



June 2014

## FOUNDATION INVESTIGATION AND DESIGN REPORT

### Swamp/Soft Ground

Reconstruction and Widening of Highway 401  
From 0.5 KM West of Regional Road 8/King Street  
Easterly to 0.5 KM East of Regional Road 24/  
Hespeler Road - 5.5 KM, GWP 4-00-00  
Ministry of Transportation, Ontario - West Region

#### Submitted to:

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

REPORT



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**FOUNDATION INVESTIGATION AND DESIGN REPORT  
SWAMP/SOFT GROUND**

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**PART A**

**FOUNDATION INVESTIGATION REPORT**

**SWAMP/SOFT GROUND**

**RECONSTRUCTION AND WIDENING OF HIGHWAY 401**

**FROM 0.5 KM WEST OF REGIONAL ROAD 8/KING STREET EASTERLY TO**

**0.5 KM EAST OF REGIONAL ROAD 24/HESPELER ROAD – 5.5 KM**

**GWP 4-00-00**

**MINISTRY OF TRANSPORTATION - WEST REGION**





### 1.0 INTRODUCTION

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

This report addresses embankment widening in areas of swamp and/or soft ground associated with the reconstruction and widening of Highway 401. The swamp areas are located at Stations 17+430 to 17+750 and Stations 18+050 to 18+100 on the north side of the highway, and Stations 17+430 to 17+720 and Stations 17+980 to 18+120 on the south side of the highway. The area immediately surrounding the Speed River Bridges has been reported under separate cover for this assignment. For the purposes of this report, Highway 401 is assumed to be oriented in an east-west direction.

The purpose of the foundation investigation is to explore the subsurface conditions at the proposed swamp/soft ground areas by drilling boreholes and carrying out in situ testing and laboratory testing on selected samples of the subsurface materials. The terms of reference for the scope of work are outlined in the MTO's Request for Proposals and in Golder Associates' proposal P0-1132-0056 dated July 23, 2010 and the revised scope letter 10-1132-0056-2000-L06 dated May 7, 2013. The work was carried out in accordance with our Quality Control Plan for Foundations Engineering dated March 8, 2012.



## 2.0 SITE DESCRIPTION

### 2.1 General

The reconstruction and widening of Highway 401 to be undertaken under GWP 4-00-00 extends from west of King Street (Regional Road 8) easterly to east of Hespeler Road (Regional Road 24) in the City of Cambridge, Region of Waterloo. This section of Highway 401 is currently a six lane divided highway oriented generally east-west. Two underpass structures for Fountain Street North and Speedsville Road, two bridges for the east and west channels of the Speed River, as well as two overhead structures for the Grand River Electric Railway (GRER) tracks and the Canadian National Railway (CNR) tracks are situated within the project limits.

The swamp/soft ground areas are within the Speed River Wetland Complex and extend from about Speedsville Road easterly to just east of Speed River on both sides of the highway. The Speed River Wetland Complex is a Provincially Significant Wetland (PSW). According to information from the Ontario Ministry of Natural Resources, the wetland complex comprises 71 per cent swamp and 29 per cent marsh.<sup>1</sup> The area immediately surrounding the Speed River Bridges has been reported under separate cover for this assignment.

The Highway 401 pavements within the swamp/soft ground areas slope upward from west to east, from elevation 279.0 metres at Station 17+430 to elevation 284.0 metres at Station 18+120. The existing off platform ground surface elevation within the swamp/soft ground area on the north side of the highway varies from elevation 277.6 metres at the west end to elevation 278.2 metres at the east end. On the south side of the highway the existing off platform ground surface elevation varies from elevation 277.5 metres at the west end to elevation 278.4 metres at the east end. Lands surrounding the swamp/soft ground areas are primarily undeveloped, some of which are used for recreational purposes.

### 2.2 Site Geology

This project lies within the physiographic region of southwestern Ontario known as the Waterloo Hills which primarily comprises sandy glacial till ridges or glacial kame moraines with outwash sands in the lower areas. The physiographic mapping indicates that the swamp/soft ground areas are situated in a former glaciofluvial spillway.<sup>2</sup> Quaternary geology mapping indicates that surficial materials in the swamp areas within the Speed River Wetland Complex consist of gravel, sand, silt, and clay stream deposits.<sup>3</sup>

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<sup>1</sup> Ontario Ministry of Natural resources, 2012. Natural Areas Reports: Speed river Wetland Complex  
<https://www.biodiversityexplorer.mnr.gov.on.ca/nhicWEB/eoNaturalAreasDetailReport.do>

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

<sup>3</sup> Karrow, P.F., 1987: Quaternary Geology of the Cambridge Area, Southern Ontario. Ontario Geological Survey, Map 2508, scale 1:50,000.



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## FOUNDATION INVESTIGATION AND DESIGN REPORT SWAMP/SOFT GROUND

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The underlying bedrock surface in the swamp/soft ground areas is typically found between elevations of 274 and 282 metres based on geologic mapping.<sup>4</sup> The depth to bedrock ranges from 3.5 to 5.0 metres. The rock formation is mapped and described as cream and brown, fine to medium crystalline dolostone of the Guelph Formation.<sup>5</sup>

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<sup>4</sup> Ontario Department of Mines, 1960: Bedrock Topography, Galt Area, Southern Ontario. Map 2030, scale 1:50,000

<sup>5</sup> Sanford, B.V., 1969: Geology, Toronto-Windsor Area, Ontario. Geological Survey of Canada, Map 1263A, scale 1:250,000.



### 3.0 INVESTIGATION PROCEDURES

The field work for the investigation was carried out between June 4 and 7, 2012, and July 11 and August 1, 2013, during which time 23 boreholes were drilled at the locations shown on the Borehole Location Plan, Drawing 1. In addition, information from the non-structural culverts report prepared for the same assignment was incorporated into this report. Data from boreholes 7, 610, 613, and 614 from Geocres Report No. 40P8-213 and from boreholes 914 and 915 from Geocres Report No. 40P8-221 was used to supplement the swamp/soft ground data. The Record of Borehole sheets for the additional boreholes are presented in Appendices C and D. The table below summarizes the locations, ground surface elevations, and depths of the boreholes.

The extent of swamp/soft ground within the Speed River Wetland Complex is generally limited to the area between the Speedville Overpass and approximately 150 metres east of the Speed River. Where space and access permitted, boreholes were advanced at the crest and toe locations of the proposed embankment widening slopes. Between Stations 17+500 and 17+750 and at about Station 18+070 on the north side of the highway, and Stations 17+450 and 18+100 on the south side of the highway the existing topography prevented access to both crest and toe locations of the proposed slopes. For these reasons, and because over the course of fourteen months the boreholes for this investigation were drilled concurrently with boreholes for other investigations associated with this assignment, the borehole numbers are not consecutive.

Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
7 (40P8-213)	4 808 565	235 994	277.57	4.75
610 (40P8-213)	4 808 501	236 009	277.05	2.16
613 (40P8-213)	4 808 518	236 010	279.65	5.26
614 (40P8-213)	4 808 550	236 006	279.63	3.89
724	4 808 581	236 610	278.42	0.52
725	4 808 585	236 610	278.24	0.36
742	4 808 500	235 988	277.50	1.98
743	4 808 505	236 039	277.47	2.29
744	4 808 491	236 041	276.81	1.13
745	4 808 493	236 091	276.85	0.55
746	4 808 505	236 091	277.59	1.89
747	4 808 505	236 141	277.51	1.46
748	4 808 492	236 142	276.78	1.37
749	4 808 496	236 191	277.52	0.67



## FOUNDATION INVESTIGATION AND DESIGN REPORT SWAMP/SOFT GROUND

Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
750	4 808 507	236 191	277.71	3.51
751	4 808 511	236 241	277.96	1.22
752	4 808 495	236 241	277.46	0.30
753	4 808 510	236 541	277.96	0.76
754	4 808 500	236 541	277.84	1.37
755	4 808 500	236 591	278.13	1.04
756	4 808 508	236 591	278.37	1.01
757	4 808 501	236 641	278.35	0.67
761	4 808 568	236 263	277.93	1.52
763	4 808 568	236 215	277.89	0.91
765	4 808 566	236 165	277.87	0.85
767	4 808 564	236 114	277.63	2.35
769	4 808 562	236 065	277.97	1.98
914 (40P8-221)	4 808 533	236 140	280.00	6.95
915 (40P8-221)	4 808 542	236 635	283.20	10.67

The investigation was carried out using track mounted drilling equipment supplied and operated by a specialist drilling contractor. In the boreholes, samples of the overburden were obtained at generally 0.75 metre intervals of depth using 50 millimetre outside diameter split spoon sampling equipment in accordance with the standard penetration test (SPT) procedures of ASTM D 1586. The recorded SPT N values are noted on the Record of Borehole sheets. According to ASTM D1586, the SPT resistance, or N value, is defined as the number of blows required by a 63.5 kilogram hammer dropped from a height of 760 millimetres to drive a split-spoon sampler a distance of 300 millimetres, after an initial 150 millimetres of penetration. In cases where it was not possible to achieve a full 450 millimetres of drive, a penetration resistance representing the number of blows to drive the sampler is recorded on the Record of Borehole. The penetration resistance obtained in the first 150 millimetres is normally neglected unless the sampler could only be driven 150 millimetres or less, in which case SPT testing was terminated after 100 blows. The results of the SPT testing as presented on the Record of Borehole sheets and in Section 4 are unmodified (not standardized for hammer efficiency, borehole diameter, rod length, etc.).

The samplers used in the investigation limit the maximum particle size that can be sampled and tested to about 40 millimetres. Therefore particles 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 native soils as discussed in the text of this report.

In addition, in-situ vane testing was carried out in accordance with ASTM D 2573 to determine the undrained shear strength of softer cohesive soils encountered in the boreholes. The boreholes were terminated between 0.3 and 3.5 metres below the existing ground surface. Groundwater conditions in the boreholes were observed



throughout the drilling operations. Groundwater monitoring standpipes were installed in boreholes 7 and 769, and piezometers were installed in boreholes 743 and 750, as indicated on the corresponding Record of Borehole sheets. The boreholes were backfilled in general accordance with current MTO procedures and Ontario Regulation 903 (as amended).

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

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



## **4.0 SUBSURFACE CONDITIONS**

### **4.1 Site Stratigraphy**

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

The boreholes drilled at the site generally encountered surficial topsoil or peat underlain by native granular soils over bedrock. The locations and elevations of the boreholes, together with the interpreted stratigraphic profiles, are shown on Drawings 1 to 3. Detailed descriptions of the subsurface conditions encountered in the boreholes are provided on the Record of Borehole sheets and are summarized in the following sections.

#### **4.1.1 Embankment Fill Materials**

Between 3.0 and 7.0 metres of existing pavement structure and embankment fill materials was encountered in boreholes 613 (40P8-213), 614 (40P8-213), 914 (40P8-221), and 915 (40P8-221). The embankment fill materials consisted of very loose to very dense sand, sand and gravel, and silty sand and gravel. Measured N values from the embankment fills ranged from 1 to greater than 100 blows per 0.3 metres. Water contents of samples of the embankment fill materials ranged from 9 to 22 per cent.

#### **4.1.2 Topsoil, Peat, and Organic Silt**

Between 100 and 1,070 millimetres of topsoil was encountered at the ground surface in boreholes 7 (40P8-213), 724, 725, and 742 to 757. An approximately 200 millimetres thick layer of topsoil was encountered beneath the embankment fill at elevation 277.0 metres in borehole 914 (40P8-221). Borehole 752 was terminated at the base of the topsoil layer due to auger refusal on inferred bedrock. The topsoil in boreholes 755 and 756 contained peat. During standard penetration testing carried for sample 1 in borehole 742, the sampler was advanced through the topsoil under the weight of the hammer.

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.

Amorphous peat was encountered at the ground surface in boreholes 610, 761, 763, 765, 767 and 769 and was between 600 and 1,370 millimetres thick. Also, a 1,530 millimetre thick layer of peat was encountered beneath



he embankment fill in borehole 613 (40P8-213). Measured N values from the peat ranged from 2 to 17 blows per 0.3 metres. During standard penetration testing carried in the peat in borehole 610 (40P8-213), the sampler was advanced through the peat under the weight of the drilling rods. The water contents of samples of the peat ranged from 97 to 278 per cent. In-situ vane shear strength testing carried out in the peat in borehole 610 yielded undrained shear strengths of 22 and 25 kilopascals (kPa) indicating a soft consistency.

Approximately 790 and 600 millimetres of organic silt was encountered beneath the peat in borehole 610 (40P8-213) and beneath a layer of sand in borehole 742 at elevations 275.7 and 275.5 metres, respectively. An N value was not measured since the sampler advanced to the underlying bedrock under the weight of the drilling rods. The water contents of samples of the organic silt were 105 and 142 per cent. In-situ vane shear strength testing carried out in the organic silt in borehole 610 (40P8-213) yielded an undrained shear strength of 10 kilopascals (kPa) indicating a very soft consistency.

### 4.1.3 Silty Sand

Loose to very dense silty sand was encountered beneath the topsoil in boreholes 7 (40P8-213), 724, 744, 747, 751, 757, and 914 (40P8-221), beneath the peat in boreholes 767 and 769, and beneath a layer of sand and gravel in borehole 746. The silty sand was between 0.2 and 1.0 metres thick and was encountered between elevations 276.2 and 278.2 metres. Cobbles were encountered in the silty sand in boreholes 724 and 757. Boreholes 724, 744, 746, 757 and 769 were terminated at the base of the silty sand layers due to refusal on inferred bedrock. Measured N values from the silty sand ranged from 10 to greater than 100 blows per 0.3 metres. Penetration resistances associated with split-spoon refusal on bedrock are not necessarily indicative of the overall relative density of the silty sand. Water contents of samples of the silty sand ranged from 7 to 27 per cent. The results of grain size distribution analyses carried out samples of the silty sand are shown on Figure A-1.

### 4.1.4 Sand

Very loose to very dense sand was encountered beneath the topsoil in boreholes 742, 743, 745, 746, 749 and 750. The sand was between 0.3 and 2.0 metres thick and was encountered between elevations 276.4 and 277.6 metres. Boreholes 745 and 749 were terminated at the base of the sand layers due to refusal on inferred bedrock. Measured N values from the sand generally ranged from 2 to 9 blows per 0.3 metres, with a single penetration resistance greater than 100 blows per 0.3 metres obtained near elevation 276 metres in borehole 743.





### 4.1.5 Sandy Silt

Approximately 0.6 metres of sandy silt was encountered beneath the topsoil in borehole 753 at elevation 277.8 metres. Borehole 753 was terminated due to refusal on inferred bedrock at the base of the sandy silt.

### 4.1.6 Sand and Gravel

Compact to very dense sand and gravel was encountered between elevations 274.5 and 277.9 metres beneath the topsoil in boreholes 725, 748, 754, 755, and 756, beneath the peat in boreholes 761, 763, 765, and 613 (40P8-213), beneath the silty sand in boreholes 747, 751 and 767, and beneath the sand in boreholes 743, 746 and 750. Where fully penetrated, the sand and gravel was generally between 0.1 and 0.9 metres thick. Borehole 750 was terminated in the sand and gravel after exploring the deposit for some 1.4 metres. Boreholes 725, 747, 748, 755, 756, 761, 763, 765 and 767 were terminated at the base of the sand and gravel layers due to refusal on inferred bedrock. The sand and gravel in boreholes 725, 743, 751, 754, 755, 756, 761, 763 and 765 was noted to be silty. Cobbles and/or boulders were encountered in the sand and gravel in boreholes 747 and 750.

Measured N values from the sand and gravel ranged from 10 to 99 blows per 0.3 metres except where split-spoon refusal was achieved at the bedrock surface. Water contents of samples of the sand and gravel ranged from 7 to 14 per cent. The results of grain size distribution analyses carried out on samples of the sand and gravel and silty sand and gravel are shown on Figures A-2 and A-3, respectively.

### 4.1.7 Bedrock

Each of the boreholes, except boreholes 7 (40P8-213), 750, 914 (40P8-221), and 915 (40P8-221) was terminated due to auger and/or split spoon refusal on inferred bedrock. The bedrock in boreholes 7 (40P8-213), 914 (40P8-221), and 915 (40P8-221) was cored between 3.6 and 4.0 metres. Boreholes 743, 751, 754, and 614 (40P8-213) were terminated after penetrating the bedrock between 0.2 and 0.4 metres. The encountered bedrock elevation varied from 274.4 to 277.9 metres and was found to slope upwards from west to east. The following table summarizes the encountered bedrock depths and elevations.

