottom of the excavation and can be adequately controlled by using perimeter ditches / cut-off trenches drained by gravity along the existing valley slope grade and/or pumped from properly filtered sumps. The groundwater level should be maintained at least 0.5 m below the proposed founding level along the culvert alignment until such time as the culvert foundations and walls are completed and backfilled to existing grade.

Surface water that currently collects and flows to form the Maskinonge River Tributary must be diverted around the proposed culvert foundation footprint during construction. Depending on the time of year that construction is carried out, surface water can be directed around the proposed culvert footprint using berms and ditches and/or the water may be contained upstream of the excavation in check dams and pumped downstream of the construction area using temporary pipes / hoses.

Surface water should be directed away from the excavation at all times to minimize disturbance to the foundation subgrade. As noted in Section 6.3.1, a working slab should be placed on the base of the prepared subgrade to protect the integrity of the bearing stratum if concrete foundations cannot be poured immediately after subexcavation, inspection and approval of the foundation subgrade.

6.8.3 Backfill and Cover / Embankment Fill

Backfill to the culvert foundation walls and wingwalls should consist of select, free draining granular fill meeting the specifications of SP110S13 (Aggregates) Granular 'A' or Granular 'B' Type II but with less than 5 percent passing the 200 sieve placed and compacted as discussed in Section 6.5. The thickness of the backfill layer during placement should be maintained equal on both sides of the culvert, with one side not exceeding the other by more than 500 mm.

Backfill to the culvert foundations below the existing ground surface and soil cover above the culvert structure should be free draining and consist of locally available and/or imported granular earth fill meeting the specifications of SP110S13 (Aggregates) Select Subgrade Material (SSM). The culvert structure should be



designed for the full overburden pressure and live load, assuming an embankment fill unit weight of 22 kN/m^3 for Granular A, 21 kN/m^3 for Granular B Type II, and 21 kN/m^3 for SSM above and/or surrounding the culvert. Settlements within the granular fill itself is expected to be less than 25 mm provided the fill is placed and compacted in accordance with SP206S03 (Earth Excavation, Grading).

6.8.4 Erosion Protection

If the river flow velocities are sufficiently high, provision should be made for scour and erosion protection. Based on discussions with AECOM, a design scour depth of 2 m below existing ground surface is required to protect the foundations at the site. To prevent surface water from flowing around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a clay seal or concrete cut-off wall / wingwall should be provided at the upstream end of the culvert. If a clay seal is adopted, the clay material should meet the requirements of OPSS 1205 (Clay Seal), and the seal should extend to a depth of 2 m below the invert level (i.e. to the design scour depth) and to a minimum horizontal distance of 2 m on either side of the culvert inlet and outlet openings, and a minimum vertical height equivalent to the high water level including treatment of adjacent side slopes.

The requirements for design of erosion protection measures for the inlet and outlet of the culvert should be assessed by the hydraulic design engineer. As a minimum, rip-rap treatment for the inlet and outlet of the culvert should be consistent with the standard presented in OPSD 810.010 (Rip-Rap Treatment for Culvert Outlets) Rip-Rap Treatment Type A, with the rip-rap placed to above the high water level, in combination with the cut-off measures noted above. Similarly, rip-rap should be provided over the full extent of the clay seal, if applicable, including the river side slopes and embankment fill slope adjacent to the culverts.

7.0 CLOSURE

This Foundation Design Report was prepared by Mr. Ted Beadle, and reviewed by Mr. Kevin J. Bentley, P.Eng., a Senior Geotechnical Engineer with Golder. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and Principal with Golder, conducted an independent quality control review of the report.



Report Signature Page

GOLDER ASSOCIATES LTD.

Ted Beadle
Geotechnical Group

Kevin J. Bentley, P.Eng.
Senior Geotechnical Engineer



Jorge M.A. Costa, P.Eng.
Designated MTO Contact, Principal



TB/KJB/JMAC/jl

n:\active\2008\1111\08-1111-0022 uma hwy 404 ext. regionof york\foundations\report\fidr\finals\maskinonge culvert\08-1111-0022 rpt final 10mar10 maskinonge river tributary culvert.docx



REFERENCES

- Canadian Geotechnical Society. 2006. Canadian Foundation Engineering Manual, 4th Edition. The Canadian Geotechnical Society c/o BiTech Publisher Ltd, British Columbia.
- Canadian Highway Bridge Design Code (CHBDC) and Commentary on CAN/CSA S6 06. 2006. CSA Special Publication, S6.1 06. Canadian Standard Association.
- Chapman, L.J., and Putnam, D.F. 1984. The Physiography of Southern, 3rd Edition. Ontario Geological Survey, Special Volume 2. Ontario Ministry of Natural Resources.
- Kulhawy, F.H. and Mayne, P.W. 1990. Manual on Estimating Soil Properties for Foundation Design. EL 6800, Research Project 1493-6. Prepared for Electric Power Research Institute, Palo Alto, California.
- Makdisi, F.I. and Seed, H.B. 1978. Simplified Procedure for Estimating Dam and Embankment Earthquake Induced Deformations. ASCE Journal of the Geotechnical Engineering Division, Volume 104, GT7, pp 849-867.
- U.S. Navy. 1982. Soil Mechanics, Foundation and Earth Structures. NAVFAC Design Manual DM 7.2, Alexandria, Virginia.

STANDARDS:

ASTM International:

ASTM D1586-08a Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

Contract Design Estimating and Documentation (CDED):

Special Provision 105S10 Amendment to OPSS 501 – Construction Specification for Compaction. Nov. 2004

Special Provision 110S13 Amendment to OPSS 1010 – Material Specification for Aggregates. April 2004.

Special Provision 206S03 Amendment to OPSS 206 – Earth Excavation, Grading. July 2007.

Ontario Provisional Standard Drawing:

OPSD 3090.101 Foundation Frost Depths for Southern Ontario. November 2005.

OPSD 3101.150 Walls – Abutment, Backfill – Minimum Granular Requirement. November 2005.

OPSD 3121.150 Walls – Retaining, Backfill – Minimum Granular Requirement. November 2005.

OPSD 810.010 Rip-Rap Treatment for Sewer and Culvert Outlets. November 2007.

Ontario Provisional Standard Specifications:

OPSS 1205 Material Specification for Clay Seal. November 2009.

Ontario Water Resources Act:

Ontario Regulation 372/97 Amendment to Ontario Regulation 903.

TABLE 1
EVALUATION OF CULVERT FOUNDATION ALTERNATIVES
Maskinonge River Tributary Culvert - Highway 404 Extension
W.P. 2005-07-00

