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**FOUNDATION INVESTIGATION AND DESIGN REPORT  
STRUCTURAL CULVERT STA. 13+389  
SITE 6-455-C, BEACOM DRAIN  
HIGHWAY 77 REHABILITATION  
GWP 139-98-00, AGREEMENT NO. 3006-E-0013  
MINISTRY OF TRANSPORTATION - SOUTHWESTERN REGION**

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

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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 northerly to Staples, approximately 11.7 kilometres. The southern project limit is Highway 3 in Leamington and the northern project limit is 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;
- Improvement 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 rehabilitation and extension of the structural culvert located on Highway 77 at Station 13+389 (Site 6-455-C). According to the General Arrangement drawing, the culvert will be extended 1.4 metres at the east end, concrete retaining walls will be added at each end to replace the existing gabion walls and erosion protection will be added to the east end where scour of the bank is occurring.

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 and 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 entirely 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. In the project area, Highway 77 is a two lane undivided rural highway with lane widths of 3.6 to 3.75 metres. The shoulders are fully paved within the Town of Blytheswood and between Highway 3 (Essex County Road 33) and Mersea Township Road 6.

Culvert Site 6-455-C is located at Station 13+389 on Highway 77 and approximately 120 metres south of Mersea Township Road 5. This culvert conveys the flows from the Beacom Drain from west to east under Highway 77. The location of this site is shown on the Key Plan, Figure 1, and site photographs are provided in Appendix B.

Scour was noted on the east bank of the Beacom Drain culvert where the channel turns approximately at a right angle. Beacom Drain is tributary to Hillman Creek. The eroded area is visible in Photo 1 in Appendix B. The land use in the vicinity of the site is primarily residential. The adjacent topography is generally flat to gently undulating with a ground surface elevation near 195 metres.

### 2.1 Site Geology

The site is situated on a sand plain within 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.

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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.

The available surficial geology mapping for the project area indicates that the predominant surficial soil is clayey silt till.<sup>2</sup> The overburden thickness within the project area ranges from 13 to 26 metres.<sup>3</sup> Immediately underlying the overburden is a medium brown limestone belonging to the Dundee Formation of the Hamilton group.

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<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.

<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 carried out on November 20 and 21, 2007 at which time four boreholes, numbered 8, 9, 13 and 14, were drilled in the area of the proposed culvert extension and retaining walls. Boreholes 8 and 9 were advanced to depths of 9.6 metres and boreholes 13 and 14 to depths of 3.1 metres.

Boreholes 8 and 9 were advanced using a truck-mounted B57 power auger supplied and operated by a specialist drilling contractor. Samples of the overburden were obtained at intervals of 0.75 metres up to a depth of 7.6 metres then at 1.5 metre intervals below this depth using 50 millimetre outside diameter split spoon sampling equipment in accordance with the standard penetration test (SPT) procedures. Boreholes 13 and 14 were drilled by staff from Golder Associates using manual drilling equipment. The SPT testing in the manually drilled holes was conducted using a non-standard hammer with a weight of 31 kilograms. The SPT N values shown on these Records of Boreholes have been adjusted to be more representative of 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 9 to monitor the groundwater level at this location. The boreholes were backfilled in accordance with current regulations, MTO recommended procedures and Ontario Regulation 128/03.

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)
8	4 660 466.0	296 706.9	191.96	9.60
9	4 660 499.1	296 717.2	191.92	9.60
13	4 660 439.3	296 723.0	190.01	3.05
14	4 660 447.4	296 702.7	189.88	3.05

The existing culvert has the following characteristics:

<u>DIMENSIONS (m)</u>	<u>TOP ELEVATION (m)</u>		<u>CONSTRUCTION</u>
	(Lt)	(Rt)	
2.44 x 1.52 x 17.07	190.94	191.01	Rigid Frame Open Footings (RFO)



## **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 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 roadbase overlying thin layers of sandy fill in the shoulder areas and topsoil near the ditches. Layers of clayey fill were found beneath the topsoil and pavement. The fill was underlain by silty clay and clayey silt deposits.

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**

Boreholes 8 and 9 were drilled in the shoulders of Highway 77. Asphalt layers 80 and 90 millimetres thick were present at the ground surface in boreholes 8 and 9, respectively. From approximately elevation 191.9 metres, the asphalt was underlain by a 0.2 metre thick layer of granular road base material.

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

Topsoil layers 80 and 130 millimetres thick were encountered at the ground surface in boreholes 13 and 14, respectively.

Granular fill materials were found at approximately elevation 191.7 metres beneath the granular road base in boreholes 8 and 9. The upper granular fill layer was 0.2 metres thick and consisted of sand. In borehole 8, the upper sand fill was underlain from elevation 191.6 metres by 1.7 metres of sandy silt fill with trace amounts of topsoil. The sandy silt fill was compact with N values of 11 and 19 blows per 0.3 metres. At elevation 189.8 metres, a lower sand fill layer was encountered beneath the sandy silt fill in borehole 8. The lower sand fill was very loose with an N value of 2 blows per 0.3 metres and a water content of 14 per cent. The results of grain size testing of a sample of the lower sand fill are presented on Figure A-1 in Appendix A.

Clayey silt fill was encountered beneath the sandy fill from elevation 191.3 metres in borehole 9 and below the topsoil in boreholes 13 and 14 from about elevation 189.9 metres. The clayey silt fill layers were 1.1 and 1.7 metres thick. The clayey silt fill is soft to stiff with N values ranging from 2 to 14 blows per 0.3 metres. Water contents in the range of 20 to 34 per cent were measured in the clayey silt fill.

