



November 2011

## FOUNDATION INVESTIGATION AND DESIGN REPORT

**Culvert Site 25-332/C**

**Station 20+023, Geographic Township of Blanshard**

**Highway 23 Structure Replacements**

**From Union Line/Perth Line 10 To Perth Line 42**

**GWP 3043-06-00, Purchase Order No. 3009-E-0020**

**Ministry of Transportation, Ontario - West Region**

**Submitted to:**

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REPORT



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LIST OF ABBREVIATIONS

LIST OF SYMBOLS

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Laboratory Test Data

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

**CULVERT SITE 25-332/C  
STATION 20+023, GEOGRAPHIC TOWNSHIP OF BLANSHARD  
HIGHWAY 23 STRUCTURE REPLACEMENTS  
FROM UNION LINE/PERTH LINE 10 TO PERTH LINE 42  
GWP 3043-06-00, PURCHASE ORDER NO. 3009-E-0020  
MINISTRY OF TRANSPORTATION, ONTARIO - WEST REGION**



## **1.0 INTRODUCTION**

Golder Associates Ltd. (Golder Associates) has been retained by Delcan Corporation (Delcan) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out the foundation investigations as part of the detail design work for GWP 3043-06-00, the replacement of the Highway 23 structures within the project limits.

This report was prepared for the replacement of the structural culvert for Fish Creek (Site Number 25-332/C) at Station 20+023, Highway 23 in the Geographic Township of Blanshard.

The purpose of the foundation investigation is to determine the subsurface conditions at the location of the proposed structure replacement by drilling boreholes and carrying out in situ testing and laboratory testing on selected samples. The terms of reference for the scope of work are outlined in the MTO's Request for Proposal and in Golder Associates' proposal P0-1132-0029 dated March 19, 2010 and our letter dated January 2011. The work was carried out in accordance with our Quality Control Plan for Foundations Engineering dated June 2010.

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



## **2.0 SITE DESCRIPTION**

### **2.1 General**

Culvert Site 25-332/C is situated on Highway 23 at the intersection with Union Line/Perth Line 10 in the Geographic Township of Blanshard, Ontario. The location of the site is shown on the Key Plan, Figure 1.

The culvert at Site 25-332/C is an L-shaped, concrete, non-rigid frame, open footing (NRFO) culvert 4.27 metres wide, 1.52 metres high and 53.30 metres long. The original date of construction is not known. Each end of the culvert was extended by 6.1 metres in 1950. Two triangular openings have been installed at the approximately right angled bend to receive flow from the Roger Drain which flows west along the north side of Perth Line 10 and the ditch north of the intersection on the east side of Highway 23.

The approximate culvert invert elevation is 307.0 metres. The culvert conveys flows from Fish Creek from west to east under Highway 23 and north to south beneath Perth Line 10. The location of the culvert is shown on the Key Plan, Figure 1, and site photographs are provided in Appendix B.

Land use in the vicinity of the site is primarily rural agricultural. The adjacent topography is of low relief and ground surface elevations in the vicinity of the culvert range from about 308 to 317 metres.

### **2.2 Site Geology**

This site lies within the physiographic region of southwestern Ontario known as the Stratford Till Plain<sup>1</sup>. The soils generally consist of silty clay with variable silt and clay contents.

Based on the Ontario Division of Mines Map 2366 entitled "Quaternary Geology, St. Mary's, Southern Ontario", the site lies in an area of primarily alluvial deposits consisting of gravel, sand and silt as well as Rannoch clayey to silty till.

The Geologic Survey of Canada Map 1263A entitled "Geology, Toronto-Windsor Area, Ontario" indicates that the subcropping bedrock in the area of site is limestone of the Dundee formation of Middle Devonian age. Based on the Ontario Division of Mines Map P.266 entitled "Bedrock Topography Series, St. Mary's Area, Southern Ontario", the bedrock surface at the site subcrops at about elevation 291 metres or some 18 metres below ground surface.

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



### 3.0 INVESTIGATION PROCEDURES

The field investigation at this site was carried out between May 31 and June 6, 2011 at which time six boreholes, numbered 201 to 206, were drilled at the locations shown on Drawing 1.

The boreholes were drilled using a power auger supplied and operated by a specialist drilling contractor. Samples of the overburden were typically obtained at depth intervals of 0.75 metres using 50 millimetre outside diameter split spoon sampling equipment in accordance with the Standard Penetration Test procedures (ASTM D1586).

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

Groundwater conditions in the boreholes were observed throughout the drilling operations and these observations are provided on the corresponding Record of Borehole sheets. The boreholes were backfilled in accordance with current regulations, MTO recommended procedures and Ontario Regulation 372/07.

The field work was supervised on a full-time basis by an experienced member of our engineering staff who arranged for underground 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's 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.

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 coordinates, ground surface elevations and depths of the boreholes.

Borehole	Location (m)		Ground Surface Elevation	Borehole Depth
	Northing	Easting	(m)	(m)
201	4 800 731	402 089	309.21	6.46
202	4 800 760	402 096	307.87	8.08
203	4 800 755	402 102	309.22	9.60
204	4 800 728	402 128	308.85	8.84
205	4 800 720	402 114	307.50	8.08
206	4 800 723	402 098	309.26	8.08



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The existing culvert has the following characteristics:

Dimensions (m)	Obvert Elevation (m)		Construction
	Lt	Rt	
4.27 x 1.52 x 53.30	308.029	308.080	Non-Rigid Frame Open

As shown on Drawing 1, the culvert has an irregular alignment.





## **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 and stratigraphic profiles 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.

The boreholes drilled at the site generally encountered topsoil or granular fill underlain by surficial layers of sand and gravel or silts underlain by sandy silt till.

The locations and elevations of the boreholes together with the interpreted stratigraphic profile are shown on Drawing 1. A detailed description of the subsurface conditions encountered in the boreholes is provided on the Record of Borehole sheets and is summarized below.

#### **4.1.1 Topsoil**

Topsoil was encountered at ground surface in boreholes 202, 204 and 205. The thickness of the topsoil varied from 200 to 460 millimetres. Materials designated as topsoil in this report were classified solely based on visual and textural evidence. Testing of organic content or for other nutrients was not carried out. Therefore, the use of materials classified as topsoil cannot be relied upon for support and growth of landscaping vegetation.

#### **4.1.2 Fill**

Boreholes 201, 203 and 206, drilled through the roadway shoulders, encountered sand and gravel fill at the ground surface. The sand and gravel fill was about 1.4 metres thick. The sand and gravel fill had N values, as determined in the standard penetration testing, of 9 to 27 blows per 0.3 metres and water contents of 3 to 6 per cent.

Fill was encountered beneath the topsoil in boreholes 202 and 204 and beneath the shoulder granulars in boreholes 201, 203 and 206. The fill was variable and consisted of silt, sandy silt, silty sand and gravel and clayey silt. The fill materials were encountered between elevations 307.7 and 308.5 metres and were 0.3 to 1.1 metres thick. The fill had N values of 4 to 6 blows per 0.3 metres and water contents of 12 to 27 per cent.

A grain size distribution curve for a sample of the fill is presented on Figure A-1.



#### **4.1.3 Clayey Silt**

In boreholes 202, 203 and 205, layers of clayey silt were encountered beneath the fill, silt and topsoil, respectively, from elevations 306.3 to 307.4 metres. The clayey silt layers ranged from 0.3 to 0.9 metres thick.

The clayey silt deposits had N values of 8 and 11 blows per 0.3 metres indicating a firm to stiff consistency. The clayey silt had a water content of 20 per cent. The clayey silt is of low plasticity based on a single Atterberg limits determination carried out on a sample obtained during standard penetration testing. The plastic limit, liquid limit and plasticity index were 18, 26 and 8 per cent, respectively. The Atterberg limits data for the clayey silt are presented on Figure A-6.

The results of the grain size testing conducted on a clayey silt sample are presented on Figure A-2.

#### **4.1.4 Sand and Gravel**

Layers of compact sand and gravel were encountered underlying the fill in borehole 201 and beneath the clayey silt in borehole 202 at elevations 307.1 and 306.5 metres, respectively. The sand and gravel layers were about 0.8 metres thick.

The sand and gravel had N values of 19 and 25 blows per 0.3 metres with a water content of 8 per cent.

A grain size distribution curve for a sample of sand and gravel recovered from the standard penetration testing is presented on Figure A-3.

#### **4.1.5 Silt**

Layers of loose silt were encountered beneath the fill in boreholes 203 and 204 at elevations 306.7 and 307.5 metres, respectively. The silt layers were 0.4 and 0.8 metres thick. The silt had an N value of 5 blows per 0.3 metres and water contents of 20 and 23 per cent.

#### **4.1.6 Sandy Silt**

Layers of loose to compact sandy silt were found beneath the fill in borehole 206 and beneath the clayey silt in borehole 205 at elevations 307.1 and 306.7 metres, respectively. The sandy silt layers were about 0.8 metres thick.

