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**FOUNDATION INVESTIGATION AND DESIGN REPORT  
STRUCTURAL CULVERT, STATION 17+709  
SITE 6-457-C, COWAN D&W DRAIN  
HIGHWAY 77 REHABILITATION  
GWP 139-98-00, AGREEMENT NO. 3006-E-0013  
MINISTRY OF TRANSPORTATION - SOUTHWESTERN REGION**

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## TABLE OF CONTENTS

<u>SECTION</u>	<u>PAGE</u>
 <b>PART A – FOUNDATION INVESTIGATION REPORT</b>	
1.0 INTRODUCTION.....	1
2.0 SITE DESCRIPTION.....	2
2.1 Site Geology .....	2
3.0 INVESTIGATION PROCEDURES.....	4
4.0 SUBSURFACE CONDITIONS.....	6
4.1 Site Stratigraphy .....	6
4.1.1 Pavement Structure .....	6
4.1.2 Topsoil and Fill.....	6
4.1.3 Clayey Silt.....	7
4.1.4 Silty Fine Sand.....	7
4.1.5 Sand .....	7
4.1.6 Sandy Silt.....	7
4.2 Groundwater Conditions.....	8
5.0 MISCELLANEOUS.....	9
 <b>PART B – FOUNDATION DESIGN REPORT</b>	
6.0 ENGINEERING RECOMMENDATIONS .....	10
6.1 General.....	10
6.2 Foundations.....	10
6.2.1 Frost Protection .....	11
6.3 Bedding .....	11
6.4 Backfill .....	11
6.5 Lateral Earth Pressures for Design .....	11
6.6 Construction Considerations .....	13
6.7 Excavations and Temporary Cut Slopes .....	13
7.0 MISCELLANEOUS.....	16

LIST OF ABBREVIATIONS

LIST OF SYMBOLS

RECORD OF BOREHOLE SHEETS

FIGURE 1 - Key Plan

DRAWING 1 - Borehole Locations and Soil Strata

APPENDIX A - Laboratory Test Data

APPENDIX B - Site Photographs

**PART A**  
**FOUNDATION INVESTIGATION REPORT**

**STRUCTURAL CULVERT, STATION 17+709**  
**SITE 6-457-C, COWAN D&W DRAIN**  
**HIGHWAY 77 REHABILITATION**  
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## 1.0 INTRODUCTION

Golder Associates Ltd. (Golder Associates) has been retained by Philips Engineering Ltd. (Philips) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations as part of the detail design work for GWP 139-98-00. Highway 77 will be rehabilitated from its southern terminus in Leamington to Staples approximately 11.7 kilometres. The southern project limit is just south of Highway 3 in Leamington and the northern limit is near the junction with Essex County Road 8 in Staples. The project also includes reconstruction and widening of an approximately 350 metre long section of Essex County Road 8 within the Highway 77/Essex County Road 8 interchange area. The scope of work for the proposed rehabilitation project includes:

- Pavement rehabilitation;
- Cross section revisions;
- Minor road widening and grade raise;
- Improvements to surface and subsurface drainage;
- Improvements to drainage structures;
- Intersection improvements including turning lanes and illumination;
- Entrance upgrades;
- Guide rail replacement; and,
- Subsurface utility engineering.

The improvements to the drainage structures will include the replacement, extension or rehabilitation of five structural culverts. This report addresses the foundation investigation for the partial replacement of the structural culvert located on Highway 77 at Station 17+709 (Site 6-457-C).

The purpose of the foundation investigation is to determine the subsurface conditions at the location of the proposed works 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, in Golder Associates' proposal P61-3143-1 dated September 14, 2006 and our letter dated November 8, 2007. The work was carried out in accordance with our Quality Control Plan for Foundations Engineering originally issued on December 13, 2006 and revised February 19, 2007.

Philips provided Golder Associates with a general arrangement drawing for the proposed structure and a base plan for this project in digital format as well as hard copies of the Contract Drawings for this project.

## 2.0 SITE DESCRIPTION

Along Highway 77, the project limits of GWP 139-98-00 extend from Station 11+652 at the south side of Highway 3 northerly to Station 23+022 at the intersection with Essex County Road 8. The project also includes reconstruction of the Highway 77 S-E Ramp at the Essex County Road 8 intersection and reconstruction and some widening of Essex County Road 8 from Station 9+960 to Station 10+310. Approximately 11.4 kilometres of Highway 77 is within the Municipality of Leamington. Within the Community of Staples, the remaining 0.3 kilometres runs along Essex County Road 8 which marks the border between the Municipality of Leamington and the Town of Lakeshore. Highway 77 is co-signed with Essex County Road 8 in the short east-west section which joins the northern leg to Highway 401 and the southern leg leading to Leamington.

Culvert Site 6-457-C is located at Station 17+709 on Highway 77 and approximately 8 metres south of the centreline of Mersea Township Road 8 in the Community of Blytheswood. At this location, the Cowan D&W Drain crosses under Highway 77 from west to east. The location of the project is shown on the Key Plan, Figure 1, and in the photographs in Appendix B.

In the vicinity of the culvert, the Cowan D&W Drain flows in a grassed channel which parallels Mersea Township Road 8. The land use in the vicinity of the site is primarily residential with some commercial properties. The adjacent topography is generally flat to gently undulating with ground surface elevations ranging from 192 to 197 metres.

### 2.1 Site Geology

The site is situated on the Essex Clay Plain, a subregion of the physiographic region of southern Ontario known as the St. Clair Clay Plains.<sup>1</sup> This subregion is described as a beveled till plain with little relief that has been locally smoothed by shallow deposits of lacustrine clay deposited in depressions in the till. The prevailing soil type is reported to be the Brookston clay loam. Near Leamington, there is a small morainic hill composed primarily of sand and gravel.

The available surficial geology mapping for the project area indicates that it is predominantly an area of till (sandy silt and/or clayey silt) and glaciofluvial gravel or gravelly sand.<sup>2</sup> The

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<sup>1</sup> L.J. Chapman and D.F. Putnam, 1984. *The Physiography of Southern Ontario*. Third Edition. Ontario Geological Survey, Special Volume 2.

<sup>2</sup> Vagners, U. J., 1972. *Quaternary Geology of the Windsor-Essex Area, (Western and Eastern Parts) Southern Ontario*. Ontario Department of Mines and Northern Affairs, Preliminary Maps P. 749 and P.750, Geological Series.

overburden thickness within the project area ranges from 32.0 to 34.7 metres.<sup>3</sup> Immediately underlying the overburden is a medium brown limestone followed by a brown and tan limestone containing quartz sand grains and chert belonging to the Dundee Formation of the Hamilton Group.

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<sup>3</sup> Vagners, U.J., Sado, E.V., and Yundt, S.E. 1973. *Drift Thickness of the Windsor-Essex Area (Western and Eastern Parts)*, Southern Ontario, Ontario Division of Mines, Preliminary Maps P.814 and P.815, Drift Thickness Series.

### **3.0 INVESTIGATION PROCEDURES**

The field investigation at this site was conducted on November 20 and 22, 2007 at which time three boreholes, numbered 6, 7 and 17, were drilled in the area of the proposed culvert replacement. Borehole 6 was advanced to a depth of 8.8 metres, borehole 7 to 8.1 metres and borehole 17 to a depth of 3.1 metres.

Boreholes 6 and 7 were advanced using a truck-mounted P57 power auger supplied and operated by a specialist drilling contractor. Samples of the overburden were obtained at intervals of 0.75 metres using 50 millimetre outside diameter split spoon sampling equipment in accordance with the standard penetration test (SPT) procedures. Borehole 17 was drilled by staff from Golder Associates using manual drilling equipment. The SPT testing in the manually drilled borehole was conducted using a non-standard hammer weight of 31 kilograms and the SPT N values shown on the Record of Borehole have been adjusted to approximate standard values.

Groundwater conditions in the boreholes were observed throughout the drilling operations and these observations are provided on the corresponding Record of Borehole sheets. A standpipe was installed in borehole 7 to monitor the groundwater levels at this location. The boreholes were backfilled in accordance with current regulations, MTO recommended procedures and Ontario Regulation 903.

