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SPECIALISTS MANAGING THE EARTH

FOUNDATION INVESTIGATION AND DESIGN REPORTS – NOISE BARRIER EAST OF COUNTY RD 45 INTERCHANGE HIGHWAY 401, COBOURG, ONTARIO, W.P. NO. 205-00-01, GEOCRES 30M16- 46

AECOM

TRANETOB10434AA-AJ
November 23, 2011

Coffey Geotechnics Inc.
20 Meteor Drive Etobicoke Ontario M9W 1A4 Canada

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SPECIALISTS MANAGING THE EARTH

November 23, 2011

AECOM
5080 Commerce Boulevard
Mississauga, ON L4W 4P2

Attention: Ms. Peggy Baleka

Dear Ms. Baleka:

RE: Foundation Investigation and Design Reports, Noise Barrier East of County Road 45 Interchange, Highway 401, Cobourg, Ontario W.P. No. 205-00-01

Coffey Geotechnics Inc (Coffey) is pleased to present the Foundation Investigation and Design Reports for the proposed noise barrier to be located east of County Road 45 interchange, south of Highway 401, Cobourg, Ontario.

Please call us on 416 213 1255 should you require further clarification on any aspects of the reports.

For and on behalf of Coffey Geotechnics Inc.

Ramon Miranda, P.Eng.

Principal

Distribution: Original held by Coffey Geotechnics Inc.

1 hard copy to AECOM

1 hard copy to MTO Project Manager

1 hard copy to MTO Pavements and Foundation Section

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FOUNDATION INVESTIGATION REPORT NOISE BARRIER EAST OF COUNTY RD 45 INTERCHANGE, HIGHWAY 401 COBOURG, ONTARIO W.P. NO. 205-00-01, , GEOCRES 30M16- 46

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CONTENTS

CONTENTS

FOUNDATION INVESTIGATION REPORT
NOISE BARRIER – EAST OF COUNTY ROAD 45 INTERCHANGE
HIGHWAY 401, COBOURG, ONTARIO
W.P. 205-00-01

1 INTRODUCTION

At the request of AECOM, Coffey Geotechnics Inc. (Coffey) has prepared this foundation investigation report for a proposed noise barrier wall to be located east of County Road 45 interchange, south of Highway 401, Cobourg, Ontario. The work was carried out as part of the Highway 401 Expansion (6-Laning) from Burnham Street to approximately 2.0 km east of Nagle Road, within the Town of Cobourg and Township of Hamilton, Ontario. There are two noise barrier walls proposed for the project namely, to the east and west of County Road 45. This report deals with the walls to be constructed east of County Road 45, while those to the west are reported under separate cover. The foundation investigation was generally carried out in accordance with Coffey proposal (Reference PO 9236, dated May 25, 2009) and the requirements of the RFP.

The purpose of the investigation was to obtain information about the subsurface conditions at the site by means of boreholes, and to assess the engineering characteristics of the subsurface soils by means of field and laboratory tests.

This report provides factual information concerning subsurface conditions, in situ test and laboratory test results, based on the foundation investigation undertaken.

2 SITE DESCRIPTION AND PHYSIOGRAPHY

2.1 Site Description

The site is located between Stations 18+800 and 19+380, along the south side of Highway 401, east of County Road 45 Interchange in Cobourg, Ontario. The proposed noise barrier alignment is curved on the western end which is parallel to the alignment of the proposed N/S-E ramp of the County Road 45 interchange and then becomes straight which is adjacent to the south fence of the highway.

At the time of our investigation, vegetation such as grass and trees occupied the site. Beyond the fence line, residential houses are located. The ground elevation at the noise barrier location varies from slightly lower (maximum 1.5 m lower) than the existing highway grade then gradually becomes higher on the eastern end, to about 2.5 m higher.

Cobourg Creek is located about 900 m to the west of the site and Midtown Creek West about 170 m to the east of the site.

Photographs of the site are presented in Appendix C.

2.2 Physiography

According to "The Physiography of Southern Ontario" by L.J. Chapman and D.F. Putnam, 1984, the proposed noise barrier is located within the physiographic region known as the Iroquois Plain. The Iroquois

Plain was previously inundated by a body of water known as Lake Iroquois, the fore-runner of the present Lake Ontario. Iroquois Plain at Cobourg is about five kilometres in width and has a peculiar belted pattern. The land within the project area is covered by glaciolacustrine deposits overlying sandy glacial till deposits.

The bedrock underlying the project area is known to belong to the Trenton and Black River Groups (Simcoe Group), which are approximately 480 million years old, and consist of primarily limestone, with some dolostone, shale, arkose and sandstone (Bedrock Geology of Ontario, Southern Sheet, Map 2544 and Geological Highway Map Southern Ontario, Map 2441).

3 METHOD OF INVESTIGATION

3.1 Fieldwork

The fieldwork for the investigation was carried out between August 2010 and November 2010 and comprised of drilling ten boreholes (W6 to W15) at the locations shown on the Borehole Location Plan, Drawing 1. Table 1 below presents a summary of the borehole details.

Table 1: Borehole Details

Borehole No.	Station	Offset from Hwy 401 C/L	Existing Ground Elevation (m)	Drilled Depth (m)
W6	18+799*	11 m Right of C/L*	110.0	9.5
W7	18+880	44 m Right of C/L	109.5	6.6
W8	18+947	31 m Right of C/L	110.5	6.6
W9	19+005	33 m Right of C/L	111.4	6.6
W10	19+072	31 m Right of C/L	111.9	6.3
W11	19+117	31 m Right of C/L	112.5	6.3
W12	19+171	32 m Right of C/L	113.5	6.6
W13	19+251	34 m Right of C/L	115.3	6.3
W14	19+321	32 m Right of C/L	116.0	6.4
W15	19+372	30 m Right of C/L	115.2	7.9

Note: *Station and offset were referenced to the proposed N/S-E ramp centreline of the County Road 45 interchange.

The borehole drilling was carried out by Eastern Soil Investigation Limited and Strong Soil Search, using track mounted (Bombardier) drill rigs. Each borehole was advanced using solid flight augers within the soil materials, to depths of about 6.3 to 9.5 m below the ground surface. Standard Penetration Tests (SPTs) were carried out at selected depth intervals, to assess the soil strength and obtain samples for logging and testing purposes. SPTs were carried out in general accordance with ASTM D1586. The test consists of freely dropping a 63.5 kg hammer a vertical distance of 0.76 m to drive a 51 mm outside diameter (OD) split-barrel (SS-split-spoon) sampler into the ground. The number of blows of the hammer required to drive the sampler into the relatively undisturbed ground by a vertical distance of 0.30 m is recorded as the Standard Penetration Resistance or the N-value of the soil which is indicative of the compactness condition of granular (or cohesionless) soils (gravels, sands and silts) or the consistency of cohesive soils (clays and clayey soils).

The soil samples were described in the field, placed in appropriate containers, labelled and transported to our Etobicoke geotechnical laboratory where the samples underwent further detailed visual examination and samples were selected for geotechnical laboratory testing.

Groundwater levels and inflows, observed in the open boreholes during drilling, were recorded. No long term groundwater level monitoring was carried out for the site. Upon drilling completion, the boreholes were grouted using a cement/bentonite mixture, as per MTO procedures.

The borehole locations were located on site, using existing site features. The borehole location coordinates and ground elevations were subsequently measured by the client's surveyors and were provided to Coffey.

A Coffey representative was present during the drilling operations to direct sampling and testing, record test results and log materials encountered.

Appendix A presents the Record of Borehole Sheets.

3.2 Laboratory Testing

Soil samples obtained during the investigation were taken to our Etobicoke laboratory. The following tests were performed on selected soil samples:

- Natural moisture content tests;
- Grain size analyses (sieve and hydrometer tests); and
- Atterberg Limits tests.

Appendix B presents laboratory test results sheets for all the tests carried out except the natural moisture content results as they are presented on the Record of Borehole Sheets in Appendix A.

4 SUBSURFACE CONDITIONS

Detailed descriptions of the materials encountered in the boreholes are presented on the Record of Borehole Sheets in Appendix A. Explanation of Terms Used in Report is presented in Appendix D.

Drawing 1 presents the borehole location plan and the generalized subsurface profile along the proposed noise barrier.

In general, below a veneer of topsoil and some fill (encountered in Borehole W6 only), the site is underlain by native soils consisting of silty sand to sandy silt, clayey silt and silty sand to sandy silt till. The fill was encountered in Borehole W6 only and was found to extend 2.0 m below the ground surface. The silty sand to sandy silt deposit was generally on top of clayey silt except in Borehole W12 where it was found to be interbedded with it and in Boreholes W6 and W15 where it was absent. The extent of the silty sand to sandy silt and clayey silt deposits generally varied from 0.8 to 5.6 m below the ground surface but they were thicker (i.e. greater than 6.6 m) in Boreholes W7 and W8 where these boreholes were terminated within the clayey silt deposit. The underlying silty sand to sandy silt till deposit was generally encountered at Elevations 115.1 to 105.8 m in Boreholes W6 and W9 to W15, inclusive. The top of till deposit was found to be highest at the eastern end of the site and the lowest was found just before the western end where it was not encountered. All boreholes, except for Boreholes W7 and W8, were terminated within the silty sand to sandy silt till deposit at 6.3 to 9.5 m below the ground surface or at Elevations 109.6 to 100.5 m. Boreholes W7 and W8 were terminated within clayey silt.