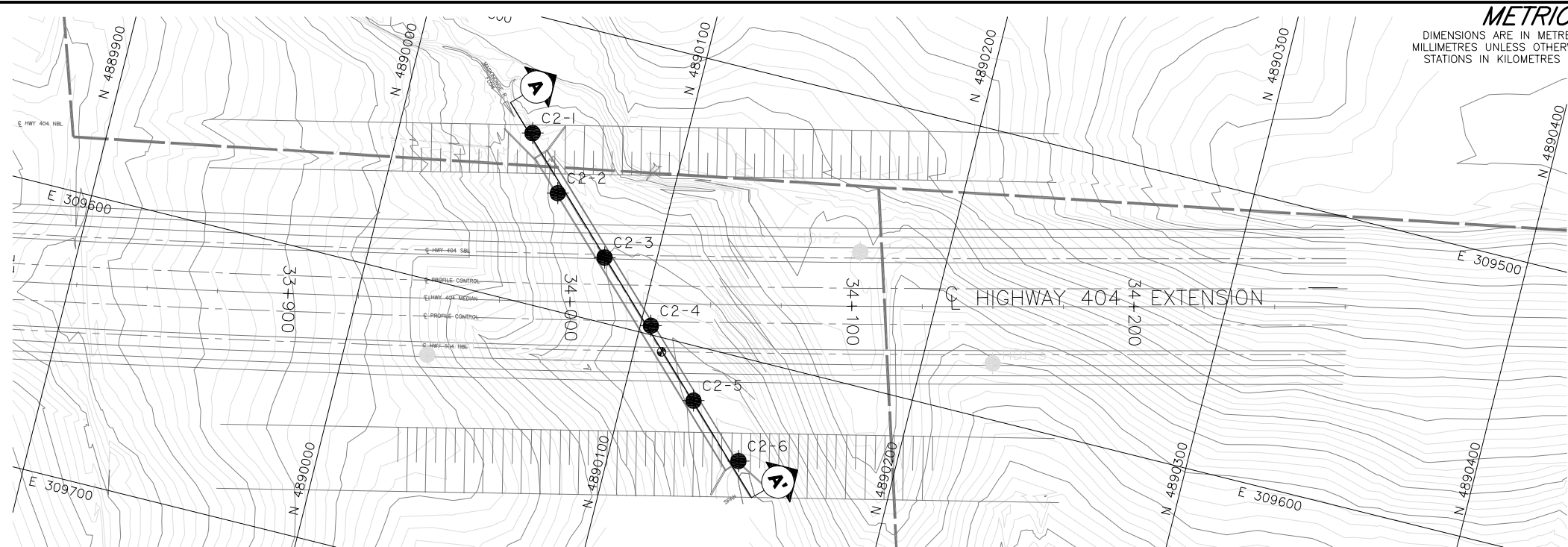
Footing Option	Rank	Advantages	Disadvantages	Relative Costs¹	Risks/Consequences
<i>Open Footing Culvert</i>	1	<ul style="list-style-type: none"> • Routine excavation and construction procedure; • Shallow sub-excavation depth • Natural streambed can be restored after construction 	<ul style="list-style-type: none"> • Dewatering / Diversion of surface water required in order to pour concrete footings "in the dry"; 	<ul style="list-style-type: none"> • Low relative costs (\$40,000) compared to other options. 	<ul style="list-style-type: none"> • Potential difficulties in maintaining integrity of foundation subgrade if adequate dewatering / diversion of surface water is not performed.
<i>Closed Bottom Culvert (Raft Foundation or Box Culvert)</i>	NP	<ul style="list-style-type: none"> • Routine excavation and construction procedure; • Shallow sub-excavation depth 	<ul style="list-style-type: none"> • Design scour depth requires bottom of culvert to be at least 2 m below streambed and terrestrial opening requires obvert located 3 m above streambed; thus, box culvert geometry is large; • Dewatering required to place and compact bedding layer and/or engineered fill for precast box unit or pour concrete base "in the dry" for cast-in-place. 	<ul style="list-style-type: none"> • Higher costs (\$60,000) compared to open footings assuming same level of dewatering is required. 	<ul style="list-style-type: none"> • Potential difficulties in maintaining integrity of foundation subgrade if adequate dewatering / diversion of surface water is not performed.
<i>Deep Foundations (i.e. Piles or Caissons)</i>	NP	<ul style="list-style-type: none"> • Greater axial resistance available for design. 	<ul style="list-style-type: none"> • High water table will require dewatering for construction of pile caps in the dry; • Site preparation / access routes for construction equipment must be assessed. 	<ul style="list-style-type: none"> • Higher costs (\$100,000) compared to shallow footings. 	

Notes:

1. The approximate costs are rough estimates and provided only for comparison purposes.

NP = not practical

n:\active\2008\1111\08-1111-0022 uma hwy 404 ext. regionof york\foundations\report\fidr's\finals\maskinonge culvert\08-1111-0022d table 1_evaluation culvert foundation alternatives.docx



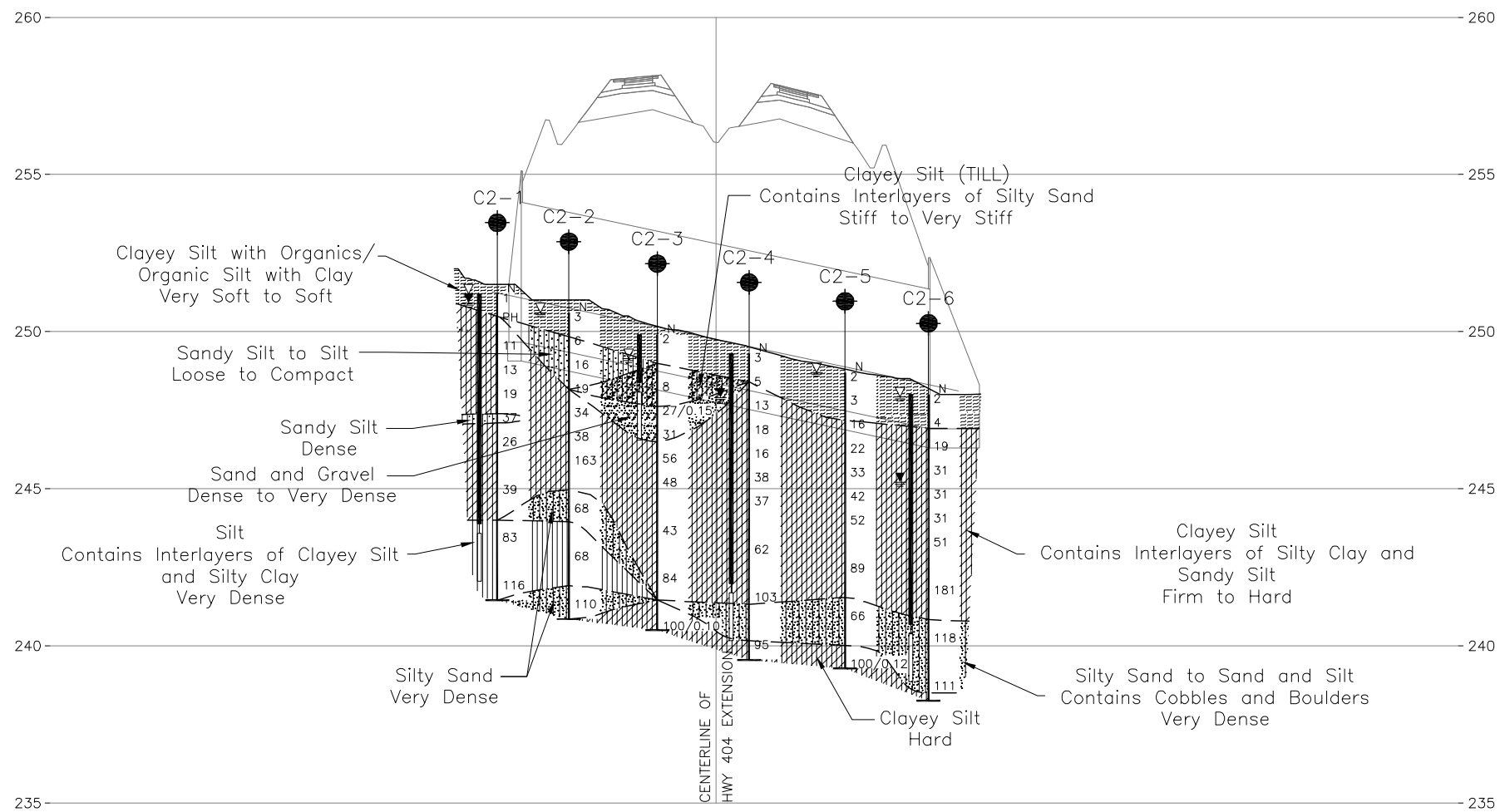
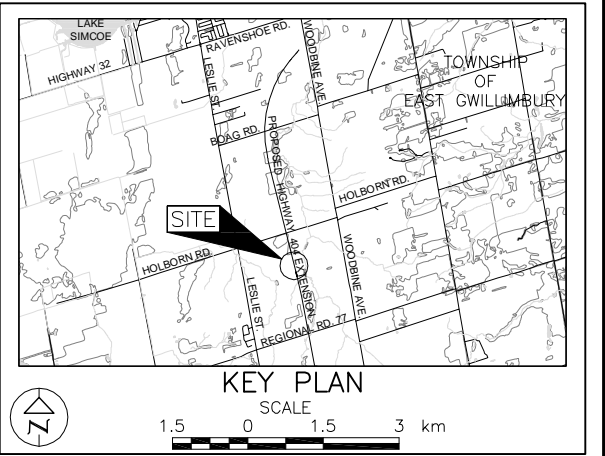
METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 2005-07-00

HIGHWAY 404 EXTENSION
MASKINONGE RIVER TRIBUTARY CULVERT
BOREHOLE LOCATION AND SOIL STRATA

SHEET

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PROFILE A-A' ALONG MASKINONGE RIVER TRIBUTARY CULVERT ALIGNMENT

LEGEND

- Borehole - Current Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL in piezometer, measured on June 12, 2009
- WL upon completion of drilling

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
C2-1	251.2	4890050.4	309545.5
C2-2	250.6	4890064.2	309564.0
C2-3	249.9	4890085.8	309582.1
C2-4	249.3	4890107.6	309601.6
C2-5	248.7	4890128.7	309623.7
C2-6	248.0	4890149.3	309640.6

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

The boundaries between soil strata have been established only at borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

