



July 2014

FOUNDATION INVESTIGATION AND DESIGN REPORT

**Speed River Tributary Culvert 33-500/C, Station 16+357
Reconstruction and Widening of Highway 401
From 0.5 KM West of Regional Road 8/King Street
Easterly to 0.5 KM East of Regional Road 24/
Hespeler Road - 5.5 KM, GWP 4-00-00
Ministry of Transportation – West Region**

Submitted to:

Mr. Henry Huotari, P.Eng., Senior Project Manager, Principal
Delcan Corporation (a Parsons Company)
214-1069 Wellington Road South
London, Ontario
N6E 2H6

REPORT



**A world of
capabilities
delivered locally**

Report Number: 10-1132-0056-2000-R07

Geocres No. 40P8-218

Distribution:

8 Copies - Delcan Corporation (a Parsons Company)
2 Copies - Golder Associates Ltd.





Table of Contents

PART A - FOUNDATION INVESTIGATION REPORT

1.0 INTRODUCTION.....	1
2.0 SITE DESCRIPTION.....	2
2.1 General.....	2
2.2 Site Geology	2
3.0 INVESTIGATION PROCEDURES	3
4.0 SUBSURFACE CONDITIONS.....	4
4.1 Site Stratigraphy	4
4.1.1 Pavements	5
4.1.2 Topsoil	5
4.1.3 Fill	5
4.1.4 Silty Sand.....	6
4.1.5 Sand and Silt.....	6
4.1.6 Sand.....	6
4.1.7 Silty Clay.....	6
4.1.8 Clayey Silt.....	7
4.1.9 Sandy Silt.....	7
4.1.10 Silt.....	7
4.1.11 Sand and Gravel	7
4.1.12 Dolostone Bedrock.....	8
4.2 Groundwater Conditions	8
5.0 MISCELLANEOUS	10

PART B - FOUNDATION DESIGN REPORT

6.0 ENGINEERING RECOMMENDATIONS.....	11
6.1 General.....	11
6.2 Culvert Foundations.....	12
6.2.1 Geotechnical Resistances.....	13
6.2.2 Frost Treatment	13
6.2.3 Resistance to Lateral Forces/Sliding Resistance	13



FOUNDATION INVESTIGATION AND DESIGN REPORT SPEED RIVER TRIBUTARY CULVERT, SITE 33-500/C

6.3	Bedding	14
6.4	Backfill and Cover	14
6.5	Embankment Widening and Settlement	14
6.6	Drop Structure	15
6.6.1	Foundations – Drop Structure	15
6.6.2	Resistance to Lateral Forces	15
6.7	Retaining Walls	16
6.7.1	Wingwall Options	16
6.7.2	Foundations – Retaining Walls	17
6.7.3	Resistance to Lateral Forces	18
6.8	Liquefaction Potential and Seismic Analysis	19
6.8.1	Seismic Parameters	19
6.8.2	Seismic Hazard Assessment	19
6.9	Lateral Earth Pressures for Design	19
6.10	Construction Considerations	21
6.10.1	General	21
6.10.2	Erosion and Scour Protection	21
6.10.3	End Treatments and Camber	22
6.11	Excavations and Groundwater Control	22
6.11.1	Staging and Temporary Roadway Protection	23
7.0	MISCELLANEOUS	25
LIST OF ABBREVIATIONS		
LIST OF SYMBOLS		
RECORD OF BOREHOLE SHEETS		
FIGURE 1 - Key Plan		
DRAWING 1 - Borehole Locations and Soil Strata		
APPENDICES		
APPENDIX A		
Laboratory Test Data		
APPENDIX B		
Additional Boreholes and Laboratory Test Data		



PART A

FOUNDATION INVESTIGATION REPORT

**SPEED RIVER TRIBUTARY CULVERT 33-500/C, STATION 16+357
RECONSTRUCTION AND WIDENING OF HIGHWAY 401
FROM 0.5 KM WEST OF REGIONAL ROAD 8/KING STREET EASTERLY TO
0.5 KM EAST OF REGIONAL ROAD 24/HESPELER ROAD – 5.5 KM
GWP 4-00-00
MINISTRY OF TRANSPORTATION - WEST REGION**



1.0 INTRODUCTION

Golder Associates Ltd. (Golder Associates) has been retained by Delcan Corporation (a Parsons Company) (Delcan) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations as part of the detail design work for GWP 4-00-00. The project involves the detail design for the reconstruction and widening of Highway 401 from 0.5 kilometres west of Regional Road 8/King Street easterly to 0.5 kilometres east of Regional Road 24/Hespeler Road.

This report addresses the replacement of the culvert at Station 16+357 (Site 33-500/C) located approximately 0.9 kilometres east of Regional Road 17/Fountain Street.

The purpose of the foundation investigation is to explore the subsurface conditions at the location of the proposed structure by drilling boreholes and carrying out in situ testing and laboratory testing on selected samples. The terms of reference for the scope of work are outlined in the MTO's Request for Proposal and in Golder Associates' proposal P0-1132-0056 dated July 23, 2010 and our revised scope letter 10-1132-0056-2000-L02, dated May 28, 2012. The work was carried out in accordance with our Quality Control Plan for Foundations Engineering dated September 23, 2010.

Delcan provided Golder Associates with preliminary drawings for this project in digital format.



2.0 SITE DESCRIPTION

2.1 General

The site of the Speed River Tributary culvert is located in the City of Cambridge, Region of Waterloo, Ontario. The culvert crosses Highway 401 at Station 16+357, with an approximately 45 degree skew to the highway. Initially, it was proposed to replace the culvert at approximately 60 metres east of the existing structure, perpendicular to the highway centreline; however, the current design involves replacing the culvert at the approximate existing location and alignment. The location of the project is shown on the Key Plan, Figure 1.

For the purposes of this report, Highway 401 and the culvert are assumed to be oriented in an east-west direction and a northwest-southeast direction, respectively. This section of Highway 401 is currently a six lane divided highway oriented generally east-west. The Speed River Tributary flows south in a channel located between rural agricultural/residential properties. The tributary flows through an existing 1.22x1.22x99.0 metre concrete open footing culvert which has a 1.20x1.20x8.6 metre concrete box culvert extension at the outlet (right). It then flows into a 30 metre long 1.5 metre diameter corrugated steel pipe (CSP) culvert beneath Leisure Lodge Road in Riverside Park.

2.2 Site Geology

This project lies within the physiographic region of southwestern Ontario known as the Waterloo Hills which primarily comprises sandy glacial till ridges or glacial kame moraines with outwash sands in the lower areas. The physiographic mapping indicates that the site is situated in a former glaciofluvial spillway area.¹

The quaternary geology mapping indicates that the site is located on a deposit of Maryhill Till, bordered closely to the west by a deposit of Port Stanley Till.² The underlying bedrock surface is typically between elevation 274 and 282 metres based on geologic mapping.³ The rock formation is mapped and described as cream and brown, fine to medium crystalline dolomite of the Guelph Formation.⁴

¹ Chapman, L.J. and Putnam, D.F., 1984: The Physiography of Southern Ontario, Third Edition. Ontario Geological Survey, Special Volume 2.

² Karrow, P.F., 1987: Quaternary Geology of the Cambridge Area, Southern Ontario. Ontario Geological Survey, Map 2508, scale 1:50,000

³ Ontario Department of Mines, 1960: Bedrock Topography, Galt Area, Southern Ontario. Map 2030, scale 1:50,000

⁴ Sanford, B.V., 1969: Geology, Toronto-Windsor Area, Ontario. Geological Survey of Canada, Map 1263A, scale 1:250,000.



3.0 INVESTIGATION PROCEDURES

The field work for the investigation was carried out between May 31 and September 25, 2012 and September 10 and 12, 2013, during which time 7 boreholes (600 series) were drilled at the locations shown on the Borehole Location Plan, Drawing 1. Initially 3 boreholes (601, 602, and 603) were advanced along the proposed perpendicular replacement alignment. However, as the design has changed to replacement at the existing alignment, four additional boreholes (601A, 602A, 603A and 604) were advanced. Also, boreholes 811 and 813 (Geocres No. 40P8-227) were advanced for the retaining walls portion of this assignment and have been utilized in this report. The table below summarizes the borehole locations, ground surface elevations at the borehole locations, and borehole depths.

Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
601	4 808 240	235 018	297.18	13.35
601A	4 808 168	234 941	289.25	7.68
602	4 808 191	235 063	291.40	12.50
602A	4 808 156	235 091	283.78	7.74
603	4 808 216	235 035	291.38	9.27
603A	4 808 160	234 965	294.09	13.78
604	4 808 171	235 010	293.00	14.94
811	4 808 168	235 067	284.54	8.47
813	4 808 158	235 022	292.86	10.36

The investigation was carried out using truck and track mounted drilling equipment supplied and operated by a specialist drilling contractor. In the boreholes, samples of the overburden were obtained at generally 0.76 and 1.5 metre intervals of depth using 50 millimetre outside diameter split spoon sampling equipment in accordance with the standard penetration test (SPT) procedures of ASTM D1586. The recorded SPT N values are noted on the Record of Borehole sheets. According to ASTM D1586, the SPT resistance, or N value, is defined as the number of blows required by a 63.5 kilogram hammer dropped from a height of 760 millimetres to drive a split-spoon sampler a distance of 300 millimetres following an initial penetration of 150 millimetres. In cases where it was not possible to achieve a full 450 millimetres of drive, a penetration resistance representing the number of blows to drive the sampler is recorded on the Record of Borehole. The penetration resistance obtained in the first 150 millimetres is normally neglected unless the sampler could only be driven 150 millimetres or less, in which case SPT testing was terminated after 100 blows. The results of the SPT testing as presented on the Record of Borehole sheets and in Section 4 are unmodified (not standardized for hammer efficiency, borehole diameter, rod length, etc.).



The samplers used in the investigation limit the maximum particle size that can be sampled and tested to about 40 millimetres. Therefore, particles or objects that may exist within the soils that are larger than this dimension will not be sampled or represented in the grain size distributions. Larger particle sizes including cobbles are known to be present in the fill materials and native sand and gravel as discussed in the text of this report.

The boreholes were terminated between 7.7 and 14.9 metres below the existing pavement or ground surface. Groundwater conditions in the boreholes were observed throughout the drilling operations and groundwater observation standpipes were installed in boreholes 601A and 811 as indicated on the corresponding Record of Borehole sheets. The boreholes were backfilled in general accordance with current MTO procedures and Ontario Regulation 903 (as amended).

The field work was monitored on a full-time basis by experienced Golder staff members who also located the boreholes in the field, monitored the drilling, sampling, and in situ testing operations, logged, and surveyed the boreholes. The samples were identified in the field, placed in labelled containers, and transported to our London laboratory for further examination and testing. Index and classification tests consisting of water content determinations, grain size distribution analyses, and Atterberg Limits determinations were carried out on selected samples. The results of the testing are shown on the Record of Borehole sheets and in Appendix A.

The locations of the boreholes are shown on the Record of Borehole sheets and on Drawing 1, attached.

4.0 SUBSURFACE CONDITIONS

4.1 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes, together with the results of the in situ testing and the laboratory testing carried out on selected samples, are provided on the attached Record of Borehole sheets following the text of this report and in Appendix A. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous samples and observations of drilling resistance and, therefore, may represent transitions between soil and rock types rather than exact planes of geological change. Further, the subsurface conditions will vary between and beyond the borehole locations.

The boreholes drilled at the site generally encountered existing pavement structure or surficial topsoil, overlying fill materials and buried topsoil, overlying layers of native silty sand to silt and sand, and sand and gravel, overlying a more extensive deposit of sand and gravel at depth. The bedrock surface was encountered in the borehole drilled near the culvert outlet.

The locations and elevations of the boreholes, together with the interpreted stratigraphic profiles, are shown on Drawing 1. Detailed descriptions of the subsurface conditions encountered in the boreholes are provided on the Record of Borehole sheets and summarized in subsequent report sections.

Descriptions of the subsurface conditions encountered in boreholes 601, 602, and 603, advanced for the initial proposed replacement alignment, have not been included in the summary in the following report sections. The



corresponding Record of Borehole sheets and associated laboratory test data have been included in Appendix B for reference.

4.1.1 Pavements

Asphaltic concrete pavement was encountered at the ground surface in boreholes 603A, 604, and 813. The asphaltic concrete was about 150 to 240 millimetres thick at the borehole locations, and was underlain by 150 to 830 millimetres of granular base materials. The granular base material in borehole 603A had a measured N value of 52 blows per 0.3 metres.

4.1.2 Topsoil

Approximately 1160 and 270 millimetres of topsoil was encountered at the ground surface in boreholes 601A and 811, respectively. Approximately 240 millimetres of buried topsoil was encountered within the fill materials in borehole 604 at elevation 288.8 metres. Approximately 310 millimetres of buried topsoil was encountered beneath the fill materials in borehole 813 at elevation 285.7 metres. Measured N values of 13 to 26 blows per 0.3 metres were obtained within the topsoil. The water content of a sample of the buried topsoil in borehole 813 was 19 per cent.

Materials designated as topsoil in this report were classified solely based on visual and textural evidence. Testing of organic content or for other nutrients was not carried out. Therefore, the use of materials classified as topsoil cannot be relied upon for support and growth of landscaping vegetation.

4.1.3 Fill

Fill materials predominantly consisting of granulars were encountered in each of the boreholes. Cohesive fill was encountered in borehole 602A only. Borehole 601A was advanced north of the highway and boreholes 811 and 602A were advanced south of the existing highway. Between 0.4 and 2.1 metres of loose to compact granular fill materials were encountered beneath the topsoil in boreholes 601A and 811 and from the ground surface in borehole 602A. Boreholes 603A, 604, and 813 were advanced through the existing Highway 401 platform and encountered between 5.6 and 7.9 metres of compact to very dense granular fill materials beneath the pavement structure. A layer of buried topsoil was encountered within the fill materials in borehole 604, as noted above.

The granular fill materials had measured N values of between 4 and greater than 100 blows per 0.3 metres. Water contents of samples of the fill materials ranged from 5 to 12 per cent. Grain size distribution curves for samples of the granular fill material are provided on Figure A-1.



4.1.4 Silty Sand

Compact to very dense silty sand was encountered in borehole 601A beneath the fill materials at elevation 287.7 metres, beneath the silty clay in borehole 604 at elevation 283.7 metres, and beneath the buried topsoil in borehole 813 at elevation 285.4 metres. The silty sand layers were between 1.2 and 1.5 metres thick. Measured N values from the silty sand ranged from 10 to 64 blows per 0.3 metres. Water contents of samples of the silty sand ranged from 9 to 19 per cent. Grain size distribution curves for samples of the silty sand are provided on Figure A-2.

4.1.5 Sand and Silt

Layers of compact to very dense sand and silt were encountered in borehole 603A beneath the fill materials and beneath the silty clay at elevations 287.4 and 283.1 metres, respectively. A measured N value from the upper sand and silt was 12 blows per 0.3 metres and N values from the lower sand and silt ranged from 72 to greater than 100 blows per 0.3 metres. The water contents of samples of the sand and silt were 19 and 20 per cent. Grain size distribution curves for samples of the sand and silt are provided on Figure A-3.

4.1.6 Sand

Layers of compact to dense sand was encountered beneath the silty sand in boreholes 601A at elevation 286.5 metres, below the sand and silt in borehole 603A at elevation 286.6 metres, and beneath the clayey silt in borehole 813 at elevation 283.4 metres. The sand was about 0.8 and 2.3 metres thick in boreholes 601A and 603A, respectively. Borehole 813 was terminated in the sand after exploring some 0.9 metres. Measured N values from the sand ranged from 10 to 42 blows per 0.3 metres. The water contents of selected samples of sand ranged from 9 to 18 per cent. Grain size distribution curves for samples of the sand are provided on Figure A-4.

4.1.7 Silty Clay

Very stiff to hard silty clay was encountered between elevations 283.6 and 284.8 metres beneath the sand and gravel in borehole 601A, beneath the silty sand and gravel in borehole 603A, and beneath the fill material in borehole 604. The silty clay was 0.5 to 1.1 metres thick. The silty clay had measured N values of 23 to 72 blows per 0.3 metres. Water contents of samples of the silty clay were 19 and 20 per cent. Atterberg Limits determinations carried out on samples of the silty clay yielded liquid limits of 38 and 39 per cent, plastic limits of 20 and 21 per cent, and plasticity indices of 17 and 20 per cent, indicating intermediate plasticity. The results of



the Atterberg limits determinations are shown on Figure A-8. Grain size distribution curves for samples of the silty clay are provided on Figure A-5.