Borehole	Encountered Bedrock	
	Depth (m)	Elevation (m)
7 (40P8-213)	0.8	276.7
610 (40P8-213)	2.2	274.9
613 (40P8-213)	5.3	274.4



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Borehole	Encountered Bedrock	
	Depth (m)	Elevation (m)
614 (40P8-213)	3.8	275.8
724	0.5	277.9
725	0.4	277.9
742	2.0	275.5
743	1.9	275.6
744	1.1	275.7
745	0.6	276.3
746	1.9	275.7
747	1.5	276.1
748	1.4	275.4
749	0.7	276.9
751	1.0	277.0
752	0.3	277.2
753	0.8	277.2
754	1.1	276.8
755	1.0	277.1
756	1.0	277.4
757	0.7	277.7
761	1.5	276.4
763	0.9	277.0
765	0.9	277.0
767	2.3	275.3
769	2.0	276.0
914 (40P8-221)	3.4	276.6
915 (40P8-221)	7.0	276.3

The bedrock in boreholes 7 (40P8-213), 914 (40P8-221), and 915 (40P8-221) was cored using NQ sized coring equipment. The Rock Quality Designation (RQD) for three runs of rock core from each borehole ranged from 0 to 100 per cent, indicating very poor to excellent rock quality. An average RQD of 60 per cent for nine runs of core indicates fair rock quality.



### 4.2 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling and sampling. Groundwater was encountered in boreholes 7, 610, 742 to 748, 750, 751, 753 to 757, 761, 763, 765, 767, and 769. The encountered depths and elevations are summarized in the following table.

Borehole	Ground Surface Elevation (m)	Encountered Groundwater	
		Depth (m)	Elevation (m)
7 (40P8-213)	277.6	0.2	277.4
610 (40P8-213)	277.1	0.0	277.1
613 (40P8-213)	279.7	1.8	277.9
614 (40P8-213)	279.6	2.4	277.2
724	278.4	*	*
725	278.2	*	*
742	277.5	0.0	277.5
743	277.5	0.8	276.7
744	276.8	0.0	276.8
745	276.9	0.1	276.8
746	277.6	0.8	276.8
747	277.5	0.8	276.7
748	276.8	+0.1	276.9
749	277.5	*	*
750	277.7	0.6	277.1
751	278.0	1.1	276.9
752	277.5	*	*
753	278.0	0.6	277.4
754	277.8	0.9	276.9
755	278.1	0.6	277.5
756	278.4	0.7	277.7
757	278.4	0.4	278.0
761	277.9	0.4	277.5
763	277.9	0.3	277.6
765	277.9	0.5	277.4
767	277.6	0.0	277.6



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Borehole	Ground Surface Elevation (m)	Encountered Groundwater	
		Depth (m)	Elevation (m)
769	278.0	1.4	276.6
914 (40P8-221)	280.0	2.7	277.3
915 (40P8-221)	283.2	4.7	278.5

\* Groundwater level not established.

+ Groundwater level above ground surface.

Groundwater monitoring standpipes were installed in boreholes 7(40P8-213) and 769 and piezometers were installed in boreholes 743 and 750. The measured groundwater depths and elevations are summarized in the following table.

Borehole	Ground Surface Elevation (m)	Measured Groundwater		
		Date	Depth (m)	Elevation (m)
7 (40P8-213)	277.57	*July 31, 2013	0.56	277.01
		Aug. 12, 2013	0.41	277.16
		**Oct.17, 2013	0.28	277.29
743	277.47	*June 4, 2012	0.76	276.71
		Jan. 25, 2013	0.63	276.84
		Nov. 20, 2013	0.61	276.86
750	277.71	*June 7, 2013	0.63	277.08
		Jan. 25, 2013	0.77	276.94
		Nov. 20, 2013	0.74	276.97
769	277.97	*Aug. 1, 2013	0.46	277.51
		Aug. 12, 2013	0.51	277.46
		Nov. 20, 2013	0.46	277.51

\* Following installation.

\*\* Prior to decommissioning.

The above-noted water levels are not considered to be representative of the long-term, stabilized groundwater conditions. Based on the encountered and measured groundwater levels, the inferred groundwater level is expected to generally follow the original ground surface. On the south side of the highway, the inferred groundwater level is expected to be near elevation 277.0 metres from Speedville Road to the west Speed River Channel. East of Speed River the groundwater level varies from elevation 277.5 to 278.0 metres near Station 18+100. On the north side of the highway, the groundwater level is expected to be at about elevation 277.5 metres with groundwater levels between Stations 18+050 and 18+100 expected to be below elevation 277.9 metres, or the termination depth of boreholes 724 and 725. Groundwater levels are expected to fluctuate seasonally and are expected to be higher during periods of sustained precipitation or during spring melt



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## FOUNDATION INVESTIGATION AND DESIGN REPORT SWAMP/SOFT GROUND

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conditions. In wetland areas within the Speed River floodplain, groundwater levels will also be influenced by the flow in the river channels.



### 5.0 MISCELLANEOUS

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

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

#### GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED

Nicole A. Gould, P.Eng.

ORIGINAL SIGNED

Azmi, M. Hammoud, P.Eng.  
Associate

ORIGINAL SIGNED

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

NG/DUP/AMH/cr

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**FOUNDATION INVESTIGATION AND DESIGN REPORT  
SWAMP/SOFT GROUND**

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**PART B**

**FOUNDATION DESIGN REPORT**

**SWAMP/SOFT GROUND**

**RECONSTRUCTION AND WIDENING OF HIGHWAY 401**

**FROM 0.5 KM WEST OF REGIONAL ROAD 8/KING STREET EASTERLY TO**

**0.5 KM EAST OF REGIONAL ROAD 24/HESPELER ROAD – 5.5 KM**

**GWP 4-00-00**

**MINISTRY OF TRANSPORTATION - WEST REGION**



## **6.0 ENGINEERING RECOMMENDATIONS**

This section of the report provides our recommendations on the foundation aspects of the design of embankments constructed within the swamp/soft ground areas. For the purpose of this report, soft ground includes Marshland and any other wetland zone with compressible soils including peat and organic silt. The recommendations are based on our interpretation of the factual information obtained during the investigation. Geotechnical design assumptions were based on the preliminary cross-sections provided by Delcan. It should be noted that the interpretation and recommendations are intended for use only by the design engineer. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods, and scheduling.

### **6.1 General**

This report addresses the construction of embankment widenings within soft ground areas within the wetland. No areas of high fill placement have been identified within these areas. The swamp/soft ground areas within the Speed River Wetland Complex extend from about Speedville Road to just east of Speed River. Linearly, these areas are located from Station 17+430 to 17+750 and Station 18+050 to 18+100 on the north side of the highway, and from Station 17+430 to 17+720 and Station 17+980 to 18+120 on the south side of the highway. The area immediately surrounding the Speed River bridges has been reported under separate cover for this assignment. For the purposes of this report Highway 401 is assumed to be oriented in an east-west direction.

The elevation of the Highway 401 pavements within the swamp/soft ground area slopes upward from west to east, from elevation 279.0 metres at Station 17+430 to elevation 284.0 metres at Station 18+120. The existing off platform ground surface elevation within the swamp area on the north side of the highway varies from elevation 277.6 metres at the west end to elevation 278.2 metres at the east end. On the south side of the highway, the existing off platform elevation varies from elevation 277.5 metres at the west end to elevation 278.4 metres at the east end.

### **6.2 Embankments**

Based on the cross sections provided by Delcan, it is understood that within the swamp/soft ground areas the highway platform is to be widened by up to 14 metres on each side and the embankments will range from about 2 to 4 metres in height. Side slopes of the proposed cross sections will have inclinations no steeper than 2 horizontal (H) to 1 vertical (V). The cross sections show the existing side slopes maintained during embankment widening in accordance with Ontario Provincial Standard Drawing (OPSD) 203.030. At the time of construction of the existing embankment, the procedure was to remove the organic soil from below the footprint of an





embankment core with side slopes inclined at 1.5H to 1V from the shoulder of the roadway. Borehole 915 (40P8-221) advanced in the highway median east of Speed River, and borehole 614 (40P8-213) advanced at the north crest of the existing embankment indicate removal of the organic soils. However, borehole 914 (40P8-221) advanced in the highway median west of Speed River, and borehole 613 (40P8-213) advanced at the south crest of the existing embankment suggest that embankment fills at these locations were constructed over organic soil.

Typical stability and settlement mitigation options considered for construction of embankments over swamps include full sub-excavation of organic soils, preloading or surcharging with toe berms, staged construction, and the use of wick drains or lightweight fill. Based on the subsurface conditions encountered in the boreholes, it is recommended that full sub-excavation of the organic soils is utilized. In this regard, it is recommended that the toe of the existing embankment be sub-excavated back in 3 metre wide strips to a 1H to 1V slope from the crest of the embankment to remove any trapped organic soil in accordance with OPSD 203.020. Due to the relatively shallow depths of organic soils encountered, the granular nature of the native soils, and the generally shallow depth to bedrock, stability and settlement issues are not anticipated.

Embankment fill alternatives include rock fill, granular fill, and expanded polystyrene (EPS) lightweight fill; however, based on the existing embankment fills being granular, local availability of granular fill materials, and the relatively shallow depth to competent founding soils and bedrock, it is anticipated that the widened embankments will be constructed using granular fill. Detailed recommendations for embankment construction are presented in Section 6.5.

### 6.2.1 Stability

Due to the relatively shallow depth to bedrock in the investigated areas and the granular nature of the native soils, no stability issues are anticipated for the embankment widenings in the swamp areas, provided all organic materials are removed from the embankment widening subgrades. Critical sections from each segment of swamp/soft ground were selected for slope stability analyses using SLOPE/W, a commercially available software package for limit equilibrium stability analyses. The critical cross-sections selected for slope stability and settlement analyses correspond to the greatest new embankment height and/or the maximum thickness of loose soils and are discussed in the following report sections. A factor of safety against instability of at least 1.3 was found to be available for the slopes as presented in the cross sections. For slope stability analyses, it has been assumed that removal of organic materials and subgrade preparation are carried out as described in this report. The results of the stability analyses conducted for the critical sections are discussed in Section 6.3 and are presented in Appendix B.



### 6.2.2 Settlement

The depth of the native granular overburden was found to be generally minimal (less than 2 metres) and proposed fill thicknesses are relatively low; therefore, it is anticipated that the settlement of the foundation soils will occur over a relatively short time period during construction. As such, settlement will be negligible in most of the swamp areas provided all organic deposits are removed from below the proposed embankment widenings including the existing side slopes. Isolated areas of deeper soil deposits and/or loose soils were encountered during the foundation investigation and will be subject to marginally greater settlements. Settlement of the founding soils at critical sections was calculated using the modified Hough's method for calculating immediate settlement of embankments on cohesionless soils, the results of which are discussed in Section 6.3, below. Additional settlement of the embankment fill materials should be anticipated.

### Settlement Performance Requirements

The MTO restricts the total post-construction settlement of the paved portion of a roadway for embankment widenings on freeways to 50 millimetres over a 20 year period. The settlement analyses have indicated that settlement across the areas of swamp/soft ground will be well within this criteria.

## 6.3 Site Specific Recommendations

### 6.3.1 South Side of Highway 401 – Station 17+430 to 17+720

The embankments along this section of Highway 401 will be widened 11 to 12 metres and up to about 3.0 metres in height. The subsurface conditions in this area are presented on Drawing 2, Sections A-A and B-B. The topography of this area is generally flat and low-lying marshland.

The subsurface soils encountered in the boreholes advanced in this section of marsh generally comprised between 0.2 and 1.1 metres of surficial topsoil underlain by between 0.0 to 1.5 metres of native granular soils over bedrock. Also, boreholes 610 (40P8-213), 613 (40P8-213), and 742, advanced at about Station 17+450, encountered 1.4 to 2.1 metres of very soft to firm peat and/or very soft organic silt. Borehole 750, advanced at about Station 17+650, encountered 3.4 metres of granular materials and did not intercept the bedrock surface. The native granular soils included very loose to compact sand and silty sand and very dense sand and gravel. The bedrock surface was between elevations 275.4 and 277.2 metres, or about 0.3 to 2.0 metres below the ground surface except near Station 17+650Rt where the depth to bedrock is greater. The inferred groundwater level in the marsh is about elevations 277.0 metres, or between 0.1 metres above the ground surface to 1.0 metres below the ground surface in the widened areas.



It is recommended that the surficial topsoil be sub-excavated and the embankment widening be founded on the native loose to very dense silty sand, sand and gravel, or the bedrock. Also, the buried organic silt and peat in the area of boreholes 610 (40P8-213) and 742 should be fully sub-excavated. If inspection of the embankment subgrade near Station 17+500 indicates a significant amount of organic material is contained within the surficial loose sands, this should be sub-excavated to elevation 276 metres. It is anticipated that removal of organic materials will require excavation below the groundwater level from about Station 17+430 to 17+625.

The critical section for slope stability selected within this area is at Station 17+450, near borehole 742, where excavation up to 2.0 metres is expected for full removal of organic materials, and total maximum height of new fill will be about 3.0 metres. The existing embankment was constructed on a 1.5 metre thick peat layer. A factor of safety of 1.8 was calculated for the embankment side slope. The results of the stability analysis carried out for this section is shown on Figure B-1 in Appendix B.

Negligible settlements of the native soils other than the organic deposits are anticipated except in areas where loose saturated native soils form the subgrade. Settlements of the native granular soils in the range of 20 to 25 millimetres are expected near boreholes 743 (at Station 17+500) and 750 (at Station 17+650) where near-surface loose sands are present. Construction of a working platform and/or restrictions on use of heavy equipment as outlined in Section 6.4 will likely be required where loose saturated sands form the subgrade. Full sub-excavation of the loose sand near Station 17+650 will reduce settlement but may not be economical given the high groundwater level.

### 6.3.2 North Side of Highway 401 – Station 17+430 to 17+750

The section of wetland on the north side of the highway, west of Speed River, which extends from Station 17+430 to 17+750, will have embankment widenings of between 12 and 14 metres and up to about 3.2 metres in height. The subsurface conditions in this area are shown on Drawing 3, Section C-C. The topography of this area is generally flat and low-lying marshland.

The subsurface soils encountered in the boreholes advanced in this area typically comprised between 0.6 and 1.4 metres of surficial peat underlain by between 0.1 and 1.5 metres of native granular soils over bedrock. The native granular soils included loose to very dense silty sand and compact to very dense silty sand and gravel. Peat was not found at borehole 7 (40P8-213) where a 0.4 metre thick topsoil layer overlaid 0.5 metres of very dense silty sand over bedrock or at borehole 614 (40P8-213). The bedrock surface was encountered between elevations 275.3 and 277.0 metres, or about 0.8 to 2.3 metres below the ground surface. The groundwater level in this marshy area has been inferred at about elevation 277.5 metres, or some 0.1 to 0.6 metres below the ground surface.

It is recommended that the surficial peat and topsoil be sub-excavated in the widened areas and below the existing side slopes and the embankment widening be founded on the native loose to very dense silty sand to silty sand and gravel or the bedrock. It is anticipated that removal of organic materials will require excavation below the groundwater level throughout this portion of the marsh.



The critical section for slope stability selected within this swampy area is at Station 17+575, near borehole 767, where excavation up to 0.8 metres is expected for full removal of organic materials, and total maximum height of new fill will be about 3.2 metres. A factor of safety of 2.4 was calculated for the embankment side slope. The results of stability analysis carried out for this section is presented on Figure B-1 in Appendix B.

Settlement of the native soils due to proposed embankment widenings is anticipated to be negligible except in localized areas. In the vicinity of Stations 17+575 and 17+725, near boreholes 767 and 761, respectively, settlement of the loose granular soils will be less than 10 millimetres. Some trafficability problems may occur during subgrade preparation and placement of the lowermost lifts of embankment fill near Station 17+575. The saturated silty sand foundation materials can be left in place if the recommendations in Section 6.4 are adhered to.

### 6.3.3 South Side of Highway 401 – Station 17+980 to 18+120

The embankment widenings on the south side of the highway, east of Speed River, from Station 17+980 to 18+120, will be 10 to 11 metres wide and up to about 3.5 metres in height. The subsurface conditions in this area can be seen on Drawing 3, Sections D-D and E-E. The topography of this area is generally flat and low-lying. This portion of the Speed River Wetland Complex is a transition area from a marsh to a swamp with the vegetation consisting of shrubs, grasses, and trees.