The Record of Borehole Sheets and the profile provided indicate the subsurface conditions only at the borehole locations. Note that the material boundaries indicated on the logs are approximate and based on visual observations. These boundaries typically represent a transition from one material type to another and should not be regarded as an exact plane of geological change. It should be pointed out that the subsurface conditions may vary across this site.

The following summarizes the surface conditions encountered in the boreholes.

4.1 Topsoil

Topsoil, about 0.10 to 0.25 m thick, was encountered at the ground surface.

Note that in our experience, the thickness of organic rich soils frequently varies in between and beyond borehole locations.

4.2 Fill

Fill was encountered in Borehole W6 only. It was found below the topsoil and extends to 2.0 m below the ground surface or to Elevation 108.0 m. The fill was described as gravelly sand with traces to some silt and clay.

The following is the grain size distribution of a sample taken from the relatively finer component of the gravelly sand fill, as presented in Figure B1, in Appendix B.

Gravel:	13 %
Sand:	74 %
Silt and Clay:	13 %

The fill is described as a granular (non-cohesive) soil type.

Standard Penetration Tests yielded SPT N-values of 44 to 98 blows/0.3 m within the fill, indicating dense to very dense condition.

4.3 Silty Sand to Sandy Silt

Below the topsoil, typically, a silty sand to sandy silt deposit was encountered in the boreholes. Except in Boreholes W6 and W15, where it was not encountered. In Borehole W9, the deposit was found to be somewhat coarser and was described as sand with some sit content while in Borehole W12, this deposit interbedded with clayey silt deposit 0.8 m below the ground surface or at Elevation 112.7 m, with a thickness of 0.5 m. This deposit was found to extend to 0.7 to 1.3 m below the ground surface or to Elevations 115.1 to 108.5 m. It's thickness at the borehole locations was found to range from 0.5 to 1.2 m.

The silty sand to sandy silt is considered non-cohesive (i.e. granular) in nature.

SPT N-values of 5 to 25 blows/0.3 m were recorded within this deposit, indicating a loose to compact condition. Typically, the SPT N-values indicating loose condition were recorded near the ground surface.

4.4 Clayey Silt

A clayey silt deposit was encountered at 0 to 2.0 m below the ground surface or at Elevations 115.1 to 108.0 m, generally below the silty sand to sandy silt deposit except in Borehole W6 where it was encountered below the fill, in Boreholes W12 and W15 where it was encountered below the topsoil and in Boreholes W13 and W14 where it was absent. In Borehole W12, as discussed above, a 0.5 m thick silty sand to sandy silt deposit was encountered within the clayey silt deposit. This deposit was found to have a thickness ranging from 1.2 to 4.3 m where it was fully penetrated (i.e. Boreholes W6, W9, W10, W11, W12 and W15). In these boreholes the deposit was found to extend to Elevations ranging from 113.5 m (Borehole W15) to 105.8 m (Borehole W10). Boreholes W7 and W8 were terminated within this deposit at 6.6 m below the ground surface or at Elevations 103.9 to 102.9 m, after penetrating it for a vertical distance of 5.6 and 5.3 m, respectively.

Based on a visual examination of the soil samples recovered, the deposit is described a basically cohesive soil with occasional non-cohesive (i.e. granular) silty sand seams. It basically consists of clayey silt with traces to some sand.

The following is the grain size distribution of one sample retrieved from clayey silt deposit, as presented in Figure B2, in Appendix B.

Gravel:	0 %
Sand:	8 %
Silt:	56 %
Clay:	36 %

Atterberg Limits test was also conducted on the same sample retrieved from this deposit and indicated the following results, also shown in Figure B3, in Appendix B.

Liquid Limit:	27 %
Plastic Limit:	16 %
Plasticity Index:	11 %

The Atterberg Limits test results indicate a clayey soil of low plasticity (i.e. a CL material).

Standard Penetration Tests yielded SPT N-values of 9 to 42 blows/0.3 m within the deposit indicating stiff to hard consistency but typically stiff to very stiff. An isolated SPT N-value of 7 blows/0.3 m was recorded in Borehole W9, near the interface with the overlying sand deposit, indicating a firm consistency.

4.5 Silty Sand to Sandy Silt Till

Below the clayey silt and sandy silt (in Boreholes W13 and W14 only), a glacial till deposit was encountered at 0.8 to 5.6 m below the ground surface or at Elevations 115.1 to 105.8 m. In Boreholes W7 and W8, this till deposit was not encountered as these boreholes were terminated within the overlying clayey silt deposit. Typically, the top of the till deposit was found to be highest at the eastern end of the site and lowest just before the western end. This till deposit is described as a heterogeneous mixture of silty sand to sandy silt with traces of gravel and clay. The presence of clayey silt seams, clay pockets, gravelly layers and cobbles were also noted within this deposit. All boreholes, except Borehole W7 and W8, were terminated within this till deposit at 6.3 to 9.5 m below the ground surface or at Elevations 109.6 to 100.5 m.

The following is the grain size distribution of two typical samples retrieved from this deposit, as presented in Figure B4, in Appendix B.

Gravel:	11 – 13 %
Sand:	32 – 49 %
Silt and Clay:	38 – 57 %

Figure B4, in Appendix B, also shows the grain size distribution of a gravelly layer sample taken within the till deposit, as follows.

Gravel:	40 %
Sand:	29 %
Silt and Clay:	31%

The till is a granular (i.e. non-cohesive) soil type. As mentioned before, the presence of cobbles and boulders were inferred in the deposit. Their present should always be anticipated in such glacial deposits, owing to their mode of deposition.

Typically, SPT N-values of 35 to in excess of 100 blows/0.3 m were recorded within the till deposit indicating a dense to very dense condition. In Borehole W13, relatively lower SPT N-values of 22 to 26 blows/0.3 m were recorded on top of this deposit, near the interface with the overlying sandy silt deposit, indicating a localized compact condition.

4.6 Groundwater Conditions

Groundwater levels were observed in the open boreholes while drilling and upon completion of each borehole. The groundwater levels observed during the investigation are presented on the Record of Borehole Sheets in Appendix A and are summarized in the following table.

Table 2: Groundwater Level Observations

Borehole No.	Date of Water Level Measurement	Measured Water Level Depth/Elevation (m)	Comments
W6	Nov 16, 2010	3.8 / 106.2* (spoon wet at 2.3 / 107.7)	measured upon borehole completion
W7	Nov 15, 2010	0.9 / 108.6* (spoon wet at 1.5 / 108.0)	measured upon borehole completion
W8	Aug 6,2010	2.3 / 108.2* (spoon wet at 2.3 / 108.2)	measured upon borehole completion
W9	Aug 6, 2010	caved in at 3.1 / 108.3* (spoon wet at 4.6 / 106.8)	measured upon borehole completion
W10	Aug 5, 2010	Dry to and caved in at 5.5 / 106.4* (spoon wet at 2.3 / 109.6)	measured upon borehole completion
W11	Aug 5, 2010	Dry* (spoon wet at 6.1 / 106.4)	measured upon borehole completion
W12	Aug 5, 2010	caved in at 4.3 / 109.2* (spoon wet at 3.8 / 109.7)	measured upon borehole completion
W13	Aug 5, 2010	Dry*	measured upon borehole completion
W14	Aug 4, 2010	Dry to and caved in at 5.8 / 110.2*	measured upon borehole completion
W15	Aug 5, 2010	4.0 / 111.2* (wet below 5.5 / 109.7)	measured upon borehole completion

Note: * Groundwater level measured not stabilized.

These short term groundwater observations may not represent the stabilized groundwater conditions at the site.

Based on the moisture condition of the soil samples and our observations, the site groundwater level at the time of our investigation was generally 2 to 5 m below the existing ground grades and varied from about Elevation 111 m on the east side to Elevation 107 m on the west.

There are two water bodies near the site namely, Cobourg Creek about 900 m to the west of the site and Midtown Creek West about 170 m to the east of the site. Based on our other reports for the project, the groundwater elevations near these water bodies are at Elevation 93.0 to 92.5 m at the Cobourg Creek site and at Elevation 109.4 to 109.0 m at the Midtown Creek West site. As there was no long term groundwater monitoring carried out for this site, the measured groundwater levels may be dipping toward the mentioned water bodies or it may be perched groundwater levels.