The field work was supervised on a full-time basis by an experienced member of our engineering staff who arranged for utility locates, directed the drilling, sampling and in-situ testing operations, logged the boreholes and cared for the samples obtained. The soil samples were identified in the field, placed in labelled containers and transported to Golder Associates' 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 field and laboratory testing are given on the Record of Borehole sheets and in Appendix A.

Temporary traffic control was carried out in accordance with the Ontario Traffic Manual, Temporary Conditions, Book 7, dated March 2001.

The as-drilled borehole locations and ground surface elevations are shown on the Record of Borehole sheets and on Drawing 1.

The table below summarizes the culvert location and the coordinates, ground surface elevations and depths of the associated boreholes.

<u>BOREHOLE</u>	<u>LOCATION (m)</u>		<u>GROUND SURFACE ELEVATION</u>	<u>BOREHOLE DEPTH</u>
	<u>Northing</u>	<u>Easting</u>	(m)	(m)
6	4664753.8	296936.9	193.63	8.84
7	4664762.8	296966.2	193.63	8.08
17	4664761.9	296914.3	192.48	3.05

The existing culvert has the following characteristics:

<u>DIMENSIONS (m)</u>	<u>OBVERT ELEVATION (m)</u>		<u>CONSTRUCTION</u>
	(Lt)	(Rt)	
2.74 x 1.22 x 45.72	193.03	193.03	Non-Rigid Frame Open Footing (NRFO)



## **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 and laboratory testing carried out on selected samples are given 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 sampling and observations of drilling resistance and may represent transitions between soil types rather than exact planes of geological change. Subsurface conditions will vary between and beyond the borehole locations.

In general, the boreholes encountered surficial asphalt and granular road base in the shoulder areas and topsoil near the drain. Layers of clayey fill were found beneath the topsoil and pavement. The fill was underlain by predominantly clayey silt deposits interlayered with silty fine sand, sandy silt and sand.

The locations of the boreholes are shown on the attached Drawing 1. A detailed description of the subsurface conditions encountered in the boreholes is provided on the Record of Borehole sheets and is summarized in the following sections.

#### **4.1.1 Pavement Structure**

A 120 millimetre thick layer of asphalt was encountered at the ground surface in borehole 6. The asphalt was underlain by a 0.25 metre thick layer of granular road base material from elevation 193.5 metres. A 0.3 metre thick layer of granular road base was encountered at ground surface in borehole 7.

#### **4.1.2 Topsoil and Fill**

A 130 millimetre thick topsoil layer was encountered at the ground surface in borehole 17.

Granular fill materials were encountered at elevation 193.3 metres beneath the granular road base in boreholes 6 and 7. The fill consisted of silty sand to elevation 193.1 metres in borehole 6 and fine to medium sand to elevation 193.2 metres in borehole 7.

Clayey silt fill was encountered beneath the granular fill in boreholes 6 and 7 from elevations 193.1 and 193.2 metres, respectively, and beneath the topsoil in borehole 17 from elevation 192.4 metres. The clayey silt fill layers were 0.9, 1.0 and 2.0 metres thick in boreholes 6, 7 and 17,

respectively. The cohesive fill layers were soft to firm with N values ranging from 3 to 7 blows per 0.3 metres. The natural water contents of the clayey silt fill were about 28 per cent.

#### **4.1.3 Clayey Silt**

Clayey silt was encountered beneath the clayey silt fill in boreholes 6 and 7 from elevation 192.3 metres and beneath a layer of sand in borehole 17 from elevation 189.6 metres.

The clayey silt was firm to very stiff with N values ranging from 7 blows per 0.3 metres to 25 blows per 0.3 metres. The results of in situ vane testing indicated an undrained shear strength of over 144 kilopascals. The natural water contents of the clayey silt varied between about 17 and 19 per cent. The clayey silt is of low to intermediate plasticity based on average plastic and liquid limits of 17 and 35 per cent, respectively, and an average plasticity index of 18 per cent. The results of the Atterberg limits determinations are shown on Figure A-2.

The results of grain size analyses conducted on samples of the clayey silt are shown on Figure A-1.

#### **4.1.4 Silty Fine Sand**

A 0.3 metre thick layer of silty fine sand was encountered in the clayey silt stratum in borehole 7 from elevation 190.5 metres. The results of grain size testing on a sample of silty fine sand are presented in Appendix A on Figure A-3. The silty fine sand was compact with an N value of 24 blows per 0.3 metres. The natural water content of a sample of the silty fine sand was about 15 per cent.

#### **4.1.5 Sand**

A 0.8 metre thick layer of fine to medium sand was encountered beneath the clayey silt fill in borehole 17 from elevation 190.4 metres. The results of grain size testing on a sample of sand are shown on Figure A-5. The sand was compact with an N value of 24 blows per 0.3 metres. The natural water content of a sample of the sand was about 20 per cent.

#### **4.1.6 Sandy Silt**

A 1.7 metre thick layer of sandy silt was encountered beneath the silty fine sand in borehole 7 from elevation 190.1 metres. The results of grain size testing on samples of sandy silt are shown on Figure A-4. The sandy silt was compact with N values of 13 and 15 blows per 0.3 metres. As shown on Figure A-2, the sandy silt is of slight plasticity based on plastic and liquid limits of 11.8

and 15.4 per cent, respectively, and a plasticity index of 3.7 per cent. The natural water content of a sample of the sandy silt was about 10 per cent.

## 4.2 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling and sampling. Groundwater was encountered at a depth of 1.4 metres or at elevation 191.1 metres in borehole 17 and at a depth of 5.0 metres or at elevation 188.6 metres in borehole 7. Borehole 6 was dry during and upon completion of drilling.

A standpipe was installed in borehole 7 to monitor the groundwater conditions. The most recent groundwater reading was obtained on December 28, 2007 where the groundwater level was measured at elevation 192.4 metres or at a depth of 1.2 metres below the ground surface.

Details of the groundwater conditions encountered and subsequently measured in the installations are provided on the Record of Borehole sheets and are summarized below.

BOREHOLE	GROUND SURFACE ELEVATION (m)	ENCOUNTERED GROUNDWATER LEVEL		INSTALLATION	MEASURED GROUNDWATER LEVEL					
		Depth (m)	Elevation (m)		Nov. 20, 2007		Nov. 28, 2007		Dec. 28, 2007	
					Depth (m)	Elevation (m)	Depth (m)	Elevation (m)	Depth (m)	Elevation (m)
6	193.63	Dry	Dry	-	-	-	-	-	-	-
7	193.63	5.03	188.60	Standpipe	7.57	186.06	1.40	192.23	1.24	192.39
17	192.48	1.37	191.11	-	-	-	-	-	-	-

The groundwater levels are expected to fluctuate seasonally and are likely to be higher during periods of sustained precipitation or spring melt.

The prevailing groundwater level has been inferred at approximately elevation 192.5 metres. The water level in the Cowan D&W Drain was measured at elevation 191.99 metres on November 20, 2007.

## **5.0 MISCELLANEOUS**

The investigation was carried out using power equipment supplied and operated by B.U.D. Environmental Services Ltd. which is an Ontario Ministry of Environment licensed well contractor and manually operated equipment owned by Golder Associates. The field operations were supervised by Mr. Mike Arthur and Mr. Dennis Verschoor under the direction of 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 of Types C and D aggregates. This report was prepared by Ms. Dirka U. Prout, P. Eng. under the direction of the Project Manager, Mr. Philip R. Bedell, P. Eng. This report was reviewed by Mr. Fintan J. Heffernan, P. Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

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## **PART B**

### **FOUNDATION DESIGN REPORT**

**STRUCTURAL CULVERT, STATION 17+709**

**SITE 6-457-C, COWAN D&W DRAIN**

**HIGHWAY 77 REHABILITATION**

**GWP 139-98-00, AGREEMENT NO. 3006-E-0013**

**MINISTRY OF TRANSPORTATION - SOUTHWESTERN 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 proposed partial replacement of the structural culvert situated in the project area on Highway 77 at Station 17+709 (Site 6-457-C). The existing culvert consists of a 2.74 metre span non-rigid frame open footing (NRFO) culvert with a length of 45.7 metres and height of 1.22 metres.