4.1.8 Clayey Silt

Layers of very stiff clayey silt, 0.4 and 0.5 metres thick, were encountered beneath the fill material in borehole 811 and beneath the silty sand in borehole 813, at elevations 283.2 and 283.9 metres, respectively. The clayey silt had measured N values of 16 and 23 blows per 0.3 metres. The average water content of two samples of clayey silt was 18 per cent.

4.1.9 Sandy Silt

A 1.3 metre thick layer of very dense sandy silt was encountered in borehole 601A beneath the silty clay at elevation 283.2 metres. Measured N values from the sandy silt were 65 and 77 blows per 0.3 metres. The water content of a sample of the sandy silt was 19 per cent. A grain size distribution curve for a sample of the sandy silt is provided on Figure A-6.

4.1.10 Silt

A 0.4 metre thick layer of very dense silt was encountered in borehole 604 beneath the silty sand at elevation 282.5 metres. A single measured N value from the silt was greater than 100 blows per 0.3 metres.

4.1.11 Sand and Gravel

Compact to very dense sand and gravel was encountered in boreholes 601A, 602A, 603A, 604, and 811. An upper layer of sand and gravel was encountered in boreholes 601A and 603A beneath the sand at elevations 285.7 and 284.3 metres and was 1.5 and 0.8 metres thick, respectively. A lower deposit of sand and gravel was encountered in boreholes 601A, 602A, 603A, 604, and 811 between elevations 281.3 and 282.4 metres. The sand and gravel in borehole 811 was 6.5 metres thick. Boreholes 601A, 602A, and 603A were terminated in the sand and gravel after exploring some 0.4 to 5.6 metres. The upper layer of sand and gravel in borehole 603A was noted to be silty. Cobbles were noted within the sand and gravel in borehole 811.

Measured N values from the sand and gravel ranged from 16 to greater than 100 blows per 0.3 metres. Water contents of samples of the sand and gravel ranged from 7 to 12 per cent. Grain size distribution curves for samples of the sand and gravel are provided on Figure A-7.



4.1.12 Dolostone Bedrock

Borehole 602A was terminated on inferred bedrock due to auger and split spoon refusal at elevation 276.0 metres. Dolostone bedrock was encountered in borehole 811 at elevation 276.3 meters. Borehole 811 was terminated in the rock following SPT refusal at elevation 276.1 metres.

4.2 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling and sampling. A summary of the encountered groundwater levels is provided in the table below.

Borehole	Ground Surface Elevation (m)	Encountered Groundwater Level	
		Depth (m)	Elevation (m)
601A	289.3	1.9	287.3
602A	283.8	5.2	278.6
603A	294.1	6.9	287.2
604	293.0	8.7	284.3
811	284.5	5.9	278.6
813	292.9	*	*

* Groundwater level not established

The above-noted encountered water levels are not considered to be representative of the long-term, stabilized groundwater conditions.

Groundwater observation standpipes were installed in boreholes 601A and 811. Installation details are provided on the corresponding Record of Borehole sheets following the text of this report. The standpipes in boreholes 601A and 811 were decommissioned on October 17, 2013 and November 8, 2012, respectively. The measured groundwater levels are summarized in the following table.

Borehole	Ground Surface Elevation (m)	Measured Water Level			
		Following Installation		Prior to Decommission	
		Date	Elevation (m)	Date	Elevation (m)
601A	289.25	Sept. 10, 2013	286.84	Oct. 17, 2013	287.40
811	284.54	May 31, 2012	277.45	Nov. 8, 2012	278.80



FOUNDATION INVESTIGATION AND DESIGN REPORT SPEED RIVER TRIBUTARY CULVERT, SITE 33-500/C

Water levels in the watercourse were measured at various locations as summarized in the following table.

Location	Date	Measured Water Level Elevation (m)
Culvert inlet – near borehole 601A	September 16, 2013	288.19
Culvert outlet – near borehole 602A	September 16, 2013	279.57
Contributing drain south of highway – near borehole 811	May 31, 2012	281.89

Based on the measured and encountered groundwater levels, the inferred groundwater level is expected to vary between elevation 287.5 metres at the north end of the culvert alignment to elevation 279.0 metres at the south end. The groundwater levels are expected to fluctuate seasonally and are expected to be higher during periods of sustained precipitation or during spring melt conditions.



5.0 MISCELLANEOUS

This investigation was carried out using equipment supplied and operated by Aardvark Drilling Inc., an Ontario Ministry of Environment licensed well contractor. The field operations were supervised by Mr. Michael Arthur and Mr. Lubo Kosci, P.Eng. under the direction of the Site Investigation Manager Mr. David J. Mitchell.

The laboratory testing was carried out at Golder Associates' London laboratory under the direction of Mr. Chris M. Sewell. The laboratory is an accredited participant in the MTO Soil and Aggregate Proficiency Program and is certified by the Canadian Council of Independent Laboratories for testing Types C and D aggregates. This report was prepared by Ms. Nicole A. Gould, P.Eng. under the direction of the Project Engineer, Ms. Dirka U. Prout, P.Eng. This report was reviewed by Mr. Azmi M. Hammoud, P.Eng. An independent quality review of this report was carried out by Mr. Fintan J. Heffernan, P. Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED

Dirka U. Prout, P.Eng.
Project Engineer

ORIGINAL SIGNED

Azmi M. Hammoud, P.Eng.
Associate

ORIGINAL SIGNED

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

NG/DUP/AMH/FJH/cr

Golder, Golder Associates and the GA globe design are trademarks of Golder Associates Corporation.

n:\active\2010\1132 - geotechnical\1132-0000\10-1132-0056 delcan - gwp 4-00-00 - hwy 401\ph 2000 - foundations\reports\r07 culvert station 16+357\10113320056-2000-r07 jul 10 14
(final) parts a&b-culvert station 16+357.docx



PART B

FOUNDATION DESIGN REPORT

**SPEED RIVER TRIBUTARY CULVERT 33-500/C, STATION 16+357
RECONSTRUCTION AND WIDENING OF HIGHWAY 401
FROM 0.5 KM WEST OF REGIONAL ROAD 8/KING STREET EASTERLY TO
0.5 KM EAST OF REGIONAL ROAD 24/HESPELER ROAD – 5.5 KM
GWP 4-00-00
MINISTRY OF TRANSPORTATION - WEST REGION**



6.0 ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides our recommendations on the foundation aspects of the design of the replacement of the Speed River Tributary Culvert (Site 33-500/C) located at Station 16+357. The recommendations are based on our interpretation of the factual information obtained during the investigation. It should be noted that the interpretation and recommendations are intended for use only by the design engineer. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. 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, and scheduling.

The existing culvert is located at Station 16+357, with an approximately 45 degree skew to the highway. The existing structure includes the original construction of a 1.22x1.22x99.0 metre open footing culvert and a 1.2x1.2x8.6 metre box culvert extension extending to the south highway right-of-way. Also a 1.5x30 metre CSP culvert, contiguous with the exiting culvert, extends from about the southern right-of-way limit to south of the adjacent Leisure Lodge Road. The existing culvert invert elevations are approximately 288.2 metres at the inlet on the north side of Highway 401, and 282.5 metres at the outlet on the south side of Highway 401.

It has been indicated that it is proposed to replace the existing culvert beneath Highway 401 at about 5 metres east of the existing alignment with a 1.83x2.50 metre pre-cast concrete box culvert with a 1 per cent grade. Also, it is proposed to construct a cantilever retaining wall and drop structure at the culvert outlet on the south side of Highway 401 within the highway right-of-way. The drop structure will provide a head drop of about 3.2 metres and the water will then flow beneath Leisure Lodge Road within a second replacement culvert. The culvert replacement beneath the highway will be about 125 metres long with inlet and outlet invert elevations of about 288.2 and 287.0 metres, respectively. Dimensions and invert elevations of the Leisure Lodge Road culvert have not been provided at the time of this report; however it anticipated that the culvert will be about 16 metres long and the invert will vary from about elevation 283.8 metres at the drop structure to about 282.0 metres at the outlet on the south side of Leisure Lodge Road.

In addition to box culvert designs, consideration may be given to the design of open footing culverts. The Highway 401 culvert will be constructed beneath the proposed Rogers Road retaining wall, Site 33+499/R. Highway 401 in this section will be widened 12 metres to the north and 7 meters to the south. No grade raise is anticipated; however, the additional fill height in the widened areas will be about 3 metres on the north side and 4.5 metres on the south side.



6.2 Culvert Foundations

The subsurface conditions encountered during the investigation generally consisted of the existing pavement structure or surficial topsoil, overlying fill materials and buried topsoil, overlying layers of native silts, sands, and sand and gravel, overlying a more extensive deposit of sand and gravel above the bedrock at depth. The groundwater elevation is expected to vary between elevation 287.5 metres at the north end of the culvert alignment to elevation 279.0 metres south of Leisure Lodge Road.

The culverts should be designed to withstand the appropriate weight of fill and traffic loading including the anticipated additional surcharge loads from the proposed Rogers Road retaining wall. If open footing culverts are constructed, a frost cover of 1.4 metres below the invert level must be provided. It is not necessary to found a box culvert at the standard depth for frost penetration protection purposes as pre-cast box culvert structures are tolerant of small magnitude movements related to freeze-thaw cycles should these occur. A box culvert should, however, be founded below any existing fill and surficial organic materials. For the Highway 401 culvert, it is anticipated that topsoil and/or existing fill materials will be present at the proposed founding elevations for the approximately southern two thirds of a box culvert or the southern approximately half of an open footing culvert. The topsoil and existing fill materials should be removed from the culvert footprint and replaced with lean concrete fill or compacted Ontario Provincial Standard Specifications (OPSS) Granular A or Granular B Type II fill.

A nominal base slab thickness of 300 millimetres has been assumed for pre-cast box culvert sections. Allowing for placement of 300 to 400 millimetres of granular bedding and a levelling course, if required, it is anticipated that a box culvert beneath the highway can be founded on:

- compact silty sand to sand at or below elevation 287.0 metres in the northern third of the Highway 401 culvert (boreholes 601A and 603A); and
- lean concrete fill or compacted granular fill placed on compact silty sand to sand and/or very stiff to hard silty clay at or below between elevations 284.8 and 287.4 metres in the southern two thirds (boreholes 603A, 604 and 813)

If the culvert beneath the highway is replaced with an open footing design, the footings may be founded on:

- dense sand at or below elevation 286.5 metres in the northern half; and
- lean concrete fill or compacted granular fill placed on compact to dense silty sand to sand and/or hard silty clay at or below between elevations 284.8 and 285.4 metres in the southern half.

A box or open footing culvert beneath Leisure Lodge Road may be founded on the compact to very dense sand and gravel at or below elevation 281.7 to 282.8 metres (boreholes 602A and 811).

Any observed fill materials, topsoil or soft or loose soils should be removed to the native soils. Any low areas should be brought to design grade using lean concrete fill or compacted Granular A or Granular B Type II fill.



6.2.1 Geotechnical Resistances

The compact to very dense native granular materials and the hard clayey silt to silty clay are suitable for support of the proposed culverts. A factored geotechnical resistance at Ultimate Limit States (ULS) of 525 kilopascals (kPa) and a geotechnical reaction at Serviceability Limit States (SLS) of 350 kPa may be used for design of foundations for an open footing culvert founded on spread footings. A box culvert may be designed for a factored geotechnical resistance at ULS of 450 kPa and a geotechnical reaction at SLS of 300 kPa. The SLS value corresponds to a maximum of 25 millimetres of total settlement for new culvert construction.

6.2.2 Frost Treatment

Frost treatment in the form of a frost taper symmetrical about the culvert centreline should be provided in accordance with Ontario Provincial Standard Drawing (OPSD) 803.010. The frost penetration depth for this area is 1.4 metres below ground surface. Strip footings for an open footing culvert should be founded at a minimum depth of 1.4 metres below the lowest surrounding grade.

6.2.3 Resistance to Lateral Forces/Sliding Resistance

The resistance to lateral forces/sliding resistance between the culvert bases and the bedding materials or founding soil should be calculated in accordance with Section 6.7.5 of the Canadian Highway Bridge Design Code (CHBDC). The angle of friction, δ , and the coefficient of friction, $\tan \delta$, for the various structure types has been summarized in the following table.

Wall Type	Interaction	Angle of Friction, δ (degrees)	Coefficient of Friction, $\tan \delta$
Open Footing Concrete Culvert	Cast-in-place concrete footing on native granular soils	34	0.67
	Cast-in-place concrete footing on native silty clay	24	0.45
Pre-Cast Concrete Box Culvert	Pre-cast concrete footing on Granular A levelling pad	33	0.65

In accordance with the CHBDC Section 6.7.5, a factor of 0.8 is applied in the equation to calculate the factored horizontal geotechnical resistance, H_{ri} , as follows:

$$H_{ri} = 0.8A'c' + 0.8V\tan\delta > H_f$$

Where:

$$A' = \text{effective contact area, square metres}$$



c'	=	Nil
$\tan \delta$	=	as given above
V	=	unfactored vertical force, kilonewtons
H_f	=	factored horizontal load, kilonewtons

6.3 Bedding

For a pre-cast box culvert, bedding should be placed above a properly prepared subgrade from which all frozen, soft, uncompacted fill, organic materials, or other deleterious material have been removed. Subexcavated material below the design subgrade elevation should be replaced with compacted OPSS Granular A or Granular B, Type II fill material. It is recommended that the box culvert units be placed on a minimum compacted thickness of 300 millimetres of OPSS Granular A bedding material and a minimum 75 millimetre thick levelling course consisting of uncompacted Granular A or fine aggregates as specified in OPSS 422 as amended by MTO Special Provision (SP) 422S01.

6.4 Backfill and Cover

The excavations for the culverts should exceed the culvert dimensions by at least one metre on each side to promote good workmanship and effective compaction of the fill. The backfill should consist of free-draining granular materials such as OPSS Granular A or Granular B Type II placed and compacted in accordance with OPSS 501. All backfill and cover materials should be placed in accordance with OPSS 902. Heavy compaction equipment should not be used immediately adjacent to the walls and roof of the culvert. The height of backfill adjacent to the culvert walls should be maintained equal on both sides of the structure during all stages of backfill placement.

6.5 Embankment Widening and Settlement

This section of Highway 401 will be widened 12 metres to the north and 7 meters to the south. No grade raise to the roadway is anticipated; however, the additional fill height in the widened areas will be about 3 metres on the north side and 4.5 metres on the south side. Due to the generally granular nature of the native soils and the minimal thickness of the cohesive layers encountered at the site, it is anticipated that the total settlement due to the embankment widenings will be less than the MTO settlement limits of 25 millimetres total within 20 metres of the transition zone (abutment area) and 50 millimetres total for a widened embankment on freeways (MTO Embankment Settlement Criteria for Design, July 2010).



6.6 Drop Structure

Based on the information provided by Delcan, it is understood that a drop structure is to be constructed at the outlet of the Highway 401 culvert. The drop structure will provide a head drop of approximately 3.2 metres. Consideration may be given to constructing the structure using pre-cast or cast-in-place (CIP) concrete elements. For a pre-cast structure, granular bedding and a leveling course should be provided in accordance with the manufacturer's specifications.

6.6.1 Foundations – Drop Structure

It is understood that the structure is to be founded at about elevation 283.8 metres; however, the subsurface conditions encountered in borehole 811 indicate that existing fill materials are present at this elevation. Any topsoil or fill materials should be removed and replaced with lean concrete fill or compacted granular fill. The drop structure may be founded on the lean concrete fill or compacted granular fill, if required, the native very stiff clayey silt at or below elevation 283.2 metres or the underlying compact to very dense native sand and gravel. A factored geotechnical resistance at ULS of 450 kPa and a geotechnical reaction at SLS of 300 kPa may be used for design. The SLS value corresponds to 25 millimetres of settlement.

