November 2011

FOUNDATION INVESTIGATION AND DESIGN REPORT

Culvert Site 25-333/C
Station 13+030, Geographic Township of Fullarton
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:
Mr. Henry Huotari, P.Eng., Senior Project Manager, Principal
Delcan Corporation
1069 Wellington Road South, Suite 214
London, Ontario
N6E 2H6

REPORT

Report Number: 10-1132-0029-7000-R03

Geocres No: 40P6-25

Distribution:

6 Copies - Delcan Corporation
2 Copies - Golder Associates Ltd.

Golder Associates

Table of Contents

PART A - FOUNDATION INVESTIGATION REPORT

1.0 INTRODUCTION 1

2.0 SITE DESCRIPTION 2

2.1 General 2

2.2 Site Geology 2

3.0 INVESTIGATION PROCEDURES 3

4.0 SUBSURFACE CONDITIONS 4

4.1 Site Stratigraphy 4

4.1.1 Fill 4

4.1.2 Topsoil 5

4.1.3 Silt 5

4.1.4 Clayey Silt 5

4.1.5 Sands 5

4.1.6 Clayey Silt Till 5

4.1.7 Sandy Silt Till 6

4.2 Groundwater Conditions 6

5.0 MISCELLANEOUS 8

PART B - FOUNDATION DESIGN REPORT

6.0 ENGINEERING RECOMMENDATIONS 9

6.1 General 9

6.2 Foundations 9

6.2.1 Geotechnical Resistances 10

6.2.2 Frost Treatment 10

6.2.3 Other Design Considerations 10

6.3 Bedding 10

6.4 Backfill 10

6.5 Liquefaction Potential and Seismic Analysis 11

6.5.1 Seismic Parameters 11

6.5.2 Seismic Hazard Assessment 11

6.6 Lateral Earth Pressures for Design 11
6.7 Construction Considerations 13
6.8 Excavations and Temporary Cut Slopes 13
6.8.1 Staging and Temporary Roadway Protection 14
7.0 MISCELLANEOUS 16

LIST OF ABBREVIATIONS
LIST OF SYMBOLS
RECORD OF BOREHOLE SHEETS
FIGURE 1 – Key Plan
DRAWING 1 – Borehole Locations and Soils Strata

APPENDICES

APPENDIX A
Laboratory Test Data

APPENDIX B
Site Photographs

PART A

FOUNDATION INVESTIGATION REPORT

CULVERT SITE 25-333/C
STATION 13+030, GEOGRAPHIC TOWNSHIP OF FULLARTON
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 at the Russeldale Drain at Station 13+030 in the Geographic Township of Fullarton, Site Number 25-333/C.

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 25, 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 25-333/C is situated on Highway 23 approximately 1 kilometre north of Perth Line 16 in the Geographic Township of Fullarton, Ontario. The location of the site is shown on the Key Plan, Figure 1.

The culvert at Site 25-333/C is a concrete, non-rigid frame, open footing culvert 3.05 metres wide, 1.52 metres high and 25.60 metres long. The approximate culvert invert elevation is 327.0 metres. The culvert conveys flows from Russeldale Drain east to west under Highway 23. 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 with a wooded area on the west side of Highway 23. The adjacent topography is generally flat and ground surface elevations in the vicinity of the culvert range from about 327 to 330 metres.

2.2 Site Geology

This project lies within the physiographic region of southwestern Ontario known as the Stratford Till Plain[1]. 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 the 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 36 metres below ground surface.

[1] 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 on May 30 and May 31, 2011 at which time three boreholes, numbered 301 to 303, 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)
301	4 805 145	404 689	329.97	10.36
302	4 805 121	404 680	330.01	14.17
303	4 805 114	404 696	327.60	11.06

The existing culvert has the following characteristics:

Dimensions (m)	Obvert Elevation (m)		Construction
	Lt	Rt	
3.05 x 1.52 x 25.60	327.31	327.48	Non-Rigid Frame Open

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 encountered variable fill materials overlying layers of clayey silt and sands underlain by clayey silt till with pockets of sandy silt till and silty sand.

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 Fill

All of the boreholes encountered fill at the ground surface. The upper granular fill extended to a depth of 1.4 to 2.1 metres and consisted of either sand and gravel or silt. In boreholes 301 and 302, the sand and gravel fill was underlain by clayey silt fill from elevations 327.8 and 328.5 metres, respectively.

The compact sand and gravel fill had N values, as determined in the standard penetration testing, of 11 and 13 blows per 0.3 metres. Water contents in the fill ranged from 3 to 39 per cent but were generally less than 9 per cent. A water content of 39 per cent was measured in a sample retrieved from elevation 326.3 metres in borehole 303 which contained some topsoil.

The soft to firm clayey silt fill had N values of 3 to 7 blows per 0.3 metres. The clayey silt fill had water contents of 14 to 25 per cent and was of low plasticity based on two samples with plastic limits of 14 and 15 per cent, liquid limits of 22 and 25 per cent and plasticity indices of 8 and 9 per cent. The Atterberg limits data for the clayey fill are presented on Figure A-6.

Grain size distribution curves for samples of the clayey fill are presented on Figure A-1 in Appendix A.

4.1.2 Topsoil

A layer of buried topsoil was encountered beneath the fill in borehole 302 at about elevation 327.1 metres. The buried topsoil was about 0.9 metres thick with an N value of 3 blows per 0.3 metres and a water content of 34 per cent.

4.1.3 Silt

A layer of silt was encountered beneath the fill in borehole 301 at elevation 326.6 metres. The silt layer was about 0.5 metres thick and had a water content of 26 per cent. The silt was inferred to be very loose.

4.1.4 Clayey Silt

Layers of clayey silt were encountered in boreholes 301, 302 and 303 beneath the silt, topsoil and fill, respectively, from elevation 326.1 to 326.2 metres. The clayey silt layers were 0.6 to 0.8 metres thick.

The clayey silt deposits had N values of 7 to 11 blows per 0.3 metres indicating a firm to stiff consistency. The clayey silt had water contents of 14 to 16 per cent.

4.1.5 Sands

Sand was encountered underlying the clayey silt in boreholes 301, 302 and 303 at elevations 325.3 to 325.6 metres. The sand was 1.5 to 2.7 metres thick and consisted of fine sand interlayered with sand, silty sand and sandy silt.

The sand layers had N values of 8 to 20 blows per 0.3 metres. Samples of the sand had water contents of 18 to 27 per cent.

Grain size distribution curves for samples of the sand and silty sand obtained during standard penetration testing are presented on Figures A-2 and A-3, respectively.

4.1.6 Clayey Silt Till

A stratum of very stiff to hard clayey silt till was encountered beneath the sands between elevations 317.2 and 324.1 metres. Boreholes 301 and 302 were terminated in the clayey silt till after exploring it for 0.6 to 1.4 metres.

The clayey silt till had N values of 23 to 98 blows per 0.3 metres and water contents of 5 to 16 per cent. The clayey silt till is of low plasticity based on three Atterberg limits determinations carried out on samples obtained during standard penetration testing. The plastic limits ranged from 13 to 15 per cent, the liquid limits ranged from 25 to 30 per cent and the plasticity indices ranged from 12 to 14 per cent. The Atterberg limits data for the clayey silt till are presented on Figure A-6.

Grain size distribution curves for samples of the clayey silt till are presented on Figure A-4.

Cobbles were encountered in the clayey silt till. Cobbles and boulders should be anticipated throughout the clayey silt till deposits.

4.1.7 Sandy Silt Till

Layers of dense to very dense sandy silt till were encountered within the clayey silt till in boreholes 302 and 303 from elevations 319.5 and 318.8 metres, respectively. Borehole 303 was terminated in the sandy silt till after exploring it for 2.2 metres. Where fully penetrated in borehole 302, the sandy silt till layer was 2.3 metres thick.

The sandy silt till had N values of 48 blows per 0.3 metres to 184 blows per 225 millimetres and water contents of 5 to 10 per cent. The sandy silt till is of low plasticity based on two Atterberg limits determinations with plastic limits of 11 and 12 per cent, liquid limits of 16 and 19 per cent and plasticity indices of 5 and 7 per cent. 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 were encountered in the sandy silt till. Cobbles and boulders should be anticipated throughout the sandy silt till deposits.

