

Golder Associates Ltd.

2390 Argentia Road
Mississauga, Ontario, Canada L5N 5Z7
Telephone 905-567-4444
Fax 905-567-6561



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FOUNDATION
INVESTIGATION AND DESIGN REPORT
CULVERT EXTENSIONS
QEW WIDENING FROM HIGHWAY 406
TO GARDEN CITY SKYWAY
ST. CATHARINES, ONTARIO
G.W.P 607-00-00

Submitted to:

Morrison Hershfield
235 Yorkland Boulevard, Suite 600
Toronto, Ontario
M2J 1T1

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PART A

**FOUNDATION INVESTIGATION REPORT
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield (MH) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services associated with the widening of the Queen Elizabeth Way (QEW) between Highway 406 and the Garden City Skyway in the City of St. Catharines, in the Region of Niagara. Foundation engineering services are required for the widening or replacement of five structures (Third Street overpass, Martindale Road underpass, Lake Street underpass, Geneva Street overpass, and Welland Avenue overpass), new retaining walls and noise barrier walls, culvert extensions, and high mast light poles.

This report addresses the proposed extension of three existing structural culverts, associated with the widening of the QEW. A foundation investigation has been carried out to determine the subsurface conditions at each of the proposed culvert extension locations, as identified in the following table:

<i>Culvert Location</i>	<i>Structure Site No.</i>	<i>Comments</i>
Station 18+635	18-285C	Northward extension of existing access tunnel, west of Third Street
Station 19+166	18-286C	Southward extension of Richardson Creek culvert, 100 m east of the QEW-Highway 406 interchange
Station 19+465	18-287C	Northward extension of Grapeview Creek culvert, 350 m east of the QEW-Highway 406 interchange

The terms of reference and scope of work for the foundation investigation are outlined in MTO's Request for Proposal for Agreement No. 2005-A-000564, issued in July 2002, and in Section 6.8 of MH's *Technical Proposal* for G.W.P. 607-00-00.

2.0 SITE DESCRIPTION

The three culvert sites addressed in this report are located along the QEW in the vicinity of Third Street, Highway 406 and Martindale Road, in the City of St. Catharines, in the Region of Niagara. The overall surface topography along the QEW in this area is flat-lying to gently sloping toward Lake Ontario (to the north).

The access tunnel, located along the QEW about 200 m west of Third Street and used for local access from the north to the south side of the QEW, is a 3.0 m wide by 2.7 m high concrete structure of unknown foundation type. At this site, the natural ground surface is at about Elevation 88 m and the QEW has been constructed on embankment fill with its grade at approximately Elevation 93 m. To the northeast of the access tunnel, an approximately 6 m high stockpile of earth fill is present.

The Richardson Creek culvert is located along the QEW approximately 120 m east of Highway 406. This structure consists of a 3.7 m wide by 2.4 m high concrete rigid frame box culvert, with its invert at approximately Elevation 78.9 m. At this location, the natural ground surface is at about Elevation 81 m, and the QEW grade is at about Elevation 88 m.

The Grapeview Creek culvert is located approximately 400 m east of Highway 406. This structure consists of a 3.0 m wide by 1.8 m high concrete rigid frame box culvert, with its invert at approximately Elevation 82.9 m. The natural ground surface in the vicinity of Grapeview Creek is at approximately Elevation 83 m, and the QEW grade at about Elevation 90 m to 91 m.

3.0 INVESTIGATION PROCEDURES

A subsurface investigation was carried out by Golder at the culvert extension locations in May and June 2005. A total of six boreholes (Boreholes C1-1, C1-2, C2-1, C2-2, C3-1 and C3-2) were advanced, with two boreholes advanced within or near each of the three proposed culvert extensions. The borehole locations are shown on Drawing 1.

The boreholes were drilled using a track-mounted drill rig, supplied and operated by Walker Drilling Ltd. of Utopia, Ontario. The boreholes were advanced using solid stem augers to depths ranging from 7.9 m to 12.8 m below the existing ground surface. Samples of the overburden were obtained at 0.75 m and 1.5 m intervals of depth, using 50 mm outside diameter split-spoon samplers driven by an automatic hammer in accordance with the Standard Penetration Test (SPT) procedure. The water level in the open boreholes was observed throughout the drilling operations, and a standpipe piezometer was installed in one borehole at each culvert location to monitor the groundwater level at each site.

The field work was supervised on a full-time basis by a member of Golder's staff who located the boreholes in the field, directed the drilling, sampling, and 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 testing. Index and classification tests (water content determinations, Atterberg limits tests, and grain size distribution tests) were carried out on selected soil samples.

The borehole locations were measured relative to known site features, and the ground surface elevations were determined from the digital terrain model (DTM) for this project. The borehole locations (MTM NAD83 northing and easting coordinates) and ground surface elevations (referenced to geodetic datum) are summarized in the following table and are shown on Drawings 1 and 2.

<i>Culvert Location</i>	<i>Borehole Number</i>	<i>MTM NAD83 Northing (m)</i>	<i>MTM NAD83 Easting (m)</i>	<i>Ground Surface Elevation (m)</i>
Station 18+635 North Side	C1-1	4782054.3	321860.1	88.6
	C1-2	4782064.3	321860.1	88.3
Station 19+166 South Side	C2-1	4781948.3	322381.7	81.0
	C2-2	4781943.3	322380.9	81.0
Station 19+465 North Side	C3-1	4781976.0	322689.8	83.5
	C3-2	4781996.7	322712.9	82.0

4.0 SITE GEOLOGY AND STRATIGRAPHY

4.1 Regional Geological Conditions

This area of the QEW lies within the Iroquois Plain physiographic region, as delineated in *The Physiography of Southern Ontario*¹ and *Urban Geology of Canadian Cities*².

The Iroquois Plain extends around the western shores of Lake Ontario; on the south side of the lake, in the St. Catharines area, the Plain is located between the present Lake Ontario shorebluffs and the foot of the Niagara Escarpment. The Plain is comprised of the flat to undulating lake bed and beaches of the former glacial Lake Iroquois, which occupied this area during the last glacial recession.

The surficial soils in the Iroquois Plain are typically comprised of glaciolacustrine clays and silts. However, in the St. Catharines area, surficial deposits of beach sand and gravel are present. The surficial sands, silts and clays are underlain by an extensive till deposit; portions of the till are considered to be “water-lain” (that is, formed by sediment rain-out either from a floating ice margin or from iceberg dumping), resulting in a predominantly massive, matrix-supported structure, as well as relatively thin sand to silt stringers or interlayers. This extensive till deposit may be underlain by or interlayered with a lower glaciolacustrine clay deposit, although this glaciolacustrine layer is absent in some portions of the Iroquois Plain in the St. Catharines area. Finally, the till and/or glaciolacustrine layer may be underlain by a lower till unit, that typically has increasing gravel content with proximity to the underlying bedrock (Menzies and Taylor, 1998).

The overburden soils are underlain by red shale bedrock of the Queenston Formation. This shale formation contains siltstone interlayers as well as “occasional patches of gypsum” (Menzies and Taylor, 1998).

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.

² J. Menzies and E.M. Taylor. “Urban Geology of St. Catharines-Niagara Falls, Region Niagara”. In *Urban Geology of Canadian Cities*, Geological Association of Canada Special Paper 42, Ed. P.F. Karrow and O.L. White, 1998.

4.2 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of the in situ and laboratory testing are given on the borehole records and on Figures 1 to 6 following the text of this report. The stratigraphic boundaries shown on the borehole records are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

In summary, the native subsoil conditions encountered at the culvert extension sites consist of a thin surficial deposit of firm to very stiff clayey silt to silty clay, underlain by a till deposit that typically consists of stiff to hard clayey silt; at the Richardson Creek culvert site, the clayey silt till grades to a compact to very dense silty sand to sandy silt till; and at the Grapeview Creek culvert site, the clayey silt till contains water-bearing cohesionless interlayers that range in composition from silty sand to silt.

A detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections. Stratigraphic profiles at the culvert locations are shown on Drawing 2.

4.2.1 Topsoil

Approximately 100 mm of topsoil was encountered immediately below the ground surface in Borehole C1-1, at the access tunnel location.

4.2.2 Fill

Between 0.7 m and 1.5 m of fill was encountered immediately below the topsoil or ground surface at all of the culvert sites, as follows:

- In Borehole C1-1 at the access tunnel site, 0.7 m of fill was encountered below Elevation 88.5 m (below the topsoil);
- In Boreholes C2-1 and C2-2 at the Richardson Creek culvert site, 0.8 m of fill was encountered below Elevation 81.0 m (immediately below the ground surface); and
- In Borehole C3-1 at the Grapeview Creek culvert site, 1.5 m of fill was encountered below Elevation 83.5 m (immediately below the ground surface).

The fill typically consists of clayey silt containing some sand, trace gravel, and trace quantities of organic material, except in Borehole C1-1 at the access tunnel site, where the fill is comprised of silty sand containing some gravel and trace quantities of organic material.

The measured SPT “N” values within the fill range from 8 to 18 blows per 0.3 m of penetration; based on these results, the clayey silt fill has a stiff to very stiff consistency, and the silty sand fill has a compact relative density.

4.2.3 Surficial Clayey Silt to Silty Clay

A 0.6 m to 1.5 m thick layer of surficial clayey silt to silty clay was encountered at the culvert sites as follows:

- At the access tunnel site, 0.8 m of surficial clayey silt was encountered below Elevation 88.3 m (immediately below the ground surface) in Borehole C1-2; the surficial clayey silt was absent in Borehole C1-1 at this site.
- At the Richardson Creek culvert site, 1.5 m and 0.6 m of surficial clayey silt was encountered below Elevation 80.2 m (below the fill) in Boreholes C2-1 and C2-2, respectively.
- At the Grapeview Creek culvert site, 0.8 m of surficial silty clay was encountered below Elevation 82.0 m (below existing fill) in Borehole C3-1, and 0.8 m of surficial clayey silt was encountered below Elevation 82.2 m (immediately below the ground surface) in Borehole C3-2.

This surficial deposit consists of clayey silt to silty clay containing some sand, trace to some gravel, and trace quantities of organic material. The results of grain size distribution testing conducted on two selected samples of the surficial clayey silt to silty clay are shown on Figure 1.