A musty odour was noted in the fills below elevation 191.6 metres in borehole 8 and below elevation 191.3 in borehole 9 suggesting that some organic materials may have been incorporated into these fills.

#### **4.1.3 Silty Clay**

Silty clay was encountered from approximately elevation 189.1 metres beneath the granular fill at borehole 8.

The silty clay was stiff to very stiff with N values ranging from 12 blows to 15 blows per 0.3 metres. A water content of 19 per cent was measured in the silty clay. The silty clay is of intermediate plasticity based on plastic and liquid limits of 20 and 37 per cent, respectively, and a plasticity index of 17 per cent. The results of the Atterberg limits testing are shown on the Plasticity Chart, Figure A-4.

The results of a particle size analysis conducted on a sample of the silty clay obtained from the standard penetration testing are shown on Figure A-2.

#### **4.1.4 Clayey Silt**

Clayey silt was found beneath the silty clay from elevation 186.8 metres in borehole 8 and below the fill from elevations 188.1 to 189.8 metres in boreholes 9, 13 and 14. All four boreholes were terminated in the clayey silt.

The clayey silt was firm to very stiff with N values ranging from 5 to 26 blows per 0.3 metres. The water content of the clayey silt varied between 14 and 16 per cent. The clayey silt is of low plasticity based on average plastic and liquid limits of 15 and 28 per cent, respectively, and an average plasticity index of 13 per cent. The results of the Atterberg limits determinations are shown on Figure A-4.

The results of grain size analyses conducted on samples of clayey silt are shown on Figure A-3.

## 4.2 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling and sampling. Groundwater was encountered at a depth of 2.6 metres or at elevation 189.3 metres in borehole 8. This is likely groundwater which is perched in the granular fill which overlies the native cohesive deposits. Groundwater was also encountered at elevation 188.1 metres in borehole 14. Boreholes 9 and 13 were dry during and upon completion of drilling.

A standpipe was installed in borehole 9 to monitor the groundwater conditions. The most recent groundwater reading was obtained on December 11, 2007 where the groundwater level was measured at elevation 190.7 metres or at a depth of 1.3 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		MEASURED GROUNDWATER LEVEL					
		Depth (m)	Elevation (m)	Nov. 20, 2007		Nov. 28, 2007		Dec. 11, 2007	
				Depth (m)	Elevation (m)	Depth (m)	Elevation (m)	Depth (m)	Elevation (m)
8	191.96	2.62	189.34	-	-	-	-	-	-
9	191.92	Dry	Dry	7.49	184.43	3.02	188.90	1.25	190.67
13	190.01	Dry	Dry	-	-	-	-	-	-
14	189.89	1.83	188.06	-	-	-	-	-	-

Based on the encountered and measured groundwater level measurements, the long term groundwater level in the clayey silt and silty clay is inferred to be near elevation 190.7 metres.

The water level in the Beacom Drain was at elevation 189.65 metres on November 20, 2007.

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

## **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 STA. 13+389**  
**SITE 6-455-C, BEACOM DRAIN**  
**HIGHWAY 77 REHABILITATION**  
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## **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 rehabilitation and extension of the structural culvert situated in the project area on Highway 77 at Station 13+389 (Site 6-455-C). The existing culvert consists of a 2.44 x 1.52 x 17.07 metre rigid frame open footing (RFO) concrete culvert.

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 upgrading of the Beacom Drain culvert with a 1.4 metre extension at the east end, increasing the height of the header walls by 400 millimetres, replacement of the existing gabion baskets at the inlet and outlet with new concrete retaining walls and placement of a rip-rap treatment at the outlet to guard against scour. The design drawings indicate that the footings for the proposed extension and retaining walls will be placed at the same elevation as the footings for the existing culvert. The new retaining wall on the west end will have openings for 600 millimetre and 825 millimetre diameter storm sewers.

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.

### **6.2 Foundations**

The subsoils encountered in the boreholes advanced during the investigation typically consist of topsoil and surficial fills over stiff silty clay and firm to very stiff clayey silt. The groundwater level was estimated to be at about elevation 191 metres. The water level in the Beacom Drain was measured at elevation 189.7 metres on November 20, 2007.

The culvert extension 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 borehole locations and the culvert invert at approximately elevation 188.0 metres, the culvert can be founded on spread footings at or below elevation 188 metres in the stiff to very stiff silty clay and stiff to very stiff clayey silt.

For footings bearing directly on the native silty clay or clayey silt, the recommended factored geotechnical resistance at Ultimate Limit States (ULS) and the geotechnical resistance at

Serviceability Limit States (SLS) are 300 kilopascals and 200 kilopascals, respectively, assuming a maximum allowable settlement of 25 millimetres and a 0.75 metre wide footing for design of the foundations. For design, unfactored coefficients of sliding of 0.53 may be used for the clayey silt and 0.45 for the silty clay.

### **6.2.1 Frost Protection**

All footings should be provided with a minimum of 1.2 metres of earth cover or thermal equivalent for frost protection purposes.

## **6.3 Backfill**

Backfill around the culvert should be carried out in accordance with Ontario Provincial Standard Drawing (OPSD) 803.010. 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 III.

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 6.5 should be provided at the outlet.

