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DRAFT

**FOUNDATION INVESTIGATION
AND DESIGN REPORT
CULVERTS
HIGHWAY 401-COUNTY ROAD 30 INTERCHANGE
RAMP AND GRADE IMPROVEMENTS
G.W.P. 256-98-00**

*Georges
3/6-180*

Submitted to:

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November 2007

06-1111-057-1



TABLE OF CONTENTS

<u>SECTION</u>	<u>PAGE</u>
PART A - FOUNDATION INVESTIGATION REPORT	
1.0 INTRODUCTION	1
2.0 SITE DESCRIPTION	2
3.0 INVESTIGATION PROCEDURES	3
4.0 SITE GEOLOGY AND STRATIGRAPHY	5
4.1 Regional Geological Conditions	5
4.2 Site Stratigraphy	5
4.2.1 Fill	6
4.2.2 Peat	6
4.2.3 Silt to Silty Sand	7
4.2.4 Silty Sand Till to Clayey Silt Till	7
4.2.5 Sand and Gravel	8
4.3 Groundwater Conditions	9
5.0 CLOSURE	10
PART B - FOUNDATION DESIGN REPORT	
6.0 ENGINEERING RECOMMENDATIONS	11
6.1 General	11
6.2 Foundation Options for Culverts	11
6.3 Strip Footings for Open Footing Culverts and Wing Walls/Retaining Walls ...	12
6.3.1 Founding Elevations	12
6.3.2 Geotechnical Resistance	13
6.3.3 Resistance to Lateral Loads	14
6.4 Box Culverts/Extensions	14
6.4.1 Founding Elevations	14
6.4.2 Geotechnical Resistance	15
6.4.3 Resistance to Lateral Loads	15
6.5 Steel H-Pile Foundations	16
6.5.1 Founding Elevations	16
6.5.2 Axial Geotechnical Resistance	16
6.5.3 Resistance to Lateral Loads	17
6.6 Settlement	18
6.7 Culvert Backfill and Erosion Protection	20
6.8 Lateral Earth Pressures for Design	21
6.9 Construction Considerations	23
6.9.1 Groundwater and Surface Water Control	23
6.9.2 Excavations and Temporary Roadway Protection	24
6.9.3 Subgrade Protection	25
7.0 CLOSURE	26

In Order
Following
Page 26

Lists of Abbreviations and Symbols
Records of Boreholes 07-1, 07-4, and 07-9 to 07-13
Drawings 1 and 2
Figures 1 to 6
Appendix A

LIST OF DRAWINGS

Drawing 1 Highway 401-County Road 30, Proctor's Creek Culverts (Culvert 2) – Borehole Locations and Soil Strata
Drawing 2 Highway 401-County Road 30, Proctor's Creek Culverts (Culverts 14 and 14a) – Borehole Locations and Soil Strata

LIST OF FIGURES

Figure 1 Grain Size Distribution Test Results – Silt to Sand and Silt Fill
Figure 2 Plasticity Chart – Sand and Silt and Clayey Silt Fill
Figure 3A/3B Grain Size Distribution Test Results – Silt to Sandy Silt
Figure 4 Grain Size Distribution Test Result – Silty Sand Till to Clayey Silt Till
Figure 5 Plasticity Chart – Clayey Silt Till
Figure 6 Grain Size Distribution Test Results – Sand and Gravel

LIST OF APPENDICES

Appendix A Non-Standard Special Provisions

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PART A

**FOUNDATION INVESTIGATION REPORT
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Giffels Associates Limited (Giffels) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for culvert extensions and new culverts along Proctor's Creek, and for embankments 4.5 m or more in height within a section of the realigned W-N/S ramp, at the Highway 401-County Road 30 interchange near Brighton, Ontario.

This report addresses the culvert extensions and new culverts along Proctor's Creek, as follows:

- extension of the south end of Culvert 2 under Telephone Road/County Road 30 in the northwest quadrant of the interchange;
- extension of the north and south ends of Culvert 14, or replacement of Culvert 14, under the proposed W-N/S Ramp (along the existing access road alignment); and
- new Culvert 14a under the proposed new access/service road.

The terms of reference and scope of work for the foundation investigation are outlined in MTO's Request for Proposal, dated May 2006, and in Section 6.8 of Giffels' Technical Proposal for this assignment, which were subsequently amended to include the south extension of Culvert 2 under Telephone Road/County Road 30 in the northwest quadrant of the interchange.

2.0 SITE DESCRIPTION

The culvert sites are located in the northwest and southwest quadrants of the Highway 401-County Road 30 interchange near Brighton, Ontario. The culverts included in this study convey Proctor's Creek, which flows from north to south at the site, under Telephone Road in the northwest quadrant of the interchange, and under the existing W-N/S Ramp and service road in the southwest quadrant of the interchange.

The natural ground surface immediately adjacent to Proctor's Creek is at approximately Elevation 192.5 m beside Telephone Road at Culvert 2 in the northwest quadrant of the interchange, between approximately Elevation 188.0 m and 189.2 m at Culvert 14 at the existing service road, and at approximately Elevation 187.6 m to 188.0 at the proposed new access road to the south. The creek channel is about 2 m to 3 m in width, with the creek bed at about Elevation 191.5 m to 187 m, declining from north to south. To the east and west of the creek, the natural ground surface rises to approximately Elevation 203 m. Highway 401, County Road 30, Telephone Road, the existing W-N/S Ramp and the existing service road are all constructed on embankments that are between 2.5 m and 8 m in height in the vicinity of Proctor's Creek.

The natural ground surface in the area is generally grass-covered, with scattered trees and shrubs.

3.0 INVESTIGATION PROCEDURES

The field work for this subsurface investigation was carried out in May and July 2007, during which time seven boreholes were advanced at the culvert sites. Five of the boreholes (Boreholes 07-1, 07-4, 07-9, 07-10, and 07-13) were advanced using a CME-55 track-mounted drill rig, and two of the boreholes (Boreholes 07-11 and 07-12) were advanced using portable drilling equipment, all supplied and operated by Marathon Drilling Company Ltd. of Ottawa, Ontario.

The borehole locations are shown on Drawings 1 and 2. The boreholes that were drilled using a track-mounted drill rig were advanced to depths of between 12.6 m and 18.9 m, while the boreholes that were drilled using portable equipment were advanced to depths of 4.9 m and 9.1 m, and terminated within very dense soils.

Soil samples were obtained at 0.75 m and 1.5 m intervals of depth, using 50 mm outside diameter split-spoon samplers in accordance with the Standard Penetration Test (SPT) procedure. The groundwater conditions in the open boreholes were observed throughout the drilling operations and are noted on the borehole logs following the text of this report. Slight artesian groundwater pressures were encountered in Boreholes 07-9 and 07-11, as noted on the records for these boreholes; upon completion, all boreholes, including Boreholes 07-9 and 07-11, were backfilled to the ground surface using bentonite pellets, mixed in places with auger cuttings.

The field work was supervised on a full-time basis by members 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 further examination and laboratory testing. Index and classification tests consisting of water contents, Atterberg limits and grain size distributions were carried out on selected soil samples.

The borehole locations were measured in the field relative to the existing culvert and the roadway, and the ground surface elevation at the borehole locations was confirmed using the digital terrain mapping (DTM) for this project. The borehole locations (northing and easting coordinates referenced to MTM NAD83 coordinate system) and ground surface elevations (referenced to geodetic datum) are summarized in the following table and are shown on Drawings 1 and 2.

<i>Borehole Number</i>	<i>Northing (m)</i>	<i>Easting (m)</i>	<i>Ground Surface Elevation (m)</i>
07-1	4,882,198.0	203,025.3	190.4
07-4	4,882,094.4	202,988.4	187.6
07-9	4,882,190.1	203,023.8	189.2
07-10	4,882,111.7	202,995.2	188.0
07-11	4,882,213.5	203,017.2	190.0
07-12	4,882,564.2	203,060.1	195.1
07-13	4,882,574.5	203,055.2	199.4

4.0 SITE GEOLOGY AND STRATIGRAPHY

4.1 Regional Geological Conditions

The area of Highway 401 and County Road 30 lies within the Iroquois Plain physiographic region, as delineated in *The Physiography of Southern Ontario*¹; the Iroquois Plain extends around the western and northern shores of Lake Ontario. The soils within this physiographic region represent the flat to undulating lake bed and beaches of the former glacial Lake Iroquois, which occupied the Lake Ontario basin during the last glacial recession.

The soils in the Iroquois Plain are typically comprised of glaciolacustrine clays and silts, though deposits of sand to sand and gravel are also known to be present. The overburden soils are underlain by limestone bedrock of the Trenton Group.

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 Record of Borehole sheets; the results of the laboratory testing are also shown 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 subsoil conditions encountered at the culvert sites consist of topsoil or existing embankment fill overlying a deposit of loose to very dense silt to silty sand, which is underlain in some of the boreholes by a layer of dense to very dense sand and gravel, and a till deposit that ranges in composition from silty sand to sand and silt, to clayey silt.

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

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.

4.2.1 Fill

Approximately 2.5 m and 1.2 m of fill materials were encountered in Boreholes 07-1 and 07-11, which were drilled through the existing service road embankment and at the toe of the existing W-N/S Ramp embankment, respectively; the base of the fill was encountered in these boreholes at Elevations 188.0 m and 188.8 m. Approximately 2.6 m and 8.2 m of fill materials were encountered in Boreholes 07-12 and 07-13, respectively, which were drilled near the toe and through the shoulder of the Telephone Road embankment in the northwest quadrant of the Highway 401-County Road 30 interchange; the base of the fill was encountered in these boreholes at Elevations 192.5 m and 191.2 m.

The existing embankment fill typically consists of sand and silt containing trace to some gravel and trace clay. A thin layer of cohesive fill, consisting of clayey silt containing trace to some sand and trace gravel, was encountered below the sand and silt fill in Boreholes 07-1 and 07-13. The results of grain size distribution testing carried out on four selected samples of the fill are shown on Figure 1. Atterberg limits testing was completed on one sample of the sand and silt fill and one sample of the clayey silt fill, and measured plastic limits of 12 and 14 per cent, liquid limits of 15 and 19 per cent, and plasticity indices of 3 and 5 per cent; these results, which are plotted on a plasticity chart on Figure 2, confirm that the sand and silt fill is non-plastic, and that the cohesive fill is a clayey silt of low plasticity.

The measured SPT "N" values within the sand and silt fill vary from 2 to 38 blows per 0.3 m of penetration. The fill as encountered in Boreholes 07-1, 07-11 and 07-12, which were advanced near the toes of existing embankments, has a very loose to loose relative density, based on measured SPT "N" values of 2 to 8 blows per 0.3 m of penetration. The Telephone Road embankment fill as encountered in Borehole 07-13, which was drilled through the shoulder of this local road, has a loose to dense (but generally compact) relative density, based on measured SPT "N" values of 6 to 38 blows per 0.3 m of penetration (but typically 13 to 17 blows per 0.3 m of penetration).

The measured SPT "N" values within the clayey silt were 5 and 8 blows per 0.3 m of penetration, indicating that the cohesive fill has a firm to stiff consistency.

4.2.2 Peat

A 100 mm to 600 mm thick layer of peat was encountered below the existing fill in Boreholes 07-1, 07-11 and 07-12, and an 800 mm thick layer of peat was encountered immediately below the ground surface in Borehole 07-9.

Progressing from upstream to downstream along Proctor's Creek, the base of the peat was encountered at Elevation 192.1 m in Borehole 07-12 near Culvert 2 in the northwest quadrant of the interchange, at Elevation 188.2 m in Borehole 07-11 on the north side of Culvert 14, at Elevation 187.8 m in Borehole 07-1 near the central portion of Culvert 14, and at Elevation 188.4 m in Borehole 07-9 near the south end of Culvert 14.