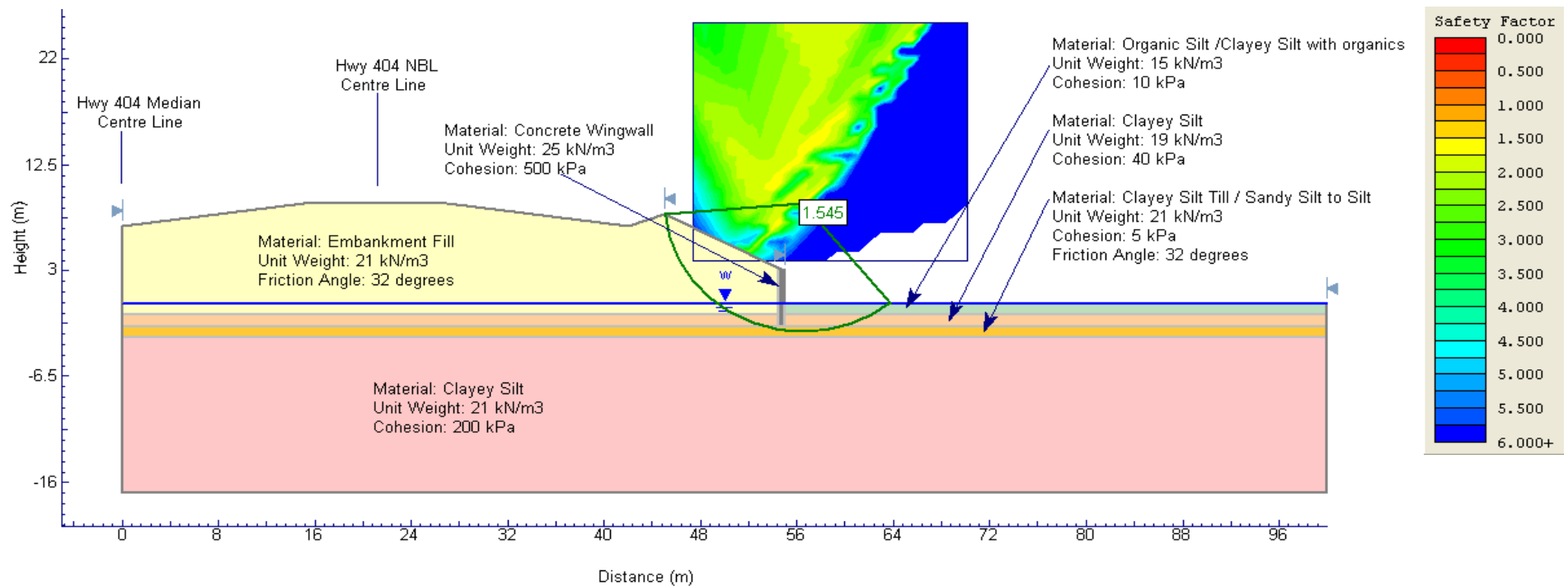
REFERENCE

Base plans provided in digital format by AECOM, drawing files "76808.dwg" and "76809.dwg", received, November, 16, 2009 and drawing file "2538-199-00_00-ST-1001-To Golder-091126.dwg", received November 26, 2009.

NO.	DATE	BY	REVISION
Geocres No. 31D-495			
HWY. 404		PROJECT NO. 08-1111-0022	
SUBM'D.		CHKD. TB	DATE: Mar. 2010
DRAWN: JFC/RJ		CHKD. KJB	APPD.
		DIST.	
		SITE:	
		DWG. 1	

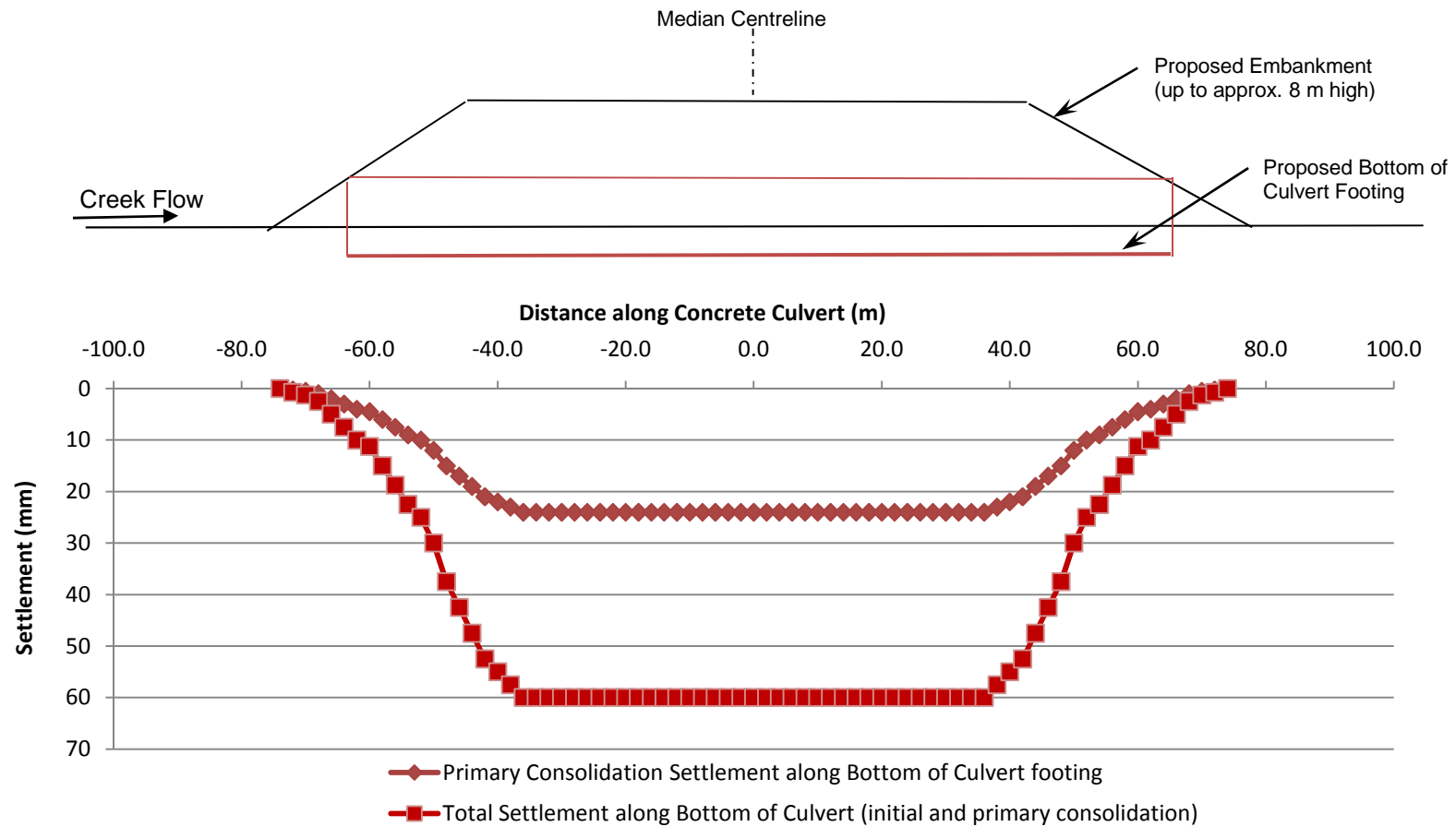
Static Global Stability Analysis Results
Maskinonge River Tributary Culvert and Wingwall - Station 34+065
2H : 1V Cut Slope

FIGURE 1



ESTIMATED SETTLEMENT PROFILE MASKINONGE RIVER TRIBUTARY CULVERT

FIGURE 2



NOT TO SCALE

Date: Dec-09
Project: 08-1111-0022D

Golder Associates

Drawn: KJB
Checked: JMAC



APPENDIX A

Record of Boreholes



LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
$\ln x$,	natural logarithm of x
\log_{10}	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
F	factor of safety
V	volume
W	weight

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ϵ	linear strain
ϵ_v	volumetric strain
η	coefficient of viscosity
ν	poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - \mu$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
μ	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight*)
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

(a) Index Properties (continued)

w	water content
w_l	liquid limit
w_p	plastic limit
I_p	plasticity index $= (w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index $= (w - w_p) / I_p$
I_C	consistency index $= (w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index $= (e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_a	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation pressure
OCR	over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$

(d) Shear Strength

T_p, T_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction $= \tan \delta$
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 + \sigma_3)/2$ or $(\sigma'_1 + \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 + \sigma_3)$
S_t	sensitivity

* Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1 $\tau = c' + \sigma' \tan \phi'$
2 shear strength = (compressive strength)/2



LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
SS	Split-spoon
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH:	Sampler advanced by hydraulic pressure
PM:	Sampler advanced by manual pressure
WH:	Sampler advanced by static weight of hammer
WR:	Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils Consistency