The subsurface soils encountered in the boreholes advanced in this area generally comprised between 0.2 and 0.8 metres of surficial topsoil underlain by between 0.3 and 0.9 metres of native granular soils over bedrock. The native granular soils included sandy silt, silty sand, and silty sand and gravel. The bedrock surface was encountered between elevations 276.8 and 277.8 metres, or about 0.7 to 1.1 metres below the ground surface. The groundwater level in this portion of the wetland was inferred to be between elevations 277.0 metres, near Station 18+000, and 278.0 metres, near Station 18+100, or between 0.6 and 1.0 metres below the ground surface.

It is recommended that the surficial topsoil be sub-excavated and the embankment widening be founded on the native silty sand, sandy silt, silty sand and gravel, or the bedrock. It is anticipated that removal of organic materials will require excavation to the groundwater level east of Station 18+025.

Station 18+050, near boreholes 755 and 756, was selected as the critical section for slope stability. At this location excavation up to 0.8 metres is expected for full removal of organic materials including below the existing side slopes, and the total maximum height of new fill will be about 3.5 metres. A factor of safety of 1.8 was calculated for the embankment side slope. The results of stability analysis carried out at this section are shown on Figure B-2 in Appendix B.

The depth of the granular overburden is less than 1 metre. As such, negligible settlement of the native soils is anticipated in this area.



### 6.3.4 North Side of Highway 401 – Station 18+050 to 18+100

The wetland area on the north side of the highway, east of Speed River, which extends from Station 18+050 to 18+100, will have embankment widenings of about 10.0 to 10.5 metres wide and up to about 3.5 metres in height. The subsurface conditions in this area are shown in profile on Drawing 3, Section F-F. This swampy area is generally flat and low-lying and trees are the predominant vegetation.

The subsurface soils encountered in the boreholes advanced in this swamp area comprised about 0.3 metres of surficial topsoil underlain by about 0.2 metres of native granular soils over bedrock. The native granular soils consisted of silty sand and silty sand and gravel. The bedrock surface was encountered at elevation 277.9 metres, or about 0.4 to 0.5 metres below the ground surface. The groundwater level in this swamp area was not encountered in boreholes 724 and 725 and has been assumed to be below elevation 277.9 metres, or the termination depth of these boreholes.

It is recommended that the surficial topsoil be sub-excavated and the embankment widening be founded on the native silty sand, silty sand and gravel, or the bedrock. The groundwater level is not expected to be encountered in this swamp area during removal of organic materials.

Slope stability analysis was carried out at Station 18+070, near boreholes 724 and 725. The proposed widening will require full removal of up to 0.3 metres of organic materials, and placement of new embankment fill to a total maximum height of new fill of about 3.5 metres. A factor of safety of 2.3 was calculated for the embankment side slope. The results of stability analysis carried out for this section is presented on Figure B-2 in Appendix B.

The depth of the granular overburden is less than 1 metre. As such, negligible settlement of the native soils is anticipated in this area.

## 6.4 Subgrade Preparation

A significant portion of the Highway 401 embankment widening will occur in sensitive wetland areas. Groundwater control measures as discussed in Section 6.6 should be implemented prior to and during the site preparation phase.

Based on the subsurface conditions encountered in the boreholes, the thickness of organic soils in the swampy and marshy areas generally range from 0.2 to 1.4 metres; therefore, the excavation method and hydraulic backhoes for removal of organic materials and other compressive deposits is considered suitable for this site. Following clearing and grubbing of the embankment widening areas, all unsuitable subgrade materials including layers of topsoil, peat, and organic silt, as noted previously, and all frozen materials should be stripped from the plan limits of the proposed works. The organic soils should be removed in accordance with Ontario Provincial standard Specifications (OPSS) 209, OPSS.PROV 206, and OPSD 203.020.

The exposed soil or rock embankment foundation should be inspected under the direction of a geotechnical Quality Verification Engineer (QVE) prior to fill placement. Proof-rolling of the embankment earth foundation material may not be feasible especially where saturated fine, loose to compact sands are present. The strength



of the subgrade may be increased by provision of temporary ditches installed prior to the start of embankment construction. The use of heavy construction equipment in such areas should be limited until a working platform consisting of a minimum thickness of 1.0 metre of Granular B (Type II or coarse Type III) is placed. This working platform can be prepared by end dumping and bulldozing the embankment material with nominal to no compaction. Any areas of unsuitable subgrade soils identified should be sub-excavated and replaced with Select Subgrade Materials (SSM) only above a minimum distance of 600 millimetres above the groundwater level. Backfill placed on saturated subgrades including over-excavated areas should consist of Granular B Type II, or a coarse Granular B Type III.

### 6.5 Embankment Construction

Except for the top approximately 0.5 metres, where Granular A and B Type III material will be placed for the pavement structure, embankment fills placed 600 millimetres or more above the groundwater level should consist of an approved granular borrow such as SSM. Consideration may be given to using native granular material excavated from cut areas of this project provided it meets the gradation requirements of SSM.

Where embankment construction is to be carried out in wet areas, including up to 600 millimetres above the groundwater level, the embankment fill should consist of Granular B Type II or a coarse Granular B Type III. In several areas embankment construction may not be possible without placement of a working platform as discussed in Section 6.4. Additional short-term settlement and deformation of embankment fill materials placed below the water level should be anticipated. Short-term settlement of un-compacted granular embankment fill placed below the water level in the range of 10 to 15 per cent of the un-compacted thickness should be expected. The grading contractor should carry out a program of settlement monitoring to ensure deformations have subsided prior to constructing the overlying pavement structure. A Non-Standard Special Provision (NSSP) should be included in the Contract Documents to indicate the need for settlement monitoring.

Embankment fill materials should be placed in maximum 300 millimetre thick loose lifts, properly benched into the existing embankments in accordance with OPSD 208.010, and compacted. Upon completion of filling to the pavement subgrade level, the embankment side slopes should be trimmed to a final inclination of 2H to 1V or flatter. All grading and embankment construction should be conducted in accordance with OPSS 206 (November 2013) and MTO Special Provision (SP) 105S10 (amendment to OPSS 501).

Because a significant portion of the embankment widening will occur in a PSW, environmental considerations and regulations may exist which could affect the proposed works. Environmental considerations are beyond the scope of this report and have not been discussed. A NSSP should be included in the Contract Documents to alert the contractor to any environmental considerations for excavation and embankment construction within a PSW that may exist.





## **6.6 Groundwater Control**

Excavations for removal of organic material or soft soils will extend below the groundwater level in parts of the swamp areas. Groundwater flow into the open excavations should be anticipated. Unwatering of the excavations may be advantageous for the placement of embankment fill material, but may be restricted due to environmental regulations concerning construction in a PSW. As such, embankment fill materials placed below the groundwater level should consist of a coarse granular material as described above. If allowed, temporary and/or permanent ditches should be constructed to lower the groundwater levels. In addition, it is preferred that the work be carried out in the summer or early fall during periods of low precipitation. Surface water should be directed away from the excavations at all times. A NSSP should be included in the Contract Documents to alert the contractor to the need for excavation below the groundwater level and for groundwater control.

## **6.7 Excavations**

Excavations for embankment widening subgrade preparation may encounter the existing embankment fill materials, organic materials such as topsoil, peat, and organic silt, native granular soils, and bedrock. Temporary open cut slopes within these soils should be maintained no steeper than 1H to 1V and localized sloughing and ground movements should be expected. Where excavations extend below the groundwater level in granular soils, it may be necessary to use flatter slopes or blanketing the slopes with coarse granular materials to maintain the stability of the cut slopes.

All excavations should be carried out in accordance with the latest edition of the Ontario Occupational Health and Safety Act and Regulations for Construction Projects. Any existing embankment fill materials, any organic materials that may be encountered at the site, and the native granular materials below the groundwater table would be classified as Type 3 soils. Properly dewatered native granular materials and native granular materials above the groundwater table may be considered Type 2 soils.

## **6.8 Reuse of Excavated Materials**

Consideration may be given to using native granular material excavated from cut areas of this project provided it meets the gradation requirements of SSM. It is expected that native sands and sand and gravel may be acceptable for reuse. The placement water content of embankment fills should be at or near the optimum water content as determined by a standard Proctor test. Saturated native materials selected for reuse should be stockpiled and allowed to dry prior to placement as embankment fill.

Organic materials such as topsoil, organic silt, and peat are not considered acceptable for use as embankment fill; however, these materials may be stockpiled for future use in landscaping, as appropriate.



### 6.9 Erosion Protection

Temporary erosion and sediment control measures should be implemented during construction in accordance with OPSS 805. The completed side slopes of the widened embankments should be topsoiled and seeded or sodded, as applicable, immediately after construction. If permanent erosion protection measures will be delayed significantly after final grading, the surface should be roughened or provided with a temporary erosion protection blanket.





## **7.0 MISCELLANEOUS**

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

**GOLDER ASSOCIATES LTD.**

**ORIGINAL SIGNED**

Nicole A. Gould, P.Eng.

**ORIGINAL SIGNED**

Azmi, M. Hammoud, P.Eng.  
Associate

**ORIGINAL SIGNED**

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

NG/DUP/AMH/cr

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## LIST OF ABBREVIATIONS

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

### I. SAMPLE TYPE

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

### III. SOIL DESCRIPTION

#### (a) Cohesionless Soils

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

### II. PENETRATION RESISTANCE

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

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

#### Consistency

	<u>kPa</u>	<u>psf</u>
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

#### (b) Cohesive Soils

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

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

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

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

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

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

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm<sup>2</sup> pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance ( $Q_t$ ), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

### IV. SOIL TESTS

w	water content
$w_p$	plastic limit
$w_l$	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
$D_R$	relative density (specific gravity, $G_s$ )
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
$SO_4$	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  $= (\text{compressive strength})/2$
  - \* 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 724**

1 OF 1

**METRIC**

PROJECT 10-1132-0056  
W.P. 4-00-00 LOCATION N 4808580.9 , E 236609.8 ORIGINATED BY MA  
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE July 11, 2013 CHECKED BY



SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
278.42	GROUND SURFACE							20	40	60	80	100					
0.00	TOPSOIL, silty, sandy Brown																
0.30	SILTY SAND, trace gravel, with cobbles Brown						278										
0.52	END OF BOREHOLE																
	Auger refusal on inferred bedrock.																
	Borehole dry during drilling on July 11, 2013.																

**RECORD OF BOREHOLE No 725**

1 OF 1

**METRIC**

PROJECT 10-1132-0056  
W.P. 4-00-00 LOCATION N 4808584.9 , E 236609.8 ORIGINATED BY MA  
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE July 11, 2013 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)	
278.24	GROUND SURFACE							20	40	60	80	100					
0.00	TOPSOIL, silty, sandy, with rootlets Brown						278										
0.36	SILTY SAND AND GRAVEL Brown END OF BOREHOLE																
	Auger refusal on inferred bedrock.																
	Borehole dry during drilling on July 11, 2013.																

**RECORD OF BOREHOLE No 742**

1 OF 1

**METRIC**

PROJECT 10-1132-0056  
W.P. 4-00-00 LOCATION N 4808499.8 , E 235987.6 ORIGINATED BY MA  
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE June 6, 2012 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							
277.50	GROUND SURFACE							20	40	60	80	100						
0.00	TOPSOIL, sandy, with rootlets Brown and black						277											
276.43			1	SS	2													
1.07	SAND, fine to medium, some silt Very loose Grey						276											
1.37	ORGANIC SILT, some sand, with shells Very soft grey		2	SS	WH											105		
275.52	END OF BOREHOLE																	
1.98	Auger refusal on inferred bedrock.  Groundwater encountered at about 277.5m during drilling on June 6, 2012.																	

**RECORD OF BOREHOLE No 743**

1 OF 1

**METRIC**

PROJECT 10-1132-0056  
W.P. 4-00-00 LOCATION N 4808504.5 , E 236038.5 ORIGINATED BY MA  
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE June 4, 2012 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	×	LAB VANE								
277.47	GROUND SURFACE							20	40	60	80	100								
0.00	TOPSOIL, sandy, with rootlets Brown																			
277.04																				
0.43	SAND, fine to medium, some silt, some organic material Loose to very dense Brown to grey		1	SS	5		277													
275.82			2	SS	100/ 150mm		276													
1.65	SILTY SAND AND GRAVEL, Very dense																			
1.89	Grey																			
275.18	DOLOSTONE (BEDROCK)		3	SS	100/ 0mm															
2.29	END OF BOREHOLE																			
	Split-spoon refusal on inferred bedrock.																			
	Groundwater encountered at about elev. 276.7m during drilling on June 4, 2012.																			
	Water level measured in piezometer at elev. 276.71m after installation.																			
	Water level measured in piezometer at elev. 276.84m on January 25, 2013.																			
	Water level measured in piezometer at elev. 276.86m on November 20, 2013.																			

**RECORD OF BOREHOLE No 744**

1 OF 1

**METRIC**

PROJECT 10-1132-0056  
W.P. 4-00-00 LOCATION N 4808491.4 , E 236040.6 ORIGINATED BY MA  
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE June 7, 2012 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																		
276.81	GROUND SURFACE							20	40	60	80	100						
0.00	TOPSOIL, silty																	
0.15	Brown																	
	SILTY SAND, trace gravel, trace clay																	
	Loose to very dense		1	SS	100/225mm		276										1 74 20 5	
275.68	Brown to grey														○			
1.13	END OF BOREHOLE																	
	Auger & Split-spoon refusal on inferred bedrock.																	
	Groundwater encountered at about elev. 276.8m during drilling on June 7, 2012.																	








**RECORD OF BOREHOLE No 745**

1 OF 1

**METRIC**

PROJECT 10-1132-0056  
W.P. 4-00-00 LOCATION N 4808492.5 , E 236090.6 ORIGINATED BY MA  
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE June 7, 2012 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									
276.85	GROUND SURFACE							20	40	60	80	100					
0.10	TOPSOIL, sandy Brown																
276.30	SAND, fine, trace silt, trace organic material																
0.55	Brown END OF BOREHOLE																
	Auger refusal on inferred bedrock.																
	Groundwater encountered at about elev. 276.8m during drilling on June 7, 2012.																

**RECORD OF BOREHOLE No 746**

1 OF 1

**METRIC**

PROJECT 10-1132-0056  
W.P. 4-00-00 LOCATION N 4808505.3 , E 236090.5 ORIGINATED BY MA  
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE June 7, 2012 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT  w <sub>p</sub>	NATURAL MOISTURE CONTENT  w	LIQUID LIMIT  w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE										WATER CONTENT (%)	
277.59	GROUND SURFACE					▽	277												
0.00	TOPSOIL, sandy, with rootlets Brown																		
276.98																			
0.61	SAND, fine to medium, some silt Brown		1	SS	53		276												
0.88	SAND AND GRAVEL, trace silt Very dense																		
276.22	Brown																		
1.37	SILTY SAND, fine to coarse, some gravel Compact to very dense Grey		2	SS	100/ 200mm														
275.70	END OF BOREHOLE																		
1.89	Auger refusal on inferred bedrock.  Groundwater encountered at about elev. 276.8m during drilling on June 7, 2012.																		

**RECORD OF BOREHOLE No 747**

1 OF 1

**METRIC**

PROJECT 10-1132-0056  
W.P. 4-00-00 LOCATION N 4808504.5 , E 236140.8 ORIGINATED BY MA  
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE June 7, 2012 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 (%)		
								20	40	60	80	100						20	40	60
277.51	GROUND SURFACE																			
0.00	TOPSOIL, sandy, with rootlets Brown																			
276.93							277													
0.58	SILTY SAND, fine, some gravel Very dense Brown		1	SS	100/ 125mm	▽														
0.88																				
276.05	SAND AND GRAVEL, trace silt, with cobbles and boulders Grey																			
1.46	END OF BOREHOLE																			
	Auger refusal on inferred bedrock.																			
	Groundwater encountered at about elev. 276.7m during drilling on June 7, 2012.																			

**RECORD OF BOREHOLE No 748**

1 OF 1

**METRIC**

PROJECT 10-1132-0056  
W.P. 4-00-00 LOCATION N 4808491.7 , E 236142.0 ORIGINATED BY MA  
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE June 7, 2012 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									WATER CONTENT (%)			GR	SA	SI	CL
								20	40	60	80	100											
276.78	GROUND SURFACE																						
0.00	TOPSOIL, silty, with peat and rootlets Brown to black																						
276.11																							
0.67	SAND AND GRAVEL, some silt, trace clay Compact Brown and grey		1	SS	28									o				55	30				
275.41																		13	2				
1.37	END OF BOREHOLE																						
	Auger refusal on inferred bedrock.																						
	Groundwater encountered at about elev. 276.9m during drilling on June 7, 2012.																						