4.2.3 Silt to Silty Sand

A deposit of silt to silty sand was encountered below the fill and peat (where present) or immediately below the ground surface in all of the boreholes except Borehole 07-12. Progressing from upstream to downstream along Proctor's Creek, the surface of this deposit was encountered at Elevation 191.2 m in Borehole 07-13 at Telephone Road in the northwest quadrant of the interchange, between Elevations 187.8 m and 188.4 m in Boreholes 07-1, 07-9 and 07-11 at Culvert 14, and at Elevations 187.6 m and 188.0 m in Boreholes 07-4 and 07-10 near the new access road. This deposit was fully penetrated in Boreholes 07-1, 07-4, 07-9, 07-10 and 07-11; based on these boreholes, the deposit ranges from 3.0 m to 10.8 m in thickness. The silt deposit was not fully penetrated in Borehole 07-13, where it extends for a thickness of at least 10.7 m.

The deposit varies in composition from a silt containing trace to some sand and trace clay, to sandy silt containing trace gravel, to silty sand containing trace to some gravel and trace clay. The results of grain size distribution testing carried out on eleven selected samples of this deposit are shown on Figures 3A and 3B. Atterberg limits testing was completed on one sample of the silt from Borehole 07-9, and determined this sample to be non-plastic.

The measured SPT "N" values within the silt to silty sand deposit typically range from 0 blows (weight of hammer) to 21 blows per 0.3 m of penetration, except in Borehole 07-13 where the SPT "N" values range from 40 to 104 blows per 0.3 m of penetration. As noted on the borehole records, the lower recorded SPT "N" values (typically less than about 4 to 8 blows per 0.3 m of penetration) are considered to result from sample disturbance due to groundwater inflow to the borehole. The deposit is, therefore, considered to have a generally loose to compact relative density, except at Borehole 07-13 where the deposit has a dense to very dense relative density.

4.2.4 Silty Sand Till to Clayey Silt Till

Glacial till deposits were encountered below the silt to silty sand deposit in Boreholes 07-1, 07-4, 07-10 and 07-11, and immediately below the fill and peat in Borehole 07-12; the till deposit was not encountered within the investigated depth in Boreholes 07-9 and 07-13.

Based on the results from these boreholes, the till deposit is discontinuous and its surface elevation is variable across the site. Where present, the surface of the till was generally

encountered between Elevations 178.9 m and 183.8 m, except in Borehole 07-12 in the northwest quadrant of the interchange where the till surface was encountered at Elevation 192.1 m. The till deposit was fully penetrated in Borehole 07-1, where it was 4.4 m in thickness. Although not fully penetrated in Borehole 07-4, the till deposits have a total thickness (including sand and gravel layer/interlayer, as discussed in Section 4.2.5) of at least 8.8 m.

The till deposit typically varies in composition from silty sand to sandy silt, containing some gravel and trace clay. However, the lower portion of the till, below Elevation 177.2 m in Borehole 07-4 and below Elevation 178.9 m in Borehole 07-10, consists of clayey silt containing trace to some sand and trace gravel. The results of grain size distribution testing conducted on three samples of silty sand to sandy silt till and one sample of clayey silt till are shown on Figure 4.

Atterberg limits testing was completed on two samples of the clayey silt till, and measured plastic limits of 15 and 16 per cent, liquid limits of 29 and 31 per cent, and plasticity indices of 14 and 15 per cent; these results, which are plotted on a plasticity chart on Figure 5, confirm that the cohesive till is a clayey silt of low plasticity. Atterberg limits testing was completed on one sample of the silty sand till from Borehole 07-4, and determined this sample to be non-plastic.

The measured SPT "N" values within the silty sand to sandy silt till ranged from 3 to 92 blows per 0.3 m of penetration; however, as noted on the borehole records, the lower SPT "N" values (3 blows per 0.3 m of penetration) are considered to have resulted from sample disturbance due to groundwater inflow to the borehole. The silty sand to sandy silt till is therefore considered to have a compact to very dense relative density. The measured SPT "N" values within the clayey silt till range from 89 to 107 blows per 0.3 m of penetration, indicating that the clayey silt till has a hard consistency.

4.2.5 Sand and Gravel

A layer of sand and gravel was encountered below the silty sand till in Borehole 07-1, within the silty sand to clayey silt till in Borehole 07-4, and below the silt in Borehole 07-9. The surface of the sand and gravel was encountered between Elevations 175.5 m and 180.3 m in these boreholes. The sand and gravel was fully penetrated only in Borehole 07-4, where the layer/interlayer was found to be 3.1 m in thickness.

The result of a grain size distribution test completed on one sample of the sand and gravel is shown on Figure 6.

The measured SPT "N" values within the sand and gravel layers ranged from 33 to 116 blows per 0.3 m of penetration, to greater than 70 blows per 0.15 m of penetration, indicating that the deposit has a dense to very dense relative density.

4.3 Groundwater Conditions

The water levels were observed in the boreholes following completion of drilling, and these observations are noted on the borehole records following the text of this report. Artesian groundwater conditions were observed in Boreholes 07-9 and 07-11 immediately following completion of the drilling and prior to withdrawal of the hollow stem augers; in both boreholes, the artesian groundwater pressures subsided immediately following withdrawal of the hollow stem augers, and these boreholes were backfilled to the ground surface (above any caved soils as noted on the borehole records) using bentonite pellets.

Based on the moisture conditions and water levels observed during drilling, and the groundwater level as measured in piezometers installed elsewhere at this site, the groundwater level associated with the near-surface silt to silty sand soils along Proctor's Creek varies from about Elevation 194.7 m near Culvert 2 in the northwest quadrant of the interchange, to about Elevation 188 m to 189 m near Culvert 14 under the existing access/service road, to about Elevation 186 m near Culvert 14a south of the existing access/service road. This water level is typically just below the original ground surface in these areas, and near the water level in the adjacent Proctor's Creek channel.

Higher water levels (about Elevation 189.5 m to 190 m) have been measured in the open boreholes at the Culvert 14 site, associated with the groundwater conditions in the deeper silty sand and sand and gravel (aquifer) deposits encountered below the silt deposit at this location. To the east of the creek valley, where the ground surface rises, the groundwater level measured in a standpipe piezometer has been measured at approximately Elevation 193.2 m.

The groundwater level at the culvert sites should be expected to fluctuate as a result of seasonal variations in precipitation and the Proctor's Creek water levels.

5.0 CLOSURE

This Foundation Investigation Report was prepared by Mr. Matthew Kelly, and reviewed by Ms. Lisa Coyne, P. Eng., an Associate and geotechnical engineer with Golder. Mr. Jorge Costa, P.Eng., a Principal of and Designated MTO Contact for Golder, conducted an independent review of the report.

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PART B

**FOUNDATION DESIGN REPORT
CULVERTS
HIGHWAY 401-COUNTY ROAD 30 INTERCHANGE
RAMP AND GRADE IMPROVEMENTS
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6.0 ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides foundation design recommendations for the culvert extensions or new culvert construction associated with the Highway 401-County Road 30 interchange improvements. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during a subsurface investigation at this site. The interpretation and recommendations are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to design the foundations for the proposed new culvert and 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.

6.2 Foundation Options for Culverts

Extension or new construction of three structural culverts is proposed as part of the Highway 401-County Road 30 interchange improvements, as follows:

- extension of the south end of Culvert 2 under Telephone Road, in the northwest quadrant of the interchange;
- extension of the north and south ends of Culvert 14, or replacement of Culvert 14, under the proposed W-N/S Ramp (along the existing access road alignment), in the southwest quadrant of the interchange; and
- new Culvert 14a under the proposed new access/service road, in the southwest quadrant of the interchange.

Details regarding each of the existing and new culverts and, where applicable, the proposed extensions, are provided in the following table:

<i>Culvert Number</i>	<i>Existing Culvert Dimensions/Type</i>	<i>Embankment Height</i>	<i>Invert Elevation</i>	<i>Proposed Extension</i>
2	2.4 m wide x 1.7 m high concrete box	8 m	192.8 m (north) 191.5 m (south)	14.0 m south
14	3.2 m wide x 1.8 m high concrete box	5 m	188.5 m (north) 188.1 m (south)	14.0 m north 15.5 m south
14a (New)	New culvert	3 m	187.1 m (north) 187.0 m (south)	—

Either “open footing” (shallow foundations) or box culvert extensions/new culverts are feasible from a foundations perspective for all three of the culvert sites; if higher bearing resistances are required at Culverts 14 and 14A, deep foundations (driven steel H-piles) or micropiles could be used. Recommendations for shallow foundations, box culverts and deep foundations are provided in Sections 6.3, 6.4 and 6.5, respectively. Micropile foundations, while feasible, would require a site-specific design, are generally much more expensive than other types of foundations, would not eliminate the need for groundwater control at this site; a micropile design could be provided if this alternative foundation type is pursued further.

From a foundations perspective, a box culvert extension or new box culvert has an advantage over shallow and deep foundations (open footing culverts) in terms of minimizing the depth of excavation and groundwater control requirements for each of the culvert sites. However, in general, the choice of foundation type for the extensions or new culverts can be determined on the basis of hydrological, fisheries or structural requirements and, where applicable, compatibility with the existing culvert type.

6.3 Strip Footings for Open Footing Culverts and Wing Walls/Retaining Walls

6.3.1 Founding Elevations

Open footing culvert extensions or new culverts, and any associated wing walls/retaining walls, can be supported on strip footings founded below the fill and any loose surficial soils, on the generally compact silt deposit or, where present at founding level, the compact to very dense sandy silt till. Strip footings for open footing culvert extensions or new replacements, and for any associated wing walls/retaining walls, should be founded at a minimum depth of 1.5 m below the lowest surrounding grade, to provide adequate protection against frost penetration. If water will flow through the culvert year-round, frost protection for the culvert footings is not necessary; however, adequate frost protection for the wing wall/retaining wall footings would still be required.

The following founding elevations are recommended for strip footings for support of the new culverts or culvert extensions.

<i>Culvert Number</i>	<i>Invert Elevation</i>	<i>Maximum Founding Elevation (Frost Protection Required)</i>	<i>Maximum Founding Elevation (Frost Protection Not Required)</i>
2	191.5 m (south)	190.0 m (south)	191.0 m (south)
14	188.5 m (north) 188.1 m (south)	187.0 m (north) 186.6 m (south)	188.0 m (north) 187.5 m (south)
14a (New)	187.1 m (north) 187.0 m (south)	185.6 m (north) 185.5 m (south)	186.5 m (north) 186.5 m (south)

Assuming that frost protection is required, the maximum founding levels identified above will require excavation to a depth of up to 4.5 m below the groundwater level at Culvert 2, and up to 2 m below the groundwater level at Culverts 14 and 14a, within the fine-grained (silt, or sandy silt till) deposits. If frost protection is not required, the maximum founding levels identified above would require excavation to a depth of up to 3.5 m below the groundwater level at Culvert 2, and up to about 1 m below the groundwater level at Culverts 14 and 14a. Groundwater control will be required for construction of strip footings founded within the silt deposit or sandy silt till deposit. As discussed further in Section 6.9, it is recommended that a Non-Standard Special Provision (NSSP) be included in the Contract Documents to address dewatering for foundation construction at the culvert sites.

The silt or sandy silt till subgrade for the footings will be susceptible to loosening and degradation on exposure to water and construction traffic. It is recommended that a 100 mm thick layer of lean mix concrete or mass concrete be placed on the footing subgrade to form a working mat for construction of the culvert extension or culvert replacement, to protect the subgrade from degradation; this aspect is discussed further in Section 6.9.

6.3.2 Geotechnical Resistance

Strip footings placed on the properly prepared subgrade, at or below the elevations identified in Section 6.3.1, should be designed based on the following factored geotechnical resistances at ULS and geotechnical resistances at SLS.