Atterberg limits testing was carried out on three selected samples of this surficial deposit, and measured plastic limits of 16 to 23 per cent, liquid limits of 25 to 37 per cent, and plasticity indices of 10 to 14 per cent. The results, which are plotted on a plasticity chart on Figure 2, confirm that this material varies from a clayey silt of low plasticity to a silty clay of intermediate plasticity.

The measured SPT “N” values within this stratum range from 4 to 17 blows per 0.3 m of penetration, indicating that the surficial clayey silt to silty clay has a firm to very stiff consistency.

4.2.4 Clayey Silt Till

The fill (where present) and surficial clayey silt to silty clay are underlain by a till deposit, the surface of which was encountered at the culvert sites as follows:

- At the access tunnel, the surface of the till was encountered at Elevation 87.8 m and 87.5 m in Boreholes C1-1 and C1-2, respectively (at a depth of 0.8 m in both boreholes). The clayey silt till deposit is at least 12 m in thickness at this site.
- At the Richardson Creek culvert site, the surface of the clayey silt till was encountered at Elevation 78.7 m (a depth of 2.3 m) in Borehole C2-1, and at Elevation 79.6 m (at a depth of 1.4 m) in Borehole C2-2. The clayey silt till deposit is approximately 3.2 m to 3.8 m in thickness at this site.
- At the Grapeview Creek culvert site, the surface of the clayey silt till was encountered at Elevations 81.2 m and 81.4 m in Boreholes C3-1 and C3-2, respectively (at depths of 2.3 m and 0.8 m at these locations). The clayey silt till deposit is at least 6.8 m to 9.9 m thick, including interlayers, at this site.

The till deposit consists of clayey silt containing trace to some sand and trace gravel; cobbles were noted within the clayey silt till below a depth of 4.6 m in Borehole C1-1. Silty sand seams were observed within the clayey silt till in Boreholes C1-1 and C3-2, and thicker interlayers of silty sand to silt were encountered within the till at the Grapeview Creek culvert site (Boreholes C3-1 and C3-2); such interlayers are discussed separately under Section 4.2.6. The results of grain size distribution testing conducted on three selected samples of the clayey silt till are presented on Figure 3.

Atterberg limit testing was conducted on ten selected samples of the clayey silt till, and measured plastic limits of 12 to 17 per cent, liquid limits of 18 to 30 per cent, and plasticity indices of 6 to 13 per cent. The results, which are plotted on a plasticity chart on Figure 4, confirm that this till is a clayey silt of low plasticity.

The consistency of the clayey silt till deposit varies as follows:

- At the access tunnel site (Boreholes C1-1 and C1-2), the upper 3 m of the clayey silt till deposit has a firm to stiff consistency, based on measured SPT “N” values of 5 to 9 blows per 0.3 m of penetration; however, an in situ vane shear test measured an undrained shear strength exceeding 100 kPa, suggesting that this material has a stiff to very stiff consistency. Below this, the clayey silt till has a very stiff to hard consistency, based on measured SPT “N” values of 15 to 50 blows per 0.3 m of penetration.
- At the Richardson Creek culvert site (Boreholes C2-1 and C2-2), the clayey silt till has a stiff to very stiff consistency, based on measured SPT “N” values that range from 12 to 29 blows per 0.3 m of penetration.
- At the Grapeview Creek culvert site (Boreholes C3-1 and C3-2), the measured SPT “N” values range from 9 to 92 blows per 0.3 m of penetration, but are typically between 12 and 40 blows per 0.3 m of penetration. Based on these results, the clayey silt till at this culvert site typically has a stiff to hard consistency.

4.2.5 Silty Sand to Sandy Silt Till

In Boreholes C2-1 and C2-2 at the Richardson Creek culvert site, the clayey silt till grades to a non-plastic till below 6.1 m and 4.6 m depth, respectively; the surface of the non-plastic till was encountered in these boreholes between Elevations 74.9 m and 76.4 m, and the layer is 4.6 m thick as encountered in Borehole C2-1, where it was fully penetrated. A 0.8 m thick interlayer of non-plastic till was also encountered within the clayey silt till in Borehole C3-2 at the Grapeview Creek culvert site; the surface of this cohesionless till layer was encountered at about Elevation 79.7 m (at a depth of approximately 2.3 m).

The non-plastic till varies in composition from silty sand, to sand and silt, to sandy silt, containing trace to some clay and trace gravel. The results of grain size distribution tests carried out on three selected samples of the silty sand to sandy silt till are shown on Figure 5.

The measured SPT "N" values in the silty sand to sandy silt till are typically greater than 79 blows per 0.3 m of penetration, indicative of a very dense relative density. However, an SPT "N" value of 23 blows per 0.3 m of penetration was measured near the surface of this deposit in Borehole C2-2, indicating that the upper portion of the silty sand to sandy silt till at this location has a compact relative density.

4.2.6 Silty Sand to Silt Interlayers Within Clayey Silt Till

Wet cohesionless soil interlayers were encountered within the clayey silt till deposit in Boreholes C3-1 and C3-2, which were advanced at the Grapeview Creek culvert site. The layers range in composition from silty sand containing trace to some gravel, to silt containing trace clay and sand; the result of a grain size distribution test on one selected sample of the silt interlayer is shown on Figure 6.

The silty sand to silt interlayers were encountered at approximately Elevation 75.4 m to 74.4 m (about 7.6 m depth) in Boreholes C3-1 and C3-2, respectively. The silty sand interlayer was found to be approximately 3.1 m thick in Borehole C3-1, where it was fully penetrated; Borehole C3-2 was terminated after 0.6 m of penetration into a silt interlayer. A second silty sand interlayer was encountered at the base of Borehole C3-1, below Elevation 70.8 m (at a depth of approximately 12.2 m); this borehole was terminated approximately 0.2 m into this interlayer.

The measured SPT "N" values within the silty sand to silt interlayers vary from 9 to 19 blows for the interlayers encountered at about 7.6 m depth (indicative of a loose to compact relative density). The interlayer encountered at the base of Borehole C3-1, below Elevation 70.8 m, has a very dense relative density, based on one measured SPT "N" value of greater than 100 blows per 0.3 m of penetration.

4.2.7 Bedrock

Red shale bedrock of the Queenston Formation was encountered at Elevation 70.3 m (at a depth of 10.7 m below ground surface) in Borehole C2-1, which is located at the Richardson Creek culvert extension. This borehole was extended 1.6 m into the shale bedrock by augering and split-spoon sampling. The measured SPT "N" values within the shale bedrock were greater than 100 blows per 0.3 m of penetration.

4.3 Groundwater Conditions

The silty sand to sandy silt till soils and the seams/interlayers of silty sand to silt were observed to be wet during drilling operations. The water level observed in the open boreholes during and upon completion of drilling varied between 1.5 m and 6.0 m depth below the ground surface.

A standpipe piezometer was installed in one borehole at each site to monitor the groundwater level; the following table summarizes the water levels measured in the piezometers:

<i>Borehole No.</i>	<i>Culvert Location</i>	<i>August 8, 2005</i>		<i>December 6, 2005</i>	
		<i>Depth</i>	<i>Elevation</i>	<i>Depth</i>	<i>Elevation</i>
C1-1	Access Tunnel	2.5 m	86.1 m	2.2 m	86.4 m
C2-1	Richardson	0.3 m	80.7 m	0.2 m above g.s.	81.2 m
C3-2	Grapeview	1.3	80.7 m	0.9 m	81.1 m

It should be noted that the groundwater levels at the culvert sites are anticipated to fluctuate as a result of seasonal variations in precipitation, runoff, temperature and creek water levels.


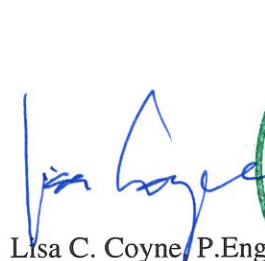
5.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Shannon Palmer, EIT, and reviewed by Ms. Lisa Coyne, P. Eng., an Associate and geotechnical engineer with Golder. Mr. Fintan Heffernan, P.Eng., a Designated MTO Contact for Golder, conducted an independent review of the report.


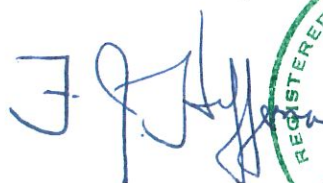
GOLDER ASSOCIATES LTD.



Shannon Palmer, EIT
Geotechnical Group



Lisa C. Coyne, P.Eng.
Associate



Fintan J. Heffernan, P.Eng.
Designated MTO Contact

SLP/LCC/FJH/lcc

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PART B

**FOUNDATION DESIGN REPORT
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6.0 ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the proposed culvert extensions associated with the widening of the QEW. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigations at the site. The interpretation and recommendations provided are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to design the foundations for the proposed culvert extensions. Where comments are made on construction they are provided in order to highlight those aspects which could affect the design of the project, and for which special provisions or operational constraints may be required in the Contract Documents. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods, scheduling and the like.

6.1 General

The following table summarizes the size and type of the existing culverts, along with the proposed invert elevation and length for the proposed extensions.

Culvert	Station	Existing Culvert Type	Invert Elevation for Extension	Extension Length
Access Tunnel	18+635 North Side	2.7 x 3.0 m (Unknown Culvert Type)	Approx. 88.6 m	6 m
Richardson Creek	19+166 South Side	3.7 x 2.4 m (Rigid Frame Box Culvert)	78.9 m	10 m
Grapeview Creek	19+465 North Side	3.0 x 1.8 m (Rigid Frame Box Culvert)	82.9 m	5 m

Based on the subsurface conditions at the culvert extension locations and the anticipated loading under the widened embankments, it is recommended that box culvert extensions be adopted or that the culverts and any associated headwalls be supported on shallow foundations; consideration could be given to subexcavation of the firm surficial clayey silt to silty clay and/or the upper firm portion of the clayey silt till (see Section 6.2) in order to minimize settlements under the culvert extension and embankment loading. The use of deep foundations is not recommended since a suitable founding stratum is present at or near the proposed invert/founding level for the culvert extensions.

It is understood that, at this time, box culvert extensions are planned for all three culvert locations. New wingwalls are planned for the access tunnel culvert extension.