	C_u , S_u	psf
	kPa	
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

PROJECT 08-1111-0022		RECORD OF BOREHOLE No C2-1				1 OF 1 METRIC						
G.W.P. 2005-07-00		LOCATION N 4890050.4 ; E 309545.5				ORIGINATED BY TB						
DIST _____ HWY 404		BOREHOLE TYPE 108 mm O.D. Solid Stem Auger				COMPILED BY JFC						
DATUM Geodetic		DATE June 5, 2009				CHECKED BY KJB						
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa				W _p W W _L
251.2	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	10 20 30		
0.0	CLAYEY SILT with organics, trace to some sand, containing rootlets, oxidation staining and layers of silty clay		1	SS	1		251					
250.5	Very soft Dark brown Moist		2	TO	PH		250					
0.7	CLAYEY SILT, trace to some sand, containing oxidation staining and interlayers of silty clay and sandy silt		3	SS	11		249					
	Firm to very stiff Brown to grey Moist		4	SS	13		248					
			5	SS	19		247					
247.4	Sandy SILT, trace clay		6	SS	37		246					
247.1	Dense Grey Wet		7	SS	26		245					
4.1	CLAYEY SILT, trace sand, containing interlayers of silty clay		8	SS	39		244					
	Very stiff to hard Grey Moist		9	SS	83		243					
			10	SS	116		242					
244.0	SILT, trace sand, containing interlayers of clayey silt and silty clay											
7.2	Very dense Grey Moist											
241.5	END OF BOREHOLE											
9.8	NOTES: 1. Water level in open borehole at ground surface upon completion of drilling. 2. Water level in piezometer at a depth of 0.3 m below ground surface (Elev. 250.9 m) on June 12, 2009. 3. Laboratory Consolidation Test performed on clayey soil taken from Sample No. 2. 4. Water level in piezometer at a depth of 0.3 m (Elev. 250.9 m) below ground surface on June 12, 2009.											


PROJECT		08-1111-0022		RECORD OF BOREHOLE No C2-2				1 OF 1 METRIC						
G.W.P.		2005-07-00		LOCATION		N 4890064.2 ; E 309564.0		ORIGINATED BY TB						
DIST		HWY 404		BOREHOLE TYPE		108 mm O.D. Solid Stem Auger		COMPILED BY JFC						
DATUM		Geodetic		DATE		June 3, 2009		CHECKED BY KJB						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _p	W	W _L		
250.6	GROUND SURFACE													
0.0	CLAYEY SILT with organics, some sand, containing rootlets and oxidation staining		1	SS	3									
249.8	Soft Dark brown Moist		2	SS	6									
0.8	Sandy SILT to SILT, some sand, trace to some clay, trace gravel Loose to compact Brown to grey Wet		3	SS	16									
248.2	CLAYEY SILT, trace to some sand Very stiff to hard Grey Moist		4	SS	19									
2.4			5	SS	34									
			6	SS	38									
			7	SS	163									
245.0	Silty SAND, trace clay Very dense Grey Wet		8	SS	68									
244.0	SILT, trace clay Very dense Grey Wet		9	SS	68									
241.9	Silty SAND, trace clay Very dense Grey Wet		10	SS	110									
240.9	END OF BOREHOLE													
9.8	NOTES: 1. Water level at ground surface upon completion of drilling.													

MIS-MTO 001 08-1111-0022.GPJ GAL-MISS.GDT 10/3/10 DD/SAC

MIS-MTO 001 08-1111-0022.GPJ GAL-MISS.GDT 10/3/10 DD/SAC

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

PROJECT 08-1111-0022				RECORD OF BOREHOLE No C2-4				1 OF 1 METRIC											
G.W.P. 2005-07-00				LOCATION N 4890107.6 ; E 309601.6				ORIGINATED BY TB											
DIST _____ HWY 404				BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger				COMPILED BY JFC											
DATUM Geodetic				DATE June 4, 2009				CHECKED BY KJB											
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)	
								20	40	60	80	100						20	40
249.3	GROUND SURFACE																		
0.0	CLAYEY SILT with organics, trace to some sand, containing rootlets and oxidation staining Soft to firm Dark brown Moist		1	SS	3														
248.4			2	SS	5														
0.9	CLAYEY SILT, trace to some sand, containing interlayers of silty clay below 1.5 m, containing oxidation staining to 6.1 m Firm to hard Brown Moist		3	SS	13														
			4	SS	18														
			5	SS	16														
			6	SS	38														
			7	SS	37														
			8	SS	62														
			9	SS	103														
241.3	Silty SAND, trace gravel, trace clay, containing cobbles and boulders Very dense Grey Wet																		
240.2	CLAYEY SILT, trace sand Hard Grey Moist		10	SS	95														
239.6	END OF BOREHOLE																		
9.8	NOTES: 1. Water level in open borehole at a depth of 3.9 m below ground surface (Elev. 245.4 m) upon completion of drilling. 2. Water level in piezometer at a depth of 1.4 m below ground surface (Elev. 247.9 m) on June 12, 2009.																		

PROJECT 08-1111-0022		RECORD OF BOREHOLE No C2-5				1 OF 1 METRIC											
G.W.P. 2005-07-00		LOCATION N 4890128.7 ; E 309623.7				ORIGINATED BY TB											
DIST _____ HWY 404		BOREHOLE TYPE 108 mm O.D. Solid Stem Auger				COMPILED BY JFC											
DATUM Geodetic		DATE June 3, 2009				CHECKED BY KJB											
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)
248.7	GROUND SURFACE																
0.0	Organic SILT with clay, trace to some sand, containing rootlets and oxidation staining Very soft to soft Dark brown to brown Moist		1	SS	2												
			2	SS	3												
247.2																	
1.5	CLAYEY SILT, trace to some sand, containing interlayers of silty clay, containing oxidation staining to a depth of 3.1 m Very stiff to hard Brown Moist Becoming grey at a depth of 2.7 m		3	SS	16												
			4	SS	22												
			5	SS	33												
			6	SS	42												
			7	SS	52												
			8	SS	89												
241.5																	
7.2	SAND and SILT, trace clay Very dense Grey Wet		9	SS	66												
240.0																	
8.7	CLAYEY SILT, trace sand Hard Grey Moist																
239.3			10	SS	100/0.12												
9.4	END OF BOREHOLE																
NOTES: 1. Water level at ground surface upon completion of drilling.																	

MIS-MTO 001 08-1111-0022.GPJ GAL-MISS.GDT 10/3/10 DD/SAC

PROJECT 08-1111-0022			RECORD OF BOREHOLE No C2-6			1 OF 1 METRIC															
G.W.P. 2005-07-00			LOCATION N 4890149.3 ; E 309640.6			ORIGINATED BY TB															
DIST _____ HWY 404			BOREHOLE TYPE 108 mm O.D. Solid Stem Auger			COMPILED BY JFC															
DATUM Geodetic			DATE June 7, 2009			CHECKED BY KJB															
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ					
								20 40 60 80 100	20 40 60 80 100	W _p	W	W _L	10 20 30								
248.0	GROUND SURFACE																				
0.0	Organic SILT with clay, some sand, containing rootlets, oxidation staining and sand interlayers Very soft to soft Dark brown Moist to wet		1	SS	2																
246.9			2A	SS	4		247														
1.1	CLAYEY SILT, trace to some sand, trace gravel, containing interlayers of silty clay and oxidation staining to a depth of 4.6 m Firm to hard Brown to grey Moist		2B																		
			3	SS	19		246														
			4	SS	31		245														
			5	SS	31		244														
			6	SS	31		243														
			7	SS	51		242														
							241														
240.8			8	SS	181		240														
7.2	Silty SAND, trace clay Very dense Grey Wet		9	SS	118		239														
238.5			10A	SS	111																
9.8	CLAYEY SILT, trace to some sand Hard Grey Moist END OF BOREHOLE		10B																		
	NOTES: 1. Water level in open borehole at a depth of 0.1 m below ground surface (Elev. 247.9 m) upon completion of drilling. 2. Water level in piezometer at a depth of 2.8 m below ground surface (Elev. 245.2 m) on June 12, 2009.																				

MIS-MTO 001 08-1111-0022.GPJ GAL-MISS.GDT 10/3/10 DD/SAC



APPENDIX B

Laboratory Test Results

Silt

The graph displays the grain size distribution for two different samples. The x-axis represents grain size in millimeters on a logarithmic scale, ranging from 0.0001 to 100 mm. The y-axis represents the percentage of material finer than a given grain size, ranging from 0 to 100 percent. The top of the graph also includes scales for U.S.S. Sieve size (meshes/inch) and Size of openings in inches.