<i>Culvert Number</i>	<i>Footing Width</i>	<i>Factored Geotechnical Resistance at ULS</i>	<i>Geotechnical Resistance at SLS*</i>
2	0.6 m	300 kPa	250 kPa
	0.9 m	325 kPa	250 kPa
14	0.6 m	175 kPa	150 kPa**
	0.9 m	200 kPa	150 kPa**
14a	0.6 m	175 kPa	150 kPa
	0.9 m	200 kPa	150 kPa

* For 25 mm of total settlement for the given footing width.

** As discussed further in Section 6.6, up to approximately 50 mm to 60 mm of total settlement will occur under the 7.5 m high embankment loading at Culvert 14. This culvert should be designed to accommodate this total magnitude of settlement (including the necessary camber), and a maximum differential settlement of approximately 25 mm between the footings.

The ULS resistance and settlement are dependent on the footing size, configuration and applied loads; the geotechnical resistances should, therefore, be reviewed if the selected footing width or founding elevation differs significantly from those given above.

The geotechnical resistances provided above 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 Section 6.7.2 of the *Canadian Highway Bridge Design Code (CHBDC)*.

6.3.3 Resistance to Lateral Loads

Resistance to lateral forces / sliding resistance between the concrete footings for the culvert extensions or culvert replacement and the subgrade should be calculated in accordance with Section 6.7.5 of the *CHBDC*. For cast-in-place concrete footings founded on compact silt or compact to very dense sandy silt till, the coefficient of friction, $\tan \phi'$, can be taken as 0.45. This value is unfactored; in accordance with the *CHBDC*, a factor of 0.8 is to be applied in calculating the horizontal resistance.

6.4 Box Culverts/Extensions

6.4.1 Founding Elevations

Box culvert extensions or new box culverts can be founded below any existing fill and peat, supported on the generally compact silt or (where encountered at Culvert 2) compact to very dense sandy silt till. It is understood that the concrete base slab for a new box culvert or box culvert extension would have a thickness of about 300 mm, and that approximately 400 mm of fill would be placed on top of the concrete base slab to create a soil-lined channel; therefore, the base slab for the new box culvert or box culvert extensions would be founded as follows:

<i>Culvert Number</i>	<i>Invert Elevation</i>	<i>Maximum Founding Elevation</i>
2	191.5 m (south)	190.8 m (south)
14	188.5 m (north)	187.8 m (north)
	188.1 m (south)	187.4 m (south)
14a (New)	187.1 m (north)	186.4 m (north)
	187.0 m (south)	186.3 m (south)

Based on the founding elevations identified above, the new box culverts or box culvert extensions will require excavation to a depth of about 3.5 m below the groundwater level at Culvert 2, and up to about 1 m below the groundwater level at Culverts 14 and 14a, within the fine-grained (silt, or sandy silt till) deposits. Groundwater control will be required for construction of new box culverts or box culvert extensions founded within the silt deposit or sandy silt till deposit. As discussed further in Section 6.9, it is recommended that an NSSP be included in the Contract Documents to address dewatering for box culvert construction.

The silt or sandy silt till subgrade for the new box culvert or box culvert extensions will be susceptible to loosening and degradation on exposure to water and construction traffic. It is recommended that a 100 mm thick layer of lean mix concrete or mass concrete be placed on the subgrade within the box culvert footprint to form a working mat for construction of the culvert extension or culvert replacement, to protect the subgrade from degradation; this aspect is discussed further in Section 6.9. In this case, a 75 mm thick levelling pad of Granular A (meeting the gradation requirements set out in Ontario Provincial Standard Specification (OPSS) 1010) or fine aggregate (meeting the gradation requirements set out in OPSS 1002) could be provided on top of the concrete mat to provide a "levelling pad" for the new box culvert or box culvert extensions.

6.4.2 Geotechnical Resistance

New box culverts or box culvert extensions placed on the properly prepared subgrade, at or below the elevations identified in Section 6.4.1, should be designed based on the following factored geotechnical resistances at ULS and geotechnical resistances at SLS.

<i>Culvert Number</i>	<i>Culvert Span</i>	<i>Factored Geotechnical Resistance at ULS</i>	<i>Geotechnical Resistance at SLS*</i>
2	2.4 m	300 kPa	250 kPa
14	3.2 m	225 kPa	150 kPa**
14a	3.2 m	225 kPa	150 kPa

* For 25 mm of total settlement for the given footing width.

** As discussed further in Section 6.6, up to approximately 50 mm to 60 mm of total settlement will occur under the 7.5 m high embankment loading at Culvert 14. This culvert should be designed to accommodate this total magnitude of settlement (including the necessary camber), and a maximum differential settlement of approximately 25 mm between the footings.

The ULS resistance and settlement are dependent on the footing size, configuration and applied loads; the geotechnical resistances should, therefore, be reviewed if the culvert span or founding elevation differs significantly from those given above.

The geotechnical resistances provided above 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)*.

6.4.3 Resistance to Lateral Loads

Resistance to lateral forces / sliding resistance between the base slab for the culvert extensions or culvert replacement and the subgrade should be calculated in accordance with Section 6.7.5 of the *CHBDC*. For cast-in-place concrete box culverts founded on compact silt or compact to very

dense sandy silt till, the coefficient of friction, $\tan \phi'$, can be taken as 0.45. For pre-cast concrete box culverts founded on compact silt or compact to very dense sandy silt till, the coefficient of friction, $\tan \delta$, can be taken as 0.4. These values are unfactored; in accordance with the CHBDC, a factor of 0.8 is to be applied in calculating the horizontal resistance.

6.5 Steel H-Pile Foundations

6.5.1 Founding Elevations

The pile caps should be provided with a minimum of 1.5 m of soil cover, or equivalent, to provide adequate protection against frost penetration. To accommodate the pile cap and frost protection cover soil, it is estimated that excavation will be required to a depth of up to 2 m below the groundwater level at Culverts 14 and 14A, within the fine-grained (silt to silty sand) soil deposits; groundwater control will be required for construction of the pile caps. As discussed further in Section 6.9, it is recommended that a Non-Standard Special Provision (NSSP) be included in the Contract Documents to address groundwater control for foundation construction at the culvert sites.

The new culverts or culvert extensions can be supported on steel H-piles driven to found within the "100-blow" soil, which varies in composition from sand and gravel at Culvert 14, to clayey silt till at Culvert 14A. For design, the following pile tip levels may be assumed based on the borehole results:

<i>Foundation Element</i>	<i>Borehole Number(s)</i>	<i>Pile Tip Elevation</i>
Culvert 14	07-1, 07-9, 07-11	176 m
Culvert 14A	07-4, 07-10	176 m

The piles should be stiffened with MTO flange plates for protection during driving, in accordance with OPSS 903.07.05.04, in the event that cobbles and boulders are encountered within the soil deposits at this site.

6.5.2 Axial Geotechnical Resistance

For HP 310x110 or HP 310x79 piles driven to the design founding elevations within the very dense sand and gravel or hard clayey silt till, a factored axial resistance of 1,200 kN can be used for design. The axial geotechnical resistance at SLS may be taken as 1,000 kN.

Pile installation should be in accordance with MTO's Special Provision SP903S01. The pile termination or set criteria will be dependent on the pile driving hammer type, helmet, selected pile and length of pile; the criteria must therefore be established at the time of construction after the piling equipment is known. For piles driven into the hard or very dense deposits to the design

tip elevations given in Section 6.5.1, the following note is considered appropriate for the design and site conditions assuming a resistance factor of 0.5 is applied to the use of the Hiley formula:

"Piles to be driven in accordance with Standard SS 103-11 using an ultimate capacity of 2,400 kN per pile."

6.5.3 Resistance to Lateral Loads

Lateral loading could be resisted fully or partially by the use of battered steel H-piles. If vertical piles are used, the resistance to lateral loading will have to be derived from the soil in front of the piles.

The resistance to lateral loading in front of the pile may be calculated using subgrade reaction theory where the coefficient of horizontal subgrade reaction is determined based on the equations given below (CFEM, 1992, as noted in Section 6.8.7.3 of the CHBDC).

For cohesionless soils:

$$k_h = \frac{n_h z}{B} \quad \text{where}$$

k_h is the coefficient of horizontal subgrade reaction (MPa/m);
 n_h is the constant of subgrade reaction (MPa/m);
 z is the depth (m); and
 B is the pile diameter (m).

For cohesive soils:

$$k_h = \frac{67s_u}{B} \quad \text{where}$$

k_h is the coefficient of horizontal subgrade reaction (kPa/m);
 s_u is the undrained shear strength of the soil (kPa); and
 B is the pile diameter (m).

The following ranges for the value of n_h and s_u may be assumed in the structural analyses. Approximate elevation intervals are given in the table for each deposit for each foundation element; however, the deposit boundaries vary at each of the foundation elements, and reference should be made to the borehole records and to the interpreted stratigraphic sections on Drawing 2 to assess the variation along each foundation element.

Soil Unit	n_h	s_u
Culvert 14:		
Compact silt to silty sand above Elevation 180 m	3 MPa/m	—
Compact to dense silty sand till above Elevation 177.5 m	5 MPa/m	—
Very dense silty sand till / Very dense sand and gravel below Elevation 177.5 m	15 MPa/m	—

<i>Soil Unit</i>	<i>n_h</i>	<i>s_u</i>
Culvert 14A		
Loose to compact silt to silty sand and compact silty sand till above Elevation 179 m	3 MPa/m	—
Dense to very dense sand and gravel between Elevation 179 m and 177 m	9 MPa/m	—
Hard clayey silt till below Elevation 177 m	—	500 kPa

A maximum factored lateral resistance at ULS of 110 kN and maximum lateral resistance at SLS (for 10 mm of horizontal deflection at pile cap level) of 40 kN are recommended for HP 310x110 or HP 310x79 piles, based on the “Assessed Horizontal Passive Resistance and Geotechnical Reaction at SLS” provided under Clause C6.8.7.1, Table C6.4 of the *Commentary on CHBDC* (November 2006).

Group action for lateral loading should also be considered when the pile spacing in the direction of the loading is less than six to eight pile diameters. Group action can be evaluated by reducing the coefficient of horizontal subgrade reaction in the direction of loading by a reduction factor, R , as follows:

<i>Pile Spacing in direction of Loading (d = Pile Diameter)</i>	<i>Subgrade Reaction Reduction Factor</i>
8d	1.00
6d	0.70
4d	0.40
3d	0.25

Reference: Foundations and Earth Structures – Design Manual 7.2, NAVFAC DM-7.2.
Department of the Navy, Naval Facilities Engineering Command (1982).

The subgrade reaction reduction factor should be interpolated for pile spacings in between those provided above.

6.6 Settlement

Some settlement of the foundation soils will occur below the new culvert or culvert extensions as a result of the placement of additional fill to accommodate embankment widening/grade raising (at the Culvert 2 and 14 sites) or new embankment construction (at the Culvert 14a site).

In order to estimate the magnitude of settlement, analyses were carried out using the commercially-available program Unisettle (Version 3.0). The settlement of the founding soils has been estimated using the elastic deformation moduli given below, based on correlations (Bowles,

1982)² with the SPT "N" values and engineering judgement from experience with similar soils in southern Ontario.

<i>Soil Unit</i>	<i>Bulk Unit Weight</i>	<i>Elastic Modulus</i>
Embankment fill	21 kN/m ³	-
Generally compact silt to silty sand	19 kN/m ³	15 MPa
Dense to very dense silt or sandy silt till (at Culvert 2 site)	21 kN/m ³	40 MPa
Compact to very dense silty sand till	21 kN/m ³	40 MPa
Hard clayey silt till	21 kN/m ³	100 MPa
Very dense sand and gravel	21 kN/m ³	90 MPa

The settlement of the foundation soils under the embankment grade raise/widening or new embankment construction is estimated as follows; these settlements will be completed relatively quickly during and immediately following the embankment construction.