## **6.4 Lateral Earth Pressures for Design**

The lateral pressures acting on the proposed culvert extension and retaining walls 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 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> 22 kN/m <sup>3</sup>	<u>Granular B Type III</u> 21kN/m <sup>3</sup>
Fill unit weight:		
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 cast-in-place concrete culvert with a concrete working slab may be based on an unfactored angle of friction between the native soil and concrete interface of 24 degrees for the stiff to very stiff silty clay and 28 degrees for the stiff to very stiff clayey silt. 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
$\delta'$	=	24 degrees – silty clay 28 degrees – clayey silt
$V$	-	unfactored vertical force, kilonewtons
$H_f$	-	factored horizontal load, kilonewtons

The following values may be used for the unfactored coefficient of passive pressure,  $K_p$ , for the portion of the culvert wall and footing below the invert:

<u>Soil Type</u>	<u>Effective Angle of Internal Friction</u> (°)	<u><math>K_p</math></u>
Silty Clay	26	2.6
Clayey Silt	30	3.0



## **6.5 Construction Considerations**

The founding soils are sensitive to disturbance and softening due to water seepage and/or ponding. Since a cast-in-place culvert is to be constructed, placement of a working slab of lean concrete will be required at the base of the culvert excavations for the footing area. Exposure without protection of the working slab will result in softening of the founding soils. The cleaned excavation base should be inspected by qualified geotechnical personnel prior to placing the working slab. It is recommended that the footing excavation be carried out such that the final 0.5 metres of excavation is completed with the geotechnical personnel on site and the working slab placed immediately after footing inspection.

Inlet seals, outlet cutoffs and filters are not considered necessary as the potential for uplift and piping is low. The provision of camber for the culvert extension 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.

## **6.6 Excavations and Temporary Cut Slopes**

Excavations for the culvert extension and new retaining walls will encounter surficial topsoil and fills and the stiff to very stiff silty clay and stiff to very stiff clayey silt. The considerations with respect to protection of the founding soils, as given in Section 6.5 under the heading Construction Considerations, must be recognized.

The excavations will extend below the inferred groundwater elevation of approximately 191 metres. Perched groundwater is to be expected in the granular fill which overlies the native cohesive soils. When necessary, groundwater can be controlled by pumping from properly filtered sumps located in the base of the excavation. Sumps should be maintained outside of the actual footing limits. Minimal groundwater flow is expected from the silty clay and clayey silt. Temporary open cut slopes should be maintained no steeper than 1 horizontal to 1 vertical. It may be necessary to use flatter slopes or blanket cut slopes in the granular fill with coarse, free draining material in order to enhance the stability.

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.

The design drawings indicate that road construction in the vicinity of the culvert will consist of removal of the asphalt pavement from the concrete surface in the driving lanes and full depth removal in the shoulder areas. The removals and pavement reconstruction will be staged and will require no excavation beneath the pavement. However, for construction of the culvert extension and retaining walls, if space is restricted and will not permit open cuts, a temporary support system should be installed to support the sides of the excavation and permit the use of vertical cuts. 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.

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 silty clay and clayey silt materials would be classified as Type 2 or 3 soils depending on consistency.

## **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.

### **GOLDER ASSOCIATES LTD.**

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## LIST OF ABBREVIATIONS

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

### I. SAMPLE TYPE

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

### III. SOIL DESCRIPTION

#### (a) Cohesionless Soils

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

### II. PENETRATION RESISTANCE

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

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) 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 <sub>4</sub>	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 8**

1 OF 1

**METRIC**

PROJECT 06-1130-202-0-2  
G.W.P. 139-98-00 LOCATION N 4660446.0 ; E 296706.9 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									
								○ UNCONFINED + FIELD VANE									
								● QUICK TRIAXIAL × LAB VANE									
								WATER CONTENT (%)									
191.96		GROUND SURFACE						20	40	60	80	100					
0.08		ASPHALT															
0.24		FILL, sand and gravel (crushed)															
0.40		Brown															
		FILL, sand, trace gravel															
		Brown															
		FILL, sandy silt, some gravel, trace															
		topsoil															
		Compact															
189.83																	
2.13		FILL, sand fine to medium, some silt,															
		trace gravel, musty odour															
		Very loose															
		Brown															
189.06																	
2.90		SILTY CLAY, some sand, trace															
		gravel															
		Stiff															
		Grey															
	</																

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○<sup>3%</sup> STRAIN AT FAILURE

**RECORD OF BOREHOLE No 13**

1 OF 1

**METRIC**

PROJECT 06-1130-202-0-2  
G.W.P. 139-98-00 LOCATION N 4660439.3 ; E 296723.0 ORIGINATED BY DV  
DIST HWY 77 BOREHOLE TYPE MANUAL DRILLING COMPILED BY LMK  
DATUM GEODETIC DATE November 21, 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      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE												
190.01	GROUND SURFACE							20	40	60	80	100								
0.08	TOPSOIL, silty Brown						189													
188.80	FILL, clayey silt, trace sand, trace gravel Stiff Grey		1	SS	9															
1.21	CLAYEY SILT, some sand, trace gravel Very stiff Brown becoming grey at about elev. 188.0m		2	SS	26															
							188													
			3	SS	17		187													
186.96																				
3.05	END OF BOREHOLE																			
	Borehole dry during drilling on November 21, 2007.																			