It should be noted that groundwater levels are subject to variations due to the influence of rainfall, temperature, local drainage, seasons and other factors. Development of perched groundwater tables may occur, as discussed above, following periods of rainfall and groundwater may rise to the ground surface, particularly in response to surface water temporarily accumulating in the more pervious silty sand to sandy silt overlying the relatively less pervious clayey silt deposit.

For and on behalf of Coffey Geotechnics Inc.

for **Delfa Sarabia, M.Eng.**

Senior Geotechnical Engineer

LICENSED PROFESSIONAL ENGINEER
RAMON MIRANDA
PROVINCE OF ONTARIO

Ramon Miranda, P.Eng.

Principal

REGISTERED PROFESSIONAL ENGINEER
Z. S. OZDEN
PROVINCE OF ONTARIO

Zuhtu Ozden, P.Eng.

Senior Principal

Drawing

NOTES:

FOR DETAILED SUBSURFACE CONDITIONS REFER TO RECORD OF BOREHOLE SHEETS.

METRIC

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

CONT No.

GWP: 205-00-01

NOISE BARRIER - SOUTH OF HWY 401,
EAST OF COUNTY RD. 45 INTERCHANGE
BOREHOLE LOCATION PLAN
AND SOIL STRATA

SHEET

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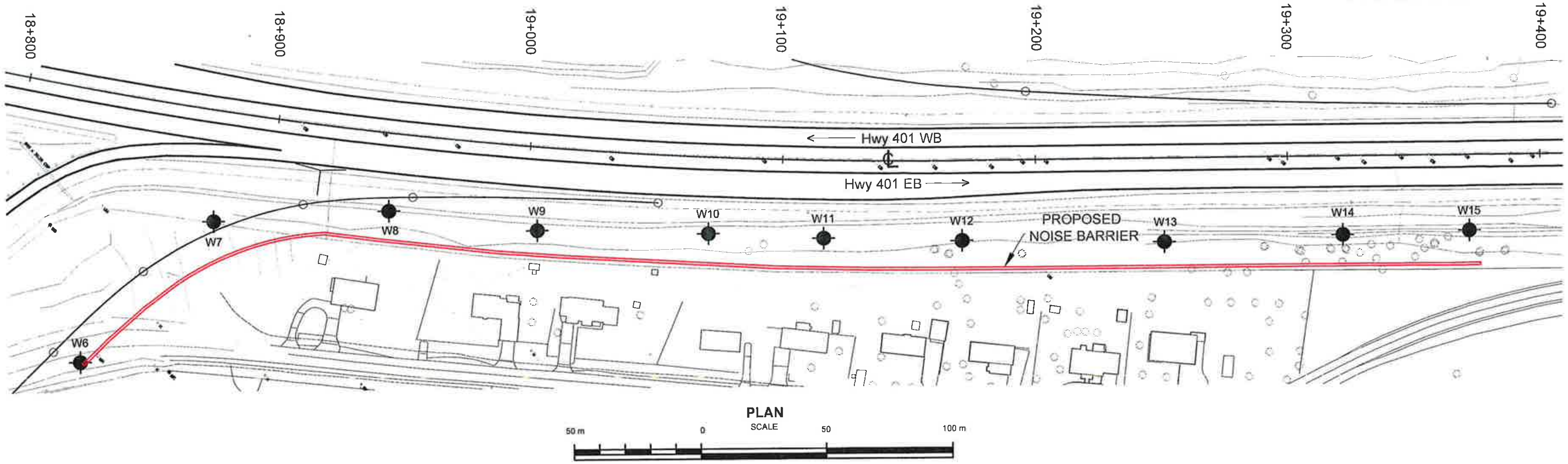
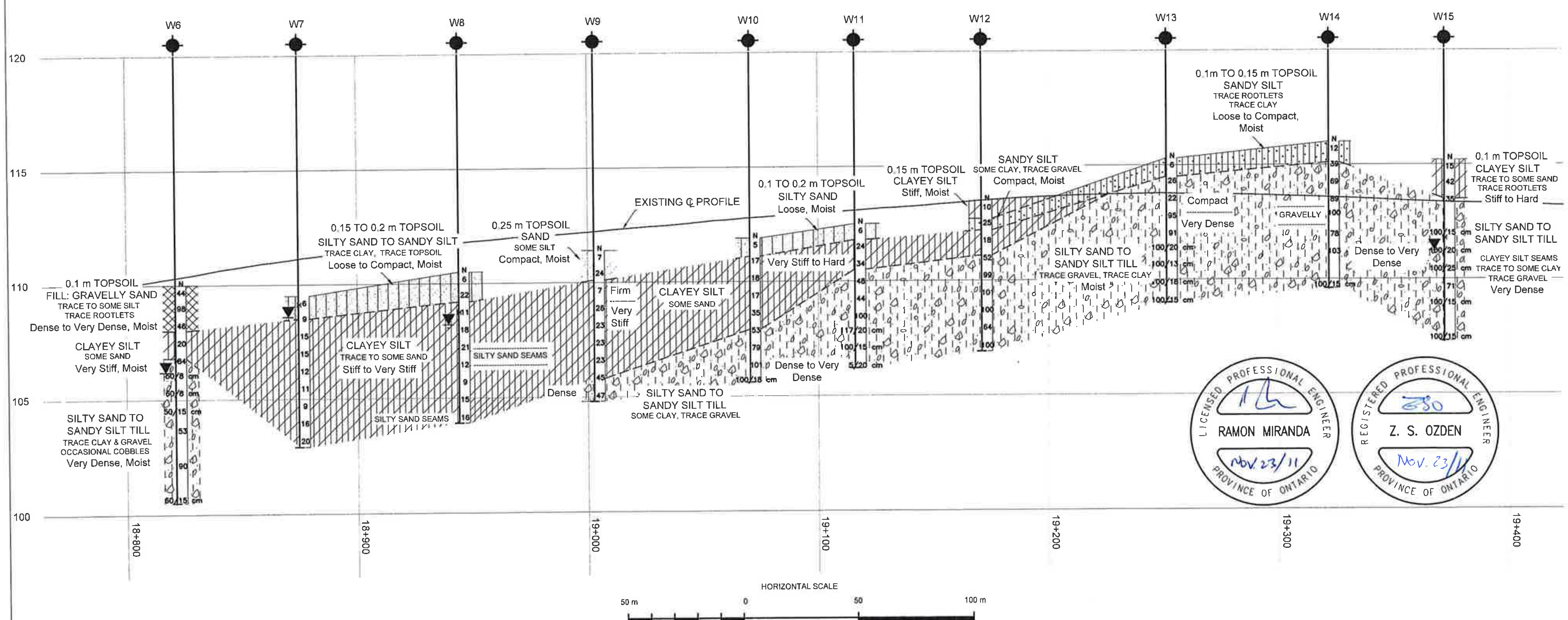


KEY PLAN
N.T.S.



LEGEND

- Borehole
- Borehole & Cone
- N — Blows/0.3m (Std. Pen. Test, 475 J/blow)
- Water Level at Time of Investigation (W. L. NOT STABILIZED)
- Water Level in Piezometer
- Piezometer

No.	ELEVATION	EASTING	NORTHING
W6	110.0	411531.6	4872686.0
W7	109.5	411534.2	4872763.1
W8	110.5	411583.6	4872811.9
W9	111.4	411633.2	4872844.7
W10	112.0	411684.8	4872888.2
W11	112.5	411720.6	4872917.1
W12	113.5	411762.3	4872952.5
W13	115.3	411822.8	4873005.1
W14	116.1	411873.9	4873053.8
W15	115.2	411910.4	4873088.4

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

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

REVISIONS	DATE	BY	DESCRIPTION

Geocres No. 30M16-46

TRANETOB10434AA			DIST
SUBM'D	CHECKED	DATE Nov.23, 2011	SITE
DRAWN SH	CHECKED RM	APPROVED ZO	DWG 1

Appendix A

Record of Borehole Sheets

TRANETOB10434AA: Highway 401

RECORD OF BOREHOLE No W6

METRIC

GWP G.W.P 205-00-01	LOCATION Station 18+799, 11 m Rt of C/L of Proposed N/S-E Ramp (E 411531.6, N 4872686.0)		ORIGINATED BY LG
DIST HWY 401	BOREHOLE TYPE Solid Stem Auger		COMPILED BY SK
DATUM Geodetic	DATE 11/16/2010		CHECKED BY ZO

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
110.0	GROUND SURFACE					
0.0	0.1 m **TOPSOIL**	1	SS	44		
	FILL: Gravelly Sand tr. to some silt tr. rootlets brown, dense to v. dense, moist	2	SS	98		
		3	SS	46		13 74 (13)
108.0 2.0	**CLAYEY SILT** some sand grey, v. stiff, moist	4	SS	20		Spoon wet below 2.3 m
106.8 3.2	tr. gravel	5	SS	84		
	SILTY SAND TO SANDY SILT TILL tr. clay and gravel occ. cobbles grey, v. dense, moist	6	SS	50 / 8 cm	▼*	
		7	SS	60 / 8 cm		Spoon bouncing @ 4.7 m
		8	SS	50 / 15 cm		
		9	SS	53		11 32 40 17
		10	SS	90		
100.5 9.5		11	SS	60 / 15 cm		

End of Borehole.
Water level @ 3.8 m (not stabilized)* upon completion.
Borehole caved-in @ 6.3 m upon completion.