- **Culvert 2 site:** Approximately 10 mm of settlement of the foundation soils is predicted below the southward extension of this culvert, due to the widening of the approximately 8 m high Telephone Road and County Road 30 embankments.
- **Culvert 14 site:** The new W-N/S Ramp embankment will be approximately 7.5 m in height at this culvert site. If earth/granular fill is used for the new embankment construction, it is estimated that a total of 60 mm of elastic compression will occur below the ramp pavement and shoulders, which will affect the existing culvert (if extensions are adopted) or the central portion of the new culvert (if a complete replacement is adopted); below the mid-point of the new ramp embankment side slopes, it is predicted that approximately 30 mm to 35 mm of elastic compression will occur in the founding soils. If rock fill is used for the new embankment construction adjacent to Culvert 14, it is estimated that a total of 50 mm to 55 mm of elastic compression will occur below the ramp pavement and shoulders; below the mid-point of the new ramp embankment side slopes, it is estimated that approximately 25 mm to 30 mm of elastic compression will occur in the founding soils. The culvert should be designed and constructed with the necessary camber to accommodate the total predicted settlement. If culvert extensions are adopted, the connection between the existing culvert and its extensions should be designed to accommodate the above-noted magnitudes of settlement; where a new (replacement) culvert is adopted, articulated joints should be provided to accommodate this magnitude of settlement.
- **Culvert 14a site:** Approximately 10 mm to 15 mm of settlement of the foundation soils is predicted for this new culvert under the loading from the approximately 1.5 m high new access/service road embankment.

² Bowles, J.E. 1982. *Foundation Analysis and Design*. Third Edition, McGraw-Hill Book Company.

6.7 Culvert Backfill and Erosion Protection

Backfill to culvert walls should consist of granular fill meeting the requirements of OPSS 1010 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 culvert could consist of OPSS 1010 Granular A or Granular B Type II fill, or select earth fill; alternatively, where steeper embankment side slopes are desirable along the new W-N/S Ramp to minimize impacts on the Proctor's Creek floodplain, consideration is being given to the use of rock fill for the embankment construction, and rock fill can be used as backfill over the new Culvert 14 in this area. The new culvert and culvert extensions should be designed for the full overburden pressure and live load, assuming an embankment fill unit weight of 22 kN/m³ for Granular A, 21 kN/m³ for Granular B Type II backfill or select earth fill, or 19 kN/m³ for rock fill.

If the Proctor's Creek flow velocities are sufficiently high, provision should be made for scour and erosion protection. 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 new culverts or extensions. If a clay seal is adopted, the clay material should meet the requirements of OPSS 1205, and the seal should extend from a depth of 1 m below the scour level to 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, including along the embankment slope. Alternatively, a clay blanket may be constructed, extending upstream for a length of three times the culvert height and along the adjacent slope to a height of two times the culvert height or the high water level, whichever is greater.

The requirements for and design of erosion protection measures for the inlet and outlet of the various culverts should be assessed by the hydraulic design engineer. As a minimum, rip-rap treatment for the outlet of the culverts should be consistent with the standard presented in Ontario Provincial Standard Drawing (OPSD) 810.010, Rip-Rap Treatment Type A. Erosion protection for the inlet of the culverts should follow the standard presented in OPSD 810.010, similar to Rip Rap Treatment Type A with the rip-rap placed up to the toe of slope level, in combination with the cut-off measures noted above. Similarly, rip-rap should be provided over the full extent of the clay blanket, including the creek side slopes and fill slope over the culverts.

6.8 Lateral Earth Pressures for Design

The lateral earth pressures acting on the culvert extension walls and 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.

The following recommendations are made concerning the design of the walls. As discussed in Section 6.7, these recommendations assume that the backfill to the culvert walls consists of free-draining granular fill meeting the requirements of OPSS Granular A or B Type II, placed and compacted in accordance with MTO's Special Provision SP105S10, with longitudinal drains and weep holes installed as necessary 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. 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 1.5 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 Type II
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)	

- Where the wing wall/retaining wall support allows lateral yielding of the stem, active earth pressures should be used in the geotechnical design of the structure. Where the wall support does not allow lateral yielding (which typically applies to a culvert or rigid frame structure), at-rest earth pressures should be assumed for the geotechnical design. The movement to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure, may be taken as follows:
 - Rotation of approximately 0.002 about the base of a vertical wall;
 - Horizontal translation of 0.001 times the height of the wall; or
 - A combination of both.

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

- Seismic loading will result in increased lateral earth pressures acting on the culvert walls or wing walls/retaining walls. The walls should be designed to withstand the combined lateral loading for the appropriate static pressure conditions given above, plus the earthquake-induced dynamic earth pressure. According to Table A3.1.7 of the *CHBDC*, this site is located in Seismic Zone 1. The site-specific zonal acceleration ratio for Brighton is 0.05. Based on experience, for the subsurface conditions at the culvert sites, a 20 per cent amplification of the ground motion may occur, resulting in an increase in the ground surface acceleration from 0.05g to 0.06g. The seismic lateral earth pressure coefficients given below have been derived based on a design zonal acceleration ratio of $A = 0.06$.
- In accordance with Sections 4.6.4 and C.4.6.4 of the *CHBDC* and its *Commentary*, for structures which allow lateral yielding, the horizontal seismic coefficient, k_h , used in the calculation of the seismic active pressure coefficient, is taken as 0.5 times the zonal acceleration ratio (i.e. $k_h = 0.03$). For structures that do not allow lateral yielding, k_h is taken as 1.5 times the zonal acceleration ratio (i.e. $k_h = 0.09$). The seismic active earth pressure coefficient is also dependent on the vertical component of the earthquake acceleration, k_v . Three discrete values of vertical acceleration are typically selected for analysis, corresponding to $k_v = +2/3 k_h$, $k_v = 0$, and $k_v = -2/3 k_h$.

- The following seismic active pressure coefficients (k_{AE}) for the two cases (Case I and Case II) may be used in design; these coefficients reflect the maximum K_{AE} obtained using the k_h and three values of k_v as described above. It should be noted that these seismic earth pressure coefficients assume that the back of the wall is vertical and the ground surface behind the wall is flat.

SEISMIC ACTIVE PRESSURE COEFFICIENTS, K_{AE}

Wall Condition	Case I	Case II	
		Granular A	Granular B Type II
Yielding wall	0.32	0.26	0.30
Non-yielding wall	0.37	0.30	0.34

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

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

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

where K is either the static active earth pressure coefficient (K_a) or the static at rest earth pressure coefficient (K_o), as applicable;
 K_{AE} is the seismic active earth pressure coefficient;
 γ' is the effective unit weight of the soil (kN/m^3) taken as the soil unit weight given in previous sections for fill materials;
 d is the depth below the top of the wall (m); and
 H is the height of the wall above the toe (m).

6.9 Construction Considerations

6.9.1 Groundwater and Surface Water Control

Control of the surface water and groundwater will be necessary at the new culvert or culvert extension sites to allow for excavation and foundation construction to be carried out in dry conditions.

Depending on the Proctor's Creek flow at the time of construction, the surface water flow could be passed through the culvert area by means of a temporary pipe, or diverted by pumping from behind a temporary cofferdam. Surface water should be directed away from the excavation areas, to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade soils; further discussion on this aspect is provided in Section 6.9.3.

As discussed in Sections 6.3, 6.4 and 6.5, foundations for the new culverts or culvert extensions will require excavation to between 1 m and 4.5 m below the groundwater level at the site. Appropriate groundwater control will be required to allow excavation and foundation subgrade preparation in the water-bearing silt to silty sand deposit and silty sand till deposit; this could involve the use of interlocking steel sheet piles extended to sufficient depth to avoid piping, and/or the use of a specialized eductor system designed and installed by a specialist contractor. It is recommended that a Non-Standard Special Provision (NSSP) be included in the Contract Documents to warn the Contractor of the soil conditions and the requirement for design and installation of a groundwater control system for these culvert sites. An example NSSP is provided in Appendix A.

6.9.2 Excavations and Temporary Roadway Protection

Temporary excavations for the new culverts or culvert extensions will extend through existing embankment fill, peat, and into the loose to compact silt or compact to very dense silt/sandy silt till. Excavation works must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act and Regulations for Construction Projects. The existing fill and the loose portions of the silt to silty sand soils are classified as Type 3 soil, according to the OHSA. Where space permits, and provided that appropriate dewatering to maintain the water level below the base of the foundation excavations, temporary open-cut excavations through these materials should be made with side slopes formed no 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 existing access road/new W-N/S Ramp and at the intersection of County Road 30 and Telephone Road to facilitate the culvert extension or new culvert construction 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 may remain present adjacent to the excavation can tolerate this level of deformation.

6.9.3 Subgrade Protection

The silt and sandy silt till soils that are exposed at the footing or box culvert subgrade level will be susceptible to disturbance from construction traffic and/or ponded water. In order to limit this degradation, it is recommended that a working mat of lean concrete be placed on the subgrade within four hours after preparation, inspection and approval of the footing subgrade. This requirement can be addressed either with a note on the General Arrangement drawing, or with a Non-Standard Special Provision (NSSP). A sample NSSP to address this requirement is included in Appendix A.

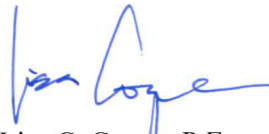
7.0 CLOSURE

This Foundation Design Report was prepared by Mr. Matthew Kelly, and reviewed by Ms. Lisa Coyne, P. Eng., an Associate and geotechnical engineer with Golder. Mr. Jorge Costa, P.Eng., a Principal of and Designated MTO Contact for Golder, conducted an independent review of the report.

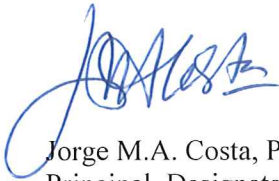
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LIST OF ABBREVIATIONS

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.)

(b) Cohesive Soils

Consistency	c_u, s_u kPa	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 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.

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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

RECORD OF BOREHOLE No 07-1

1 OF 2 **METRIC**

PROJECT 06-1111-057

W.P. 256-98-00

LOCATION N 4882198.0 ; E 203025.3

ORIGINATED BY SB

DIST HWY 401

BOREHOLE TYPE Track-Mounted CME-55, 108mm I.D. Hollow Stem Augers

COMPILED BY MWK

DATUM Geodetic

DATE May 7, 2007

CHECKED BY LCC/JMAC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			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 (%)		
190.4	GROUND SURFACE						20 40 60 80 100								
0.0	TOPSOIL						20 40 60 80 100								
0.2	Sand and silt, trace to some gravel, trace clay, containing rootlets (FILL) Loose Brown Moist		1	SS	7	∇	190						12 43 40 5		
			2	SS	8		189						0 2 84 14		
188.8															
1.6	Clayey silt, trace sand (FILL) Firm Brown Moist		3	SS	5		188								
188.0	PEAT		4	SS	4										
2.6	SILT, trace to some sand, trace clay Compact Brown to grey Moist to wet		5	SS	16		187								
			6	SS	21		186						0 10 80 10		
			7	SS	13		185								
			8	SS	3*		184								
			9	SS	WH*		183						0 7 89 4		
			10	SS	19	182									
179.8						180									
10.6	Silty SAND, some gravel, trace clay (TILL) Compact to very dense Grey Moist		11	SS	22	179									
			12	SS	47	178						23 49 25 3			
			13	SS	92	177									
175.5						176									

Continued Next Page

+³, X³: Numbers refer to Sensitivity O³% STRAIN AT FAILURE

MIS-MTO 001 061111057MTO.GPJ GAL-MISS.GDT 11/15/07 JFC

RECORD OF BOREHOLE No 07-1

2 OF 2 **METRIC**

PROJECT 06-1111-057

W.P. 256-98-00

LOCATION N 4882198.0 ; E 203025.3

ORIGINATED BY SB

DIST HWY 401

BOREHOLE TYPE Track-Mounted CME-55, 108mm I.D. Hollow Stem Augers

COMPILED BY MWK

DATUM Geodetic

DATE May 7, 2007

CHECKED BY LCC/JMAC

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	W _p	W	W _L		
14.9	SAND and GRAVEL Very dense																
174.9	Grey		14	SS	91/15												
15.5	Wet END OF BOREHOLE																
Notes: 1. * Low SPT "N" values (WH and 3 blows/0.3 m of penetration) are the result of sample disturbance due to groundwater inflow to the borehole. 2. Water level in open borehole at a depth of 2.1 m (Elev. 188.3 m) on completion of drilling.																	