The sandy silt had N values of 7 and 11 blows per 0.3 metres and water contents of 3 and 12 per cent. The sandy silt is of low plasticity based on a single Atterberg limits determination carried out on a sample obtained



during the standard penetration testing. The plastic limit, liquid limit and plasticity index were 17, 21 and 4 per cent, respectively. The Atterberg limits data for the sandy silt are presented on Figure A-6.

A grain size distribution curve for a sample of the sandy silt is presented on Figure A-4.

#### **4.1.7 Sandy Silt Till**

Sandy silt till was encountered beneath the clayey silt in borehole 203, beneath the sand and gravel in boreholes 201 and 202, beneath the silt in borehole 204 and beneath the sandy silt in boreholes 205 and 206. The sandy silt till was encountered between elevations 305.6 and 306.7 metres. All of the boreholes were terminated in the sandy silt till after exploring it for 3.6 to 6.7 metres.

The sandy silt till was loose to very dense with N values of 8 to over 100 blows per 0.3 metres and water contents of 5 to 12 per cent and an average water content of about 8 per cent. The sandy silt till is of low plasticity based on a single Atterberg limits determination carried out on a sample obtained during the standard penetration testing. The plastic limit, liquid limit and plasticity index were 12, 16 and 4 per cent, respectively. The Atterberg limits data for the sandy silt till are presented on Figure A-6.

Grain size distribution curves for samples of the sandy silt till are presented on Figure A-5. Cobbles and boulders were encountered in the sandy silt till.

## **4.2 Groundwater Conditions**

Groundwater conditions were observed during and on completion of drilling and sampling and standpipes were installed in boreholes 201 and 205. Installation details are provided on the Record of Boreholes 201 and 205 following the text of this report. A summary of the encountered and measured groundwater levels is provided in the following table:

<b>Borehole</b>	<b>Ground Surface Elevation (m)</b>	<b>Encountered Groundwater Elevation (m)</b>	<b>Installation</b>	<b>Measured Groundwater Elevation (m)</b>
				<b>June 8, 2011</b>
201	309.21	307.1	Standpipe	307.13
202	307.87	306.5	-	-
203	309.22	306.6	-	-
204	308.85	305.9	-	-
205	307.50	306.0	Standpipe	305.77
206	309.26	307.3	-	-



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Groundwater was encountered in the boreholes at depths of 1.4 to 3.0 metres or between elevations 305.9 and 307.3 metres.

Standpipes were installed in boreholes 201 and 205. On June 8, 2011, the water level in the standpipes installed in boreholes 201 and 205 was about 2.1 and 1.7 metres below ground surface or at about elevation 307.1 and 305.8 metres, respectively.

On June 6, 2011, the water levels in Fish Creek near the culvert inlet and outlet were at about elevations 306.5 and 306.4 metres, respectively.

The above-noted water levels are not considered to be representative of the long-term, stabilized groundwater conditions as the readings were taken for a short duration only. Based on the groundwater level measurements and colour change from brown to grey, the groundwater level has been inferred at elevation 307 metres. The groundwater levels are expected to fluctuate seasonally and are expected to be higher during periods of sustained precipitation or during spring melt conditions.



## **5.0 MISCELLANEOUS**

This investigation was carried out using equipment supplied and operated by Aardvark Drilling Ltd., an Ontario Ministry of Environment licensed well contractor. The field operations were supervised by Mr. Randy Axford and Mr. Matthew Rhody 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 Types C and D aggregates. This report was prepared by Mr. Tyson Pitt, P.Eng. under the direction of the Team Leader, 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**

**CULVERT SITE 25-332/C  
STATION 20+023, GEOGRAPHIC TOWNSHIP OF BLANSHARD  
HIGHWAY 23 STRUCTURE REPLACEMENTS  
FROM UNION LINE/PERTH LINE 10 TO PERTH LINE 42  
GWP 3043-06-00, PURCHASE ORDER NO. 3009-E-0020  
MINISTRY OF TRANSPORTATION, ONTARIO - WEST REGION**



## **6.0 ENGINEERING RECOMMENDATIONS**

### **6.1 General**

This section of the report provides our recommendations on the foundation design aspects of the replacement of the Fish Creek structural culvert at Station 20+023 in the Geographic Township of Blanshard on Highway 23 (Site 25-332/C).

The recommendations are based on our interpretation of the factual data obtained from the six boreholes advanced during the investigation at this site. The interpretation and recommendations are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to design the proposed culvert foundations. As such, where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

The existing culvert is a concrete, non-rigid frame, open footing culvert 4.27 metres wide, 1.52 metres high and 53.30 metres long. Based on the drawings provided by Delcan, the existing culvert is to be replaced with a culvert oriented northwest-southeast through the intersection of Highway 23 and Union Line/Perth Line 10. The new culvert will be a cast-in-place (CIP) concrete box culvert 5.0 metres wide, 1.8 metres high and 51.5 metres long. This culvert will handle flows from Fish Creek only. A second smaller, 2.4 metre wide, 1.8 metre high and 25.0 metre long culvert will convey flows from Roger Drain from north to south below Perth County Line 10.

The existing culvert is to be replaced using open cut installation methods. Traffic staging will be required to facilitate the open trench installation of the new culvert.

### **6.2 Foundations**

The subsurface conditions encountered during the investigation generally consisted of topsoil or surficial granular fill and layers of sand and gravel or silts underlain by sandy silt till. A groundwater elevation of 307 metres has been inferred for the purposes of design.

The replacement culvert should be designed to withstand the appropriate weight of fill and traffic loading. Based on the soil conditions encountered at the borehole locations and the culvert invert elevation of approximately 306.1 metres, the replacement culvert may be founded at or below elevation 306 metres in the compact to very dense sandy silt till.



### **6.2.1 Geotechnical Resistances**

The compact to very dense sandy silt till at or below elevation 306 metres is suitable for support of the proposed culvert replacement. A factored geotechnical resistance at Ultimate Limit States (ULS) of 400 kilopascals and a geotechnical resistance at Serviceability Limit States (SLS) of 300 kilopascals may be used for design purposes. The SLS value corresponds to 25 millimetres of settlement.

### **6.2.2 Frost Treatment**

Frost treatment in the form of a frost taper symmetrical about the culvert centreline must be provided in accordance with Ontario Provincial Standard Drawing (OPSD) 803.010. The frost penetration depth for this area is 1.4 metres below ground surface.

## **6.3 Other Design Considerations**

An inlet seal and an outlet filter are not required for this type of culvert. Inlet and outlet erosion control measures are to be provided based on the results of the hydraulic assessments conducted by others. The design criteria provided by Delcan indicated that there will be limited embankment widening (less than 1 metre along each side) and no change in grade at the location of the Fish Creek Culvert. The provision of camber for the culvert replacement is not required since the foundation soils and extent of embankment widening are such that excessive post-construction or differential settlements are not anticipated. The new box culvert is to be provided with a cut-off wall at each end in accordance with CHBDC Clause 1.9.5.6.

## **6.4 Backfill**

The excavation for the new culvert should exceed the culvert dimensions by at least one metre on each side to allow for good workmanship and effective compaction of the fill.

Based on the results of the boreholes, the existing fill is not suitable for reuse as backfill. Thus, the backfill should consist of free-draining, non-frost susceptible granular materials such as OPSS Granular A or Granular B, Type III, placed and compacted in accordance with OPSS 902. Prior to placement of backfill materials, the founding surface should be inspected by a Quality Verification Engineer (QVE) qualified in geotechnical engineering.

Heavy compaction equipment should not be used immediately adjacent to the walls and roof of the culvert. The height of backfill adjacent to the culvert walls should be maintained equal on both sides of the structure during all stages of backfill placement.





## **6.5 Liquefaction Potential and Seismic Analysis**

### **6.5.1 Seismic Parameters**

The site is located near Mitchell, Ontario. According to Table A.3.1.1 of the Canadian Highway Bridge Design Code (CHBDC), the zonal acceleration ratio,  $A$ , applicable to this site is 0.00. The corresponding acceleration related seismic zone,  $Z_a$  is 0. Based on the site stratigraphy, the soil profile type is categorized as Type I with a seismic site response coefficient,  $S$ , of 1.0 based on the CHBDC criteria.

### **6.5.2 Seismic Hazard Assessment**

The soils at the site are not considered to be susceptible to liquefaction and, therefore, a detailed evaluation of the liquefaction potential of the foundation soils is not considered warranted.

## **6.6 Lateral Earth Pressures for Design**

Lateral pressures acting on the proposed culvert and any associated retaining walls will depend on the type and method of placement of the backfill materials, the nature of the soil behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure and the drainage conditions behind the walls.