6.6.2 Resistance to Lateral Forces

The lateral pressures acting on the drop structure will depend on the backfill soils, the type and method of placement of the backfill materials behind the structure, and the subsequent lateral movement of the structure. The resistance to lateral forces/sliding resistance between the cast-in-place or pre-cast concrete elements and leveling pads or native founding soils should be calculated in accordance with Section 6.7.5 of the CHBDC. Assuming that the founding soils are not loosened/disturbed during excavation and footing construction, the following angles of friction and corresponding unfactored coefficient of friction, $\tan \delta$, may be used for the interaction between the base of the structure and the founding soils.

Structure Type	Interaction	Angle of Friction, δ (degrees)	Coefficient of Friction, $\tan \delta$
Cast-in-place	Cast-in-place concrete footing on native soils	34	0.67
Pre-cast	Pre-cast concrete footing on Granular A levelling pad	33	0.65



6.7 Retaining Walls

A cantilever retaining wall is proposed to be construed in conjunction with the drop structure at the outlet of the Highway 401 culvert. Also, the culverts may have wingwalls or header walls to limit the length and impacts to the water course. The wingwalls for the culvert replacements could consist of reinforced concrete gravity or cantilever walls, concrete toe walls, reinforced soil system (RSS) walls, or gabion walls. A concrete gravity wall could consist of pre-cast elements or be CIP; however, pre-cast wingwalls are preferred for compatibility with pre-cast culverts.

6.7.1 Wingwall Options

Reinforced Concrete Gravity and Cantilever Walls

Construction of reinforced concrete gravity or cantilever walls is geotechnically feasible. Compared to a concrete toe wall or RSS walls, footings for gravity and cantilever walls must be constructed with a frost cover of 1.4 metres. This may result in a longer foundation construction time compared to a pre-cast concrete toe wall or RSS wall, particularly if CIP walls are erected. Groundwater control will likely be required since footing excavations will be advanced below the groundwater level and/or the drain water level.

Concrete Toe Walls

Concrete toe walls are geotechnically feasible for use as wingwalls provided the walls have a maximum height of less than 1.8 metres above the final ground surface. Concrete toe walls 0.8 to 1.8 metres in height require a minimum embedment depth of 450 millimetres and should be constructed to bear on undisturbed soil. The embedment depth is defined as the distance from the underside of the toe wall foundation to the top of finished grade in front of the wall. The concrete toe wall should be designed in accordance with the requirements for a Type II Concrete Toe Wall as shown on OPSD 3120.100. Compared to concrete gravity and cantilever walls, construction costs and time may be reduced if a pre-cast concrete toe wall is used.

RSS Walls

If the heights of the wingwalls will be relatively low, RSS walls utilizing an interlocking block system and geogrid reinforcement is a geotechnically feasible alternative. Retained Soil System walls are proprietary systems which are to be designed by the supplier and constructed in accordance with their specifications. The internal stability of the mechanically-reinforced soil walls should be verified by the RSS supplier/designer. If a RSS block system wall is selected, the geotechnical aspects of the global stability of the detailed retaining wall design should be reviewed prior to construction. Depending on the design approach selected, an embedment depth equivalent to the frost depth may not be required for foundations of an RSS block system wall. This wall type can be constructed relatively quickly and inexpensively using small equipment.



Gabion Walls

Construction of gabion walls is geotechnically feasible at the site. Gabion walls require the least amount of space behind the wall. Gabion walls do not require an embedment depth equivalent to the frost depth provided it is founded on a granular pad of 300 millimetres compacted thickness and the foundations have adequate embedment to provide a stable structure. Advantages of gabion walls compared to more rigid structures include the ability to accommodate differential settlements, dissipation of the energy of flowing water, and are free-draining provided an adequate filter is placed behind the wall. Gabion walls can be constructed relatively quickly with minimal equipment and materials. The life expectancy of a gabion wall can be extended by utilizing PVC-coated galvanized steel baskets. Gabion walls are to be constructed in accordance with OPSS 512 as amended.

6.7.2 Foundations – Retaining Walls

Based on the information provided by Delcan, it is anticipated that the retaining wall associated with the drop structure will be a cantilever type wall approximately 6 metres in height and founded at elevation 283 metres. At this elevation the retaining wall will be founded on compact to very dense sand to silty sand or sand and gravel. A factored geotechnical resistance at ULS of 450 kPa and a geotechnical reaction at SLS of 300 kPa may be used for design. The SLS value corresponds to 25 millimetres of settlement.

Cast-in-place reinforced concrete gravity and cantilever walls founded on concrete strip footings must be provided with a frost cover of 1.4 metres below the adjacent ground or thermal equivalent. Assuming the adjacent ground is at the Highway 401 culvert inlet invert elevation of 288.2 metres and at the anticipated Leisure Lodge Road outlet invert elevation of 282.0 metres, foundations for wingwalls of these types must be founded at or below elevations 286.8 and 280.6 metres, respectively, on the compact to very dense granular soils. A factored geotechnical resistance at ULS of 450 kPa and a geotechnical reaction at SLS of 300 kPa may be used for design. The SLS value corresponds to 25 millimetres of settlement. The wingwalls should be structurally separate from the box culvert to accommodate some differential settlement.

Pre-cast concrete toe walls must be embedded a minimum depth of 450 millimetres beneath the adjacent ground. Assuming the adjacent ground is as noted above, foundations for concrete toe walls at the Highway 401 culvert inlet and Leisure Lodge Road culvert outlet must be founded at or below elevations 287.7 and 281.5 metres, respectively, on the compact to very dense granular soils. A factored geotechnical resistance at ULS of 450 kPa and a geotechnical reaction at SLS of 300 kPa may be used for design. The SLS value corresponds to 25 millimetres of settlement. Pre-cast concrete toe wall units should be founded on a 75 millimetre thick levelling pad consisting of uncompacted Granular A.

Retained Soil System walls may be designed such that the facing blocks are constructed on a levelling pad. The levelling pad should be constructed using a minimum of 300 millimetres of Granular A. As noted previously, depending on the design selected by the RSS supplier, it may not be necessary to provide 1.4 metres of earth cover or thermal equivalent for frost protection. However the foundations must have adequate embedment to provide a stable structure. Typically the embedment depth, defined as the distance between the top of the levelling pad and the top of the adjoining finished grade, is a minimum of 500 millimetres.



FOUNDATION INVESTIGATION AND DESIGN REPORT SPEED RIVER TRIBUTARY CULVERT, SITE 33-500/C

The geotechnical resistances recommended above for pre-cast concrete toe walls are applicable to RSS walls founded on a granular levelling pad.

Gabion walls may be founded directly on a 300 millimetre thick compacted Granular A pad placed on the compact to very dense granular soils at or below about elevations 287.7 and 281.5 metres at the Highway 401 culvert invert and Leisure Lodge Road culvert outlet, respectively. Alternatively, gabion baskets can be placed at the frost depth on compact to very dense granular soils at or below elevations 286.8 and 280.6 metres at the Highway 401 culvert invert and Leisure Lodge Road culvert outlet, respectively. The geotechnical resistances recommended above for design of pre-cast concrete toe walls may be used for design of gabion walls. If required, a granular levelling course approximately 75 millimetres in thickness may be placed on the founding strata for gabion walls. Non-woven geotextile is to be placed between the gabions and the backfill in accordance with OPSS 512, OPSS 1860, and the manufacturer's specifications.

All wingwall foundations must be protected against scour as noted in the CHBDC Section 1.9.5.

6.7.3 Resistance to Lateral Forces

The lateral pressures acting on the retaining walls will depend on the backfill soils, the type and method of placement of the backfill materials behind the walls, and the subsequent lateral movement of the structures. The resistance to lateral forces/sliding resistance between the cast-in-place or pre-cast concrete footing, RSS block facing units, or gabion cages and leveling pads or native founding soils should be calculated in accordance with Section 6.7.5 of the CHBDC. Each retaining wall shall be checked for overturning. Assuming that the founding soils are not loosened/disturbed during excavation and footing construction, the following angles of friction and corresponding unfactored coefficient of friction, $\tan \delta$, may be used for the interaction between the base of the walls and the founding soils.

Wall Type	Interaction	Angle of Friction, δ (degrees)	Coefficient of Friction, $\tan \delta$
Reinforced Concrete Gravity or Cantilever Wall on concrete strip footings	Cast-in-place concrete footing on native soils	34	0.67
Concrete Toe Wall	Pre-cast concrete footing on Granular A levelling pad	33	0.65
	Pre-cast concrete footing on native soils	33	0.65
RSS Block System Wall	Pre-cast concrete block facing units on Granular A levelling pad	33	0.65
Gabion Wall	Gabion cage on Granular A pad	35	0.70
	Gabion cage on native soils	35	0.70



6.8 Liquefaction Potential and Seismic Analysis

6.8.1 Seismic Parameters

The site is located in Cambridge, Ontario. According to Table A.3.1.1 of the CHBDC, the zonal acceleration ratio, A , applicable to this site is 0.05. The corresponding acceleration related seismic zone, Z_a , is 1. Based on the current version of the CHBDC the importance category of the replacement culvert is “other”. The corresponding seismic performance zones (SPZ) to this importance category is 1.

It should be noted that the MTO views culverts with spans greater than 3 metres as being similar to bridges. Single-span bridges need not be analyzed for seismic loads, regardless of SPZ. However, design forces for restraining elements and support lengths must meet the minimum requirements as outlined in CHBDC Clause 4.4.5.1. The designer should ensure that the selected culvert design meets the seismic requirements for buried structures as outlined in Clause 7.5.5 of the CHBDC.

The effects of site conditions on the response of the culvert are to be included in the determination of the seismic loads. The site stratigraphy generally consists of native sand, silt, sand and gravel, and silty clay to clayey silt overlying bedrock. The underlying bedrock is located approximately 6 to 8 metres below the ground surface in the vicinity of the site. Based on the site stratigraphy, the soil profile type is categorized as Type I with a seismic site response coefficient, S , of 1.0 based on the CHBDC criteria.

6.8.2 Seismic Hazard Assessment

A preliminary screening of the soil stratigraphy was conducted using the procedure outlined by the Federal Highway Administration⁵ and the 2006 version of the Canadian Foundation Engineering Manual (CFEM). Although the native granular materials at the site are saturated, the likelihood of these soils liquefying is very low. Considering the foregoing, the liquefaction potential is considered to be low. A detailed evaluation of the liquefaction potential of the native soils and the impact of liquefaction on the proposed culvert foundations is not considered warranted.

6.9 Lateral Earth Pressures for Design

The lateral pressures acting on the proposed structures will depend on the type and method of placement of the backfill materials, on the nature of the soil behind the backfill, on the magnitude of surcharge including

⁵ Federal Highway Administration (FHWA). (1997). “Design Guidance: Geotechnical Earthquake Engineering For Highways. Volume I – Design Principles.” *Geotechnical Engineering Circular No. 3: FHWA-SA-97-076*, Washington, D.C.



FOUNDATION INVESTIGATION AND DESIGN REPORT SPEED RIVER TRIBUTARY CULVERT, SITE 33-500/C

construction loadings, on the freedom of lateral movement of the structures, and on the drainage conditions behind the walls.

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

- Select free-draining granular fill meeting the specifications of OPSS Granular A or Granular B Type II, but with less than 5 per cent passing the No. 200 sieve, should be used as backfill behind the culvert walls. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements with respect to subdrains and frost taper should be in accordance with OPSD 803.010, 3121.150, and 3190.100.
- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the culvert extensions, in accordance with CHBDC Section 6.9.1 and Figure C6.6. Compaction equipment should be used in accordance with OPSS 501 as amended by SP 105S21. Other surcharge loadings should be accounted for in the design, as required.
- For Case (a), the restrained case, the pressures are based on the existing embankment fill materials consisting of select subgrade material (SSM) and the following parameters (unfactored) may be used:

Soil unit weight: 20 kN/m³

Coefficients of lateral earth pressure:

'at rest' or restrained, K_0 0.50

- If the wall support does not allow lateral yielding (restrained structure), at-rest earth pressures should be assumed for geotechnical design. The granular fill should be placed in a zone with a width equal to at least 1.4 metres behind the culvert walls (case (a) from commentary on CHBDC Figure C6.6).
- If the wall support allows lateral yielding (unrestrained structure), active earth pressures may be used in the geotechnical design of the structure. The granular fill should be placed in a wedged shaped zone with a width equal to at least 1.4 metres at the footing level against a cut slope which begins at the footing level and extends upwards at a maximum inclination of 1 horizontal to 1 vertical (case (b) from commentary on CHBDC Figure C6.20).
- For walls backfilled using granular materials in accordance with case (b), the following parameters (unfactored) may be assumed:

	<u>GRANULAR A</u>	<u>GRANULAR B</u> (Type II)
Fill unit weight:	22 kN/m ³	21 kN/m ³



Coefficients of static lateral earth pressure:

'active' or unrestrained, K_a	0.27	0.27
'passive', K_p	3.7	3.7

6.10 Construction Considerations

6.10.1 General

Care should be taken during construction to avoid disturbance of the subgrade prior to constructing foundations. All topsoil, organics, and soft or loose soils should be removed from below the proposed founding elevation. Subgrade preparation should be performed and monitored in accordance with OPSS 902.

The cleaned excavation base should be inspected by a geotechnical Quality Verification Engineer (QVE) and where cast-in-place concrete foundations are to be constructed, a lean concrete working slab should be placed immediately after inspection to protect the founding materials. It is recommended that the footing excavation be carried out such that the final 0.5 metres of excavation is completed with the QVE on site with construction of the working slab commencing immediately after inspection. A Non Standard Special Provision (NSSP) should be added to the Contract Documents specifying protection of the founding soil through use of working slabs for CIP concrete foundations.

6.10.2 Erosion and Scour Protection

Water flowing beneath a culvert could potentially cause undermining and scouring. Seepage flowing around the culvert walls has the potential to remove fines from the embankment fill and lead to piping and erosion. The foundations should be adequately protected against scour as noted in Section 1.9.5.2 of the CHBDC. Scour protection for the culvert backfill and stream bank should be provided to protect the roadway, approach embankments, and culvert as appropriate.

In addition, sediment control such as silt fences and erosion control blankets may be required during construction and diversion/piping of the watercourse to minimize migration of fine particles should be carried out. Consideration could be given to using suitable non-woven geotextile and rip rap, as required, to provide erosion protection based on hydraulic requirements. Rip-rap treatment at the culvert outlets should be provided in accordance with OPSD 810.010.



6.10.3 End Treatments and Camber

As required by the CHDBC, a pre-cast concrete box culvert should be designed with cutoff walls, at least at the upstream end, to prevent undermining or possible collapse of the ends. Considering the presence of predominantly very dense to dense granular materials below the founding elevations, the provision of camber for the replacement culverts is not required.

6.11 Excavations and Groundwater Control

Excavations for the proposed works will encounter topsoil, fill materials, sand, silt, sand and gravel, and clayey silt to silty clay. Temporary open cut slopes within these materials should be maintained no steeper than 1 horizontal to 1 vertical and localized sloughing and ground movements should be expected. All debris, cobbles, and boulders should be removed from slope surfaces. Where excavations extend below the groundwater level in granular soils, it may be necessary to use flatter slopes. All excavations should be carried out in accordance with the latest edition of the Ontario Occupational Health and Safety Act and Regulations for Construction Projects, specifically O.Reg. 2013/91 Part III Excavations. The fill and any cohesionless materials below the groundwater level would be classified as Type 3 soils. The native cohesionless materials above the groundwater level and native cohesive soils would be classified as Type 2 soils.

The inferred groundwater level at the site is expected to vary between elevation 287.5 metres at the north end of the culvert alignment to elevation 279.0 metres south of Leisure Lodge Road. It is anticipated that excavations for the culvert construction may encounter the groundwater, particularly in the north approximately one third of the culvert if an open footing design is used. If excavations extend below the groundwater table, dewatering of the saturated granular deposits will be required.

It is anticipated that groundwater at the site may be controlled by using properly filtered sumps at the base of the excavation. Sumps should be maintained outside the actual footing limits. The hydraulic conductivities for the various native granular materials have been estimated, based on empirical methods, and summarized in the following table.

Soil	Hydraulic Conductivity (cm/s)
Silty sand	1.2×10^{-4}
Silt and sand	5.1×10^{-4}
Sand	9.6×10^{-4}
Sandy silt	3.6×10^{-5}
Sand and gravel, trace silt	9.4×10^{-4}



Based on these values and the anticipated excavation dimensions it is anticipated that a Permit to Take Water is not necessary for this site.