MIS-MTO 001 061111057MTO.GPJ GAL-MISS.GDT 11/15/07 JFC

RECORD OF BOREHOLE No 07-4

1 OF 1 **METRIC**

PROJECT 06-1111-057

W.P. 256-98-00

LOCATION N 4882094.4 ; E 202988.4

ORIGINATED BY SB

DIST HWY 401

BOREHOLE TYPE Track-Mounted CME-55, 108mm I.D. Hollow Stem Augers

COMPILED BY MWK

DATUM Geodetic

DATE May 9, 2007

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		+ FIELD VANE							● QUICK TRIAXIAL × REMOULDED		
187.6	GROUND SURFACE						20	40	60	80	100								
0.0	Silty SAND, trace clay, containing rootlets and organics Very loose Brown Moist		1	SS	WH		187												
186.8			2	SS	8		186												
0.8	SILT, trace to some sand, trace clay Loose to compact Grey Moist to wet		3	SS	15		185												
			4	SS	11		184												
			5	SS	10		183												
183.8																			
3.8	Silty SAND, trace to some gravel, some clay (TILL) Compact Grey Moist to wet		6	SS	3*														
			7	SS	3*														
			8	SS	26														
180.3																			
7.3	SAND and GRAVEL, trace to some silt Dense to very dense Grey Wet		9	SS	33														
			10	SS	70/15														
177.2																			
10.4	CLAYEY SILT, trace sand and gravel (TILL) Hard Grey Moist		11	SS	105														
175.0			12	SS	104														
12.6	END OF BOREHOLE																		
	Notes: 1. * Low SPT "N" values (3 blows/0.3 m of penetration) are the result of sample disturbance due to groundwater inflow to the borehole. 2. Water level in open borehole at a depth of 1.5 m (Elev. 186.1 m) on completion of drilling.																		

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

MIS-MTO 001 061111057MTO.GPJ GAL-MISS.GDT 11/15/07 JFC

RECORD OF BOREHOLE No 07-9

1 OF 2 **METRIC**

PROJECT 06-1111-057

W.P. 256-98-00

LOCATION N 4882190.1 ; E 203023.8

ORIGINATED BY SB

DIST HWY 401

BOREHOLE TYPE Track-Mounted CME-55, 108mm I.D. Hollow Stem Augers

COMPILED BY MWK

DATUM Geodetic

DATE May 11, 2007

CHECKED BY LCC/JMAC

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			20	40	60	80	100		
189.2	GROUND SURFACE													
0.0	PEAT		1	SS	2		189							
188.4							188							
0.8	SILT, trace to some sand, trace clay Compact Brown to grey Moist to wet		2	SS	16		188							
			3	SS	11		187							
			4	SS	11		186							
			5	SS	13		185							
			6	SS	8*		184							
			7	SS	13		183							
			8	SS	5*		182							
			9	SS	16		181							
			10	SS	7*		180							
			11	SS	16		179							
177.6			12	SS	116		178							
11.6	SAND and GRAVEL Very dense Grey Wet						177							
176.6	END OF BOREHOLE													
12.6														

MIS-MTO 001 061111057MTO.GPJ GAL-MISS.GDT 11/15/07 JFC

Continued Next Page

+³, X³: Numbers refer to Sensitivity O³% STRAIN AT FAILURE

+³, X³: Numbers refer to Sensitivity O³% STRAIN AT FAILURE

PROJECT 06-1111-057		RECORD OF BOREHOLE No 07-10		1 OF 1 METRIC	
W.P. 256-98-00		LOCATION N 4882111.7 ; E 202995.2		ORIGINATED BY SB	
DIST _____ HWY 401		BOREHOLE TYPE Track-Mounted CME-55, 108mm I.D. Hollow Stem Augers		COMPILED BY MWK	
DATUM Geodetic		DATE May 11, 2007		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 (%)
188.0	GROUND SURFACE					▽									
0.0	Silty SAND, containing organics and rootlets Very loose Brown and black Moist		1	SS	1										
187.2															
0.8	Sandy SILT, trace gravel, containing rootlets Compact Grey Moist to wet		2	SS	15										
			3	SS	9										
185.7															
2.3	SILT, trace to some sand, trace clay Loose to compact Grey Wet		4	SS	9										
			5	SS	8										
			6	SS	6*										
			7	SS	6*										
182.2															
5.8	Silty SAND, trace gravel Compact Grey Wet		8	SS	5*										
			9	SS	4*										
178.9															
9.1	CLAYEY SILT, some sand, trace gravel (TILL) Hard Grey Moist		10	SS	89										
			11	SS	96										
175.4															
12.6	END OF BOREHOLE		12	SS	107										
	Notes: 1. * Low SPT "N" values (4, 5 and 6 blows/0.3 m of penetration) are the result of sample disturbance due to groundwater inflow to the borehole. 2. Water level in open borehole at a depth of 2.1 m (Elev. 185.9 m) on completion of drilling.														

MIS-MTO 001 061111057MTO.GPJ GAL-MISS.GDT 11/15/07 JFC

RECORD OF BOREHOLE No 07-11

1 OF 1 **METRIC**

PROJECT 06-1111-057

W.P. 256-98-00

LOCATION N 4882213.5 ; E 203017.2

ORIGINATED BY SB

DIST HWY 401

BOREHOLE TYPE Portable Drilling Equipment, NQ Casing

COMPILED BY MWK

DATUM Geodetic

DATE May 14, 2007

CHECKED BY LCC/JMAC




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			20	40	60	80	100		
190.0	GROUND SURFACE													
0.0	Sand and silt, some gravel, trace clay, containing rootlets (FILL) Very loose Brown to grey Moist		1	SS	2									
188.8			2	SS	2		189							
1.2	PEAT, containing silty sand seams Very soft Wet		3	SS	2									
188.2														
1.8	SILT, trace to some sand, trace gravel, trace clay Compact Grey Wet		4	SS	10		188							
							187							
			5	SS	12		186							
			6	SS	21		185							
							184							
			7	SS	6*									
							183							
182.4														
7.6	Silty SAND, some gravel, trace clay (TILL) Very dense Grey Wet		8	SS	25/1		182							
180.9							181							
9.1	END OF BOREHOLE		9	SS	25/1									
	Notes: 1. * Low SPT "N" value (6 blows/0.3 m of penetration) is the result of sample disturbance due to groundwater inflow to the borehole. 2. Borehole advanced using portable drilling equipment with a half-weight hammer. SPT "N" values shown on this log have been adjusted to reflect "N" values that would be obtained using a standard - weight hammer. 3. Water flowing (artesian conditions) from borehole on completion of drilling. 4. Borehole sealed with bentonite.													

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

MIS-MTO 001 061111057MTO.GPJ GAL-MISS.GDT 11/15/07 JFC

PROJECT <u>06-1111-057</u>		RECORD OF BOREHOLE No 07-12		1 OF 1 METRIC	
W.P. <u>256-98-00</u>		LOCATION <u>N 4882564.2 ; E 203060.1</u>		ORIGINATED BY <u>SB</u>	
DIST <u> </u> HWY <u>401</u>		BOREHOLE TYPE <u>Portable Drilling Equipment, NQ Casing</u>		COMPILED BY <u>MWK</u>	
DATUM <u>Geodetic</u>		DATE <u>May 15, 2007</u>		CHECKED BY <u>LCC</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								20 40 60 80 100										10 20 30		

195.1	GROUND SURFACE															
0.0	Sand and silt, trace to some gravel, containing rootlets and organics (FILL) Very loose to loose Brown to grey at 1.5m Moist		1	SS	2	▽	195									
			2	SS	5		194									
			3	SS	3		193									
192.5			4	SS	5		192									
2.6	PEAT						191									
192.1																
3.0	Sandy SILT, some gravel, trace clay (TILL) Compact to very dense Grey Moist to wet		5	SS	14											
			6	SS	30/15											
190.2			7	SS	25/15											
4.9	END OF BOREHOLE															
	Notes: 1. Borehole advanced using portable drilling equipment with a half-weight hammer. SPT "N" values shown on this log have been adjusted to reflect "N" values that would be obtained using a standard - weight hammer. 2. Water level in open borehole at a depth of 0.4 m (Elev. 194.7 m) on completion of drilling.															

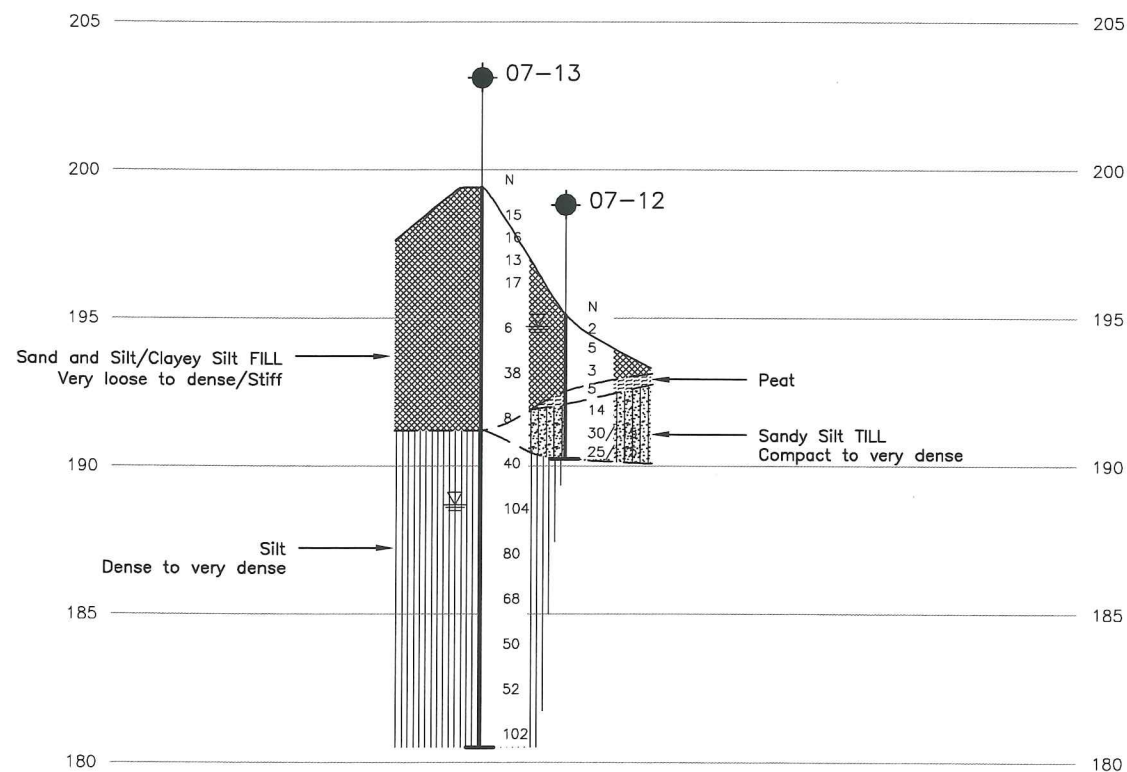
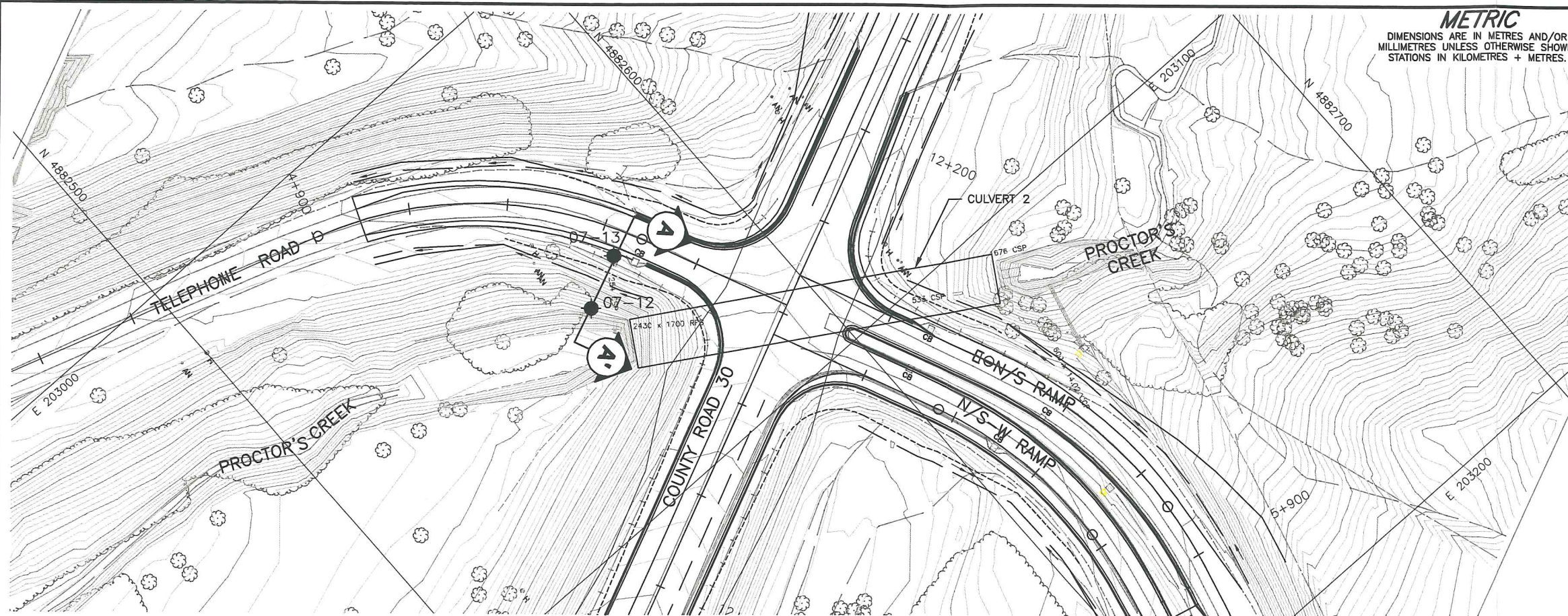
+³, ×³: Numbers refer to Sensitivity ○^{3%} STRAIN AT FAILURE