PROJECT <u>10-1132-0056</u>		<b>RECORD OF BOREHOLE No 749</b>		1 OF 1		<b>METRIC</b>	
W.P. <u>4-00-00</u>		LOCATION <u>N 4808496.3 , E 236190.9</u>		ORIGINATED BY <u>MA</u>			
DIST <u>          </u> HWY <u>401</u>		BOREHOLE TYPE <u>POWER AUGER, HOLLOW STEM</u>		COMPILED BY <u>LMK</u>			
DATUM <u>GEODETIC</u>		DATE <u>June 7, 2012</u>		CHECKED BY <u>          </u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>p</sub>	W	W <sub>L</sub>		
								20   40   60   80   100						
								○ UNCONFINED   + FIELD VANE						
								● QUICK TRIAXIAL   × LAB VANE						
									WATER CONTENT (%)					
								20   40   60   80   100	10   20   30					
277.52	GROUND SURFACE													
0.00	TOPSOIL, sandy Brown													
0.24	SAND, fine to medium, some silt Brown													
276.85							277							
0.67	END OF BOREHOLE													
	Auger refusal on inferred bedrock.													
	Borehole dry during drilling on June 7, 2012.													

LDN\_MTO\_06 10-1132-0056-2000.GPJ LDN\_MTO.GDT 03/02/14

**RECORD OF BOREHOLE No 750**

1 OF 1

**METRIC**

PROJECT 10-1132-0056  
W.P. 4-00-00 LOCATION N 4808506.5 , E 236190.8 ORIGINATED BY MA  
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE June 7, 2012 CHECKED BY

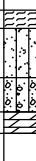
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED		+ FIELD VANE		● QUICK TRIAXIAL						× LAB VANE		○
277.71	GROUND SURFACE							20	40	60	80	100								
0.00	TOPSOIL, sandy, with rootlets																			
0.15	Brown																			
	SAND, fine to medium																			
	Loose																			
	Brown																			
275.58																				
2.13	SAND AND GRAVEL, some silt, with cobbles Very dense Grey																			
			1	SS	4															
			2	SS	9															
			3	SS	79															
			4	SS	99															
274.20																				
3.51	END OF BOREHOLE																			
	Groundwater encountered at about elev. 277.1m during drilling on June 7, 2012.																			
	Water level measured in piezometer at elev. 277.08m after installation on June 7, 2012.																			
	Water level measured in piezometer at elev. 276.94m on January 25, 2013.																			
	Water level measured in piezometer at elev. 276.97m on November 20, 2013.																			

**RECORD OF BOREHOLE No 751**


1 OF 1

**METRIC**

PROJECT 10-1132-0056  
W.P. 4-00-00 LOCATION N 4808511.1, E 236240.7 ORIGINATED BY MA  
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE June 7, 2012 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>p</sub> W                      W <sub>L</sub>					
277.96	GROUND SURFACE							20	40	60	80	100			
0.00	TOPSOIL, sandy														
0.18	Brown														
277.29	SILTY SAND, trace gravel														
0.67	Brown														
276.95	SILTY SAND AND GRAVEL, Very dense		1	SS	75/ 25mm	▽	277								
1.01	Brown and grey														
1.22	DOLOSTONE														
	END OF BOREHOLE														
	Auger refusal on inferred bedrock.														
	Groundwater encountered at about elev. 276.9m during drilling on June 7, 2012.														

PROJECT <u>10-1132-0056</u>		<b>RECORD OF BOREHOLE No 752</b>		1 OF 1	<b>METRIC</b>
W.P. <u>4-00-00</u>	LOCATION <u>N 4808494.6 , E 236241.0</u>	ORIGINATED BY <u>MA</u>			
DIST <u></u> HWY <u>401</u>	BOREHOLE TYPE <u>POWER AUGER, HOLLOW STEM</u>	COMPILED BY <u>LMK</u>			
DATUM <u>GEODETIC</u>	DATE <u>June 7, 2012</u>	CHECKED BY <u></u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>p</sub>	W	W <sub>L</sub>		GR SA SI CL			
277.46	GROUND SURFACE																
0.00	TOPSOIL, silty Brown																
0.30	END OF BOREHOLE																
	Auger refusal on inferred bedrock.																
	Borehole dry during drilling on June 7, 2012.																





**RECORD OF BOREHOLE No 753**




1 OF 1

**METRIC**

PROJECT 10-1132-0056  
W.P. 4-00-00 LOCATION N 4808509.5 , E 236540.5 ORIGINATED BY LK  
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY WDF  
DATUM GEODETIC DATE July 23, 2013 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
277.96	GROUND SURFACE																
0.00	TOPSOIL, silty, sandy Black																
0.21	SANDY SILT, trace gravel Brown		1	AS													
277.20	END OF BOREHOLE		2	SS	100/ 0mm												
0.76	Split-spoon refusal on inferred bedrock.  Groundwater encountered at about elev. 277.4m during drilling on July 23, 2013.																

PROJECT <u>10-1132-0056</u>		<b>RECORD OF BOREHOLE No 754</b>		1 OF 1 <b>METRIC</b>	
W.P. <u>4-00-00</u>		LOCATION <u>N 4808499.5 , E 236540.5</u>		ORIGINATED BY <u>LK</u>	
DIST <u>          </u> HWY <u>401</u>		BOREHOLE TYPE <u>POWER AUGER, HOLLOW STEM</u>		COMPILED BY <u>WDF</u>	
DATUM <u>GEODETIC</u>		DATE <u>July 23, 2013</u>		CHECKED BY <u>          </u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						WATER CONTENT (%)			GR	SA	SI	CL
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    x LAB VANE												
277.84	GROUND SURFACE						277													
0.00	TOPSOIL, silty, sandy Black																			
0.21	SILTY SAND AND GRAVEL Dense to very dense Brown		1	SS	92															
276.77	Assumed DOLOSTONE																			
1.07			2	SS																
1.37	END OF BOREHOLE				100/ 0mm															
	Auger & Split-spoon refusal on inferred bedrock.																			
	Groundwater encountered at about elev. 276.9m during drilling on July 23, 2013.																			

**RECORD OF BOREHOLE No 755**

1 OF 1

**METRIC**

PROJECT 10-1132-0056  
W.P. 4-00-00 LOCATION N 4808500.2 , E 236590.5 ORIGINATED BY LK  
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY WDF  
DATUM GEODETIC DATE July 24, 2013 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 (%)
278.13	GROUND SURFACE							20	40	60	80	100					
0.00	TOPSOIL, silty, sandy, some gravel, with peat Black to brown		1	AS			278										
277.46																	
0.67	SILTY SAND AND GRAVEL		2	SS	100/ 125mm												
277.09	Compact to very dense Brown																
1.04	END OF BOREHOLE																
	Split-spoon refusal on inferred bedrock.																
	Groundwater encountered at about elev. 277.5m during drilling on July 24, 2013.																

**RECORD OF BOREHOLE No 756**

1 OF 1

**METRIC**



PROJECT 10-1132-0056  
W.P. 4-00-00 LOCATION N 4808508.2 , E 236590.5 ORIGINATED BY LK  
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY WDF  
DATUM GEODETIC DATE July 25, 2013 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									WATER CONTENT (%)			GR	SA	SI	CL
								20	40	60	80	100					20	40	60				
278.37	GROUND SURFACE																						
0.00	TOPSOIL, silty, with peat and rootlets Black		1	AS																			
277.61	SILTY SAND AND GRAVEL, trace clay Dense to very dense Brown		2	SS	100/ 100mm													27	33	35	5		
0.76	END OF BOREHOLE																						
1.01	Split-spoon refusal on inferred bedrock.  Groundwater encountered at about elev. 277.7m during drilling on July 25, 2013.																						

PROJECT <u>10-1132-0056</u>		<b>RECORD OF BOREHOLE No 757</b>		1 OF 1		<b>METRIC</b>	
W.P. <u>4-00-00</u>		LOCATION <u>N 4808501.4 , E 236640.6</u>		ORIGINATED BY <u>LK</u>			
DIST <u>          </u> HWY <u>401</u>		BOREHOLE TYPE <u>POWER AUGER, HOLLOW STEM</u>		COMPILED BY <u>WDF</u>			
DATUM <u>GEODETIC</u>		DATE <u>July 24, 2013</u>		CHECKED BY <u>          </u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL
								○ UNCONFINED	+	FIELD VANE	● QUICK TRIAXIAL	×	LAB VANE	W <sub>p</sub>	W		W <sub>L</sub>			
278.35	GROUND SURFACE						20	40	60	80	100									
0.00	TOPSOIL, silty																			
0.15	Black																			
277.68	SILTY SAND, some gravel, with cobbles and boulders		1	AS																
0.67	Very dense Brown		2	SS	100/ 25mm															
	END OF BOREHOLE																			
	Split-spoon refusal on inferred bedrock.																			
	Groundwater encountered at about elev. 278.0m during drilling on July 24, 2013.																			

PROJECT <u>10-1132-0056</u>		<b>RECORD OF BOREHOLE No 761</b>		1 OF 1	<b>METRIC</b>
W.P. <u>4-00-00</u>	LOCATION <u>N 4808568.3 , E 236263.2</u>	ORIGINATED BY <u>MA</u>			
DIST <u></u> HWY <u>401</u>	BOREHOLE TYPE <u>POWER AUGER, HOLLOW STEM</u>	COMPILED BY <u>WDF</u>			
DATUM <u>GEODETIC</u>	DATE <u>August 1, 2013</u>	CHECKED BY <u></u>			




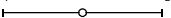
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL
								20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>					
277.93	GROUND SURFACE																			
0.00	PEAT, amorphous Black																			
277.29																				
0.64	SILTY SAND AND GRAVEL, trace clay Compact Grey		1	SS	10								o				24	50	21	5
276.41			2	SS	100/ 0mm															
1.52	END OF BOREHOLE  Auger & Split-spoon refusal on inferred bedrock.  Groundwater encountered at about elev. 277.5m during drilling on Aug. 1, 2013.																			

**RECORD OF BOREHOLE No 763**

1 OF 1

**METRIC**

PROJECT 10-1132-0056  
W.P. 4-00-00 LOCATION N 4808567.6 , E 236215.2 ORIGINATED BY MA  
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY WDF  
DATUM GEODETIC DATE August 1, 2013 CHECKED BY



SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>p</sub> W                      W <sub>L</sub>				
277.89 0.00	GROUND SURFACE PEAT, amorphous Black						277							
277.10 0.79 0.91	SILTY SAND AND GRAVEL Very dense Grey END OF BOREHOLE  Auger & Split-spoon refusal on inferred bedrock.  Groundwater encountered at about elev. 277.6m during drilling on Aug. 1, 2013.		1	SS	100/ 150mm									

**RECORD OF BOREHOLE No 765**

1 OF 1





**METRIC**

PROJECT 10-1132-0056  
W.P. 4-00-00 LOCATION N 4808566.2 , E 236165.2 ORIGINATED BY MA  
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY WDF  
DATUM GEODETIC DATE August 1, 2013 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						
277.87 0.00	GROUND SURFACE PEAT, amorphous Black					▽								
277.17 0.70 0.85	SILTY SAND AND GRAVEL Very dense Grey END OF BOREHOLE  Auger & Split-spoon refusal on inferred bedrock.  Groundwater encountered at about elev. 277.4m during drilling on Aug. 1, 2013.		1	SS	100/ 100mm									



PROJECT <u>10-1132-0056</u>		<b>RECORD OF BOREHOLE No 767</b>		1 OF 1		<b>METRIC</b>	
W.P. <u>4-00-00</u>		LOCATION <u>N 4808564.4 , E 236114.2</u>		ORIGINATED BY <u>MA</u>			
DIST <u>          </u> HWY <u>401</u>		BOREHOLE TYPE <u>POWER AUGER, HOLLOW STEM</u>		COMPILED BY <u>WDF</u>			
DATUM <u>GEODETIC</u>		DATE <u>August 1, 2013</u>		CHECKED BY <u>          </u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE	w <sub>p</sub>	w	w <sub>L</sub>		
277.63 0.00	GROUND SURFACE PEAT, amorphous Black														GR SA SI CL	
276.84 0.79	SILTY SAND, fine to medium, trace clay Loose to compact Brown		1	SS	10							○			1 70 24 5	
276.26 1.37	SAND AND GRAVEL, some silt, trace clay Compact Grey		2	SS	19						○				25 53 18 4	
275.34 2.35	DOLOSTONE, inferred bedrock END OF BOREHOLE  Auger refusal at about elev. 275.30m  Groundwater encountered at about elev. 277.6m during drilling on Aug. 1, 2013.		3	SS	100/ 50mm											

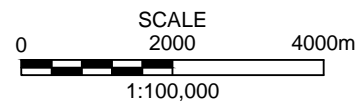
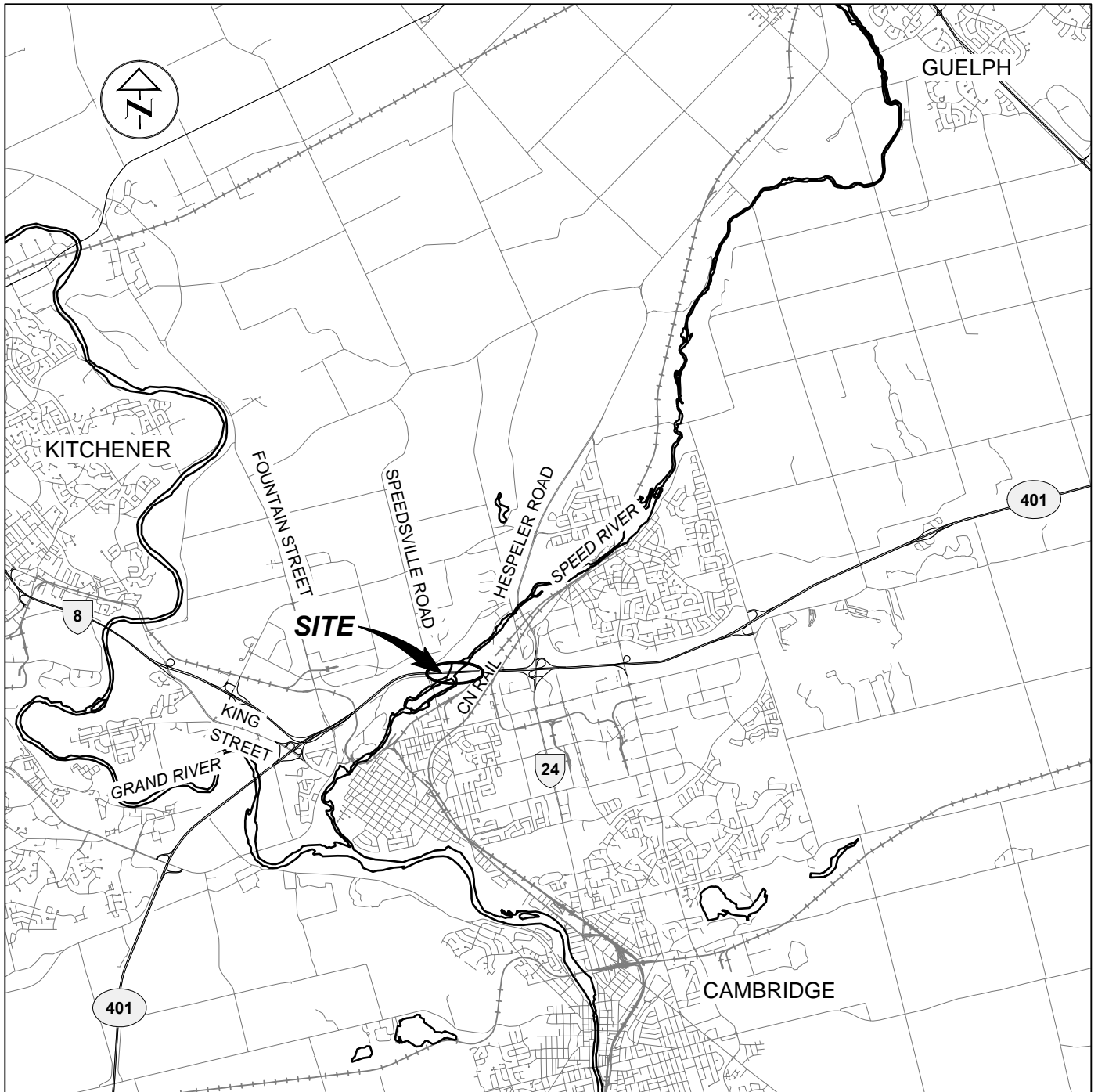
**RECORD OF BOREHOLE No 769**

1 OF 1

**METRIC**

PROJECT 10-1132-0056  
W.P. 4-00-00 LOCATION N 4808562.1, E 236065.2 ORIGINATED BY MA  
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY WDF  
DATUM GEODETIC DATE August 1, 2013 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE	WATER CONTENT (%)					
277.97 0.00	GROUND SURFACE PEAT, amorphous Soft Black						20	40	60	80	100						
276.60 1.37	SILTY SAND, some gravel, trace clay Very dense Grey		1	SS	2												
275.99 1.98	END OF BOREHOLE		2	SS	51												12 54 28 6
	Auger & Split-spoon refusal on inferred bedrock.																
	Groundwater encountered at about elev. 276.6m during drilling on August 1, 2013.																
	Water level measured in piezometer at elev. 277.51m after installation on August 1, 2013.																
	Water level measured in piezometer at elev. 277.46m on August 12, 2013.																
	Water level measured in piezometer at elev. 277.51m on November 20, 2013.																