Plot headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH (kPa): O UNCONFINED, + FIELD VANE, ● POCKET PENETR., × LAB VANE (20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; ELEVATION SCALE 110–101.

+ ³, × ³: Numbers refer to Sensitivity

15 -○- 5 (20 above, 10 below) (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

TRANETOB10434AA: Highway 401

RECORD OF BOREHOLE No W7

METRIC

GWP G.W.P 205-00-01	LOCATION Station 18+880, 44 m Rt of C/L (E 411534.2, N 4872763.1)	ORIGINATED BY LG
DIST ___ HWY 401	BOREHOLE TYPE Solid Stem Auger	COMPILED BY SK
DATUM Geodetic	DATE 11/15/2010	CHECKED BY ZO

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%)
109.5	GROUND SURFACE						
0.0	0.2 m **TOPSOIL**						
	dk. brown	1	SS	6		109	
	brown						
108.5 / 1.0	**SILTY SAND TO SANDY SILT** tr. to some clay and gravel, loose, moist	2	SS	9	▼*		
	CLAYEY SILT some sand grey, stiff to v. stiff	3	SS	15		108	Spoon wet @ 1.5 m
		4	SS	15		107	
		5	SS	12		106	
		6	SS	11			
		7	SS	9		105	
		8	SS	16		104	
	tr. gravel	9	SS	20		103	
102.9 / 6.6	End of Borehole. Water level @ 0.9 m (not stabilized)* upon completion. Borehole caved-in @ 1.8 m upon completion.						

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH (kPa): ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE — 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m³

GR SA SI CL

+3, ×3 Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

TRANETOB10434AA: Highway 401

RECORD OF BOREHOLE No W8

METRIC

GWP G.W.P 205-00-01 LOCATION Station 18+947, 31 m Rt of C/L (E 411583.6, N 4872811.9) ORIGINATED BY LG

DIST HWY 401 BOREHOLE TYPE Solid Stem Auger COMPILED BY SK

DATUM Geodetic DATE 8/6/2010 CHECKED BY ZO

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
110.5	GROUND SURFACE					
0.0	0.15 m **TOPSOIL** dk. brown	1	SS	6		
	SILTY SAND TO SANDY SILT trace clay, trace topsoil brown, loose to compact, moist	2	SS	22		
109.2 / 1.3	**CLAYEY SILT** tr. to some sand grey, stiff to v. stiff; moist	3	SS	11		
	wet	4	SS	18	▼*	spoon wet below 2.3 m
	silty sand seams	5	SS	21		
		6	SS	12		0 8 56 36
		7	SS	9		
		8	SS	15		
103.9	silty sand seams	9	SS	16		
6.6	End of Borehole. Water level @ 2.3 m (not stabilized)* upon completion. Borehole caved-in @ 4.6 m upon completion.					

Elevation scale: 110, 109, 108, 107, 106, 105, 104

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH (kPa): O UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE — 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m^3

+ 3, × 3: Numbers refer to Sensitivity — 20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No W9

METRIC

GWP	G.W.P 205-00-01	LOCATION	Station 19+005, 33 m Rt of C/L (E 411633.2, N 4872844.7)
DIST		HWY 401	
BOREHOLE TYPE	Solid Stem Auger	ORIGINATED BY	LG
DATUM	Geodetic	COMPILED BY	SK
DATE	8/6/2010	CHECKED BY	ZO

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
111.4	GROUND SURFACE
0.0	0.25 m **TOPSOIL**
	SAND some silt, brown, compact, moist (dk. brown / brown)
110.1 / 1.3	**CLAYEY SILT** tr. to some sand, grey, moist (firm / v. stiff)
105.8 / 5.6	**SILTY SAND TO SANDY SILT TILL** some clay, trace gravel, grey, dense, moist to wet
104.8 / 6.6	End of Borehole. Borehole caved-in @ 3.1 m upon completion.

SAMPLES

NUMBER	TYPE	"N" VALUES
1	SS	7
2	SS	24
3	SS	7
4	SS	26
5	SS	23
6	SS	23
7	SS	23
8	SS	45
9	SS	47

GROUND WATER CONDITIONS | ELEVATION SCALE: 111, 110, 109, 108, 107, 106, 105

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH (kPa): O UNCONFINED + FIELD VANE ● POCKET PENETR. X LAB VANE: 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L

WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m^3

REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

spoon wet below 4.6 m

$+^3, \times^3$: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No W10

METRIC

GWP G.W.P 205-00-01 LOCATION Station 19+072, 31 m Rt of C/L (E 411684.9, N 4872888.2) ORIGINATED BY LG

DIST HWY 401 BOREHOLE TYPE Solid Stem Auger COMPILED BY SK

DATUM Geodetic DATE 8/5/2010 CHECKED BY ZO

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
111.9	GROUND SURFACE					
0.0	0.2 m **TOPSOIL** **SILTY SAND** blackish brown to brown tr. rootlets, loose, moist	1	SS	5		
111.1 0.8	**CLAYEY SILT** some sand v. stiff to hard brown / grey	2	SS	17		
		3	SS	18		
		4	SS	17		spoon wet below 2.3 m
		5	SS	35		
107.9 4.0	**SILTY SAND TO SANDY SILT TILL** tr. gravel grey, v. dense, moist	6	SS	53		
		7	SS	79		13 49 (38)
		8	SS	101	▽	
105.6 6.3		9	SS	100 / 18 cm		

End of Borehole.
Borehole dry upon completion.
Borehole caved-in @ 5.5 m upon completion.

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH (kPa): O UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE 20 40 60 80 100

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L — WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

ELEVATION SCALE: 111, 110, 109, 108, 107, 106

+ 3, × 3 Numbers refer to Sensitivity; 15-◇-5 (20/10) (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No W11

METRIC

GWP G.W.P 205-00-01 LOCATION Station 19+117, 31 m Rt of C/L (E 411720.6, N 4872917.1) ORIGINATED BY LG

DIST HWY 401 BOREHOLE TYPE Solid Stem Auger COMPILED BY SK

DATUM Geodetic DATE 8/5/2010 CHECKED BY ZO

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%)
112.5	GROUND SURFACE				
0.0	0.1 m **TOPSOIL** **SILTY SAND** brown, loose, moist	1	SS	6	
111.8 / 0.7	**CLAYEY SILT** some sand brown, v. stiff to hard, moist	2	SS	24	
		3	SS	34	
110.5 / 2.0	**SILTY SAND TO SANDY SILT TILL** tr. to some clay and gravel grey, moist	4	SS	48	
	clayey silt seams	5	SS	44	
	dense / v. dense	6	SS	100	
		7	SS	117 / 20 cm	Auger grinding @ 4.5 and 5.3 m
		8	SS	100 / 15 cm	
106.2		9	SS	105 / 20 cm	Spoon wet
6.3	End of Borehole. Borehole was dry and open upon completion.				

Column headings also include: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (112, 111, 110, 109, 108, 107); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH (kPa): O UNCONFINED, + FIELD VANE, ● POCKET PENETR., × LAB VANE (20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (10 20 30); UNIT WEIGHT γ kN/m³; GR SA SI CL.

$+^3, \times^3$: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

TRANETOB10434AA: Highway 401

RECORD OF BOREHOLE No W12

METRIC

GWP G.W.P 205-00-01	LOCATION Station 19+171, 32 m Rt of C/L (E 411762.3, N 4872952.5)		ORIGINATED BY LG
DIST	HWY 401	BOREHOLE TYPE Solid Stem Auger	COMPILED BY SK
DATUM Geodetic	DATE 8/5/2010		CHECKED BY ZO

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%)
113.5	GROUND SURFACE						
0.0	0.15 m **TOPSOIL** **CLAYEY SILT** brown, stiff, moist		1	SS	10		
112.7 / 0.8	**SANDY SILT** some clay, tr. gravel brown, compact, moist		2	SS	25		
112.2 / 1.3	**CLAYEY SILT** tr. to some sand brown, v. stiff, moist		3	SS	18		
111.1 / 2.4	**SILTY SAND TO SANDY SILT TILL** some clay, tr. to some gravel brown to grey, v. dense, moist to wet		4	SS	52		
			5	SS	99		
			6	SS	101	▽	spoon wet below 3.8 m
			7	SS	100		
			8	SS	64		
			9	SS	100		
106.9 / 6.6	End of Borehole. Borehole caved-in @ 4.3 m upon completion.						