Two data series are plotted:

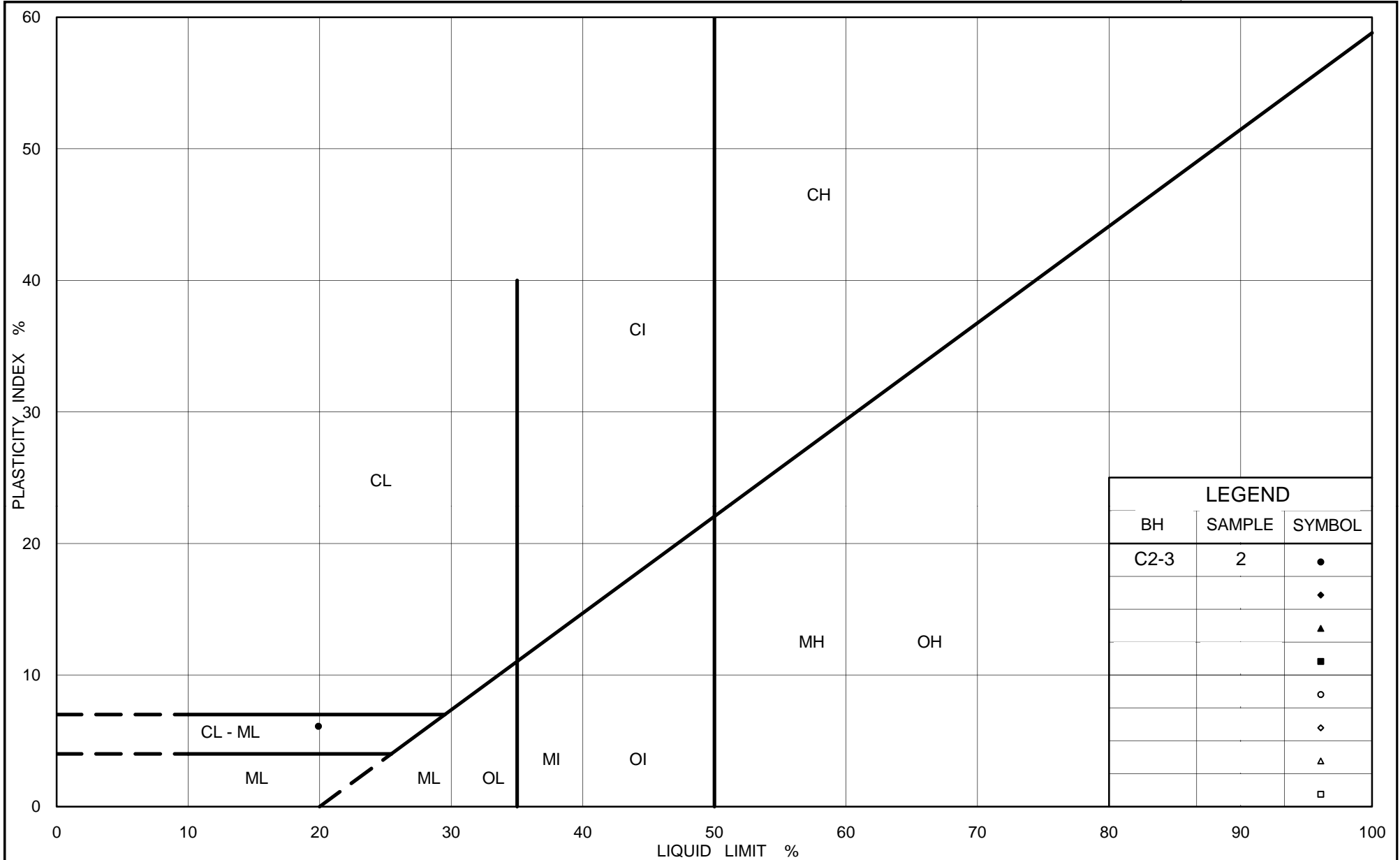
- Series 1 (Square Markers):** This curve starts at approximately 5% finer for 0.00075 mm, rises to about 40% finer at 0.006 mm, and reaches 100% finer at approximately 0.075 mm. It remains at 100% finer for all larger grain sizes.
- Series 2 (Circular Markers):** This curve starts at approximately 5% finer for 0.00075 mm, rises to about 20% finer at 0.006 mm, and reaches 100% finer at approximately 0.075 mm. It remains at 100% finer for all larger grain sizes.

Both samples exhibit a similar distribution pattern, with the square-marked sample being slightly finer than the circular-marked sample in the intermediate grain size range.

SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C2-2	3	248.8
■	C2-2	9	242.7