Surface water runoff should be directed away from the excavations at all times. The existing culvert flows will need to be diverted/piped during construction. Surficial water seepage into the excavations should be expected and will be heavier during periods of sustained precipitation. Surface water should be directed away from the excavations at all times. The appropriate NSSP should be included in the contract documents to alert the contractor about the need for adequate control of surface and groundwater flows.

The exposed native soils may consist of silty clay and clayey silt which will be sensitive to disturbance from construction activities once exposed to moisture. Therefore, it will be essential to redirect surface water flow away from the excavations and construct all granular levelling pads or cast-in-place concrete footings during the same day the excavation is completed to the planned subgrade elevation.

6.11.1 Staging and Temporary Roadway Protection

It is understood that the replacement culverts will be constructed in stages in conjunction with other portions of this project. Based on the Preliminary Staging Concept Plans provided by Delcan on November 12, 2013, the staging in the area of the culvert replacement will proceed as follows:

- Stage 1: Shift eastbound traffic onto median shoulder and construct the portion of culvert beneath the Highway 401 eastbound lanes.
- Stage 2: Construct eastbound lane retaining walls, drop structure, and Leisure Lodge Road culvert.
- Stage 3: Shift eastbound and westbound traffic to newly widened eastbound lanes and construct the portion of culvert beneath the Highway 401 westbound lanes, from the median north.
- Stage 4: Shift eastbound and westbound traffic to newly widened westbound lanes.
- Stage 5: Shift eastbound traffic to eastbound lanes and construct the central portion of culvert beneath the median.

Temporary roadway protection systems will be required where space is restricted and will not permit open cuts, to support the sides of excavations and permit the use of vertical cuts. Protection systems are to be designed by the contractor and the limits of the systems are to be determined by the contractor. Temporary support systems could consist of soldier piles and lagging or steel sheet piles. Excavation support systems should be designed and constructed in accordance with OPSS 539 and the design should limit the lateral movement of the temporary shoring system to meet Performance Level 2. The contractor is responsible for the complete detailed design of the protection system.

Where the support to the wall is provided by anchors or rakers, the wall design should be based on a triangular earth pressure distribution using the design parameters given below. The raker/anchor support must be designed to accommodate the loads applied from pressures and surcharge pressures from area, line, or point loads as well as the impact of sloping ground behind the system. Passive toe restraint to the soldier piles may



FOUNDATION INVESTIGATION AND DESIGN REPORT SPEED RIVER TRIBUTARY CULVERT, SITE 33-500/C

be determined using a triangular pressure distribution acting over an equivalent width equal to three times the pile socket diameter.

The unfactored triangular earth pressure distribution (p in kN/m^2 ; increasing with depth) can be calculated as follows:

$$p = K_a (\gamma H + q)$$

where H = the height of the excavation at any point in metres

K_a = active coefficient of earth pressure

γ = soil unit weight

q = surcharge for traffic and other loading

The support systems may be designed using the parameters provided in the table below. These parameters are provided to assist with design for the unfactored ultimate resistance and loading conditions and may not result in a temporary support design that adequately controls ground and structure displacements. Achieving adequate displacement control in accordance with the MTO performance criteria may require designs that result in a system that is stiffer than might otherwise be required based on the soil parameters provided in the table below.

Soil Type	Coefficient of Earth Pressure			Internal Angle of Friction (degrees)	Unit Weight (kN/m^3)
	Active, K_a	At Rest, K_o	Passive, K_p		
Fill	0.36	0.53	2.8	28	19
Sand to silty sand	0.36	0.53	2.8	28	19
Clayey silt to silty clay	0.42	0.59	2.4	24	18
Sand and gravel	0.27	0.43	3.7	35	21

The earth pressure coefficients identified above may be applied assuming a horizontal ground surface behind the retaining structure. Where the ground surface behind the retaining structure is sloped, the earth pressure coefficients provided in the table above must be increased.



7.0 MISCELLANEOUS

This report was prepared by Ms. Nicole A. Gould, P.Eng. under the direction of the Project Engineer, Ms. Dirka U. Prout, P.Eng, and reviewed by Mr. Azmi M. Hammoud, P.Eng. An independent quality review of this report was conducted by Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED

Dirka U. Prout, P.Eng.
Project Engineer

ORIGINAL SIGNED

Azmi M. Hammoud, P.Eng.
Associate

ORIGINAL SIGNED

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

NG/DUP/AMH/FJH/cr

Golder, Golder Associates and the GA globe design are trademarks of Golder Associates Corporation.

n:\active\2010\1132 - geotechnical\1132-0000\10-1132-0056 delcan - gwp 4-00-00 - hwy 401\ph 2000 - foundations\reports\r07 culvert station 16+357\10113320056-2000-r07 jul 10 14 (final) parts a&b-culvert station 16+357.docx

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.) split spoon sampler for a distance of 300 mm (12 in.)

(b) Cohesive Soils

Consistency

	c_u, s_u	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.

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

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

RECORD OF BOREHOLE No 601A

1 OF 1

METRIC

PROJECT 10-1132-0056
W.P. 4-00-00 LOCATION N 4808168.3 , E 234941.0 ORIGINATED BY MA
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY AMG
DATUM GEODETIC DATE September 10, 2013 CHECKED BY

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	× LAB VANE									
289.25	GROUND SURFACE						20	40	60	80	100									
0.00	TOPSOIL, silty, sandy Compact Brown						20	40	60	80	100									
288.09			1	SS	18															
1.16	FILL, sand and gravel, trace silt Compact Brown																			
287.73																				
1.52	SILTY SAND, some gravel, trace clay Compact Brown		2	SS	11															
286.51			3	SS	25															
2.74	SAND, some gravel, trace silt Dense Brown																			
285.74			4	SS	42															
3.51	SAND AND GRAVEL, some clayey silt layers Very dense Brown																			
			5	SS	81															
			6	SS	58															
284.22																				
5.03	SILTY CLAY, trace sand Hard Brown																			
			7	SS	33															
283.22																				
6.03	SANDY SILT, trace clay Very dense Brown																			
			8	SS	65															
			9	SS	77															
281.94																				
7.31																				
281.57	SAND AND GRAVEL, some silt Very dense Brown																			
			10	SS	45/ 50mm															
7.68	END OF BOREHOLE																			
	Groundwater encountered at about elev. 287.3m during drilling on September 10, 2013.																			
	Water level measured at elev. 286.84m following installation on September 10, 2013.																			
	Water level measured in standpipe at elev. 287.40m on October 17, 2013.																			
	Installation decommissioned on October 17, 2013.																			

RECORD OF BOREHOLE No 602A

1 OF 1

METRIC

PROJECT 10-1132-0056
W.P. 4-00-00 LOCATION N 4808156.0 , E 235091.0 ORIGINATED BY MA
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY AMG
DATUM GEODETIC DATE September 10, 2013 CHECKED BY

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 (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)			GR	SA	SI	CL
								20	40	60	80	100					○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL				
283.78	GROUND SURFACE																						
0.00	FILL, silty sand, some gravel, trace clay, trace topsoil Loose Brown						283											15	47	29	9		
282.41			1	SS	4								○										
1.37	FILL, clayey silt, some sand, trace topsoil Soft Brown		2	SS	4		282																
281.65																							
2.13	SAND AND GRAVEL, trace silt, trace clay Compact to very dense Brown		3	SS	34		281						○					57	30	(13)			
			4	SS	39																		
			5	SS	60/ 25mm		280																
			6	SS	39		279																
			7	SS	27		278																
			8	SS	29																		
			9	SS	82/ 125mm		277						○					60	27	8	5		
276.04			10	SS	100/ 25mm																		
7.74	END OF BOREHOLE Auger & Split-spoon refusal on inferred bedrock. Groundwater encountered at about elev. 278.6m during drilling on September 10, 2013.																						

RECORD OF BOREHOLE No 603A

1 OF 1

METRIC

PROJECT 10-1132-0056

W.P. 4-00-00

LOCATION N 4808159.5, E 234964.5

ORIGINATED BY MA

DIST HWY 401

BOREHOLE TYPE POWER AUGER, HOLLOW STEM

COMPILED BY AMG

DATUM GEODETIC

DATE September 12, 2013

CHECKED BY

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									
294.09	PAVEMENT SURFACE						20	40	60	80	100						
0.00	ASPHALT						294										
0.24	FILL, sand and gravel, crushed, trace silt Very dense Brown																
293.02			1	SS	52		293										
1.07	FILL, sand and gravel, some silt, trace clay Compact to very dense Brown																
			2	SS	51												
							292										
			3	SS	56												
			4	SS	14		291										
			5	SS	36		290										
			6	SS	42												
288.91							289										
5.18	FILL, fine to medium sand, some silt, trace topsoil Dense Brown		7	SS	31												
288.15																	
5.94	FILL, silty sand and gravel, trace topsoil Dense Brown		8	SS	30		288										
287.38																	
6.71	SAND AND SILT, trace gravel, trace clay Compact Brown		9	SS	12		287										
286.62																	
7.47	SAND, fine to medium, some silt, trace gravel, trace clay Loose to compact Brown		10	SS	7		286										
			11	SS	28												
285.09							285										
9.00	SAND, fine, trace silt Dense Brown		12	SS	36												
284.34																	
9.75	SILTY SAND AND GRAVEL, Very dense Brown		13	SS	66		284										
283.57																	
10.52	SILTY CLAY, trace sand Hard Brown		14	SS	72		283										
283.09																	
11.00	SAND AND SILT, trace clay Very dense Brown		15	SS	100/ 125mm		282										
			16	SS	83												
281.29							281										
12.80	SAND AND GRAVEL, some silt Very dense Brown																
280.31			17	SS	100/ 75mm												
13.78	END OF BOREHOLE																
	Groundwater encountered at about elev. 287.2m during drilling on September 12, 2013.																

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

LDN_MTO_06 10-1132-0056-2000.GPJ LDN_MTO_GDT 24/12/13

PROJECT		10-1132-0056		RECORD OF BOREHOLE NO 004		1 OF 2		METRIC	
W.P.		4-00-00		LOCATION		N 4808171.3 , E 235010.1		ORIGINATED BY	
DIST		HWY 401		BOREHOLE TYPE		POWER AUGER, HOLLOW STEM		COMPILED BY	
DATUM		GEODETIC		DATE		August 19, 2013		CHECKED BY	

[illegible]

PROJECT <u>10-1132-0056</u>		RECORD OF BOREHOLE No 604		2 OF 2	METRIC
W.P. <u>4-00-00</u>	LOCATION <u>N 4808171.3 , E 235010.1</u>	ORIGINATED BY <u>MA</u>			
DIST <u></u> HWY <u>401</u>	BOREHOLE TYPE <u>POWER AUGER, HOLLOW STEM</u>	COMPILED BY <u>WDF</u>			
DATUM <u>GEODETIC</u>	DATE <u>August 19, 2013</u>	CHECKED BY <u></u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m³	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	10 20 30	GR SA SI CL					
	SAND AND GRAVEL, some silt, trace clay Very dense Brown						279										
278.06			18	SS	65												
14.94	END OF BOREHOLE																
	Groundwater encountered at about elev. 284.3m during drilling on August 19, 2013.																

LDN_MTO_06 10-1132-0056-2000.GPJ LDN_MTO.GDT 24/12/13

RECORD OF BOREHOLE No 811

1 OF 1

METRIC

PROJECT 10-1132-0056
W.P. 4-00-00 LOCATION N 4808167.7 , E 235067.0 ORIGINATED BY MA
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK
DATUM GEODETIC DATE May 31, 2012 CHECKED BY

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									
								○ UNCONFINED	+ FIELD VANE								
284.54	GROUND SURFACE						20	40	60	80	100						
0.00	TOPSOIL, silty, trace gravel Brown																
0.27	FILL, silty sand and gravel Compact Brown																
283.17			1	SS	15												
1.37	CLAYEY SILT, trace sand, trace gravel Very stiff Brown		2	SS	16												
282.77																	
1.77	SAND AND GRAVEL, some silt, trace clay, with cobbles Compact to very dense Brown		3	SS	91												
			4	SS	100/ 75mm												
			5	SS	43												
			6	SS	53												
			7	SS	37												
			8	SS	25												
			9	SS	61												
			10	SS	44												
276.31																	
8.23	Weathered DOLOSTONE		11	SS	100/ 100mm												
8.47	END OF BOREHOLE																
	Groundwater encountered at about elev. 278.6m during drilling on May 31, 2012.																
	Water level measured in standpipe at elev. 277.45m following installation on May 31, 2012.																
	Water level measured in standpipe at elev. 278.80m on November 8, 2012.																
	Installation decommissioned on November 8, 2012.																







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

RECORD OF BOREHOLE No 813

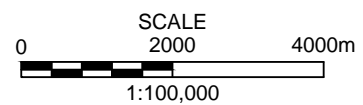
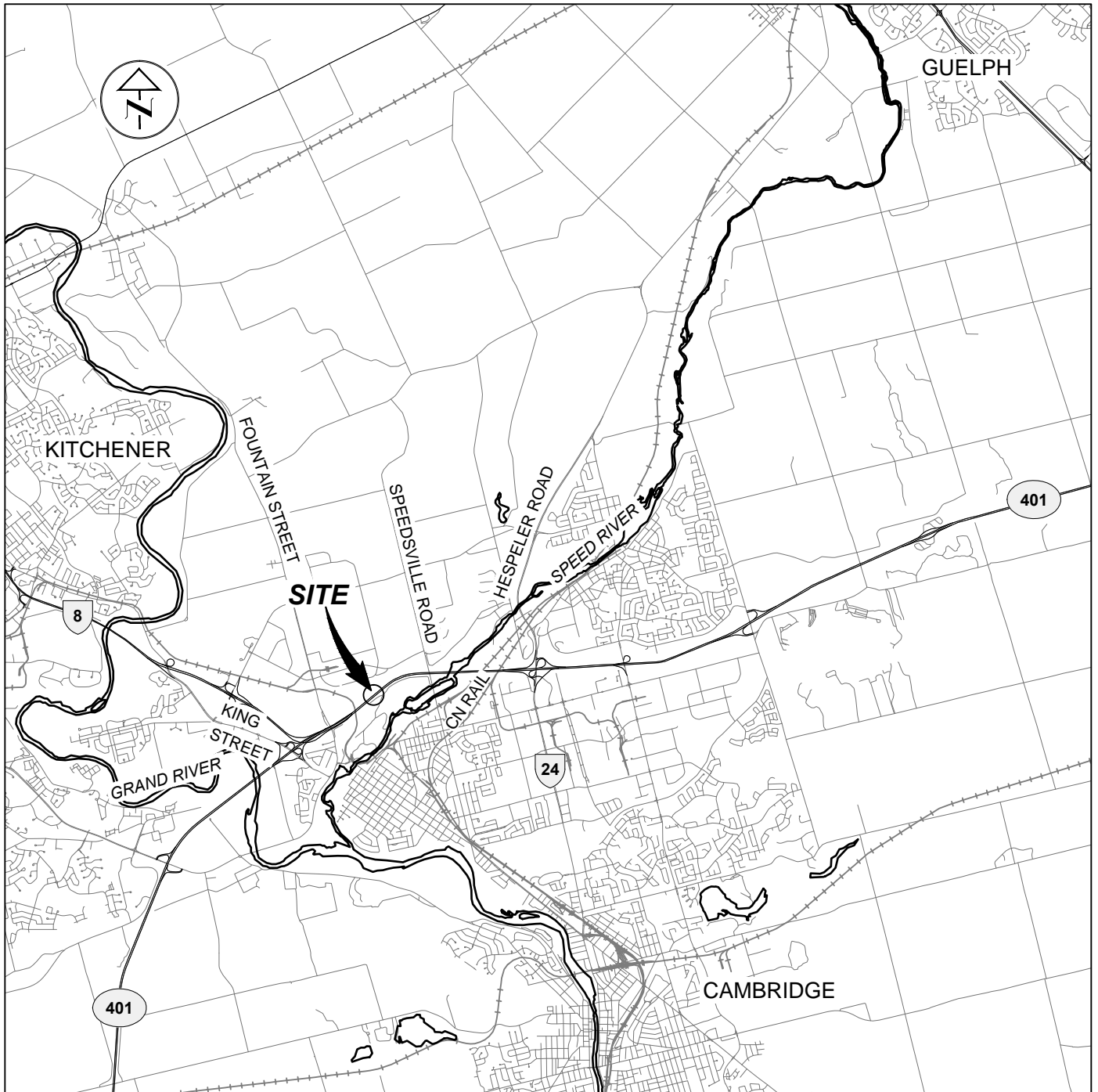
1 OF 1

METRIC

PROJECT 10-1132-0056
W.P. 4-00-00 LOCATION N 4808157.6 , E 235022.4 ORIGINATED BY MA
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK
DATUM GEODETIC DATE November 15, 2012 CHECKED BY

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	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)		
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE								
								20	40	60	80						100		
292.86	PAVEMENT SURFACE																		
0.00	ASPHALT																		
0.21	FILL, sand and gravel, trace silt																		
0.37	Brown																		
	FILL, sand and gravel, trace silt, with cobbles Compact to dense Brown		1	SS	50		292												
			2	SS	25														
291.04																			
1.82	FILL, silty sand, some gravel																		
	Compact Brown																		
			3	SS	15														
289.96																			
2.90	FILL, sand and gravel, some silt, with cobbles Dense to very dense Brown																		
			4	SS	34														
			5	SS	46/ 100mm														
			6	SS	35														
287.68																			
5.18	FILL, sand, trace to some gravel, trace to some silt, trace clay Compact Brown																		
			7	SS	26														
			8	SS	26														
285.70			9	SS	26														
7.16	TOPSOIL, sandy, trace gravel																		
285.39	Compact Black																		
7.47	SILTY SAND, trace to some gravel, trace clay Compact Brown to grey		10	SS	14		285												
			11	SS	10														
283.87																			
8.99	CLAYEY SILT, trace sand																		
283.41	Very stiff Brown		12	SS	23														
9.45	SAND, fine to medium, trace silt Compact Brown																		
			13	SS	10														
282.50																			
10.36	END OF BOREHOLE																		
	Borehole dry during drilling on November 15, 2012.																		