ELEVATION SCALE: 113, 112, 111, 110, 109, 108, 107

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH (kPa): ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE — 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L

WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m³

GR SA SI CL

+³, ×³: Numbers refer to Sensitivity — 20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No W13

METRIC

GWP	G.W.P 205-00-01	LOCATION	Station 19+251, 34 m Rt of C/L (E 411822.9, N 4873005.1)
DIST		HWY 401	BOREHOLE TYPE: Solid Stem Auger
DATUM	Geodetic	DATE	8/5/2010

ORIGINATED BY: LG
COMPILED BY: SK
CHECKED BY: ZO

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
115.3 / 0.0	GROUND SURFACE; 0.15 m **TOPSOIL**; **SANDY SILT** brown, loose, moist	1	SS	6		115	
114.5 / 0.8	**SILTY SAND TO SANDY SILT TILL** tr. gravel, tr. clay, brown to grey, moist	2	SS	26		114	
	clay pockets	3	SS	22			
	compact / v. dense	4	SS	95		113	
		5	SS	91		112	
		6	SS	100 / 20 cm		111	Auger grinding @ 3.8 m
		7	SS	100 / 13 cm			
		8	SS	100 / 18 cm		110	Auger grinding @ 5.3 m
		9	SS	100 / 15 cm		109	
109.0 / 6.3	End of Borehole. Borehole was dry and open upon completion.						

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH (kPa): ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L

WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m³

$+^3, \times^3$ Numbers refer to Sensitivity

15-⊕-5 (20 / 10) (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

Foundation Design

TRANETOB10434AA: Highway 401

RECORD OF BOREHOLE No W14

1 OF 1

METRIC

GWP G.W.P 205-00-01 LOCATION Station 19+321, 32 m Rt of C/L (E 411873.9, N 4873053.8) ORIGINATED BY LG

DIST HWY 401 BOREHOLE TYPE Solid Stem Auger COMPILED BY SK

DATUM Geodetic DATE 8/4/2010 CHECKED BY ZO

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
116.0	GROUND SURFACE					116	
0.0	0.1 m **TOPSOIL** **SANDY SILT** tr. rootlets, tr. clay brown, compact, moist	1	SS	12			
115.1 / 0.9	**SILTY SAND TO SANDY SILT TILL** trace gravel, trace clay greyish brown, moist; dense	2	SS	39		115	
	v. dense	3	SS	69		114	
		4	SS	89		113	
	gravelly	5	SS	100			40 29 (31)
		6	SS	78		112	
		7	SS	103		111	
		8	AS		▽	110	
109.6 / 6.4		9	SS	100 / 15 cm			

End of Borehole.
Borehole was dry upon completion.
Borehole caved-in @ 5.8 m.

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH (kPa): ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE — 20 40 60 80 100
PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L
WATER CONTENT (%): 10 20 30
UNIT WEIGHT γ kN/m³

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No W15

METRIC

GWP G.W.P 205-00-01 LOCATION Station 19+372, 30 m Rt of C/L (E 411910.4, N 4873088.4) ORIGINATED BY LG

DIST HWY 401 BOREHOLE TYPE Solid Stem Auger COMPILED BY SK

DATUM Geodetic DATE 8/5/2010 CHECKED BY ZO

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE
115.2	GROUND SURFACE					
0.0	0.1 m **TOPSOIL** **CLAYEY SILT** tr. to some sand, tr. rootlets brown, stiff to hard	1	SS	15		115
		2	SS	42		114
113.5 1.7	**SILTY SAND TO SANDY SILT TILL** dense	3	SS	35		
	v. dense	4	SS	109		113
		5	SS	100 / 15 cm		112
	clayey silt seams	6	SS	100 / 20 cm	▼*	111
	tr. to some clay tr. gravel, grey	7	SS	100 / 25 cm		110
	moist / wet	8	SS	71		
		9	SS	100 / 15 cm		109
						108
107.3		10	SS	100 / 15 cm		
7.9	End of Borehole. Water level @ 4.0 m (not stabilized)* upon completion. Borehole caved-in @ 4.6 m upon completion.					

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH (kPa): O UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L

WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m³

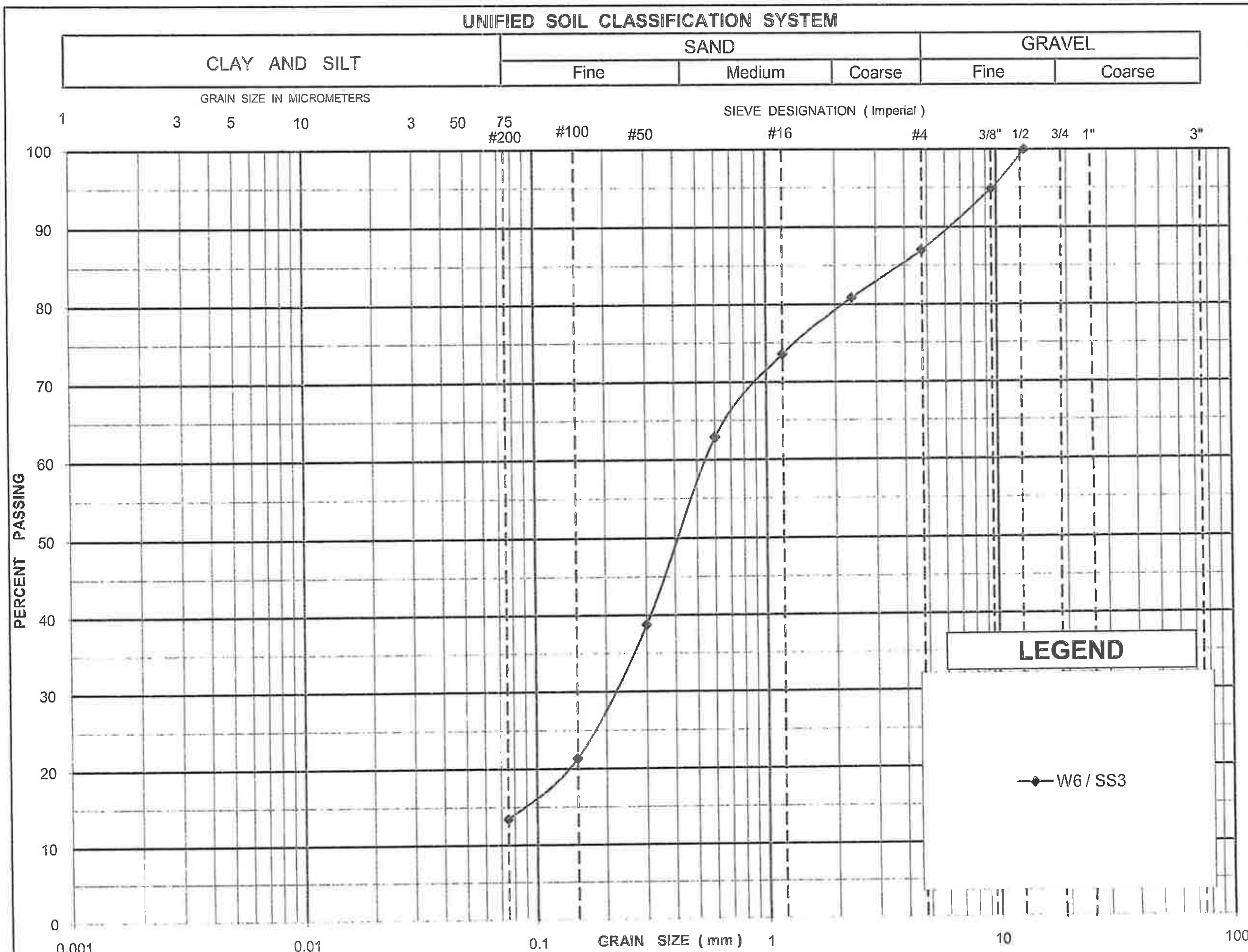
REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