4.2 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling and sampling and a standpipe was installed in borehole 301. Installation details are provided on the Record of Borehole 301 following the text of this report. A summary of the encountered and measured groundwater levels is provided in the following table:

Borehole	Ground Surface Elevation (m)	Encountered Groundwater Elevation (m)	Installation	Measured Groundwater Elevation (m)
				June 8, 2011
301	329.97	325.4	Standpipe	325.93
302	330.01	325.6	-	-
303	327.60	325.3	-	-

Groundwater was encountered in the boreholes at depths of 2.3 to 4.6 metres or between elevations 325.3 and 325.6 metres.

On June 8, 2011, the water level in the standpipe installed in borehole 301 was about 4.0 metres below ground surface or at about elevation 325.9 metres. This standpipe was decommissioned on June 8, 2011. On June 8, 2011, the water level in Russeldale Drain was at about elevation 325.9 metres; water levels in the drain were reported to be near elevation 326 metres in April 2010.

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 measured and encountered groundwater levels, the inferred groundwater level is at elevation 326 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., who is 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.

GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED

Tyson Pitt, P.Eng.
Project Engineer

ORIGINAL SIGNED

Philip R. Bedell, P.Eng.
Senior Consultant

ORIGINAL SIGNED

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

TP/PRB/FJH/ly

n:\active\2010\1132 - geotechnical\1132-0000\10-1132-0029 delcan - gwp 3043-06-00 - hwy 23\ph 7000 - detail fdns\reports\r03 - russeldale drain culvert\1011320029-7000-r03 - nov 22 11 - (final) parts a&b russeldale drain culvert.docx

PART B

FOUNDATION DESIGN REPORT

CULVERT SITE 25-333/C
STATION 13+030, GEOGRAPHIC TOWNSHIP OF FULLARTON
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

November 2011
Report No. 10-1132-0029-7000-R03

6.0 ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides our recommendations on the foundation aspects of the design of the replacement of the Russeldale Drain structural culvert at Station 13+030 in the Geographic Township of Fullarton on Highway 23 (Site 25-333/C).

The recommendations are based on our interpretation of the factual data obtained from the three 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 3.05 metres wide, 1.52 metres high and 25.60 metres long. The existing culvert has invert elevations of 326.02 metres at the inlet and 325.96 metres at the outlet. Based on the drawings provided by Delcan, the existing culvert is to be replaced with a culvert oriented east-west just north of the existing culvert. It is understood that the new culvert will be a pre-cast box culvert or a cast-in-place culvert 3.0 metres wide, 2.4 metres high and 29.1 metres long constructed approximately 4 metres north of the existing culvert.

It is proposed to replace the existing culvert using open cut installation methods. Traffic staging and temporary on site detours 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 surficial, variable fill materials overlying layers of clayey silt and sands underlain by clayey silt till with pockets of silty sand and sandy silt till. A groundwater elevation of 326 metres has been inferred for the purpose 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 325.8 metres, the replacement culvert may be founded at or below elevation 325.8 metres in the compact sand and/or silty sand.

6.2.1 Geotechnical Resistances

The compact sands and silty sand at or below elevation 325.8 metres are suitable for support of the proposed culvert replacement. A factored geotechnical resistance at Ultimate Limit States (ULS) of 200 kilopascals and a geotechnical resistance at Serviceability Limit States (SLS) of 125 kilopascals maybe 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 design frost depth for this area is 1.4 metres below ground surface.

6.2.3 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 replacement culvert. The provision of camber is not required since the foundation soils 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.

6.3 Bedding

If a pre-cast culvert is installed, bedding is to be placed on a properly prepared subgrade from which all frozen, soft, uncompacted fill, organic materials or other deleterious materials have been removed. The pre-cast box units should be placed on a minimum 75 millimetre thick levelling course consisting of uncompacted Granular A or fine aggregates as specified in MTO Special Provision (SP) 422S01.

6.4 Backfill

The excavation for the new culvert should exceed the culvert dimensions by at least a 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 501. All bedding, backfill and cover materials should be placed in accordance with OPSS 902 and SP 422 S01. Prior to placement of bedding and 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 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 for pre-cast box culverts.

- 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 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 stem, in accordance with CHBDC Figure C6.6 Compaction equipment should 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:

	GRANULAR A	GRANULAR B (Type III)
Fill unit weight:	22 kN/m^3	21kN/m^3
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 compact sand or silty sand 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
δ	=	30 degrees (compact sand or silty sand)
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 3.0 based on an unfactored effective angle of internal friction, ϕ', of 30 degrees. In general, it is recommended that the frictional resistance of the top 1 metre of soil in front of any wall be ignored due to disturbance caused by frost action.

6.7 Construction Considerations

Care should be taken during construction to avoid disturbance of the subgrade prior to constructing foundations for the culvert. Proactive dewatering will be required to maintain the integrity of the granular founding soils. 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 cleaned excavation base should be inspected by a geotechnical QVE and a working slab placed immediately after inspection to protect the founding materials. It is recommended that the footing excavation be carried out such that the final 0.5 metres of excavation is completed with the QVE on site with construction of the culvert bottom slab commencing immediately after inspection. A Non Standard Special Provision (NSSP) should be added to the Contract Documents specifying protection of the founding soil by the use of a working slab.

Erosion and scour protection for the culvert aprons 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 Ontario Provincial Standard Drawing 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 clayey silt till. Contractors should also be prepared for the presence of cobbles and boulders within the till strata.

It is anticipated that the excavations will extend below the inferred groundwater level elevation of 326 metres. Hydraulic conductivity values for the saturated sand layers were estimated using the grain size distribution curves and range from about 3.6×10^{-5} to 3.6×10^{-3} centimetres per second. Pumping from well points and/or properly filtered sumps located at the base of the excavations will be required to provide groundwater control. A Permit To Take Water is not considered necessary at this time.

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 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.

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. 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 and any cohesionless materials below the groundwater level at this site would be classified as Type 3 soils. The native clayey materials, properly dewatered cohesionless materials and glacial tills would be classified as Type 2 soils.

6.8.1 Staging and Temporary Roadway Protection

Replacement of the existing Russeldale Drain culvert will be conducted in three stages using open cut construction and a signalized single lane temporary detour. In the first stage, a temporary extension will be added to the west end of the existing culvert and a temporary detour constructed on the west side of Highway 23 and the east half of the replacement culvert constructed. In the second stage, temporary extensions will be added to the east ends of the existing and replacement culverts, a temporary detour constructed on the east side, then the west end of the existing culvert will be replaced and the west end of the new culvert will be built. The final stage will involve temporary extension of the west end of the replacement culvert, reestablishment of the temporary detour on the west side of Highway 23 and demolishing of the east end of the existing structure. It is anticipated that the work can be carried out using open cut construction and sloped cuts. However, where space is limited and open cuts cannot be constructed, temporary excavation support systems should be used.

Soldier pile and lagging wall systems or steel sheet piles could be used for temporary roadway protection. The temporary shoring will have a maximum height of about 4.2 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 kN/m^2; increasing with depth) can be calculated as follows:

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

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

K_a = active coefficient of earth pressure

γ = soil unit weight

q = surcharge for traffic and other loading

For the granular fill, the unfactored rectangular earth pressure distribution (p in 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

γ = 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 (kN/m^3)
	Active, K_a	At Rest, K_o	Passive, K_p		
Fill	0.36	0.53	2.8	28	19
Silt/Topsoil	0.38	0.55	2.7	27	18
Clayey Silt	0.38	0.55	2.7	27	19

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.

ORIGINAL SIGNED

ORIGINAL SIGNED

Tyson Pitt, P.Eng.
Project Engineer

Philip R. Bedell, P.Eng.
Senior Consultant

ORIGINAL SIGNED

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

TP/PRB/FJH/ly

n:\active\2010\1132 - geotechnical\1132-0000\10-1132-0029 delcan - gwp 3043-06-00 - hwy 23\ph 7000 - detail fdns\reports\r03 - russeldale drain culvert\1011320029-7000-r03 - nov 22 11 - (final) parts a&b russeldale drain 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

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.)