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

- Select free-draining granular fill meeting the specifications of OPSS Granular A or Granular B, Type III, but with less than 5 per cent passing the No. 200 sieve, should be used as backfill behind the culvert and retaining walls. Longitudinal drains and weep holes should be installed within any cast-in-place concrete walls to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements with respect to subdrains and frost taper should be in accordance with OPSD 803.010.
- The granular fill may be placed either in a zone with a width equal to at least 1.4 metres behind the back of the stem (Case (a) from Commentary on CHBDC Figure C6.20) or within the wedge-shaped zone defined by a line drawn at a maximum slope of 1 horizontal to 1 vertical or flatter extending up and back from the rear face of the foundation (Case (b) from Commentary on CHBDC Figure C6.20).
- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the culvert wall in accordance with CHBDC Figure 6.6. Compaction equipment should



## FOUNDATION INVESTIGATION AND DESIGN REPORT FISH CREEK CULVERT, SITE 25-332/C

be used in accordance with OPSS 501. Other surcharge loadings should be accounted for in the design, as required.

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

	<u>GRANULAR A</u>	<u>GRANULAR B</u> (Type III)
Fill unit weight:	22 kN/m <sup>3</sup>	21kN/m <sup>3</sup>
Coefficients of static 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 wedge shaped zone with a width equal to at least 1.4 metres at the footing level against a cut slope which begins at the footing level and extends upwards at a maximum inclination of 1 horizontal to 1 vertical.
- If the wall support does not allow lateral yielding (which is typically the case for a rigid concrete box culvert), at-rest earth pressures should be assumed for geotechnical design. The granular fill should be placed in a zone with a width equal to at least 1.4 metres behind the culvert walls.
- Resistance to lateral forces (i.e. sliding resistance) for a cast-in-place wall footing with a concrete working slab may be based on the unfactored angle of friction between the sandy silt till and the 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 kilopascals
$\delta$	=	35 degrees (sandy silt silt till)
$V$	-	unfactored vertical force, kilonewtons
$H_f$	-	factored horizontal load, kilonewtons

The unfactored coefficient of passive pressure for the portion of the culvert wall below the ground surface may be taken as 3.7 based on an unfactored effective angle of internal friction,  $\phi'$ , of 35 degrees.



## **6.7 Construction Considerations**

Care should be taken during construction to avoid disturbance of the sandy silt till subgrade prior to constructing foundations for the culvert. All topsoil, organics and soft or loose soils should be removed from below the proposed founding elevation and wasted or reused as landscaping fill, as required. Subgrade preparation should be performed and monitored in accordance with OPSS 902. The founding soils are sensitive to disturbance and softening due to water seepage and/or ponding. Placement of a 75 millimetre thick working slab of lean concrete should be provided in the base of the culvert excavation in the footing area(s). The cleaned excavation base should be inspected by the QVE prior to placing the working slab and the working slab should be placed immediately after footing inspection. The appropriate Non Standard Special Provision (NSSP) should be added to the Contract Documents outlining the requirement for the use of a working slab to protect the foundation soils.

Erosion and scour protection for the culvert inlet and outlet 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/piping of the watercourse to mitigate migration of fine soil particles.

## **6.8 Excavations and Temporary Cut Slopes**

Excavations will extend through the existing Highway 23 pavement structure and embankment fill and into the underlying sand and gravel, silts and sandy silt till. Contractors should be prepared for the presence of cobbles and boulders within the sandy silt till and groundwater in the sand and gravel, sandy silt and silt deposits.

Pumping from properly filtered sumps located in the base of the excavations may be required to provide groundwater control. A Permit To Take Water is not considered necessary.

Sumps should be maintained outside of the actual foundation limits. 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 existing culvert flows will need to be diverted/piped during construction. The appropriate NSSP should be included in the Contract Documents to alert the contractor about the need for adequate control of surface and groundwater flows.

Temporary open cut slopes within the fill materials should be maintained no steeper than 1 horizontal to 1 vertical and localized sloughing and ground movements should be expected. Use of flatter side slopes, or blanketing of the slopes with coarse material may be needed to enhance the stability of cuts in sand and gravel due to the higher seepage volumes. All excavations should be carried out in accordance with the latest edition of the Ontario Occupational Health and Safety Act and Regulations for Construction Projects. The fill, silts and sand and gravel below the groundwater level at this site would be classified as Type 3 soils. The sandy silt till, granular soils above the groundwater level and properly dewatered granular soils would be classified as Type 2 soils.



### **6.8.1 Staging and Temporary Roadway Protection**

Temporary roadway protection and/or embankments for detours will be required to facilitate open cut construction in stages to permit continued two-lane traffic on the highway. Based on drawings provided by Delcan, it is understood that construction will be carried out in 4 stages. In Stage 1, temporary culvert extensions would be provided for the Fish Creek and Rogers Drain inlets on the northwest and northeast sides of the existing culvert, a temporary detour would be constructed to the west of Highway 23 and the ditch culvert beneath Union Line would be removed and replaced. Temporary roadway protection would be installed along west side of Highway 23 and the southeast end of the new culvert section constructed. In Stage 2, temporary culvert extensions would be provided on the northeast and southeast sides and a temporary detour constructed to the east of Highway 23. Temporary roadway protection would be installed in the northeast and northwest quadrants of the intersection and culvert removal and replacement carried out on the northwest side. In Stage 3 the new Fish Creek culvert would be operational and temporary culvert extensions would be provided at each end. The temporary detour to the west of Highway 23 would be re-established, and the existing culvert on the northeast quadrant would be removed. In Stage 4, temporary roadway protection would be installed so that the existing culvert on the southeast side can be removed.

Soldier pile and lagging wall systems or steel sheet piles could be used for temporary roadway protection. A soldier pile and lagging system is preferred since it may be very difficult to drive steel sheet piles into the compact to very dense sandy silt till which contains cobbles and boulders. Pre-augering may be required in order to successfully install the soldier piles in the sandy silt till. The temporary shoring will have a maximum height of 4 metres above the excavation base.

Excavation support systems should be designed and constructed in accordance with OPSS 539 and the design should limit the lateral movement of the temporary shoring system to meet Performance Level 2. The contractor is responsible for the complete detailed design of the protection system.

The design of a sheet pile wall or a braced soldier pile and lagging wall 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. 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 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

$$K_a = \text{active coefficient of earth pressure}$$
$$\gamma = \text{soil unit weight}$$



## FOUNDATION INVESTIGATION AND DESIGN REPORT FISH CREEK CULVERT, SITE 25-332/C

$q$  = surcharge for traffic and other loading

For the granular fill, the unfactored rectangular earth pressure distribution ( $p$  in  $\text{kN/m}^2$ ; constant with depth), can be calculated as follows:

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

where  $H$  = the total height of the excavation

$K_a$  = active coefficient of earth pressure

$\gamma$  = soil unit weight

$q$  = surcharge for traffic and other loading

The support systems may be designed using the following parameters:

Soil Type	Coefficient of Earth Pressure			Internal Angle of Friction (degrees)	Unit Weight ( $\text{kN/m}^3$ )
	Active, $K_a$	At Rest, $K_o$	Passive, $K_p$		
Fill	0.36	0.53	2.8	28	19
Sandy Silt to Silt	0.38	0.55	2.7	27	18
Clayey Silt	0.38	0.55	2.7	27	19
Sand and Gravel	0.31	0.47	3.3	32	21
Sandy Silt Till	0.27	-	3.7	35	24

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



## **7.0 MISCELLANEOUS**

This report was prepared by Mr. Tyson Pitt, P.Eng. under the direction of the Team Leader, 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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n:\active\2010\1132 - geotechnical\1132-0000\10-1132-0029 delcan - gwp 3043-06-00 - hwy 23\ph 7000 - detail fdns\reports\r02 - fish creek culvert\1011320029-7000-r02 - nov 22 11 - (final) - parts a&b fish creek culvert.docx

## LIST OF ABBREVIATIONS

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

### I. SAMPLE TYPE

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

### III. SOIL DESCRIPTION

#### (a) Cohesionless Soils

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

### II. PENETRATION RESISTANCE

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

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

#### (b) Cohesive Soils

Consistency	$c_u, s_u$	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

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

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

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

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

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

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

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 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 201**

1 OF 1

**METRIC**

PROJECT 10-1132-0029  
W.P. 3043-06-00 LOCATION N 4800731.2 ; E 402089.3 ORIGINATED BY RA  
DIST HWY 23 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE May 31, 2011 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									
								20	40	60	80	100					
309.21	GROUND SURFACE																
0.00	FILL, sand and gravel, some silt, with sandy silt layers Loose Brown						309										
307.84			1	SS	9		Cuttings										
307.84							308										
1.37	FILL, silt, some clay, trace sand, trace topsoil with silt seams Loose Brown		2	SS	6		Bentonite										
307.08																	
2.13	SAND AND GRAVEL, some silt, trace clay Compact Brown		3	SS	25		Sand										
306.31																	
2.90	SANDY SILT TILL, trace to some gravel, some clay, with cobbles Loose to very dense Brown becoming grey at about elev. 303.9m		4	SS	8												
			5	SS	84												
			6	SS	127												
			7	SS	123												
			8	SS	137/ 230mm												
302.75																	
6.46	END OF BOREHOLE																
	Groundwater encountered at about elev. 307.1m during drilling on May 31, 2011.																
	Water level measured at 307.13m on June 8, 2011.																