## REFERENCE

PLAN BASED ON CANMAP STREETFILES V.2008.5.

## NOTE

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

PROJECT

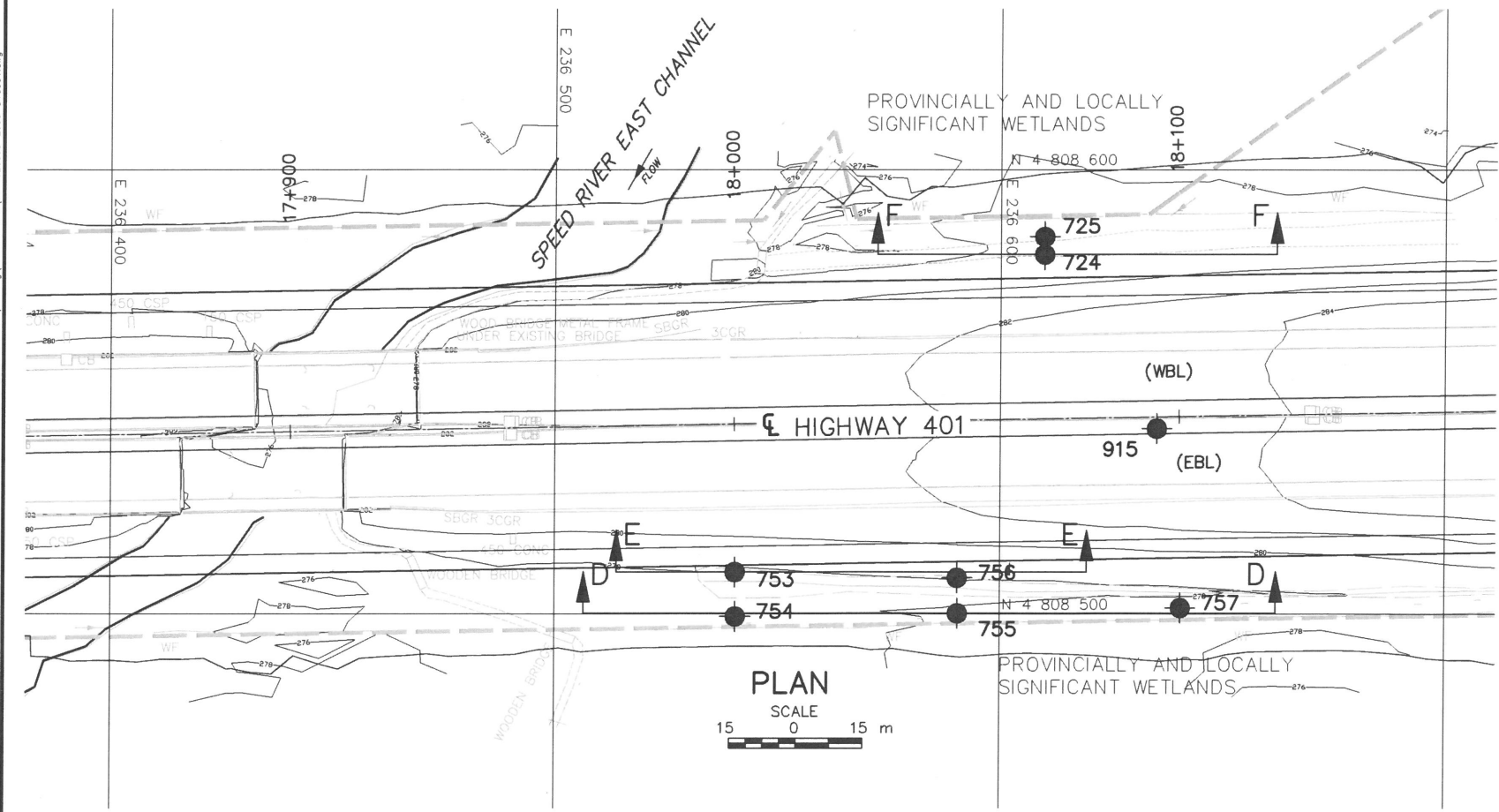
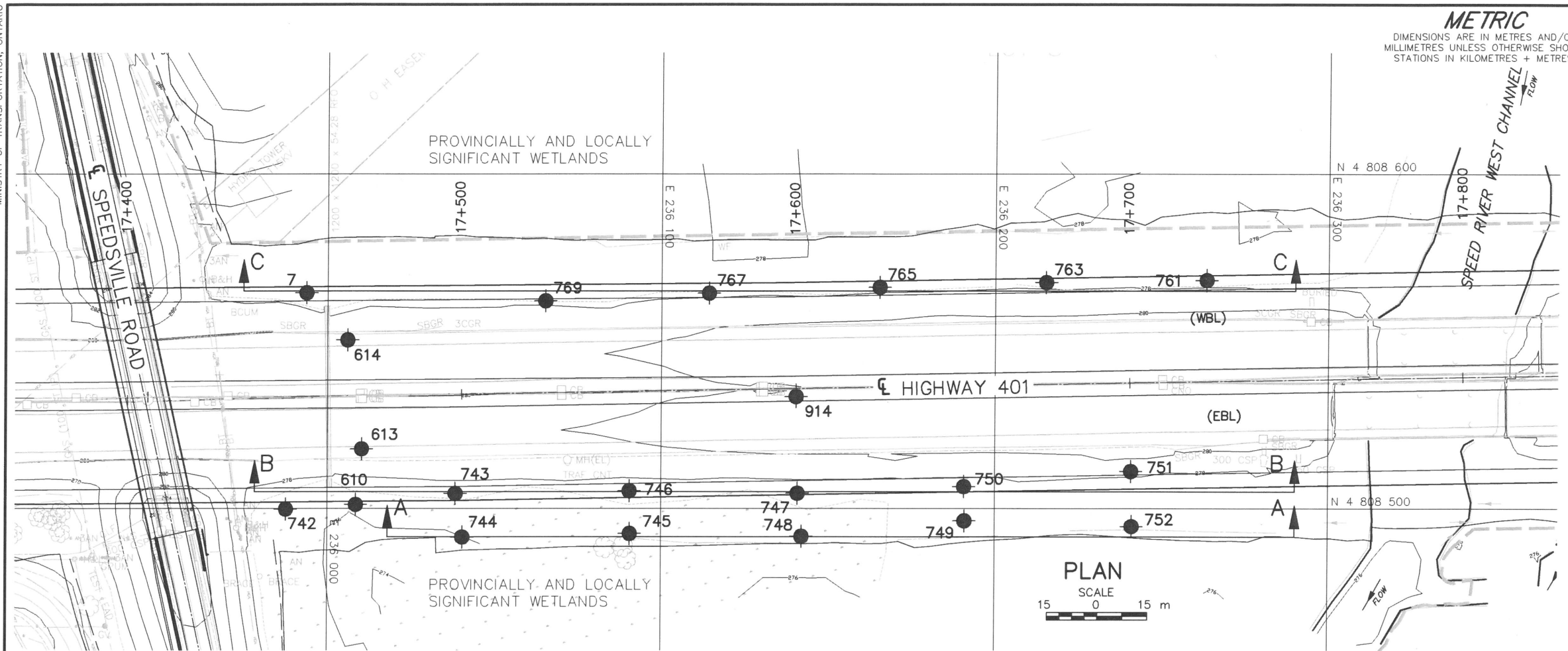
SWAMP / SOFT GROUND  
HIGHWAY 401 IMPROVEMENTS  
GWP 4-00-00

TITLE

## KEY PLAN



PROJECT No. 10-1132-0056			FILE No. 1011320056-2000-F15001	
CADD	LMK/WDF	Dec. 16/13	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.

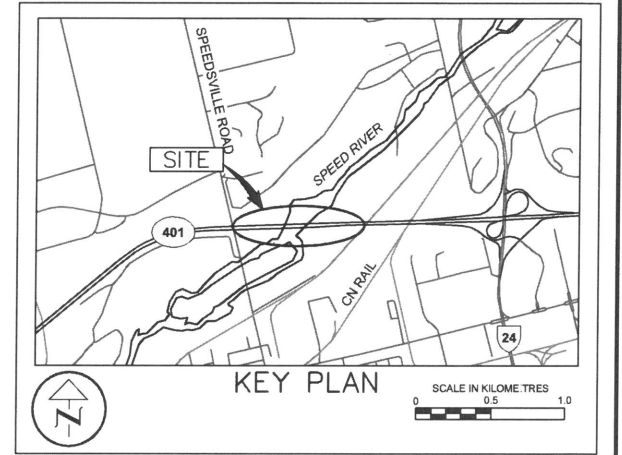
CONT No.  
WP No. 4-00-00

SWAMP / SOFT GROUND

HIGHWAY 401 IMPROVEMENTS  
BOREHOLE LOCATIONS

SHEET

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



LEGEND

Borehole - Current Investigation

No.	ELEVATION	CO-ORDINATES (MTM ZONE 10)	
		NORTHING	EASTING
724	278.42	4 808 580.9	236 609.8
725	278.24	4 808 584.9	236 609.8
742	277.50	4 808 499.8	235 987.6
743	277.47	4 808 504.5	236 038.5
744	276.81	4 808 491.4	236 040.6
745	276.85	4 808 492.5	236 090.6
746	277.59	4 808 505.3	236 090.5
747	277.51	4 808 504.5	236 140.8
748	276.78	4 808 491.7	236 142.0
749	277.52	4 808 496.3	236 190.9
750	277.71	4 808 506.5	236 190.8
751	277.96	4 808 511.1	236 240.7
752	277.46	4 808 494.6	236 241.0
753	277.96	4 808 509.5	236 540.5
754	277.84	4 808 499.5	236 540.5
755	278.13	4 808 500.2	236 590.5
756	278.37	4 808 508.2	236 590.5
757	278.35	4 808 501.4	236 640.6
761	277.93	4 808 568.3	236 263.2
763	277.89	4 808 567.6	236 215.2
765	277.87	4 808 566.2	236 165.2
767	277.63	4 808 564.4	236 114.2
769	277.97	4 808 562.1	236 065.2
Geocres No. 40P8-213			
7	277.57	4 808 564.5	235 993.6
610	277.05	4 808 501.2	236 008.5
613	279.65	4 808 517.8	236 010.3
614	279.63	4 808 550.4	236 006.0
Geocres No. 40P8-221			
914	280.00	4 808 533.4	236 140.3
915	283.20	4 808 541.7	236 635.2

**NOTES**

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

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



**REFERENCE**

Base plans provided in digital format by Delcan.

NO.	DATE	BY	REVISION
Geocres No. 40P8-222			
HWY.	401	PROJECT NO.	10-1132-0056
SUBM'D.	DUP	CHKD.	NAG
DRAWN:	WDF	CHKD.	
DATE:	Dec. 16/13	DATE:	Dec. 16/13
APPD.		APPD.	
DWG.	1	DWG.	1

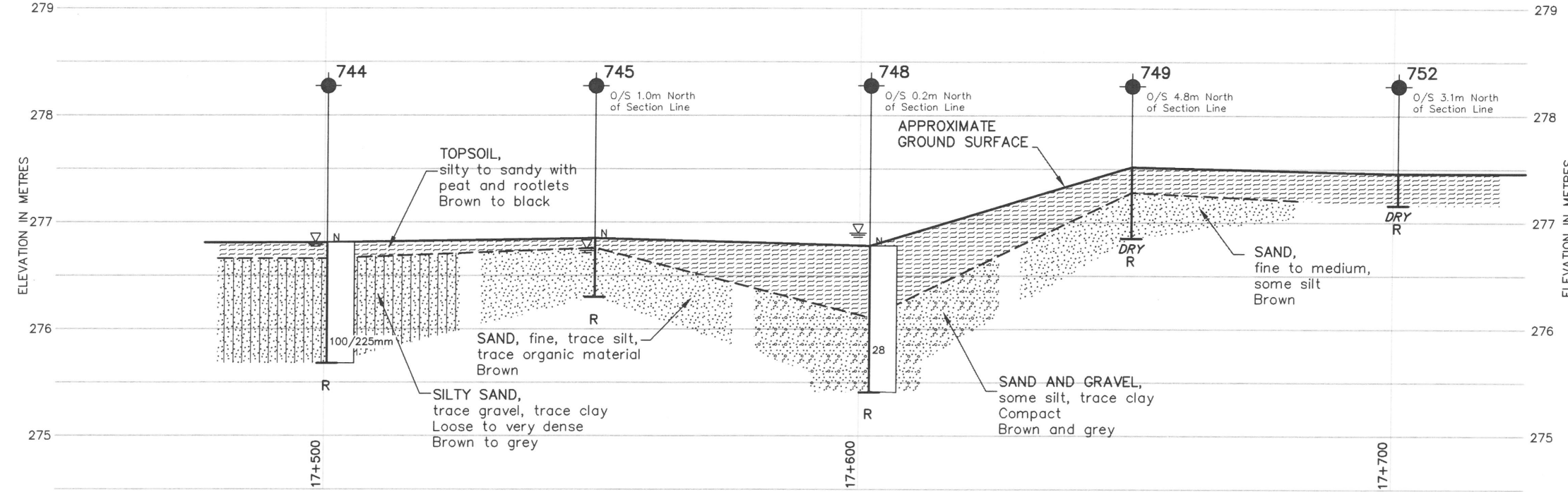
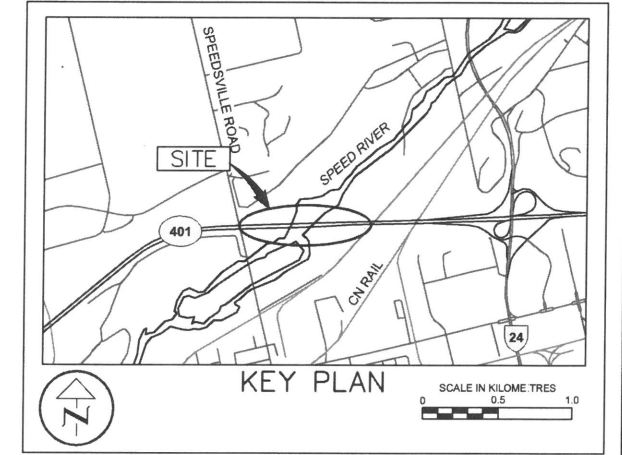
**METRIC**  
DIMENSIONS ARE IN METRES AND/OR  
MILLIMETRES UNLESS OTHERWISE SHOWN.  
STATIONS IN KILOMETRES + METRES.