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, 60º 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^2 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.

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

(b) Cohesive Soils

Consistency

	c_u, s_u kPa	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

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. General

π	3.1416
ln x,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
F	factor of safety
V	volume
W	weight

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\ \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
v	poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma$-u)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1+\sigma_2+\sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight*)
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s/\rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

(a) Index Properties (continued)

w	water content
w_l	liquid limit
w_p	plastic limit
l_p	plasticity index $= (w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index $= (w - w_p)/I_p$
I_C	consistency index $= (w_l - w)/I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index $= (e_{max} - e)/(e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_a	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation pressure
OCR	over-consolidation ratio $= \sigma'_p/\sigma'_{vo}$

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
c′	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p′	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 + \sigma_3)/2$ or $(\sigma'_1 + \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 + \sigma_3)$
S_t	sensitivity

Notes:
1. $\tau = c' + \sigma' \tan \phi'$
2. shear strength = (compressive strength)/2

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

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 301

METRIC

PROJECT 10-1132-0029
W.P. 3043-06-00 LOCATION N 4805144.5 ;E 404689.4 ORIGINATED BY RA
DIST ___ HWY 23 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK
DATUM GEODETIC DATE May 30, 2011 CHECKED BY ___

ELEV / DEPTH (m)	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	GR	SA	SI	CL
329.97	GROUND SURFACE									
0.00	FILL, sand and gravel, trace silt Compact Brown	1	SS	11		329				
328.60 / 1.37	FILL, silty sand and gravel, some clay Compact Brown	2	SS	10	Cuttings	328				
327.84 / 2.13	FILL, clayey silt, trace gravel, some sand, trace topsoil Soft Brown	3	SS	3		327	5	26	47	22
		4	SS	2						
326.62 / 3.35	SILT, some clay, trace topsoil, trace sand, trace gravel, with roots Very loose Brown				Bentonite					
326.16 / 3.81	CLAYEY SILT, trace sand, trace gravel Firm Brown	5	SS	7		326				
325.55 / 4.42	SAND, fine, trace silt, trace clay Loose Brown	6	SS	8		325	0	88	8	4
324.79 / 5.18	SILTY SAND, with silt and clayey silt layers Compact Brown	7	SS	14	Cuttings	324				
324.03 / 5.94	SAND, trace silt, with silt and clayey silt layers Compact Grey	8	SS	11	Standpipe Sand					
323.26 / 6.71	CLAYEY SILT TILL, some sand, trace gravel, with cobbles Hard Grey	9	SS	64		323				
		10	SS	55		322	2	26	41	31
		11	SS	49	Bentonite	321				
320.98 / 8.99	SILTY SAND, some gravel, some clay, with cobbles Very dense Grey	12	SS	96			28	23	29	20
320.22 / 9.75	CLAYEY SILT TILL, some gravel, some sand, with cobbles Hard Grey	13	SS	55	Cuttings	320				
319.61 / 10.36	END OF BOREHOLE									

Other column headings: STRAT PLOT; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL.

Groundwater encountered at about elev. 325.4m during drilling on May 30, 2011.

Water level measured at elev. 325.93m on June 8, 2011.

LDN_MTO_06 10-1132-0029-7000.GPJ LDN_MTO.GDT 06/09/11

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

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 302

METRIC

PROJECT 10-1132-0029

W.P. 3043-06-00 LOCATION N 4805120.6 ;E 404679.9 ORIGINATED BY RA

DIST ____ HWY 23 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK

DATUM GEODETIC DATE May 30, 2011 CHECKED BY ____

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
330.01	GROUND SURFACE					
0.00	FILL, sand and gravel, trace silt Compact Brown	1	SS	13		
328.49 1.52	FILL, clayey silt, trace sand, trace gravel, trace topsoil, with sand layers Firm Brown	2	SS	7		
		3	SS	5		7 47 29 17
327.11 2.90	TOPSOIL, silty, trace sand, trace gravel, trace clay, with roots Loose Dark brown	4	SS	3		
326.20 3.81	CLAYEY SILT, trace sand, trace gravel Stiff Brown and grey mottled	5	SS	11	∇	
325.59 4.42	SAND, fine, trace to some silt, trace clay, with silt layers Compact Brown	6	SS	13		2 78 11 9
		7	SS	19		
324.07 5.94	CLAYEY SILT TILL, some sand, some gravel, with cobbles Very stiff to hard Brown becoming grey at about elev. 323.1m	8	SS	24		
		9	SS	23		
		10	SS	32		3 23 37 37
		11	SS	35		
		12	SS	58		
		13	SS	93		
319.50 10.51	SANDY SILT TILL, trace gravel, some clay, with cobbles, gravelly below about elev. 318.0m Dense to very dense Grey	14	SS	99		8 34 35 23
		15	SS	48		
		16	SS	153		34 21 28 17
317.21 12.80	CLAYEY SILT TILL, some sand, trace gravel, with cobbles Hard Grey	17	SS	98		
		18	SS	72		
315.84 14.17	END OF BOREHOLE Groundwater encountered at about elev. 325.6m during drilling on May 30, 2011.					

Column headings: SOIL PROFILE; SAMPLES; STRAT PLOT; ELEVATION SCALE (330 to 316); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³

