THURBER ENGINEERING LTD.

FOUNDATION INVESTIGATION AND DESIGN REPORT
REPLACEMENT OF STRUCTURAL CULVERT No 30-545/C
HIGHWAY 89, 375 m WEST OF COUNTY ROAD 50
NEW TECUMSETH, ONTARIO
G.W.P. 2183-13-00

GEOCRES Number: 31D-593

SUBMITTED TO
MCINTOSH PERRY CONSULTING ENGINEERS LTD.

August 7, 2015
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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) at Structural Culvert 30-545/C located on Highway 89 approximately 3.5 km west of the town of New Tecumseth (Alliston), Ontario. Thurber carried out the investigation as a sub-consultant to McIntosh Perry Consulting Engineers Ltd (MPCE) on behalf of the Ministry of Transportation Ontario (MTO) under Agreement No. 2013-E-0053.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on this data, to provide a borehole location plan, record of boreholes, a stratigraphic profile, laboratory test results and a written description of the subsurface conditions.

2 SITE DESCRIPTION

The culvert is located on Highway 89, approximately 375 m west of County Road 50, near New Tecumseth, Ontario. It is noted that for project orientation purposes, Highway 89 within the project limits, will be assumed to run east-west. The location of Culvert 30-545/C is shown on the inset Key Plan on Drawing No. 1 in Appendix A.

Within the project limits Highway 89 is a two-lane, undivided highway with a rural cross-section with 3.75 m wide lanes and 3 m wide shoulders. Steel beam guide rail is present on both sides of the highway. The maximum height of the road embankment is approximately 3 m in the area of the culvert and the existing side slopes are graded at approximately 3H:1V. No evidence of slope instability or settlement concerns were noted during the site inspection.

The existing culvert has been identified by MTO as having been constructed in 1980. It has an open footing (rigid frame) design and a length of approximately 21 m. The culvert was rehabilitated under Contract 2008-2331. The General Arrangement Drawing from that contract indicates that it was founded on spread footings 1.1 m wide at approximate elevation 242.3 m. The culvert invert is at approximately 243.2 m. The inside dimensions of the culvert were noted as 3.66 m wide and 0.8 m vertically from top of stream bed to soffit. The culvert is covered with approximately 0.7 m of fill. Flow through the culvert is from north to south.

The lands surrounding the roadway are typically agricultural with some residential and agricultural buildings. Storm water in the area drains through ditches and culverts. Typical site photographs are presented in Appendix D.

The site is located within the Physiographic Region known as the Peterborough Drumlin Field. The drumlins throughout this region are composed of highly calcareous till underlain by limestone bedrock of the Lindsay and Verulam Formations. The terrain in the vicinity of the culvert is generally flat and is brush, and grass covered.

3 BACKGROUND – PREVIOUS INVESTIGATION

A Foundation Investigation was carried out for a possible rehabilitation of Culvert 30-545/C between 2007 and 2009 by Golder Associates (Golder). The factual results of that foundation investigation (GEOCRES Report No. 31D-451, dated January 2009) are provided in Appendix E for reference.

The investigation consisted of four sampled boreholes; two within the gravel shoulders and one at each of the inlet and outlet of the culvert. A single piezometer was installed at the site to measure groundwater levels.

For reference, the Golder report indicates the stratigraphy in the area of the culvert is generally characterized by a granular fill, over a clayey silt fill, over a clayey silt till. Bedrock was not cored during the 2007 investigation.

The results of the Golder investigation were reviewed and considered when planning the current investigation.

4 SITE INVESTIGATION AND FIELD TESTING

Prior to carrying out the drilling investigation, a site visit was conducted by Thurber personnel and the locations of the proposed boreholes were laid out on site.

As a component of our standard procedures and due diligence, Thurber contacted Ontario One Call to clear the borehole locations of underground utilities.

The field investigation for this was carried out on October 8th and 9th, 2014, and included drilling two boreholes. The approximate locations of the boreholes are shown on the Borehole Location and Soil Strata drawing in Appendix A and summarized in the Table 4-1.

Table 4-1: Borehole Summary

Borehole	Location	Ground Surface Elevation (m)	Depth (m)
14-4	North (inlet) end of culvert	243.7	2.9
14-5	Edge of pavement eastbound lane	245.3	5.3

The inlet borehole was advanced using portable drilling equipment. A CME 55 truck mounted drill equipped with hollow stem augers was used for the edge of pavement borehole. The subsurface stratigraphy encountered in the boreholes was recorded in the field by Thurber personnel. Split spoon samples were collected at regular depth intervals in the boreholes while conducting Standard Penetration Tests (SPTs), following the methods described in ASTM Standard D1586-

11. All soil samples recovered from the boreholes were placed in moisture-proof, labelled containers, and the samples returned to Thurber's Ottawa geotechnical laboratory for further examination and testing.

Groundwater levels were measured on completion of drilling in the open boreholes prior to backfilling.

The as-drilled locations of the boreholes and ground surface elevations at the borehole locations were surveyed by Thurber on October 9, 2014. The geodetic ground surface elevation at the existing benchmark located in the northwest corner of the culvert inlet of 244.27 m, as indicated on the plans provided by MTO was used as a local benchmark.

5 LABORATORY TESTING

Geotechnical laboratory testing was carried out in the Thurber geotechnical laboratory in Ottawa, Ontario, and consisted of natural moisture content determination and visual identification of all soil samples in accordance with the current MTO standards. Grain size distribution analysis and Atterberg limit testing were carried out on selected samples to MTO and ASTM standards.

The laboratory test results are presented on the Record of Borehole sheets in Appendix B and the Figures in Appendix C.

6 DESCRIPTION OF SUBSURFACE CONDITIONS

6.1 Overview / General

Reference is made to the Record of Borehole sheets in Appendix B for details of the soil stratigraphy encountered in the boreholes. A stratigraphic profile for the culvert replacement alignment is presented on the Borehole Locations and Soil Strata Drawing in Appendix A for illustrative purposes. An overall description of the stratigraphy is given in the following paragraphs; however, the factual data presented in the Record of Boreholes governs any interpretation of the site conditions.

For reference, the stratigraphy in the area of the culvert structure is generally characterized by fill material (pavement structure, culvert backfill, embankment fill), over a compact to very dense silt / clay till.

6.2 Fill: Silty Sand with Gravel

A fill layer consisting predominantly of silty sand with gravel was encountered at the ground surface of Borehole 14-5 (elevation 245.3 m), and had a thickness of 0.8 m.

The moisture content of a sample tested was 3%. The results of grain size analysis conducted on one sample of the granular fill material are presented on Fig. No C1 in Appendix C. The results are summarized in Table 6-1.

Table 6-1: Gradation Results for Silty Sand with Gravel Fill

Soil Particles	%
Gravel	28
Sand	50
Silt and Clay	22

6.3 Fill: Gravelly Sand-Silt Mixture some Clay

A fill layer consisting predominantly of a sand silt mixture was encountered beneath the surface granular fill layer in Borehole 14-5. The top of this layer was at elevation 244.5 m. The layer had a thickness of 1.5 m. This fill layer was of variable gradation and included sandy and clayey zones. The standard penetration test (SPT) 'N' values for this layer range from 6 to 9 blows per 0.3 m of penetration indicating a loose relative density.

The moisture content of the samples tested ranged from 11% to 13%. The results of grain size analysis conducted on one sample of the granular fill material are presented on Fig. No C1 in Appendix C. The results are summarized in the Table 6-2.

Table 6-2: Gradation Results for Gravelly Sand-Silt Fill

Soil Particles	%
Gravel	25
Sand	43
Silt	21
Clay	11

Atterberg Limit testing was completed on one sample. The test results are illustrated on Fig. No C3 in Appendix C and are summarized in Table 6-3. The results indicate a clayey zone of low plasticity.

Table 6-3: Atterberg Limits Test Results

Borehole	Sample	LL	PL	PI	Classification
14-5	SS-3	24	12	12	CL

6.4 Fill: Silty Clay some Sand

A fill layer consisting predominantly of silt and clay was encountered at the ground surface in Borehole 14-4 and beneath the gravelly sand-silt fill in Borehole 14-5. The top of this layer ranged in elevation from 243.0 m to 243.7 m. The layer had a thickness ranging from 1.5 m to 1.8 m. The SPT 'N' values for this layer ranged from 1 to 5 blows per 0.3 m of penetration indicating a soft to firm consistency.

The moisture content of the samples tested ranged from 23% to 40%. The results of grain size analysis conducted on one sample of the silty clay fill material are presented on Fig. No C1 in Appendix C. The results are summarized in Table 6-4.

Table 6-4: Gradation Results for Silty Clay Fill

Soil Particles	%
Gravel	1
Sand	18
Silt	60
Clay	21

Atterberg Limit testing was completed on one sample. The test results are illustrated on Fig. No C3 in Appendix C and are summarized in Table 6-5. The results indicate a clay of intermediate plasticity.

Table 6-5: Atterberg Limits Results

Borehole	Sample	LL	PL	PI	Classification
14-4	SS-2	38	20	18	CI

6.5 Glacial Till

The fill materials at the site were underlain by a glacial till material consisting predominantly of silt and clay with varying amounts of sand. Both boreholes were terminated in this stratum.

The top of this stratum ranged in elevation from 241.5 m to 241.8 m. The SPT 'N' value for this stratum ranged from 21 per 0.3 m of penetration to greater 100 blows per 0.3 m of penetration indicating a compact to very dense condition or very stiff to hard consistency.

The moisture content of the samples tested ranged from 7% to 13%. The results of grain size analysis conducted on four samples of the glacial till material are presented on Fig. No C5 in Appendix C. The results are summarized in Table 6-6.

Table 6-6: Gradation Results for Glacial Till

Soil Particles	%
Gravel	3 to 7
Sand	36 to 49
Silt	39 to 48
Clay	8 to 19

It is noted that although not observed in Boreholes 14-4 and 14-5, glacial till deposits frequently include cobbles and boulders. The high blow counts may be the result of the presence of cobbles and boulders.

Atterberg Limit testing was completed on two samples. The test results are illustrated on Figure No. C3 in Appendix C and are summarized in Table 6-7. The results indicate that the material ranges from a non-plastic silt to a silty sandy clay of low plasticity.

Table 6-7: Atterberg Limits Results

Borehole	Sample	LL	PL	PI	Classification
14-5	SS-6	21	12	9	CL
14-5	SS-7	18	11	7	CL-ML

6.6 Groundwater Conditions

Groundwater levels were measured on completion of drilling in the open boreholes prior to backfilling. Free water was observed at a depth below existing grade of 0.7 m, corresponding to an elevation of 243.0 m in Borehole 14-4. No free water was observed in Borehole 14-5.

Groundwater was reported to range from 240.1 m to 242.8 m during the 2007 investigation.

The values are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level will be influenced by the water level in the stream and ditches and may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

The water level in the creek was surveyed by Thurber on October 9, 2014 at an elevation of 243.2 m. The water level in the creek reported by MPCE on November 5, 2014 was elevation 242.9 m.

7 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. Thurber surveyed the borehole locations, and provided the northing and easting coordinates and ground surface elevations. Ohlmann Geotechnical Services (OGS) Inc. of Almonte, Ontario supplied and operated both the portable and truck-mounted CME 55 drill rigs to carry out the drilling, sampling, and in-situ testing. The drilling, and sampling operations in the field were supervised on a full time basis by Ms. Katrina Young of Thurber. Laboratory testing was carried out by Thurber in its MTO-approved laboratory in Ottawa.

Overall project management and direction of the field program was provided by Dr. Fred Griffiths, P.Eng. Interpretation of the field data and preparation of this report was completed by Christopher Murray, E.I.T. and Kenton Power, P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng. and Dr. P.K. Chatterji, P.Eng., the Designated Principal Contact for MTO Foundations Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8 GENERAL

This report presents interpretation of the geotechnical data in the factual report and provides a foundation assessment and geotechnical evaluation of feasible methods for replacement of Structural Culvert 30-545/C beneath Highway 89, approximately 375 m west of County Road 50 near New Tecumseth, Ontario.

The existing culvert has been identified by MTO as having been constructed in 1980. The General Arrangement Drawing prepared for rehabilitation purposes (Contract 2008-2331) indicates it is an open footing (rigid frame) culvert with a length of approximately 21 m founded on 1.1 m wide spread footings at approximate elevation 242.3 m. The culvert has a 3.66 m wide and 0.8 m high opening. Flow through the culvert is from north to south. The invert elevation is estimated to be at approximately elevation 243.2 m.