CONT No.  
WP No. 4-00-00

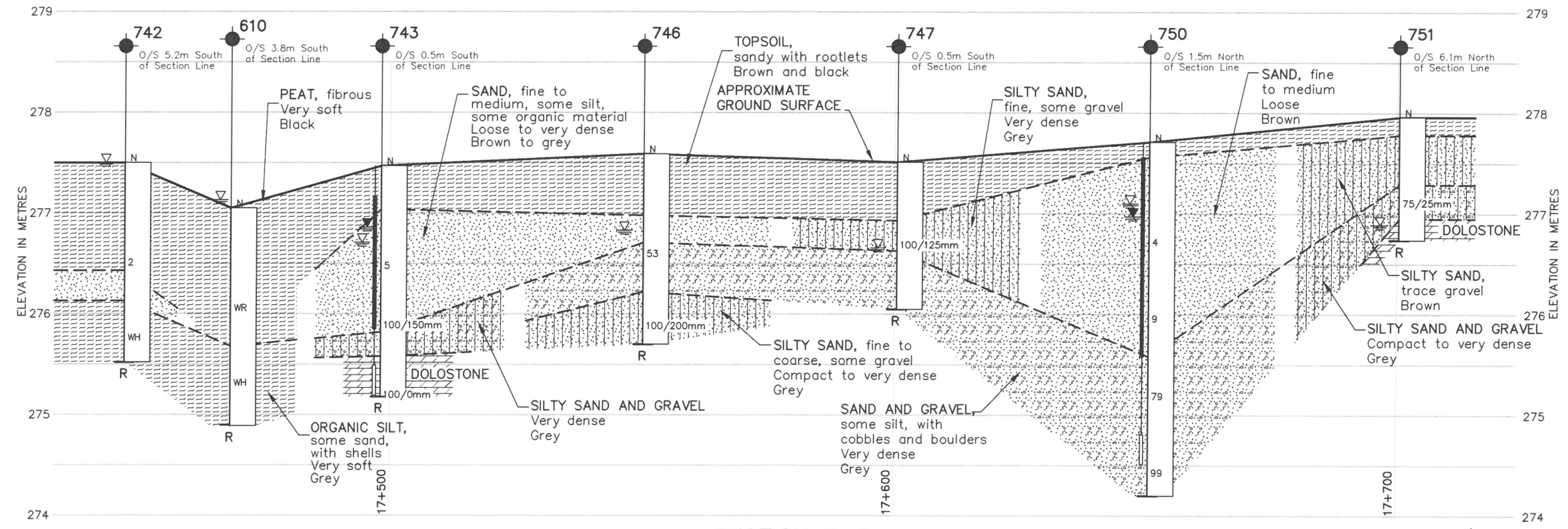
SWAMP / SOFT GROUND

HIGHWAY 401 IMPROVEMENTS  
SOIL STRATA

SHEET



SECTION A-A



SECTION B-B



- LEGEND**
- Borehole - Current Investigation
  - Seal
  - Standpipe
  - N Standard Penetration Test Value
  - 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
  - WL in piezometer/standpipe, measured on Nov. 20, 2013.
  - WL encountered during drilling
  - DRY WL not established
  - R Split-spoon / Auger refusal on inferred bedrock

No.	ELEVATION	CO-ORDINATES (MTM ZONE 10)	
		NORTHING	EASTING
742	277.50	4 808 499.8	235 987.6
743	277.47	4 808 504.5	236 038.5
744	276.81	4 808 491.4	236 040.6
745	276.85	4 808 492.5	236 090.6
746	277.59	4 808 505.3	236 090.5
747	277.51	4 808 504.5	236 140.8
748	276.78	4 808 491.7	236 142.0
749	277.52	4 808 496.3	236 190.9
750	277.71	4 808 506.5	236 190.8
751	277.96	4 808 511.1	236 240.7
752	277.46	4 808 494.6	236 241.0
Geocres No. 40P8-213			
610	277.05	4 808 501.2	236 008.5

**NOTES**

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

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

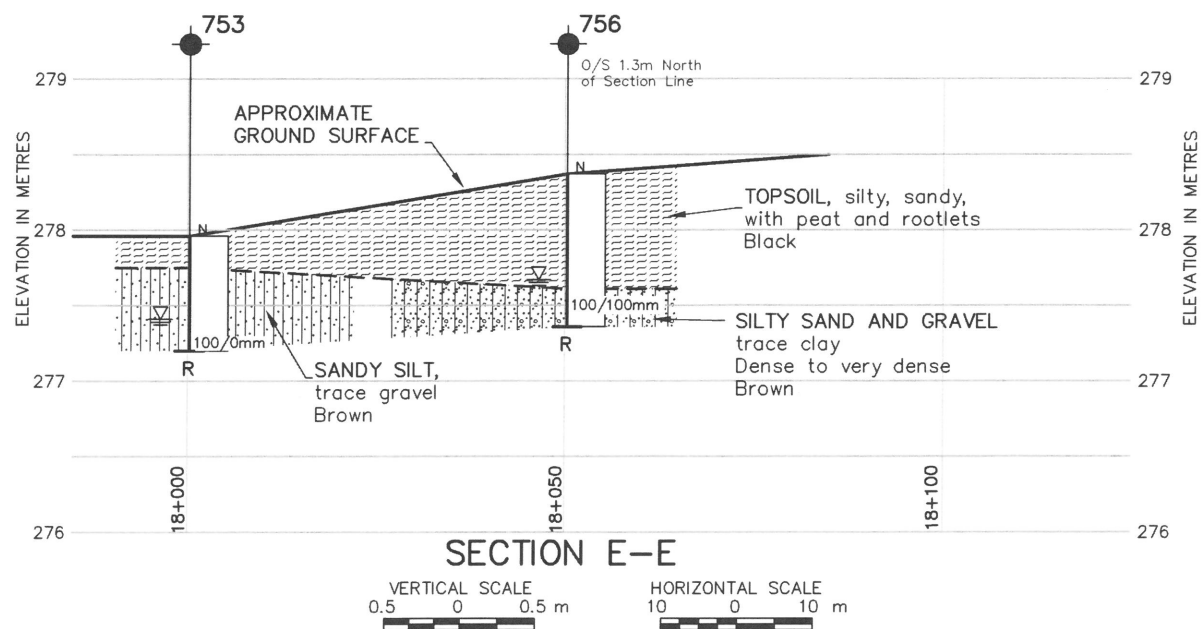
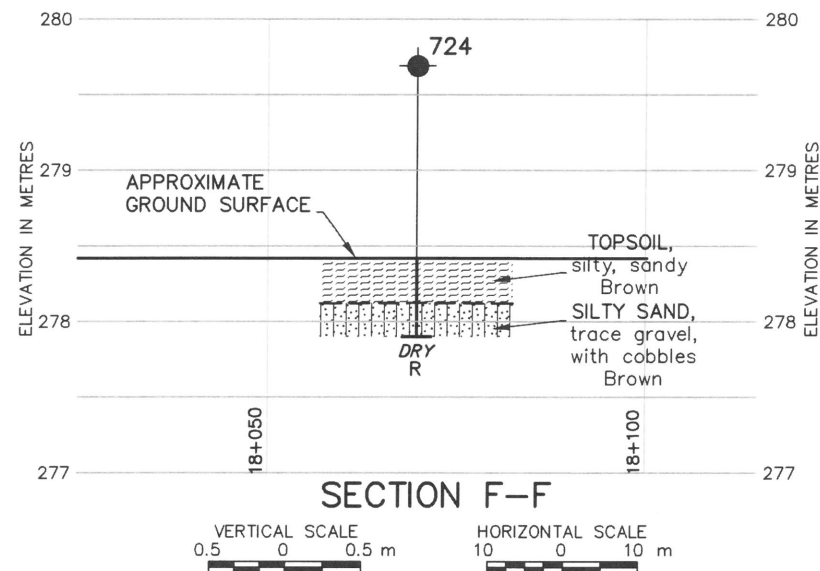
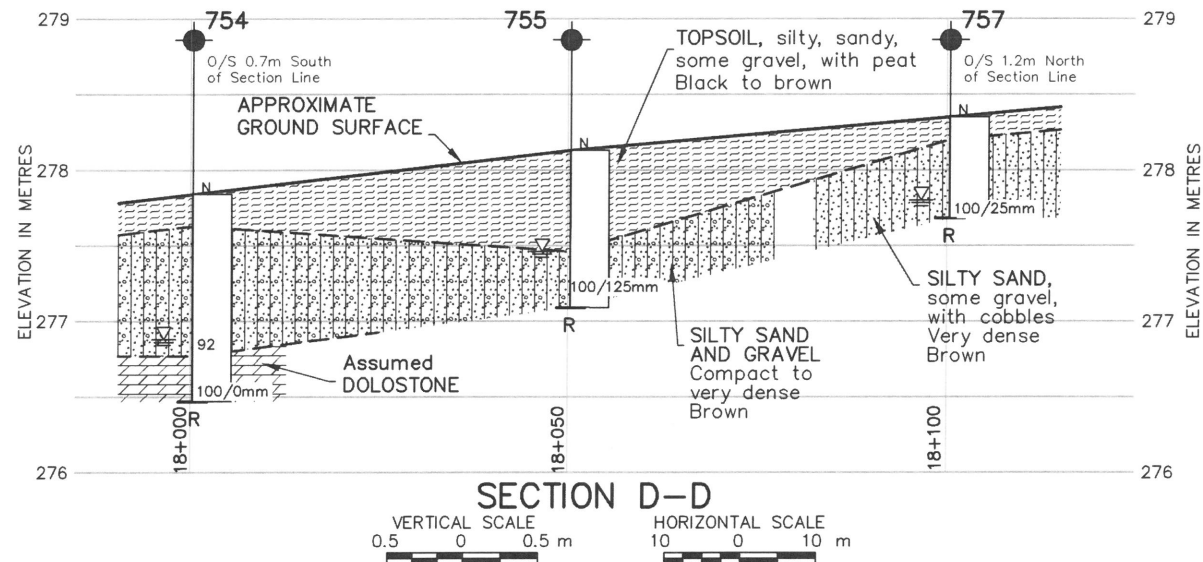
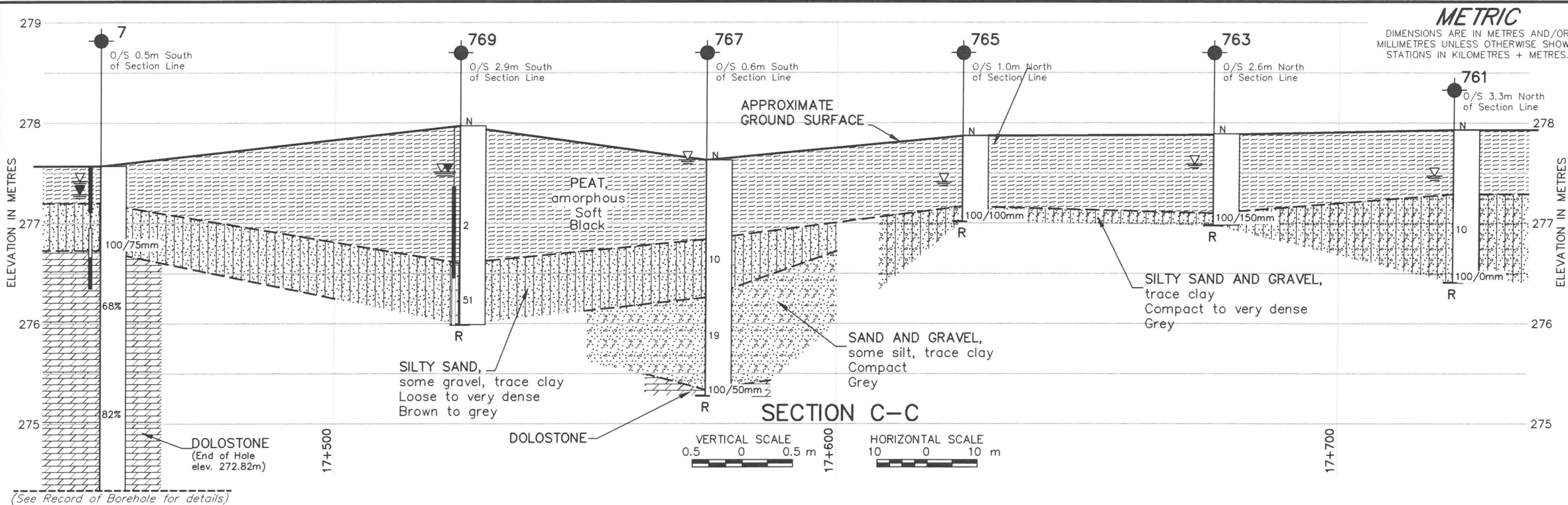
**REFERENCE**

Base plans provided in digital format by Delcan.



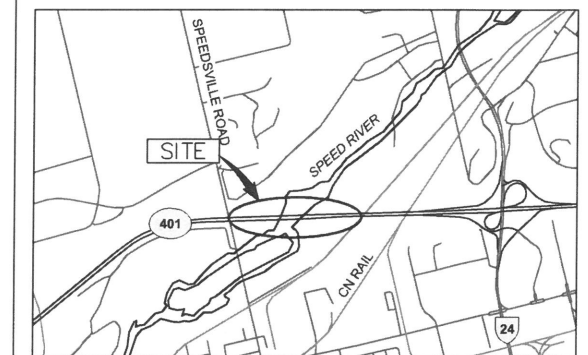
NO.	DATE	BY	REVISION
Geocres No. 40P8-222			
HWY.	401	PROJECT NO.	10-1132-0056
SUBM'D.	DUP	CHKD.	NAG
DRAWN:	WDF	CHKD.	
DATE:	Dec. 16/13	DATE:	Dec. 16/13
SITE:		APPD.	
DWG.	2		



CONT No.  
WP No. 4-00-00

SWAMP / SOFT GROUND

SHEET

HIGHWAY 401 IMPROVEMENTS  
SOIL STRATA**Golder Associates Ltd.**  
LONDON, ONTARIO, CANADA

KEY PLAN

SCALE IN KILOMETRES  
0 0.5 1.0

## LEGEND

- Borehole - Current Investigation
- Seal
- Standpipe
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 82% Rock Quality Designation (RQD)
- WL in piezometer/standpipe, measured on Nov. 20, 2013.
- WL encountered during drilling
- DRY WL not established
- R Split-spoon / Auger refusal on inferred bedrock

No.	ELEVATION	CO-ORDINATES (MTM ZONE 10)	
		NORTHING	EASTING
724	278.42	4 808 580.9	236 609.8
753	277.96	4 808 509.5	236 540.5
754	277.84	4 808 499.5	236 540.5
755	278.13	4 808 500.2	236 590.5
756	278.37	4 808 508.2	236 590.5
757	278.35	4 808 501.4	236 640.6
761	277.93	4 808 568.3	236 263.2
763	277.89	4 808 567.6	236 215.2
765	277.87	4 808 566.2	236 165.2
767	277.63	4 808 564.4	236 114.2
769	277.97	4 808 562.1	236 065.2
Geocres No. 40P8-213			
7	277.57	4 808 564.5	235 993.6

## NOTES

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

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

## REFERENCE

Base plans provided in digital format by Delcan.