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

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 303

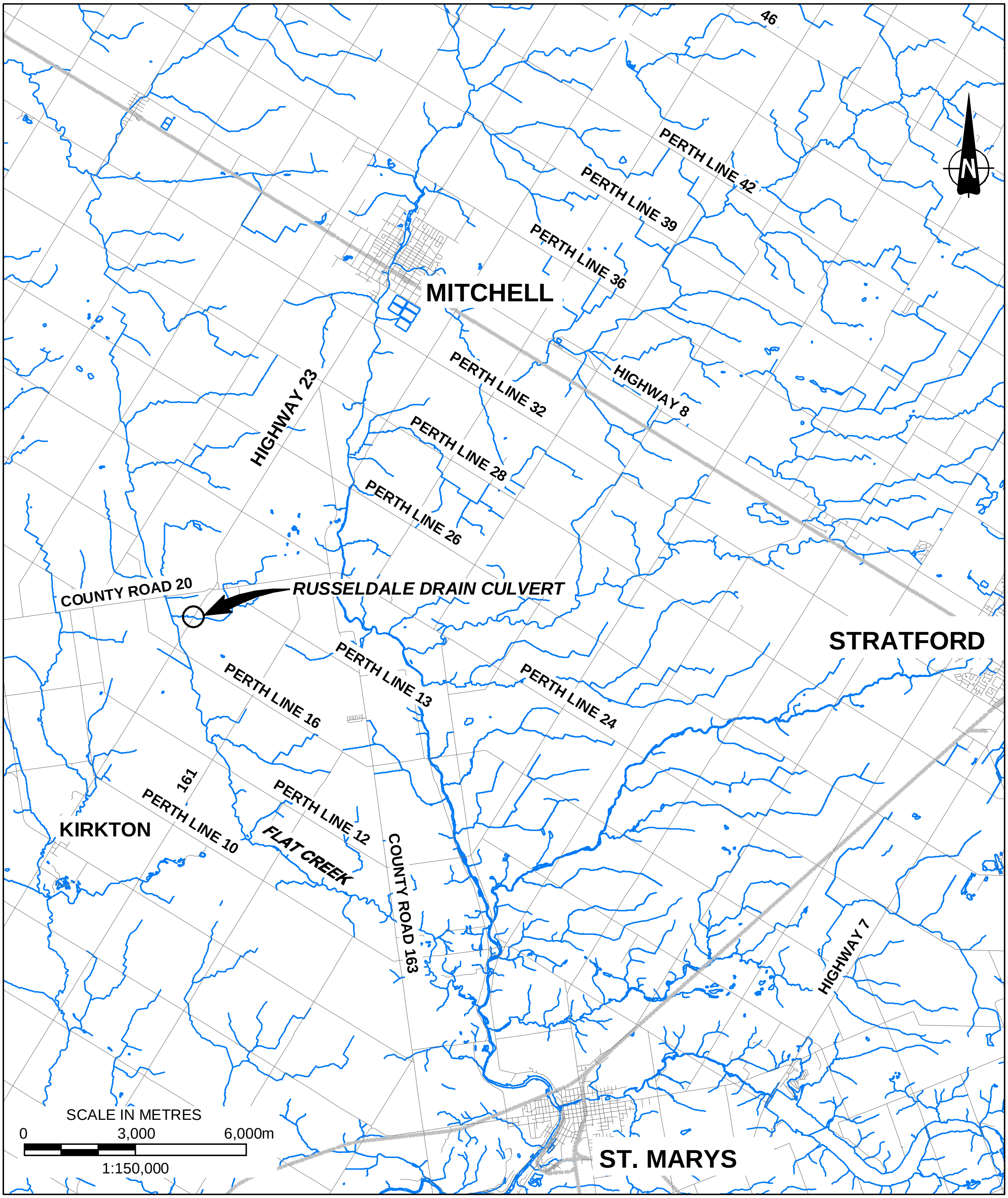
METRIC

PROJECT 10-1132-0029
W.P. 3043-06-00
LOCATION N 4805114.4 ;E 404696.3
ORIGINATED BY RA
DIST HWY 23
BOREHOLE TYPE POWER AUGER, HOLLOW STEM
COMPILED BY LMK
DATUM GEODETIC
DATE May 31, 2011
CHECKED BY

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
327.60	GROUND SURFACE				
0.00	FILL, silt, some clay, trace sand, trace gravel, some topsoil Loose Brown	1	SS	7	
		2	SS	7	
326.08 / 1.52	CLAYEY SILT, trace to some sand, trace gravel Stiff Brown	3	SS	8	
325.31 / 2.29	SAND, fine, trace silt, with silt layers Compact Grey	4	SS	20	
		5	SS	13	0 85 10 5
323.64 / 3.96	SANDY SILT, some clay, some gravel Compact Grey	6	SS	23	
		7	SS	23	
322.57 / 5.03	CLAYEY SILT TILL, some sand, trace gravel, with cobbles Hard Grey	8	SS	42	
		9	SS	40	
		10	SS	41	4 25 38 33
		11	SS	45	
318.76 / 8.84	SANDY SILT TILL, some clay, some gravel, with cobbles Very dense Grey	12	SS	121	
		13	SS	184/ 225mm	20 30 35 15
316.54 / 11.06	END OF BOREHOLE Groundwater encountered at about elev. 325.3m during drilling on May 31, 2011.				

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE (327, 326, 325, 324, 323, 322, 321, 320, 319, 318, 317); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L, WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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



REFERENCE

CANMAP STREETFILES, V2008.4.

NOTES

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

ALL LOCATIONS ARE APPROXIMATE.

PROJECT

RUSSELDALE DRAIN CULVERT
HIGHWAY 23 STRUCTURE REPLACEMENTS
GWP 3043-06-00, SITE 25-333/C

TITLE

KEY PLAN

Golder Associates
LONDON, ONTARIO

PROJECT No.		10-1132-0029	FILE No. 1011320029-7000-F03001	
			SCALE AS SHOWN	REV. 0
CADD	LMK/AMG	SEPT. 14/11	**FIGURE 1**	
CHECK				