+ ³, × ³ Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Appendix B

Laboratory Test Results



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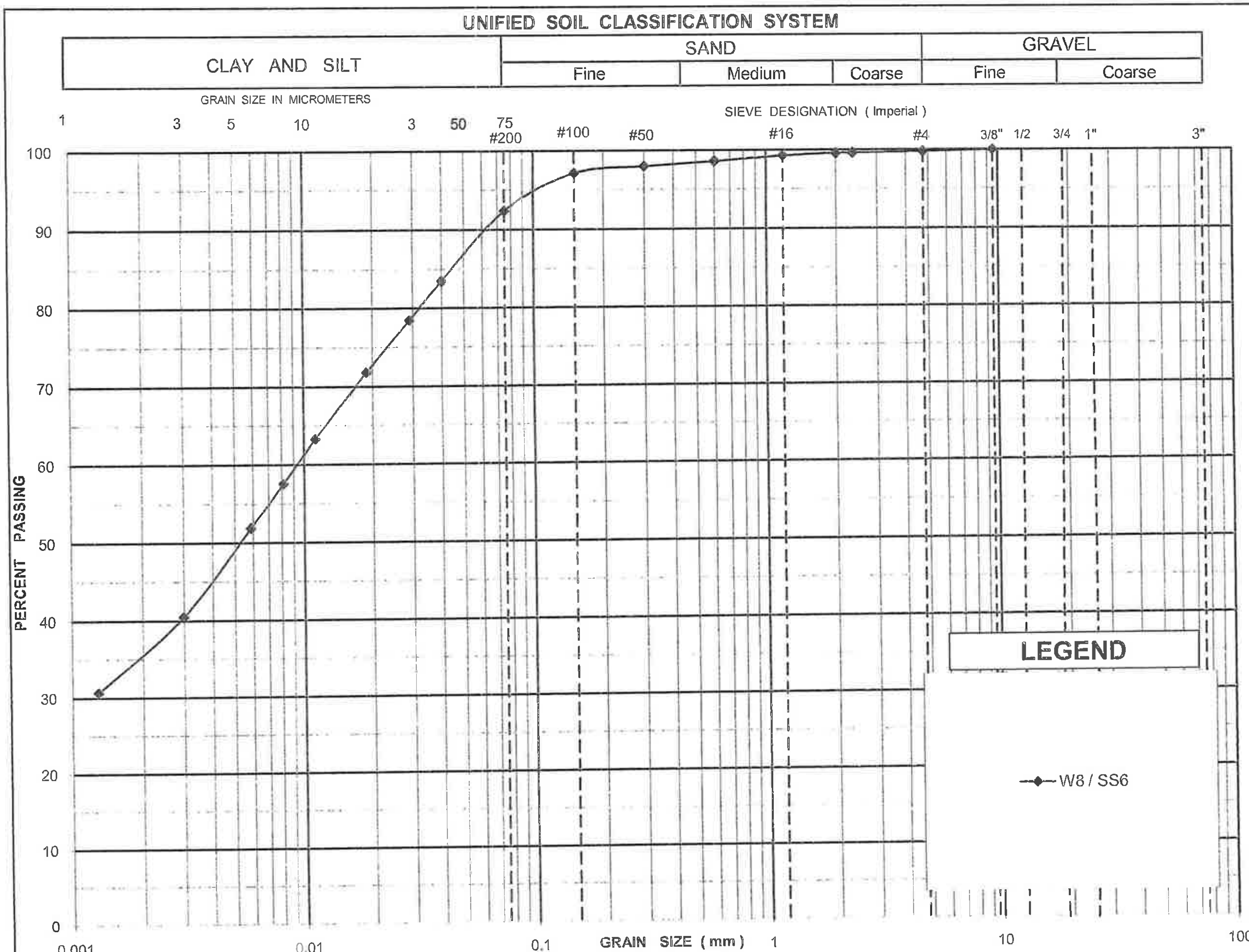
GRAIN SIZE DISTRIBUTION