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

**RECORD OF BOREHOLE No 202**

1 OF 1

**METRIC**

PROJECT 10-1132-0029  
W.P. 3043-06-00 LOCATION N 4800759.8 ; E 402095.7 ORIGINATED BY MR  
DIST HWY 23 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE June 06, 2011 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									
307.87	GROUND SURFACE							20	40	60	80	100								
0.00	TOPSOIL, silty Dark brown																			
0.20	FILL, silty sand and gravel, trace topsoil																			
307.35	Brown																			
0.52	CLAYEY SILT, trace sand, trace gravel		1	SS	11		307													
306.50	Stiff																			
1.37	Brown		2	SS	19		306													
305.74	SAND AND GRAVEL, trace silt Compact																			
2.13	Brown																			
	SANDY SILT TILL, some gravel, some clay, with cobbles		3	SS	13		305													
	Compact to very dense																			
	Brown becoming grey at about elev. 303.6m		4	SS	27															
			5	SS	100/ 125mm		304													
			6	SS	56		303													
			7	SS	53		302													
			8	SS	51															
							301													
		</																		

**RECORD OF BOREHOLE No 203**

1 OF 1

**METRIC**

PROJECT 10-1132-0029  
W.P. 3043-06-00 LOCATION N 4800754.5 ; E 402102.0 ORIGINATED BY RA  
DIST HWY 23 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE June 01, 2011 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	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)			
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE													
309.22	GROUND SURFACE						20	40	60	80	100						GR	SA	SI	CL	
0.00	FILL, sand and gravel, some silt, trace topsoil Compact Brown					▽	309														
			1	SS	27																
307.85	FILL, sandy silt, some clay, trace topsoil, trace gravel Loose Brown and grey							308													
1.37			2	SS	5																
306.72									307												
2.50	SILT, trace clay Loose Brown																				
306.32																					
2.90	CLAYEY SILT, with silt seams Firm Brown								306												
305.56																					
3.66	SANDY SILT TILL, some gravel, some clay, with cobbles Dense to very dense Brown becoming grey at about elev. 304.0m																				
									305												
							304														
							303														
							302														
							301														
							300														
299.62	END OF BOREHOLE																				
9.60	Groundwater encountered at about elev. 306.6m during drilling on June 1, 2011.																				

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

PROJECT 10-1132-0029

W.P. 3043-06-00

LOCATION N 4800728.3 :E 402127.5

ORIGINATED BY MR

DIST HWY 23

BOREHOLE TYPE POWER AUGER, HOLLOW STEM

COMPILED BY LMK

DATUM GEODETIC

DATE June 06, 2011

CHECKED BY \_\_\_\_\_

[illegible]

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

**RECORD OF BOREHOLE No 205**

1 OF 1

**METRIC**

PROJECT 10-1132-0029  
W.P. 3043-06-00 LOCATION N 4800719.7 ; E 402113.9 ORIGINATED BY RA/MR  
DIST HWY 23 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE June 01, 2011 - June 06, 2011 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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20 40 60 80 100									
								○ UNCONFINED + FIELD VANE									
								● QUICK TRIAXIAL × LAB VANE									
								20 40 60 80 100					WATER CONTENT (%)				
													10 20 30				
307.50	GROUND SURFACE																
0.00	TOPSOIL, silty, some clay Dark brown																
307.04																	
0.46	CLAYEY SILT Brown																
0.76	SANDY SILT, trace gravel, trace clay Compact Brown		1	SS	11								○				
305.98																	
1.52	SANDY SILT TILL, some clay, trace to some gravel, with cobbles Dense to very dense Brown to grey at about elev. 303.8m		2	SS	30								○				
			3	SS	42								○			6 29 48 17	
			4	SS	78								○				
			5	SS	114								○			12 33 42 13	
			6	SS	100/ 150mm								○				
			7	SS	100/ 250mm								○				
			8	SS	67								○				
			9	SS	66								○				
			10	SS	73								○				
299.42																	
8.08	END OF BOREHOLE																
	Groundwater encountered at about elev. 306.0m during drilling on June 1 & 6, 2011.																
	Water level measured at 302.17m on June 6, 2011.																
	Water level measured at 305.77m on June 8, 2011.																

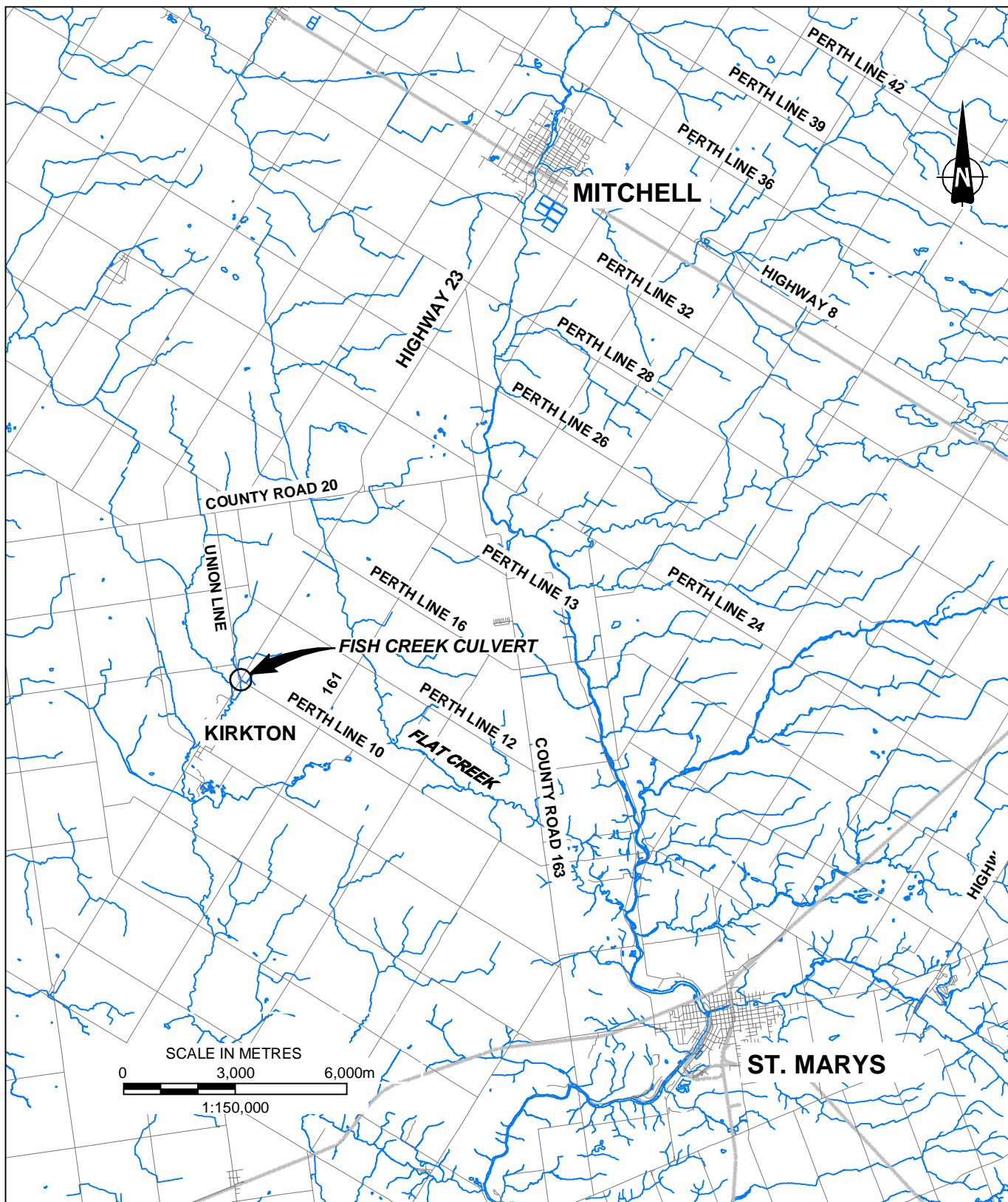
**RECORD OF BOREHOLE No 206**

1 OF 1

**METRIC**

PROJECT 10-1132-0029  
W.P. 3043-06-00 LOCATION N 4800723.0 ; E 402098.4 ORIGINATED BY RA  
DIST HWY 23 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE June 01, 2011 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										
309.26	GROUND SURFACE					▽		20	40	60	80	100						
0.00	FILL, sand and gravel, trace silt Compact Brown		1	SS	17		309								○			24 23 44 9
307.89							308										○	
1.37	FILL, clayey silt, some topsoil, some sand, trace gravel Soft Brown		2	SS	4												○	
307.13							307								○	II		
2.13	SANDY SILT, trace clay, some gravel Loose Brown		3	SS	7													
306.36							306								○			
2.90	SANDY SILT TILL, trace to some gravel, some clay, with cobbles and boulders Compact to very dense Brown becoming grey at about elev. 303.9m		4	SS	12										○			
			5	SS	34		305								○			
			6	SS	106										○			
			7	SS	154	304								○				
			8	SS	166	303								○				
			9	SS	105/ 50mm	302												
301.18			10	SS	114									○			21 32 35 12	
8.08	END OF BOREHOLE																	
	Groundwater encountered at about elev. 307.3m during drilling on June 1, 2011.																	