Drawing file: 1011320029-7000-F03001.dwg   Sep 14, 2011 - 10:17am

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

CONT No.
WP No. 3043–06–00

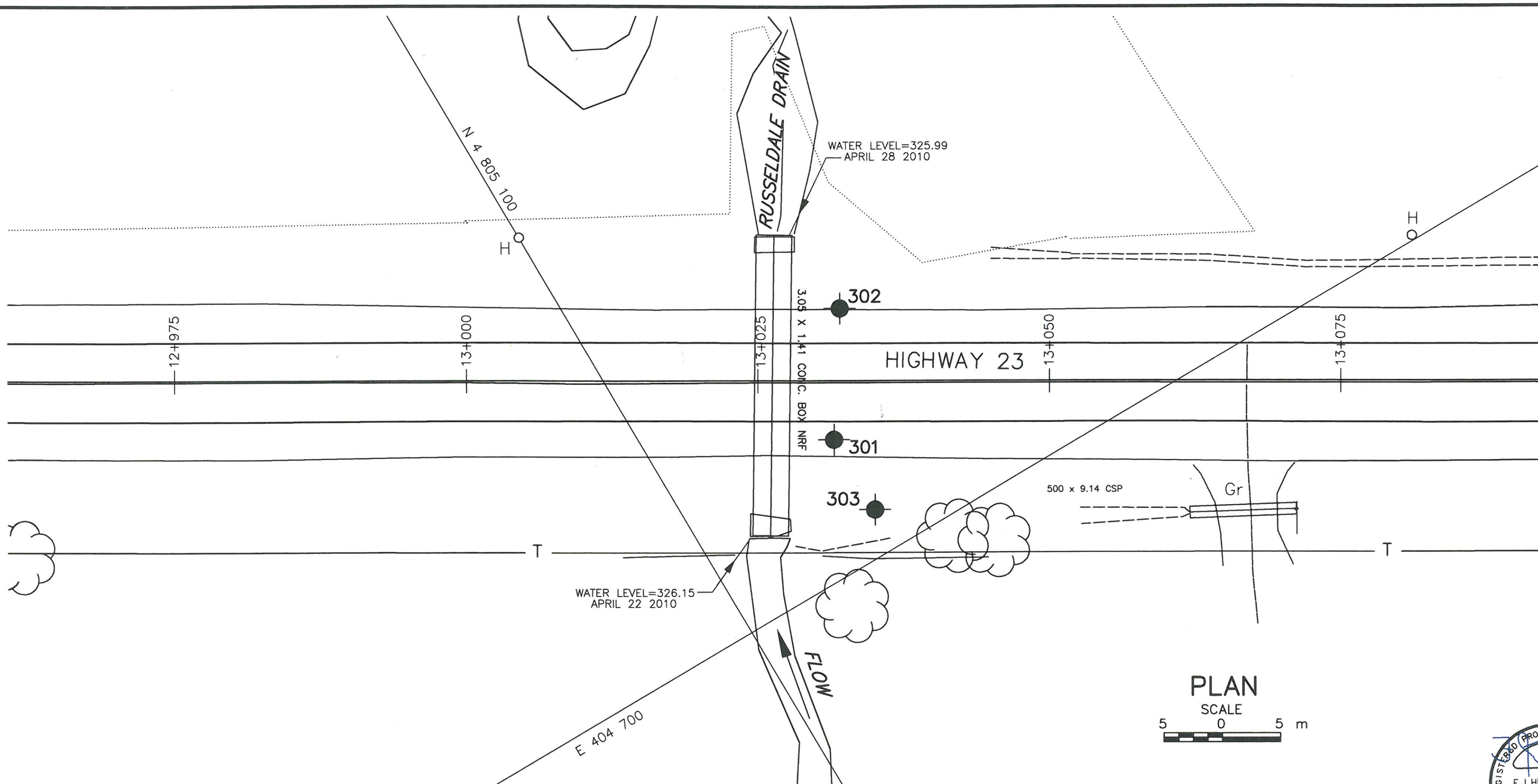
SHEET

RUSSELDALE DRAIN CULVERT

HIGHWAY 23 STRUCTURE REPLACEMENTS

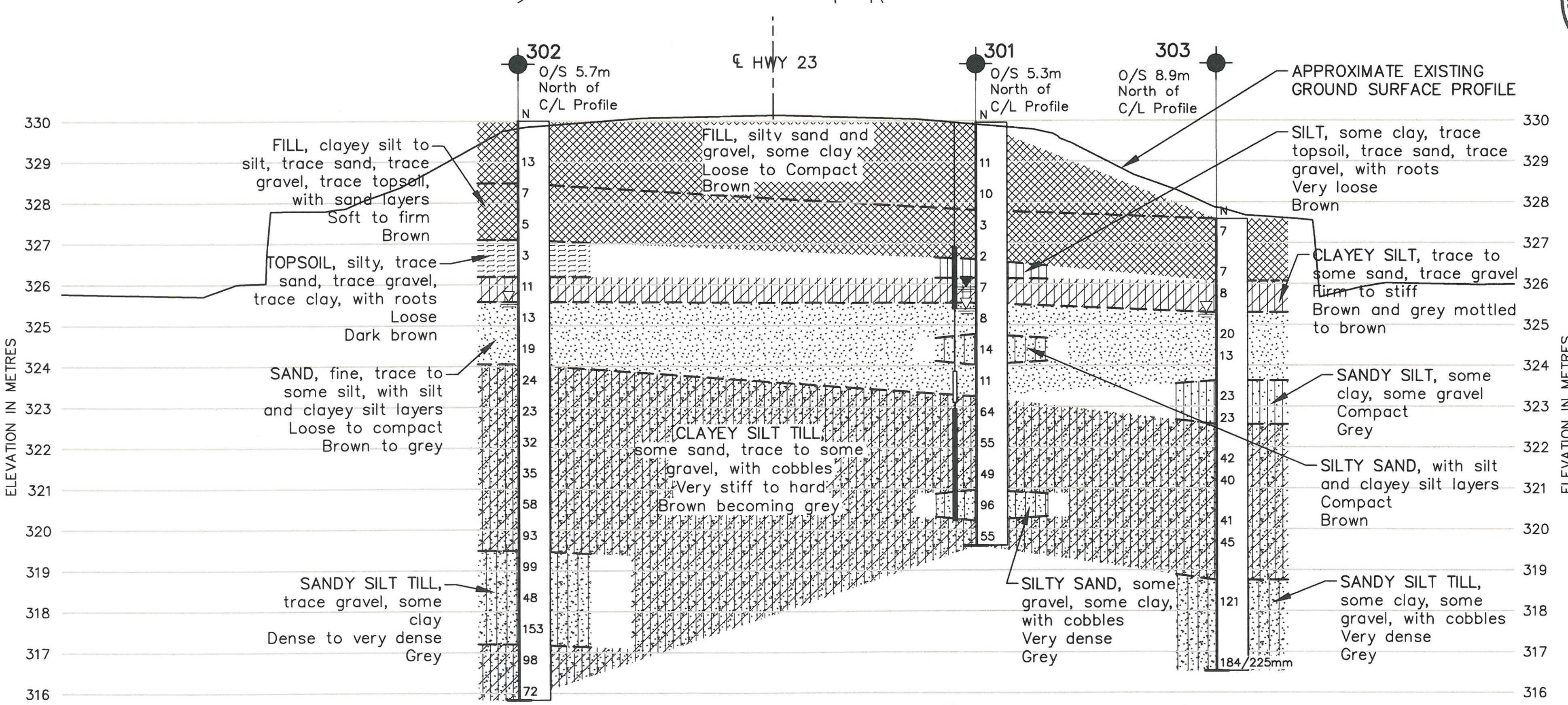
BOREHOLE LOCATIONS AND SOILS STRATA

Golder Associates Ltd.
LONDON, ONTARIO, CANADA



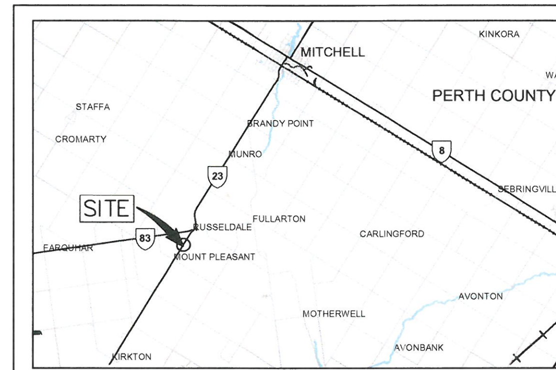
PLAN

SCALE
5 0 5 m



PROFILE ALONG ℄ OF CULVERT

SCALE
3 0 3 m



KEY PLAN

SCALE IN KILOMETRES
0 1 2

LEGEND

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

No.	ELEVATION	CO–ORDINATES (MTM ZONE 11) NORTHING	EASTING
301	329.97	4 805 144.5	404 689.4
302	330.01	4 805 120.6	404 679.9
303	327.60	4 805 114.4	404 696.3

NOTES

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

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

REFERENCE

Base plans provided in digital format by Delcan.

F.J. HEFFERNAN — REGISTERED PROFESSIONAL ENGINEER — PROVINCE OF ONTARIO

T. N.S.PITT 100132967 — LICENSED PROFESSIONAL ENGINEER — PROVINCE OF ONTARIO

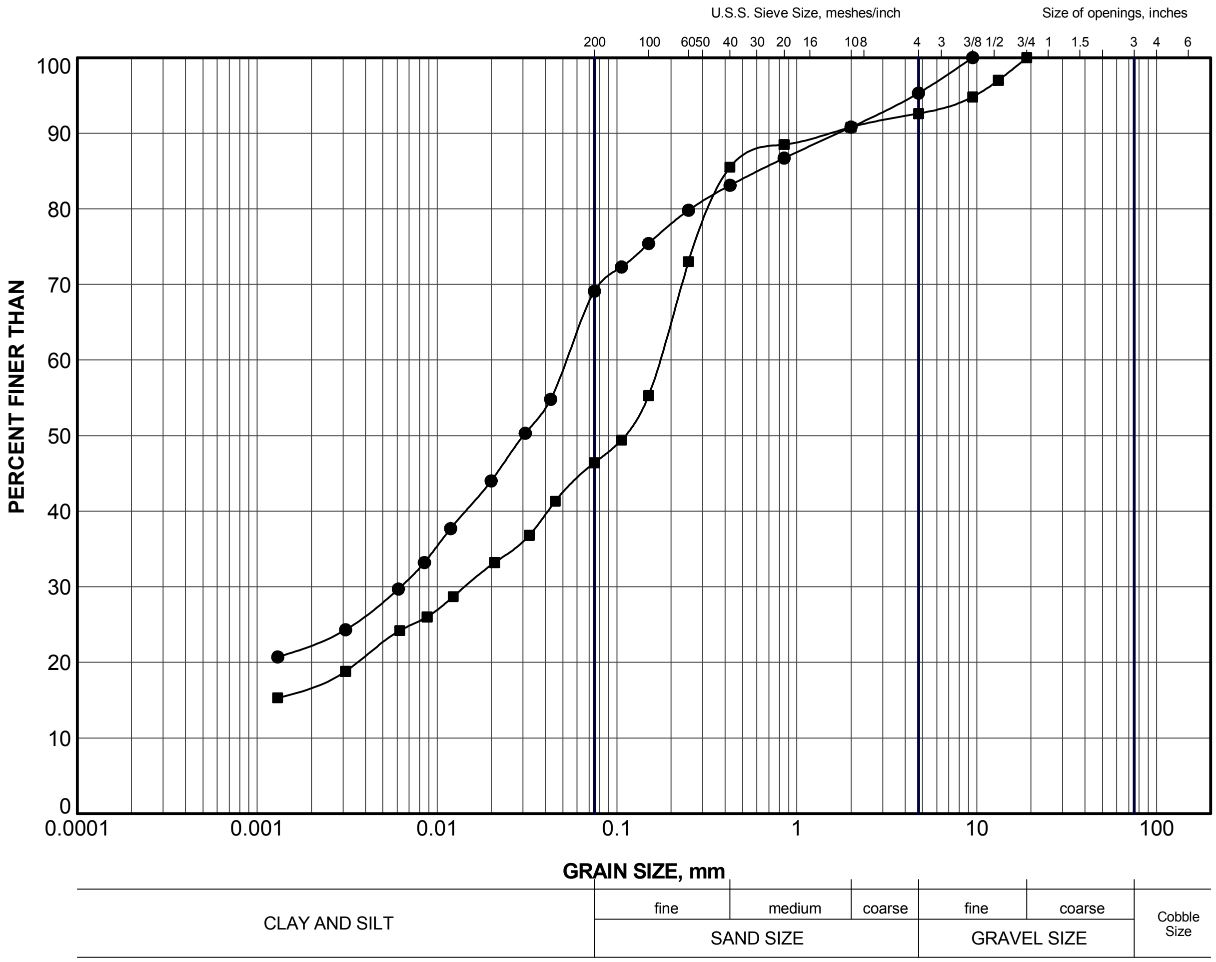
NO.	DATE	BY	REVISION

Geocres No. 40P6–25			
HWY. 23		PROJECT NO. 10–1132–0029	DIST.
SUBM'D.	CHKD.	DATE: Nov. 17/11	SITE: 25–333/C
DRAWN: LMK/DCH	CHKD.	APPD.	DWG. 1