The top of pavement at the Highway 89 centreline above the culvert is at approximate elevation 245.3 m. The existing embankment has slopes inclined at approximately 3H:1V and is 1.5 m to 3 m high. The existing roadway cross-section includes two 3.75 m lanes and 3.0 m wide shoulders. The AADT is reported to be 13,000 (2008 data, MTO iCorridor).

It is noted that the need for replacement was identified based on its current condition rather than a need to increase hydraulic capacity. The General Arrangement Drawing of July 2015 indicates that the proposed culvert is to have a span of 3.6 m, a height of 1.8 m and an invert elevation of 242.54 m at the inlet. The total length of structure is to be approximately 22 m. In addition, a concrete cutoff wall, 900 mm high is to be constructed below the inlet and outlet of the proposed culvert. The design of the proposed culvert does not include wing walls.

The frost penetration depth in the area is 1.5 m (OPSD 3090.101).

The following sections address the replacement of the existing culvert. The discussions and recommendations presented in this report are based on our understanding of the project and on the factual data obtained during the course of this investigation.

9 SEISMIC CONSIDERATIONS

In accordance with Table A3.1.1 of the Canadian Highway Bridge Design Code (CHBDC) the following seismic parameters should be used for design:

- Velocity Related Seismic Zone (Z_v) = 0
- Zonal Velocity Ratio, (V) = 0.05
- Acceleration Related Seismic Zone (Z_a) = 1
- Zonal Acceleration Ratio, (A) = 0.05

This site is classified as a Soil Profile Type I in accordance with Section 4.4.6 of the CHBDC based on the presence of stable deposits below the footings extending to less than 60 m depth.

Based on the combination of the grain size distribution, relative density of the overburden soils, and low zonal acceleration, the overburden soil at this site is classified as "not susceptible" to liquefaction during the design earthquake event.

10 CULVERT FOUNDATIONS

10.1 General

The following sections address replacement of the existing culvert. It has been assumed that the replacement culvert will be installed along the existing culvert alignment with a similar invert elevation.

10.2 Foundation Alternatives

This section presents discussions on alternate types of replacement culverts and foundation alternatives, and provides recommendations on feasible and/or preferred foundation options. Several common culvert and foundation types are listed below and a comparison of feasible alternatives, based on their respective advantages and disadvantages, is included in Appendix F.

<u>Circular Pipes (CSP or Concrete)</u>

Circular pipes are technically feasible from a foundation engineering standpoint, however, due to the shallow cover, several parallel pipes would likely be required to provide an equivalent hydraulic section.

<u>Concrete Box (Closed) Culvert</u>

It is understood based on the July 2015 General Arrangement Drawing provided, that the existing culvert could be replaced with a closed box culvert with a span of 3.6 m, an interior height of 1.8 m and an invert elevation of 242.54 m (inlet end). Subgrade preparation should consist of excavation and removal of existing foundations (estimated to extend to approximately elevation 242.3 m) as well as existing fill, soft and organic material. Since a 900 mm high, concrete cut-off wall is to be constructed at the inlet and outlet of the culvert subgrade excavation and preparation will need to include excavations to elevation 241.4 m. Note that this is below the groundwater level observed in Borehole 14-4 (243.0 m on Oct 8, 2014) and the creek level observed to be at 243.2 m on Oct 9, 2014. Subgrade preparation and bedding layer compaction must be carried out in the dry, therefore dewatering will be required to lower the groundwater level below the founding subgrade elevation.

Any subexcavated area beneath the base of culvert should be brought up to design subgrade level using Granular A backfill. The backfill should be compacted in thin lifts as per SP105S10.

For a 4 m wide box culvert supported on a well compacted granular fill founded on the native till, a factored geotechnical resistance at ULS of 420 kPa and a geotechnical resistance at SLS of 280 kPa may be used. A resistance factor of 0.5 has been applied to reach the recommended ULS value. The recommended bearing pressure at SLS corresponds to the sustained resulting in 25 mm of settlement. These resistance values apply for concentric axial loading. For eccentric or inclined loading, the geotechnical resistances must be calculated as illustrated in CHBDC Clauses 6.7.3 and 6.7.4.

Sliding resistance between the base of the culvert and the underlying granular bedding layer should be evaluated using an unfactored coefficient of friction of 0.5.

From a foundations perspective both pre-cast and cast-in-place concrete box (closed) culverts are considered feasible at this site, although a pre-cast culvert is preferred from an ease of construction point of view.

<u>Concrete, Open Footing Culvert</u>

A concrete, open footing culvert may also be considered. The founding elevation to achieve 1.5 m of frost cover would be approximately elevation 241.3 m which is deeper than the underside of the existing footings. Existing fill present at this elevation as well as soft and/or organic material should be removed and replaced with Granular A. The base of the excavation would be as deep as elevation 241.0 m which is 2.2 m below the creek water level observed on October 9, 2014. Dewatering will be required to construct the footings in the dry.

The factored geotechnical resistance at ULS for a 1.5 m wide footing founded on undisturbed compact to dense native glacial till or well compacted granular fill at or below elevation 241.3 m is 300 kPa. A resistance factor of 0.5 has been applied to reach the recommended ULS value. The recommended bearing pressure at SLS is 200 kPa corresponding to the sustained pressure resulting in 25 mm of settlement.

Sliding resistance between the base of the footings and glacial till should be evaluated using an unfactored coefficient of friction of 0.35.

A concrete open footing box culvert is considered feasible for this site provided dewatering is employed.

10.3 Construction Methodology Alternatives

This section presents discussions on alternative construction methods for replacement of the culvert.

Trenchless Techniques

Although trenchless techniques would have the advantage of minimum disruption to traffic and would avoid an excavation through the existing highway embankment, the limited cover would necessitate multiple pipe installations to achieve the equivalent hydraulic area. Trenchless techniques are not considered feasible for the site and culvert conditions.

Open Cut with Road Closure

Installation of a new culvert using open cut techniques during a full road closure is the preferred alternative from a foundation perspective. This option would allow for an expedient construction schedule and reduce costs associated with roadway protection, and avoid the need for platform widening, however, it is anticipated that a road closure is not feasible from a traffic operations perspective.

Open Cut with Staged Construction & Roadway Protection

There is insufficient platform width to allow unsupported excavations and maintain a lane of traffic. The culvert could be replaced using open cut techniques with staged construction (half and half) and roadway protection in order to keep one lane of traffic open throughout the construction period.

Open Cut with Staged Construction & Platform Widening/Lowering

Given the limited amount of cover over the existing and proposed culverts, it is not feasible to widen the roadway platform by temporarily lowering the profile. In addition, the proximity of the culvert to the intersection with Concession Road 10 (50 to 75 m) may impact the ability to shift the alignment.

10.4 Recommended Approach

From a foundation perspective, replacement of the culvert with a concrete closed box structure using open cut techniques with staged construction and temporary protection systems is considered the best alternative. The discussion and recommendations provided below are based on the culvert replacement consisting of a closed box constructed in a half and half manner as facilitated by roadway protection.

There are significant construction timing advantages of precast boxes in comparison to cast-in-place concrete construction, thus it is recommended that a precast box culvert be utilized for this project.

11 RECOMMENDATIONS

Foundation recommendations for a closed box concrete culvert are provided in the following sections. Construction of pre-cast concrete box culverts should be carried out in accordance with OPSS 422.

11.1 Excavation and Water Control

All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). The existing embankment fill above the water level is considered Type 3 soil as per the OHSA and Type 4 below water level. As the bottom of the excavations will extend below the groundwater table to the native soils they will require excavation side slopes at 1H:1V where open cut techniques are proposed and control of groundwater is achieved.

A creek diversion and/or cofferdam will likely be required. If they are effective at controlling surface water, it is likely the groundwater control can be achieved with sump and pump methods.

Excavations for culvert replacement will typically be carried out through the existing embankment fill and extend into the underlying native soils. Protection systems will be required to facilitate the proposed construction staging. Protection systems should be designed by a licensed Professional Engineer experienced in such designs. Earth pressure parameters are provided in Table 9.1. OPSS 539 “Construction Specifications for Protection Systems” must be referenced in the contract documents. It is recommended that Performance Level 2, as per Clause 539.04.02.01 (maximum horizontal displacement of 25 mm), be specified for this culvert replacement site. It is noted that cobbles and boulders are frequently found in glacial till deposits. It is recommended that the contract include an NSSP alerting bidders of the need to remove such obstructions if encountered. We suggest the following wording: ‘Excavation of the existing fill and till or installation of cofferdams and roadway protection systems could encounter obstructions which could impede excavation and/or sheet pile installation from reaching design depths. The contractor shall be prepared to remove, drill through and/or penetrate these obstructions and extend the excavations and/or sheet piles to the design depth.”

11.2 Subgrade Preparation

Subgrade preparation should include excavation and removal of the existing footings. The existing fill and any soft or organic materials must be removed and replaced with compacted Granular A.

The native subgrade will consist of a compact to very dense silt and clay till which will be susceptible to disturbance. Construction equipment should not be permitted to travel on the exposed native subgrade. In addition, compaction of granular bedding directly above the native subgrade is likely to result in disturbance of the material with pumping of fines into the granular bedding and difficulty achieving the specified degree of compaction. Placement of a Class II non-woven geotextile over the full extent of the subgrade is recommended as a separator prior to placement of a granular pad. The granular pad should be a minimum of 300 mm thick (in addition to the bedding layer) and should consist of OPSS Granular A levelled and tamped but not compacted.

Culvert construction and subgrade preparation must be carried out in the dry. This work should be carried out in accordance with OPSS 902.

11.3 Culvert Bedding and Backfill

Culvert Bedding should consist of OPSS Granular A.

Culvert backfill should consist of free-draining granular material conforming to OPSS Granular A, Granular B Type I or Granular B Type II specifications.

The backfill should be placed and compacted in simultaneous, equal lifts on both sides of the culvert. Heavy compaction equipment should not be used adjacent to the walls and roof of the culvert. Compaction should be carried out in accordance with OPSS 501.

11.4 Lateral Earth Pressures

In general, earth pressures acting on the culvert walls may be assumed to impose a triangular distribution governed by the characteristics of the backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are given by the expression:

$$P_h = K (\gamma h + q)$$

where:

P_h = horizontal pressure on the wall at depth h (kPa)
K = earth pressure coefficient
γ = bulk unit weight of retained soil (kN/m^3)
h = depth below top of fill where pressure is computed (m)
q = value of any surcharge (kPa)

Earth pressure coefficients for backfill to the culvert are dependent on the material used as backfill. Recommended unfactored values are shown in Table 11-1. As the design is based on a closed box culvert the walls will be braced at top and bottom and the at-rest coefficient should be used to assess the lateral earth pressures.

Table 11-1: Static Lateral Earth Pressure Coefficients

Parameter	Existing Embankment Fill	Granular B Type I	Granular A and Granular B Type II	Glacial Till
Soil Unit weight (kN/m^3)	20.0	21.2	22.8	19.0
Angle of Internal friction, ϕ	30°	32°	35°	27°
Walls with Horizontal Backfill				
Coefficient of earth pressure at-rest, K_0	0.50	0.47	0.43	0.55

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Parameter	Existing Embankment Fill	Granular B Type I	Granular A and Granular B Type II	Glacial Till
Coefficient of active earth pressure, K_a	0.33	0.31	0.27	0.38
Coefficient of passive earth pressure, K_p	3.0	3.2	3.7	2.7
Sloping Surface Behind Wall (2H:1V)				
Coefficient of earth pressure at-rest, K_0	0.72	0.68	0.62	0.79
Coefficient of active earth pressure, K_a	0.54	0.47	0.39	0.70

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I or at a depth of 1.7 m for Granular A or Granular B Type II.

The design of the culvert must incorporate measures such as weepholes or subdrains to permit drainage of the culvert backfill, or alternatively the culvert walls should be designed to withstand the potential build-up of hydrostatic pressures behind the walls.