**RECORD OF BOREHOLE No 14**

1 OF 1

**METRIC**

PROJECT 06-1130-202-0-2  
G.W.P. 139-98-00 LOCATION N 4660447.4 ; E 296702.7 ORIGINATED BY DV  
DIST HWY 77 BOREHOLE TYPE MANUAL DRILLING COMPILED BY LMK  
DATUM GEODETIC DATE November 21, 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									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
189.88	GROUND SURFACE						20	40	60	80	100						
0.00	TOPSOIL, silty Brown																
0.13	FILL, clayey silt, trace sand, trace topsoil Soft to stiff Grey and brown		1	SS	2												
188.05			2	SS	14												
1.83	CLAYEY SILT, some sand, trace gravel Very stiff Brown becoming grey at about elev. 187.8m																
186.83			3	SS	24												
3.05	END OF BOREHOLE																
	Groundwater encountered at about elev. 188.1m during drilling on November 21, 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

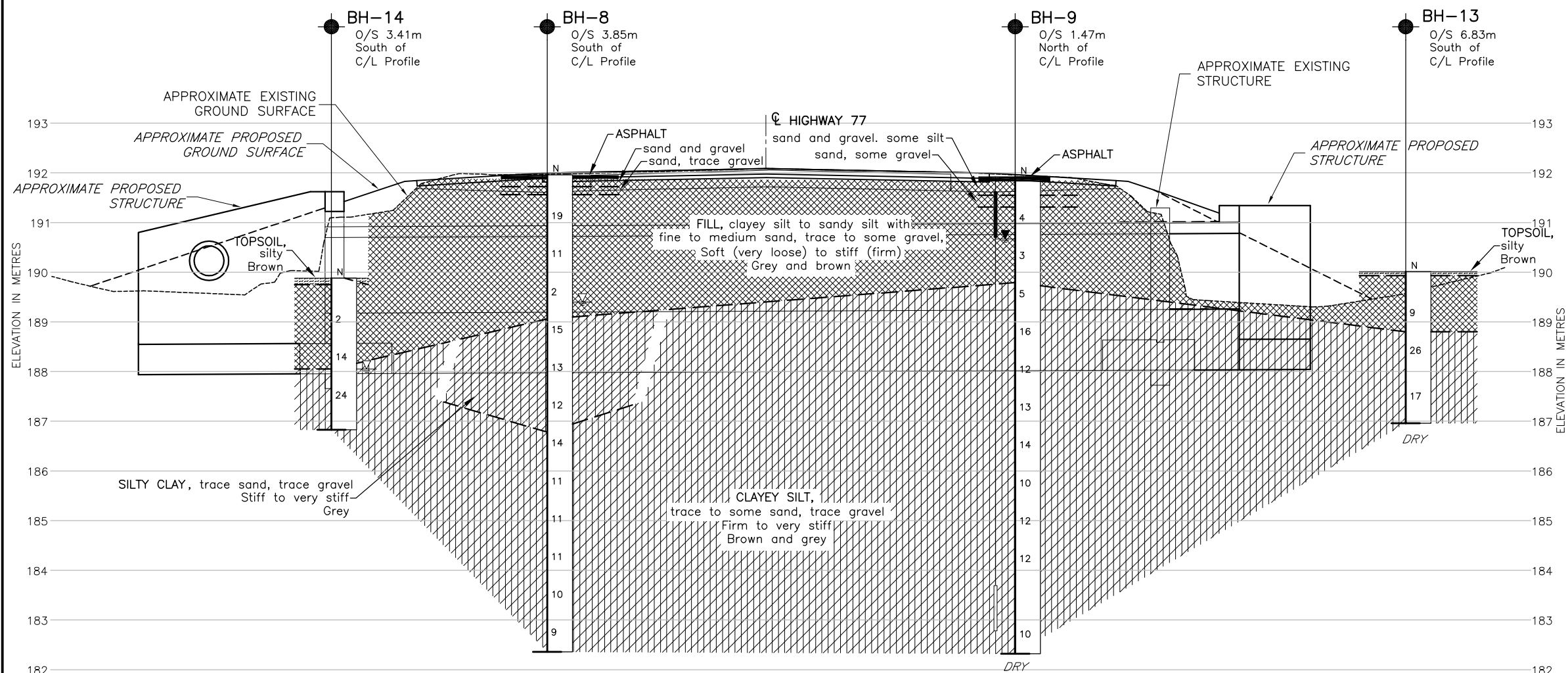
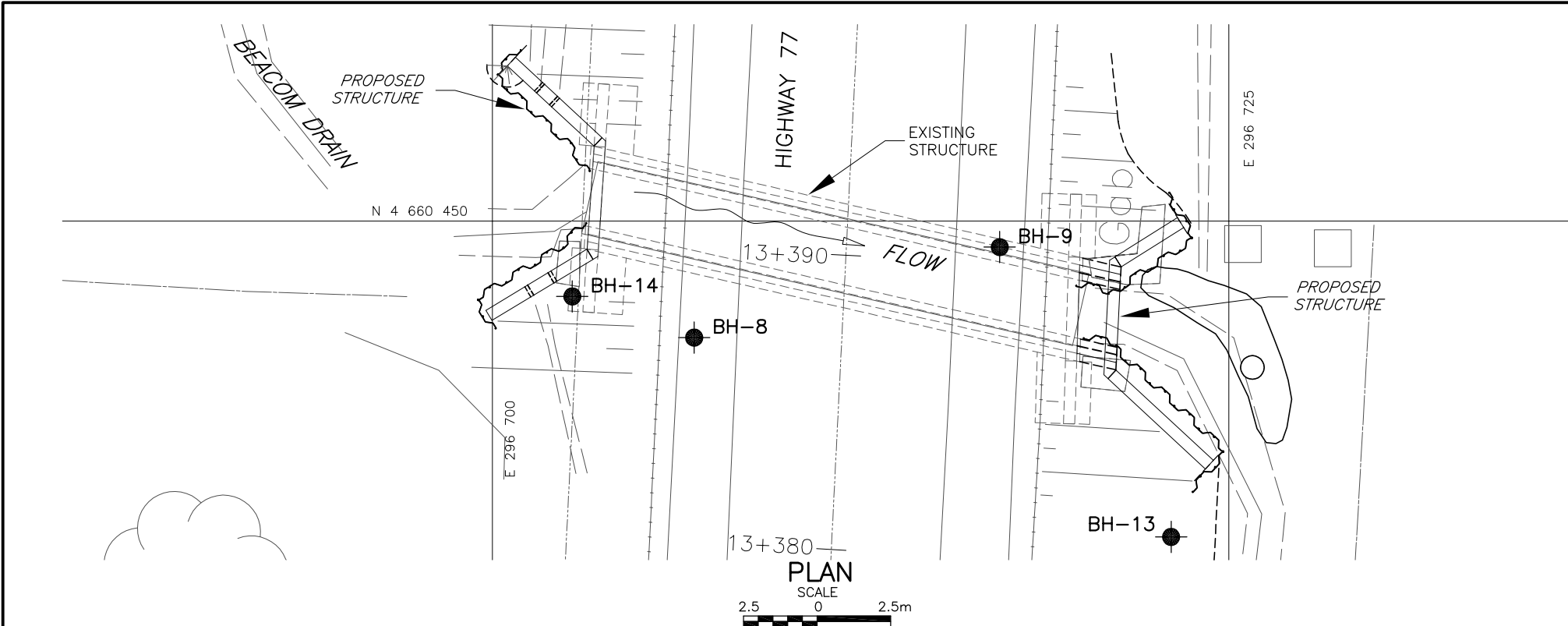
**STRUCTURAL CULVERT 13+389  
HIGHWAY 77 REHABILITATION  
GWP 139-98-00**