PLOT DATE: November 22, 2011 FILENAME: N:\active\2010\1132 - Geotechnical\1132-0000\10-1132-0029 DELCAN - GWP 3043-06-00 - HWY 23\Drafting\AutoCAD files\10113200029-7000-D03001.dwg

APPENDIX A

Laboratory Test Data



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	301	3	327.4
■	302	3	327.5

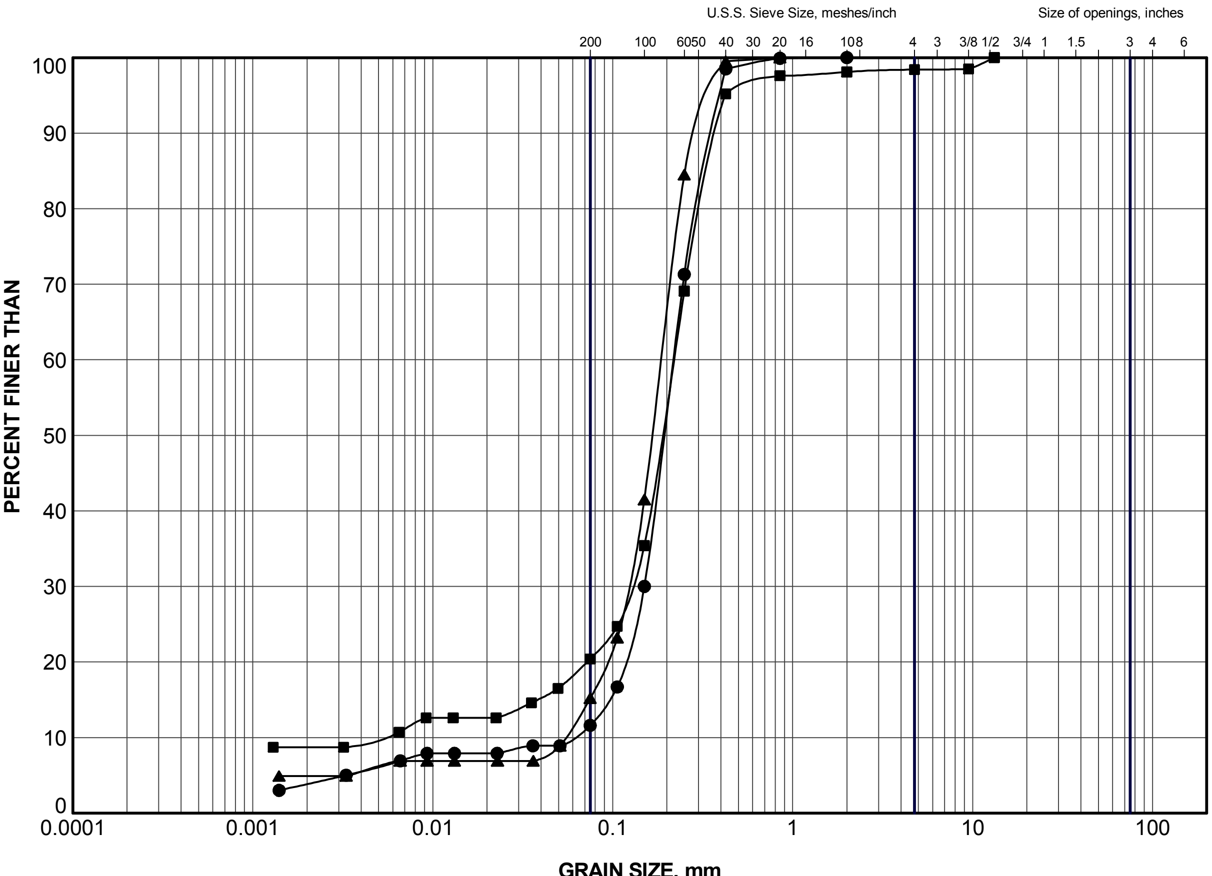
PROJECT
RUSSELDALE DRAIN CULVERT
HIGHWAY 23 STRUCTURE REPLACEMENTS
GWP 3043-06-00, SITE 25-333/C

TITLE
GRAIN SIZE DISTRIBUTION
FILL

Golder Associates
LONDON, ONTARIO

PROJECT No.	10-1132-0029	FILE No. 1011320029-7000-R030A1	
		SCALE N/A	REV.
DRAWN	DCH/AMG	SEPT. 14/11	FIGURE A-1
CHECK			

LDN_MTO_GSD-15 GLDR_LDN.GDT



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	301	6	325.2
■	302	6	325.2
▲	303	5	324.2