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



REFERENCE

PLAN BASED ON CANMAP STREETFILES V.2008.5.

NOTE

THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ACCOMPANYING TEXT.

PROJECT STRUCTURAL CULVERT, STATION 16+357
HIGHWAY 401 IMPROVEMENTS
GWP 4-00-00

TITLE

KEY PLAN



PROJECT No. 10-1132-0056		FILE No. 1011320056-2000-F07001	
CADD	AMG	SEPT. 25/12	SCALE AS SHOWN
CHECK			REV. 0

FIGURE 1

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

CONT No.
WP No. 4-00-00



STRUCTURAL CULVERT
STATION 16+357
HIGHWAY 401 IMPROVEMENTS
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



Golder Associates Ltd.
LONDON, ONTARIO, CANADA



KEY PLAN

SCALE IN KILOMETRES

LEGEND

- Borehole - Current Investigation
- Seal
- Standpipe
- Standard Penetration Test Value
- Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL in piezometer/standpipe, measured (BH 811) on Nov. 8, 2012. (BH 601A) on Oct. 17, 2013.
- WL encountered during drilling
- WL not established
- Split-spoon / Auger refusal on inferred bedrock

No.	ELEVATION	CO-ORDINATES (MTM ZONE 10)	
		NORTHING	EASTING
601	297.18	4 808 239.6	235 017.9
601A	289.25	4 808 168.3	234 941.0
602	291.40	4 808 190.5	235 062.7
602A	283.78	4 808 156.0	235 091.0
603	291.38	4 808 216.4	235 035.4
603A	294.09	4 808 159.5	234 964.5
604	293.00	4 808 171.3	235 010.1
(Geocres No. 40P8-227)			
811	284.54	4 808 167.7	235 067.0
813	292.86	4 808 157.6	235 022.4

NOTES

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

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

REFERENCE

Base plans provided in digital format by Delcan.

NO.	DATE	BY	REVISION
Geocres No. 40P8-218			
HWY.	401	PROJECT NO.	10-1132-0056
SUBM'D.	DUP	CHKD.	NAG
DRAWN:	LMK/WDF	CHKD.	DUP
DATE:	May 29/14	APPD.	FJH
SITE:	33-500/C	DWG.	1

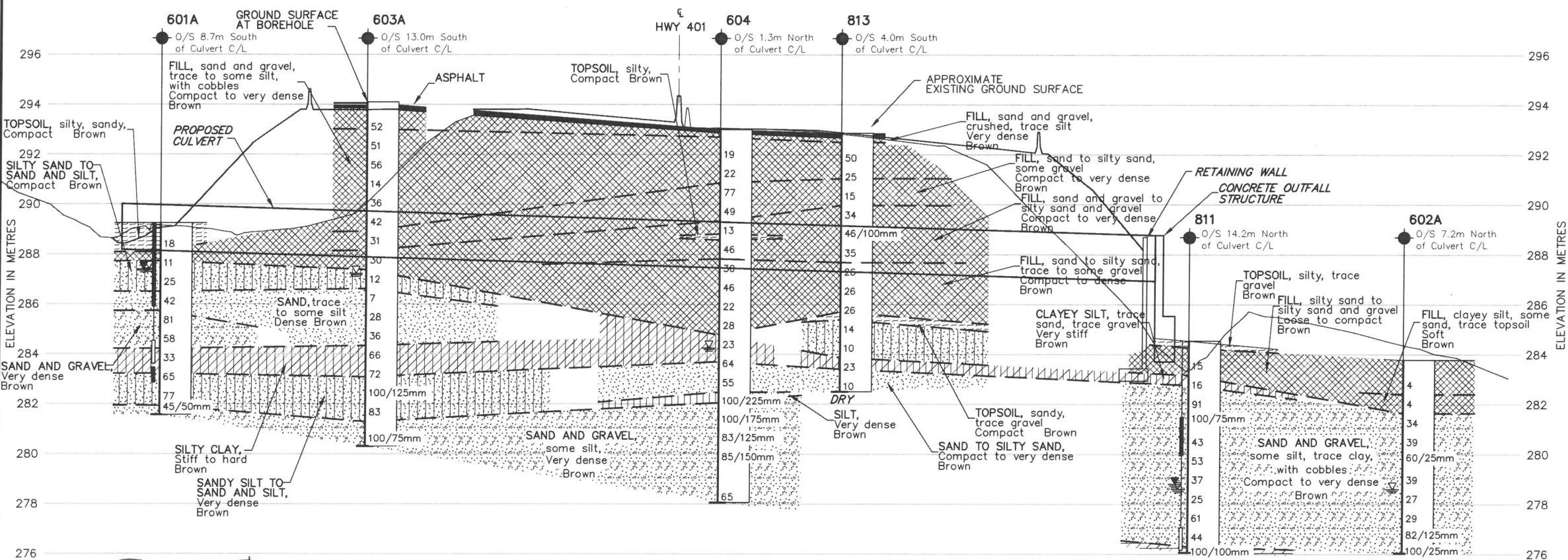
PROJ. DATE: July 11, 2014
FILENAME: N:\active\2010\1132 - Geotechnical\1132-0000\10-1132-0056 - DELCAN - GWP 4-00-00 - WP 401 Drafting\delcan files\101120056-2000-007001.dwg



PROFILE ALONG CENTRELINE OF CULVERT

HORIZONTAL SCALE
0 6 m

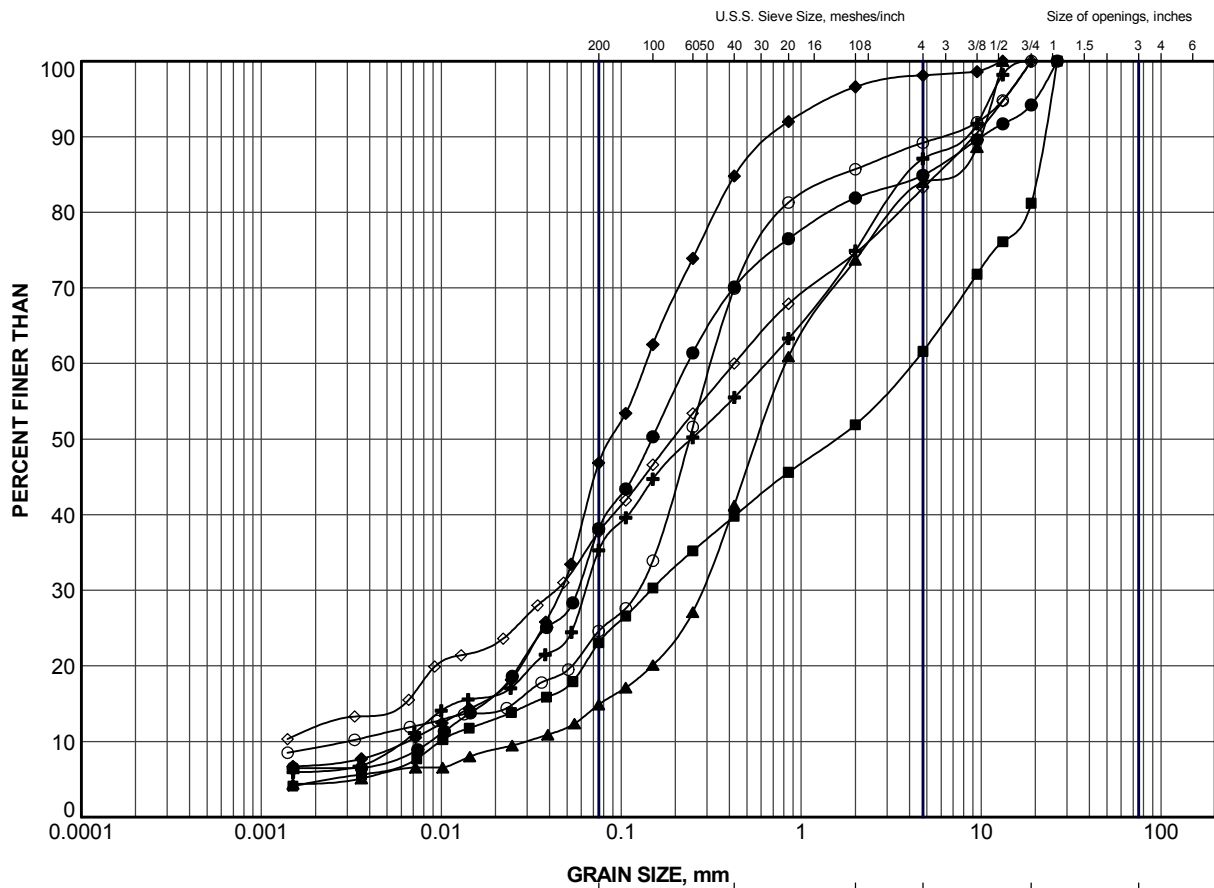
VERTICAL SCALE
0 2 m





APPENDIX A


Laboratory Test Data

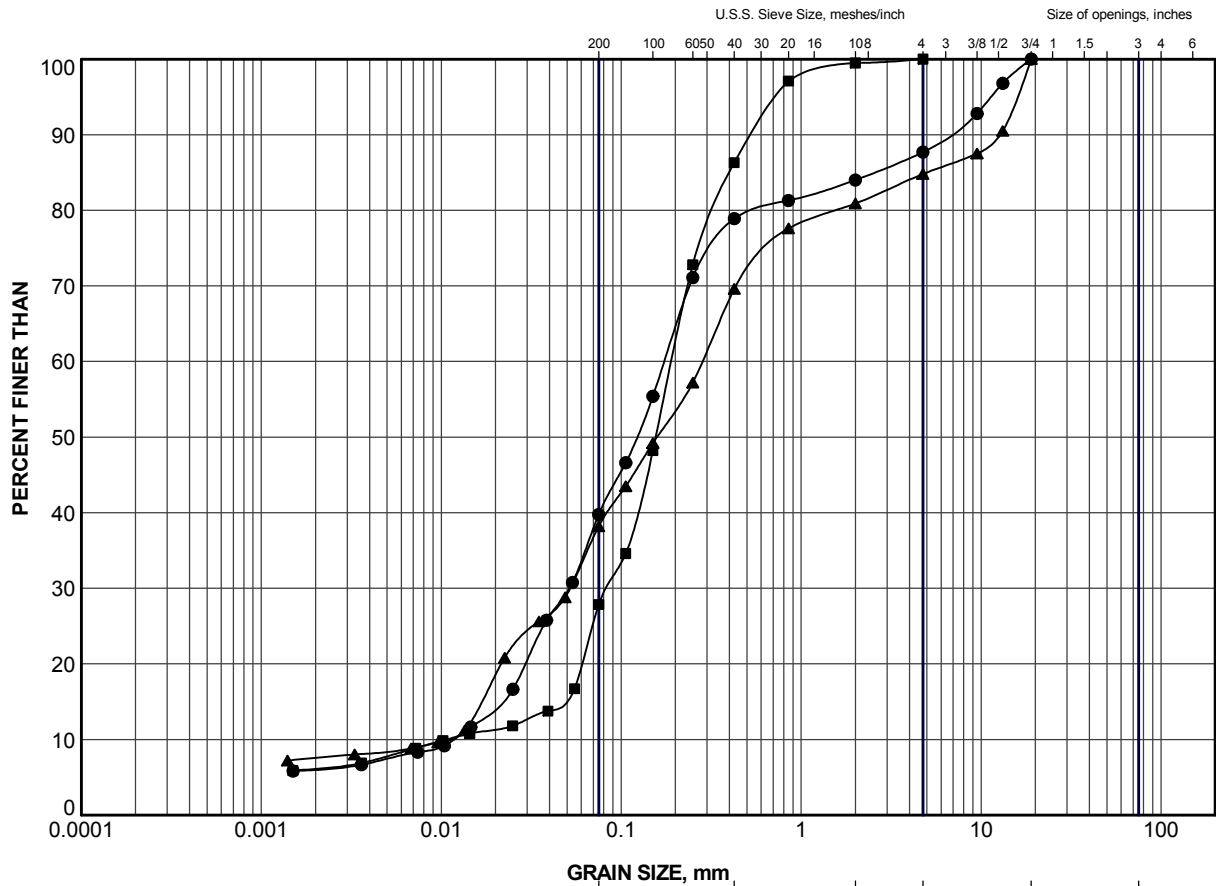


CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	602A	1	282.8
■	603A	3	291.6
▲	604	2	291.3
+	604	3	290.5
◆	604	9	285.9
◇	813	3	290.3
○	813	7	287.3


PROJECT		STRUCTURAL CULVERT STATION 16+357 HIGHWAY 401 IMPROVEMENTS GWP 4-00-00			
TITLE		GRAIN SIZE DISTRIBUTION FILL			
 Golder Associates LONDON, ONTARIO	PROJECT No.	10-1132-0056	FILE No.	1011320056-2000-F070A1	
	DRAWN	WDF	Nov. 13/13	SCALE	N/A
	CHECK			REV.	
			FIGURE A-1		