6.2 Subexcavation Requirements

Based on the borehole results, some subexcavation is recommended for the culvert extensions in order to minimize settlement of the culvert extensions, as follows:

- At the access tunnel site, the proposed extension invert is expected to be at approximately Elevation 88.6 m. Allowing for the thickness of the box base slab and granular bedding, it is anticipated that a box culvert extension would be founded at about Elevation 88 m and therefore the subgrade for this extension will consist of a minor thickness of compact silty sand fill and stiff surficial clayey silt over firm to stiff clayey silt till. Subexcavation of the silty sand fill should be carried out. Spread footings for the associated wingwalls should be founded at or below Elevation 87.5 m provided that a minimum of 1.2 m of soil cover (or equivalent) is provided for frost protection purposes.
- At the Richardson Creek culvert extension, the proposed invert elevation will be at approximately Elevation 78.9 m. Allowing for the thickness of the box base slab and bedding, the subgrade for this culvert extension will consist of stiff to very stiff clayey silt till. No subexcavation is required at this location beyond that required to place the culvert bedding (as discussed in Section 6.4). Spread footings for any associated headwalls, if they are adopted, should be founded at or below Elevation 78.5 m, provided that a minimum of 1.2 m of soil cover (or equivalent) is provided for frost protection purposes.
- At the Grapeview Creek culvert extension, the proposed invert elevation will be at about Elevation 82.9 m. Allowing for the thickness of the box base slab plus the granular bedding material, the subgrade for this box culvert extension would consist of existing fill and/or firm surficial clayey silt to silty clay. A box culvert extension could be founded at approximately Elevation 82 m, or consideration could be given to subexcavation of the firm surficial clayey silt to silty clay from under the box culvert extension, down to Elevation 81 m, in order that the extension be founded on the very stiff to hard clayey silt till.

The width to be subexcavated should be defined by lines extending from the outside edges of the culvert outward and downward at 1 horizontal to 1 vertical (1H:1V). Depending on the depth of subexcavation relative to the existing culvert base, some temporary excavation support may be required to prevent loss of bedding material and/or native soils from below the existing culvert during subexcavation.

The subgrade should be inspected following subexcavation to ensure that all soft clayey materials have been removed, then the subexcavated area should be replaced with Ontario Provincial Standard Specification (OPSS) Granular "A" or Granular "B" backfill that is placed and compacted in accordance with the requirements of MTO's Special Provision SP105S10.

Some water seepage into the subexcavations could occur, depending on the occurrence of sandy seams/lenses within the cohesive till. It is expected that the quantity of seepage could be handled

with the use of sumps within the excavation. More significantly, it will be necessary to control the surface water in Richardson and Grapeview Creeks; further discussion on this aspect is provided in Section 6.7.1.

6.3 Foundations

For any headwalls / wingwalls associated with the box culvert extensions, spread footings should be placed at a minimum depth of 1.2 m below the lowest surrounding grade, in order to provide adequate protection against frost penetration, notwithstanding any requirements for subexcavation as identified in Section 6.2.

At the access tunnel site, footings for the new wingwalls should be founded at or below Elevation 87.5 m.

At the Richardson Creek culvert site, footings for any wingwalls/headwalls should be founded at or below Elevation 78.5 m.

At the Grapeview Creek culvert site, footings for any headwalls associated with the proposed box culvert extension should either be extended to Elevation 81 m or be founded on compacted granular fill material that is placed following subexcavation to Elevation 81 m.

6.3.1 Bearing Resistance

Strip footings placed on the properly prepared subgrade, at or below the design elevations discussed above and provided in the following table, should be designed based on the following factored geotechnical resistances at Ultimate Limit States (ULS) and geotechnical resistances at Serviceability Limit States (SLS). These values are based on a 1 m wide footing. The ULS resistance and settlement are dependent on the footing size, configuration and applied loads; the geotechnical resistances should, therefore, be reviewed once the final geometry of the foundations has been established.

Culvert	Station	Relevant Boreholes	Extension Invert Elevation	Founding Elevation	Factored Resistance at ULS	Resistance at SLS*
Access Tunnel	18+635	C1-1, C1-2	Approx. 88.6 m	87.5 m	225 kPa	150 kPa
Richardson	19+166	C2-1, C2-2	78.9 m	78.5 m	450 kPa	300 kPa
Grapeview	19+465	C3-1, C3-2	82.9 m	82 m	225 kPa	150 kPa
				81 m	350 kPa	250 kPa

* For 25 mm of settlement.

The geotechnical resistances provided in this section are given under the assumption that the loads will be applied perpendicular to the surface of the footings. Where the load is not applied

perpendicular to the surface of the footing, inclination of the load should be taken into account in accordance with the *Canadian Highway Bridge Design Code (CHBDC)*.

6.3.2 Settlement Assessment

Some settlement of the clayey subsoils will occur as a result of placement of the embankment widening fill at the culvert extension locations.

A settlement assessment was carried out for the proposed embankments using UNISSETTLE (V3.0), a commercially available computer software program. The settlement of the firm to stiff surficial clayey silt to silty clay was modelled using compression and recompression indices that were derived based on correlations with laboratory data (Atterberg Limits) and review of nearby subsurface information. The void ratio was estimated using the following relationship:

$$e = wG_s/S \quad \text{where} \quad \begin{array}{l} w \text{ is the natural water content (\%)} \\ G_s \text{ is the specific gravity of the material} \\ S \text{ is the degree of saturation (\%)} \end{array}$$

The compression of the stiff to hard clayey silt till and the silty sand to sandy silt till was modelled using elastic deformation moduli based on correlations with the measured SPT "N" values. The parameters used in the analyses are summarized in the following tables:

<i>Soil Unit</i>	<i>Bulk Unit Weight</i>	<i>P_c (kPa)</i>	<i>Void Ratio</i>	<i>C_c</i>	<i>C_r</i>	<i>Elastic Modulus</i>
Access Tunnel:						
Firm to stiff clayey silt till above Elevation 85 m	18 kN/m ³	450	0.35	0.25	0.025	-
Very stiff to hard clayey silt till below Elevation 85 m	21 kN/m ³	-	-	-	-	25-50 MPa
Richardson Creek Culvert:						
Firm surficial clayey silt	18 kN/m ³	450	0.5	0.2	0.02	-
Stiff to very stiff surficial clayey silt and clayey silt till	20 kN/m ³	-	-	-	-	25 MPa
Very dense silty sand to sandy silt Till	21 kN/m ³	-	-	-	-	100 MPa
Grapeview Creek Culvert:						
Firm surficial clayey silt to silty clay above Elevation 81.2 m	18 kN/m ³	250	0.7	0.25	0.025	-
Stiff to hard clayey silt till (including interlayers) between Elevation 81.2 m and 72.3 m	19 kN/m ³	-	-	-	-	20-50 MPa
Hard clayey silt till below Elevation 72.3 m	20 kN/m ³	-	-	-	-	100 MPa

The thickness of embankment widening fill to be placed and the magnitude of predicted settlement at the culvert extensions are summarized as follows:

- At the access tunnel site, a maximum of approximately 1.5 m of additional fill will be placed on top of the existing embankment side slopes, resulting in about 15 mm of total settlement. It is predicted that the upper, firm portion of the clayey silt till that remains in place around the culvert extension will settle up to about 10 mm within approximately six months following placement of the widening fill. The underlying stiff to hard till will undergo about 5 mm of compression during and in a short period following completion of construction.
- At the Richardson Creek culvert site, a maximum of approximately 5 m of fill will be placed at the end of the existing culvert, tapering to 0 m by the end of the extension. The settlement of the foundation soils as a result of this additional embankment loading is anticipated to be about 10 mm to 15 mm. This settlement will be completed relatively quickly (within three to six months) following completion of the widening.
- At the Grapeview Creek culvert site, the cross-sectional information provided by MH shows that about 1 m of additional fill will be placed at the end of the existing culvert as part of the embankment widening and culvert extension. The settlement of the foundation soils as a result of placement of about 1 m of fill is anticipated to be about 5 mm to 10 mm.

6.3.3 Resistance to Lateral Loads

Resistance to lateral forces / sliding resistance between the concrete footings for the culvert extensions and headwalls (if required) and the properly prepared subgrade should be calculated in accordance with Section 6.7.5 of the *CHBDC*. The following table provides values for the coefficient of friction, $\tan \phi'$, assuming cast-in-place concrete footings. The values provided are unfactored; in accordance with the *CHBDC*, a factor of 0.8 is to be applied in calculating the horizontal resistance.

<i>Subgrade Material</i>	<i>$\tan \phi'$</i>
Clayey silt till	0.45
Compacted granular fill at Grapeview Creek culvert extension, if subexcavation and replacement option adopted	0.55

6.4 Bedding and Backfill

Box culvert extensions should be provided with a minimum of 300 mm of OPSS Granular "A" bedding, except where greater thickness of bedding material may be provided following subexcavation of the existing firm to stiff clayey soils as outlined in Section 6.2. The bedding should be placed and compacted in accordance with MTO's Special Provision SP105S10.

Backfill to the culvert walls should consist of granular fill meeting the requirements of OPSS Granular "A" or Granular "B" Type II, but with less than 5 per cent passing the No. 200 sieve. The backfill should be placed and compacted in accordance with MTO's Special Provision SP105S10. The fill depth during placement should be maintained equal on both sides of the culvert walls, with one side not exceeding the other by more than 500 mm.

Backfill above the culverts should also consist of OPSS Granular "A" or Granular "B" fill, to minimize differential settlements along the QEW that could arise as a result of the use of cohesive earth fill. The culverts 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" and 21 kN/m^3 for Granular "B" backfill above and surrounding the culvert.

6.5 Lateral Earth Pressures for Design

The lateral earth pressures acting on the culvert walls and any headwalls will depend on the type and method of placement of the backfill materials, on the nature of the soils behind the backfill, on the magnitude of surcharge including construction loadings, on the freedom of lateral movement of the structure, and on the drainage conditions behind the walls. For this site location, the geotechnical seismic considerations do not affect the design since it is within the lowest seismic zone given in the *CHBDC*.

The design recommendations and parameters that are provided below assume the use of Granular "A" or "B" Type II backfill and an even backfilling process on both sides of the culvert. It is also assumed that the ground surface behind the walls is level. Where there is sloping ground behind the walls (as, for example, with embankment side slopes behind headwalls or retaining walls), the coefficient of lateral earth pressure must be adjusted to account for the slope. Adjusted earth pressure coefficients are provided below for conventional embankment side slopes of 2 horizontal to 1 vertical (2H:1V).

- Longitudinal drains and weep holes should be installed through the headwalls to provide positive drainage of the granular backfill.

- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the walls, in accordance with *CHBDC* Section 6.9.3 and Figure 6.9.3. Compaction equipment should be used in accordance with MTO's Special Provision SP105S10. Other surcharge loadings should be accounted for in the design, as required.
- The granular fill may be placed either in a zone with width equal to at least 1.2 m behind the back of the wall stem (Case I in Figure C6.9.1(I) 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 (Case II in Figure C6.9.1(I) of the *Commentary to the CHBDC*).
- For Case I, the pressures are based on the existing embankment fill materials and the following parameters (unfactored) may be used:

Soil unit weight:	20 kN/m ³
-------------------	----------------------

Coefficients of static lateral earth pressure:

Active, K_a	0.33 (level ground)
	0.53 (2H:1V slope)
At rest, K_o	0.50 (level ground)
	0.80 (2H:1V slope)

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

	Granular 'A'	Granular 'B'
Soil unit weight:	22 kN/m ³	21 kN/m ³

Coefficients of static lateral earth pressure:

Active, K_a	0.27 (level ground)
	0.38 (2H:1V slope)
At rest, K_o	0.43 (level ground)
	0.61 (2H:1V slope)

- If the wall support and superstructure allow lateral yielding of the stem, active earth pressures should be used in the geotechnical design of the structure. If the wall support does not allow lateral yielding, at-rest earth pressures should be assumed for the geotechnical design.

6.6 Erosion Protection

If the Richardson Creek and Grapeview Creek velocities warrant, provision should be made for erosion protection (suitable non-woven geotextiles and/or rip-rap) in the new extension areas.

In order to prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring) or 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 should be provided at the upstream end of the new culvert extension at Grapeview Creek. If a clay seal is adopted, the clay material should meet the requirements of OPSS 1205, and the seal should be extended a minimum horizontal distance of 2 m on either side of the culvert inlet opening, and a minimum vertical height equivalent to the high water level.

6.7 Construction Considerations

6.7.1 Groundwater and Surface Water Control

The native soils at the culvert extension sites are predominantly fine-grained and cohesive, and so groundwater seepage into the excavations for the culvert extensions is expected to be minor; some seepage could occur where sandy seams or lenses are present in the cohesive till within or immediately below the depth of the foundation excavations. It is expected that the quantity of groundwater seepage could be handled with the use of properly filtered sumps within the excavation.

Control of the creek waters will be necessary at the Richardson Creek and Grapeview Creek culvert sites, in order for foundation construction to be carried out in dry conditions. The flow could be passed through or around the culvert area by means of a temporary pipe. Depending on the creek flow at the time of construction, consideration could also be given to the construction of a temporary cofferdam. Assuming that the cofferdam and/or temporary bypass are effective, any seepage into the excavation during normal creek flow conditions should be adequately controlled by pumping from properly filtered sumps within the excavation as noted above.

Surface water should be directed away from the excavation area, to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade; further discussion on this aspect is provided in Section 6.7.3.

6.7.2 Excavations and Temporary Roadway Protection

Temporary excavations for the culvert construction will extend through the existing fill, firm to very stiff surficial clayey silt to silty clay, and into the clayey silt till deposit. Excavation works must be carried out in accordance with the guidelines outlined in the latest edition of the

Occupational Health and Safety Act and Regulations for Construction Projects. The existing embankment fill and the firm portions of the surficial clayey silt or clayey silt till are classified as Type 3 soil according to the OHSA. Where space permits, temporary open-cut excavations through these materials should be made with side slopes not steeper than 1 horizontal to 1 vertical (1H:1V).

Depending on the construction staging sequence and schedule, temporary roadway protection may be required along the QEW to facilitate the culvert extension works. The temporary excavation support system should be designed and constructed in accordance with MTO's Special Provision 105S19. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in SP105S19, provided that any utilities that are present along the QEW can tolerate 25 mm of deformation.

6.7.3 Subgrade Protection

The clayey silt till that is exposed at the footing subgrade level will be susceptible to disturbance from construction traffic and/or ponded water. A Non-Standard Special Provision (NSSP) should be included in the Contract Documents to warn the contractor of this effect and limit detrimental conditions; in this regard, a working mat of lean concrete should be placed immediately after preparation and inspection of the footing subgrade. A draft NSSP that addresses this requirement has been included in Appendix A.

7.0 CLOSURE

This Foundation Design Report was prepared by Ms. Shannon Palmer, EIT, and reviewed by Ms. Lisa Coyne, P. Eng., an Associate and geotechnical engineer with Golder. Mr. Fintan Heffernan, P.Eng., a Designated MTO Contact for Golder, conducted an independent review of the report.

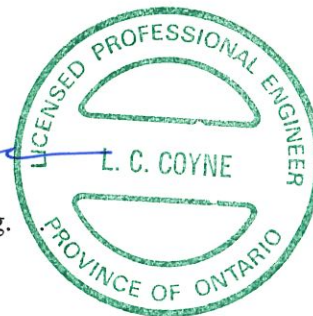
GOLDER ASSOCIATES LTD.



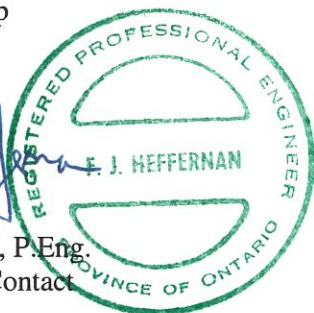
Shannon Palmer, EIT
Geotechnical Group



Lisa C. Coyne, P.Eng.
Associate



Fintan J. Heffernan, P.Eng.
Designated MTO Contact



SLP/LCC/FJH/lcc

N:\ACTIVE\2004\1111\04-1111-002 MH QEW WIDENING ST. CATHARINES\6 - REPORTS\FINAL REPORTS\04-1111-002 RPT07 07JUL CULVERT EXTENSIONS.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

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

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.)

Consistency

(b) Cohesive Soils

	$c_{u1} s_u$	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

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.

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 test¹
CIU consolidated isotropically undrained triaxial test with porewater pressure measurement¹
 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.

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 stress (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 ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation
*	Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density \times acceleration due to gravity)

(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)

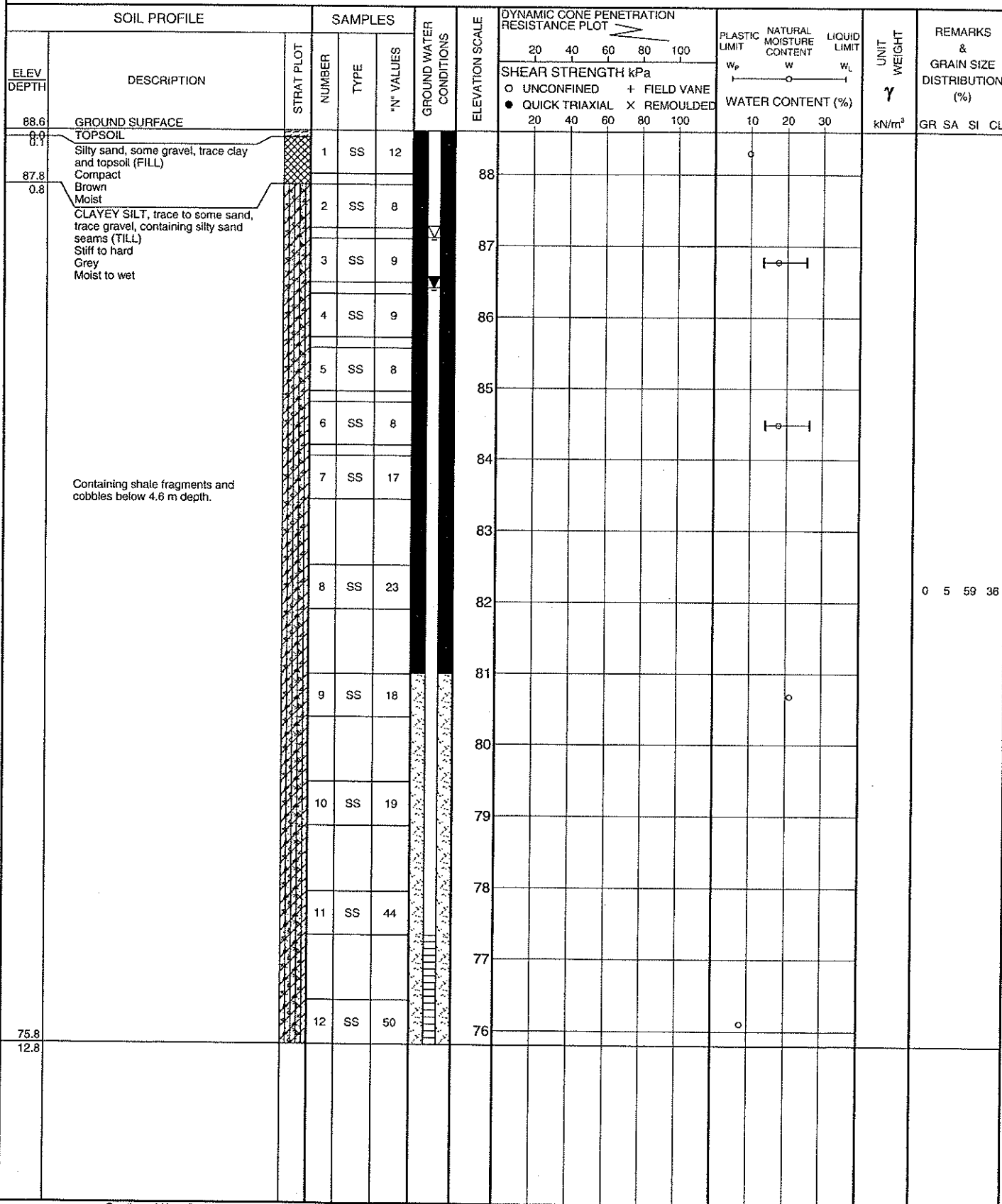
C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_a	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation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

(d) Shear Strength

τ_p, τ_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

- Notes: 1 $\tau = c' + \sigma' \tan \phi'$
2 Shear strength = (Compressive strength)/2

PROJECT 04-1111-002		RECORD OF BOREHOLE No C1-1		1 OF 2 METRIC	
W.P. 607-00-00		LOCATION N 4782054.3 ; E 321860.1		ORIGINATED BY PKS	
DIST Central HWY QEW		BOREHOLE TYPE 108 mm Diameter Solid Stem Augers		COMPILED BY KG	
DATUM Geodetic		DATE June 1, 2005		CHECKED BY LCC	



MIS-MTO 001 041111002AAMTO.GPJ GAL-MISS.GDT 5/5/06

Continued Next Page

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



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

PROJECT 04-1111-002			RECORD OF BOREHOLE No C1-2			1 OF 1 METRIC																
W.P. 607-00-00			LOCATION N 4782064.3 ; E 321860.1			ORIGINATED BY PKS																
DIST Central HWY QEW			BOREHOLE TYPE 108 mm Diameter Solid Stem Augers			COMPILED BY KG																
DATUM Geodetic			DATE June 2, 2005			CHECKED BY LOC																
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			GR SA SI CL			
88.3	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	10 20 30												
0.0	CLAYEY SILT, some sand and gravel Stiff Brown/grey Moist		1	SS	11	▽	88															
87.5							87															
0.8	CLAYEY SILT, some sand, trace gravel (TILL) Firm to very stiff Grey Moist to wet		2	SS	5		86															
			3	SS	5		85															
			4	SS	7		84															
			5	SS	5		83															
			6	SS	15		82															
			7	SS	16		81															
80.1	END OF BOREHOLE		8	SS	23																	
8.2	Note: 1. Water level in open borehole at 3.0m depth upon completion of drilling operations.																					