PROJECT

RUSSELDALE DRAIN CULVERT
HIGHWAY 23 STRUCTURE REPLACEMENTS
GWP 3043-06-00, SITE 25-333/C

TITLE

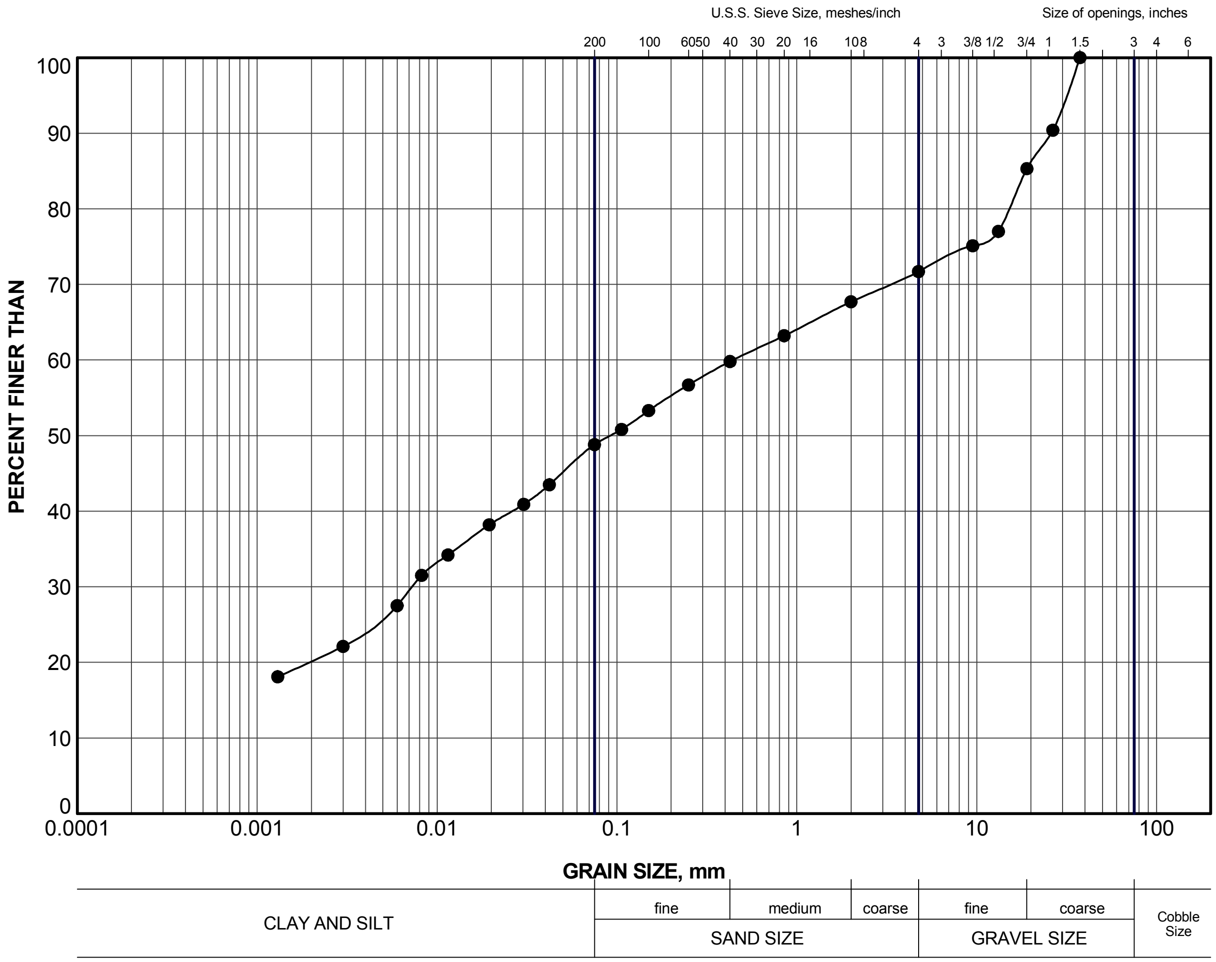
GRAIN SIZE DISTRIBUTION

SAND

Golder Associates
LONDON, ONTARIO

PROJECT No.	10-1132-0029	FILE No. 1011320029-7000-R030A2	
		SCALE N/A	REV.
DRAWN DCH/AMG	SEPT. 14/11	FIGURE A-2	
CHECK			

LDN_MTO_GSD-15 GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	301	12	320.6

PROJECT

RUSSELDALE DRAIN CULVERT
HIGHWAY 23 STRUCTURE REPLACEMENTS
GWP 3043-06-00, SITE 25-333/C

TITLE

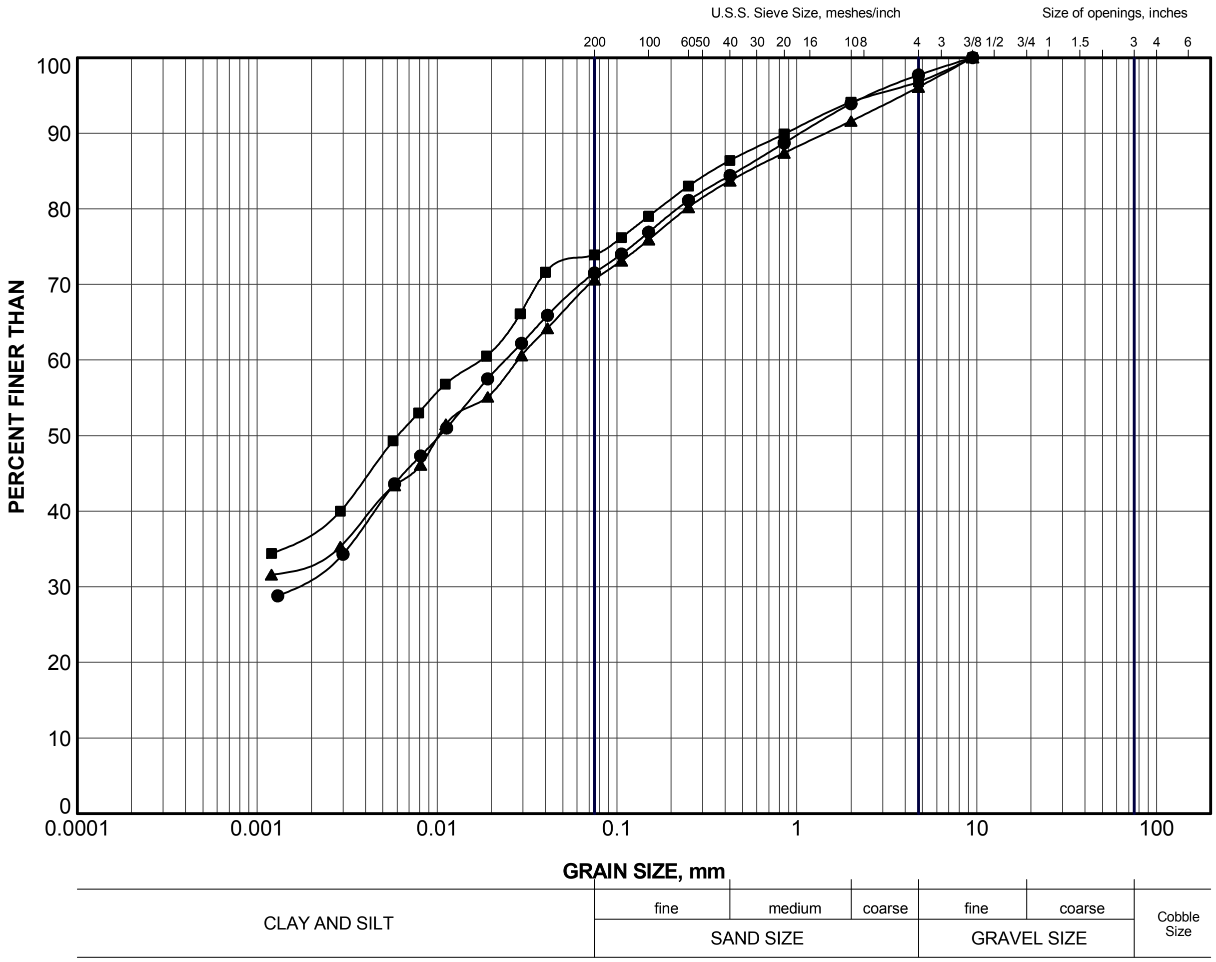
GRAIN SIZE DISTRIBUTION

SILTY SAND

Golder Associates
LONDON, ONTARIO

PROJECT No.	10-1132-0029	FILE No. 1011320029-7000-F030A3	
		SCALE N/A	REV.
DRAWN	DCH/AMG	SEPT. 14/11	FIGURE A-3
CHECK			

LDN_MTO_GSD-15 GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	301	10	322.1
■	302	10	322.2
▲	303	10	320.2