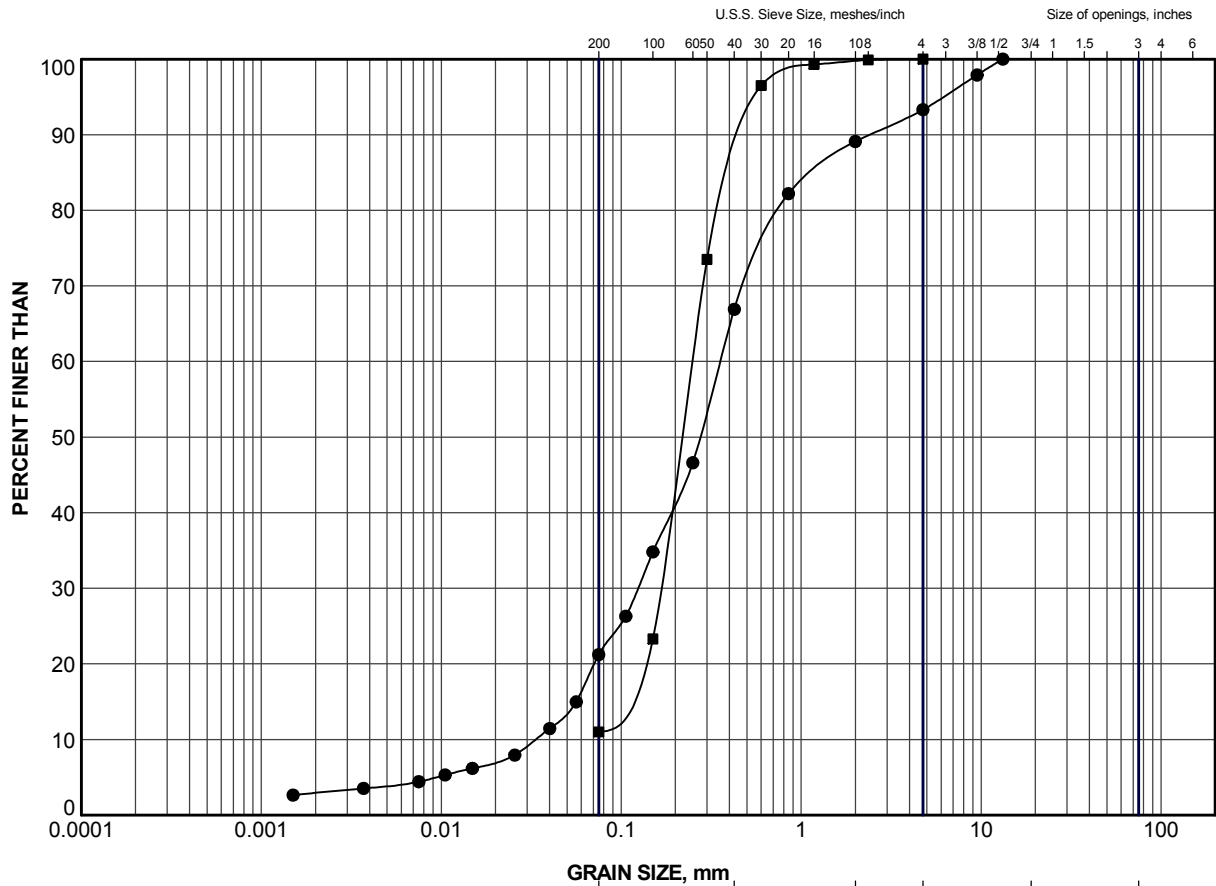


CLAY AND SILT	SAND SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	601A	3	286.9
■	604	13	282.9
▲	813	11	284.3

PROJECT		STRUCTURAL CULVERT STATION 16+357 HIGHWAY 401 IMPROVEMENTS GWP 4-00-00			
TITLE		GRAIN SIZE DISTRIBUTION SILTY SAND			
PROJECT No.		10-1132-0056		FILE No. 1011320056-2000-F070A2	
DRAWN		WDF		Nov. 13/13	
CHECK					
 Golder Associates LONDON, ONTARIO		FIGURE A-2			



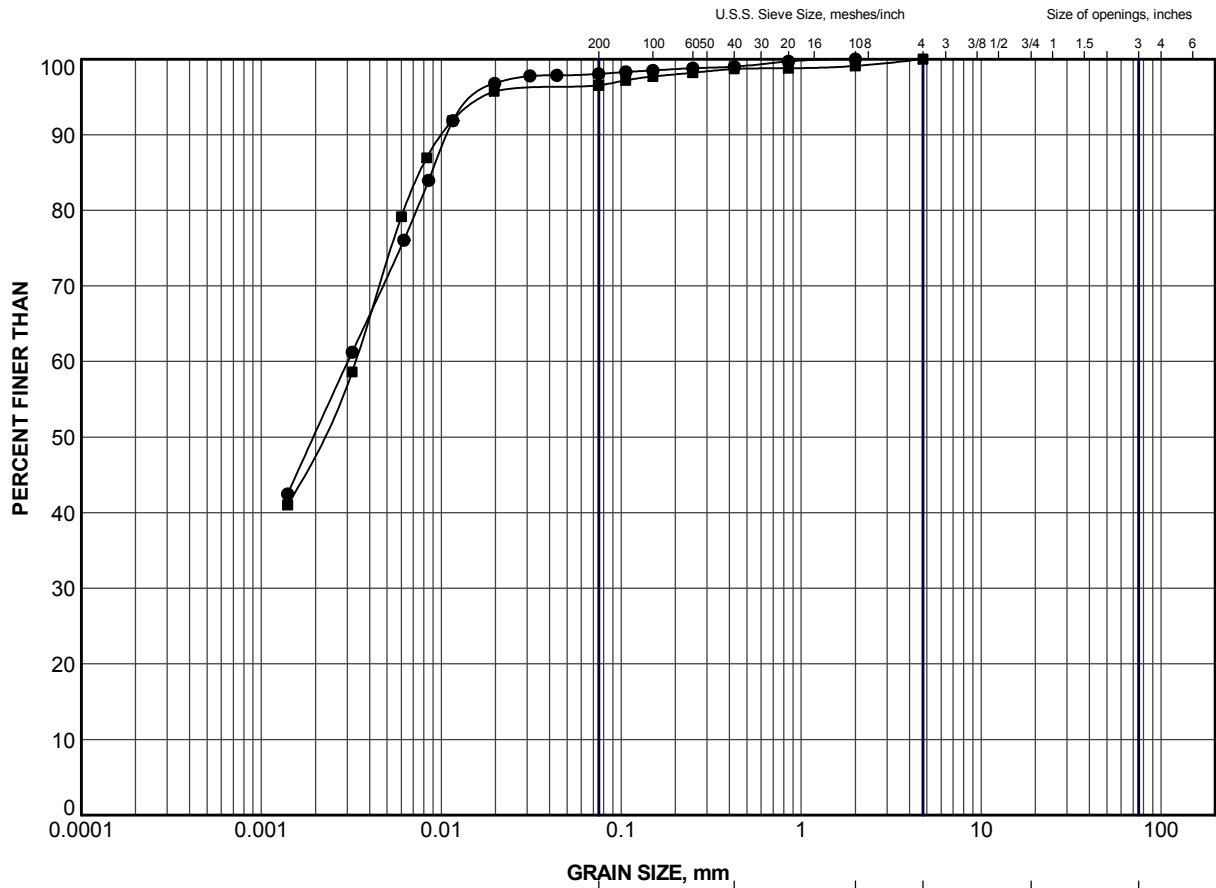
CLAY AND SILT	SAND SIZE			GRAVEL SIZE		Cobble Size
	fine	medium	coarse	fine	coarse	

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	603A	11	285.5
■	813	13	282.7

PROJECT				STRUCTURAL CULVERT STATION 16+357 HIGHWAY 401 IMPROVEMENTS GWP 4-00-00			
TITLE				GRAIN SIZE DISTRIBUTION SAND			
PROJECT No.		10-1132-0056		FILE No.		1011320056-2000-F070A4	
DRAWN		WDF		SCALE		N/A	
CHECK				REV.			
		Nov. 13/13		FIGURE A-4			




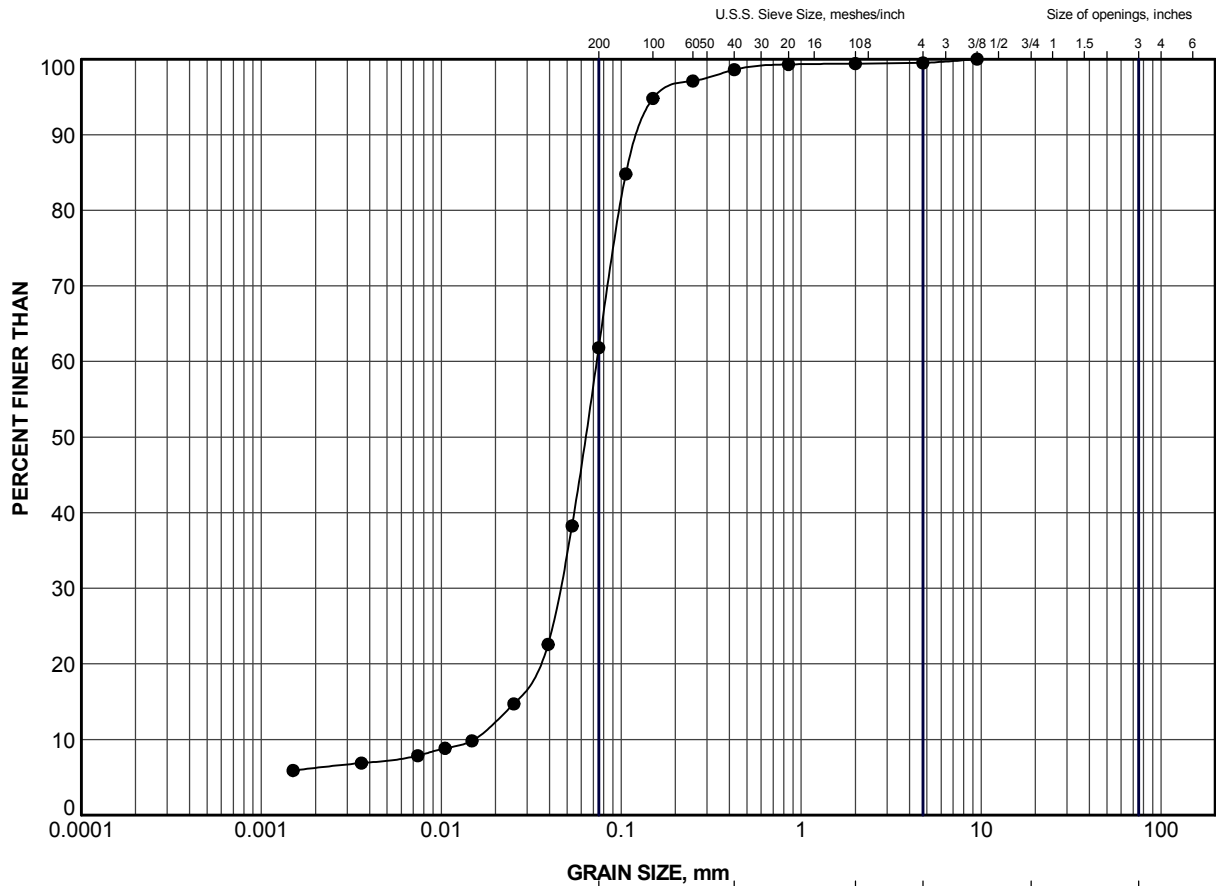


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	601A	7	283.8
■	603A	14	283.3

PROJECT				STRUCTURAL CULVERT STATION 16+357 HIGHWAY 401 IMPROVEMENTS GWP 4-00-00			
TITLE				GRAIN SIZE DISTRIBUTION SILTY CLAY			
PROJECT No.		10-1132-0056		FILE No.		1011320056-2000-F070A5	
DRAWN		WDF		SCALE		N/A	
CHECK				REV.			
		Nov. 13/13					
 Golder Associates LONDON, ONTARIO				FIGURE A-5			



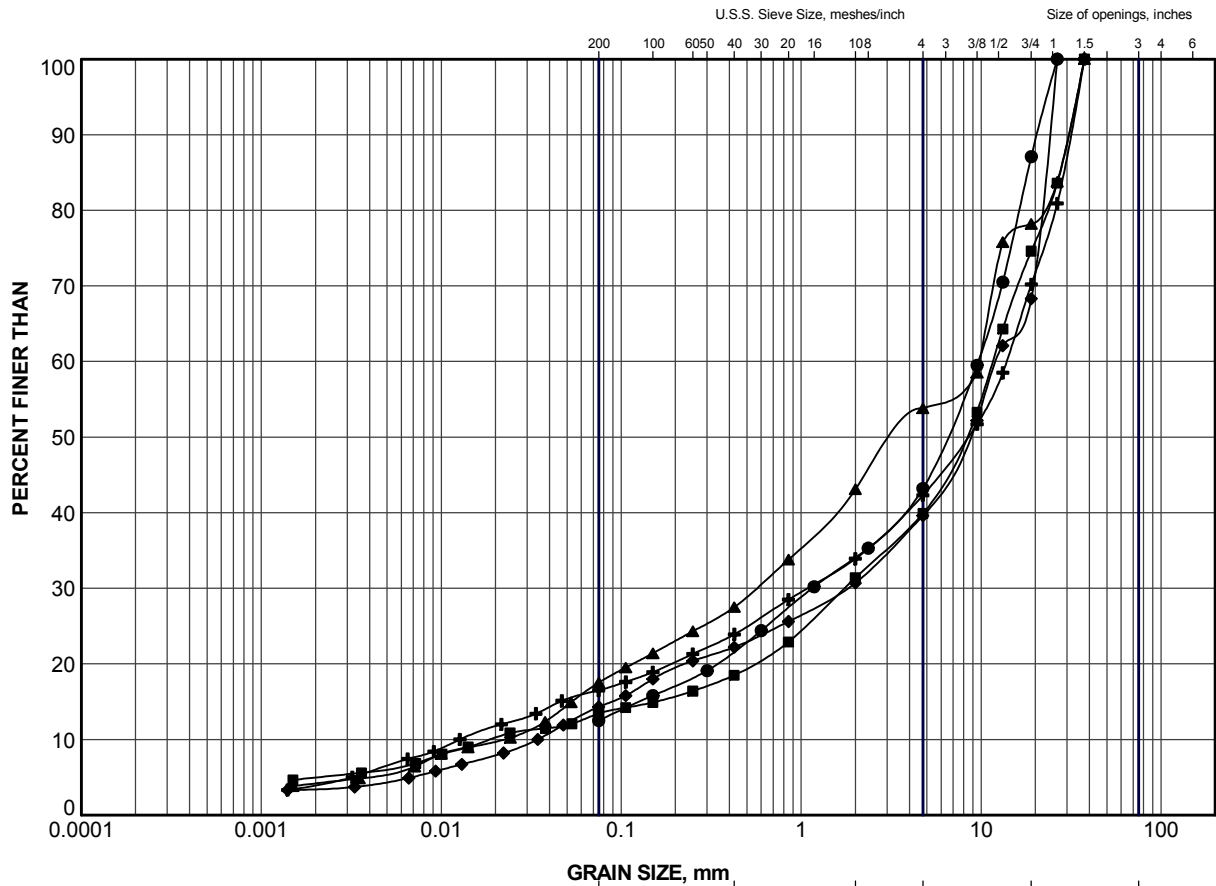
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	601A	9	282.3

PROJECT				STRUCTURAL CULVERT STATION 16+357 HIGHWAY 401 IMPROVEMENTS GWP 4-00-00			
TITLE				GRAIN SIZE DISTRIBUTION SANDY SILT			
PROJECT No.		10-1132-0056		FILE No.		1011320056-2000-F070A6	
DRAWN		WDF		Nov. 13/13		SCALE N/A REV.	
CHECK						FIGURE A-6	