## REFERENCE

CANMAP STREETFILES, V2008.4.

## NOTES

THIS DRAWING IS SCHEMATIC ONLY AND IS TO BE READ  
IN CONJUNCTION WITH ACCOMPANYING TEXT.  
ALL LOCATIONS ARE APPROXIMATE.

PROJECT

FISH CREEK CULVERT  
HIGHWAY 23 STRUCTURE REPLACEMENTS  
GWP 3043-06-00, SITE 25-332/C

TITLE

## KEY PLAN



PROJECT No. 10-1132-0029			FILE No. 1011320029-7000-F02001		
CADD	LMK/AMG	SEPT. 14/11	SCALE	AS SHOWN	REV. 0
CHECK			<b>FIGURE 1</b>		



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

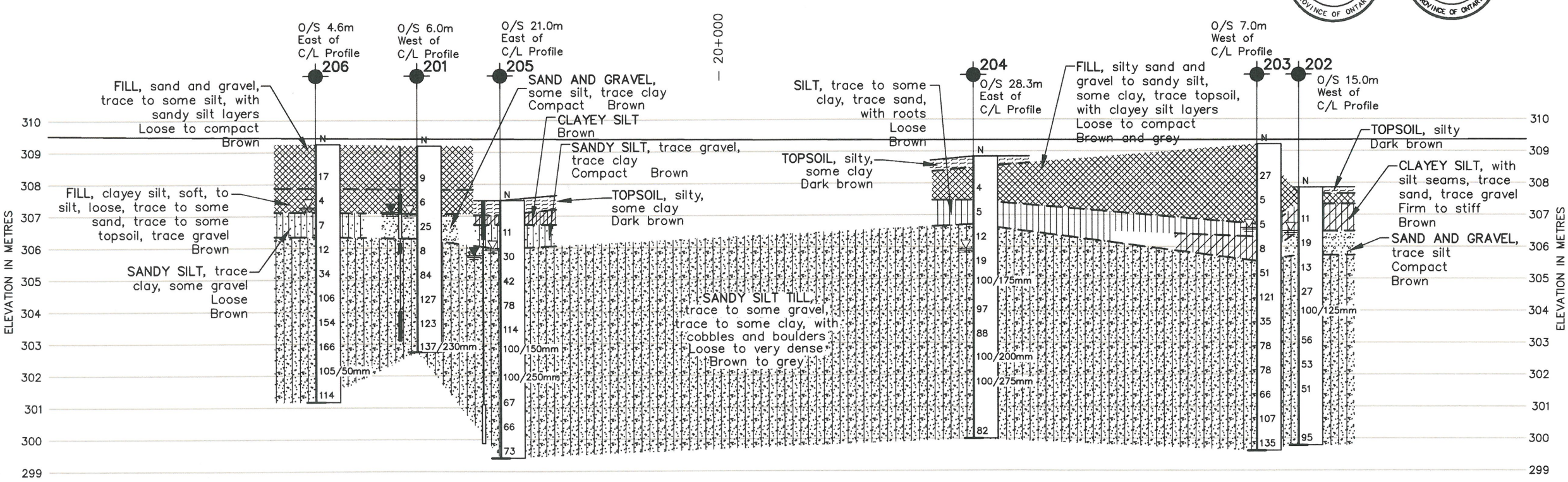
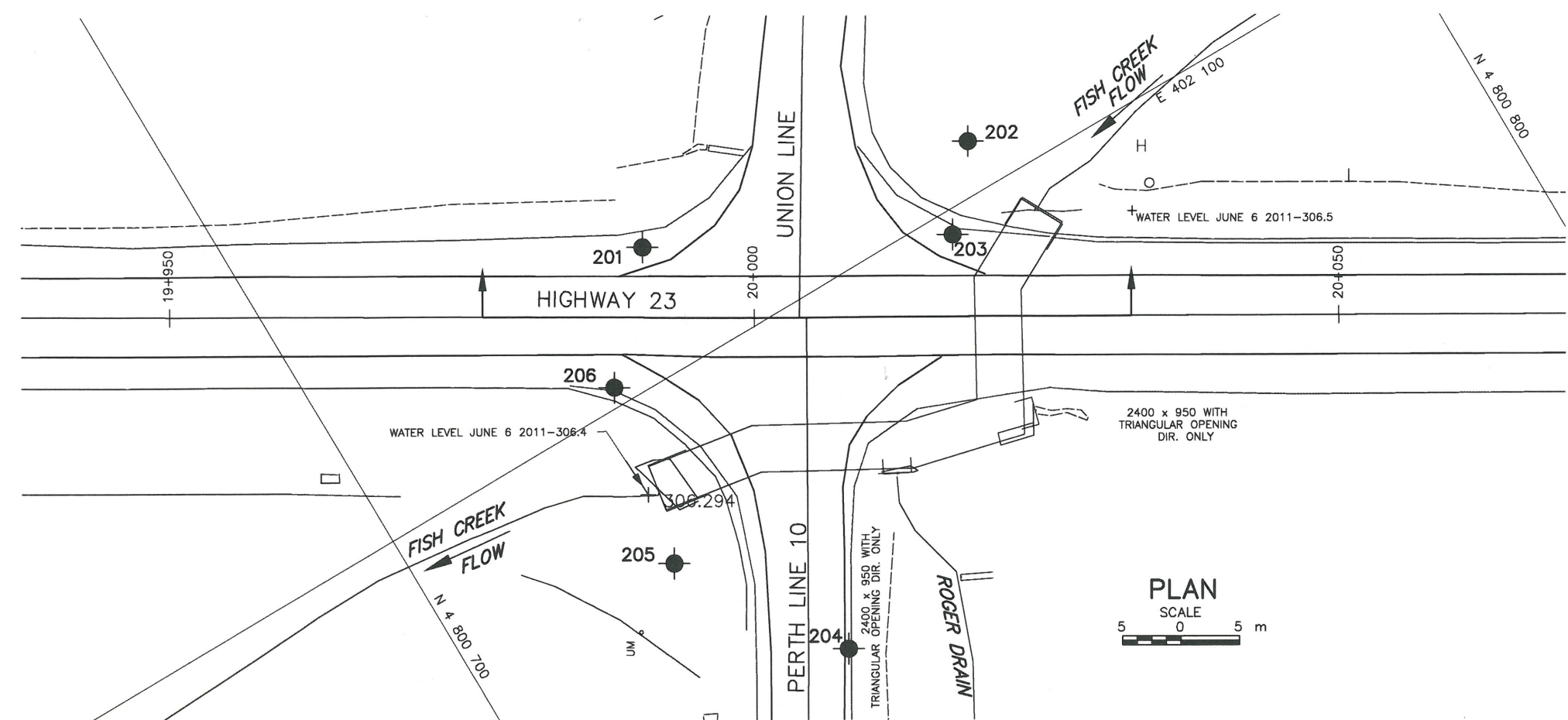
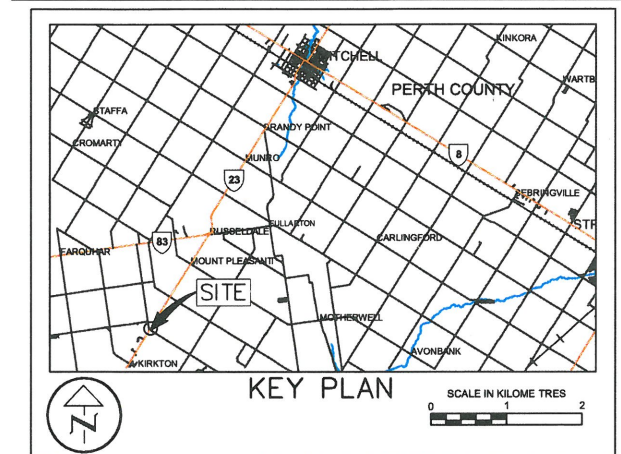
CONT No.  
 WP No. 3043-06-00



**FISH CREEK CULVERT**  
 HIGHWAY 23 STRUCTURE REPLACEMENTS  
 BOREHOLE LOCATIONS AND SOILS STRATA

SHEET

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



**LEGEND**

- Borehole
- Seal
- Standpipe
- N Inferred Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL upon completion of drilling
- WL in piezometer (June 8, 2011)

No.	ELEVATION	CO-ORDINATES (MTM ZONE 10)	
		NORTHING	EASTING
201	309.21	4 800 731.2	402 089.3
202	307.87	4 800 759.8	402 095.7
203	309.22	4 800 754.5	402 102.0
204	308.85	4 800 728.3	402 127.5
205	307.50	4 800 719.7	402 113.9
206	309.26	4 800 723.0	402 098.4

**NOTES**

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

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

**REFERENCE**

Base plans provided in digital format by Delcan.