Highway 77 is to be rehabilitated between Highway 3 in Leamington and Essex County Road 8 in Staples. The scope of work includes improvements to drainage structures including the widening and partial replacement of the existing Cowan D&W Drain culvert. The western 8.8 metres of the existing NRFO culvert is to remain in place. The remaining section of culvert will be removed and replaced with 17 precast box culvert units to form a 2.74 x 1.50 x 39.40 metre section. The existing retaining wall will be removed.

It should be noted that the interpretation and recommendations provided in the report 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.

### **6.2 Foundations**

The subsoils encountered in the boreholes advanced during the investigation typically consist of surficial asphalt and granular road base in the shoulder areas and topsoil near the drain over clayey fill overlying firm to very stiff clayey silt interlayered with compact silty fine sand, sand and sandy silt. The groundwater level was estimated to be at about elevation 192.5 metres. The water level in the Cowan D&W Drain was at elevation 192.0 metres on November 20, 2007.

The replacement culvert sections should be designed to withstand the appropriate weight of fill and traffic loading. Footing excavations should penetrate all existing fill and topsoil so that foundations bear directly on the native soils. Based on the soil conditions found at the boreholes locations and the culvert invert at approximately elevation 191.8 metres, the culvert can be placed on a bedding layer overlying the native clayey silt at about elevation 190.8 metres or lower.

For analysis of the pre-cast box sections bearing on a bedding layer placed on the native clayey silt, the recommended factored geotechnical resistance at Ultimate Limit States (ULS) and the geotechnical resistance at Serviceability Limit States (SLS) are 250 kilopascals and 175

kilopascals, respectively, assuming a maximum allowable settlement of 25 millimetres and a 3.2 metre width for design of the culvert. An unfactored coefficient of sliding of 0.5 may be used for design.

### **6.2.1 Frost Protection**

Frost treatment in the form of a frost taper symmetrical about the culvert centreline must be provided in accordance with OPSD 803.010. If the frost penetration depth of 1.2 metres results in a frost penetration line above the culvert bottom slab, then the frost taper should extend to the depth of the underside of the levelling pad.

### **6.3 Bedding**

Bedding is to be placed on a properly prepared subgrade from which all frozen, soft, uncompacted fill, organic materials or other deleterious materials have been removed. Bedding should consist of at least 150 millimetres of 19 millimetre clear stone placed in accordance with SP422S01 and any over excavation required for the removal of existing fill or footings should be backfilled with clear stone.

### **6.4 Backfill**

Backfill and cover around the culvert should be carried out in accordance with Ontario Provincial Standard Drawing (OPSD) 803.010 and SP422S01. Culvert backfill material should consist of free-draining, non-frost susceptible granular materials such as Ontario Provincial Standard Specifications (OPSS) Granular A or Granular B, Type I.

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. Adequate erosion protection as recommended in Section 6.6 should be provided at the outlet.

### **6.5 Lateral Earth Pressures for Design**

The lateral pressures acting on the proposed culvert sections will depend on the backfill soils and, where used, the type and method of placement of the backfill materials behind the wall, as well as the subsequent lateral movement of the structure. The following recommendations are made concerning the design of the culvert walls in accordance with the Canadian Highway Bridge Design Code (CHBDC).

Backfill behind the culvert walls should consist of select, free-draining granular fill meeting the specifications of OPSS Granular A or Granular B, Type I but with less than 5 per cent passing the No. 200 sieve.

Where backfill soils are placed and compacted behind the walls, a compaction surcharge equal to 12 kilopascals should be included in the lateral earth pressures for structural design in accordance with the CHBDC. Compaction equipment should be used in accordance with SP 105S10.

For walls backfilled using granular materials as noted above, the following parameters (unfactored) may be assumed:

	<u>Granular A</u>	<u>Granular B Type I</u>
Fill unit weight:	22 kN/m <sup>3</sup>	20kN/m <sup>3</sup>
Coefficients of lateral earth pressure:		
‘active’ or unrestrained, $K_a$	0.27	0.31
‘at rest’ or restrained, $K_o$	0.43	0.47

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 zone greater than 1.2 metres wide 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. If the culvert wall support does not allow lateral yielding (restrained structure), at-rest pressures should be assumed for geotechnical design. The granular fill should be placed in a zone with a width equal to at least 1.2 metres behind the culvert walls.

The resistance to sliding, for a precast concrete box culvert, may be based on an unfactored angle of friction of 28 degrees between the stiff to very stiff clayey silt and concrete. The factored horizontal geotechnical resistance,  $H_{ri}$ , should be based on CHBDC 6.7.5 as follows:

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

Where:

$A'$	-	effective contact area, square metres
$c'$	=	0
$\delta$	=	28 degrees
$V$	-	unfactored vertical force, kilonewtons
$H_f$	-	factored horizontal load, kilonewtons

The unfactored coefficient of passive pressure for the portion of the culvert wall and footing below the invert may be taken as 3.0 based on an unfactored effective angle of internal friction,  $\phi'$ , of 30 degrees.



## **6.6 Construction Considerations**

The cleaned excavation base should be inspected by qualified geotechnical personnel prior to placing the bedding. It is recommended that the excavation be carried out such that the final 0.5 metres of excavation is completed with the geotechnical personnel on site and the bedding placed immediately after footing inspection.

Inlet seals and filters are not considered necessary as the potential for uplift and piping is low. However, cutoff walls are required at the ends of the box culvert in accordance with the CHBDC. The provision of camber for the culvert is not required since the height of the overlying fill is minimal and the stiff to very stiff foundation soils are such that excessive post-construction or differential settlements are not anticipated.

Erosion and scour protection for the culvert backfill should be provided, as appropriate. 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 outlet should be provided in accordance with OPSD 810.010. In addition, sediment control such as silt fences and erosion control blankets may be required during construction and diversion of the watercourse to mitigate migration of fine soil particles.

Subgrade preparation should be performed and monitored in accordance with SP902S01.

## **6.7 Excavations and Temporary Cut Slopes**

Excavations for the replacement culvert will encounter surficial topsoil and fills and the firm to very stiff clayey silt.

Temporary open cut slopes should be maintained no steeper than 1 horizontal to 1 vertical. Excavations will extend below the inferred groundwater level at elevation 192.5 metres. Minimal groundwater flow is expected from the clayey silt. If necessary, groundwater can be controlled by pumping from properly filtered sumps situated in the excavation floor.

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

All excavations should be carried out in accordance with the current edition of the Ontario Occupational Health and Safety Act and Regulations For Construction Projects. The fill materials at this site would be classified as Type 3 soils. The native clayey silt soils would be classified as Type 2 or 3 soils depending on consistency. The compact silty fine sand, sandy silt and sand are considered Type 3 soils.

The design drawings indicate that the partial removal of the existing culvert and construction of the replacement culvert for Structure 6-457-C will be done in two stages. In stage 1, all traffic will be diverted onto the northbound lane with one lane in each direction. The western portion of the culvert will be removed from 8.8 metres beyond the inlet, replaced and the roadway reinstated. Once that operation is completed, the traffic will be switched onto the new southbound lane and the processes repeated on the east side. Mersea Township Road 8 will be closed west of Highway 77 during Stage 1, and closed east of Highway 77 during Stage 2. Temporary traffic protection system(s) will be required at the centreline of Highway 77 and sheet piling will also be needed to allow construction of the new culvert.

The temporary support system could consist of soldier piles and lagging where the H-piles would be driven to a suitable depth and horizontal lagging installed as the excavation proceeds. Support to the soldier pile and lagging wall system could be in the form of struts and walers in the case of footing excavations or rakers and anchors in the case of roadway protection excavations. Alternatively, sheet piling could be used.

The design of braced soldier pile and lagging walls should be based on a rectangular earth pressure distribution using the design parameters given below. 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.