TITLE

**KEY PLAN**



PROJECT No. 06-1130-202			FILE No. 0611302020-2-F01001	
CADD	DCH	Jan. 2/07	SCALE	AS SHOWN
CHECK			REV.	
<b>FIGURE 1</b>				



PROFILE ALONG C/L OF CULVERT AT STA. 13+389



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

CONT No.  
WP No. 139-98-00

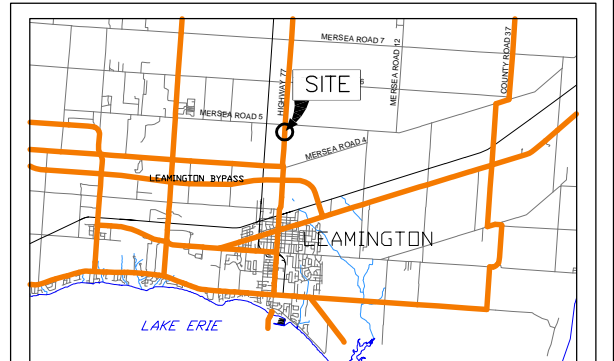


SHEET

HIGHWAY 77 REHABILITATION  
 STRUCTURAL CULVERT 13+389  
 CULVERT EXTENSION  
 BOREHOLE LOCATION AND SOIL STRATA








**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<br>(Std. Pen. Test, 475 j/blow) |
|  | WL in piezometer, measured<br>on December 11, 2007                 |
|  | WL encountered during drilling                                     |

No.	ELEVATION	CO—ORDINATES (MTM Zone 11)			
		NORTHING		EASTING	
8	191.96	4 660	446.0	296	706.9
9	191.92	4 660	449.1	296	717.2
13	190.01	4 660	439.3	296	723.0
14	189.88	4 660	447.4	296	702.7