PROJECT

RUSSELDALE DRAIN CULVERT
HIGHWAY 23 STRUCTURE REPLACEMENTS
GWP 3043-06-00, SITE 25-333/C

TITLE

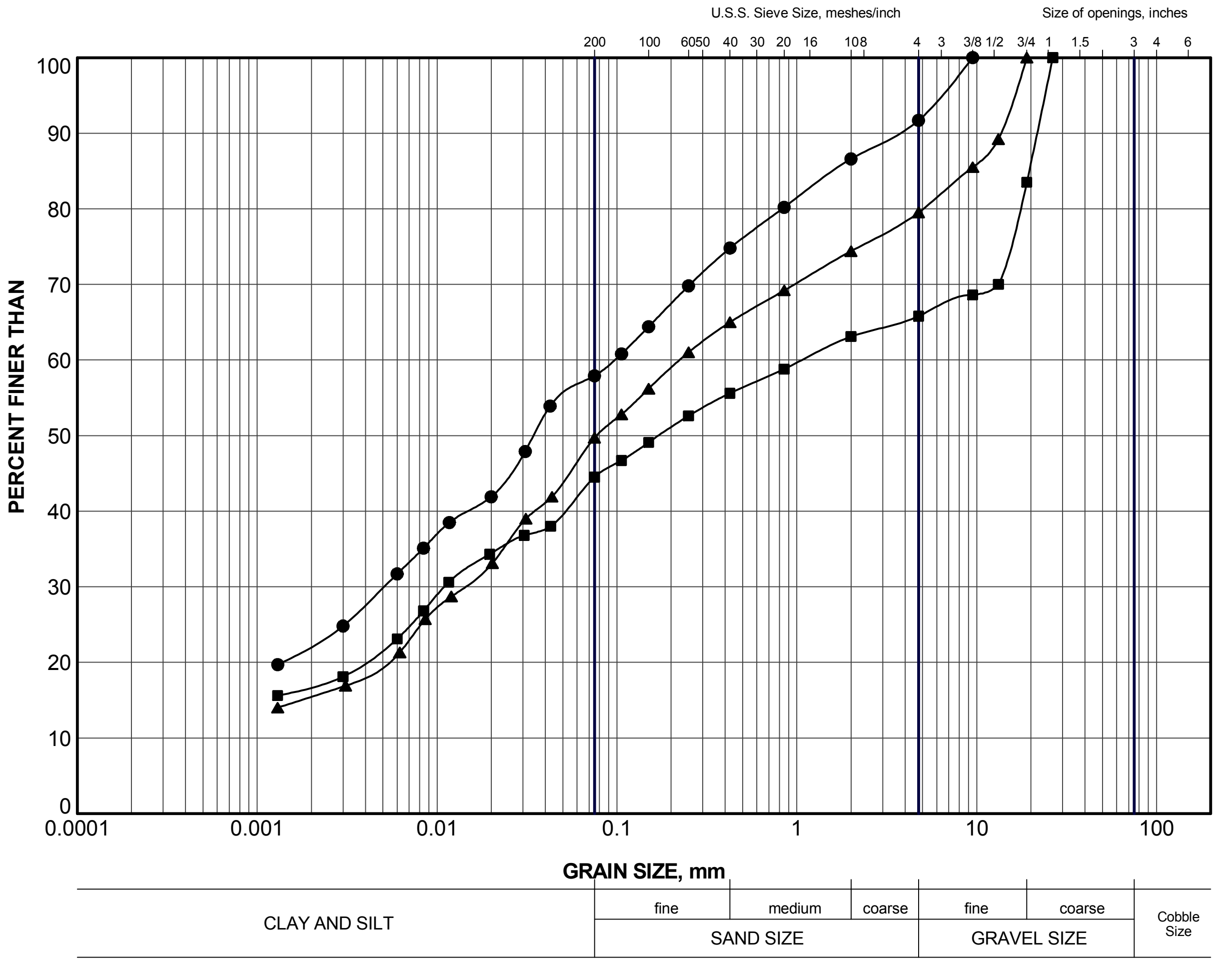
GRAIN SIZE DISTRIBUTION

CLAYEY SILT TILL

Golder Associates
LONDON, ONTARIO

PROJECT No.	10-1132-0029	FILE No. 1011320029-7000-F030A4	
		SCALE N/A	REV.
DRAWN	DCH/AMG	SEPT. 14/11	FIGURE A-4
CHECK			

LDN_MTO_GSD-15 GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	302	14	319.1
■	302	16	317.6
▲	303	13	316.7

PROJECT

RUSSELDALE DRAIN CULVERT
HIGHWAY 23 STRUCTURE REPLACEMENTS
GWP 3043-06-00, SITE 25-333/C

TITLE

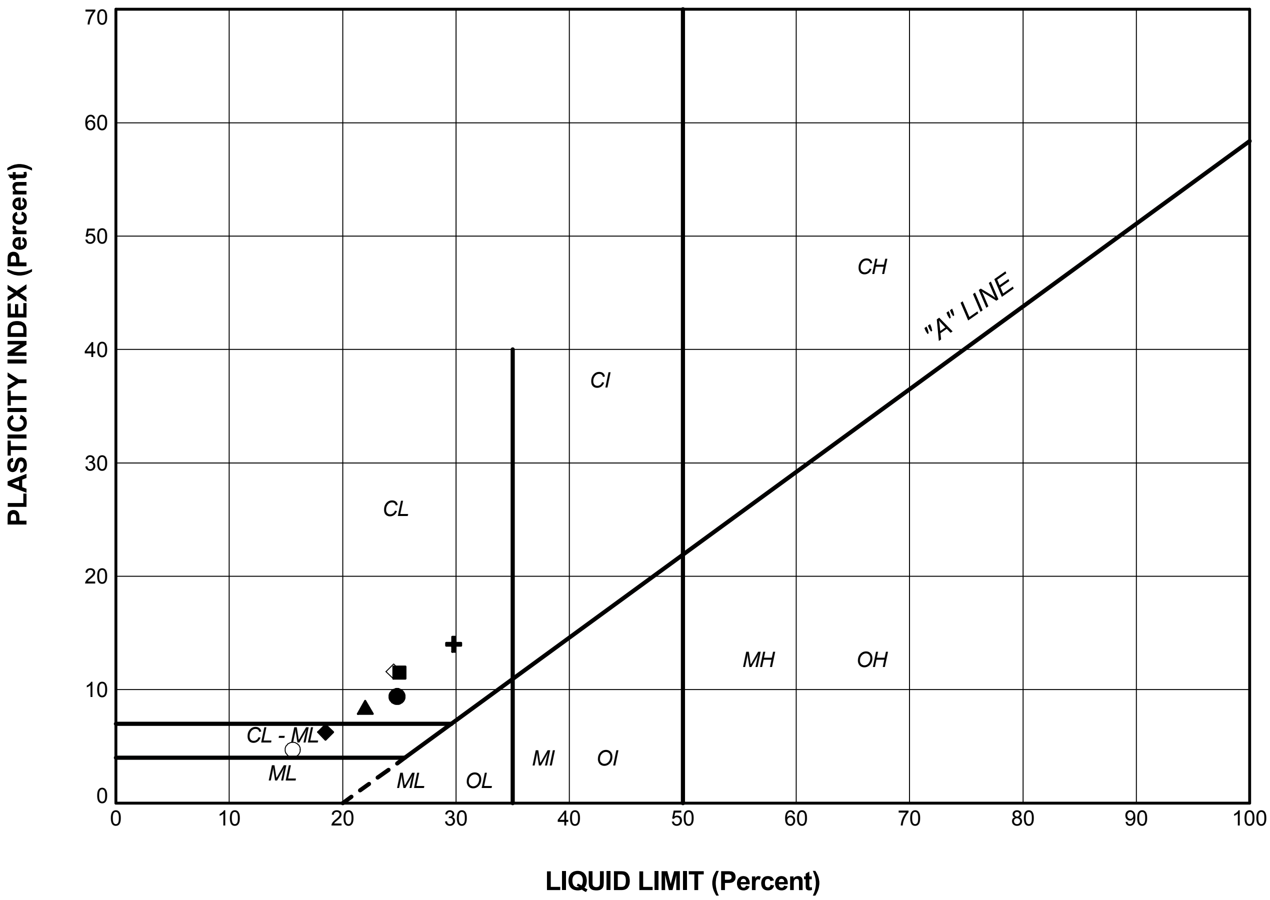
GRAIN SIZE DISTRIBUTION

SANDY SILT TILL

Golder Associates
LONDON, ONTARIO

PROJECT No.		10-1132-0029	FILE No. 1011320029-7000-F030A5	
			SCALE N/A	REV.
DRAWN	DCH/AMG	SEPT. 14/11	FIGURE A-5	
CHECK				

LDN_MTO_GSD-15 GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
Clayey FILL					
●	301	3	24.8	15.4	9.4
▲	302	3	22.0	13.6	8.5
CLAYEY SILT TILL					
■	301	10	25.0	13.5	11.5
✚	302	10	29.8	15.8	14.0
◇	303	10	24.5	12.9	11.6
SANDY SILT TILL					
◆	302	16	18.5	12.3	6.3
○	303	13	15.6	10.9	4.7

PROJECT
RUSSELDALE DRAIN CULVERT
HIGHWAY 23 STRUCTURE REPLACEMENTS
GWP 3043-06-00, SITE 25-333/C

TITLE
PLASTICITY CHART

Golder Associates
LONDON, ONTARIO

PROJECT No.	10-1132-0029	FILE No. 1011320029-7000-F030A6	
		SCALE N/A	REV.
DRAWN	DCH/AMG SEPT. 14/11	**FIGURE A-6**	
CHECK			

LDN_MTO_PI_25 GLDR_LDN.GDT

APPENDIX B

Site Photographs

Photograph 1: Russeldale Drain culvert, looking upstream at outlet.

Photograph 2: Russeldale Drain culvert, looking downstream at inlet.

Photograph 3: Russeldale Drain looking upstream of Highway 23.

n:\active\2010\1132 - geotechnical\1132-0000\10-1132-0029 delcan - gwp 3043-06-00 - hwy 23\ph 7000 - detail fdns\reports\r03 - russeldale drain culvert\1011320029-7000-r03 nov 17 11 final - app b - site photographs.docx

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

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

solutions@golder.com
www.golder.com

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

Golder Associates