PROFILE ALONG E HIGHWAY 23

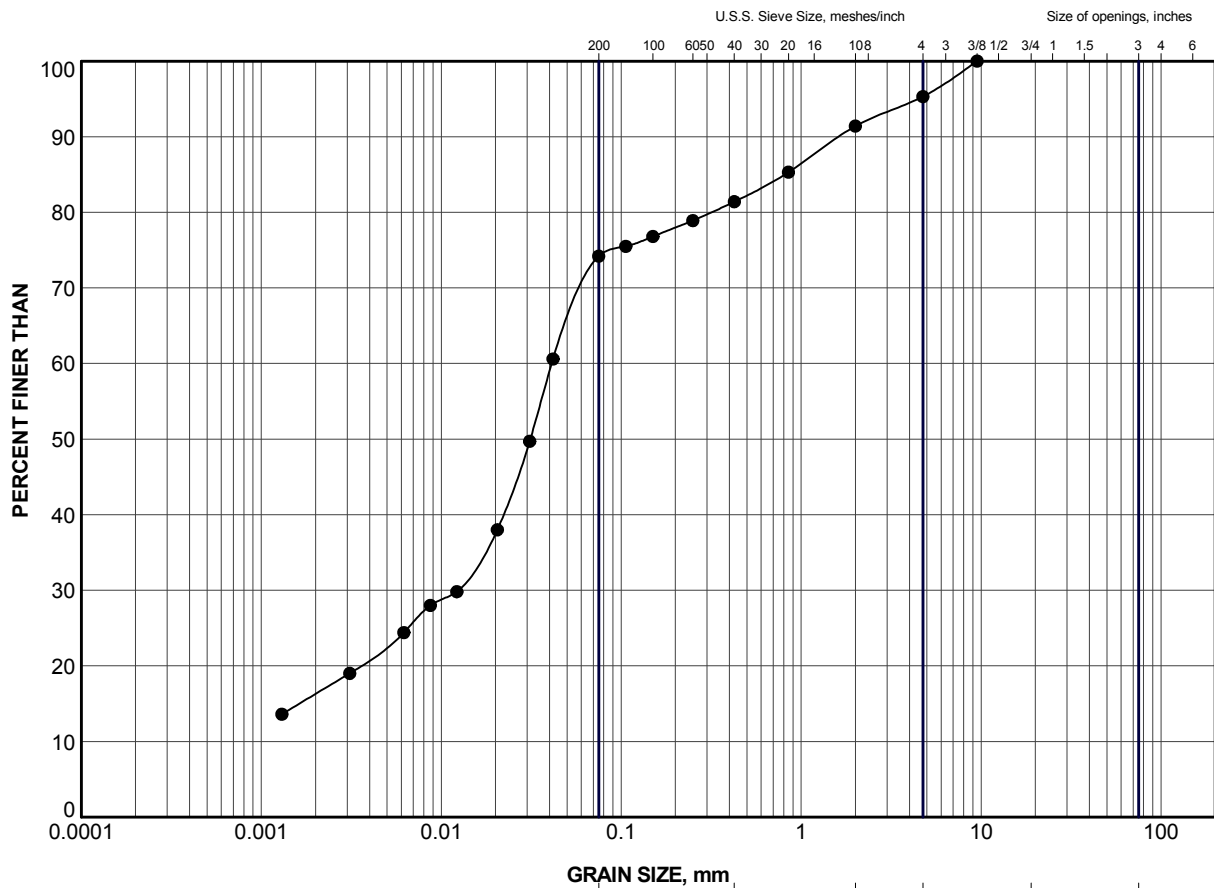
NO.	DATE	BY	REVISION
Geotecs No.	40P6-24		
HWY.	23	PROJECT NO.	10-1132-0029
SUBM'D.	CHKD.	DATE:	Aug. 18/11
DRAWN:	LMK/DCH	CHKD.	APPD.
		DIST.	SITE: 25-322/C
		DWG.	1





# **APPENDIX A**


## **Laboratory Test Data**

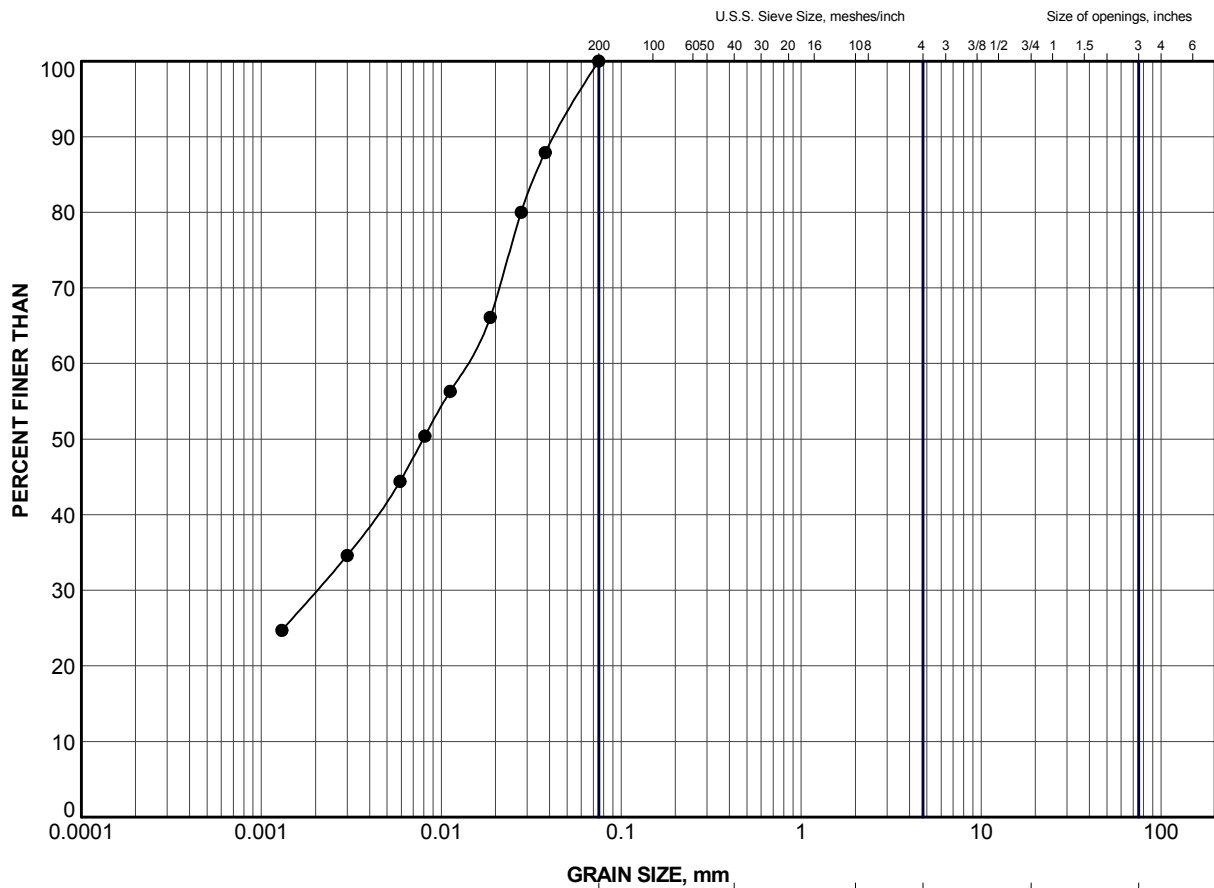


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

#### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	203	2	307.5

PROJECT		FISH CREEK CULVERT HIGHWAY 23 STRUCTURE REPLACEMENTS GWP 3043-06-00, SITE 25-332/C			
TITLE		GRAIN SIZE DISTRIBUTION FILL			
 <b>Golder Associates</b> LONDON, ONTARIO	PROJECT No.	10-1132-0029	FILE No.	1011320029-7000-F020A1	
	DRAWN	LMK/AMG	SEPT. 14/11	SCALE	N/A
	CHECK			REV.	
				<b>FIGURE A-1</b>	