11.5 Embankment Design and Construction

Embankment reconstruction, after culvert replacement, should be carried out in accordance with OPSS 206. The embankment material should consist of imported Granular A or B Type II material. Excavated granular fill may also be reused as backfill provided there is no organic material in the excavated fill and there is sufficient space to stockpile on site and control the moisture content within acceptable limits for compaction

The existing embankment is sloped at approximately 3H:1V and exhibits no signs of instability. Provided the subgrade is prepared as described in Section 11.2 and embankment fill placed as described herein, an embankment side slope of 2H:1V or flatter should remain stable. As this is a culvert replacement project, minimal embankment settlement is anticipated.

11.6 Erosion Control

Erosion protection should be provided at the culvert inlet and outlet areas. Design of the erosion protection measures must consider hydrologic and hydraulic factors and should be carried out by specialists experienced in this field.

Typically, rock protection or riprap should be provided over all surfaces with which surface water is likely to be in contact. Treatment at the outlets should be in accordance with OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS 804.

It is recommended that a clay seal or a concrete cut-off wall be used to minimize the potential for erosion near the inlet area. The clay seal should extend a minimum of 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS 1205. A geosynthetic clay liner may be used as a clay seal.

12 CONSTRUCTION CONCERNS

The planned construction methodology includes staged construction with protection systems in order to maintain traffic flow across the culvert area. Potential construction concerns include, but are not necessarily limited to, the following:

- Impact of excavation on the existing pavement surface. Daily visual inspection of the pavement surface must be carried out in the vicinity of the culvert construction. If cracks form in the pavement or settlement is observed to occur, these matters must immediately be brought to the attention of the C.A. for determining the level of remedial action that is required.
- Implementation of an adequate and effective surface water management and dewatering plan to construct the replacement culvert and subgrade in the dry.
- Removal of organics and soft soils from the culvert subgrade.
- Confirmation that the culvert backfill is adequately placed and compacted to specifications.

The successful performance of the culvert will depend largely upon good workmanship and quality control during construction. Observation of the excavation and backfilling operations by the QVE will be required during construction to confirm that the foundation recommendations are correctly implemented and material specifications are met.

13 CLOSURE

Overall project management and direction of the field program was provided by Dr. Fred Griffiths, P.Eng. Interpretation of the field data and preparation of this report was completed by Christopher Murray, E.I.T. The report was reviewed by Dr. Fred Griffiths, P.Eng. and Dr. P.K. Chatterji, P.Eng. the Designated Principal Contact for MTO Foundations Projects.

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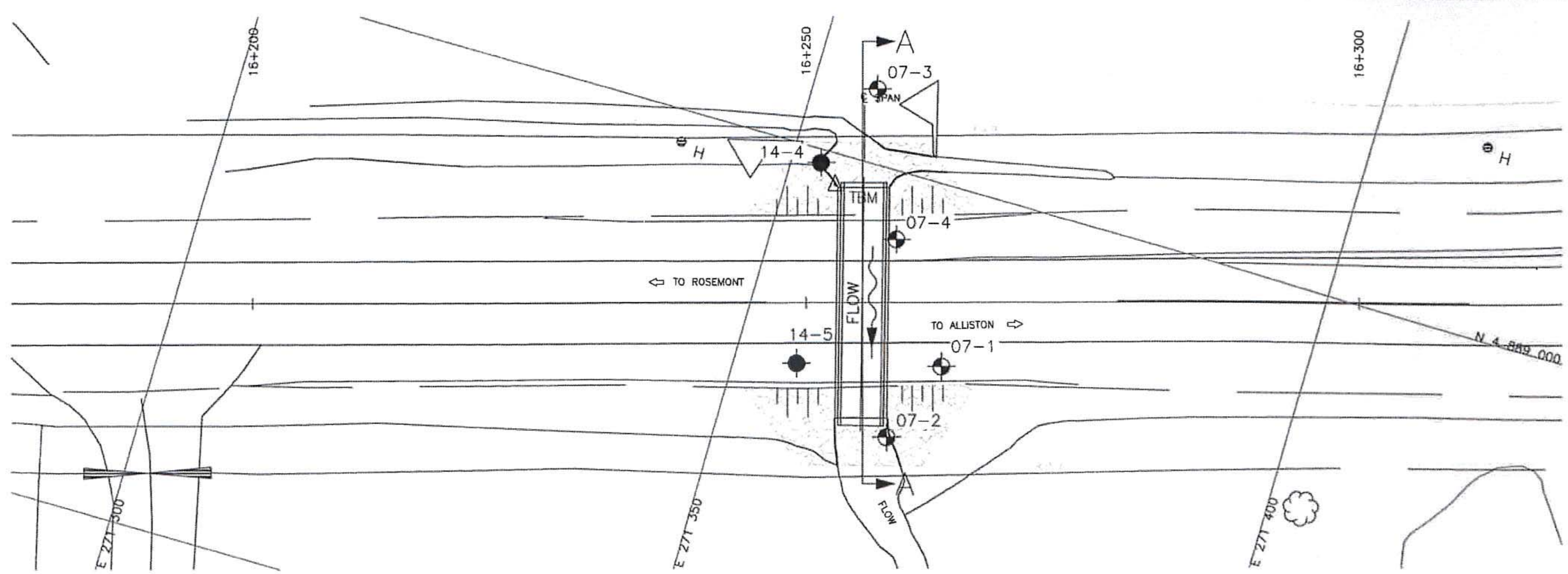
Appendix A

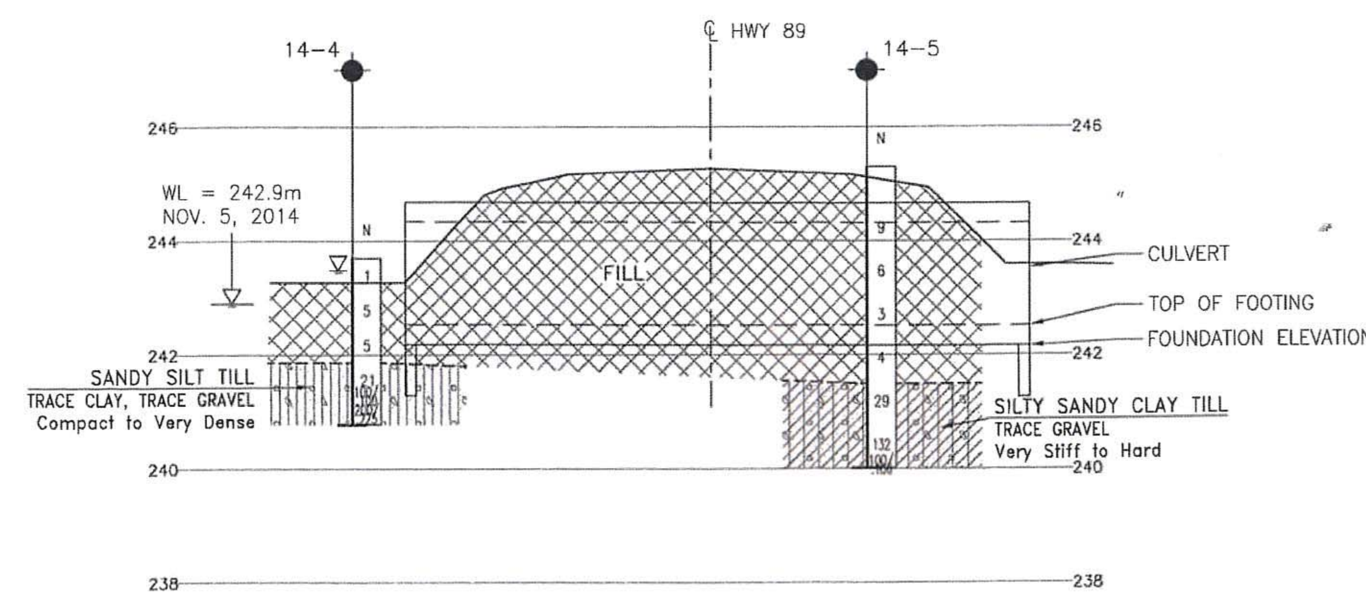
Borehole Locations and Soil Strata Drawings



PLAN

10 0 10 20m

SCALE 1:500



SECTION A-A

5 0 5 10m H 1:250

2.5 0 2.5 5m V 1:125

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No

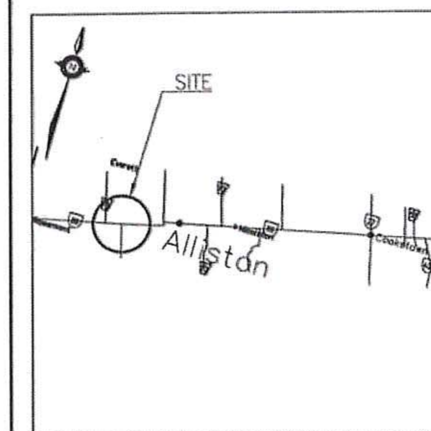
WP No 2183-13-00

HIGHWAY 89
CULVERT
30-545/C
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

McINTOSH PERRY

THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

	Borehole (Current Investigation)
	Borehole (Previous Investigation)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
07-1	245.2	4 888 984.1	271 368.2
07-2	243.4	4 888 976.6	271 365.2
07-3	244.0	4 889 006.6	271 355.7
07-4	245.1	4 888 994.0	271 361.1
14-4	243.7	4 888 998.8	271 352.7
14-5	245.3	4 888 980.8	271 355.6

LICENSED PROFESSIONAL ENGINEER P. K. CHATTERJI July 28/15 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER F. J. GRIFFITHS Aug 4/15 PROVINCE OF ONTARIO

-NOTES-

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

2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 31D-593

REVISIONS | DATE | BY | DESCRIPTION

DESIGN CM	CHK PC	CODE	LOAD	DATE JUL 2015	
DRAWN MFA	CHK FG	SITE	STRUCT	DWG 1	

FILENAME: H:\Drafting\19\3405\5\ed4055-PlanProfile(Hwy89).dwg
PLOTDATE: 7/23/2015 1:54 PM

Appendix B

Record of Borehole Sheets

THURBER

THURBER

SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

Topsoil	mixture of soil and humus capable of supporting vegetative growth
Peat	mixture of fragments of decayed organic matter
Till	unstratified glacial deposit which may include particles ranging in sizes from clay to boulder
Fill	material below the surface identified as placed by humans (excluding buried services)

TERMINOLOGY DESCRIBING SOIL STRUCTURE:

Desiccated	having visible signs of weathering by oxidization of clay materials, shrinkage cracks, etc.
Fissured	having cracks, and hence a blocky structure
Varved	composed of alternating layers of silt and clay
Stratified	composed of alternating successions of different soil types, e.g. silt and sand
Layer	> 75 mm in thickness
Seam	2 mm to 75 mm in thickness
Parting	< 2 mm in thickness

RECOVERY:

For soil samples, the recovery is recorded as the length of the soil sample recovered.

N-VALUE:

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented, the number of blows are reported over the sampler penetration in millimetres (e.g. 50/75).

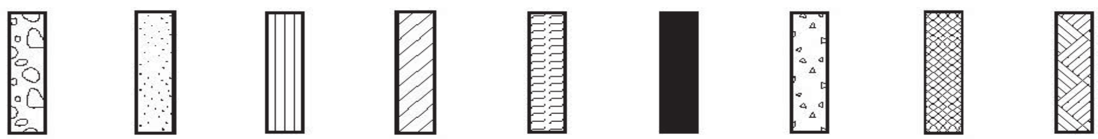
DYNAMIC CONE PENETRATION TEST (DCPT):

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to an “A” size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone 0.3 m into the soil. The DCPT is used as a probe to assess soil variability.

THURBER

STRATA PLOT:

Strata plots symbolize the soil and bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



TEXTURING CLASSIFICATION OF SOILS

Classification	**Particle Size**
Boulders	Greater than 200 mm
Cobbles	75 – 200 mm
Gravel	4.75 – 75 mm
Sand	0.075 – 4.75 mm
Silt	0.002 – 0.075 mm
Clay	Less than 0.002 mm

SAMPLE TYPES

SS	Split spoon samples
ST	Shelby tube or thin wall tube
DP	Direct push sample
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ etc.	Rock core sample obtained with the use of standard size diamond coring equipment

TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

Descriptive Term	**Undrained Shear Strength (kPa)**
Very Soft	12 or less
Soft	12 – 25
Firm	25 – 50
Stiff	50 – 100
Very Stiff	100 – 200
Hard	Greater than 200

NOTE: Clay sensitivity is defined as the ratio of the undisturbed strength over the remolded strength.

TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

Descriptive Term	**SPT "N" Value**
Very Loose	Less than 4
Loose	4 – 10
Compact	10 – 30
Dense	30 – 50
Very Dense	Greater than 50

THURBER

MODIFIED UNIFIED SOIL CLASSIFICATION

Major Divisions		Group Symbol	Typical Description
COARSE GRAINED SOIL	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILT AND CLAY SOILS $W_L < 35\%$	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		OL	Organic silts and organic silty-clays of low plasticity.
	SILT AND CLAY SOILS $35\% < W_L < 50\%$	MI	Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts.
		CI	Inorganic clays of medium plasticity, silty clays.
		OI	Organic silty clays of medium plasticity.
	SILT AND CLAY SOILS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy of silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other organic soils.

Note - W_L= Liquid Limit

THURBER

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock materials.
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structures are preserved.

TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.
Solid Core Recovery: (SCR)	Percent ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1 m in length or larger, as a percentage of total core length
Unconfined Compressive Strength: (UCS)	Axial stress required to break the specimen.
Fracture Index: (FI)	Frequency of natural fractures per 0.3 m of core run.

DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 to 2 m
Medium bedded	0.2 to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 to 60 mm
Laminated	6 to 20 mm
Thinly laminated	Less than 6 mm

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)
Extremely Strong	Greater than 250
Very Strong	100 – 250
Strong	50 – 100
Medium Strong	25 – 50
Weak	5 – 25
Very Weak	1 – 5
Extremely Weak	0.25 – 1

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 14-4

METRIC

GWP#	2183-13-00	LOCATION	Highway 89 N 4 888 998.8 E 271 352.7	ORIGINATED BY	KMY
HWY	89	BOREHOLE TYPE	Portable	COMPILED BY	KMY
DATUM	Geodetic	DATE	2014.10.08 - 2014.10.08	CHECKED BY	FJG

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
243.7										
0.0	Silty CLAY, some sand, some organics, frequent rootlets Greyish Brown **(FILL)**	1	SS	1						
					▽	243				
		2	SS	5			1	18	60	21
		3	SS	5						
241.8						242				
1.8	**Sandy SILT (ML)** trace clay, trace gravel Compact to Very Dense Grey Saturated **(TILL)**	4	SS	21			3	49	40	8
		5	SS	100/100mm						
		6	SS	200/225mm		241	7	37	48	8
240.7										
2.9	END OF BOREHOLE Splitspoon refusal at 2.9 m Groundwater level at 0.7 m in open borehole									

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

+ ³, × ³ : Numbers refer to Sensitivity

20 / 15 ◯ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 14-5

METRIC

GWP# 2183-13-00	LOCATION Highway 89 N 4 888 980.8 E 271 355.6	ORIGINATED BY KMY	
HWY 89	BOREHOLE TYPE Truck Mount CME 55 with Hollow Stem Augers	COMPILED BY KMY	
DATUM Geodetic	DATE 2014.10.08 - 2014.10.09	CHECKED BY FJG	

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
245.3								
0.0	Silty SAND with gravel Brown **(FILL)**		1	GS			245	28 50 22 (SI+CL)
244.5 0.8	Gravelly SAND-SILT mixture, some clay Brown **(FILL)**		2	SS	9		244	
	- Sand layer from 1.5 m to 1.6 m - Clayey at 1.9 m		3	SS	6			25 43 21 11
243.0 2.3	Silty CLAY, some sand Brown **(FILL)**		4	SS	3		243	
			5	SS	4		242	
241.5 3.8	**Silty Sandy CLAY (CL)** trace gravel Very Stiff to Hard Brown Moist **(TILL)**		6	SS	29		241	3 36 43 18
			7	SS	132			4 38 39 19
240.0			8	SS	100/ 100mm			
5.3	END OF BOREHOLE Splitspoon refusal at 5.3 m Borehole dry on completion							

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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

UNIT WEIGHT γ kN/m3

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Appendix C

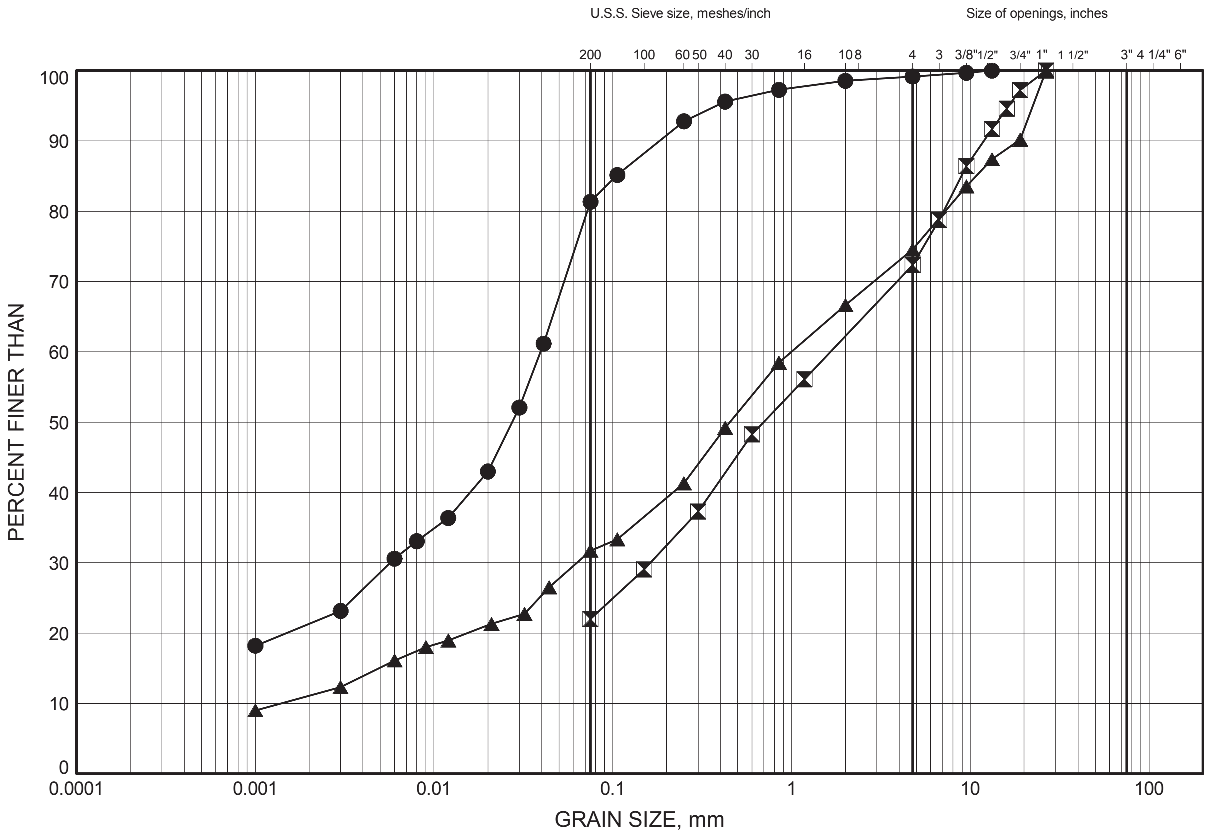
Laboratory Test Results

Highway 89

GRAIN SIZE DISTRIBUTION

FIGURE C1

Fill



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-4	0.91	242.74
⧗	14-5	0.30	245.00
▲	14-5	1.83	243.48

Date December 2014

19-3405-5

THURBER

Prep'd CM

Chkd. PC

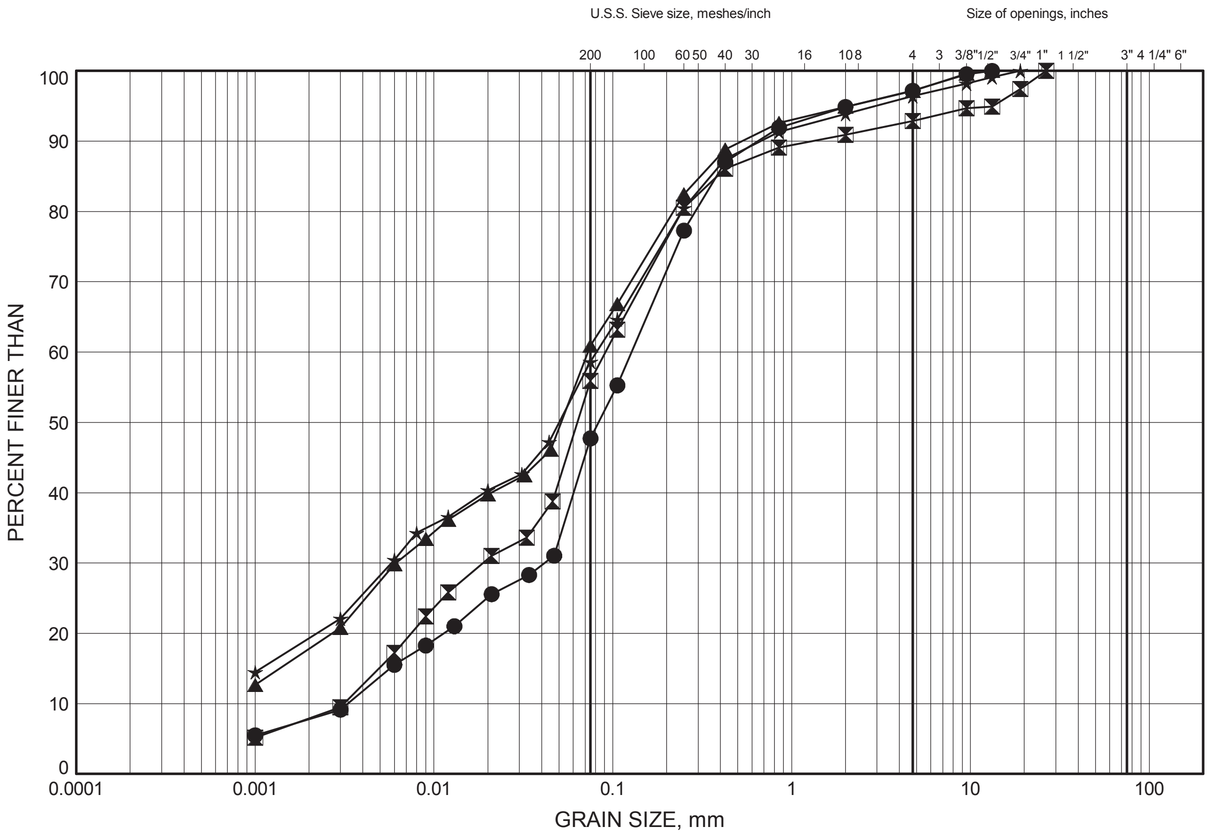
GRAIN SIZE DISTRIBUTION - THURBER 19-3405-5-HWY89.GPJ 16/12/14

Highway 89

GRAIN SIZE DISTRIBUTION

FIGURE C2

Sandy Silt to Silty Sandy Clay



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-4	2.13	241.52
⧗	14-4	2.86	240.80
▲	14-5	4.04	241.27
★	14-5	4.88	240.43