MIS-MTO 001 061111057MTO.GPJ GAL-MISS.GDT 11/15/07 JFC

PROJECT <u>06-1111-057</u>		RECORD OF BOREHOLE No 07-13		2 OF 2 METRIC	
W.P. <u>256-98-00</u>		LOCATION <u>N 4882574.5 ;E 203055.2</u>		ORIGINATED BY <u>PKS</u>	
DIST <u> </u> HWY <u>401</u>		BOREHOLE TYPE <u>Track-Mounted CME-55, 108mm I.D. Hollow Stem Augers</u>		COMPILED BY <u>MWK</u>	
DATUM <u>Geodetic</u>		DATE <u>July 4, 2007</u>		CHECKED BY <u>LCC</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE LIQUID LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
								20	40	60	80	100	W _p			W	W _L
	— CONTINUED FROM PREVIOUS PAGE —																
	SILT, trace sand and clay Dense to very dense Brown to grey Wet	<div></div>	12	SS	50		184										
								183									
			13	SS	52			182									0 0 94 6
180.5			14	SS	102		181										
18.9	END OF BOREHOLE																
	1. Water level in open borehole at a depth of 10.7 m (Elev. 188.7 m) on completion of drilling.																

MIS-MTO 001 061111057MTO.GPJ GAL-MISS.GDT 11/15/07 JFC



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

CONT No.
WP No. 256-98-00

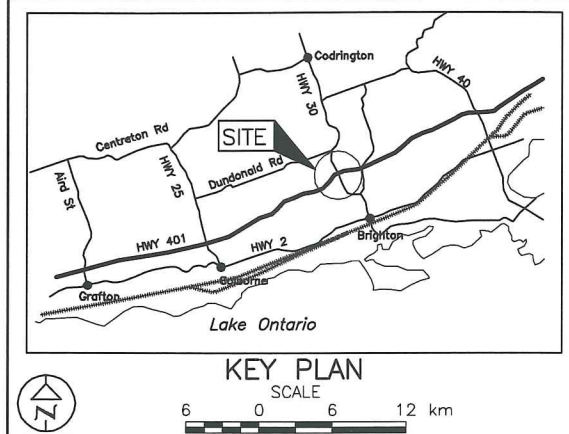
HIGHWAY 401 - COUNTY ROAD 30
PROCTOR'S CREEK CULVERTS (CULVERT 2)
BOREHOLE LOCATIONS
AND SOIL STRATA



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)
- WL in piezometer
- WL upon completion of drilling

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
07-12	195.1	4882564.2	203060.1
07-13	199.4	4882574.5	203055.2

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.

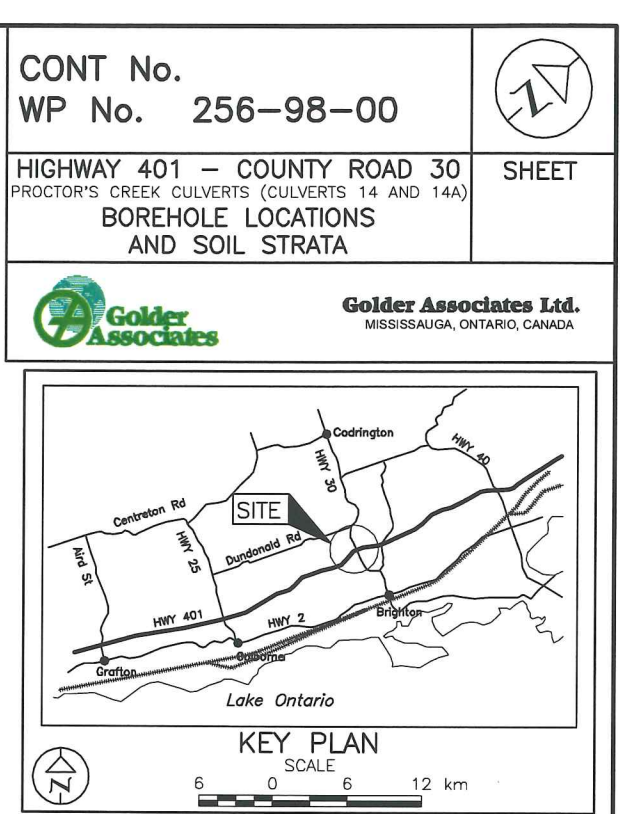
The boundaries between soil strata have been established only at borehole locations. Between Boreholes the boundaries are assumed from geological evidence.






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 plan provided in digital format by Giffels (drawing file name "401_30NEW.dwg", received May 23, 2007).

NO.	DATE	BY	REVISION
Geocres No.			
HWY. HIGHWAY 401	PROJECT NO. 06-1111-057	DIST.	
SUBM'D. MWK	CHKD. LCC	DATE: 12/4/07	SITE:
DRAWN: JFC/RJ	CHKD. MWK/LCC	APPD. LCC/JMAC	DWG. 1



LEGEND			
	Borehole - Current Investigation		
	Seal		
	Piezometer		
N	Standard Penetration Test Value		
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow); * indicates SPT "N" value affected by water inflow into borehole		
	WL in piezometer		
	WL upon completion of drilling		

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
07-1	190.4	4882198.0	203025.3
07-4	187.6	4882094.4	202988.4
07-9	189.2	4882190.1	203023.8
07-10	188.0	4882111.7	202995.2
07-11	190.0	4882213.5	203017.2

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

REFERENCE	
<p>Base plan provided in digital format by Giffels (drawing file name "+401_30NEWC.dwg", received May 23, 2007).</p>	

NO.	DATE	BY	REVISION

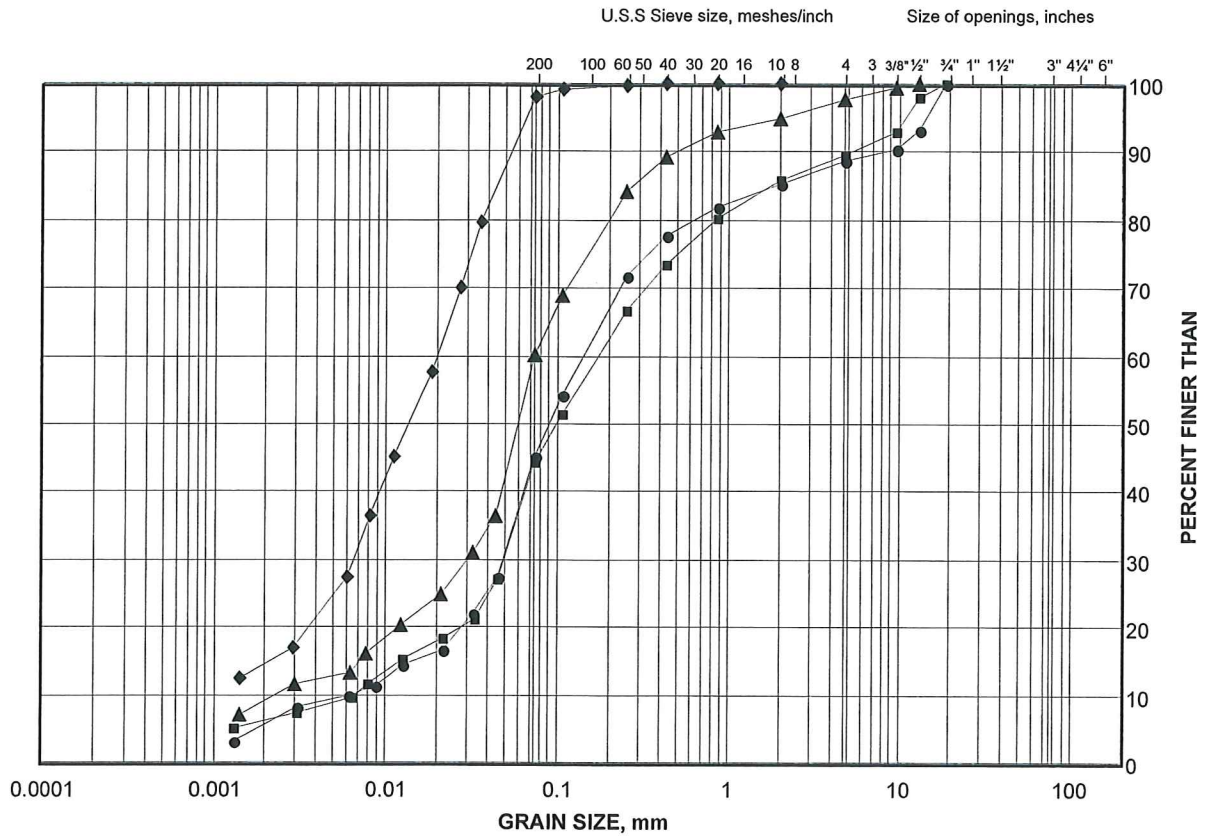
Geocres No.