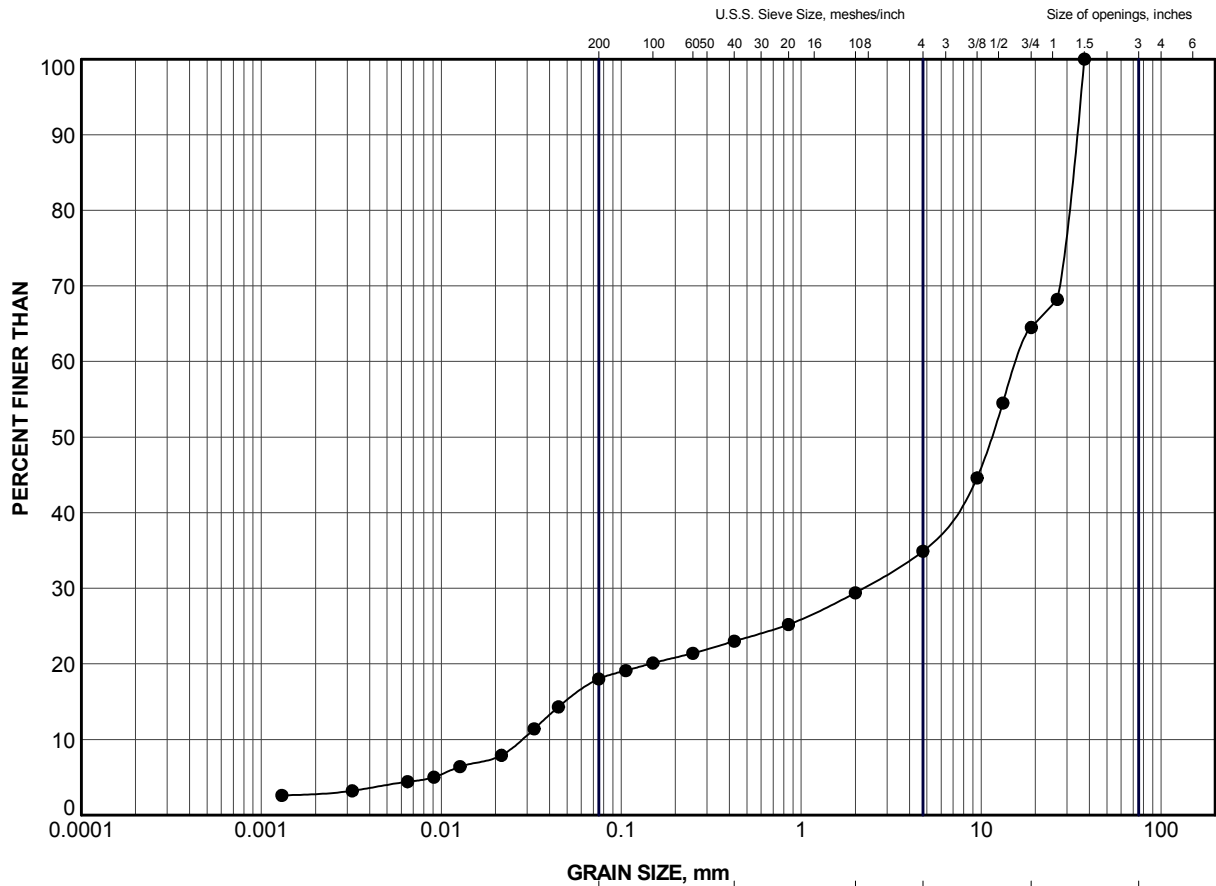
GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

#### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	203	4	305.9

PROJECT				FISH CREEK CULVERT HIGHWAY 23 STRUCTURE REPLACEMENTS GWP 3043-06-00, SITE 25-332/C			
TITLE				GRAIN SIZE DISTRIBUTION CLAYEY SILT			
PROJECT No.		10-1132-0029		FILE No.		1011320029-7000-F020A2	
DRAWN		LMK/AMG		SCALE		N/A	
CHECK				REV.			
		SEPT. 14/11		FIGURE A-2			





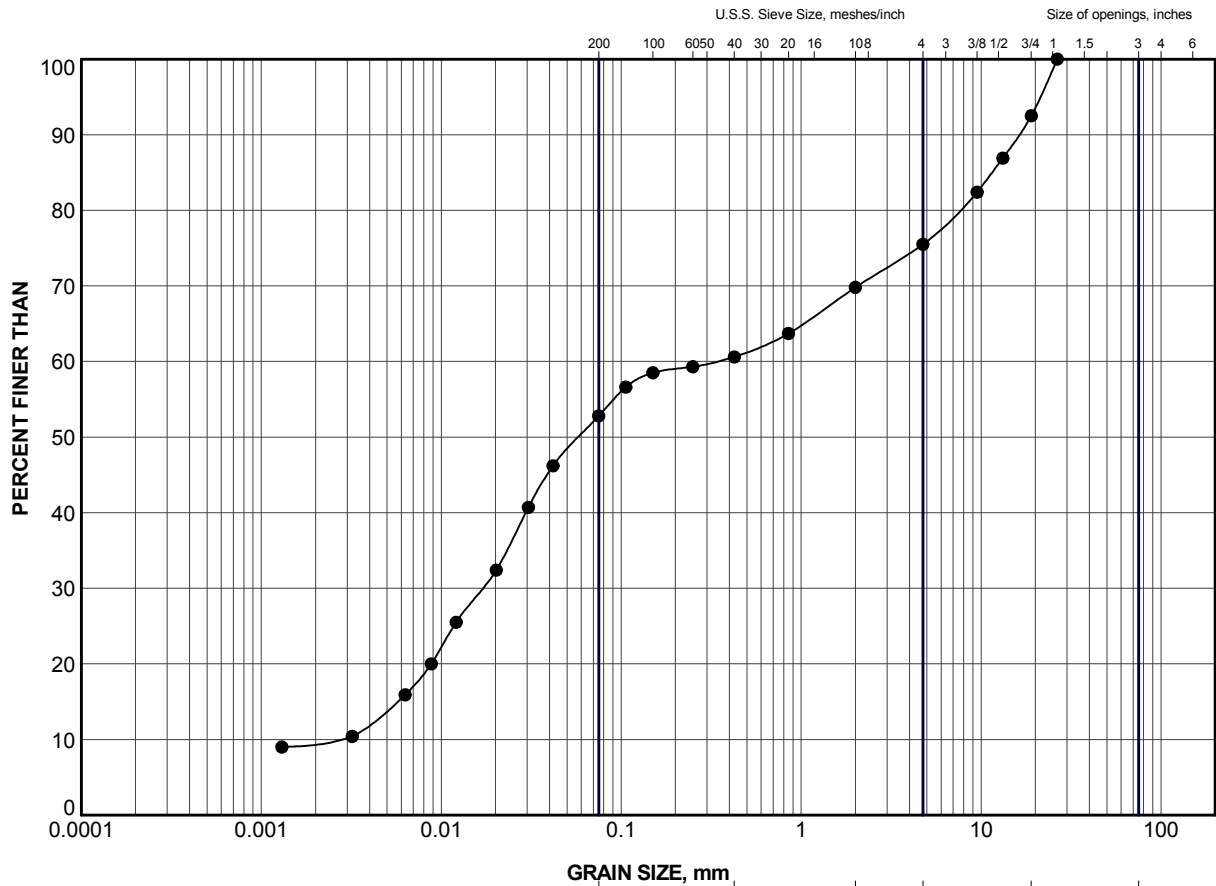
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	201	3	306.7

PROJECT				FISH CREEK CULVERT HIGHWAY 23 STRUCTURE REPLACEMENTS GWP 3043-06-00, SITE 25-332/C			
TITLE				GRAIN SIZE DISTRIBUTION SAND AND GRAVEL			
PROJECT No.		10-1132-0029		FILE No.		1011320029-7000-F020A3	
DRAWN		LMK/AMG		SCALE		N/A	
CHECK				REV.			
		SEPT. 14/11		FIGURE A-3			