GRAIN SIZE DISTRIBUTION - THURBER 19-3405-5-HWY89.GPJ 16/12/14

Date December 2014

19-3405-5

THURBER

Prep'd CM

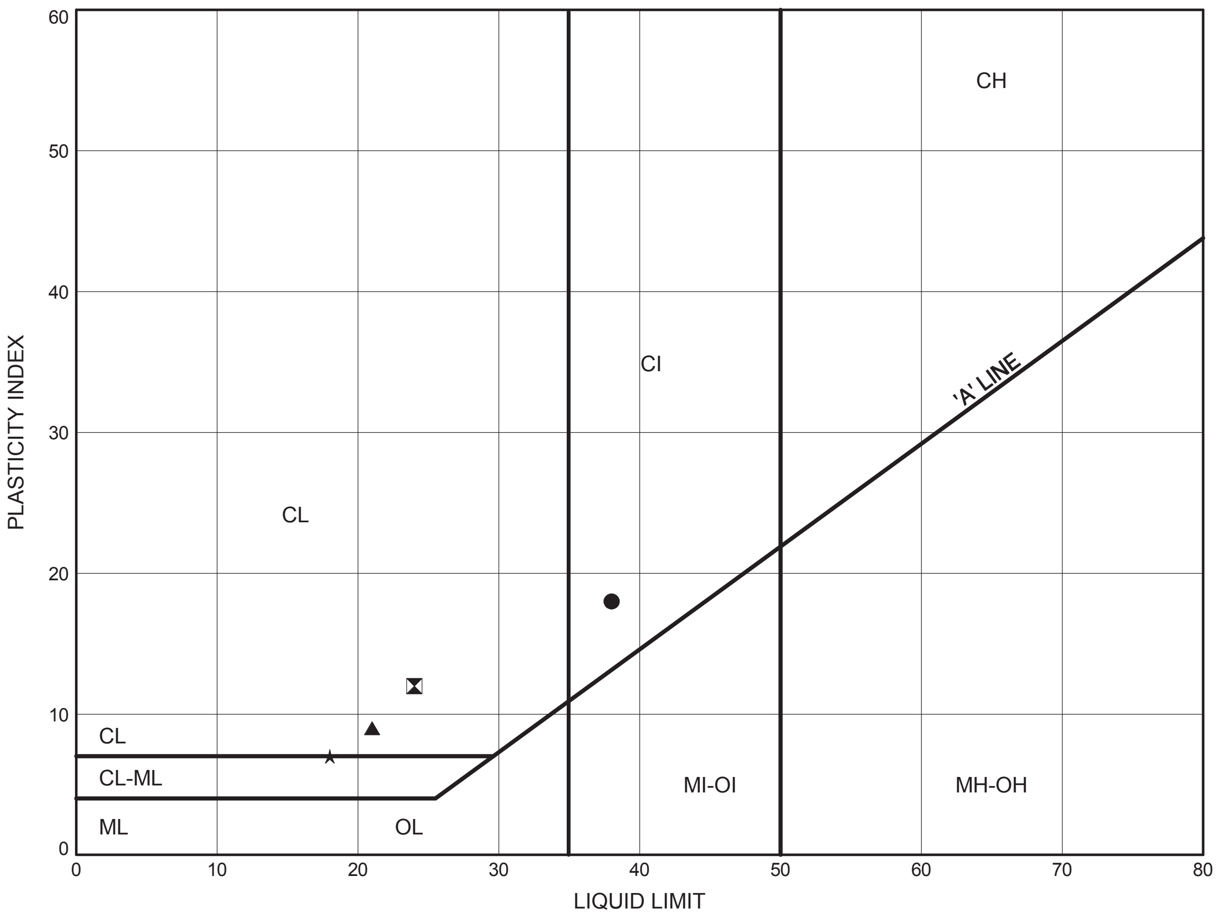
Chkd. PC

Highway 89

ATTERBERG LIMITS TEST RESULTS

FIGURE C3

Silty Clayey Sand to Sandy Silty Clay



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-4	0.91	242.74
⧗	14-5	1.83	243.48
▲	14-5	4.04	241.27
★	14-5	4.88	240.43

THURBALT 19-3405-5-HWY89.GPJ 16/12/14

Date December 2014

19-3405-5

THURBER

Prep'd CM

Chkd. PC

Appendix D

Selected Photographs of Culvert Location

Photo 1: **Culvert alignment beneath Highway 89 looking in the southwest direction**

Photo 2: **South end – existing culvert outlet.**

Appendix E

Existing GEOCRES Reports

Golder Associates

REPORT ON

FOUNDATION INVESTIGATION AND DESIGN
CULVERT REPLACEMENT AT STATION 16+255
HIGHWAY 89 PAVEMENT REHABILIZATION FROM ROSEMONT
TO 0.9 KM EAST OF COUNTY ROAD 13
SIMCOE COUNTY, ONTARIO
G.W.P. 2479-04-00

Submitted to:

McCormick Rankin Corporation
2655 North Sheridan way
Mississauga, Ontario
L5K 2P8

GEOCRES No. 31D-451

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January 2009 05-1111-034-2

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LIST OF FIGURES

LIST OF APPENDICES

PART A

FOUNDATION INVESTIGATION REPORT
CULVERT REPLACEMENT AT STATION 16+255
HIGHWAY 89 PAVEMENT REHABILITATION FROM ROSEMONT
TO 0.9 KM EAST OF COUNTY ROAD 13
SIMCOE COUNTY, ONTARIO
G.W.P. 2479-04-00

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by McCormick Rankin Corporation (MRC) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services associated with the rehabilitation of Highway 89 from Rosemont to 0.9 km east of County Road 13, in Simcoe County. Foundation engineering services are required for the widening of the Nottawasaga River Bridge (MTO Structure Site No.30-250), construction of a new retaining wall to the northwest of the widened bridge structure, and replacement of an existing concrete culvert structure at Station 16+255 between Rosemont and Alliston (Culvert 30-545C).

This report addresses the foundation investigation carried out for the proposed culvert replacement at Station 16+255 (Culvert 30-545C) as part of the Highway 89 rehabilitation project.

The terms of reference and scope of work for the foundation investigation are outlined in MTO's Request for Proposal for Agreement No. 2004-E-0032, issued in April 2005, and in Section 6.8 of MRC's *Technical Proposal* for G.W.P. 2479-04-00 as well as Golder's proposal letter dated January 22, 2007 for additional foundation engineering services relating to the proposed retaining wall and culvert replacement.

2.0 SITE DESCRIPTION

The site of the proposed culvert replacement on Highway 89, is located approximately 0.8 km east of Simcoe County Road 13, Ontario. Highway 89 in this area is approximately 7.5 m wide consisting of two lanes with 3 m wide fully paved shoulders on both sides of the highway.

The site generally consists of the raised highway embankment with gently sloping, grass covered side-slopes. Based on the general arrangement drawing provided by MRC entitled "Hwy. 89 Culvert at Sta. 16+255.000-General Arrangement", dated January 2007, the existing Highway 89 grade is between Elevation 245 m and Elevation 245.3 m and the approximate streambed is between Elevation 243.6 m (at the culvert inlet) and Elevation 243.2 m (at the culvert outlet). The existing culvert is an open footing concrete structure, 3.67 m wide and 21 m long. The opening height (creek bottom to soffit) is approximately 0.8 m.

Vegetation in the vicinity of the existing culvert consists primarily of grasses with some small shrubs.

3.0 INVESTIGATION PROCEDURES

3.1 Foundation Investigation

The subsurface investigation at the site of the proposed culvert replacement was completed on September 26, 2007. Two boreholes were advanced at the south shoulder and embankment toe of the highway, adjacent to the existing culvert; however due to access constraints in the immediate vicinity of the toe/culvert end at the north side of the embankment, one borehole was advanced 9 m north of the end of the culvert (i.e. culvert inlet) and one borehole was advanced through the north shoulder of the highway, about 6 m south of the culvert inlet. The borehole locations are shown on Drawing 1.

The field investigation was carried out using a track-mounted drill rig, supplied and operated by Walker Drilling Ltd. of Barrie, Ontario. The boreholes were advanced using 108 mm outside diameter (O.D.) solid stem augers to depths ranging from about 3.5 m to 7.8 m below the existing ground surface. Soil samples were obtained at intervals ranging from 0.75 m to 1.5 m intervals of depth, using a 50 mm outer diameter (O.D.) split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures. The groundwater conditions in the open boreholes were observed throughout the drilling operations, and a standpipe piezometer was installed in Boreholes 07-4 to permit monitoring of the groundwater level at this location. The piezometer consist of a 50 mm diameter PVC pipe with a 1.5 m long slotted screen installed within a 3 m long sand filter pack. Upon completion of drilling, the boreholes and annulus surrounding the piezometer pipe above the sand filter pack were backfilled to the surface with bentonite pellets in accordance with Ontario Regulation (O.Reg.) 903.

The field work was monitored on a full-time basis by a member of Golder's technical staff who located the boreholes in the field, cleared the site of buried utility services, directed the sampling, in situ testing operations, and logged the boreholes. The soil samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Mississauga for further examination and geotechnical laboratory testing. Index and classification tests (water content determinations, Atterberg limits and grain size distribution) as well as organic content tests were carried out on selected soil samples.

The borehole elevations were measured in the field by members of Golder's technical staff, relative to a geodetic bench mark, located at the northwest corner of the existing culvert structure (BM 621-W0427107B) and the borehole locations were measured by Golder relative to site features. The borehole locations (including MTM NAD83 northing and easting coordinates) and ground surface elevations (referenced to geodetic datum) are summarized below and are shown on Drawing 1.

Borehole Number	*MTM NAD83*		*Ground Surface Elevation (m)*
	Northing (m)	*Easting (m)*	
07-1	4888984.1	271368.2	245.1
07-2	4888976.6	271365.2	243.6
07-3	4889006.6	271355.7	243.7
07-4	4888994.0	271361.1	244.9

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The area of Highway 89 at the location of Culvert 30-545C lies within the Simcoe Lowlands physiographic region, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984[1]).

The Simcoe Lowlands comprise the lowlands bordering Georgian Bay to the west and Lake Simcoe to the east (Chapman and Putnam, 1984[1]). To the west are the plains lying between Elevation 176 m and Elevation 228 m, draining into Nottawasaga Bay by way of the Nottawasaga River and are referred to as the Nottawasaga Basin. To the east are the lowlands surrounding Lake Simcoe lying between Elevation 219 m and Elevation 259 m which are referred to as the Lake Simcoe Basin.

Within the southern portion of the Nottawasaga Basin in the Alliston area lies Adjala Township where the proposed culvert replacement site is located. The surficial soils in the Alliston area are typically comprised of sandy loam and silt loam. Most of the Nottawasaga Basin was at one time part of the floor of Lake Algonquin and its surface beds are of deltaic and lacustrine origin.

4.2 Subsoil Conditions

Four boreholes (Boreholes 07-1 to 07-4) were drilled at the site of the culvert replacement as shown on Drawing 1. Two boreholes were advanced through the existing Highway 89 north and south embankments and two borehole were drilled at the embankment toes, adjacent to the existing culvert structure.

The detailed subsurface soil and groundwater conditions as encountered in the boreholes, together with the results of the laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole sheets following the text of this report. The laboratory test results are also presented on Figures 1 to 5.

---

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

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 and the subsurface conditions will vary between and beyond the borehole locations. The inferred soil stratigraphy based on the results of the boreholes at the site of the culvert replacement is shown on Drawing 1.

In summary, the subsoil conditions encountered in the boreholes generally consist of surficial silty sand and clayey silt fill materials underlain by a very stiff to hard clayey silt with sand till deposit, which grades into a silt and sand till at the location of Borehole 07-3. A detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Fill

Fill materials were encountered in all of the boreholes immediately below the ground surface. In Boreholes 07-1, 07-2, and 07-4, the fill consists of an upper layer of silty sand, between 500 mm and 800 mm thick, overlying clayey silt containing variable amounts of sand, trace gravel, and trace quantities of organic matter. In Borehole 07-3, drilled some 9 m north of the existing culvert inlet at the north embankment toe, the fill consists of silty clay with trace sand and organic matter. The thickness of the fill ranges from about 1.8 m in Borehole 07-3 to about 3.5 m in Borehole 07-1.

The measured SPT "N" values within the fill materials typically range from 3 to 11 blows per 0.3 m of penetration, indicating a very loose to compact relative density /soft to stiff consistency . One SPT "N" value of 35 blows per 0.3 m of penetration was measured in the upper silty sand fill at the location of Borehole 07-1, which was advanced through the embankment on the south shoulder of the highway.

The clayey silt and silty clay fill materials contain variable amounts of organic matter; organic content tests carried out on samples of these materials, selected on the basis of visual and olfactory indication of organics, yielded organic contents varying from 5.2 percent to 7.2 percent for the soil samples collected between about Elevation 241.5 m and Elevation 243.5 m.

The results of one grain size distribution test carried out on a sample of the clayey silt fill is shown on Figure 1 and indicates that the sample tested is a clayey silt with sand. Atterberg limits tests carried out on two samples of the clayey fill materials encountered in Boreholes 07-2 and 07-3 yielded plastic limits of 16 percent and 24 percent, liquid limits of 26 percent and 41 percent, and corresponding plasticity indices of 10 percent and 17 percent, respectively. These results indicate that the samples tested are comprised of clayey silt of low plasticity to silty clay of intermediate plasticity as illustrated on Figure 2.

The measured water contents on samples of the fill materials vary between about 6 percent and 37 per cent.