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

PROJECT		RECORD OF BOREHOLE		No C2-1		1 OF 1		METRIC					
W.P.		LOCATION		N 4781948.3 E 322381.7		ORIGINATED BY		PKS					
DIST		BOREHOLE TYPE		108 mm Diameter Solid Stem Augers		COMPILED BY		KG					
DATUM		DATE		May 31, 2005		CHECKED BY		LCC					
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT	GR SA SI CL
81.0	GROUND SURFACE												
0.0	Clayey silt, some sand, trace gravel and shale pieces (FILL) Stiff Brown Moist		1	SS	9								
80.2													
0.8	CLAYEY SILT, some sand, trace gravel and organics Firm to very stiff Brown/grey Moist		2	SS	4		80						1 20 51 28
			3	SS	17		79						
78.7													
2.3	CLAYEY SILT, some sand, trace gravel (TILL) Stiff to very stiff Grey Moist to wet		4	SS	27		78						
			5	SS	17								
			6	SS	14		77						
	Containing shale fragments below 4.6 m depth		7	SS	29		76						
74.9							75						
6.1	SILTY SAND to SAND and SILT, trace clay and gravel containing shale fragments (TILL) Very dense Red Wet		8	SS	100/25		74						
			9	SS	100/15		73						
			10	SS	100/20		72						8 42 41 9
							71						
70.3													
10.7	Red SHALE (BEDROCK)		11	SS	100/20		70						
68.7							69						
12.3	END OF BOREHOLE		12	SS	100/13								
Note: 1. Water level in open borehole at 3.7m depth upon completion of drilling operations. 2. Water level in piezometer at 0.3m depth on August 8, 2005. 3. Water level in piezometer at 0.2m above ground surface on December 6, 2005.													

MIS-MTO 001 041111002AAMTD.GPJ GAL-MISS.GDT 5/5/06

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

PROJECT 04-1111-002

RECORD OF BOREHOLE No C2-2

1 OF 1 **METRIC**

W.P. 607-00-00

LOCATION N 4781943.3; E 322380.9

ORIGINATED BY PKS

DIST Central HWY QEW

BOREHOLE TYPE 108 mm Diameter Solid Stem Augers

COMPILED BY KG

DATUM Geodetic

DATE May 31, 2005

CHECKED BY LCC

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 (%)
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × REMOULDED						
81.0	GROUND SURFACE						20 40 60 80 100								
0.0	Clayey silt, some sand, trace gravel, shale pieces and organics (FILL)		1	SS	9										
80.2	Stiff Brown/grey														
0.8	Moist		2	SS	8		80						Organics		
79.6	CLAYEY SILT, some sand, trace gravel and organics														
1.4	Stiff Grey		3	SS	19		79								
	Moist														
	CLAYEY SILT, some sand, trace gravel (TILL)		4	SS	13		78								
	Stiff to very stiff														
	Grey		5	SS	12										
	Moist		6	SS	13		77								
76.4	SANDY SILT, trace to some clay, trace gravel (TILL)		7	SS	23		76							5 25 58 12	
4.6	Compact to very dense Grey to red														
	Moist to wet		8	SS	100/18		75								
							74								
73.2			9	SS	100/23										
7.9	END OF BOREHOLE														
	Note: 1. Water level in open borehole at 6.0 m depth upon completion of drilling operations.														

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

PROJECT 04-1111-002

RECORD OF BOREHOLE No C3-1

1 OF 1 **METRIC**

W.P. 607-00-00

LOCATION N 4781976.0 ; E 322689.8

ORIGINATED BY PKS

DIST Central HWY QEW

BOREHOLE TYPE 108 mm Diameter Solid Stem Augers

COMPILED BY KG

DATUM Geodetic

DATE June 1, 2005

CHECKED BY LCC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
83.5	GROUND SURFACE							20 40 60 80 100	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L		
0.0	Clayey silt, some sand, trace gravel and organics (FILL) Stiff to very stiff Brown Moist		1	SS	18		83						
			2	SS	8								
82.0							82						
1.5	SILTY CLAY, some sand, trace gravel and organics Firm Grey Moist		3	SS	5							2 18 59 21	
81.2							81						
2.3	CLAYEY SILT, some sand, trace gravel (TILL) Very stiff to hard Brown to grey Moist to wet		4	SS	17								
			5	SS	32		80						
			6	SS	32								
			7	SS	40		79					1 15 71 13	
							78						
	Containing shale fragments below 6.1 m depth		8	SS	43		77						
							76						
75.9							75						
7.6	SILTY SAND, trace gravel Loose to compact Grey/red Wet		9	SS	9								
							74						
			10	SS	19								
							73						
72.8							72						
10.7	CLAYEY SILT, some sand, trace gravel, containing shale fragments (TILL) Hard Red Wet		11	SS	92								
71.3													
12.4	SILTY SAND and GRAVEL, containing shale fragments Very dense Red Wet END OF BOREHOLE		12	SS	100/18								
	Note: 1. Water level in open borehole at 2.3 m depth upon completion of drilling operations.												

MIS-MTO 001 041111002AAMTO.GPJ GAL-MISS.GDT 5/5/06

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

PROJECT 04-1111-002		RECORD OF BOREHOLE No C3-2		1 OF 1 METRIC	
W.P. 607-00-00	LOCATION N 4781996.7 ; E 322712.9	ORIGINATED BY PKS			
DIST Central HWY QEW	BOREHOLE TYPE 108 mm Diameter Solid Stem Augers	COMPILED BY KG			
DATUM Geodetic	DATE May 31, 2005	CHECKED BY LCC			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _p	W	W _L		
82.2	GROUND SURFACE													
0.0	CLAYEY SILT, some sand, trace gravel and organics		1	SS	4								Organics	
81.4	Firm Brown/grey Moist													
0.8	CLAYEY SILT, some sand, trace gravel (TILL)		2	SS	12									
	Stiff to hard Brown/grey Moist to wet													
			3	SS	41									
79.9														
2.3	SAND and SILT, some gravel, trace clay, containing cobbles (TILL)		4	SS	79									30 33 26 11
79.2	Very dense Brown Wet													
3.1	CLAYEY SILT, some sand, trace gravel (TILL)		5	SS	22									
	Stiff to very stiff Grey Wet													
	Containing silty sand seams below 4.9 m depth		6	SS	20									
			7	SS	20									
			8	SS	9									
74.6														
7.6	SILT, trace clay and sand		9	SS	18									0 5 84 11
74.0	Compact Grey Wet													
8.2	END OF BOREHOLE													
	Note: 1. Water level in open borehole at 1.5m depth upon completion of drilling operations. 2. Water level in piezometer at 1.3m depth on August 8, 2005. 3. Water level in piezometer at 0.9m depth on December 6, 2005.													

MIS-MTO-001: 041111002AAMTO.GPJ GAL-MISS.GDT 5/5/06

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

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

CONT No.
WP No. 607-00-00

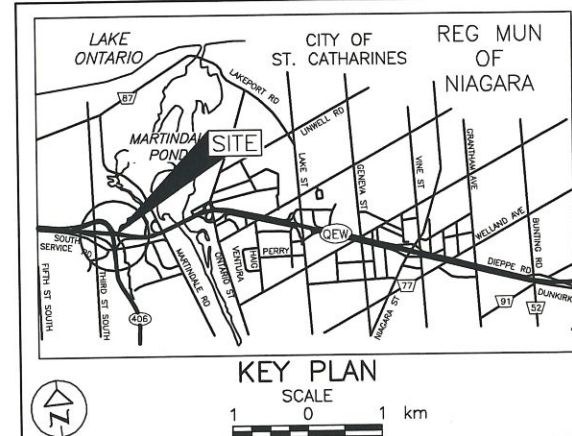


CULVERT EXTENSIONS
QEW WIDENING, ST. CATHARINES
BOREHOLE LOCATIONS

SHEET



Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



LEGEND

● Borehole - Current Investigation

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
C1-1	88.6	4782054.3	321860.1
C1-2	88.3	4782064.3	321860.1
C2-1	81.0	4781948.3	322381.7
C2-2	81.0	4781943.3	322380.9
C3-1	83.5	4781976.0	322689.8
C3-2	82.0	4781996.7	322712.9