Date: 04-Dec-09



Ministry of Transportation

Ontario

PLASTICITY CHART

Clayey Silt Till

Figure No. B2

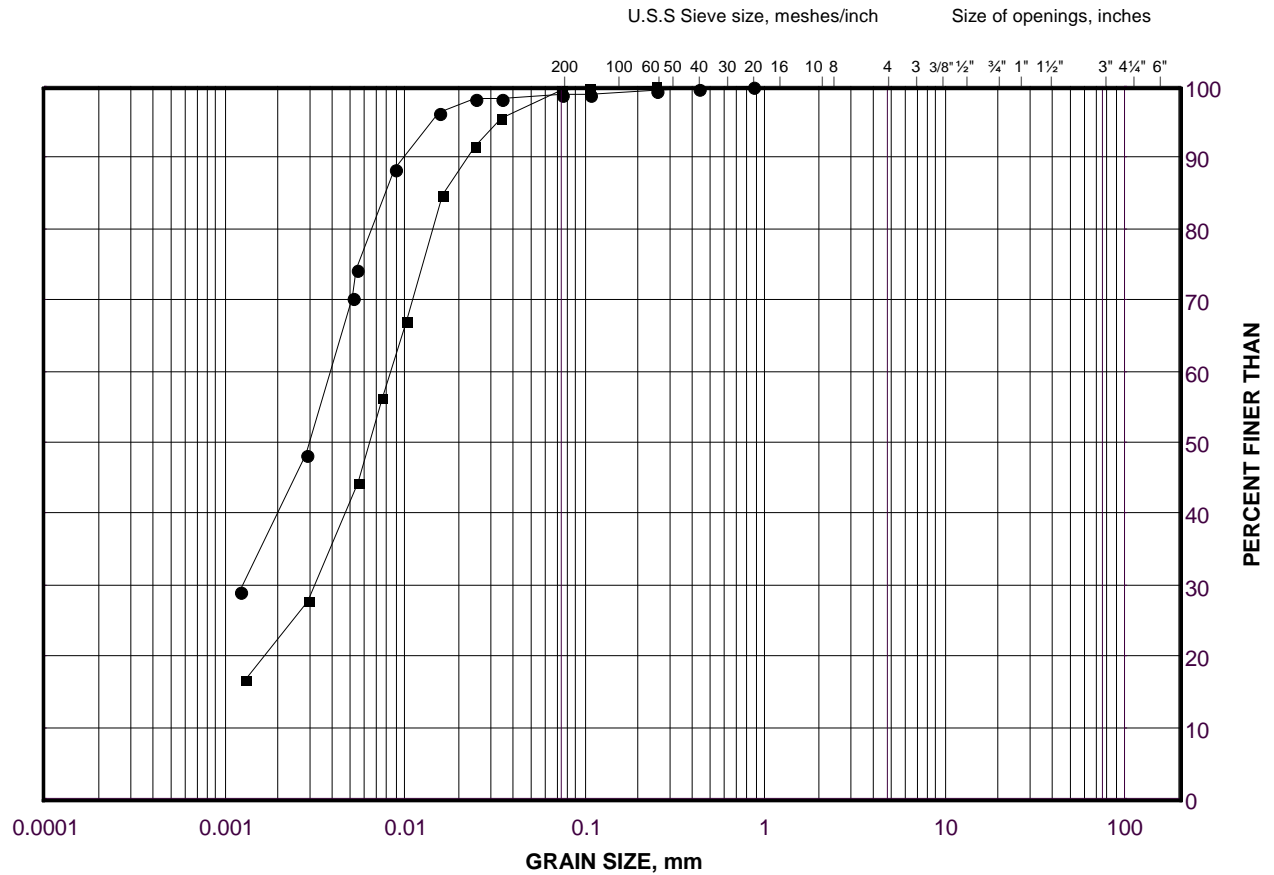
Project No. 08-1111-0022D

Checked By: KJB

GRAIN SIZE DISTRIBUTION

Clayey Silt

FIGURE B3



LEGEND

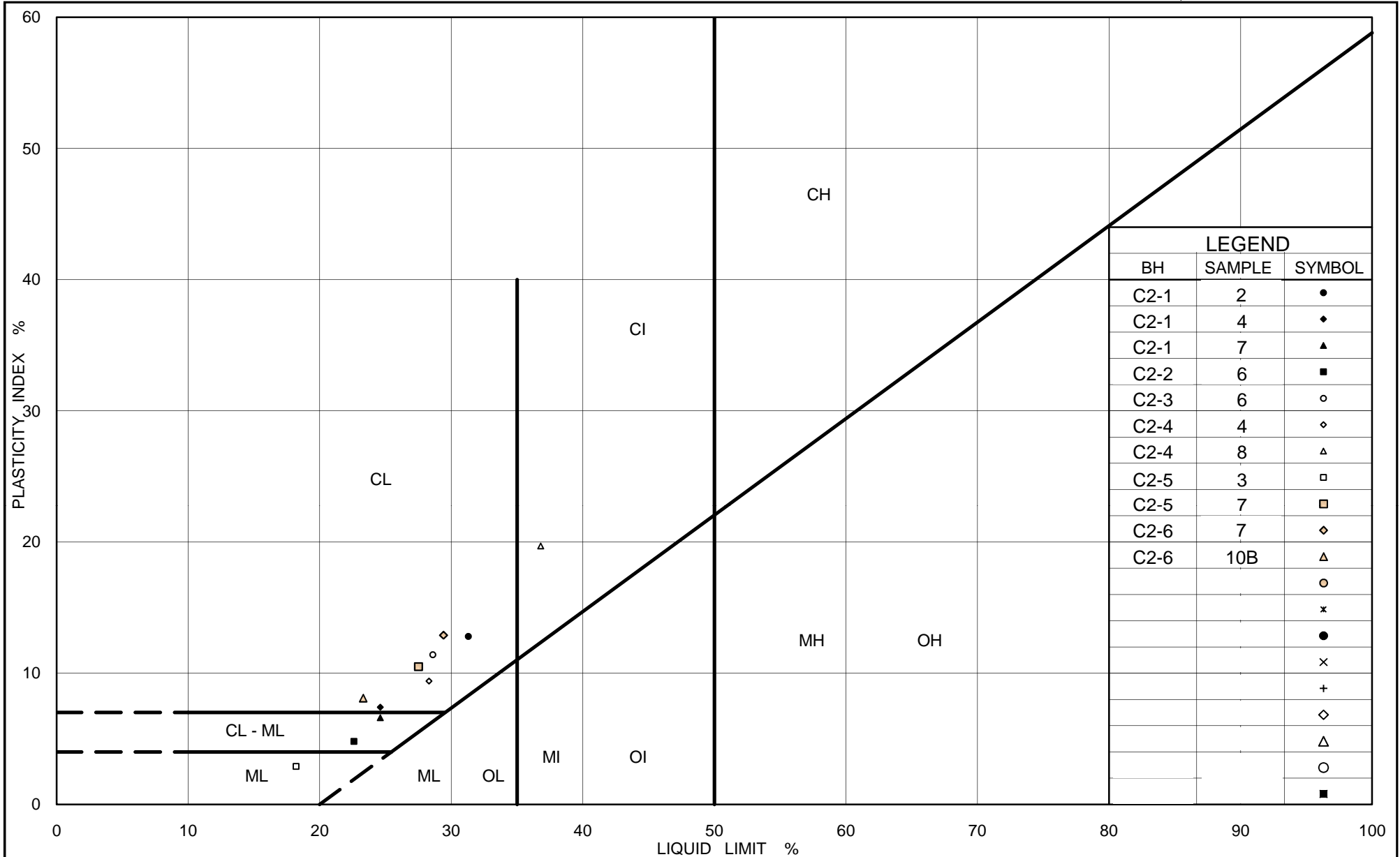
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C2-5	7	243.8
■	C2-1	7	246.3

Project Number: 08-1111-0022D

Checked By: KJB

Golder Associates

Date: 04-Dec-09



Ministry of
Transportation
Ontario

PLASTICITY CHART

Clayey Silt (Contains Silty Clay Inter-Layers)

Figure No. B4

Project No. 08-1111-0022D

Checked By: KJB

OEDOMETER CONSOLIDATION SUMMARY

FIGURE B5-A

SAMPLE IDENTIFICATION

Project Number	08-1111-0022D	Sample Number	2
Borehole Number	C2-1	Sample Depth, m	0.9-1.1

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	8		
Date Started	06/24/2009		
Date Completed	07/07/2009		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.90	Unit Weight, kN/m ³	18.20
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m ³	13.64
Area, cm ²	31.57	Specific Gravity, measured	2.74
Volume, cm ³	59.92	Solids Height, cm	0.964
Water Content, %	33.42	Volume of Solids, cm ³	30.43
Wet Mass, g	111.23	Volume of Voids, cm ³	29.49
Dry Mass, g	83.37	Degree of Saturation, %	94.5

TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t ₉₀ sec	cv. cm ² /s	mv m ² /kN	k cm/s
0.00	1.898	0.969	1.898				
4.84	1.896	0.967	1.897	18	4.24E-02	2.18E-04	9.04E-07
9.48	1.896	0.967	1.896	14	5.44E-02	5.68E-05	3.03E-07
19.55	1.887	0.958	1.891	34	2.23E-02	4.39E-04	9.61E-07
39.01	1.876	0.946	1.881	8	9.38E-02	3.09E-04	2.84E-06
77.76	1.864	0.934	1.870	6	1.24E-01	1.54E-04	1.86E-06
155.17	1.843	0.912	1.854	8	9.11E-02	1.45E-04	1.29E-06
310.31	1.791	0.858	1.817	6	1.17E-01	1.79E-04	2.04E-06
620.29	1.706	0.770	1.748	8	8.10E-02	1.44E-04	1.14E-06
1241.53	1.620	0.681	1.663	9	6.51E-02	7.29E-05	4.66E-07
2482.64	1.536	0.593	1.578	26	2.03E-02	3.57E-05	7.09E-08
1241.53	1.544	0.602	1.540				
310.31	1.562	0.621	1.553				
77.76	1.588	0.648	1.575				
19.55	1.616	0.677	1.602				
4.84	1.630	0.691	1.623				

Note:

k calculated using cv based on t₉₀ values.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	1.63	Unit Weight, kN/m ³	20.20
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m ³	15.89
Area, cm ²	31.57	Specific Gravity, measured	2.74
Volume, cm ³	51.44	Solids Height, cm	0.964
Water Content, %	27.10	Volume of Solids, cm ³	30.43
Wet Mass, g	105.96	Volume of Voids, cm ³	21.02
Dry Mass, g	83.37		