4.2.2 Clayey Silt with Sand to Silt and Sand Till

A till deposit consisting of clayey silt with sand was encountered below the fill materials between approximately Elevation 241.4 m and Elevation 242.2 m in the boreholes located on the shoulders of the roadway and the south end of the culvert. The till at the location of the Borehole 07-3 beyond the north end of the culvert is granular, comprised of silt and sand and was encountered at Elevation 241.9 m. The clayey silt with sand till extends to the termination depths of boreholes 07-1, 07-2, and 07-4 between about Elevation 237.1 m and Elevation 240.2 m.

The results of three grain size distribution tests carried out on selected samples of the clayey silt till and silt and sand till materials are shown on Figures 3 and 4, respectively. Atterberg limits tests carried out on two selected samples of the clayey silt with sand yielded plastic limits of about 9 and 10 percent, liquid limits of about 14 and 18, and corresponding plasticity indices of 5 percent and 8 percent for the clayey silt portion of this deposit, whereas a non-plastic result was obtained for the silt and sand till encountered in Borehole 07- 3. The results, plotted on Figure 5, confirm that the cohesive till deposit is a clayey silt of low plasticity. The measured water contents on samples of the clayey silt with sand till range between approximately 6 percent and 20 per cent.

The measured SPT "N" values in the clayey silt with sand till range from 26 blows per 0.3 m of penetration to 109 blows for 0.15 m of penetration, indicating a very stiff to hard consistency; while the SPT "N" values measured in the silt and sand till encountered in Borehole 07-3, range from 75 blows to 94 blows per 0.3 m of penetration, indicating a very dense relative density.

4.2.3 Groundwater Conditions

All of the open boreholes were dry upon completion of drilling. The water levels measured in the piezometer installed in Borehole 07-4 are summarized below:

Borehole Number	*Ground Surface Elevation (m)*	*Measured Groundwater Elevation (m)*	
		September 26, 2007	*October 15, 2007*
07-4	244.9	240.1	242.8

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

5.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Veronica Olatunji, and reviewed by Ms. Houda Jadi, P.Eng., a Geotechnical Engineer with Golder. Mr. Jorge M. A. Costa, P.Eng., a Designated MTO Contact and Principal with Golder conducted an independent technical review and quality control of the report.

GOLDER ASSOCIATES LTD.

Veronica Olatunji
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Houda Jadi, P. Eng.,
Geotechnical Engineer

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

VO/SH/HJ/JMAC/jl

n:\active\2005\1111\05-1111-034 mrc hwy 89 cookstown\reports\final reports\culvert replacement\05-1111-034 final rpt02 culvert replacement-jan 23-09.doc

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 cm^2 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 (Relative Density)	N 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 kPa	c_u, s_u psf
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.

S:\FINALDAT\ABBREV\2000\LOFA-D00.DOC

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 ($\sigma' = \sigma''$-u)
σ'_{vo}	initial effective overburden stress
$\sigma_1 \sigma_2 \sigma_3$	principal stresses (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1+\sigma_2+\sigma_3)/3$
τ	shear stress
u	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 ($D_R = p_s/p_w$) formerly (G_s)
e	void ratio
n	porosity
S	degree of saturation
*	Density symbol is p. Unit weight symbol is γ where γ=pg(i.e. mass density x acceleration due to gravity)

(a) Index Properties (cont'd.)

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 (overconsolidated 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	Overconsolidation ratio=σ'_p/σ'_{vo}

(d) Shear Strength

$\tau_p \tau_r$	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction=tan δ
c'	effective cohesion
c_u,s_u	undrained shear strength (ϕ=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

Notes: 1. τ=c'σ' tan |'
2. Shear strength=(Compressive strength)/2

RECORD OF BOREHOLE No BH07-1

1 OF 1 **METRIC**

PROJECT 05-1111-034
W.P. 2479-04-00
LOCATION N 4888984.1 ;E 271368.2
ORIGINATED BY SB
DIST Central HWY
BOREHOLE TYPE Power Auger, 108 mm O.D. Solid Stem Augers
COMPILED BY DD
DATUM Geodetic
DATE September 26, 2007
CHECKED BY SMM

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	NATURAL MOISTURE CONTENT w (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
245.1	GROUND SURFACE				245		
0.0	Silty sand, trace gravel (FILL) Dense Brown Moist	1	SS	35		o	
244.6 / 0.5	Clayey silt, some sand, trace gravel, containing organics (FILL) Soft to stiff Brown and grey Moist	2	SS	9	244		
		3	SS	4	243		OC 5.2%
		4	SS	5			
		5	SS	6	242	o	
241.6 / 3.5	CLAYEY SILT with sand, some gravel, containing cobbles (TILL) Hard Brown Dry	6	SS	68	241		
	Becoming grey at 4.5 m depth	7	SS	109/.15		o (with Wp–WL range)	12 37 36 15
					240		
238.8 / 6.3		8	SS	100/.05	239	o	
	END OF BOREHOLE						

Note:

1. Borehole dry upon completion of drilling.

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X REMOULDED (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³; GROUND WATER CONDITIONS; STRAT PLOT.

+3, X3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

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RECORD OF BOREHOLE No BH07-2

 METRIC

PROJECT 05-1111-034

W.P. 2479-04-00 LOCATION N 4888976.6 ;E 271365.2 ORIGINATED BY SB

DIST Central HWY BOREHOLE TYPE Power Auger, 108 mm O.D. Solid Stem Augers COMPILED BY DD

DATUM Geodetic DATE September 26, 2007 CHECKED BY SMM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR SA SI CL
243.6	GROUND SURFACE						
0.0	Silty sand, trace gravel (FILL) Loose Brown Moist	1	SS	5			
243.0 / 0.6	Clayey Silt with sand, trace gravel, containing organics (FILL) Soft to stiff Grey Moist	2	SS	3	243		
		3	SS	9	242		5 40 39 16
241.4 / 2.2	CLAYEY SILT with sand, some gravel (TILL) Hard Grey Dry	4	SS	83	241		
		5	SS	62/.15			
		6	SS	105	240		
		7	SS	76	239		
					238		
237.2		8	SS	85/.15			
6.4	END OF BOREHOLE						

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X REMOULDED 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m^3; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Note:

1. Borehole dry upon completion of drilling.

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

RECORD OF BOREHOLE No BH07-3

 METRIC

PROJECT 05-1111-034

W.P. 2479-04-00 LOCATION N 4889006.7 ;E 271355.7 ORIGINATED BY SB

DIST Central HWY BOREHOLE TYPE Power Auger, 108 mm O.D. Solid Stem Augers COMPILED BY DD

DATUM Geodetic DATE September 26, 2007 CHECKED BY SMM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%) (w_P – w – w_L)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
243.7	GROUND SURFACE									
0.0	Silty clay, trace sand, containing organics and rootlets (FILL) Soft to firm Dark brown Moist		1	SS	6					
							243			
			2	SS	3			41		OC 7.2
241.9 1.8	SILT and SAND, some gravel, trace clay, containing cobbles below 2.2 m depth (TILL) Compact to very dense Brown and grey Moist		3	SS	11		242			
			4	SS	75		241		NP	12 48 35 5
			5	SS	94					
240.2 3.5	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling.									

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X REMOULDED; 20 40 60 80 100

PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

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

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RECORD OF BOREHOLE No BH07-4

 METRIC

PROJECT 05-1111-034			
W.P. 2479-04-00	LOCATION N 4888994.0 ;E 271361.1		ORIGINATED BY SB
DIST Central HWY	BOREHOLE TYPE Power Auger, 108 mm O.D. Solid Stem Augers		COMPILED BY DD
DATUM Geodetic	DATE September 26, 2007		CHECKED BY SMM

ELEV / DEPTH (m)	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
244.9	GROUND SURFACE					
0.0	Silty sand, trace gravel (FILL) Brown Moist					
244.1 / 0.8	Clayey silt, trace to some sand, trace gravel, containing rootlets (FILL) Firm Brown Moist	1	SS	8	244	
		2	SS	6	243	
	Becoming dark grey to black, containing organics and decayed wood fibres at 2.2 m depth	3	SS	6		OC 6.7
242.2 / 2.7	CLAYEY SILT with sand, trace gravel (TILL) Very stiff to hard Grey Dry				242	
		4	SS	26		
		5	SS	83	241	
		6	SS	97/.15	240	
					239	
		7	SS	85/.15		3 44 41 12
					238	
237.1 / 7.8	END OF BOREHOLE	8	SS	107/.15		

Notes:

1. Borehole dry upon completion of drilling.

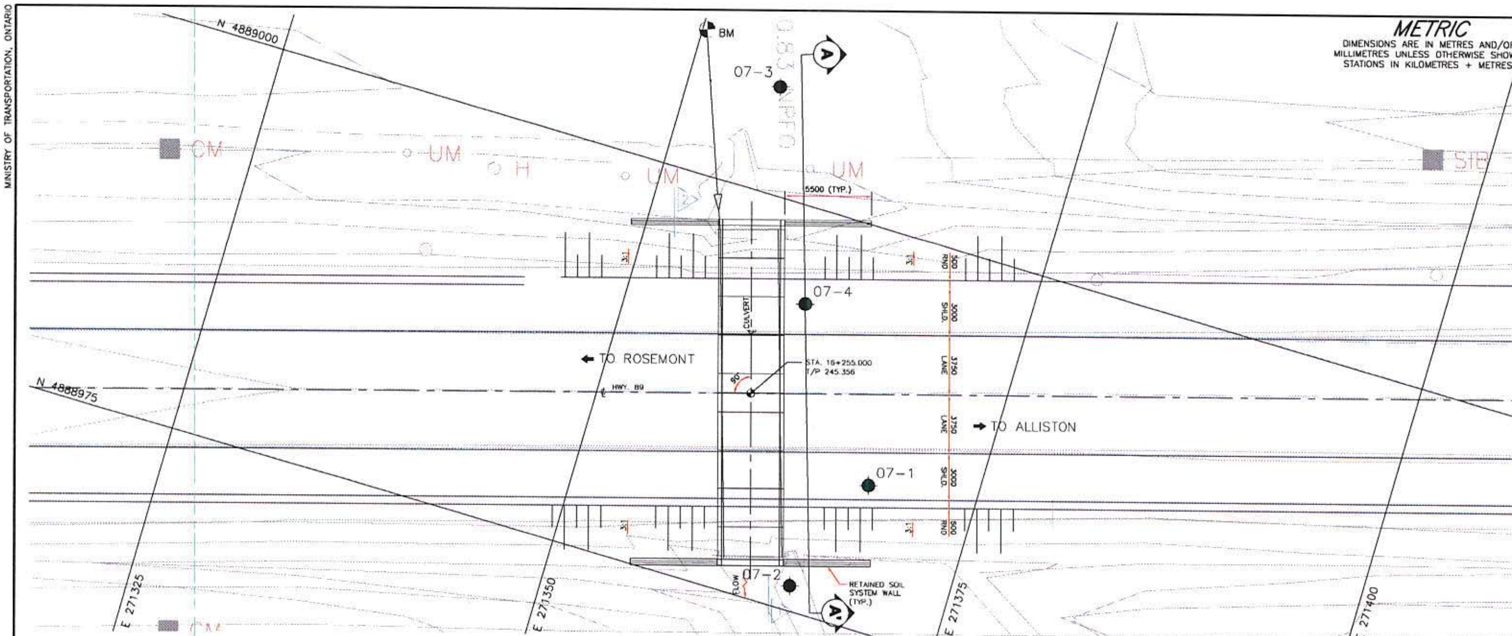
2. Water level in piezometer at a depth of 4.8 m (Elev. 240.1 m) upon completion of piezometer installation on September 26, 2007.