NOTES

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

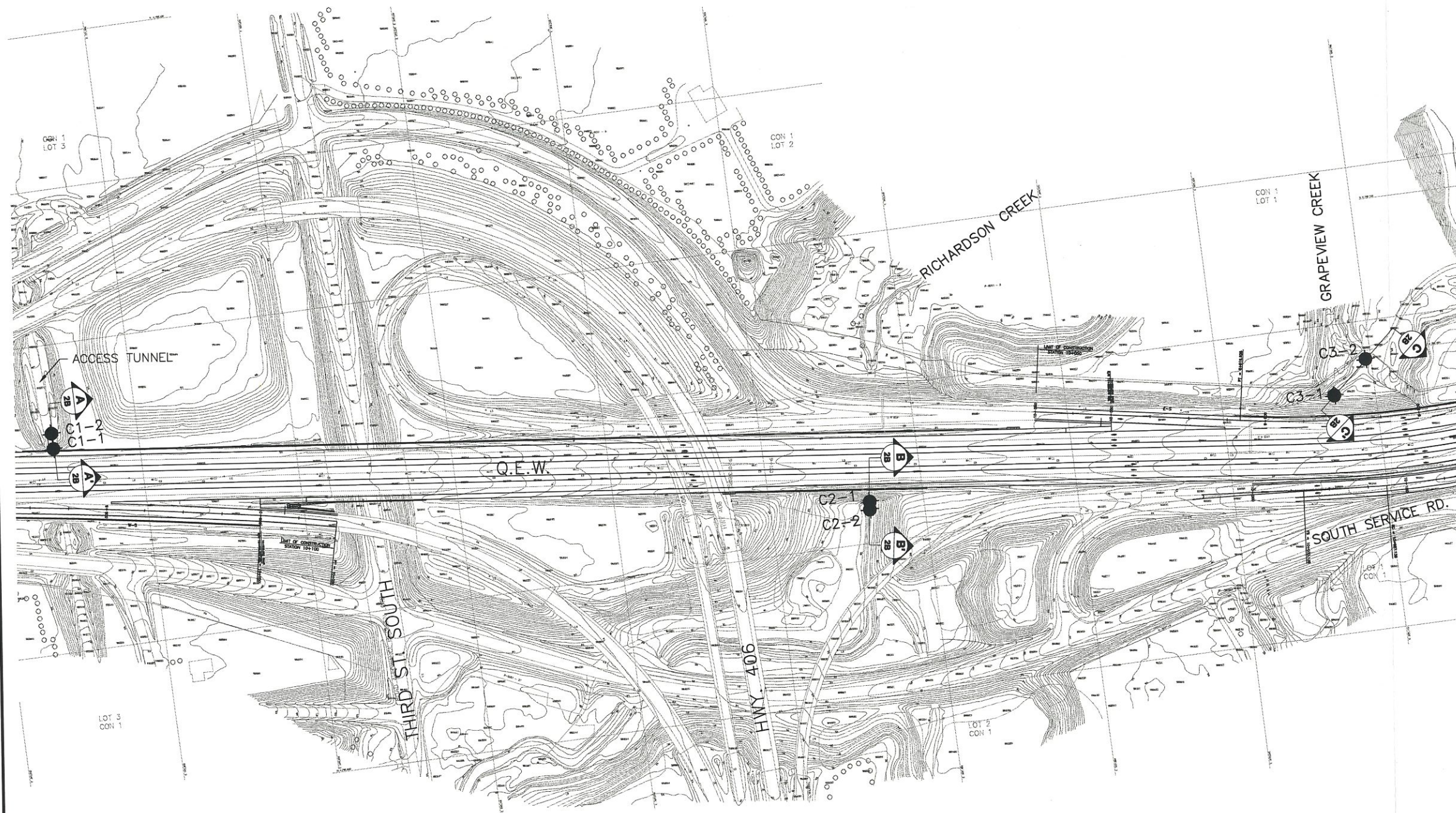
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

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 Morrison Hershfield Limited, drawing file nos. x4026design.dwg and x4026baseplan.dwg, received March 21, 2005.

NO.	DATE	BY	REVISION
Geocres No.			
HWY. QEW	PROJECT NO. 04-1111-002		DIST.
SUBM'D. PKS	CHKD. SLP	DATE: NOV 2006	SITE:
DRAWN: MSM	CHKD. SLP	APPD. LCC	DWG. 1



PLAN

SCALE
30 0 30 60 m

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

CONT No.
WP No. 607-00-00

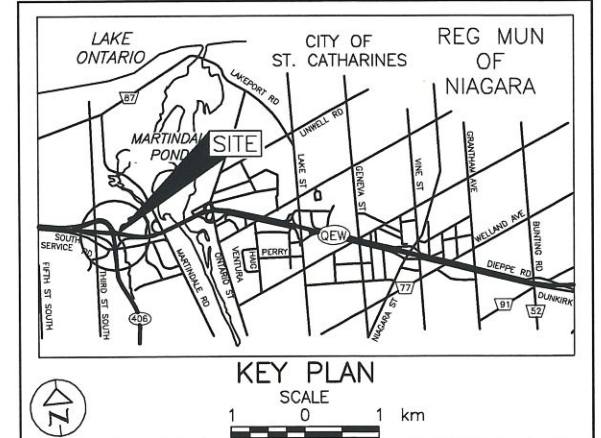
CULVERT EXTENSIONS
QEW WIDENING, ST. CATHARINES
SOIL STRATA



SHEET



Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



LEGEND	
	Borehole - Current Investigation
	Seal
	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
	WL upon completion of drilling
	WL in piezometer, measured on December 6, 2005

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
C1-1	88.6	4782054.3	321860.1
C1-2	88.3	4782064.3	321860.1
C2-1	81.0	4781948.3	322381.7
C2-2	81.0	4781943.3	322380.9
C3-1	83.5	4781976.0	322689.8
C3-2	82.0	4781996.7	322712.9

NOTES

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

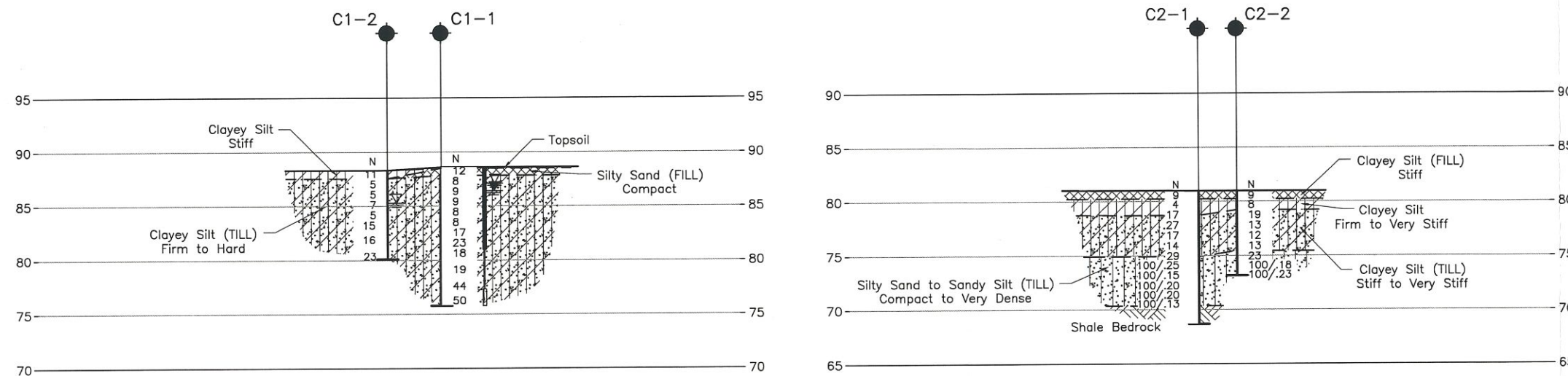
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

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REFERENCE

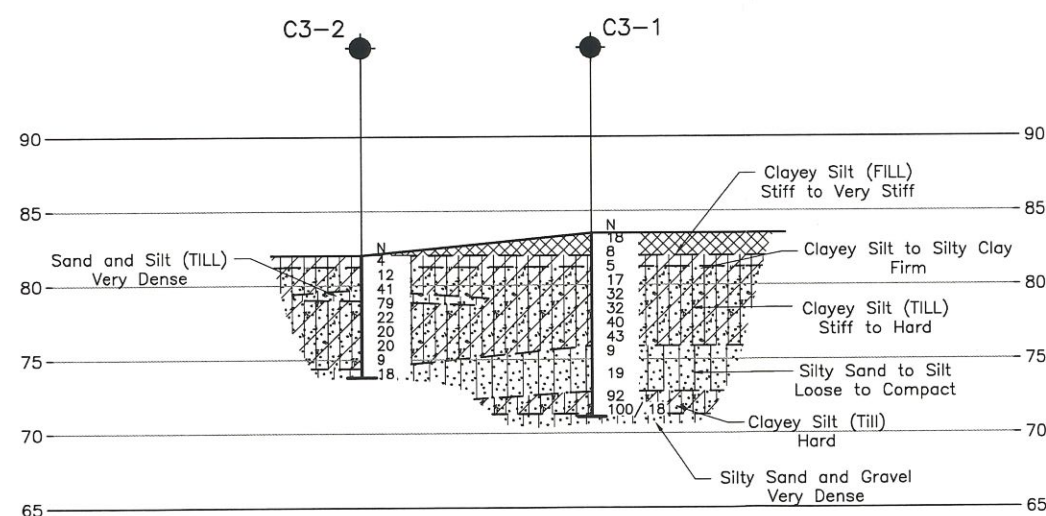
Base plans provided in digital format by Morrison Hershfield Limited, drawing file nos. x4026design.dwg and x4026baseplan.dwg, received March 21, 2005.

NO.	DATE	BY	REVISION
Geocres No.			
HWY. QEW	PROJECT NO. 04-1111-002		DIST.
SUBM'D. PKS	CHKD. SLP	DATE: NOV 2006	SITE:
DRAWN: MSM	CHKD. SLP	APPD. LCC	DWG. 2



SECTION A-A'

SECTION B-B'