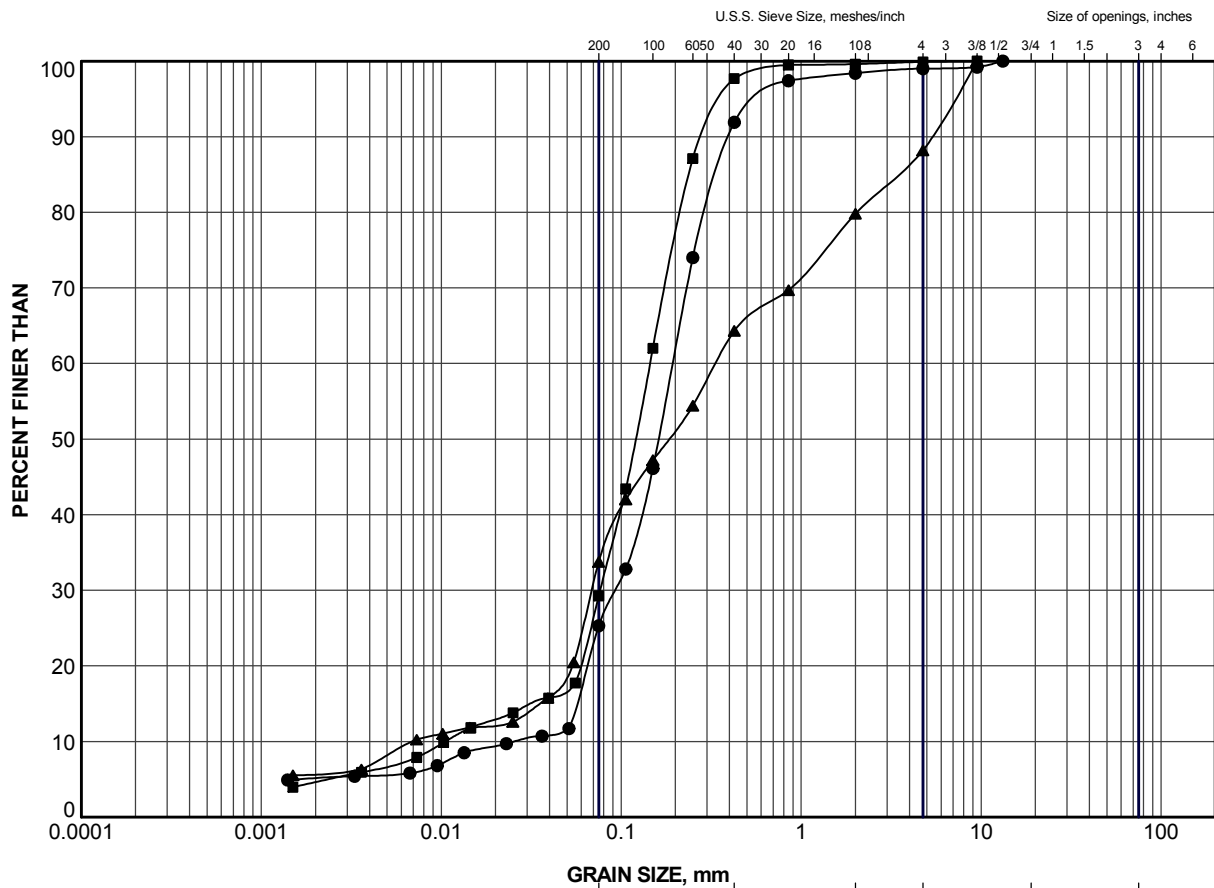


NO.	DATE	BY	REVISION
Geocres No. 40P8-222			
HWY.	401	PROJECT NO.	10-1132-0056
SUBM'D.	DUP	CHKD.	NAG
DRAWN:	WDF	CHKD.	
DATE:	Dec. 16/13	SITE:	
APPD.		DWG.	3



# **APPENDIX A**

## **Laboratory Test Data**



### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	744	1	275.9
■	767	1	276.6
▲	769	2	276.2

PROJECT

SWAMP / SOFT GROUND  
HIGHWAY 401 IMPROVEMENTS  
GWP 4-00-00

TITLE

GRAIN SIZE DISTRIBUTION  
SILTY SAND

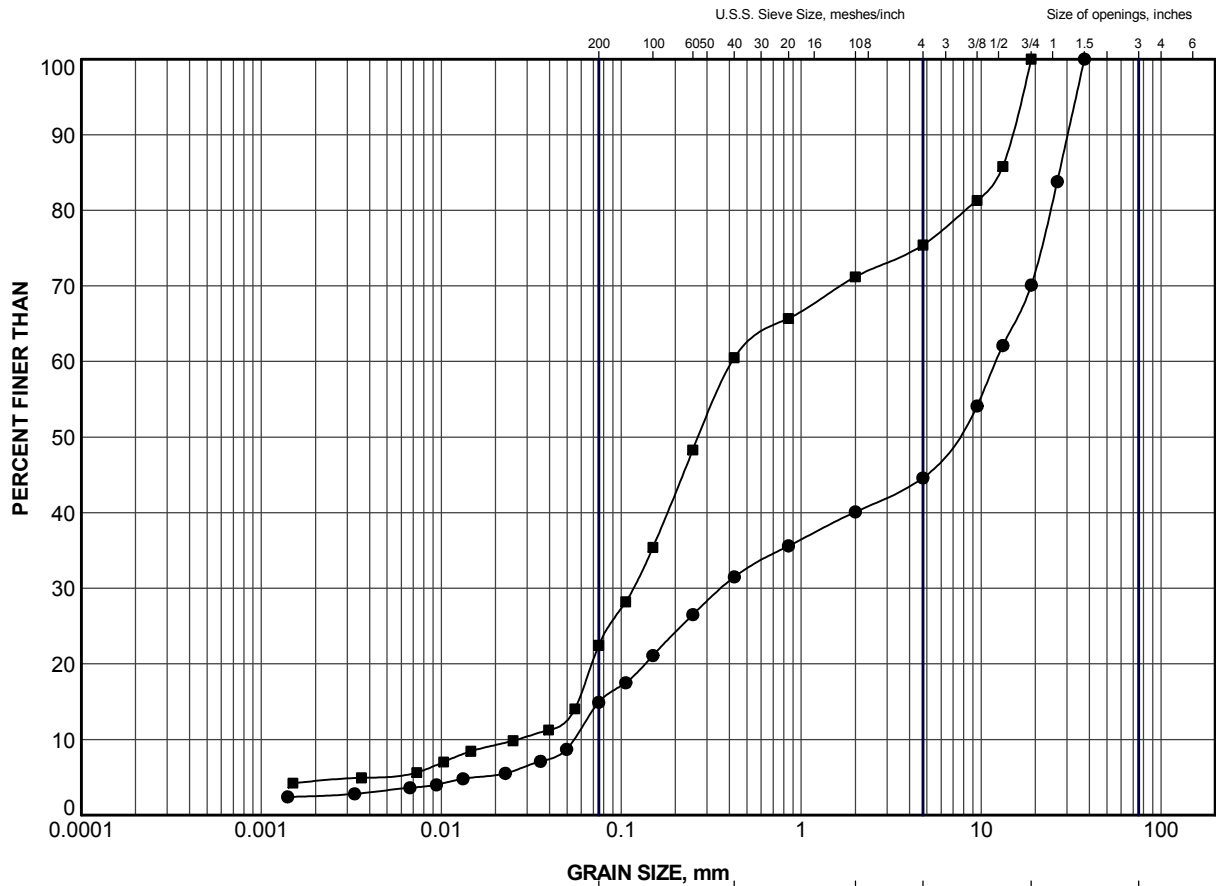


**Golder  
Associates**  
LONDON, ONTARIO

PROJECT No.	10-1132-0056	FILE No.	1011320056-2000-F150A1
DRAWN	WDF	Dec 09/13	SCALE N/A REV.
CHECK			

**FIGURE A-1**



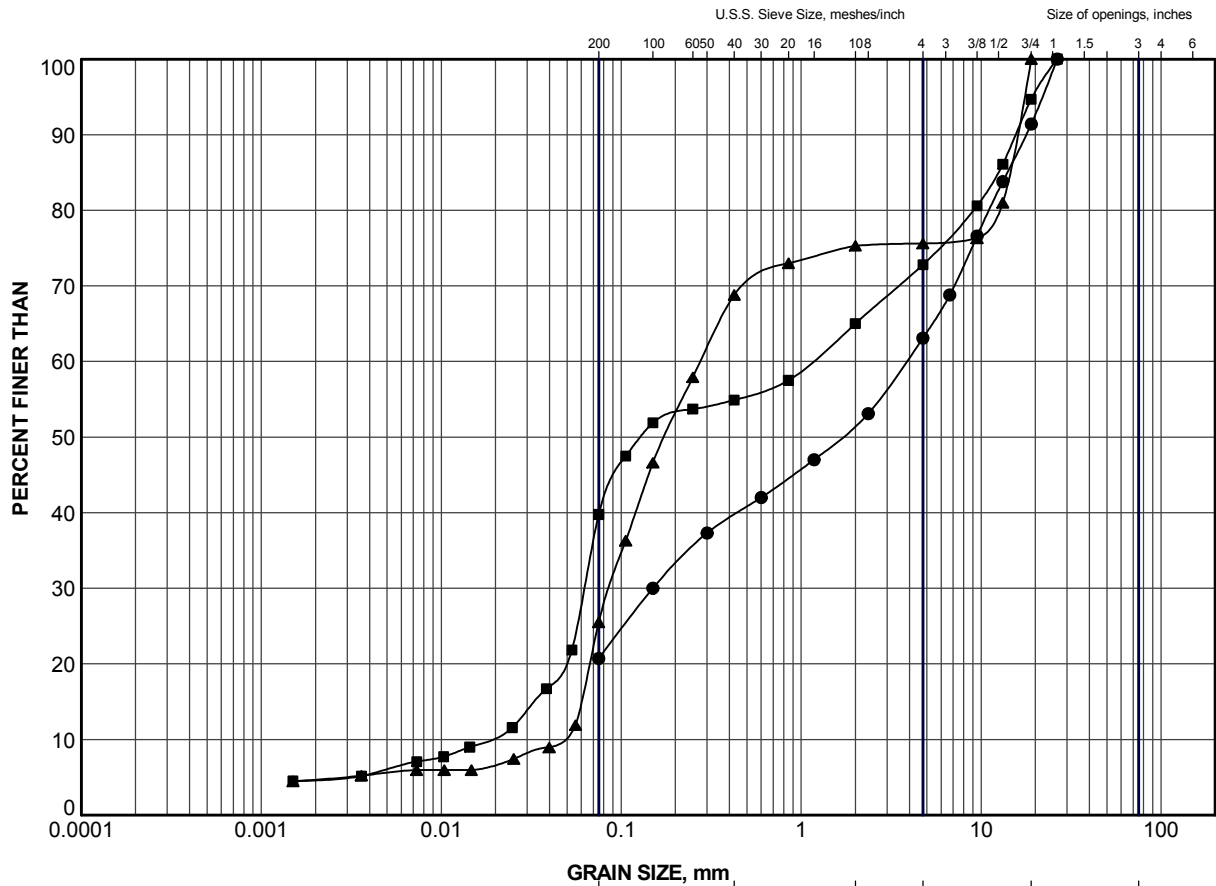


### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	748	1	275.8
■	767	2	275.9

PROJECT				SWAMP / SOFT GROUND HIGHWAY 401 IMPROVEMENTS GWP 4-00-00			
TITLE				GRAIN SIZE DISTRIBUTION SAND AND GRAVEL			
PROJECT No.		10-1132-0056		FILE No.		1011320056-2000-F150A2	
DRAWN		WDF		Dec 09/13		SCALE N/A REV.	
CHECK						FIGURE A-2	






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

#### LEGEND

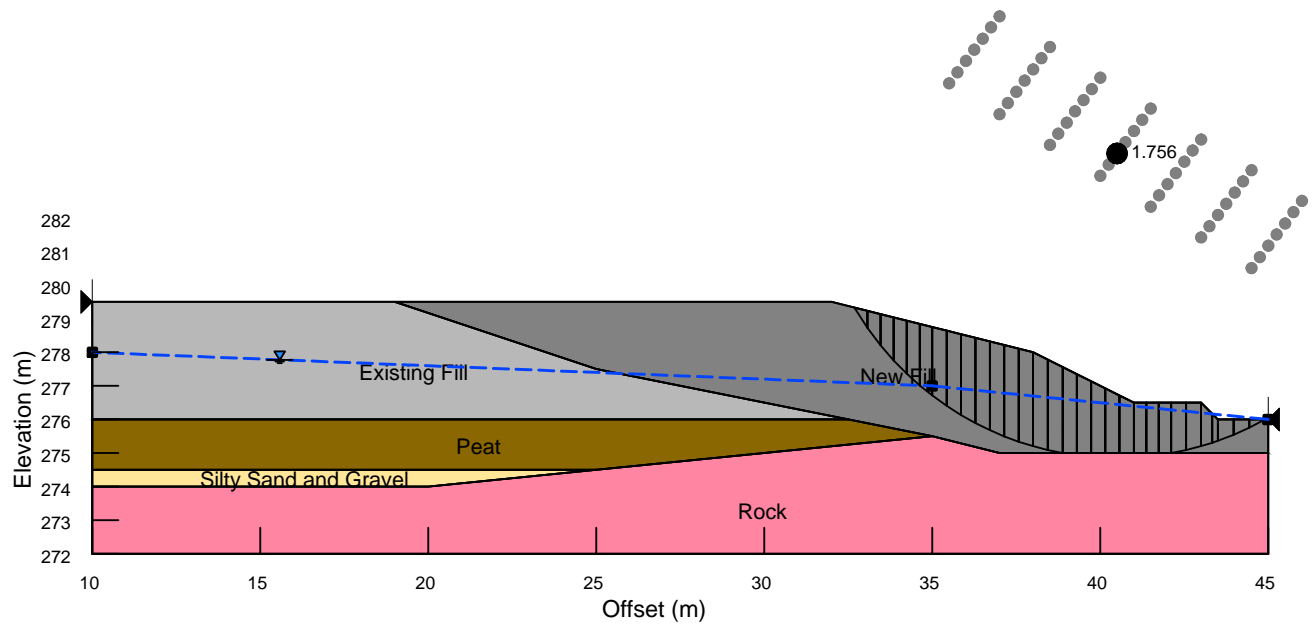
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	754	1	276.9
■	756	2	277.5
▲	761	1	276.9

PROJECT				SWAMP / SOFT GROUND HIGHWAY 401 IMPROVEMENTS GWP 4-00-00			
TITLE				GRAIN SIZE DISTRIBUTION SILTY SAND AND GRAVEL			
PROJECT No.		10-1132-0056		FILE No. 1011320056-2000-F150A3			
DRAWN		WDF		Dec 09/13		SCALE N/A REV.	
CHECK						FIGURE A-3	
 <b>Golder Associates</b> LONDON, ONTARIO							



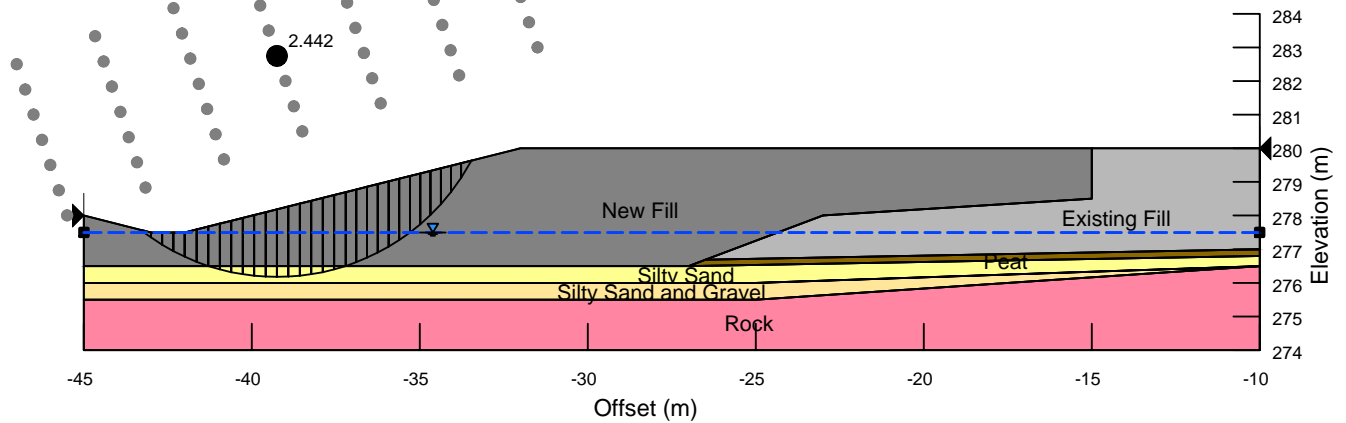
# **APPENDIX B**

## **Slope Stability Analyses**



**STA. 17+450 RT**  
(SOIL STRATIGRAPHY BASED ON BOREHOLES 610, 613 AND 742)

Soil Properties			
Soil	Angle of Friction $\phi^{\circ}$	Unit Weight, $\gamma$ (kN/m <sup>3</sup> )	Cohesion, $c_u$ (kPa)
New Fill	30	20	-
Existing Fill	30	20	-
Silty Sand	30	20	-
Silty Sand and Gravel	35	21	-
Peat & Topsoil	-	15	25



**STA. 17+580 LT**  
(SOIL STRATIGRAPHY BASED ON BOREHOLES 767 AND 914)

### NOTES

1. OFFSET = OFFSET FROM HIGHWAY CENTRELINE.
2. ANALYSES BASED ON CROSS SECTIONS SUPPLIED BY DELCAN.
3. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ACCOMPANYING TEXT.