---

NOTES

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

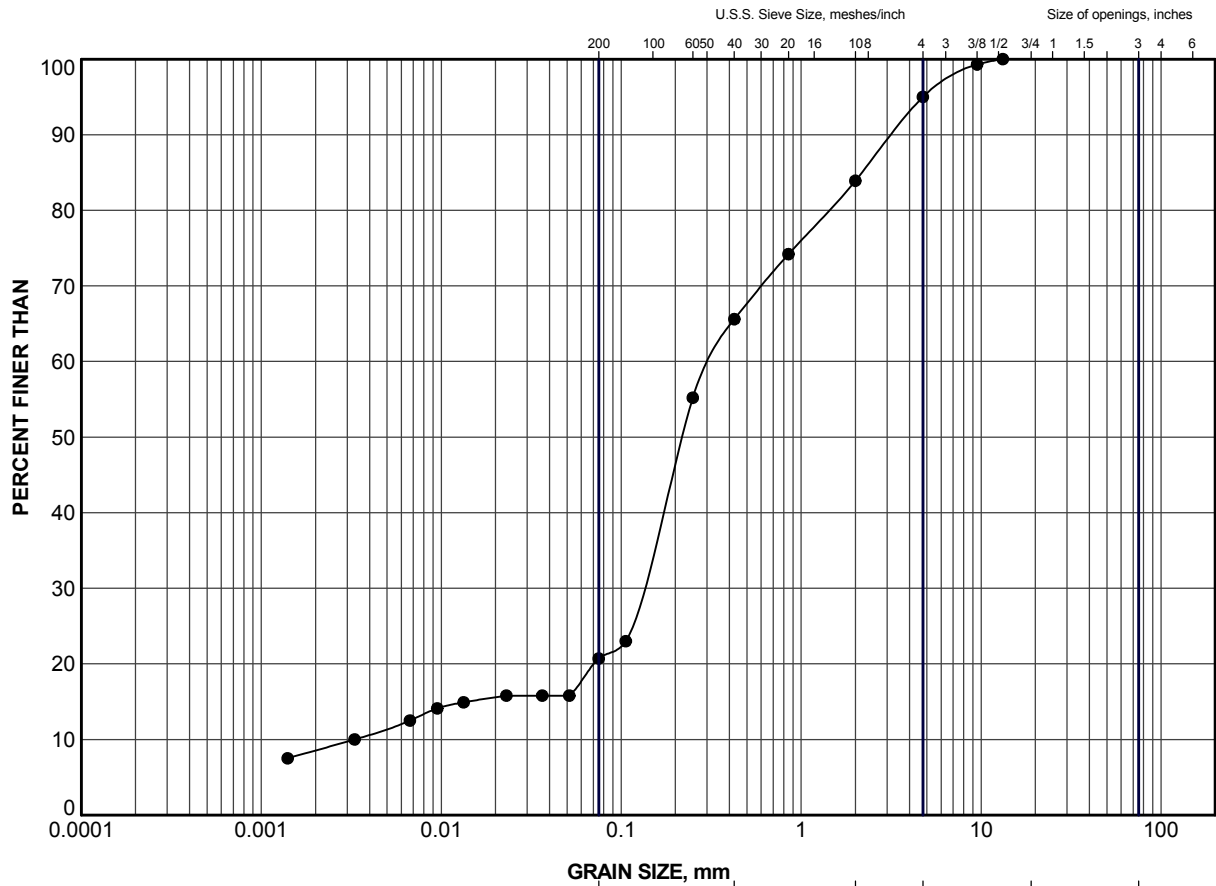
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

## REFERENCE

Preliminary base plans provided in digital format by Dillon.

NO.		DATE		BY	
Geocres No.		40J2-105			
HWY.		77		PROJECT NO. 06-1130-202-0-2	
SUBM'D.		DUP		CHKD.	
DRAWN:		DCH		CHKD.	
		APPD.		DWG.	
				1	
				SITE: 6-455-C	
				DATE: Jan. 30/08	

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



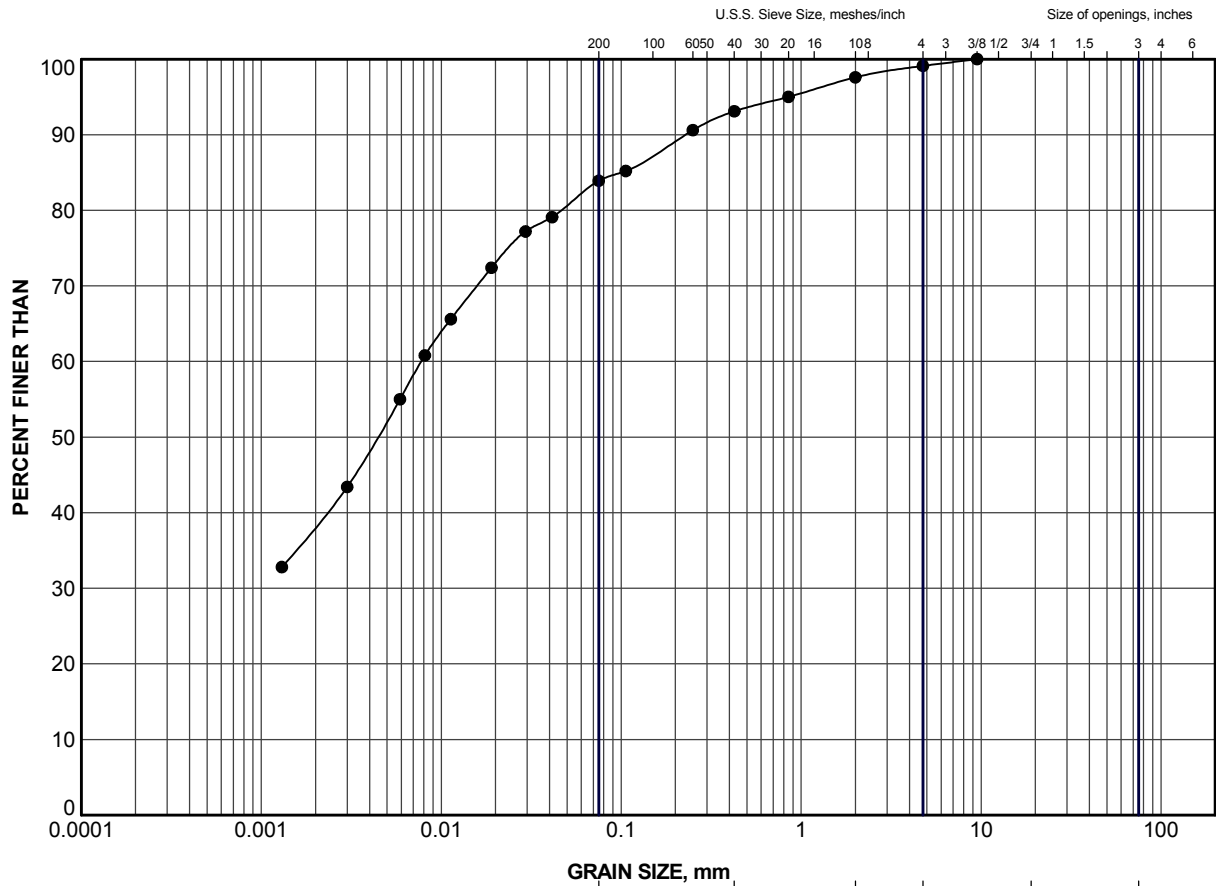
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	8	3	189.4