FILL - Gravelly Sand, trace to some silt

FIGURE NO.:	B1
PROJECT NO.:	TRANETOB10434AA
DATE :	JAN. 10, 2011



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GRAIN SIZE DISTRIBUTION

CLAYEY SILT

FIGURE NO.:	B2
PROJECT NO.:	TRANETOB10434AA
DATE :	JAN. 10, 2011

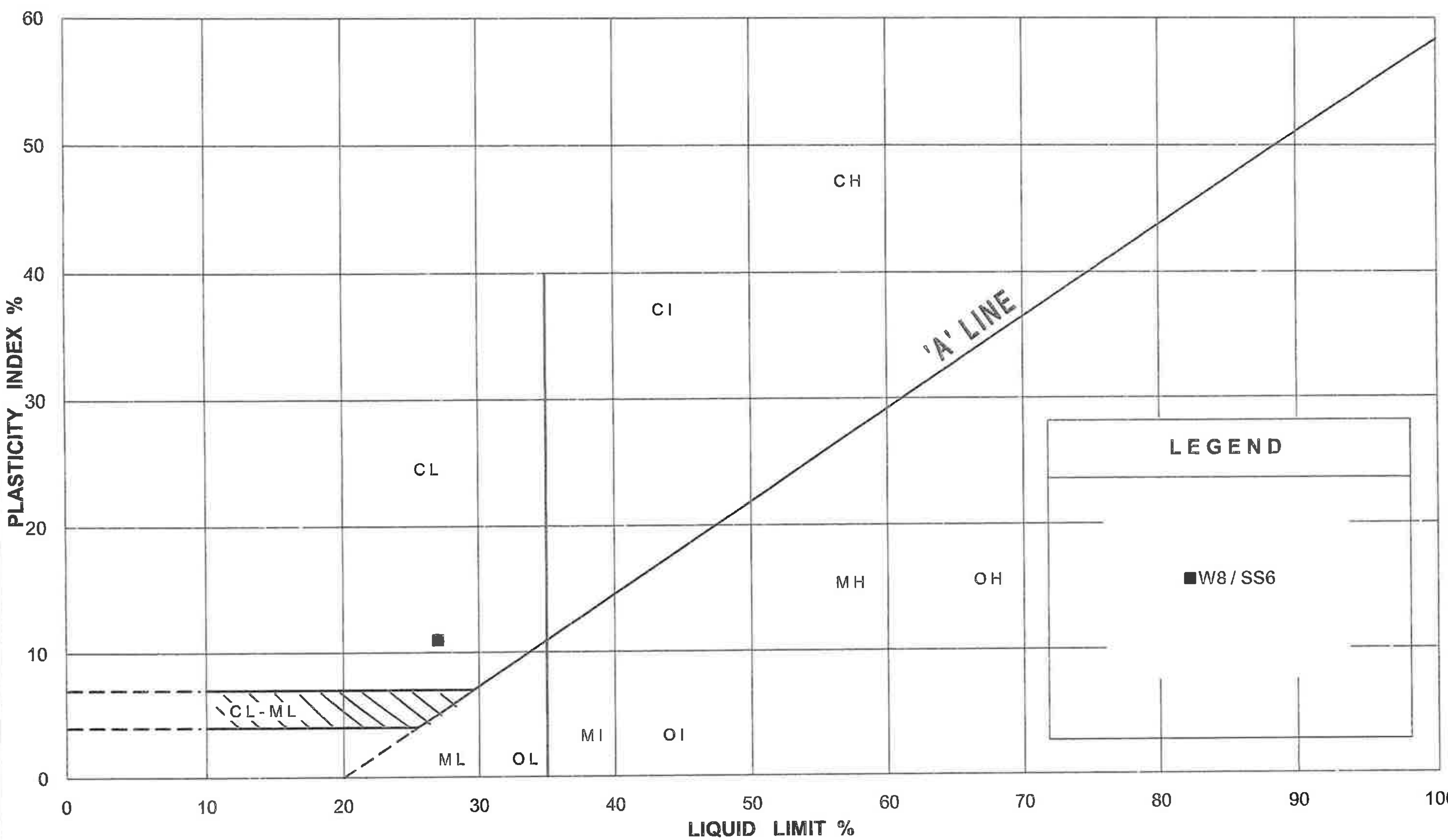

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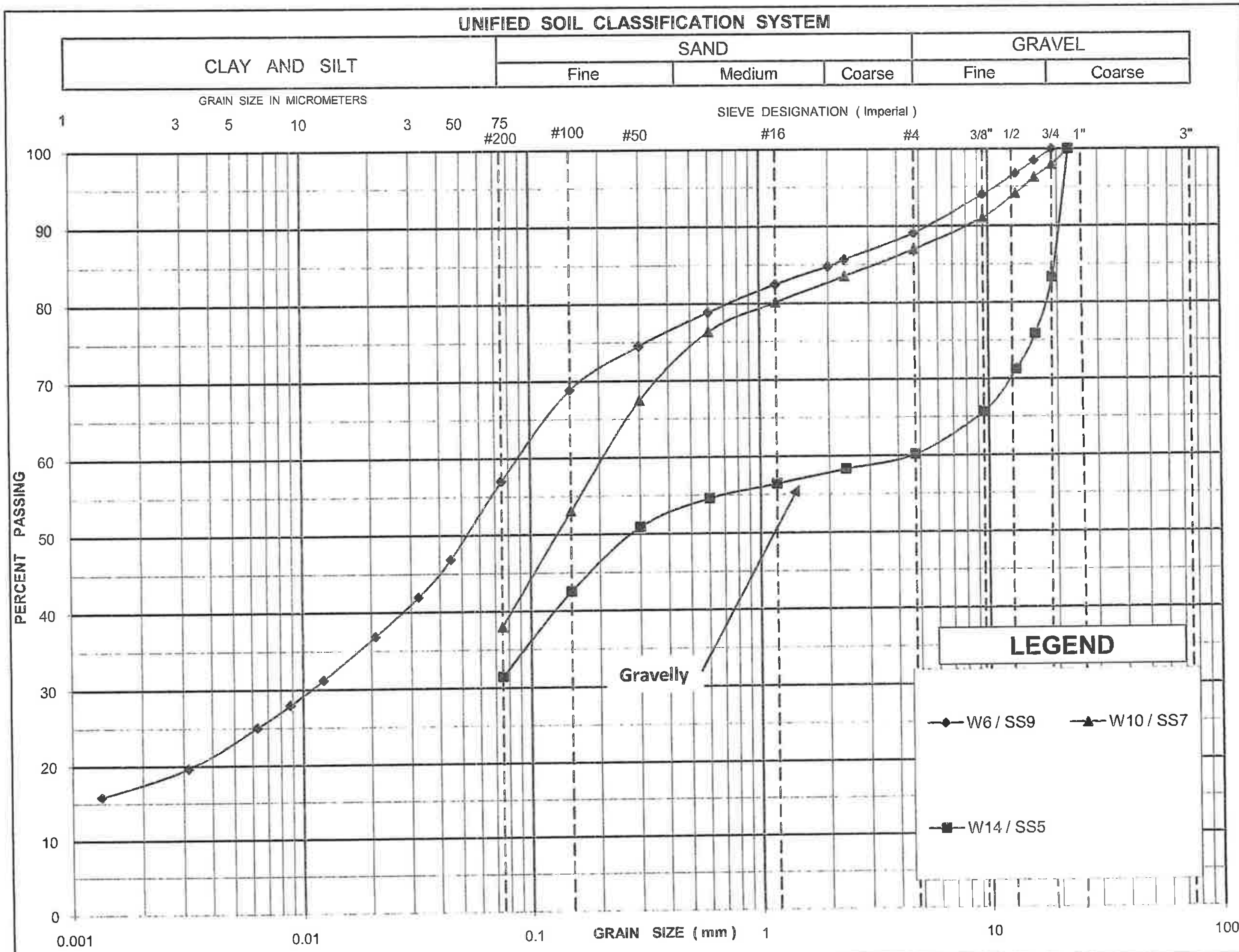
FIGURE No.	B3
REF. No.	TRANETOB10434AA
DATE	JAN. 10, 2011

PLASTICITY CHART

CLAYEY SILT



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GRAIN SIZE DISTRIBUTION

SILTY SAND TO SANDY SILT TILL

FIGURE NO.: B4
PROJECT NO.: TRANETOB10434AA
DATE: JAN. 10, 2011

Appendix C

Site Photographs

Photograph 1. Station 18+900 EB (looking west)

Photograph 2. Station 19+250 EB near the south fence line (looking east)

Photograph 3. Station 19+250 EB near the south fence line (looking west)

Photograph 4. Station 19+250 EB (looking west)

Appendix D

Explanation of Terms Used in Report

EXPLANATION OF TERMS USED IN REPORT

N-VALUE: THE STANDARD PENETRATION TEST (SPT) N-VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N-VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N-VALUE IS DENOTED THUS $\overline{N}$.

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

C_u (kPa)	0 – 12	12 – 25	25 – 50	50 – 100	100 – 200	>200
	VERY SOFT	*SOFT*	*FIRM*	*STIFF*	*VERY STIFF*	*HARD*

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 – 5	5 – 10	10 – 30	30 – 50	>50
	VERY LOOSE	*LOOSE*	*COMPACT*	*DENSE*	*VERY DENSE*

ROCKS ARE DESCRIBED BY THEIR COMPOSION AND STRUCUTRAL FEATURES AND/OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY IS:

RQD (%)	0 – 25	25 – 50	50 – 75	75 – 90	90 – 100
	VERY POOR	*POOR*	*FAIR*	*GOOD*	*EXCELLENT*

JOINT AND BEDDING:

SPACING	50mm	50 – 300mm	0.3m – 1m	1m – 3m	>3m
JOINTING	*VERY CLOSE*	*CLOSE*	*MOD. CLOSE*	*WIDE*	*VERY WIDE*
BEDDING	*VERY THIN*	*THIN*	*MEDIUM*	*THICK*	*VERY THICK*

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

SS	SPLIT SPOON	TP	THINWALL PISTON
WS	WASH SAMPLE	OS	OSTERBERG SAMPLE
ST	SLOTTED TUBE SAMPLE	RC	ROCK CORE
BS	BLOCK SAMPLE	PH	TW ADVANCED HYDRAULICALLY
CS	CHUNK SAMPLE	PM	TW ADVANCED MANUALLY
TW	THINWALL OPEN	FS	FOIL SAMPLE

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ε	%	LINEAR STRAIN
$\varepsilon_1, \varepsilon_2, \varepsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICALL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
c_c	1	COMPRESSION INDEX
c_s	1	SWELLING INDEX
c_a	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	$-^{\circ}$	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	$-^{\circ}$	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = c_u / τ_r

PHYSICAL PROPERTIES OF SOIL

P_s	kg/m^3	DENSITY OF SOLID PARTICLES	e	1,%	VOID RATIO	e_{min}	1,%	VOID RATIO IN DENSEST STATE
Υ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES	n	1,%	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
P_w	kg/m^3	DENSITY OF WATER	w	1,%	WATER CONTENT	D	mm	GRAIN DIAMETER
Υ_w	kN/m^3	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	N PERCENT – DIAMETER
P	kg/m^3	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
Υ	kN/m^3	UNIT WEIGHT OF SOIL	w_P	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
P_d	kg/m^3	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m^3/s	RATE OF DISCHARGE
Υ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL	I_P	%	PLASTICITY INDEX = $(W_L - W_L)$	v	m/s	DISCHARGE VELOCITY
P_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $(W - W_P)/ I_P$	i	1	HYDAULIC GRADIENT
Υ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $(W_L - W) / 1_P$	k	m/s	HYDRAULIC CONDUCTIVITY
P'	kg/m^3	DENSITY OF SUBMERED SOIL	e_{max}	1,%	VOID RATIO IN LOOSEST STATE	j	kN/m^3	SEEPAGE FORCE
Υ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL						

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FOUNDATION DESIGN REPORT
NOISE BARRIER EAST OF COUNTY RD 45 INTERCHANGE, HIGHWAY 401 COBOURG, ONTARIO, W.P. NO. 205-00-01, GEOCRES 30M16- 46

AECOM

TRANETOB10434AA-AJ
November 23, 2011

Coffey Geotechnics Inc.
20 Meteor Drive Etobicoke Ontario M9W 1A4 Canada

CONTENTS

FOUNDATION DESIGN REPORT
NOISE BARRIER – EAST OF COUNTY ROAD 45 INTERCHANGE
HIGHWAY 401, COBOURG, ONTARIO
W.P. 205-00-01

5 DISCUSSIONS AND RECOMMENDATIONS

5.1 General

As part of the Highway 401 Expansion (6-Laning) from Burnham Street to approximately 2.0 km east of Nagle Road, within the Town of Cobourg and Township of Hamilton, Ontario, noise barriers will be constructed. There are two noise barrier installation locations proposed for the project, each reported under separate cover.

This report presents the proposed noise barrier to be located between Stations 18+800 and 19+380, south of Highway 401, east of County Road 45 Interchange in Cobourg, Ontario. The proposed noise barrier at this location will be 5 m high and approximately 600 m long. The alignment is curved on the western end, parallel to the alignment of the proposed N/S-E ramp of the County Road 45 interchange and then becomes straight, adjacent to the south fence of the highway. Drawing 1 presents the location of the proposed noise barrier.

Ten boreholes were drilled along the proposed noise barrier alignment and these indicate that the site is generally underlain by topsoil, fill (at one borehole location only) and native soils consisting of a) silty sand to sandy silt, b) clayey silt and c) silty sand to sandy silt till. The fill, encountered in Borehole W6, near the western end of the site only, was found to extend 2.0 m below the ground surface or to Elevation 108.0 m and was described as dense to very dense gravelly sand with traces to some silt and clay. Below the topsoil, a loose to compact silty sand to sandy silt deposit was encountered throughout much of the site and extended to 0.8 to 1.3 m below the ground surface or to Elevations 115.1 to 108.5 m. The silty sand to sandy silt deposit was not encountered on the eastern and western ends of the site. Typically, below the silty sand to sandy silt deposit, a stiff to hard clayey silt deposit was encountered at Elevations 115.1 to 108.0 m. This clayey deposit was not encountered in Boreholes W13 and W14. The thickness of clayey silt deposit varies from 1.2 to 4.3 m in Boreholes W6, W9 to W12, where it was fully penetrated. In Boreholes W7 and W8, the deposit is thicker (greater than 5.3 to 5.6 m thick) where it was not fully penetrated (i.e. the boreholes were terminated within this deposit, before fully penetrating it). The underlying dense to very dense silty sand till was encountered at 0.8 to 5.6 m below the ground surface or at Elevations 115.1 to 105.8 m. However, just before the western end, at the location of Boreholes W7 and W8, the top of the till deposit may be deeper than 6.6 m below the ground surface or below Elevations 103.9 to 102.9 m as Boreholes W7 and W8 were terminated within the overlying clayey silt deposit. Typically, the top of the till deposit was found to be highest at the eastern end of the site and lower towards the west end.