Prepared By: LH

Golder Associates

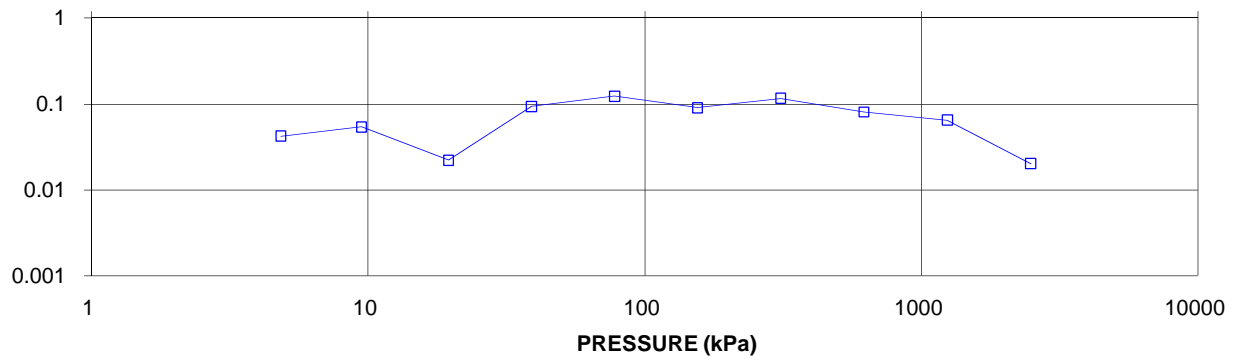
Checked By: MM

PLOTS OF CONSOLIDATION TEST RESULTS

FIGURE B5-B

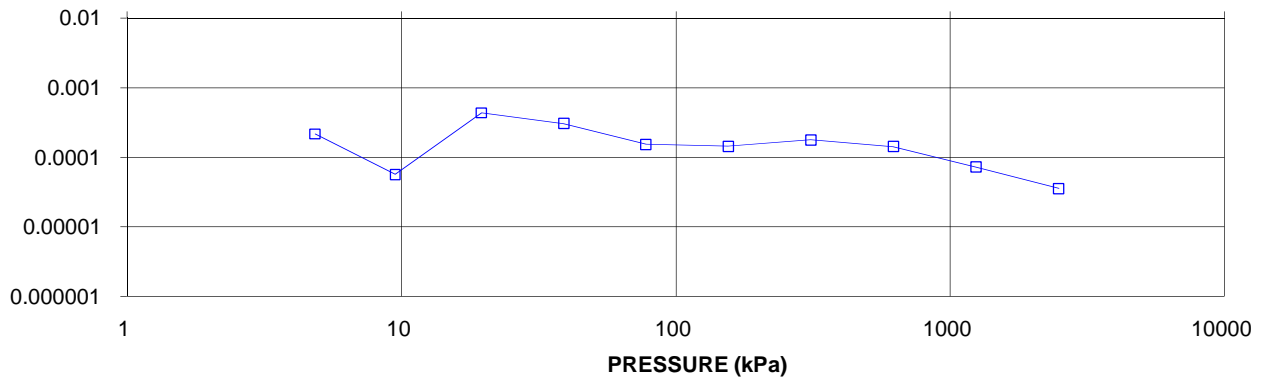
COEFFICIENT OF CONSOLIDATION,
cm²/s

CONSOLIDATION TEST
CV cm²/s VS PRESSURE (kPa)
BH C2-1 SA 2



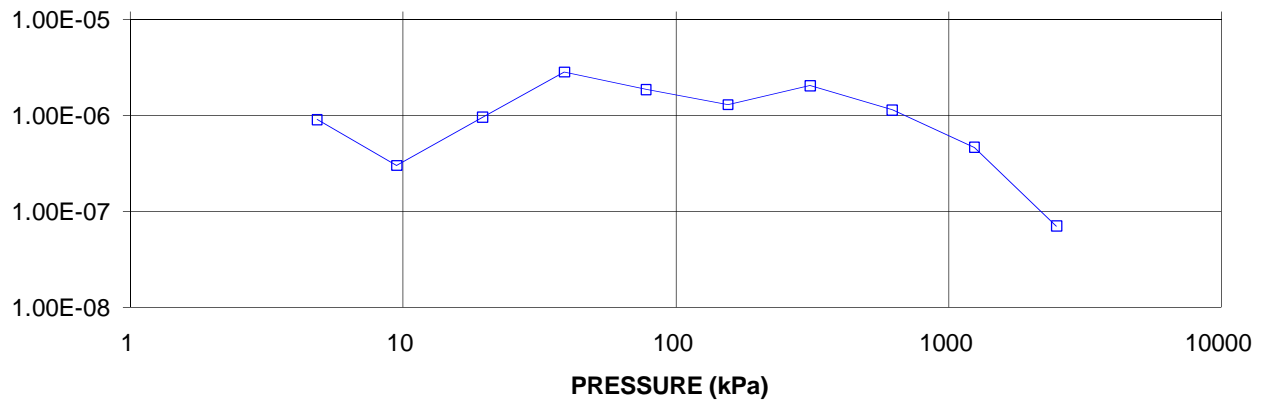
VOLUME COMPRESSIBILITY, m²/kN

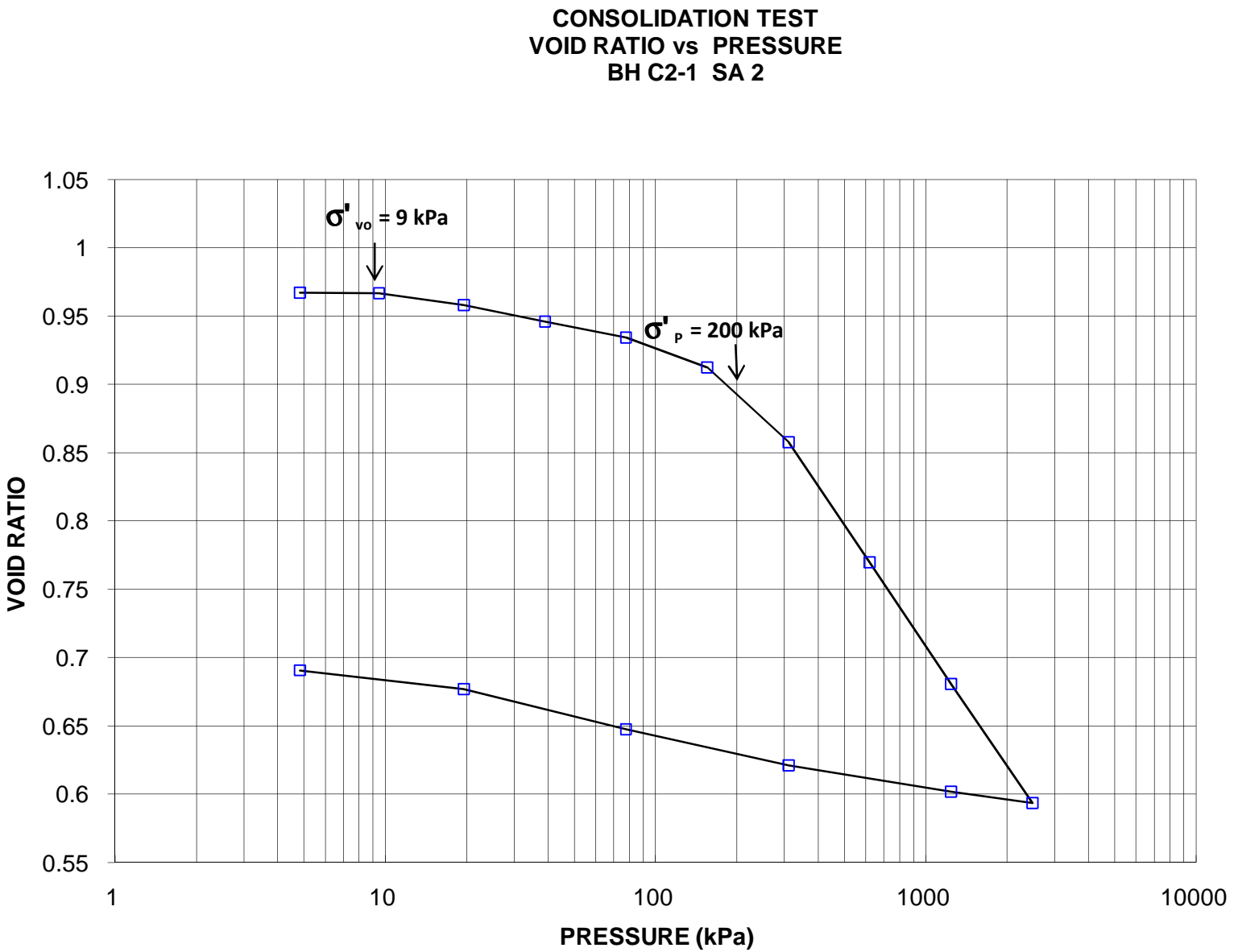
CONSOLIDATION TEST
MV m²/kN vs PRESSURE (kPa)
BH C2-1 SA 2