PROJECT				STRUCTURAL CULVERT 13+389 HIGHWAY 77 REHABILITATION GWP 139-98-00			
TITLE				GRAIN SIZE DISTRIBUTION FILL (sand)			
PROJECT No.		06-1130-202-0-2		FILE No.		0611302020-2-F010A1	
DRAWN		LMK		Dec 14/07		SCALE N/A REV.	
CHECK						FIGURE A-1	




LDN\_MTO\_NEW\_GLDR\_LDNGDT

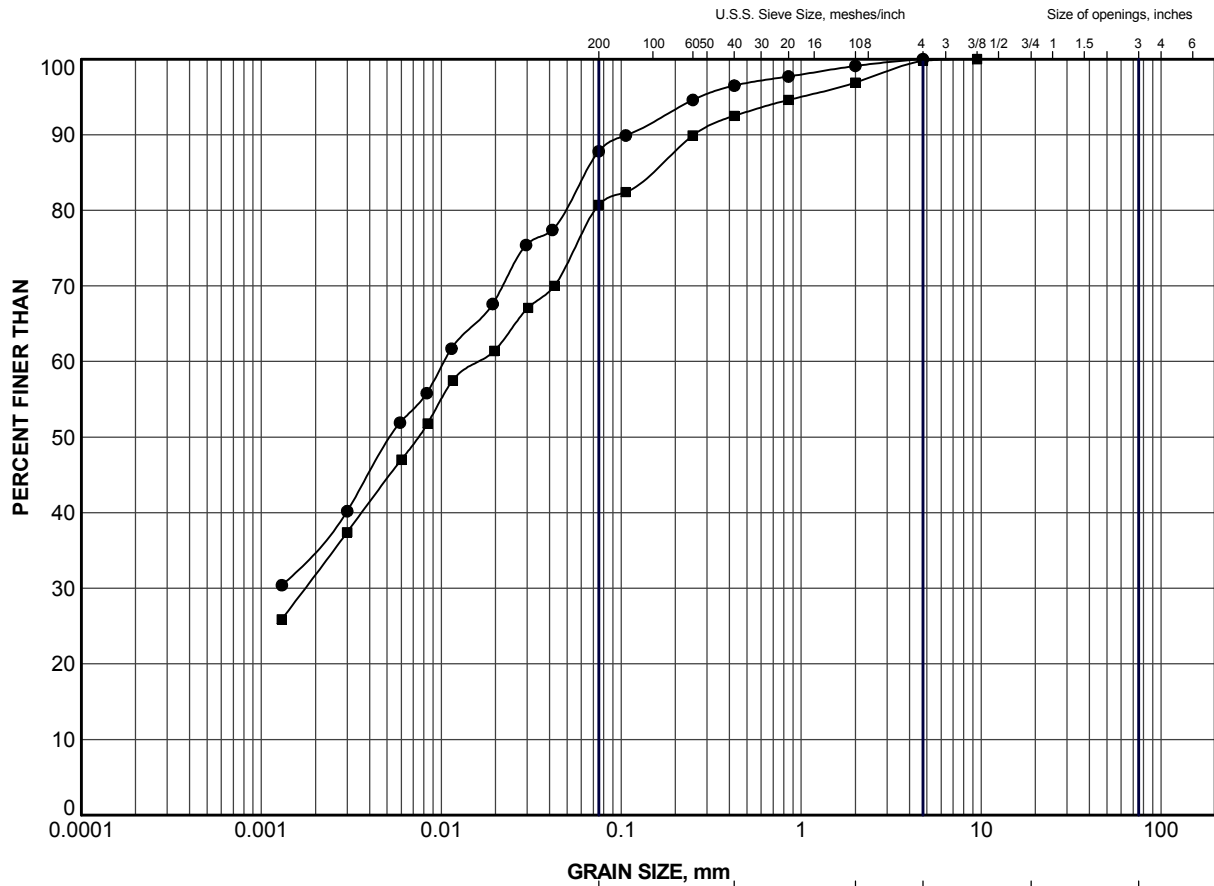


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	10	6	186.3

PROJECT				STRUCTURAL CULVERT 12+574 HIGHWAY 77 REHABILITATION GWP 139-98-00			
TITLE				GRAIN SIZE DISTRIBUTION SILTY CLAY			
 <b>Golder Associates</b> LONDON, ONTARIO		PROJECT No. 06-1130-202-0-1		FILE No. 0611302020-1-F010A2			
		SCALE N/A		REV.			
		DRAWN LMK	Dec 07/07		<b>FIGURE A-2</b>		
		CHECK					