In the cohesive soils, the unfactored triangular earth pressure distribution ( $p$  in  $\text{kN/m}^2$ ; 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
$K_a$	=	0.33 for level ground behind excavation
$\gamma$	=	soil unit weight = $20 \text{ kN/m}^3$
$q$	=	surcharge loads

In granular soils, such as backfill to the existing culvert, the unfactored rectangular earth pressure distribution ( $p$  in  $\text{kN/m}^2$ ; constant with depth), can be calculated as follows:

$$p = 0.65K_a (\gamma' H + q)$$

where  $H$  = the height of the excavation  
 $K_a$  = 0.3 for level ground behind excavation  
 $\gamma$  = soil unit weight =  $21 \text{ kN/m}^3$   
 $\gamma'$  =  $\gamma - \gamma_w$  where  $\gamma_w = 9.8 \text{ kN/m}^3$   
 $q$  = surcharge loads

Passive toe restraint to the soldier piles may be determined using a triangular pressure distribution acting over an equivalent width equal to three times the pile socket diameter. The coefficient of passive lateral earth pressure,  $K_p$ , for the socket may be taken as 3.0 for the clayey silt or silty fine sand, sandy silt and sand. The soil unit weight should be taken as  $20 \text{ kN/m}^3$  for the clayey silt and  $21 \text{ kN/m}^3$  for the granular soils, and the unit weight of water should be taken as  $9.8 \text{ kN/m}^3$ . A groundwater level at ground surface should be assumed for design.

The temporary excavation support system should be designed and constructed in accordance with MTO's Special Provision 105S19. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in SP 105S19.

## **7.0 MISCELLANEOUS**

This report was prepared by Ms. Dirka U. Prout, P.Eng. under the direction of the Project Manager, Mr. Philip R. Bedell, P. Eng. This report was reviewed by Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

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TP/DUP/PRB/FJH/cr  
n:\active\2006\1130 - geotechnical\1130-200\06-1130-202 philips - fdns gwp 139-98-00 - hwy 77\reports\(-4) 17+709\feb 1 08 - (final) parts a&b fdn inv & dsgn rpt - st 17+709  
cowan d&w drain.doc

## LIST OF ABBREVIATIONS

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

### I. SAMPLE TYPE

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

### III. SOIL DESCRIPTION

#### (a) Cohesionless Soils

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

### II. PENETRATION RESISTANCE

#### Standard Penetration Resistance (SPT), N:

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

#### Consistency

	<u>kPa</u>	<u>psf</u>
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

#### (b) Cohesive Soils

#### Dynamic Cone Penetration Resistance; $N_d$ :

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

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

**WH:** Sampler advanced by static weight of hammer

**WR:** Sampler advanced by weight of sampler and rod

#### Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm<sup>2</sup> 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 <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
$D_R$	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)
$\gamma$	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

$\pi$	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

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\epsilon$	linear strain
$\epsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	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
$\gamma'$	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
$\sigma'_p$	pre-consolidation pressure
OCR	over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$

#### (d) Shear Strength

$\tau_p, \tau_r$	peak and residual shear strength
$\phi'$	effective angle of internal friction
$\delta$	angle of interface friction
$\mu$	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  $\rho$ . Unit weight symbol is  $\gamma$  where  $\gamma = \rho g$  (i.e. mass density x acceleration due to gravity)

**RECORD OF BOREHOLE No 6**

1 OF 1

**METRIC**

PROJECT 06-1130-202-0-4

G.W.P. 139-98-00

LOCATION N 4664753.8 ;E 296936.9

ORIGINATED BY MA

DIST HWY 77

BOREHOLE TYPE POWER AUGER (SOLID STEM)

COMPILED BY LMK

DATUM GEODETIC

DATE November 20, 2007

CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE						
193.63	GROUND SURFACE						20 40 60 80 100								
0.00	ASPHALT														
0.12	FILL, sand and gravel, trace silt (crushed)														
0.37	FILL, silty sand, trace gravel Brown														
0.50	FILL, clayey silt, trace sand, trace gravel Firm		1	SS	7										
192.26	Grey and brown CLAYEY SILT, trace sand, trace gravel Firm to very stiff Brown becoming grey at about elev. 190.6m		2	SS	7										
1.37			3	SS	18										
			4	SS	25										
			5	SS	14										
			6	SS	11										
			7	SS	9										
			8	SS	8										
			9	SS	9										
			10	SS	9										
184.79	END OF BOREHOLE														
8.84	Borehole dry during drilling on November 20, 2007.														

**RECORD OF BOREHOLE No 7**

1 OF 1

**METRIC**

PROJECT 06-1130-202-0-4

G.W.P. 139-98-00

LOCATION N 4664762.8 ;E 296966.2

ORIGINATED BY MA

DIST HWY 77

BOREHOLE TYPE POWER AUGER (SOLID STEM)

COMPILED BY LMK

DATUM GEODETIC

DATE November 20, 2007

CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W <sub>p</sub> W W <sub>L</sub>				
193.63 0.00	GROUND SURFACE FILL, sand and gravel, some silt (crushed)						20 40 60 80 100										
0.40	FILL, sand fine to medium, trace silt FILL, clayey silt, trace sand, gravel, topsoil Firm Grey and brown		1	SS	6		193										
192.26 1.37	CLAYEY SILT, trace sand, trace gravel Very stiff Brown becoming grey at about elev. 190.6m		2	SS	16		192										
			3	SS	20		191										
190.46 3.17 190.13	SILTY FINE SAND Compact Brown		4	SS	24		190									1 55 31 13	
3.50	SANDY SILT, trace to some clay, trace gravel Compact Grey		5	SS	13	189											
			6	SS	15	188										5 45 39 11	
188.45 5.18	CLAYEY SILT, trace sand, trace gravel Stiff Grey		7	SS	13		187										
			8	SS	10												
			9	SS	12												
			10	SS	12												
185.55 8.08	END OF BOREHOLE																
	Groundwater encountered at about elev. 188.6m during drilling on November 20, 2007.  Water level measured at elev. 186.1m immediately after installation on November 20, 2007.  Water level measured at elev. 192.23m on November 28, 2007.  Water level measured at elev. 192.35m on December 11, 2007.  Water level measured at elev. 192.39m on December 28, 2007.																