HWY. HIGHWAY 401		PROJECT NO. 06-1111-057	DIST.
SUBM'D. MWK	CHKD. LCC	DATE: 12/4/07	SITE:
DRAWN: JFC/RJ	CHKD. MWK/J.LCC	APPD. LCC/JMAC	DWG. 2

GRAIN SIZE DISTRIBUTION TEST RESULTS

Silt to Sand and Silt Fill

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)
●	07-1	2	189.4
■	07-12	3	193.3
◆	07-1	3	188.6
▲	07-13	4	196.1

Project Number: 06-1111-057-1

Checked By: *Wazye*

Golder Associates

Date: 29-Nov-07

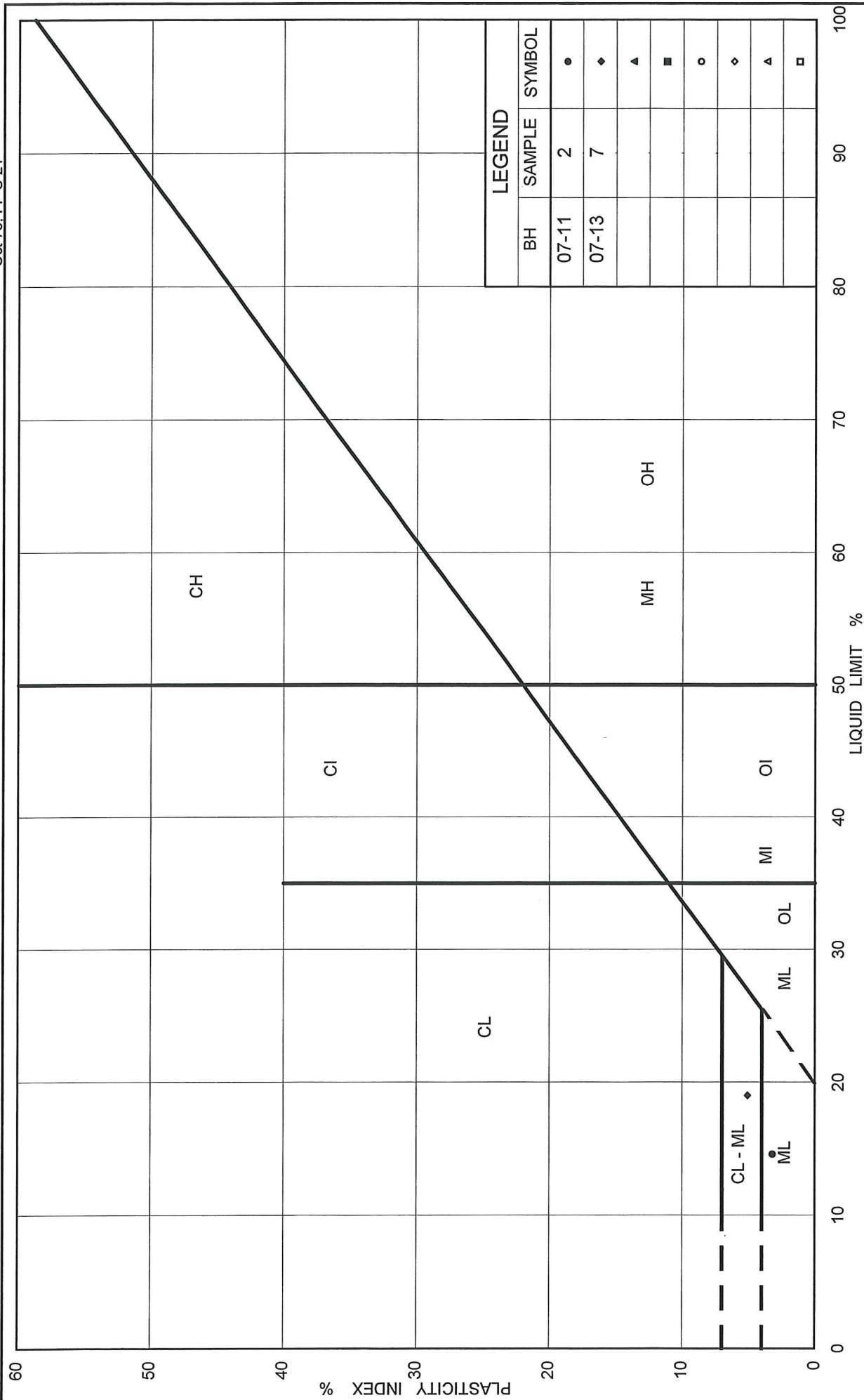


Figure 2

PLASTICITY CHART

Sand and Silt and Clayey Silt Fill

Ministry of Transportation



Ontario

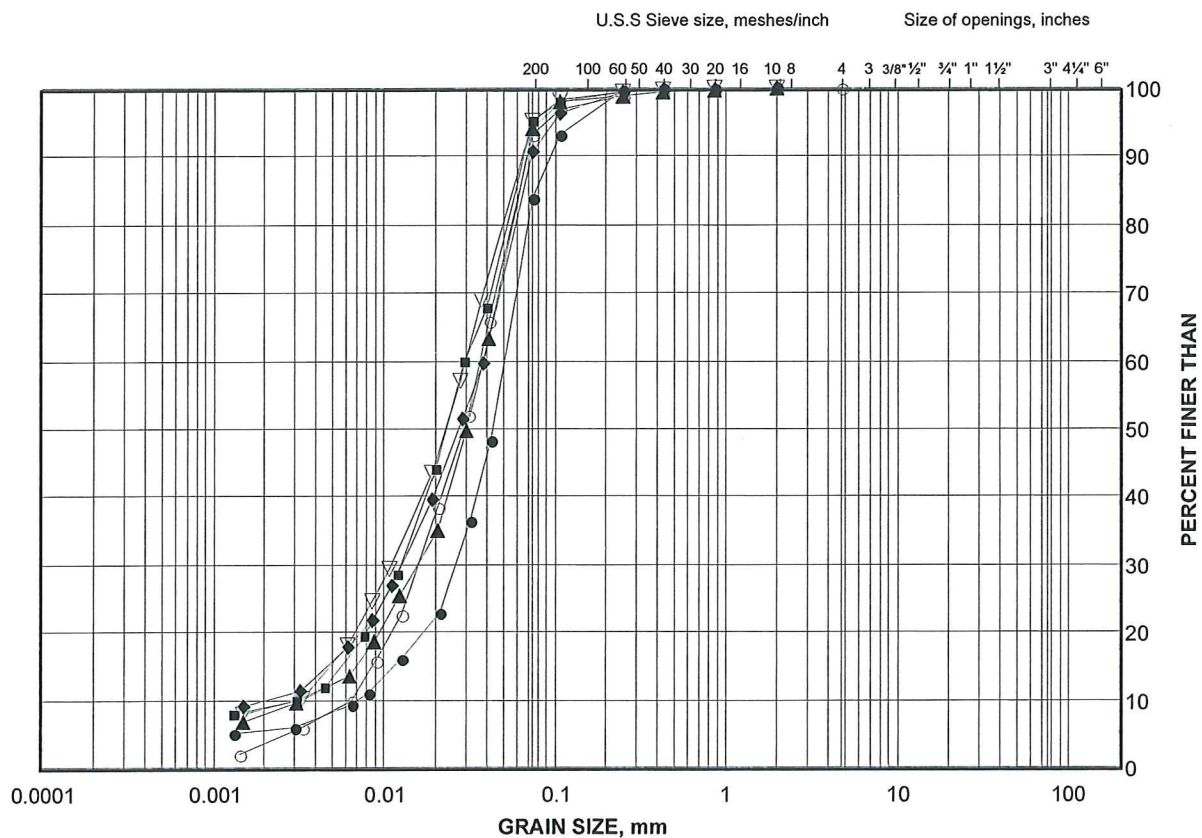
Project No. 06-1111-057-1

Checked By: *Wey*

GRAIN SIZE DISTRIBUTION TEST RESULTS

Silt to Sandy Silt

FIGURE 3A



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	07-9	5	185.8
■	07-10	6	183.9
◆	07-1	6	186.3
▲	07-11	7	183.6
▽	07-9	8	182.8
○	07-1	9	182.4

Project Number: 06-1111-057-1

Checked By: *U. Hogue*

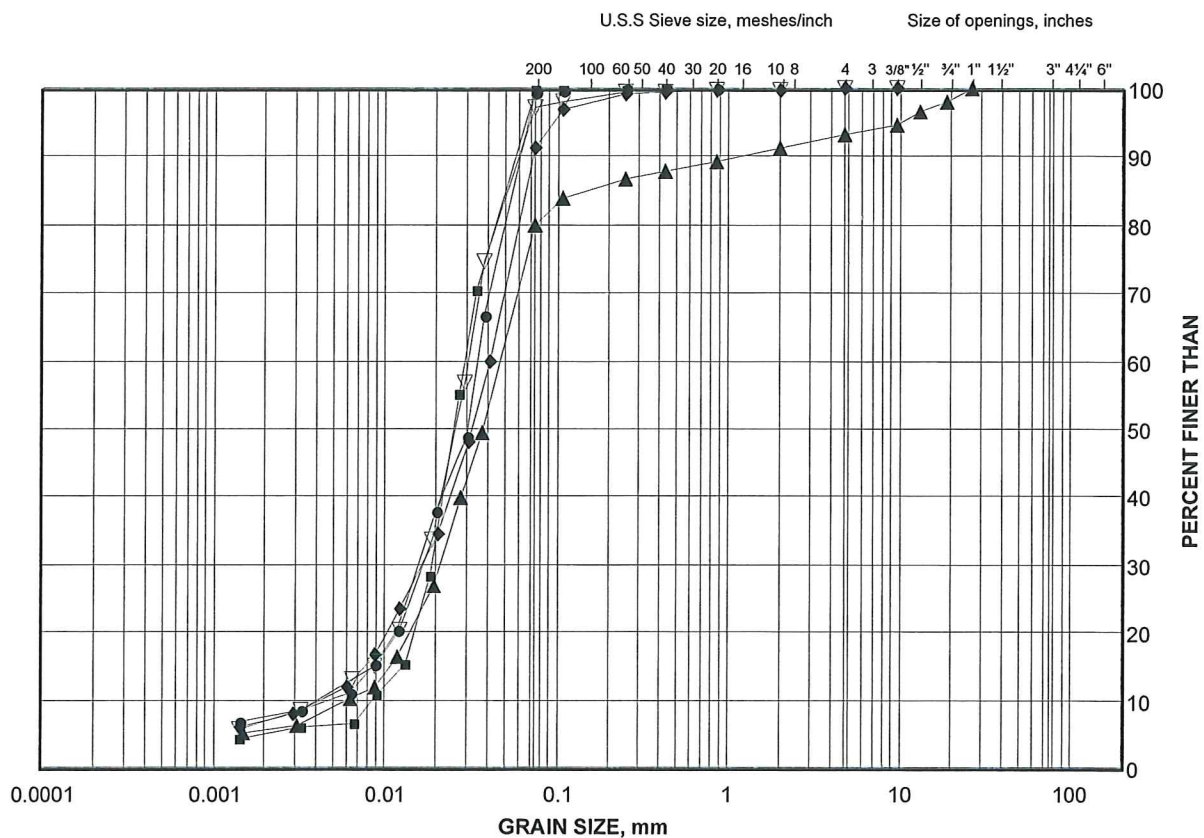
Golder Associates

Date: 29-Nov-07

GRAIN SIZE DISTRIBUTION TEST RESULTS

Silt to Sandy Silt

FIGURE 3B



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	07-13	10	186.9
■	07-13	13	182.3
◆	07-4	3	185.7
▲	07-11	4	187.8
▽	07-13	8	189.9