LDN\_MTO\_GSD\_GLDR\_LDN.GDT

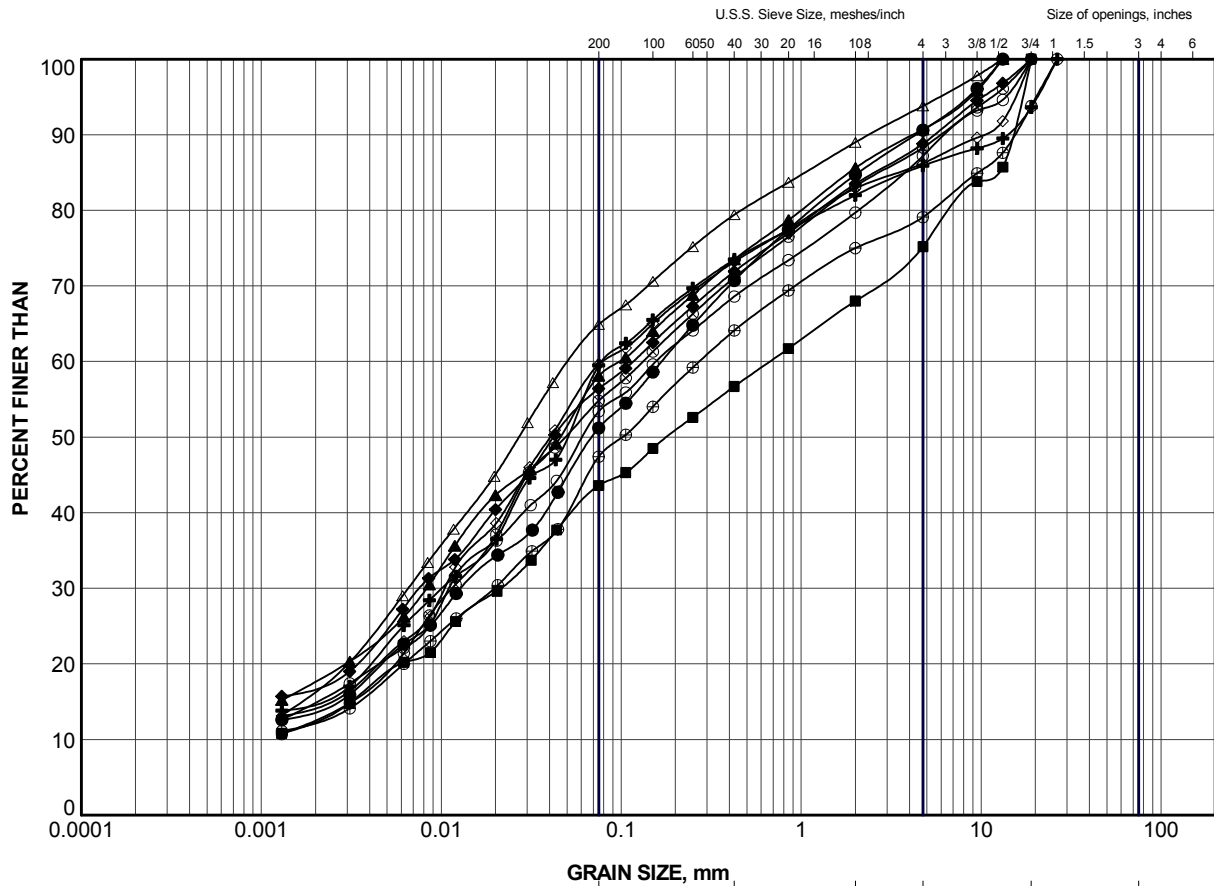


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

**LEGEND**

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	206	3	306.7

PROJECT	FISH CREEK CULVERT HIGHWAY 23 STRUCTURE REPLACEMENTS GWP 3043-06-00, SITE 25-332/C		
TITLE	GRAIN SIZE DISTRIBUTION SANDY SILT		
<b>Golder Associates</b> LONDON, ONTARIO	PROJECT No.	10-1132-0029	FILE No. 1011320029-7000-F020A4
	DRAWN	LMK/AMG	SEPT. 14/11
	CHECK		
	SCALE	N/A	REV.
			<b>FIGURE A-4</b>



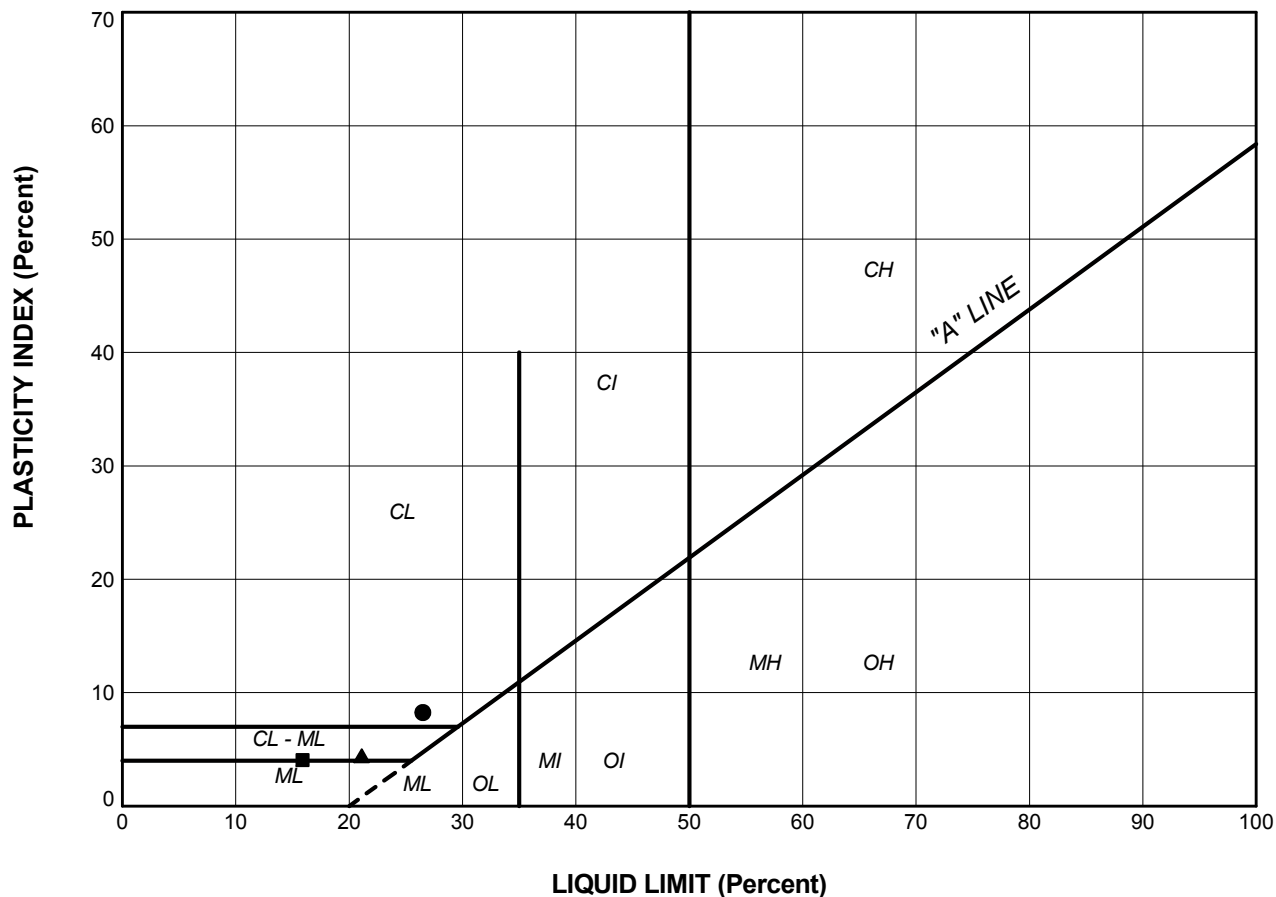
CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	201	7	303.6
■	202	6	303.1
▲	202	9	300.0
+	203	6	304.4
◆	203	11	300.6
◇	204	3	306.3
○	204	6	304.0
△	205	3	305.0
⊗	205	5	303.5
⊕	206	7	303.7


PROJECT				FISH CREEK CULVERT HIGHWAY 23 STRUCTURE REPLACEMENTS GWP 3043-06-00, SITE 25-332/C			
TITLE				GRAIN SIZE DISTRIBUTION SANDY SILT TILL			
PROJECT No.		10-1132-0029		FILE No.		1011320029-7000-F020A5	
DRAWN		LMK/AMG		SCALE		N/A	
CHECK				REV.			
		SEPT. 14/11		FIGURE A-5			





### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	203	4	26.5	18.3	8.3
■	204	3	15.9	11.9	4.1
▲	206	3	21.1	16.7	4.5

PROJECT				FISH CREEK CULVERT HIGHWAY 23 STRUCTURE REPLACEMENTS GWP 3043-06-00, SITE 25-332/C			
TITLE				PLASTICITY CHART			
PROJECT No.		10-1132-0029		FILE No.		1011320029-7000-F020A6	
DRAWN	LMK/AMG	SEPT. 14/11	SCALE		N/A		REV.
CHECK							
 <b>Golder Associates</b> LONDON, ONTARIO				<b>FIGURE A-6</b>			



# **APPENDIX B**

## **Site Photographs**





## APPENDIX B PHOTOGRAPHS



Photograph 1: Outlet of Fish Creek culvert looking upstream.



Photograph 2: Inlet of Fish Creek culvert looking downstream.



## APPENDIX B PHOTOGRAPHS



Photograph 3: Triangular inlet for Roger Drain in northeast quadrant.



Photograph 4: East-west leg of culvert as viewed from inlet.



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

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