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



**RECORD OF BOREHOLE No 17**

1 OF 1

**METRIC**

PROJECT 06-1130-202-0-4

G.W.P. 139-98-00

LOCATION N 4664761.9 ; E 296914.3

ORIGINATED BY DV

DIST HWY 77

BOREHOLE TYPE MANUAL DRILLING

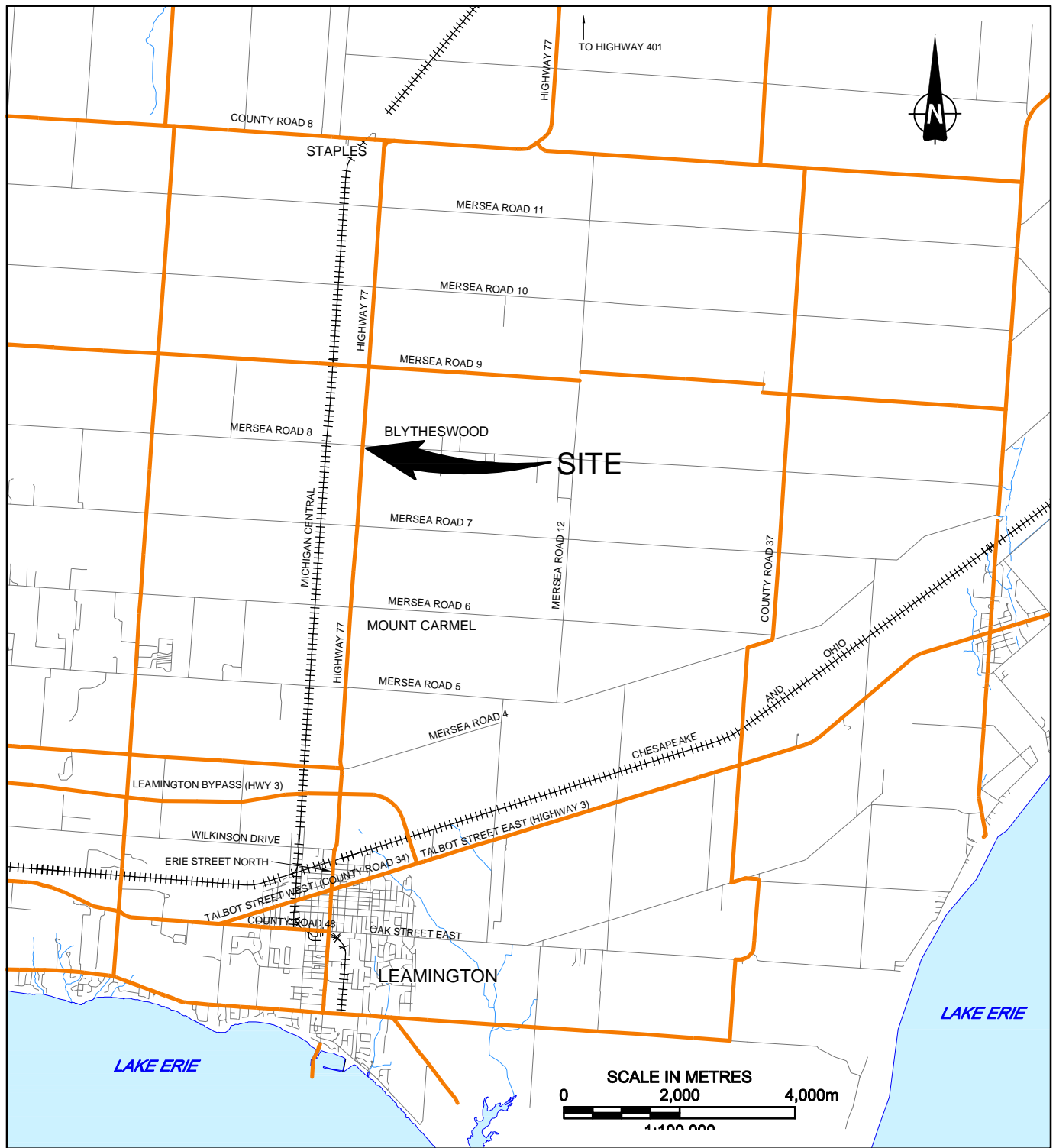
COMPILED BY LMK

DATUM GEODETIC

DATE November 22, 2007

CHECKED BY

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			SHEAR STRENGTH kPa		W <sub>p</sub>	W	W <sub>L</sub>		WATER CONTENT (%)					GR
192.48	GROUND SURFACE					▽	192	20   40   60   80   100		20   10   20   30									
0.00	TOPSOIL, silty Brown							○ UNCONFINED   + FIELD VANE											
0.13	FILL, clayey silt, trace sand, gravel, topsoil Soft Brown and grey		1	SS	3			● QUICK TRIAXIAL   × LAB VANE											
190.35			2	SS	3														
2.13	SAND, fine to medium, trace silt Compact Brown					190								0   94   2   4					
189.58			3	SS	24														
2.90	CLAYEY SILT, trace sand, trace gravel Hard Brown																		
3.05	END OF BOREHOLE																		
	Groundwater encountered at about elev. 191.1m during drilling on November 22, 2007.																		



## REFERENCE

DRAWING BASED ON CANMAP STREETFILES V2005.4.

## NOTES

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

ALL LOCATIONS ARE APPROXIMATE.

PROJECT

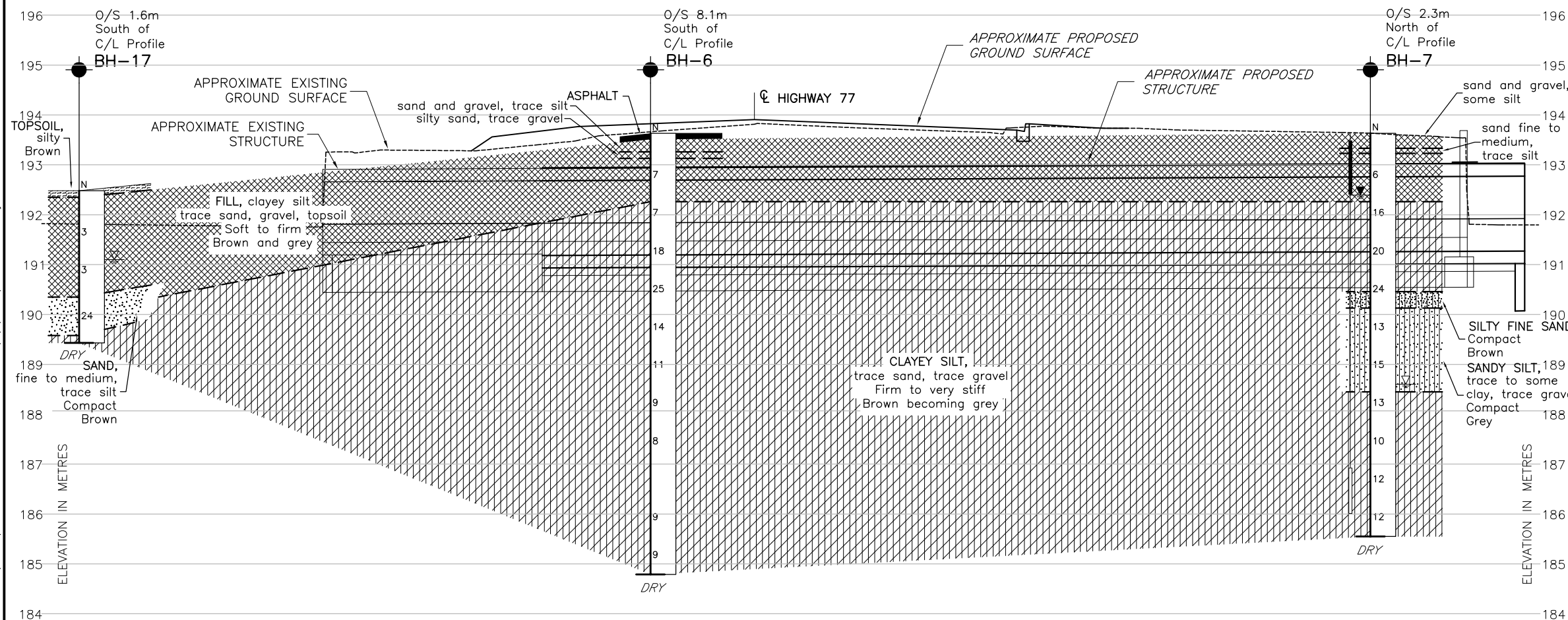
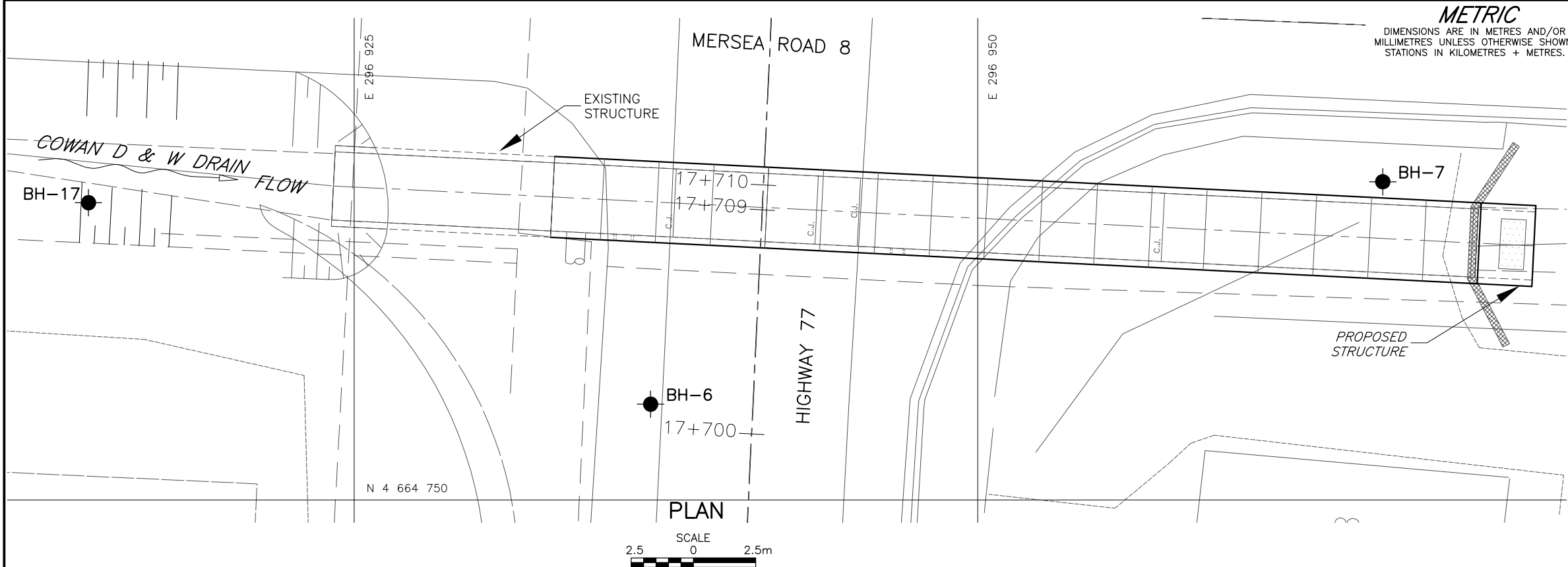
**STRUCTURAL CULVERT 17+709  
HIGHWAY 77 REHABILITATION  
GWP 139-98-00**