Project Number: 06-1111-057-1

Checked By: *Uhyne*

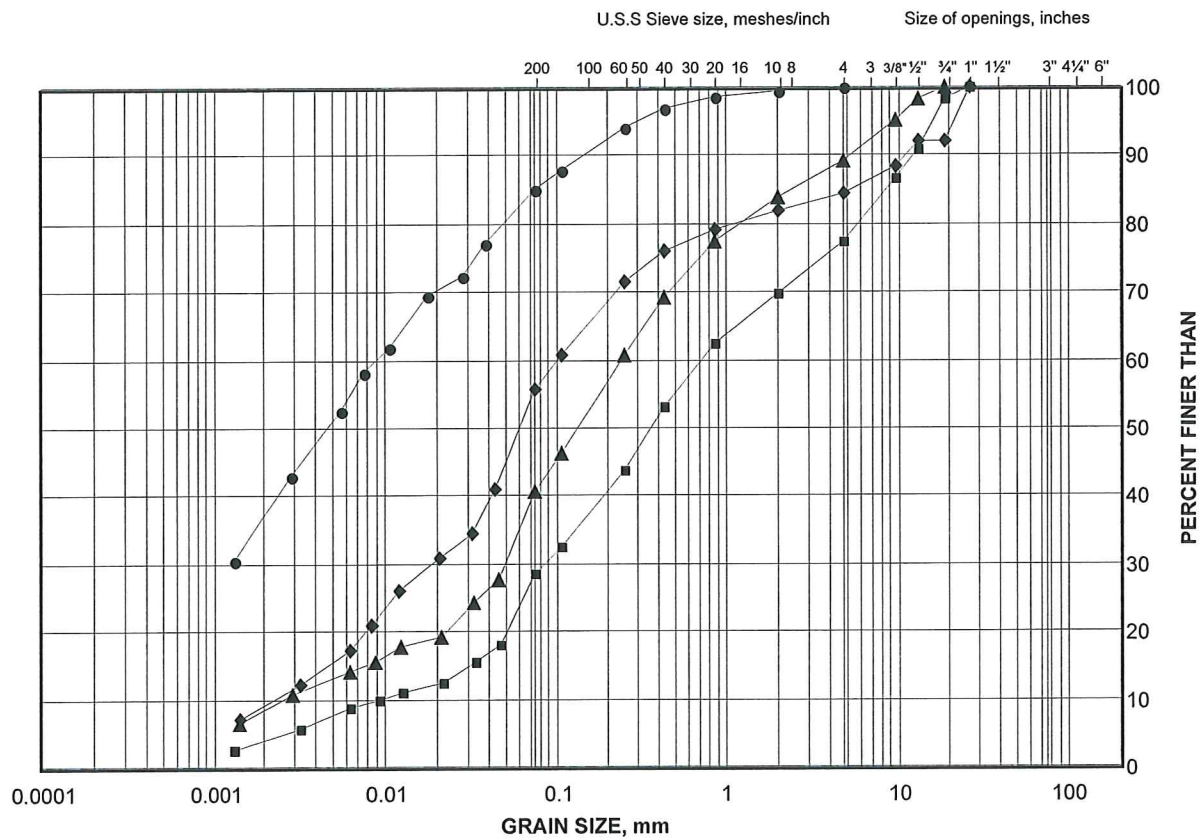
Golder Associates

Date: 29-Nov-07

GRAIN SIZE DISTRIBUTION TEST RESULTS

Silty Sand Till to Clayey Silt Till

FIGURE 4



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

LEGEND

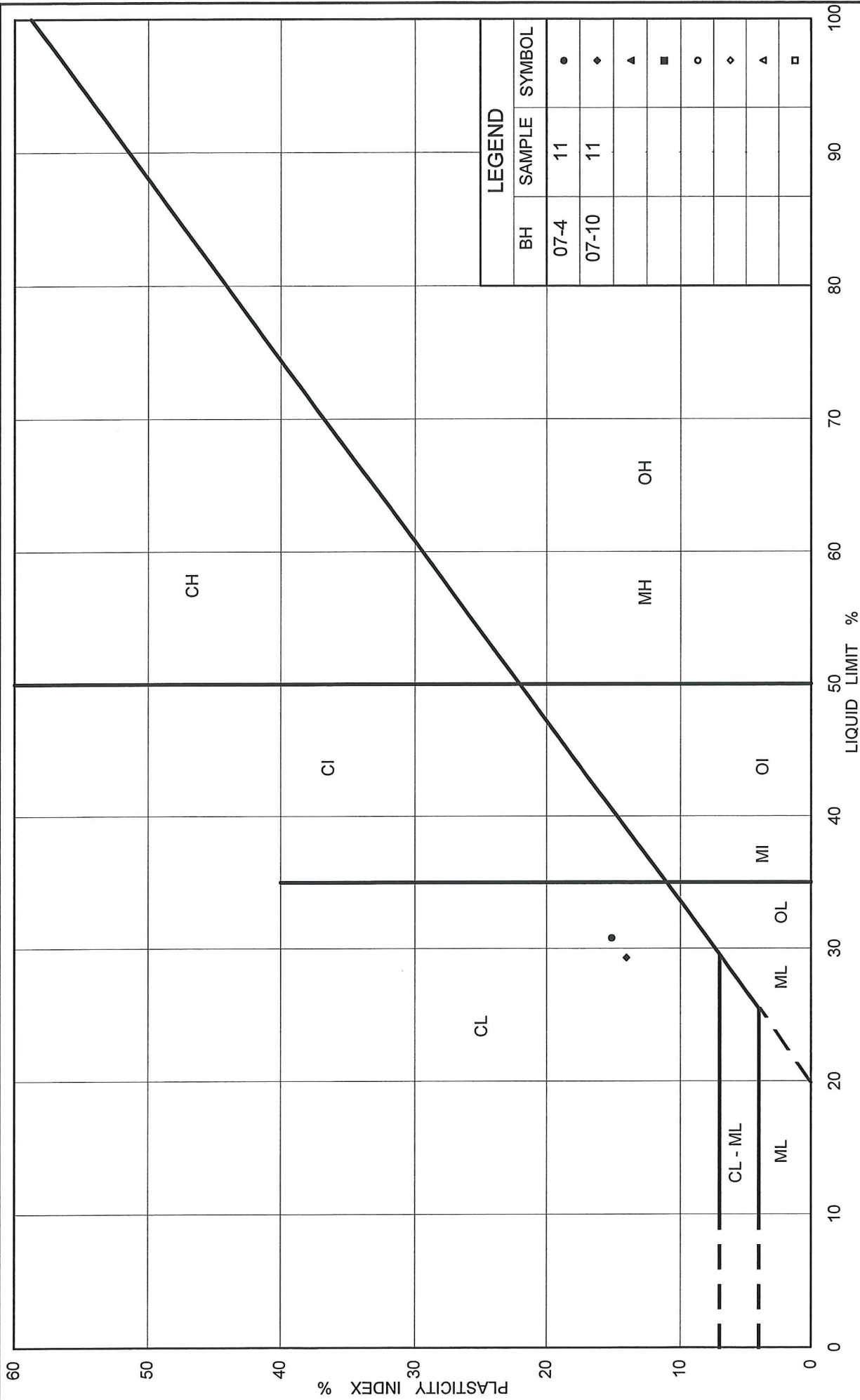
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	07-10	11	177.1
■	07-1	12	177.9
◆	07-12	5	191.7
▲	07-4	6	183.5

Project Number: 06-1111-057-1

Checked By: *[Signature]*

Golder Associates

Date: 29-Nov-07



Ministry of Transportation
Ontario

Figure 5

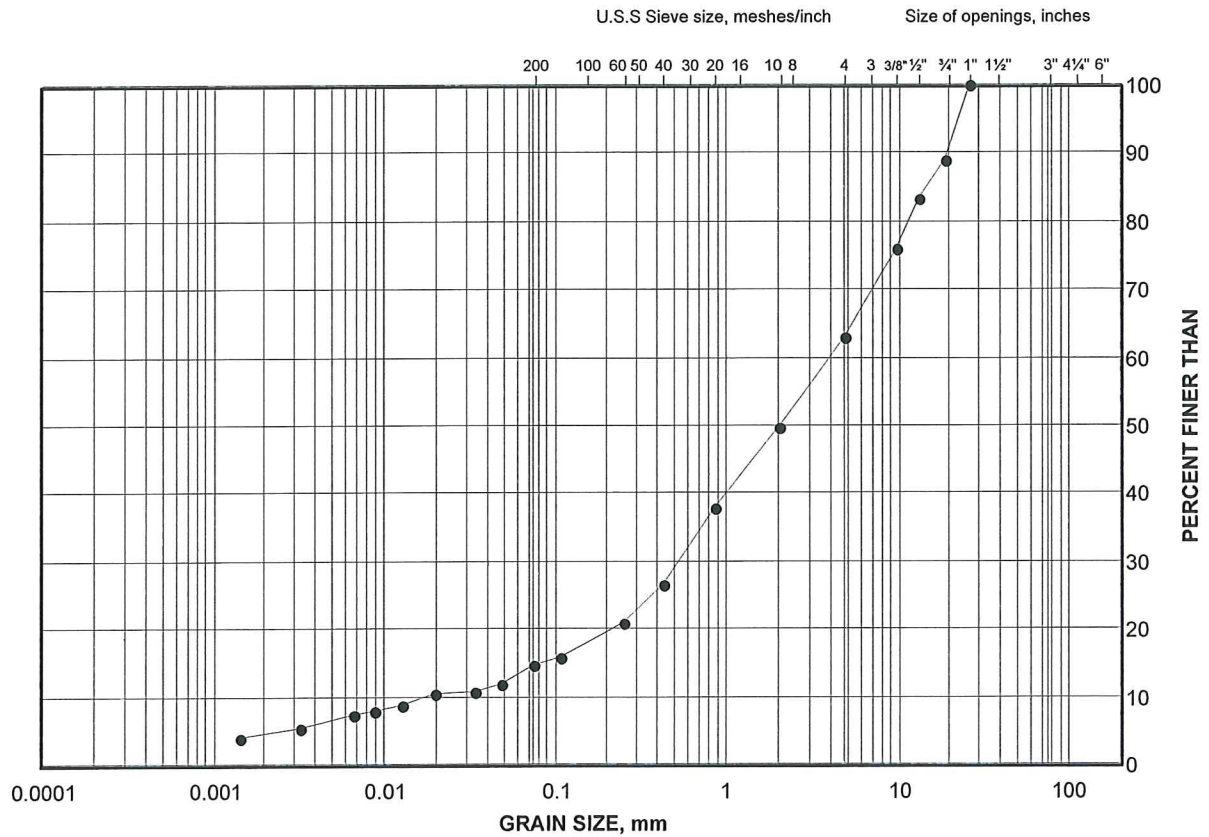
Project No. 06-1111-057-1

Checked By: *Wang*

GRAIN SIZE DISTRIBUTION TEST RESULT

Sand and Gravel

FIGURE 6



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	07-4	9	179.7

Project Number: 06-1111-057-1

Checked By: *Ulogova*

Golder Associates

Date: 29-Nov-07

DRAFT

November 2007

06-1111-057-1

APPENDIX A

NON-STANDARD SPECIAL PROVISIONS

GROUNDWATER CONTROL – Item No.

Non-Standard Special Provision

Foundations for the new culverts or culvert extensions will require excavation to between 1 m and 4.5 m below the groundwater level at the site. Appropriate groundwater control systems will have to be designed and installed to allow excavation and foundation subgrade preparation in the water-bearing silt to silty sand deposit and silty sand till deposit.

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

SUBGRADE PROTECTION – Item No.

Non-Standard Special Provision

The subgrade for the culvert foundations or box culverts will be comprised of a loose to dense silt to silty sand deposit; these soils will be susceptible to disturbance and loosening from construction traffic and ponded water. If the concrete for the footings cannot be poured within four hours after inspection and approval of the prepared subgrade, a working mat of lean concrete or mass concrete, with a minimum thickness of 100 mm, should be placed on the foundation subgrade.

Lean concrete shall have a compressive strength of at least 5 MPa, and be placed in accordance with OPSS 904.

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