PROJECT

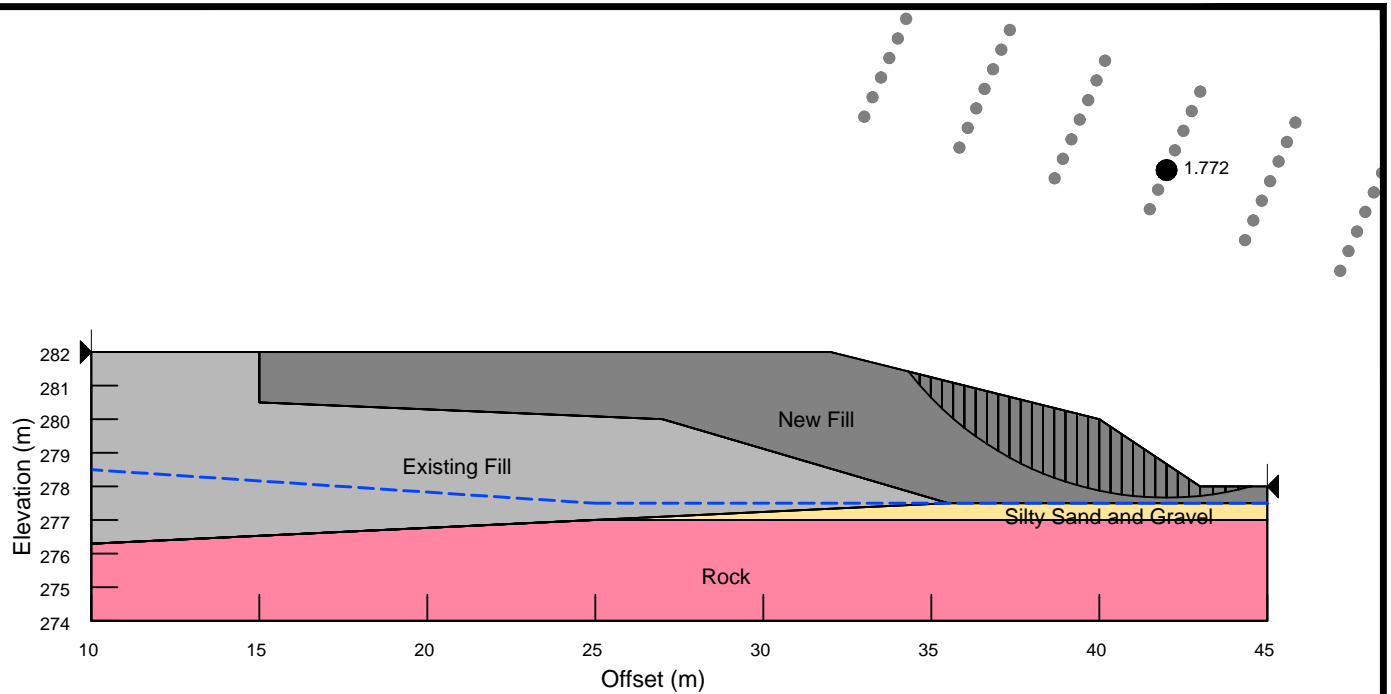
**SWAMP / SOFT GROUND  
HIGHWAY 401 IMPROVEMENTS  
GWP 4-00-00**

TITLE

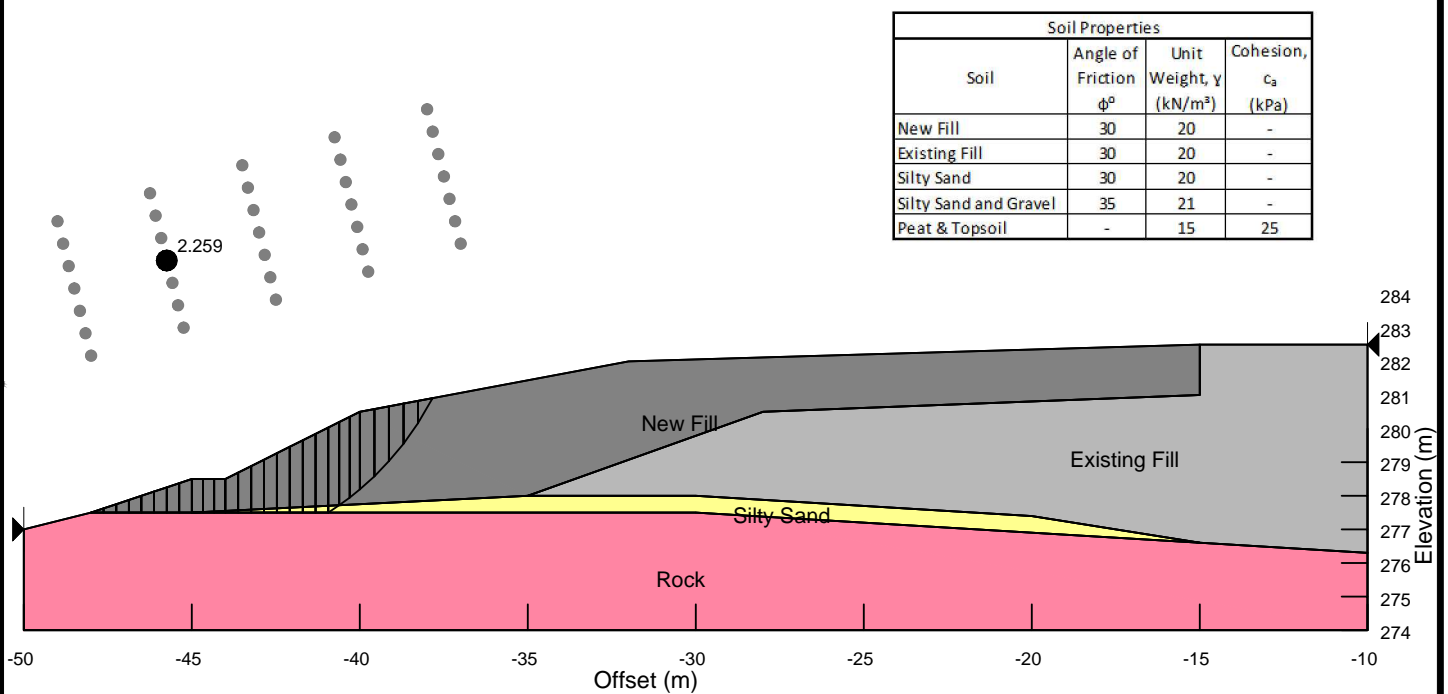
### RESULTS OF SLOPE STABILITY ANALYSES



PROJECT No.	10-1132-0056	FILE No.	1011320056-2000-F150B1
CADD	WDF	Jan. 31/14	SCALE AS SHOWN REV. 0
CHECK			<b>FIGURE B-1</b>



**STA 18+050 RT**  
(SOIL STRATIGRAPHY BASED ON BOREHOLES 755, 756 AND 915)



**STA 18+070 LT**  
(SOIL STRATIGRAPHY BASED ON BOREHOLES 724, 725 AND 915)

Soil Properties			
Soil	Angle of Friction $\phi^\circ$	Unit Weight, $\gamma$ (kN/m <sup>3</sup> )	Cohesion, $c_a$ (kPa)
New Fill	30	20	-
Existing Fill	30	20	-
Silty Sand	30	20	-
Silty Sand and Gravel	35	21	-
Peat & Topsoil	-	15	25

## NOTES

1. OFFSET = OFFSET FROM HIGHWAY CENTRELINE.
2. ANALYSES BASED ON CROSS SECTIONS SUPPLIED BY DELCAN.
3. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ACCOMPANYING TEXT.

PROJECT

**SWAMP / SOFT GROUND  
HIGHWAY 401 IMPROVEMENTS  
GWP 4-00-00**

TITLE

## RESULTS OF SLOPE STABILITY ANALYSES



PROJECT No.	10-1132-0056	FILE No.	1011320056-2000-F150B1
CADD	WDF	Jan. 31/14	SCALE Not to Scale
CHECK			REV. 0

**FIGURE B-2**



# **APPENDIX C**

**Records of Previously Drilled Boreholes,  
Geocres No. 40P8-213 (Non-Structural Culverts)**

**RECORD OF BOREHOLE No 7**

1 OF 1

**METRIC**

PROJECT 10-1132-0056

W.P. 4-00-00

LOCATION N 4808564.5 , E 235993.6

ORIGINATED BY MA

DIST HWY 401

BOREHOLE TYPE POWER AUGER, HOLLOW STEM / NQ ROCKCORE

COMPILED BY LMK

DATUM GEODETIC

DATE July 31, 2013

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								
277.57	GROUND SURFACE															
0.00	TOPSOIL, silty, with roots															
277.20	Brown															
0.37	SILTY SAND, with limestone fragments, trace organic material															
276.73	Very dense		1	SS	100/75mm											
0.84	Grey															
	DOLOSTONE, fresh, thickly bedded, buff grey to blue grey, microcrystalline, strong (R4), common stylolites, occasional vugs below elev. 274.2m. Zone of dark grey dolostone with numerous fine mud filled fractures between about elev. 275.1m and elev. 275.7m		2	NQ RC				84	68	68						
			3	NQ RC				101	85	82						
			4	NQ RC												
272.82	END OF BOREHOLE															
4.75	Groundwater encountered at about elev. 277.4m during drilling on July 31, 2013.  Water level measured at elev. 277.01m after installation on July 31, 2013.  Water level measured at elev. 277.16m on August 12, 2013.  Water level measured at elev. 277.29m on October 17, 2013 prior to decommissioning.															

PROJECT <u>10-1132-0056</u>		<b>RECORD OF BOREHOLE No 610</b>		1 OF 1		<b>METRIC</b>	
W.P. <u>4-00-00</u>		LOCATION <u>N 4808501.2 , E 236008.5</u>		ORIGINATED BY <u>MA</u>			
DIST <u>          </u> HWY <u>401</u>		BOREHOLE TYPE <u>POWER AUGER, HOLLOW STEM</u>		COMPILED BY <u>LMK</u>			
DATUM <u>GEODETIC</u>		DATE <u>June 4, 2012</u>		CHECKED BY <u>          </u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT  SHEAR STRENGTH kPa ○ UNCONFINED    + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE	PLASTIC LIMIT W <sub>p</sub> NATURAL MOISTURE CONTENT W    LIQUID LIMIT W <sub>L</sub> WATER CONTENT (%)	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						
277.05	GROUND SURFACE						277				
0.00	PEAT, fibrous Very soft to firm Black		1	SS	WR		276	Vane tests completed 1.0m east of borehole location. + 1.8 + 1.4			278
275.68	ORGANIC SILT Very soft Grey		2	SS	WR		275	+ 1.4			142
274.89	END OF BOREHOLE										
2.16	Auger refusal (Inferred Bedrock)  Groundwater encountered at about elev. 277.1m during drilling on June 4, 2012.										



PROJECT <u>10-1132-0056</u>		<b>RECORD OF BOREHOLE No 613</b>		1 OF 1		<b>METRIC</b>	
W.P. <u>4-00-00</u>		LOCATION <u>N 4808517.8 , E 236010.3</u>		ORIGINATED BY <u>LK</u>			
DIST <u>          </u> HWY <u>401</u>		BOREHOLE TYPE <u>POWER AUGER, HOLLOW STEM</u>		COMPILED BY <u>AMG/LMK</u>			
DATUM <u>GEODETIC</u>		DATE <u>September 21, 2012</u>		CHECKED BY <u>          </u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL LIMIT   MOISTURE   LIQUID CONTENT   LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
								20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>		
279.65	PAVEMENT SURFACE																
0.00	ASPHALT																
0.30	FILL, sand and gravel, crushed, trace silt Brown																
279.01																	
0.64	FILL, sand, trace clay, trace silt, trace gravel Dense Brown		1	SS	32							○				1   86   5   8	
278.35	FILL, silty sand and gravel, some topsoil Compact Brown to black		2	SS	22												
1.30																	
277.52	FILL, sand, trace to some silt, trace clay, trace gravel Compact to very loose		3	SS	16								○			7   73   12   8	
2.13																	
			4	SS	1												
276.00																	
3.65	PEAT, non fibrous Soft to firm Black		5	SS	3										144 ○		
			6	SS	17										97 ○		
274.47																	
5.26	SILTY SAND AND GRAVEL, with limestone fragments Very dense Grey END OF BOREHOLE  Split-spoon refusal (Inferred Bedrock)  Groundwater encountered at about elev. 277.9m during drilling on September 21, 2012.		7	SS	100/ 75mm												

PROJECT <u>10-1132-0056</u>		<b>RECORD OF BOREHOLE No 614</b>		1 OF 1		<b>METRIC</b>	
W.P. <u>4-00-00</u>		LOCATION <u>N 4808550.4 , E 236006.0</u>		ORIGINATED BY <u>SM</u>			
DIST <u>          </u> HWY <u>401</u>		BOREHOLE TYPE <u>POWER AUGER, HOLLOW STEM</u>		COMPILED BY <u>WDF/LMK</u>			
DATUM <u>GEODETIC</u>		DATE <u>September 25, 2012</u>		CHECKED BY <u>                    </u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE   LIQUID CONTENT   CONTENT   LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL	
								20	40	60	80	100	w <sub>p</sub>	w	w <sub>L</sub>						
279.63	PAVEMENT SURFACE																				
0.00	ASPHALT																				
0.28	FILL, sand, fine, trace clay, trace silt, trace gravel Loose to dense Brown		1	SS	25																
			2	SS	28																
			3	SS	35																
			4	SS	7																
275.82	DOLOSTONE, inferred bedrock END OF BOREHOLE		5	SS	100/ 0mm																
3.89	Auger Refusal at elev. 275.74m  Groundwater encountered at about elev. 277.2m during drilling on September 25, 2012.																				



## **APPENDIX D**

**Records of Previously Drilled Boreholes,  
Geocres No. 40P8-221 (High Mast Lights)**

**RECORD OF BOREHOLE No 914**

1 OF 1

**METRIC**

PROJECT 10-1132-0056  
W.P. 4-00-00 LOCATION N 4808533.4 , E 236140.3 ORIGINATED BY MA  
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM / NQ ROCKCORE COMPILED BY WDF/LMK  
DATUM GEODETIC DATE August 20, 2013 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											
280.00	PAVEMENT SURFACE																					
0.00	ASPHALT																					
0.15	FILL, sand and gravel, crushed, trace silt																					
0.30	Brown																					
	FILL, sand and gravel, some silt		1	SS	76																	
	Very dense																					
	Brown																					
278.63																						
1.37	FILL, silty sand, some gravel		2	SS	81																	
	Very dense																					
	Brown																					
277.87																						
2.13	FILL, sand, fine, trace clay, trace silt, trace gravel		3	SS	14																	
	Compact																					
	Brown																					
277.04																						
2.96	TOPSOIL, silty		4	SS	100/175mm																	
3.14	Compact																					
	Black																					
3.38	SILTY SAND, trace gravel, trace topsoil		5	NQ RC																		
	Very dense																					
	Brown																					
	Fresh, tan to light grey, massive to locally thick bedded, fine to medium crystalline DOLOSTONE. Common calcite-coated and carbonate filled voids between about elev. 275.7m to 274.7m (remnant fossils), local stylolite but rare. R3 strength.		6	NQ RC																		
			7	NQ RC																		
273.05	END OF BOREHOLE																					
6.95	Groundwater encountered at about elev. 277.3m during drilling on August 20, 2013.																					
	NOTE: Samples 6 and 7 were found to be highly mechanically fractured. Therefore the RQD and SCR has been estimated.																					

**RECORD OF BOREHOLE No 915**

1 OF 1

**METRIC**

PROJECT 10-1132-0056

W.P. 4-00-00

LOCATION N 4808541.7, E 236635.2

ORIGINATED BY DB

DIST HWY 401

BOREHOLE TYPE POWER AUGER, HOLLOW STEM / NQ ROCKCORE

COMPILED BY WDF/LMK

DATUM GEODETIC

DATE August 21, 2013

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											
283.20	PAVEMENT SURFACE						● QUICK TRIAXIAL	× LAB VANE												
0.00	ASPHALT							20	40	60	80	100	10	20	30					
0.15	FILL, sand and gravel, crushed, trace silt																			
282.74	Brown																			
0.46	FILL, sand and gravel, trace silt																			
0.76	Brown																			
	FILL, sand and gravel, trace silt		1	SS	98															
	Brown																			
	FILL, sand and gravel, trace to some silt, trace clay, with cobbles		2	SS	93															
	Very dense to compact																			
	Brown																			
			3	SS	77															
			4	SS	100/ 175mm															
			5	SS	103															
			6	SS	18															
			7	SS	19															
277.10																				
6.10	FILL, sand and gravel, some silt, trace topsoil, trace organics		8	SS	100/ 150mm															
	Very dense																			
	Brown																			
276.25			9	SS	100/ 75mm															
6.95	Fresh, tan to light grey, medium crystalline DOLOSTONE TO DOLOMITE LIMESTONE, thickly bedded to massive after about elev. 274.7m. Top 0.91m to 1.07m of fossil dolostone - dolomitic limestone with abundant carbonate-filled remnant fossils, vuggy throughout until about elev. 274.7m into massive grey, red crystalline Dolostone with rare stylolite. R3 - R4 strength.		10	NQ RC																
			11	NQ RC																
			12	NQ RC																
272.53																				
10.67	END OF BOREHOLE																			
	Groundwater encountered at about elev. 278.5m during drilling on August 21, 2013.																			

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[solutions@golder.com](mailto:solutions@golder.com)  
[www.golder.com](http://www.golder.com)

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