TITLE

**KEY PLAN**



PROJECT No. 06-1130-202			FILE No. 0611302020-4-F01001	
CADD	DCH	Dec. 19/07	SCALE	AS SHOWN
CHECK				REV.
			<b>FIGURE 1</b>	



PROFILE ALONG C/L OF CULVERT AT STA. 17+709

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

CONT No.  
WP No. 139-98-00

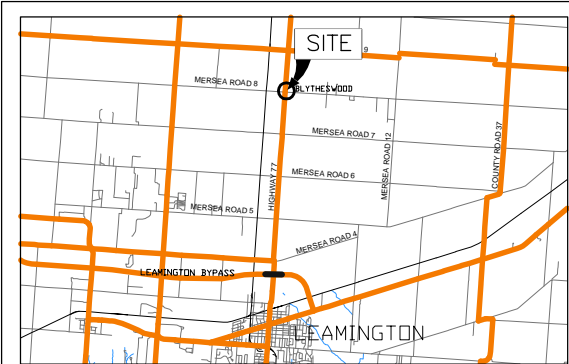


HIGHWAY 77 REHABILITATION  
STRUCTURAL CULVERT 17+709  
CULVERT WIDENING  
BOREHOLE LOCATION AND SOIL STRATA

SHEET



**Golder Associates Ltd.**  
LONDON, ONTARIO, CANADA



KEY PLAN

SCALE  
2000 0 2000m

LEGEND

- Borehole - Current Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL in piezometer, measured on December 28, 2007
- WL encountered during drilling

No.	ELEVATION	CO-ORDINATES (MTM Zone 11)	
		NORTHING	EASTING
6	193.63	4 664 753.8	296 936.9
7	193.63	4 664 762.8	296 966.2
17	192.48	4 664 761.9	296 914.3

NOTES

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

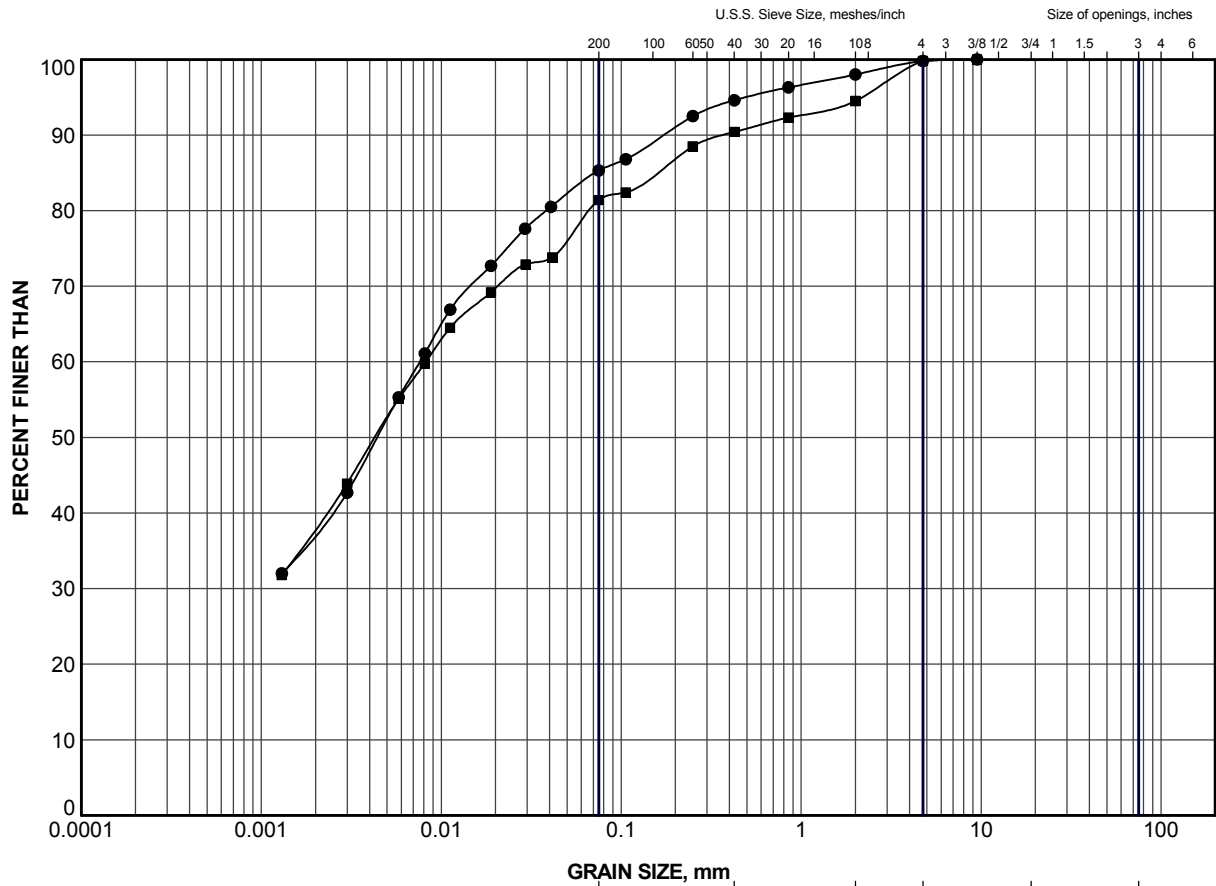
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

REFERENCE

Preliminary base plans provided in digital format by Dillon.