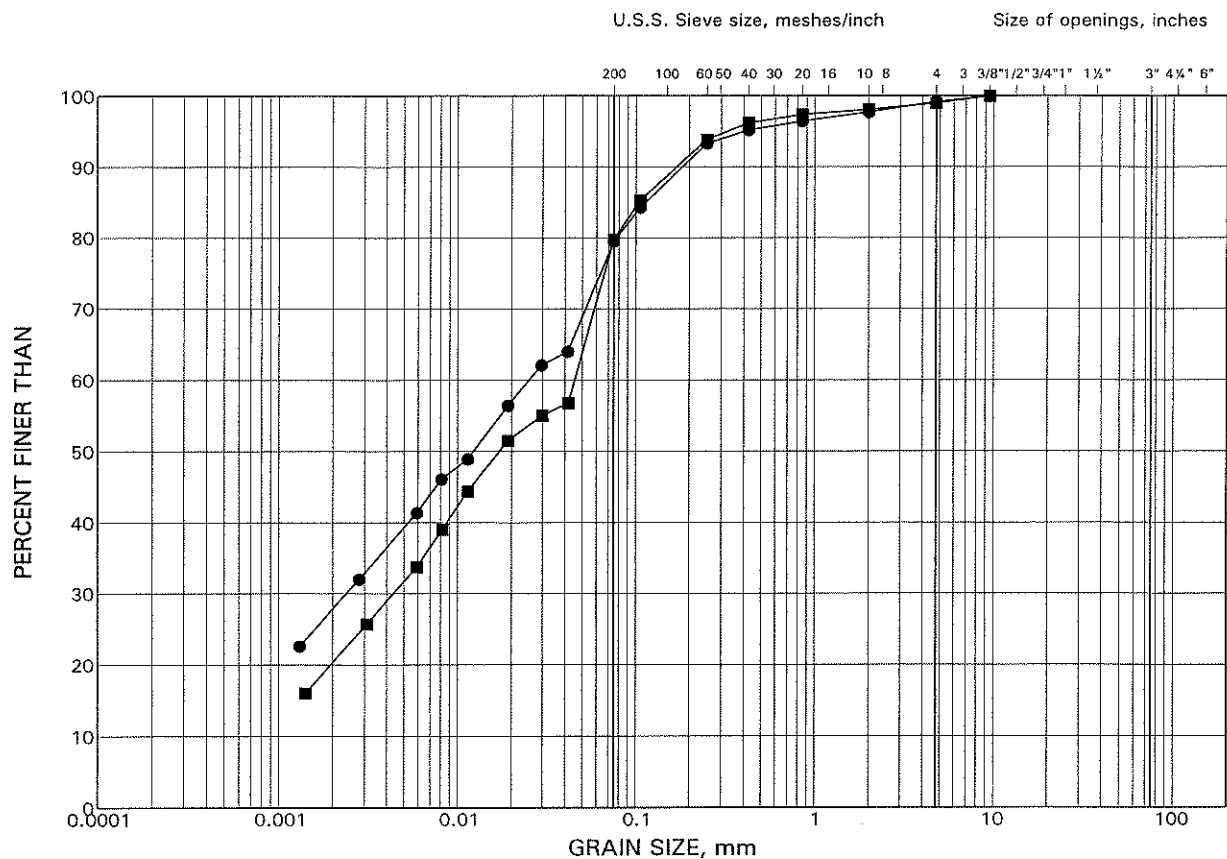
SECTION C-C'



GRAIN SIZE DISTRIBUTION TEST RESULTS

Surficial Clayey Silt to Silty Clay

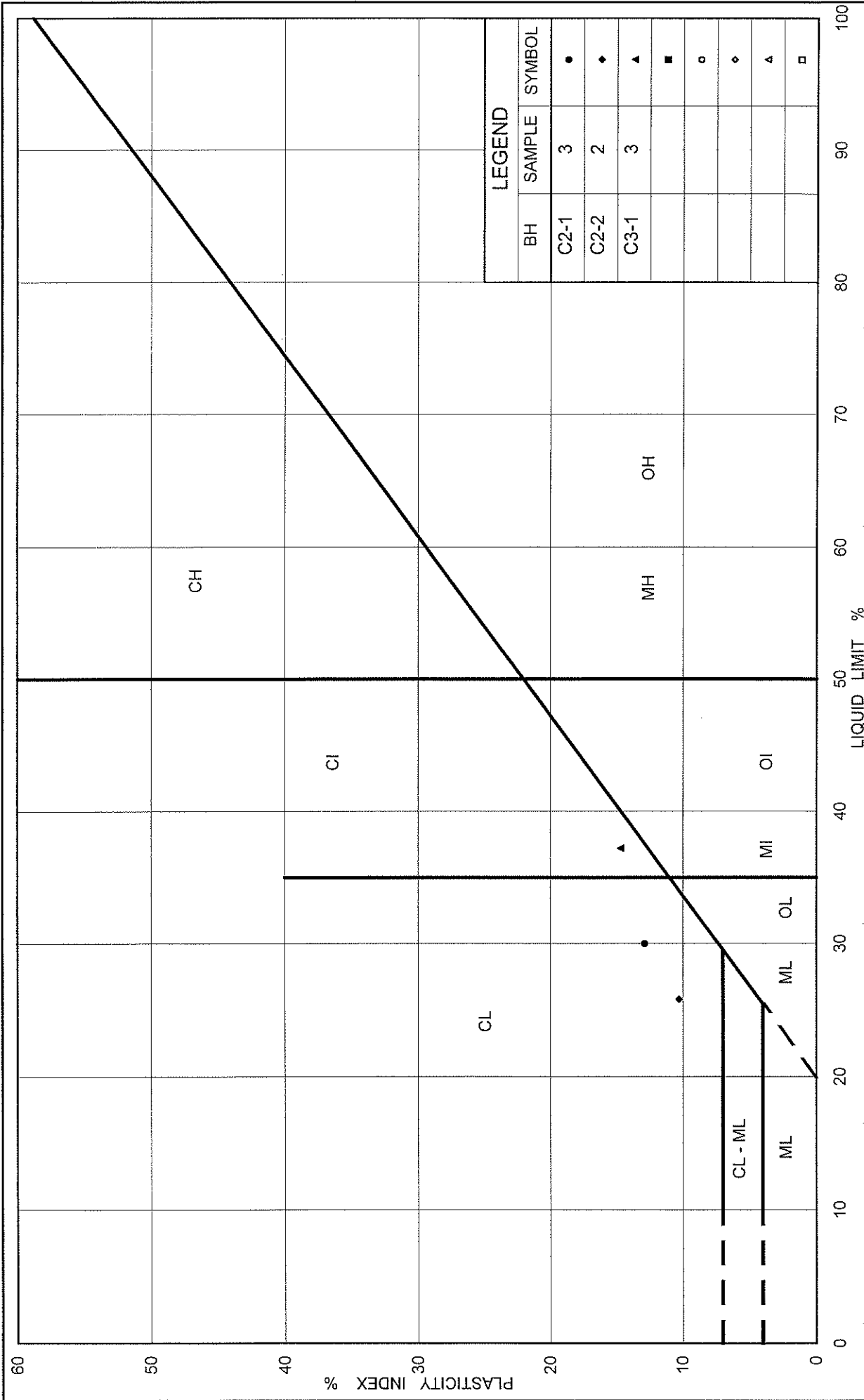
FIGURE 1



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

LEGEND

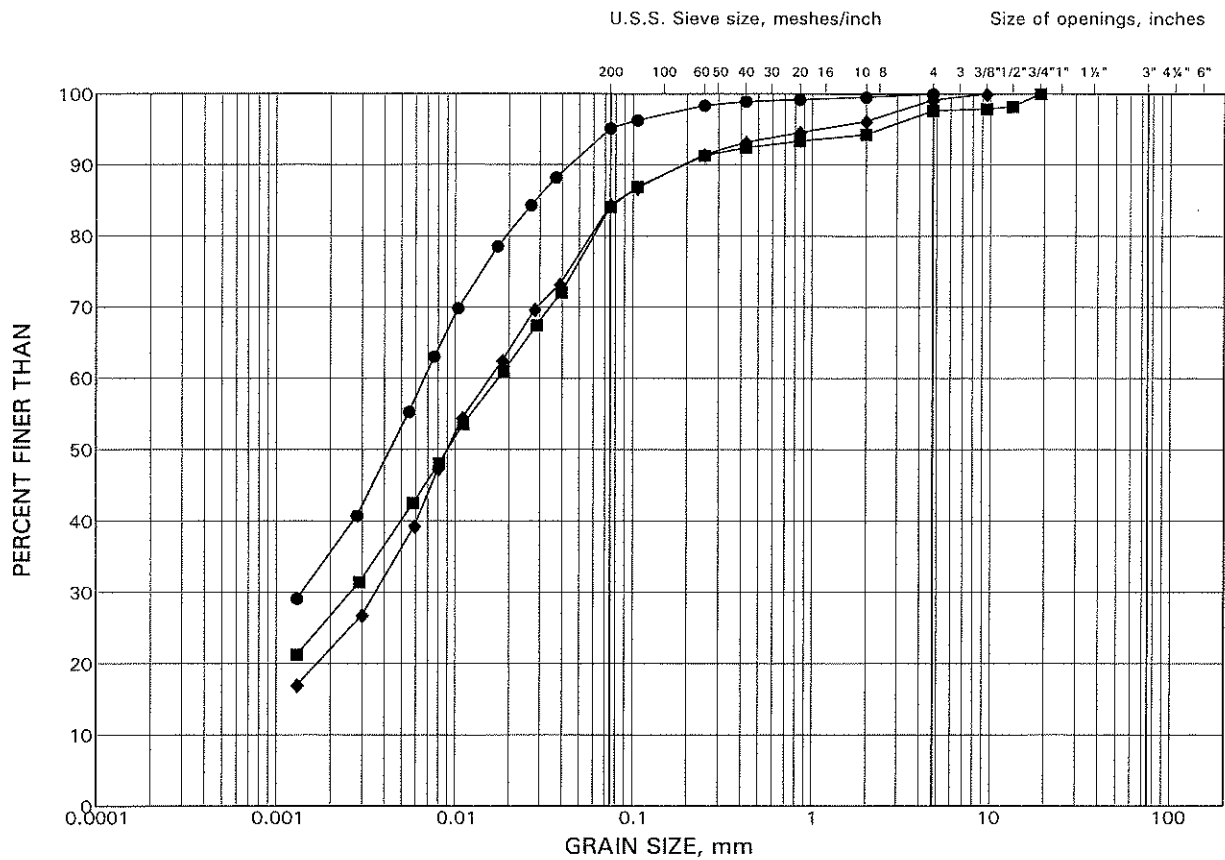
SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	C2-1	2	79.9
■	C3-1	3	81.7