3. Water level in piezometer at a depth of 2.1 m (Elev. 242.8 m) below ground surface on October 15, 2007.

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³

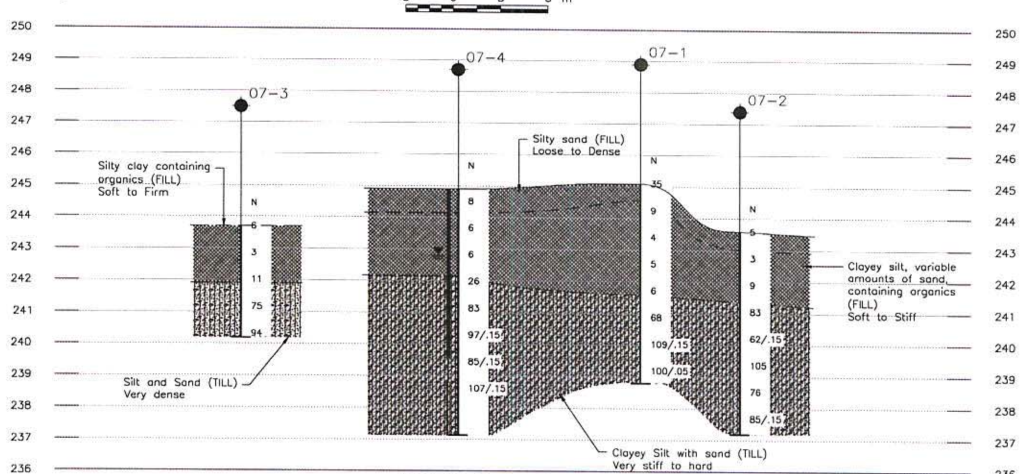
$+^3, \times^3$: Numbers refer to Sensitivity $O^{3\%}$ STRAIN AT FAILURE

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



PLAN

SCALE 3 0 3 6 m



PROFILE A–A'

SCALE HOR. 3 0 3 6 m

SCALE VERT. 1.5 0 1.5 3 m

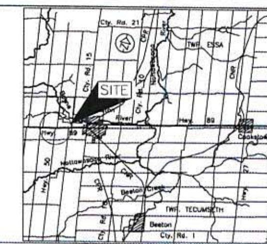
CONT No.
WP No. 2479-04-00

SHEET

HWY 89
CULVERT REPLACEMENT AT STATION 16+255
BOREHOLE LOCATION AND SOIL STRATA

Golder Associates

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



KEY PLAN
NOT TO SCALE

LEGEND

- ● Borehole – Current Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- WL in piezometer, measured on October 15, 2007

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
07-1	245.1	4888984.1	271368.2
07-2	243.6	4888976.6	271365.2
07-3	243.7	4889006.6	271355.7
07-4	244.9	4888994.0	271361.1

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.

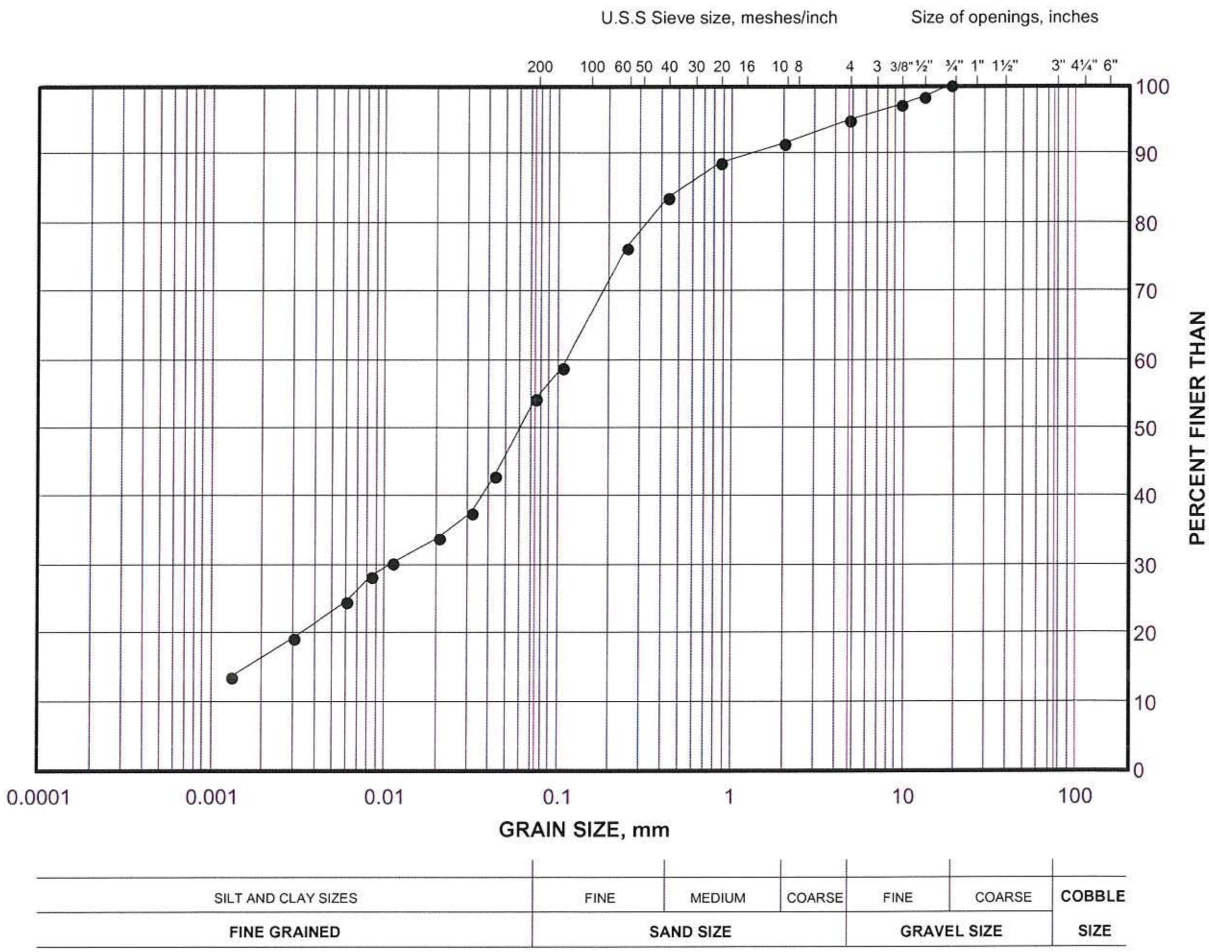
REFERENCE

Base plans provided in digital format by MRC, drawing file no. 1 entitled "HWY 89 Culvert at sta. 16+255 general arrangement", dated Jan. 2007, received Nov. 23, 2007.

NO.	DATE	BY	REVISION

Geocres No. 31D-451			
HWY.		PROJECT NO. 05-1111-034	DIST.
SUBM'D.	CHKD.	DATE: 20-Jan-2009	SITE: 30-545C
DRAWN: DD	CHKD. HJ	APPD. JMAC	DWG. 1

GRAIN SIZE DISTRIBUTION Clayey Silt with Sand (Fill)	FIGURE 1



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	07-2	3	241.8

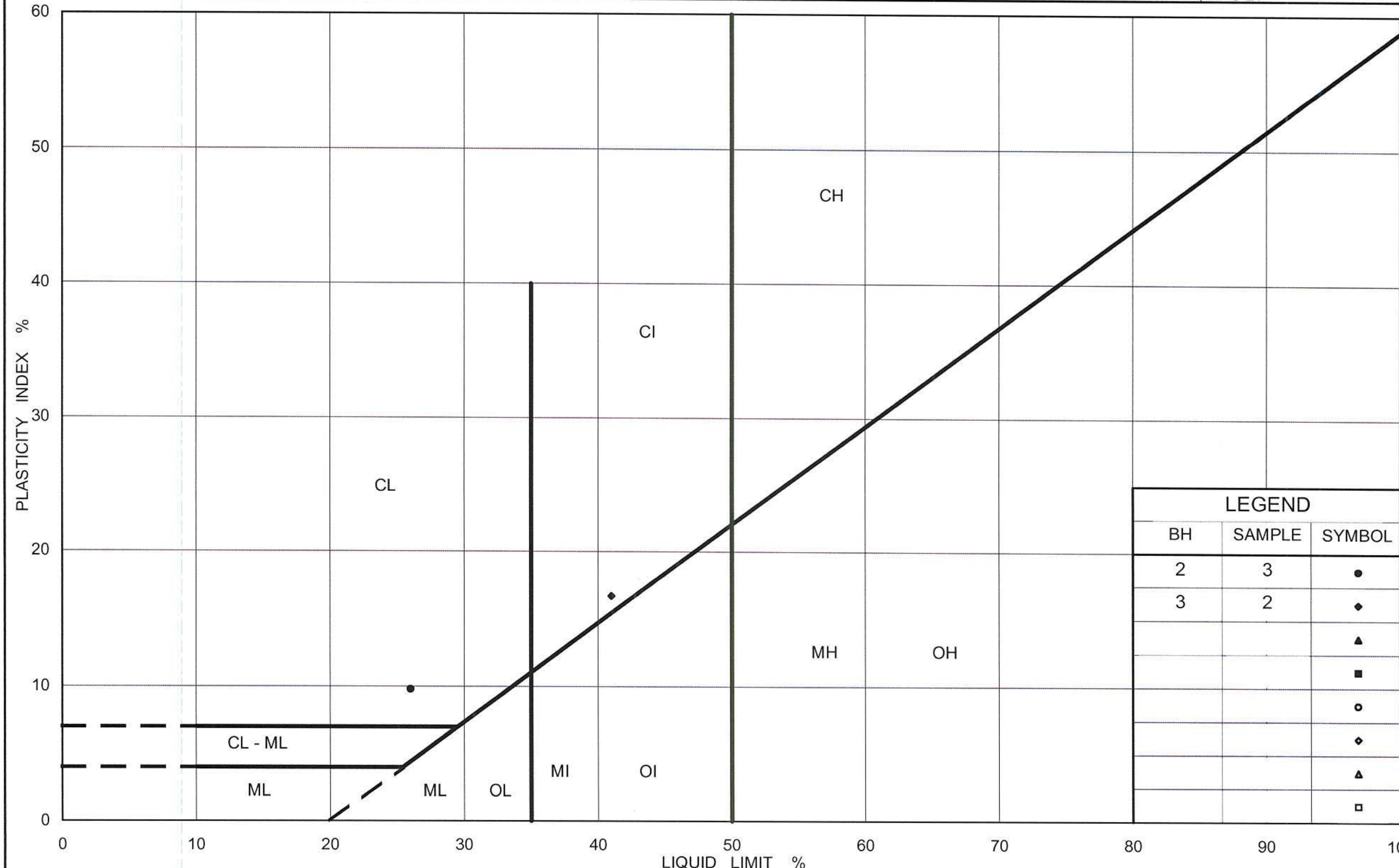
Project Number: 05-1111-034

Checked By: ______________________

Golder Associates

Date: 17-Dec-07

Oct 75, FF-S-21



LEGEND		
BH	SAMPLE	SYMBOL
2	3	●
3	2	◆
		▲
		■
		○
		◇
		△
		□

Ministry of Transportation

Ontario

PLASTICITY CHART
Clayey Silt to Silty Clay Fill

Figure No. 2

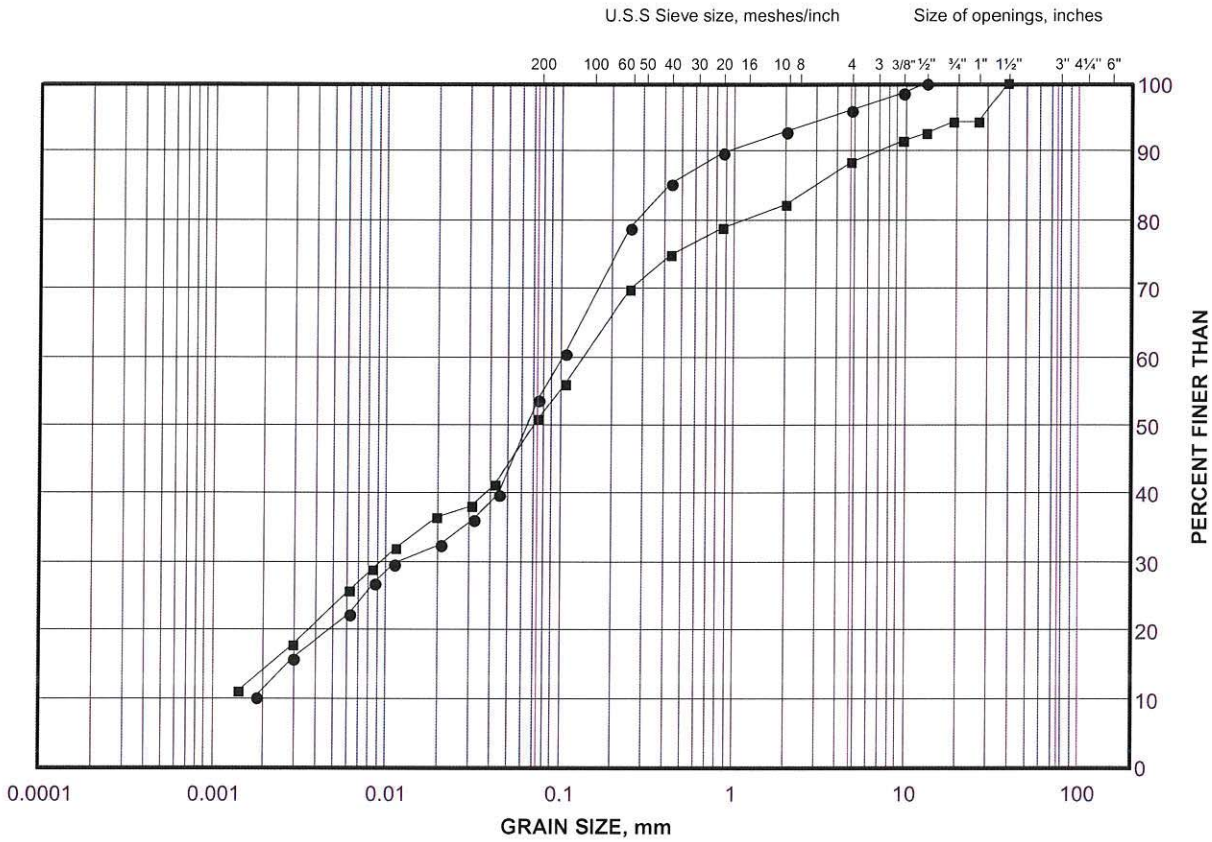
Project No. 05-1111-034

Checked By:

GRAIN SIZE DISTRIBUTION

Clayey Silt with Sand (Till)

FIGURE 3



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	07-4	7	238.8
■	07-1	7	240.5

Project Number: 05-1111-034

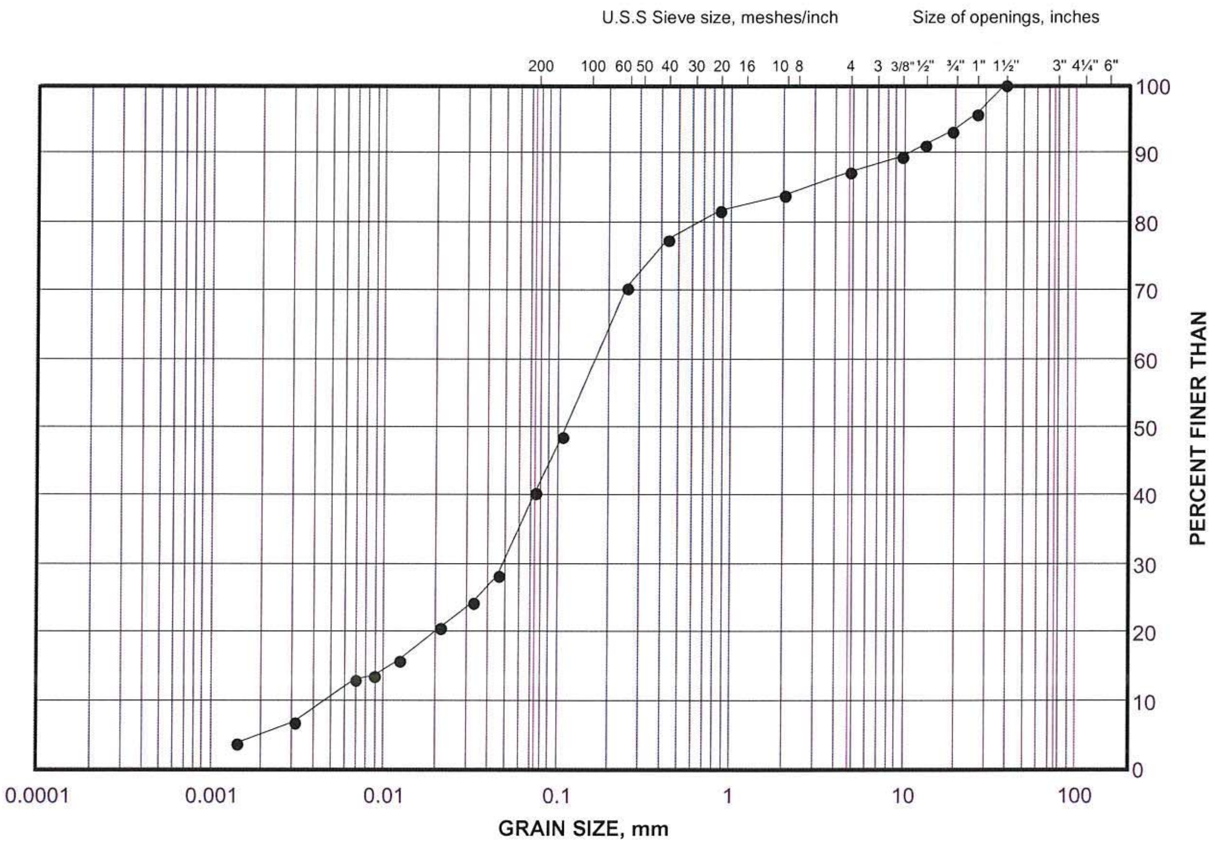
Checked By: ____________________

Golder Associates

Date: 17-Dec-07

GRAIN SIZE DISTRIBUTION
Silt and Sand (Till)

FIGURE 4



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	07-3	4	241.2

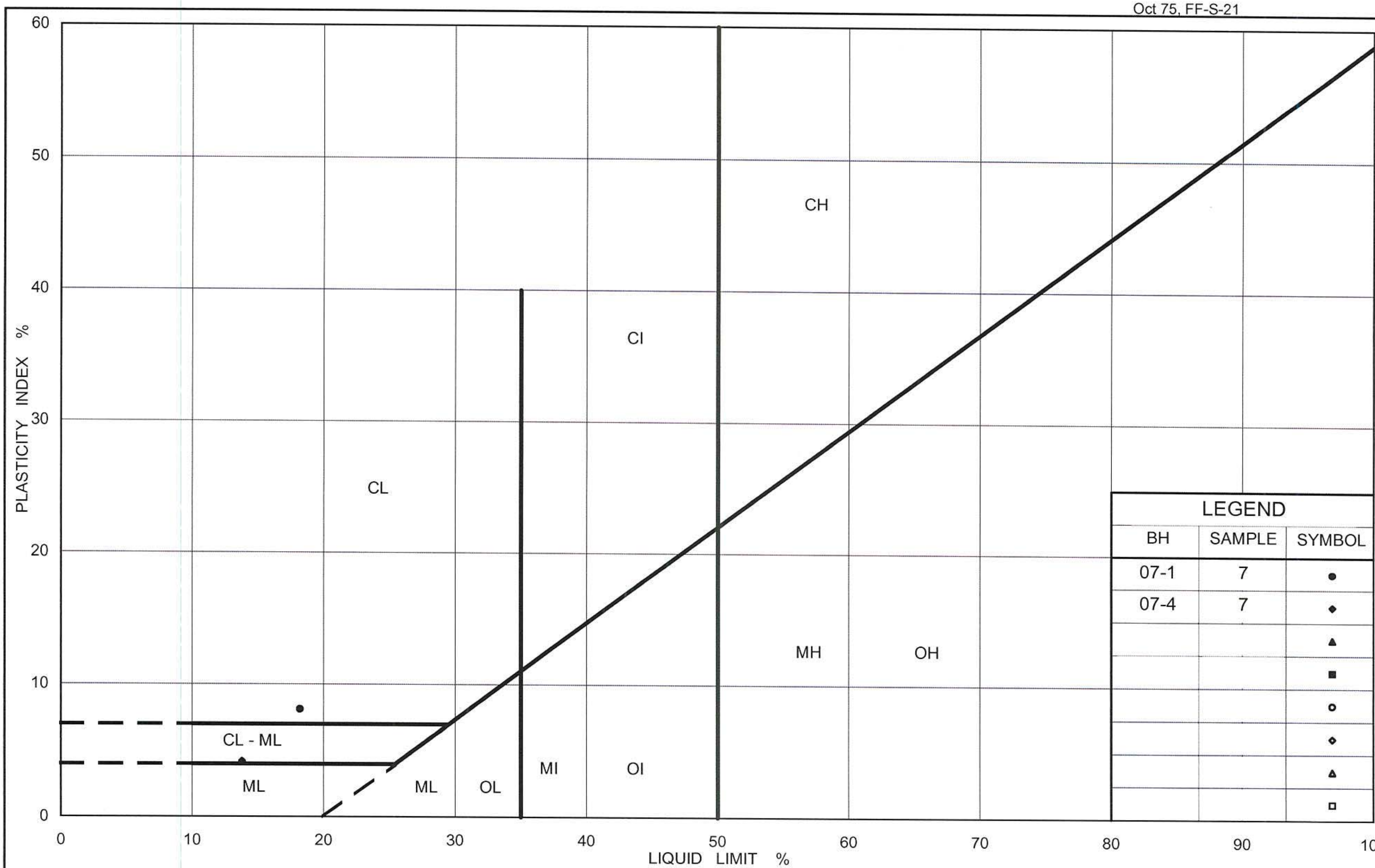
Project Number: 05-1111-034

Checked By: ______________________

Golder Associates

Date: 17-Dec-07

Oct 75, FF-S-21



BH	SAMPLE	SYMBOL
07-1	7	●
07-4	7	◆
		▲
		■
		○
		◇
		△
		□

Ministry of Transportation

Ontario

PLASTICITY CHART
Clayey Silt Till

Figure No. 5

Project No. 05-1111-034

Checked By:

APPENDIX A

NON-STANDARD SPECIAL PROVISION

SUBGRADE PROTECTION - ITEM NO.

Special Provision **January 2009**

1.0 Scope

The work under this item shall include the supply and placement of lean mix concrete, with a minimum thickness of 150 mm, on the founding level for the footings within four (4) hours of subgrade preparation and inspection.

Lean concrete should have a compressive strength of at least 5 MPa and be placed in accordance with OPSS904

2.0 Basis of Payment

Payment at the contract price for the above tender item shall include full compensation for all labour and materials to complete the work.

END OF SECTION

Appendix F

Foundation Alternatives Comparisons

List of Referenced Specifications

COMPARISON OF CULVERT ALTERNATIVES

Comment	Circular Pipe	Concrete - Open Footing Culvert	Concrete Box (closed) Culvert
Advantages	Quick installation	NA	Quick installation procedure due to use of pre-cast sections Wider base provides better load distribution and higher bearing resistance.
Disadvantages	Multiple pipes required to provide equivalent hydraulic opening	Lower bearing resistance	NA
Risks/ Consequences	NA	Potential for base disturbance if groundwater not controlled / added cost and schedule delays	Potential for base disturbance if groundwater not controlled / added cost and schedule delays
Relative Cost	low	moderate	moderate
	NOT FEASIBLE	**FEASIBLE**	**RECOMMENDED**

THURBER

COMPARISON OF CONSTRUCTION METHODOLOGY OPTIONS

Comment	Open Cut with Full Road Closure	Staged Open Cut with Roadway Protection	Staged Open Cut with embankment widening	Trenchless
Advantages	Quick installation Simple construction	Quick installation	Quick installation Simple construction	Avoids open cut. Less traffic impacts.
Disadvantages	Significant traffic impacts Requires water/groundwater control	Traffic impacts Requires roadway protection likely supported with anchoring system Requires water/groundwater control	Traffic impacts on Hwy 12 and may impact Concession Rd 10 Requires temporary extensions to culvert Requires water/groundwater control	High mobilization costs Potential face instability due to very loose saturated cohesionless soil. Requires water/groundwater control Multiple pipes required
Risks / Consequences	Dewatering challenges / extended closure of highway	Lowest risk option	Pockets of organics within footprint of embankment widening/ increase in subgrade preparation costs	Disturbance to pavement surface due to limited cover
Relative Cost	low	moderate	moderate	high
	NOT FEASIBLE	**RECOMMENDED**	**FEASIBLE**	**NOT FEASIBLE**

THURBER

List of Referenced Specifications

OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSS 206	Construction Specification for Grading
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS 501	Construction Specification for Compacting
OPSS 539	Construction Specification for Temporary Protection Systems
OPSS 804	Construction Specification for Seed and Cover
OPSS 902	Construction Specification for Excavating and Backfilling-Structures
OPSS 1205	Material Specification for Clay Seal

THURBER