LDN_MTO_GSD_GLDR_LDNG.DOT



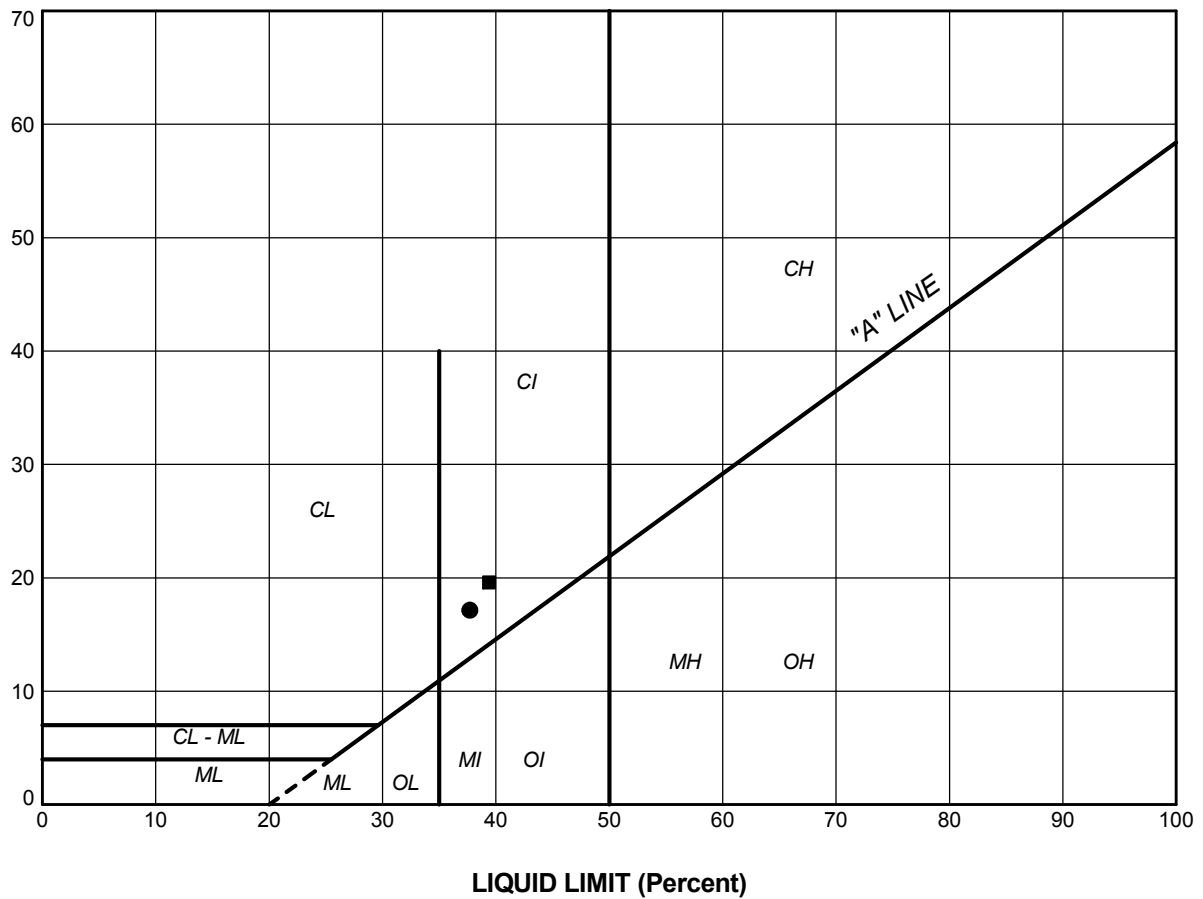
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	602A	4	280.5
■	602A	9	276.7
▲	604	15	281.3
+	811	5	280.5
◆	811	7	279.0

PROJECT				STRUCTURAL CULVERT STATION 16+357 HIGHWAY 401 IMPROVEMENTS GWP 4-00-00			
TITLE				GRAIN SIZE DISTRIBUTION SAND AND GRAVEL			
PROJECT No.		10-1132-0056		FILE No.		1011320056-2000-F070A7	
DRAWN		WDF		SCALE		N/A	
CHECK				REV.			
		Nov. 13/13					
 Golder Associates LONDON, ONTARIO				FIGURE A-7			

PLASTICITY INDEX (Percent)




SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	601A	7	37.7	20.6	17.2
■	603A	14	39.4	19.8	19.6

PROJECT		STRUCTURAL CULVERT STATION 16+357 HIGHWAY 401 IMPROVEMENTS GWP 4-00-00		
TITLE		PLASTICITY CHART		
PROJECT No.		10-1132-0056	FILE No. 1011320056-2000-F070A8	
DRAWN		WDF	Nov. 13/13	SCALE N/A REV.
CHECK				
 Golder Associates LONDON, ONTARIO		FIGURE A-8		



APPENDIX B

Additional Boreholes and Laboratory Test Data

RECORD OF BOREHOLE No 601

1 OF 1

METRIC

PROJECT 10-1132-0056

W.P. 4-00-00

LOCATION N 4808239.6 , E 235017.9

ORIGINATED BY MA

DIST HWY 401

BOREHOLE TYPE POWER AUGER, HOLLOW STEM

COMPILED BY LMK

DATUM GEODETIC

DATE June 27, 2012 - June 28, 2012

CHECKED BY

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	× LAB VANE											
297.18	GROUND SURFACE																					
0.00	TOPSOIL, sandy																					
0.21	SAND AND GRAVEL, some silt, trace clay, with cobbles Dense to very dense Brown																					
			1	SS	37																	
			2	SS	40																	
			3	SS	39																	
			4	SS	41																	
			5	SS	73																	
			6	SS	28/ 50mm																	
292.00																						
5.18	SILT AND SAND, trace gravel Very dense Brown		7	SS	66/ 75mm																	
291.36																						
5.82	SANDY SILT, trace gravel, trace clay Very dense Brown		8	SS	74/ 100mm																	
			9	SS	100/ 100mm																	
289.71																						
7.47	SAND, some gravel, some silt, with cobbles and boulders Very dense Brown Boulder at elev. 289.30m		10	SS	100/ 75mm																	
			11	SS	100/ 125mm																	
			12	SS	12/ 25mm																	
287.43																						
9.75	SAND, trace to some gravel, some silt Very dense Brown		13	SS	100/ 100mm																	
			14	SS	46/ 75mm																	
285.90																						
11.28	SILTY SAND AND GRAVEL, some silt layers and seams Very dense Brown		15	SS	100																	
			16	SS	68/ 75mm																	
284.04			17	SS	100/ 100mm																	
13.14	CLAYEY SILT, some sand, trace gravel Hard Brown																					
13.35	END OF BOREHOLE Groundwater encountered at about elev. 285.9m during drilling on June 27, 2012. Water level measured in piezometer at elev. 285.68m on June 27, 2012.																					

Water level measured in piezometer at elev. 284.84m on January 24, 2013.
Water level measured in piezometer at elev. 285.67m on November 20, 2013.

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

LDN_MTO_06 10-1132-0056-2000.GPJ LDN_MTO.GDT 24/12/13

RECORD OF BOREHOLE No 602

1 OF 1

METRIC

PROJECT 10-1132-0056
W.P. 4-00-00 LOCATION N 4808190.5 , E 235062.7 ORIGINATED BY LK
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY AMG
DATUM GEODETIC DATE September 19, 2012 CHECKED BY

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											
								20 40 60 80 100											
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE											
					WATER CONTENT (%)														
					20 40 60 80 100					10 20 30									
291.40	PAVEMENT SURFACE																		
0.00	ASPHALT																		
0.27	FILL, sand and gravel, crushed, trace silt Brown						291												
290.46																			
0.94	FILL, sand and gravel, trace to some silt Very dense Brown		1	SS	53														
			2	SS	56		290												
289.24																			
2.16	FILL, silty sand and gravel, trace clay Brown Compact		3	SS	13		289					○				30 36 29 5			
288.35																			
3.05	TOPSOIL, silty sand		4	SS	9		288												
3.35	SILT AND SAND, trace gravel, trace clay Loose to dense Brown		5	SS	32														
							287					○				6 47 41 6			
			6	SS	34														
285.92							286												
5.48	SAND AND GRAVEL, some silt, trace clay, with cobbles Very dense Brown		7	SS	156/ 225mm		285												
							284					○				28 48 17 7			
			8	SS	93		283												
			9	SS	100/ 150mm		282												
							281												
			10	SS	100/ 150mm		280												
278.90			11	SS	100/ 150mm		279												
12.50	END OF BOREHOLE																		
	Groundwater encountered at about elev. 289.2m during drilling on September 19, 2012.																		

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

LDN_MTO_06 10-1132-0056-2000.GPJ LDN_MTO.GDT 24/12/13

RECORD OF BOREHOLE No 603

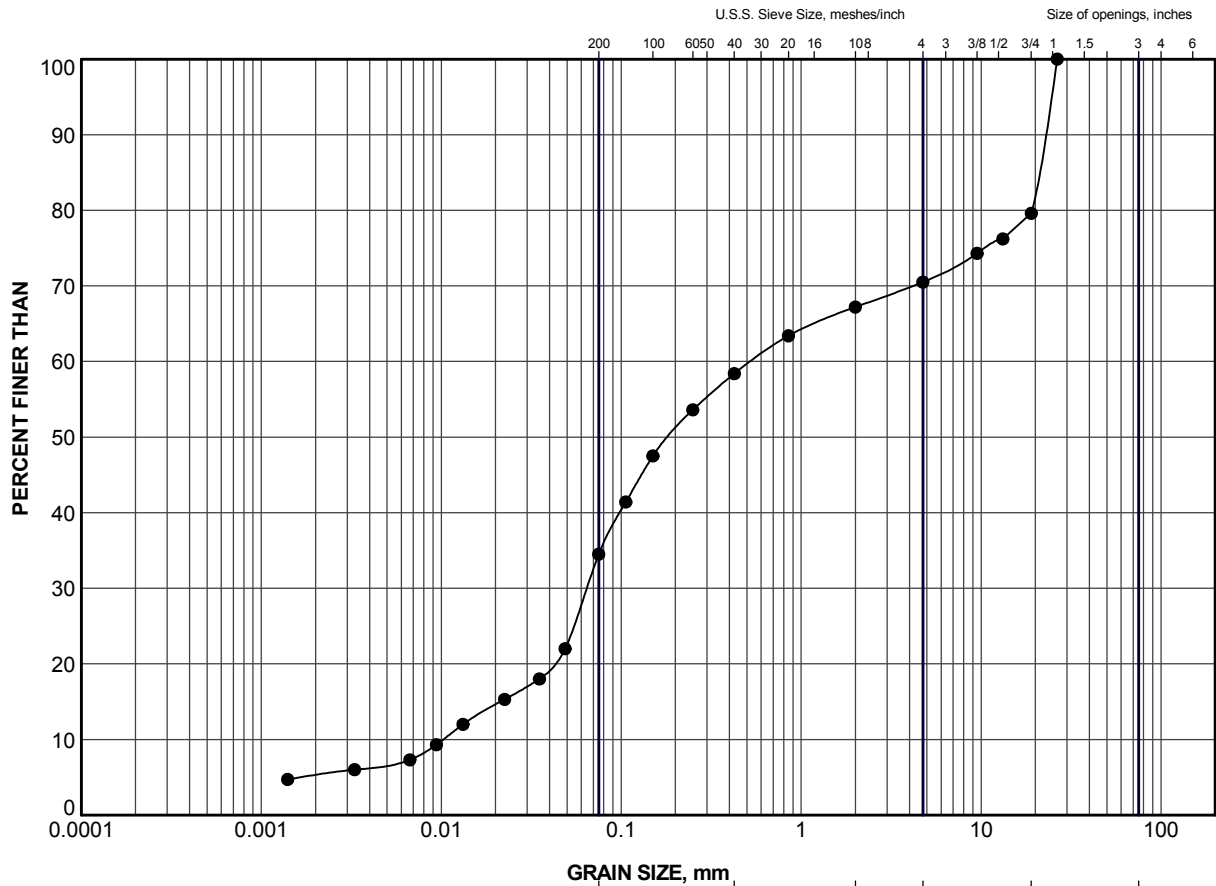
1 OF 1

METRIC

PROJECT 10-1132-0056
W.P. 4-00-00 LOCATION N 4808216.4 , E 235035.4 ORIGINATED BY LK
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY WDF
DATUM GEODETIC DATE September 25, 2012 - September 26, 2012 CHECKED BY

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									
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE	WATER CONTENT (%)					
291.38	PAVEMENT SURFACE						20	40	60	80	100						
0.00	ASPHALT																
0.27	FILL, sand and gravel, trace silt Brown																
290.74																	
0.64	SAND, some silt, trace to some gravel Compact to very dense Brown		1	SS	29												
			2	SS	78												
			3	SS	144/ 275mm												
	Inferred cobble / boulder at elev. 288.7m		4	SS	84												
			5	SS	102												
			6	SS	100/ 75mm												
286.05																	
5.33	SILTY SAND, trace to some gravel, trace silt seams, trace clay Very dense Brown		7	SS	160								○				11 53 32 4
			8	SS	171/ 275mm												
284.31																	
7.07	SAND, fine, some silt, trace gravel, trace clay Very dense Brown		9	SS	95								○				1 76 14 9
283																	
282.11																	
9.27	END OF BOREHOLE		10	SS	100/ 125mm								○				
	Groundwater encountered at about elev. 285.8m during drilling on September 25, 2012.																


LDN_MTO_06 10-1132-0056-2000.GPJ LDN_MTO.GDT 24/12/13

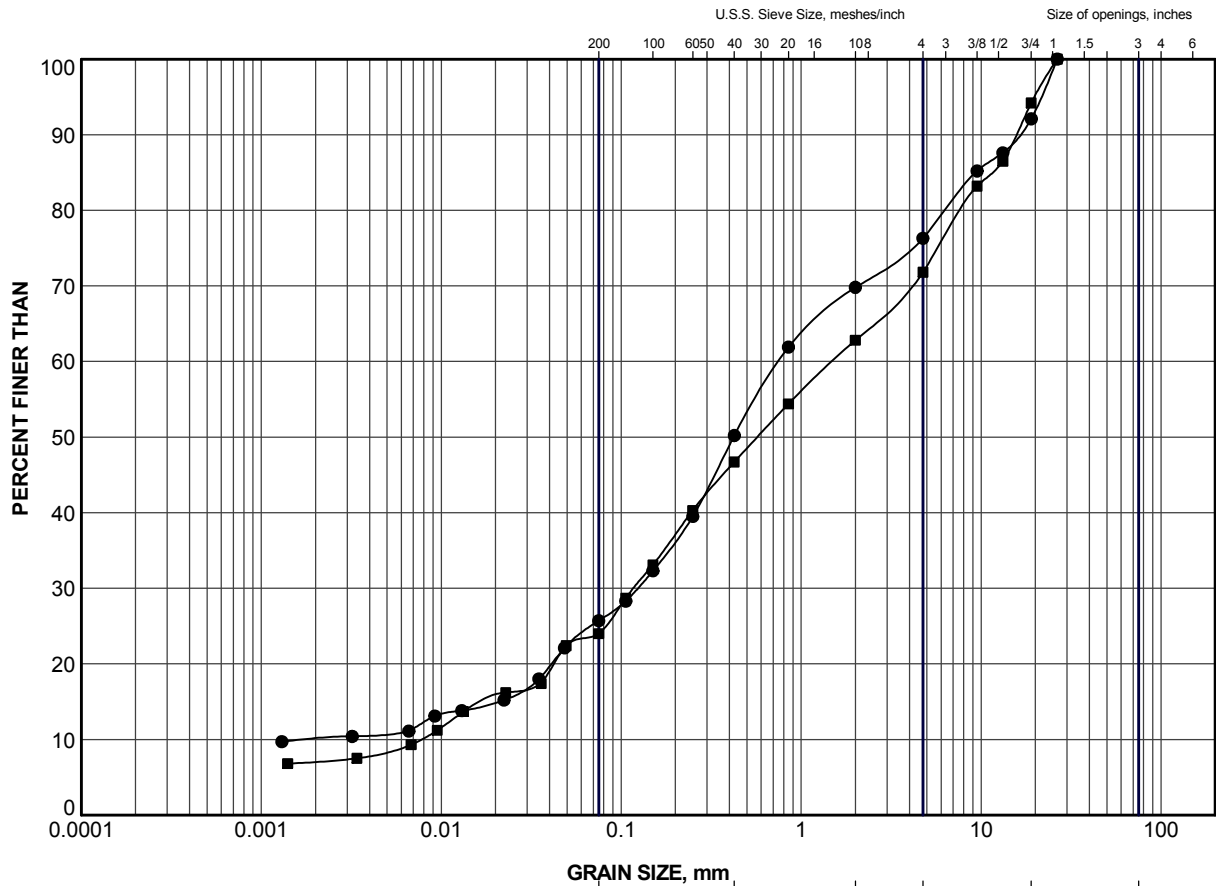


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND


SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	602	3	288.9

PROJECT				STRUCTURAL CULVERT STATION 16+357 HIGHWAY 401 IMPROVEMENTS GWP 4-00-00			
TITLE				GRAIN SIZE DISTRIBUTION FILL			
PROJECT No.		10-1132-0056		FILE No.		1011320056-2000-F070B1	
DRAWN		WDF		SCALE		N/A	
CHECK				REV.			
 Golder Associates LONDON, ONTARIO				Nov. 13/13		FIGURE B-1	