NO.	DATE	BY	REVISION
Geocres No. 40J2-106			
HWY.	77	PROJECT NO.	06-1130-202-0-4
SUBM'D.	DUP	CHKD.	DUP
DRAWN:	DCH	CHKD.	DUP
DATE:	Dec. 18/07	DIST.	6-457C
APPD.		DWG.	1

**APPENDIX A**  
**LABORATORY TEST DATA**

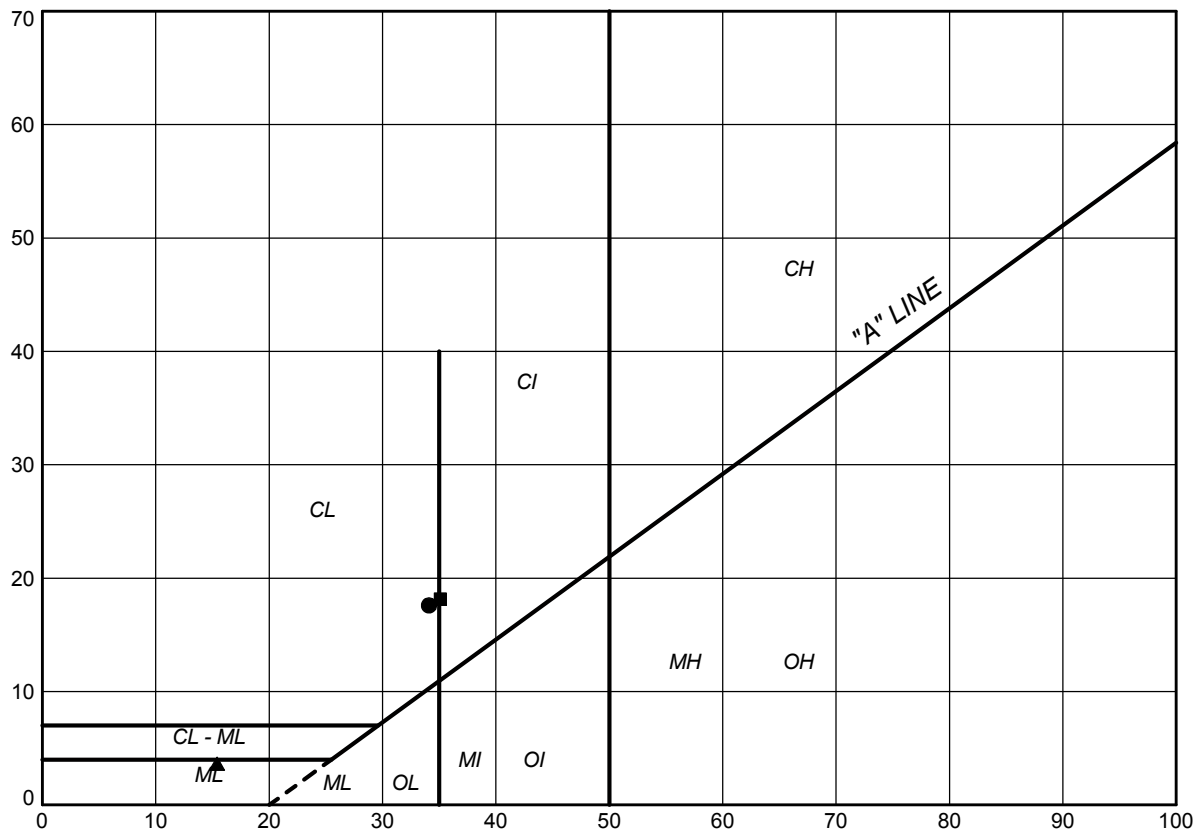


### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	6	5	189.6
■	6	7	188.1

PROJECT		STRUCTURAL CULVERT 17+709 HIGHWAY 77 REHABILITATION GWP 139-98-00			
TITLE		GRAIN SIZE DISTRIBUTION CLAYEY SILT			
 <b>Golder Associates</b> LONDON, ONTARIO		PROJECT No. 06-1130-202-0-4		FILE No. 0611302020-4-F010A1	
		SCALE N/A		REV.	
		DRAWN LMK	Dec 19/07		
CHECK					
		<b>FIGURE A-1</b>			

PLASTICITY INDEX (Percent)



LIQUID LIMIT (Percent)

SOIL TYPE  
C = Clay  
M = Silt  
O = Organic

PLASTICITY  
L = Low  
I = Intermediate  
H = High

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	6	5	34.1	16.5	17.6
■	6	7	35.1	17.0	18.2
▲	7	6	15.4	11.8	3.7


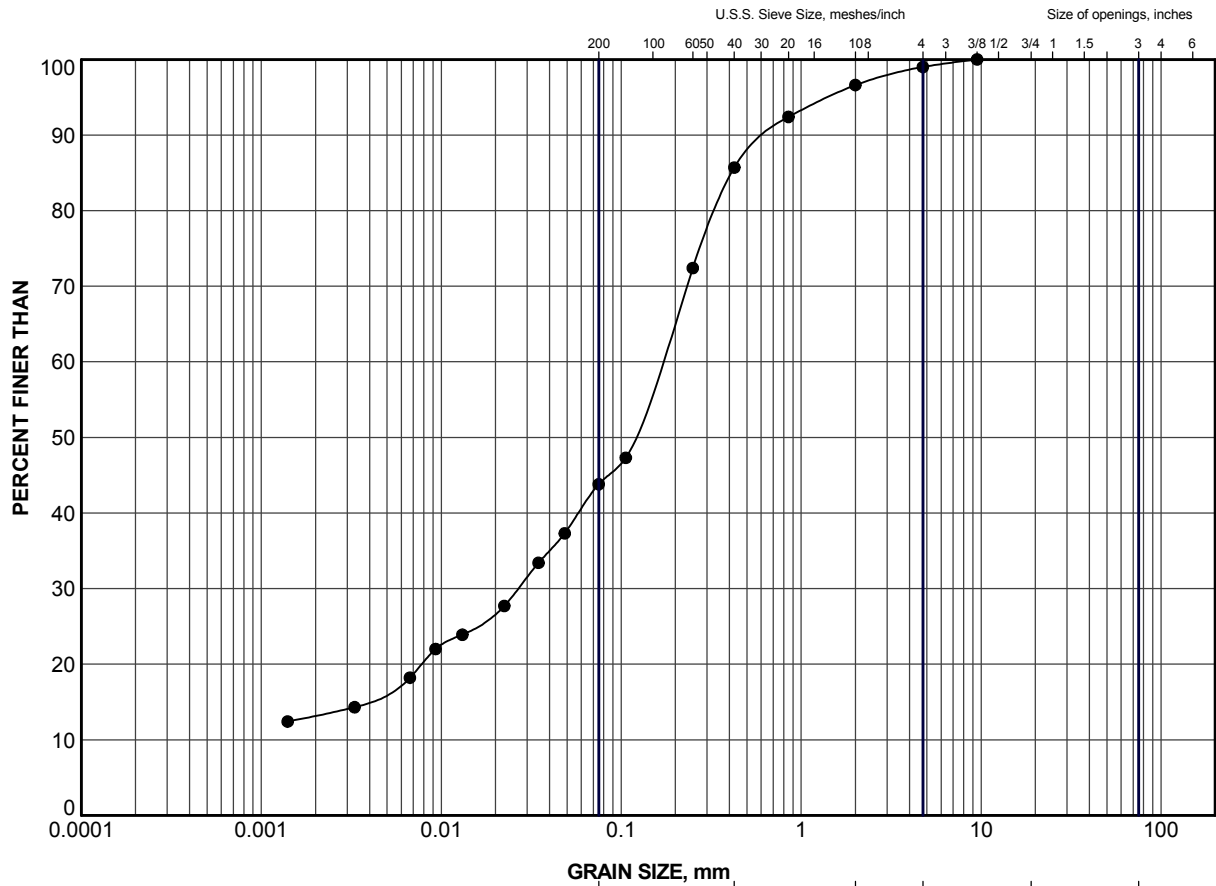
PROJECT	STRUCTURAL CULVERT 17+709 HIGHWAY 77 REHABILITATION GWP 139-98-00				
TITLE	PLASTICITY CHART				
 <b>Golder Associates</b> LONDON, ONTARIO	PROJECT No.	06-1130-202-0-4	FILE No.	0611302020-4-F010A2	
	DRAWN	LMK	Dec 19/07	SCALE	N/A
	CHECK			REV.	