LDN\_MTO\_NEW\_GLDR\_LDN.GDT

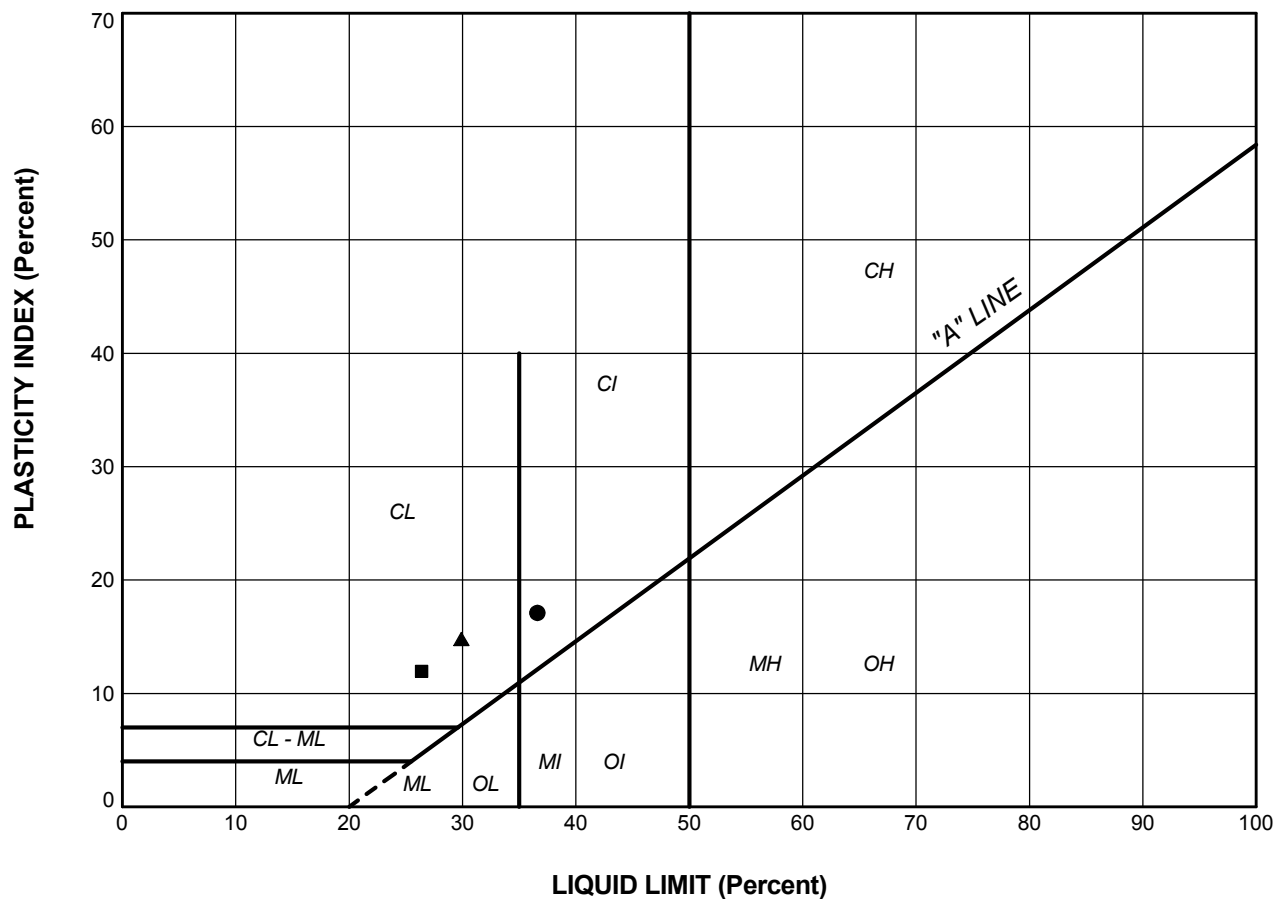


CLAY AND SILT	SAND SIZE, mm			GRAVEL SIZE, mm		Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

#### LEGEND


SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	8	7	186.4
■	9	6	187.1

PROJECT				STRUCTURAL CULVERT 13+389 HIGHWAY 77 REHABILITATION GWP 139-98-00			
TITLE				GRAIN SIZE DISTRIBUTION CLAYEY SILT			
PROJECT No.		06-1130-202-0-2		FILE No.		0611302020-2-F010A3	
DRAWN		LMK		Dec 07/07		SCALE N/A REV.	
CHECK						FIGURE A-3	
 <b>Golder Associates</b> LONDON, ONTARIO							



### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
<b>CLAYEY SILT</b>					
■	8	7	26.4	14.5	12.0
▲	9	6	29.9	15.1	14.8
<b>SILTY CLAY</b>					
●	8	5	36.6	19.5	17.1

PROJECT		STRUCTURAL CULVERT 13+389 HIGHWAY 77 REHABILITATION GWP 139-98-00	
TITLE		PLASTICITY CHART	
PROJECT No. 06-1130-202-0-2		FILE No. 0611302020-2-F010A4	
DRAWN	LMK	Dec 07/07	SCALE N/A
CHECK			REV.
 <b>Golder Associates</b> LONDON, ONTARIO			<b>FIGURE A-4</b>



**APPENDIX B**  
**SITE PHOTOGRAPHS**

**SITE PHOTOGRAPHS**



Photo 1: Station 13+389 Rt, Beacom Drain Culvert, East Side. View to the south.



Photo 2: Station 13+389 Rt, Beacom Drain Culvert, East Side. Looking west at outlet.

**Golder Associates**