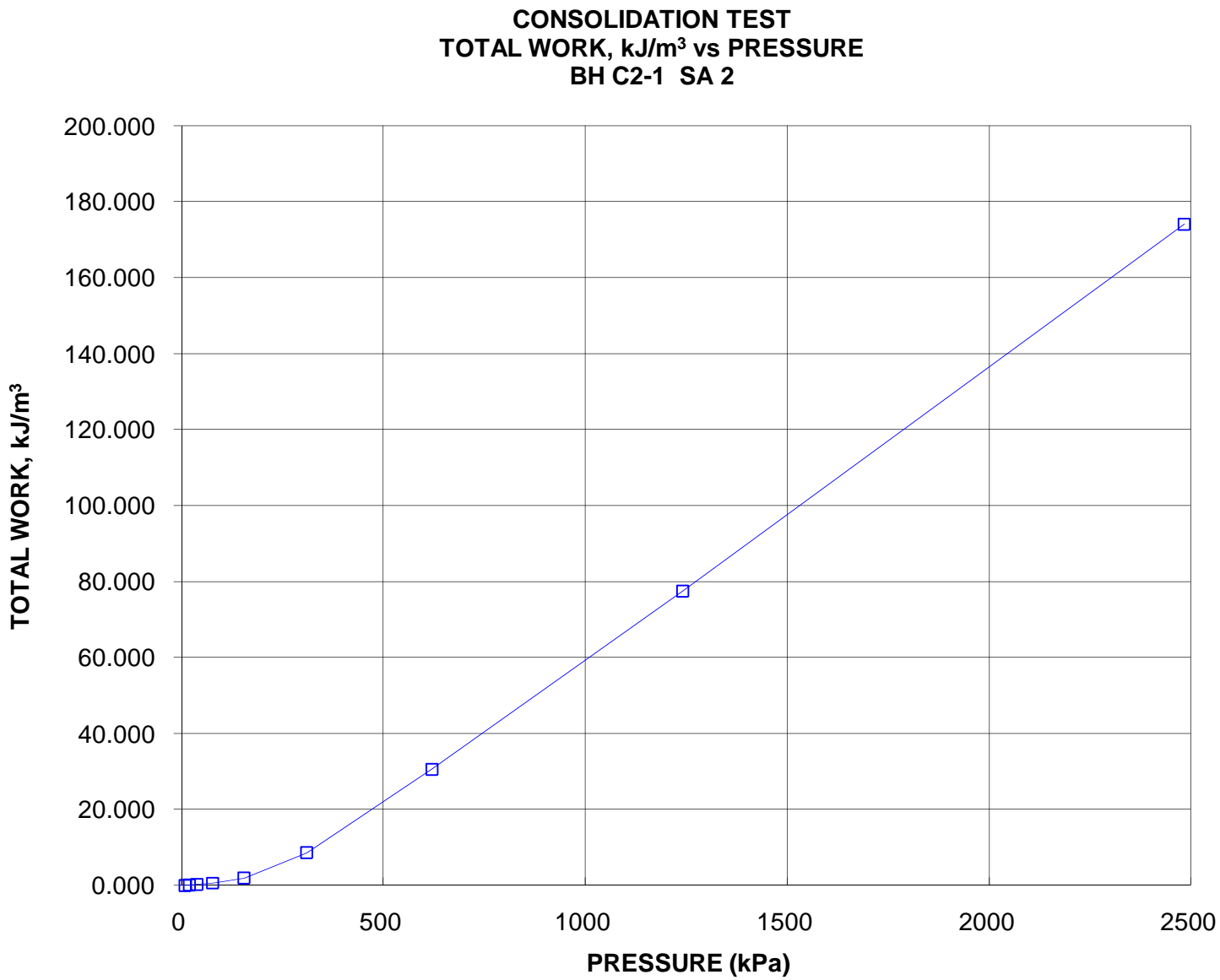


HYDRAULIC CONDUCTIVITY,
cm/s

CONSOLIDATION TEST
HYDRAULIC CONDUCTIVITY vs PRESSURE
BH C2-1 SA 2



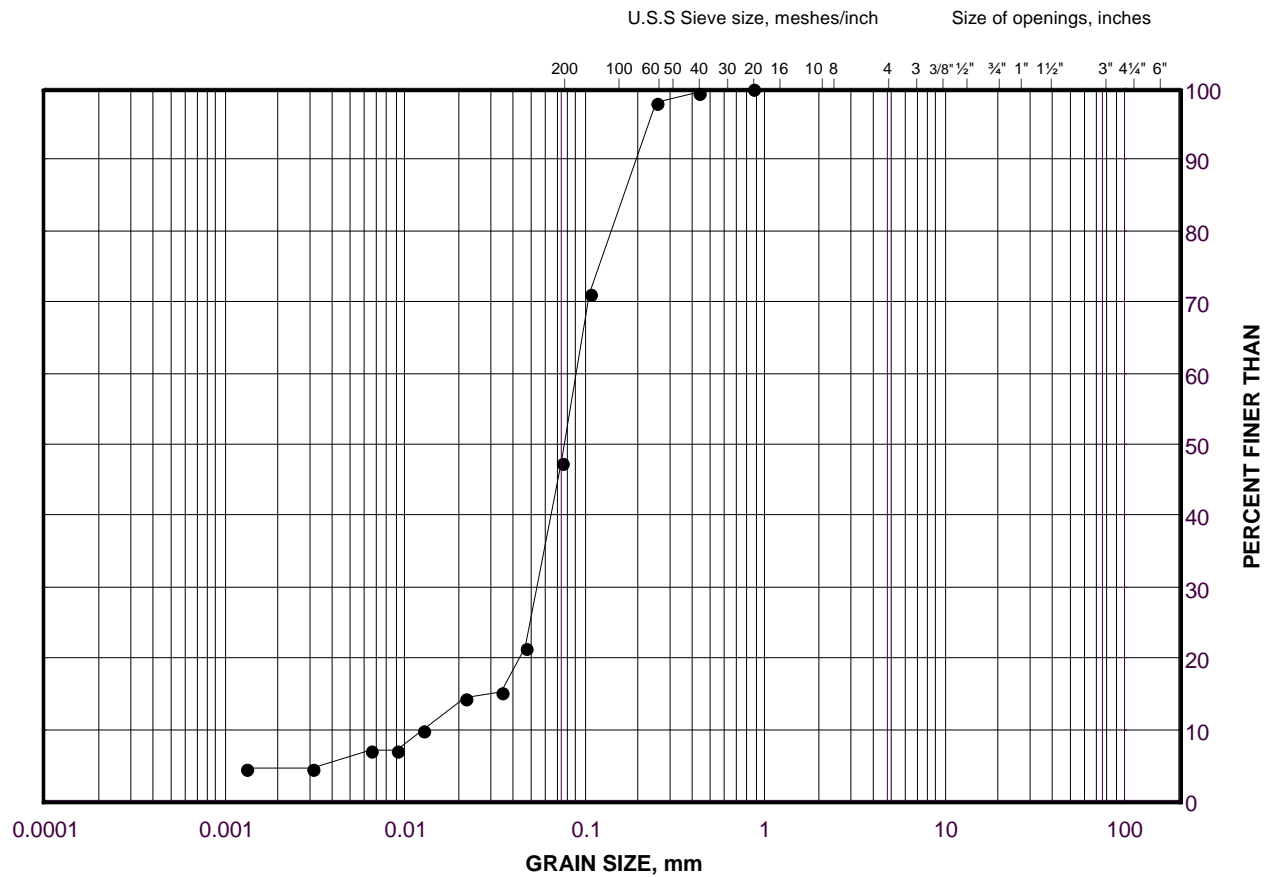




GRAIN SIZE DISTRIBUTION

Sand and Silt

FIGURE B6



SILT AND CLAY SIZES			FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED			SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	C2-5	9	240.8

Project Number: 08-1111-0022D

Checked By: KJB

Golder Associates

Date: 15-Dec-09



APPENDIX C

Non-Standard Special Provisions

Non-Standard Special Provision

SCOPE

This Special Provision covers the requirements for the supply and placement of a concrete working slab under the structure foundations. The purpose of the working slab is to protect the subgrade from disturbance and loosening due to construction traffic and ponded water and also to provide a level working surface.

CONSTRUCTION

Protection of Founding Soil:

- Following inspection and approval of the prepared subgrade, a working slab with a minimum thickness of 100 mm shall be placed on the foundation subgrade as per the contract drawings and documents. The concrete shall have a minimum 28 day compressive strength of 20 MPa.

Protection of Founding Bedrock:

- The surface of the footing founding rock shall be exposed, cleaned and any loose or fractured parts removed so that sound rock is exposed.
- The working slab shall have a minimum 28 day strength of 20 MPa.
- The working slab shall be placed on the exposed cleaned sound founding rock surface as per the contract drawings and documents.
- Thickness of the working slab shall depend on the slope and irregularities in the exposed founding rock surface. A nominal thickness and a footprint plan view area has been specified on the contract drawings and documents.

Unwatering of the excavation for the footing construction, including the construction of the working slab, may be required and is covered under a separate Tender Item. The dewatering scheme shall be done in such a manner as to prevent any disturbance to the surrounding original soil.

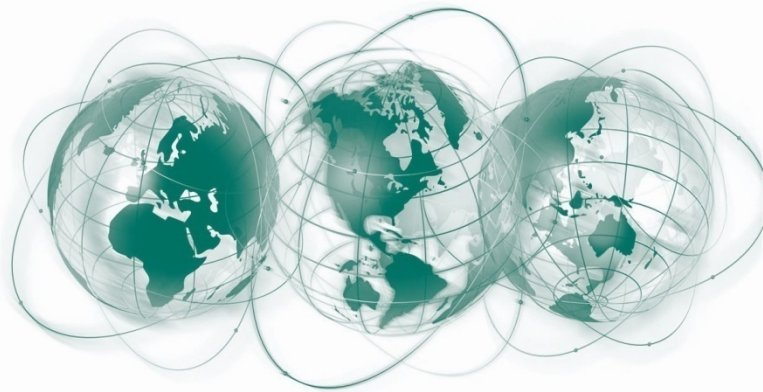
BASIS OF PAYMENT

Payment at the contract price for this Tender Item shall include full compensation for all labour, equipment and material required to do the work.

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

Africa	+ 27 11 254 4800
Asia	+ 852 2562 3658
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

solutions@golder.com
www.golder.com



Golder Associates Ltd.
2390 Argentia Road
Mississauga, Ontario, L5N 5Z7
Canada
T: +1 (905) 567 4444