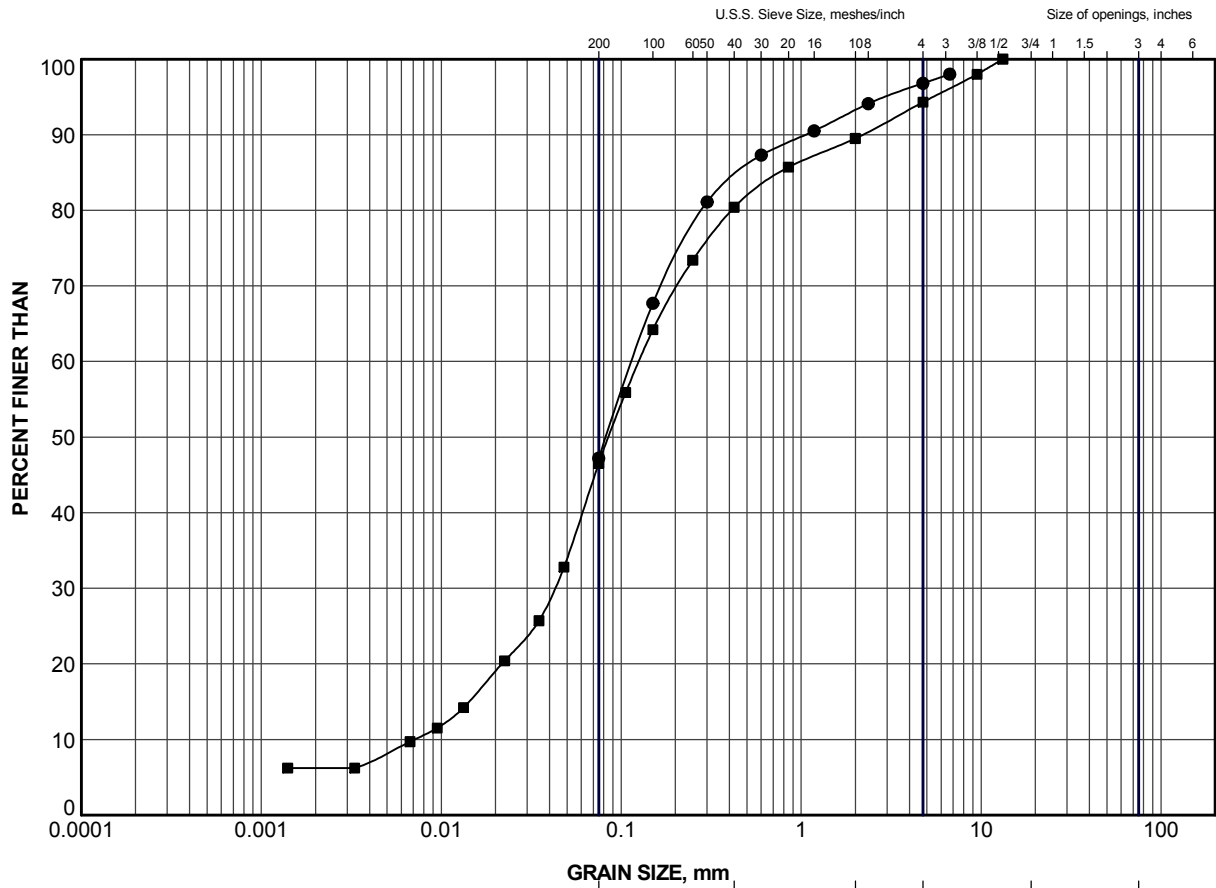


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	601	3	294.7
■	602	8	283.6

PROJECT				STRUCTURAL CULVERT STATION 16+357 HIGHWAY 401 IMPROVEMENTS GWP 4-00-00			
TITLE				GRAIN SIZE DISTRIBUTION SAND AND GRAVEL			
PROJECT No.		10-1132-0056		FILE No.		1011320056-2000-F070B2	
DRAWN		WDF		SCALE		N/A	
CHECK				REV.			
		Nov. 13/13					
 Golder Associates LONDON, ONTARIO				FIGURE B-2			

LDN_MTO_GSD_GLDR_LDN.GDT



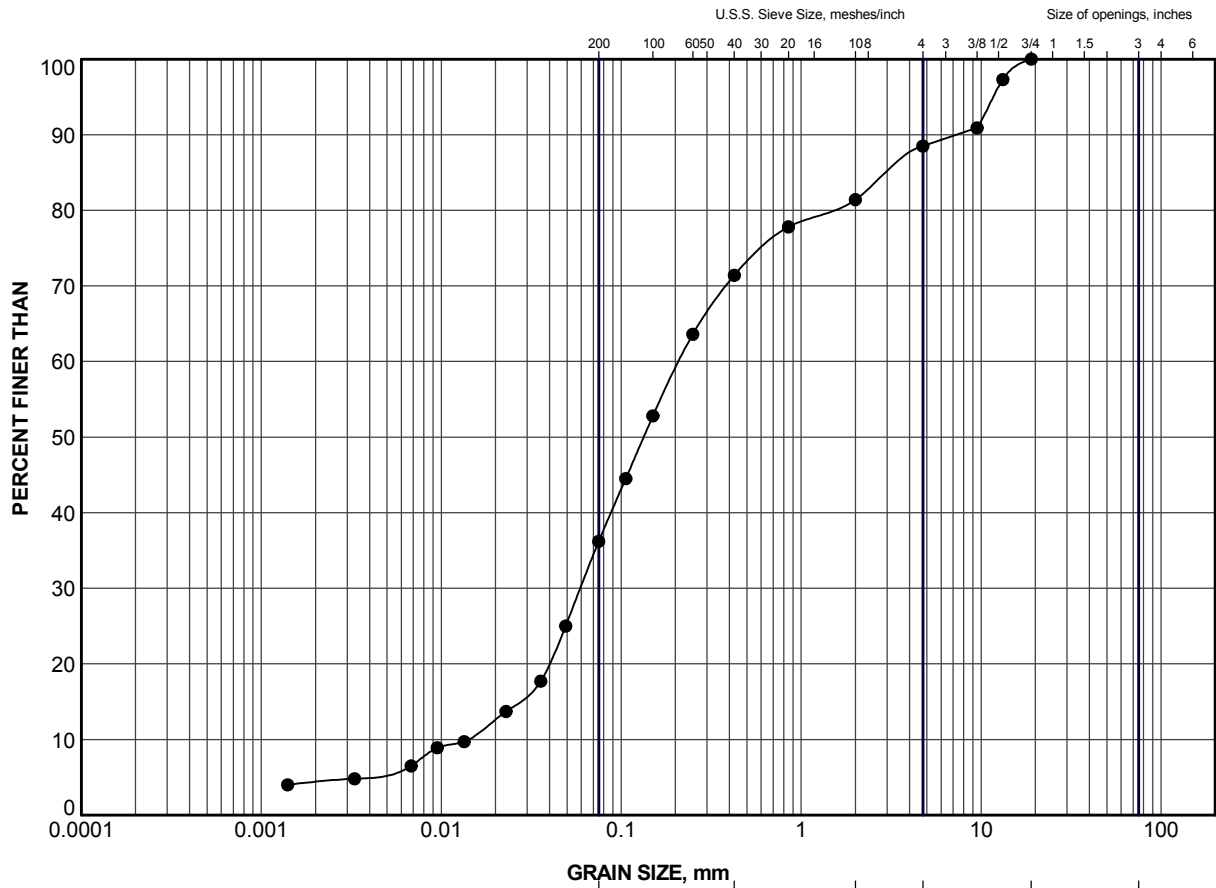
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	601	7	291.7
■	602	6	286.6

PROJECT				STRUCTURAL CULVERT STATION 16+357 HIGHWAY 401 IMPROVEMENTS GWP 4-00-00			
TITLE				GRAIN SIZE DISTRIBUTION SILT AND SAND			
PROJECT No.		10-1132-0056		FILE No.		1011320056-2000-F070B3	
DRAWN		WDF		Nov. 13/13		SCALE N/A REV.	
CHECK						FIGURE B-3	




LDN_MTO_GSD_GLDR_LDN.GDT

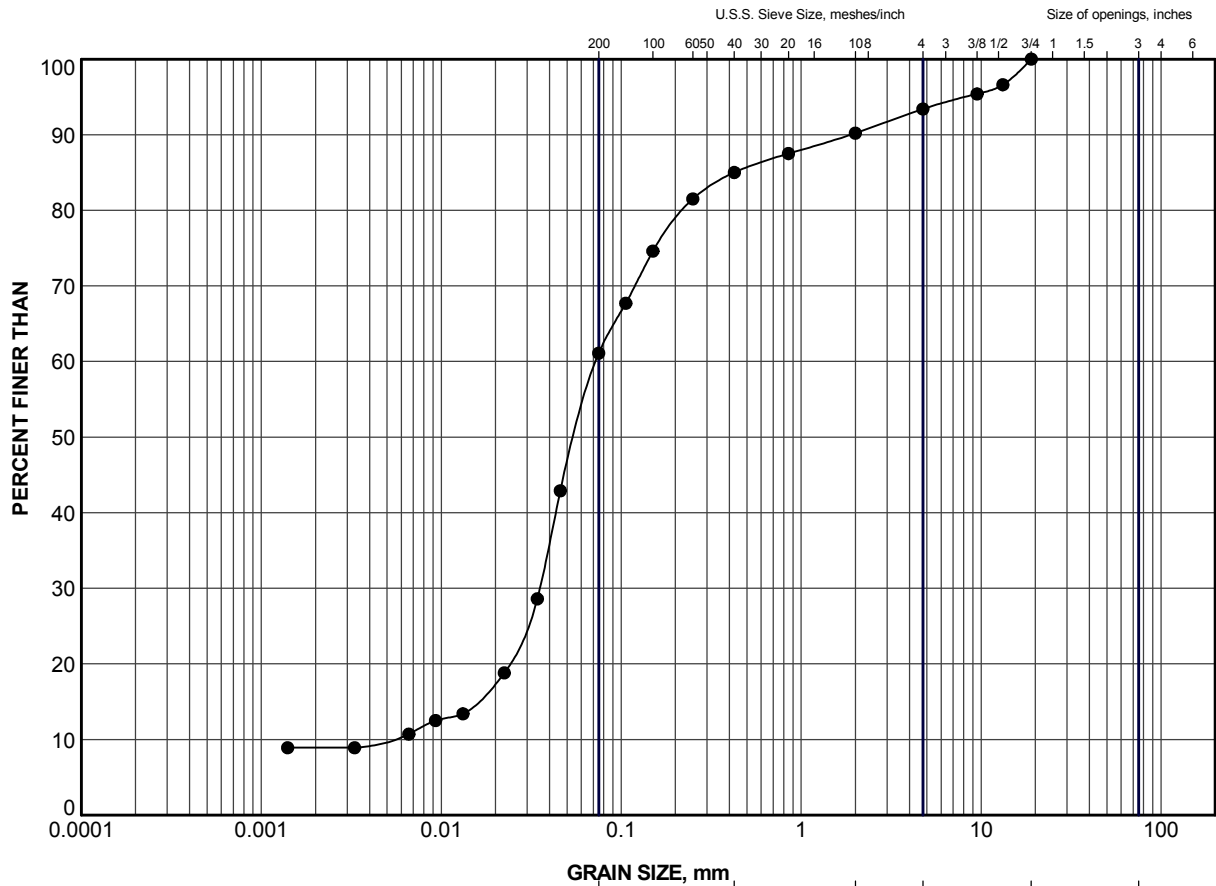


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	603	7	285.8

PROJECT		STRUCTURAL CULVERT STATION 16+357 HIGHWAY 401 IMPROVEMENTS GWP 4-00-00					
TITLE		GRAIN SIZE DISTRIBUTION SILTY SAND					
 Golder Associates LONDON, ONTARIO		PROJECT No.		10-1132-0056		FILE No. 1011320056-2000-F070B4	
						SCALE N/A	
		DRAWN		WDF		Nov. 13/13	
		CHECK					
						FIGURE B-4	

LDN_MTO_GSD_GLDR_LDN.GDT



CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	601	8	291.0

PROJECT

STRUCTURAL CULVERT STATION 16+357
HIGHWAY 401 IMPROVEMENTS
GWP 4-00-00

TITLE

GRAIN SIZE DISTRIBUTION
SANDY SILT

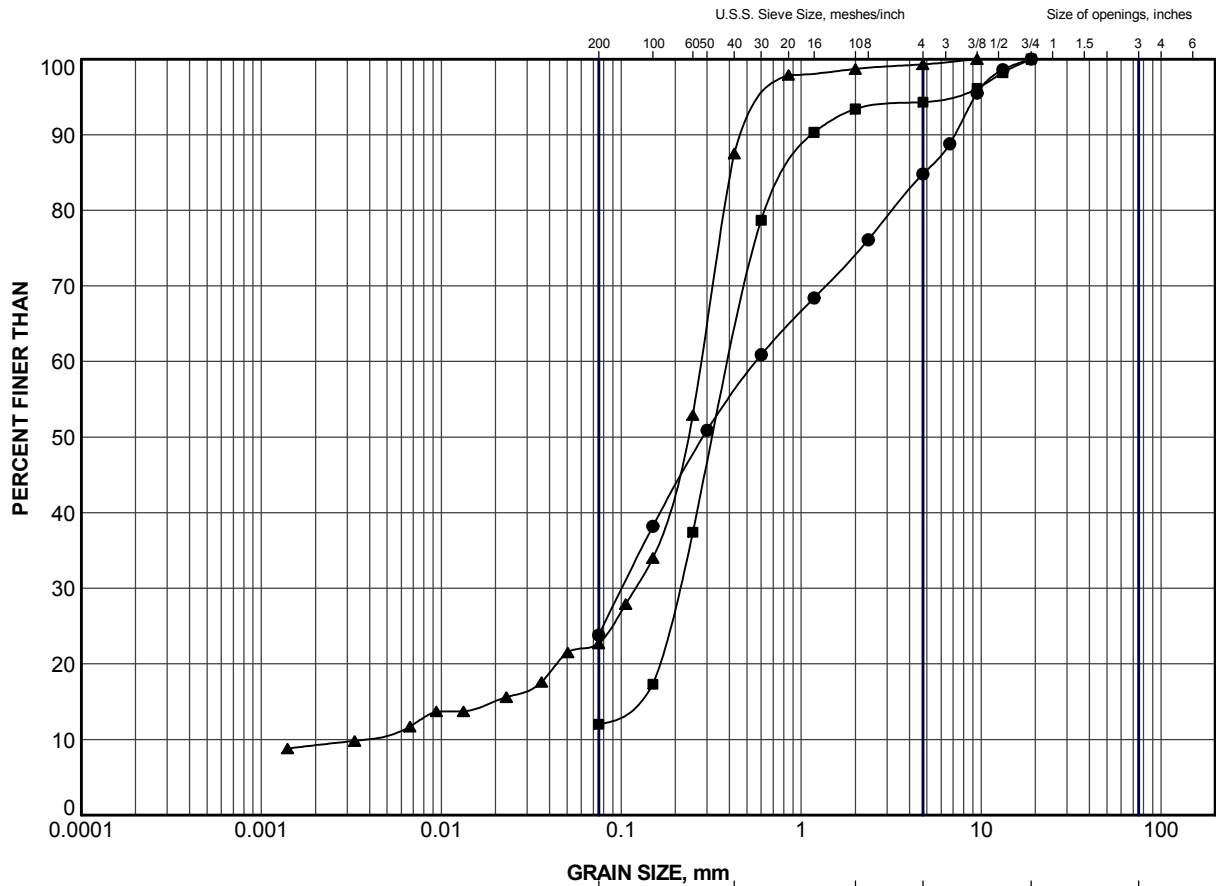
Golder Associates

LONDON, ONTARIO

PROJECT No.	10-1132-0056	FILE No.	1011320056-2000-F070B5
DRAWN	WDF	Nov. 13/13	SCALE N/A REV.
CHECK			

FIGURE B-5

LDN_MTO_GSD_GLDR_LDN.GDT



CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	601	11	288.8
■	601	14	286.3
▲	603	9	283.5

PROJECT				STRUCTURAL CULVERT STATION 16+357 HIGHWAY 401 IMPROVEMENTS GWP 4-00-00			
TITLE				GRAIN SIZE DISTRIBUTION SAND			
PROJECT No.		10-1132-0056		FILE No.		1011320056-2000-F070B6	
DRAWN		WDF		Nov. 13/13		SCALE N/A REV.	
CHECK						FIGURE B-6	



LDN_MTO_GSD_GLDR_LDN.GDT

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

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

solutions@golder.com
www.golder.com

Golder Associates Ltd.
309 Exeter Road, Unit #1
London, Ontario, N6L 1C1
Canada
T: +1 (519) 652 0099