FIGURE A-2



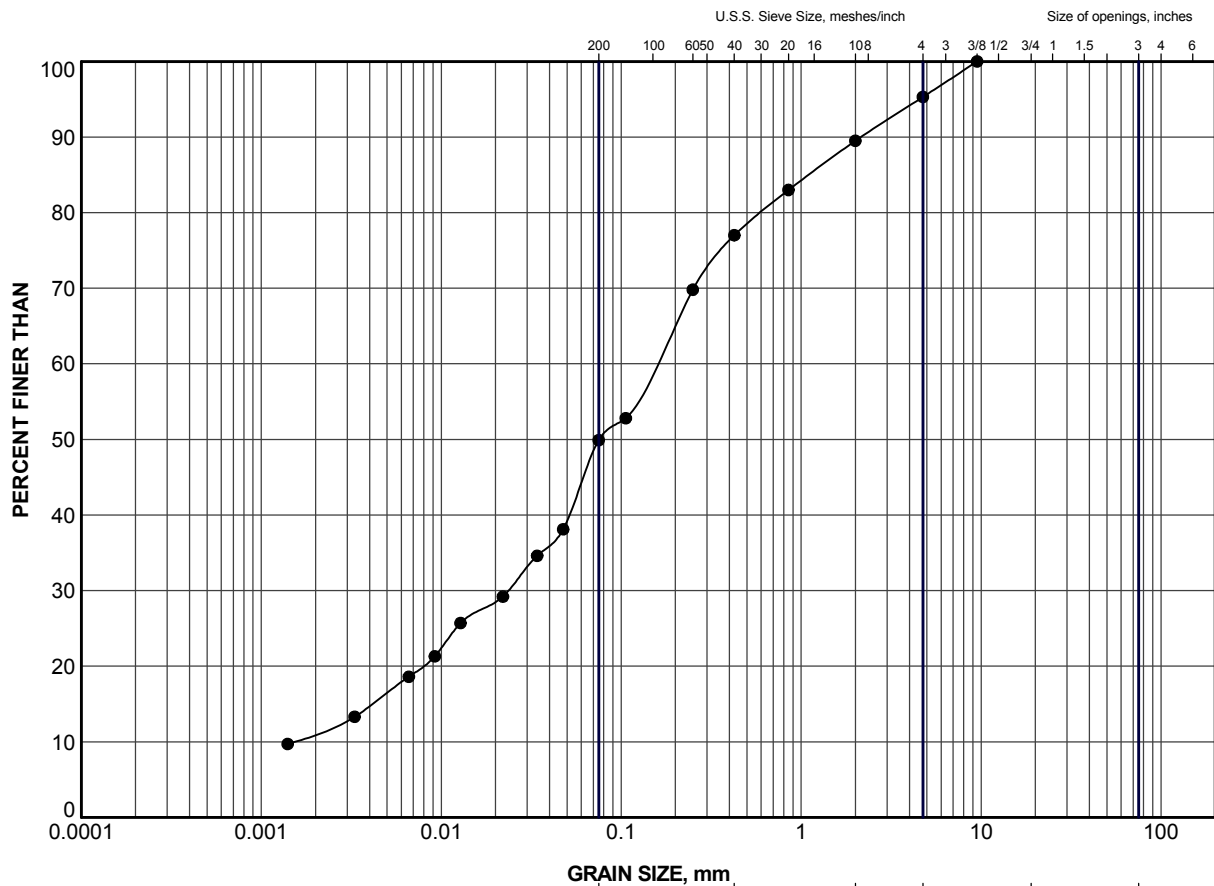
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	7	4	190.3

PROJECT		STRUCTURAL CULVERT 17+709 HIGHWAY 77 REHABILITATION GWP 139-98-00			
TITLE		GRAIN SIZE DISTRIBUTION SILTY FINE SAND			
PROJECT No. 06-1130-202-0-4		FILE No. 0611302020-4-F010A3			
DRAWN LMK		Jan 8/08		SCALE N/A	REV.
CHECK				FIGURE A-3	





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

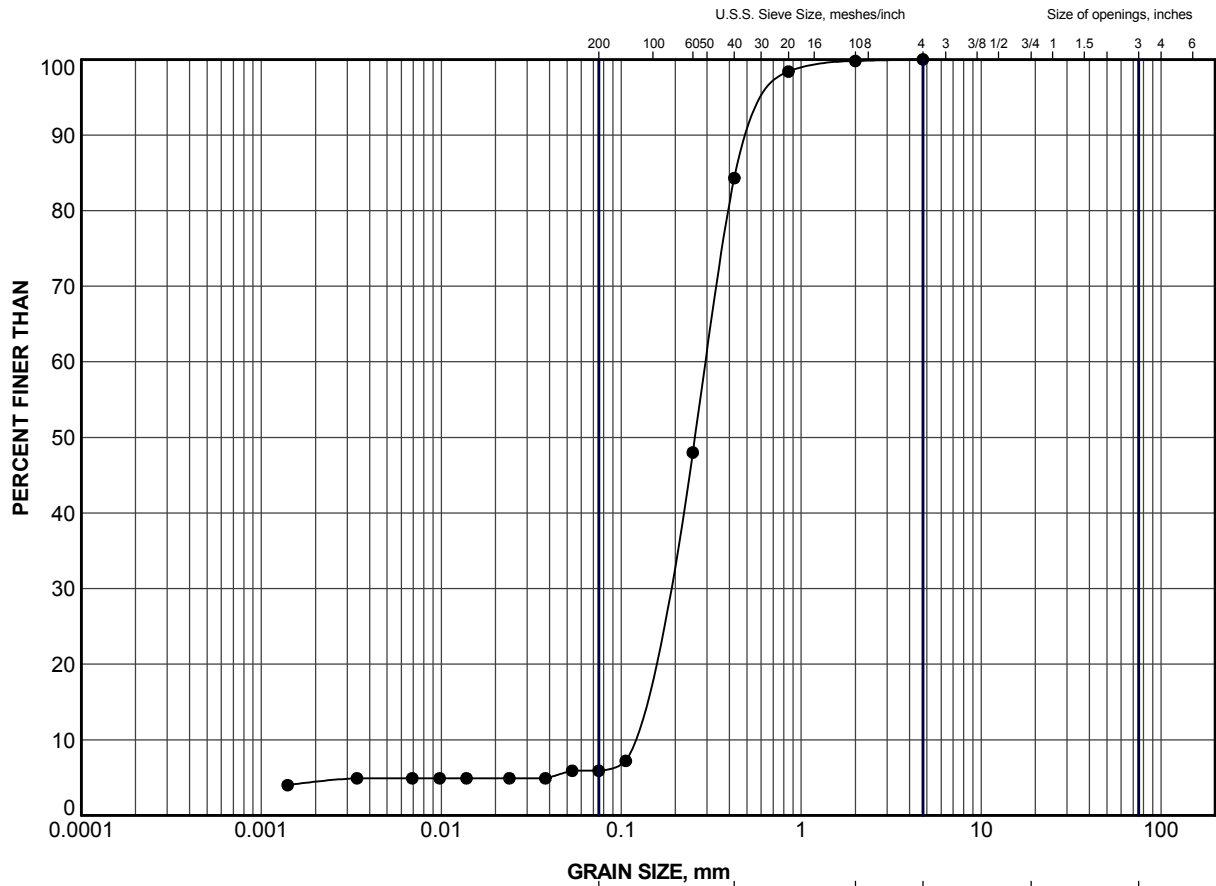
**LEGEND**

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	7	6	188.8

PROJECT				STRUCTURAL CULVERT 17+709 HIGHWAY 77 REHABILITATION GWP 139-98-00			
TITLE				GRAIN SIZE DISTRIBUTION SANDY SILT			
PROJECT No.		06-1130-202-0-4		FILE No.		0611302020-4-F010A4	
DRAWN		LMK		Dec 19/07		SCALE N/A REV.	
CHECK						FIGURE A-4	








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

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	17	3	189.8

PROJECT		STRUCTURAL CULVERT 17+709 HIGHWAY 77 REHABILITATION GWP 139-98-00	
TITLE		GRAIN SIZE DISTRIBUTION SAND	
 <b>Golder Associates</b> LONDON, ONTARIO	PROJECT No.	06-1130-202-0-4	FILE No. 0611302020-4-F010A5
	DRAWN	LMK	Jan 8/08
	CHECK		
		SCALE	N/A
		REV.	
		<b>FIGURE A-5</b>	

LDN\_MTO\_NEW\_GLDR\_LDN.GDT

**APPENDIX B**

**SITE PHOTOGRAPHS**

## SITE PHOTOGRAPHS



Photo 1: Station 17+809, inlet (west end) of Cowan D&W Drain. Looking west along Mersea Township Road 8.



Photo 2: Looking east along Mersea Township Road 8 at intersection with Highway 77 in B1.

**Golder Associates**