GRAIN SIZE DISTRIBUTION TEST RESULTS

Clayey Silt Till

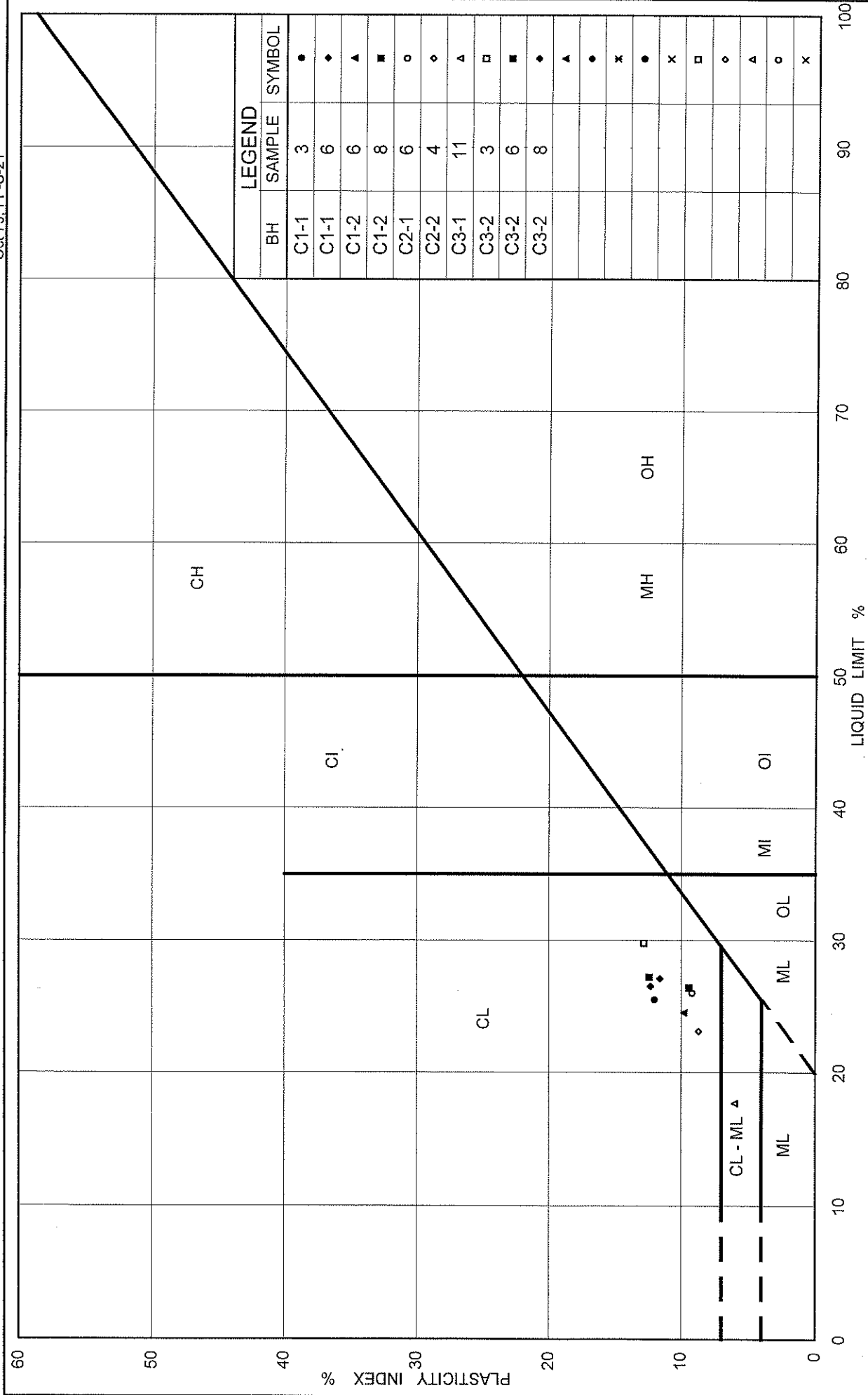
FIGURE 3



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	C1-1	8	82.2
■	C1-2	3	86.5
◆	C3-1	7	78.6



PLASTICITY CHART
Clayey Silt Till

Ministry of Transportation



Ontario

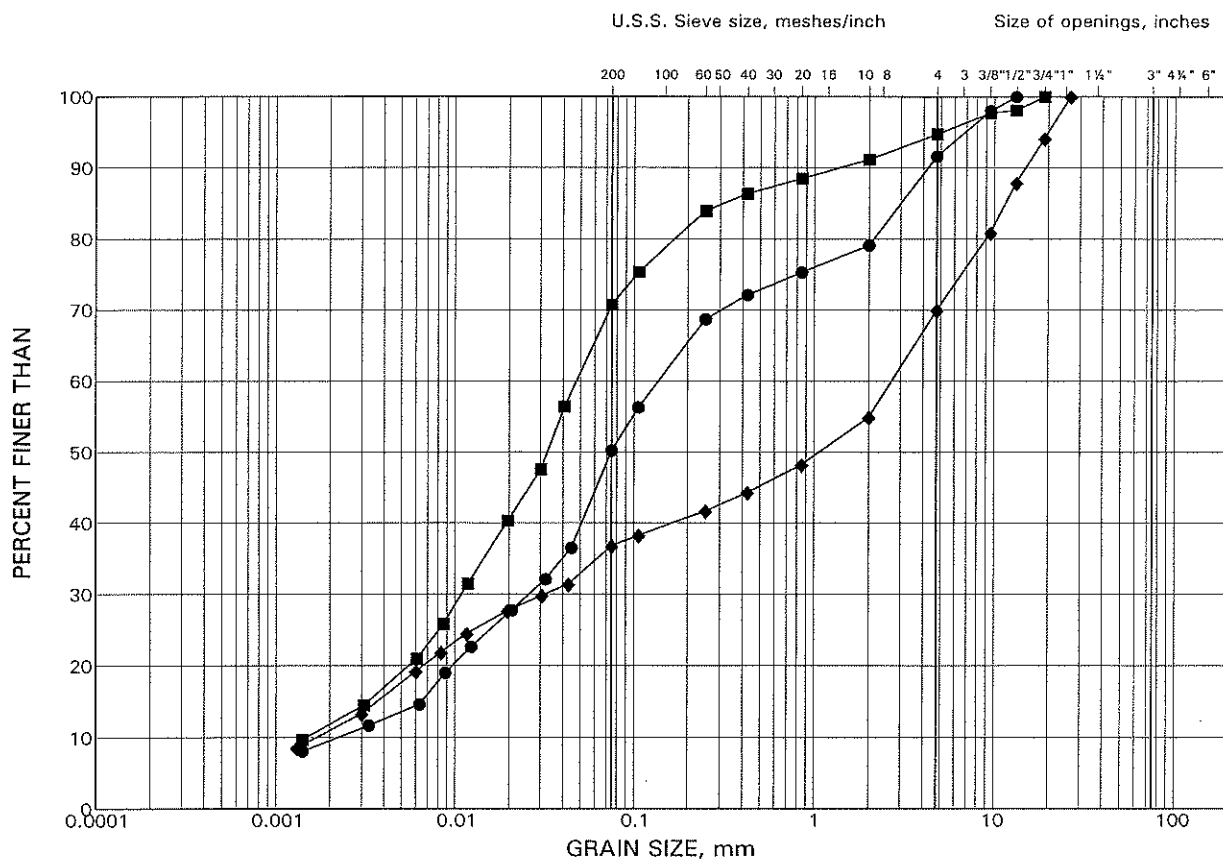
FIG No. 4

Project No. 04-1111-002

GRAIN SIZE DISTRIBUTION TEST RESULTS

Silty Sand to Sandy Silt Till

FIGURE 5



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

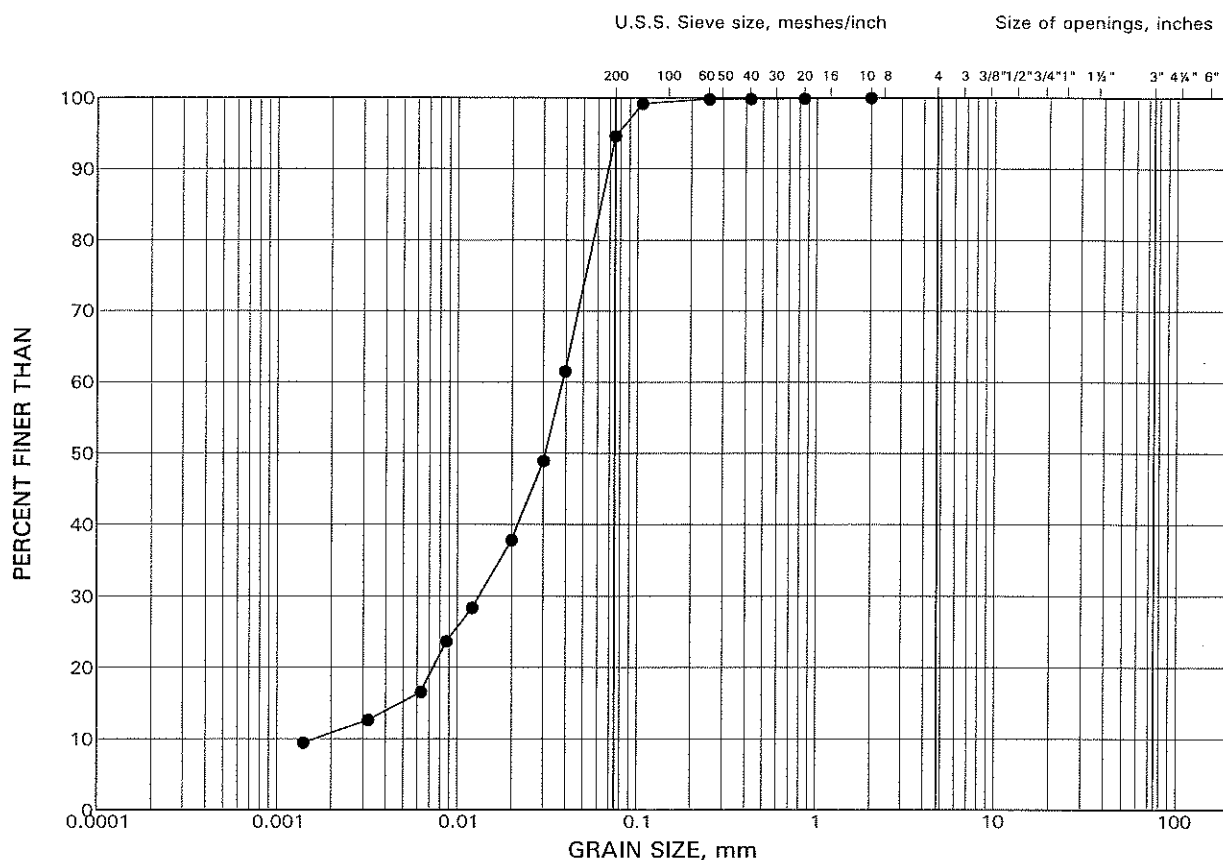
LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	C2-1	10	71.8
■	C2-2	7	76.1
◆	C3-2	4	79.4

GRAIN SIZE DISTRIBUTION TEST RESULT

Silty Sand to Silt Interlayers in Clayey Silt Till

FIGURE 6



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
•	C3-2	9	74.1

July 2006

04-1111-002-7

APPENDIX A
NON-STANDARD SPECIAL PROVISIONS

SUBGRADE PROTECTION - ITEM NO.

Special Provision

July 2006

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.

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