Based on the change of colour of the soil, moisture contents of the soil samples and the observations made in the open boreholes while drilling, it is in our opinion that the site groundwater level at the time of our investigation varied from about Elevation 111 to 107 m, increasing in elevation towards the eastern end. It is however believed that a perched water table exists in the basically granular sandy silt to silty sand layers, overlying the less pervious clayey silt deposit. The groundwater level but would be subject to seasonal variations and variations in response to major weather events, as well as variations in the level of water in the adjacent watercourses (Cobourg Creek and Midtown Creek West).

Design and construction of the foundations for the noise barrier wall shall be conducted in accordance with SP 599F01.

5.2 Design Considerations

The noise barrier will typically extend about 5 m above the ground surface. It is likely that the noise barrier will be supported on augered caissons (i.e. drilled and poured–in–place concrete foundations). Typical caisson diameters for this purpose range from 0.6 m to 0.9 m. As per MTO practice, the design is generally carried out in accordance with the method described by Broms, as detailed in the following papers.

- BROMS, B.B.: Lateral Resistance of Piles in Cohesive Soils, Journal of the Soil Mechanics and Foundation Division, ASCE, Vol. 90, No. SM2, Paper No. 3825, 1964.
- BROMS, B.B.: Lateral Resistance of Piles in Cohesionless Soils, Journal of the Soil Mechanics and Foundation Division, ASCE, Vol. 90, No. SM3, Paper No. 3909, 1964.
- BROMS, B.B.: Design of Laterally Loaded Piles, Journal of the Soil Mechanics and Foundation Division, ASCE, Vol. 91, No. SM3, 1965.

The resistance to lateral loading in front of a vertical caisson can be estimated using subgrade reaction theory where the coefficient of horizontal subgrade reaction (k_s in kN/m^3) is determined based on the equations given below (CHBDC S6-06 C6.8.7.1):

In cohesionless soils, the coefficient of horizontal subgrade reaction can be estimated from:

$$k_s = n_h z/d$$

Where k_s = coefficient of horizontal subgrade reaction

n_h = coefficient related to soil density as given in Table 3

z = depth

d = pile width.

Where the soil is primarily cohesive, the coefficient of horizontal subgrade reaction can be estimated from:

$$k_s = 67c_u/d$$

Where k_s = coefficient of horizontal subgrade reaction

c_u = undrained shear strength as given in Table 3

d = pile width.

The recommended soil parameters for the design of augered caisson foundation at each borehole location are given in the following table.

Table 3: Recommended Design Parameters

Station / Borehole Number	Elevation (m)		Type of Soil	Consistency or Compactness Condition	Undrained Shear Strength, c_u (kPa)	Internal Friction Angle, ϕ (deg)	Bulk Unit Weight, γ (kN/m^3)	Horizontal Subgrade Reaction Coefficient, n_h (kN/m^3)	Water Level depth / Elevation (m)
	From	To							
18+799* /	109.9	108.0	Fill	dense to v. dense	-	33	21	18,000	2.3 / 107.7♦
W6	108.0	106.8	cohesive	v. stiff	120	-	18.5	-	
	106.8	100.5	cohesionless	v. dense	-	35	22	11,000	
18+880 /	109.3	108.5	cohesionless	loose	-	28	17	2,200	1.5 / 108.0♦
W7	108.5	106.5	cohesive	stiff to v. stiff	100	-	18.5	-	
	106.5	104.0	cohesive	stiff	70	-	18	-	
	104.0	102.9	cohesive	v. stiff	120	-	18.5	-	
18+947 /	110.3	109.8	cohesionless	loose	-	27	17	2,200	2.3 / 108.2♦
W8	109.8	109.2	cohesionless	compact	-	31	19	6,600	
	109.2	108.2	cohesive	stiff	70	-	18	-	
	108.2	107.0	cohesive	v. stiff	120	-	18.5	-	
	107.0	105.5	cohesive	stiff	70	-	18	-	
	105.5	103.9	cohesive	v. stiff	100	-	18.5	-	
19+005 /	111.1	110.6	cohesionless	loose	-	28	17	2,200	3.1 / 108.3♦
W9	110.6	110.1	cohesionless	compact	50	31	19	6,600	
	110.1	109.0	cohesive	firm	150	-	17.5	-	
	109.0	105.8	cohesive	v. stiff	-	-	18.5	-	
	105.8	104.8	cohesionless	dense		35	22	11,000	
19+072 /	111.7	111.1	cohesionless	loose	-	28	17	2,200	2.3 / 109.6♦
W10	111.1	109.0	cohesive	v. stiff	120	-	18	-	
	109.0	107.9	cohesive	hard	200	-	18.5	-	
	107.9	105.6	cohesionless	v. dense	-	35	22	11,000	
19+117 /	112.4	111.8	cohesionless	loose	-	28	17	2,200	2.8 / 109.7-♦
W11	111.8	110.5	cohesive	v. stiff to hard	150	-	18.5	-	
	110.5	109.0	cohesionless	dense	-	34	21.5	11,000	
	109.0	106.2	cohesionless	v. dense	-	35	22	11,000	

Station / Borehole Number	Elevation (m) From	To	Type of Soil	Consistency or Compactness Condition	Undrained Shear Strength, c_u (kPa)	Internal Friction Angle, ϕ (deg)	Bulk Unit Weight, γ (kN/m^3)	Horizontal Subgrade Reaction Coefficient, n_h (kN/m^3)	Water Level depth / Elevation (m)
19+171 / W12	113.3	112.7	cohesive	stiff	70	-	17.5	-	3.8 / 109.7♦
	112.7	112.2	cohesionless	compact	-	32	18.5	6,600	
	112.2	111.1	cohesive	v. stiff	100	-	18	-	
	111.1	106.9	cohesionless	v. dense	-	35	22	11,000	
19+251 / W13	115.1	114.5	cohesionless	loose	-	28	17	2,200	5.0 / 110.3♦
	114.5	113.0	cohesionless	compact	-	33	20	6,600	
	113.0	109.0	cohesionless	v. dense	-	35	22	11,000	
19+321 / W14	115.9	115.1	cohesionless	compact	-	30	19	6,600	5.6 / 110.4♦
	115.1	109.6	cohesionless	dense to v. dense	-	35	22	11,000	
19+372 / W15	115.1	113.5	cohesive	stiff to hard	150	-	18.5	-	4.0 / 111.2♦
	113.5	107.3	cohesionless	dense to v. dense	-	35	22	11,000	

Notes:
* = Station referenced to the proposed N/S-E ramp centreline of the County Road 45 interchange.
♦ = estimated

The contribution to lateral resistance of the soil within the frost depth (i.e. 1.5 m below the final grade) should not be included in the calculations, except of course, for the weight of the soil. Research shows, however, that restraint provided at the ground surface level plays a significant role in the performance of laterally loaded structures and, therefore, the placement of well compacted, competent material at and near the ground surface immediately around the augered caisson is recommended.

While the geotechnical design of noise barrier wall foundation is governed by the horizontal (lateral) resistance, the following comments are included for axial resistances for the sake of completeness. At borehole locations W7, W8 and W9, the soil within 5 m of the ground surface consists primarily of cohesive materials to which an approximate average undrained shear strength of 75 kPa can be assigned. In this instance the following approximate axial resistances would be available for a 0.6 m diameter caisson (pile) extending to a depth of at least 5.0 m below the ground surface:

Factored Resistance at ULS = 300 kN/pile

Bearing Resistance at SLS* = 200 kN/pile

*SLS for 25 mm total settlement

For a 0.9 m diameter pile these resistances can be increased to 450 kN and 300 kN/pile, respectively.

At the remaining borehole locations, the soil below a maximum depth of 4 m consists of a dense to very dense till. At these borehole locations the following axial resistances would be available for a caisson extending at least 5.0 m below the ground surface and at least 1 m into the very dense till, for a 0.6 m diameter caisson

Factored Resistance at ULS = 450 kN/pile

Bearing Resistance at SLS* = 300 kN/pile

*SLS for 25 mm total settlement

These values can be increased to 675 kN/pile and 450 kN/pile, respectively for a 0.9 m diameter caisson, again assuming that the caisson extends at least 1 m into the dense to very dense till and at least 5.0 m below the ground surface. When recommending these values it is assumed that the bearing subgrade will not be unduly disturbed. As well, these values depend, among other factors, on the method of installation and as such they should be further discussed with us.

5.3 Construction Considerations

The construction of the proposed noise barrier should be carried out in accordance with SP 599F01.

Based on the borehole information, the installation of caissons is anticipated to be made typically within the silty sand to sandy silt, clayey silt and till deposits. Groundwater is also anticipated to be encountered during the installation of the caissons.

During construction, caissons may require the use of temporary steel casings (liners) to support the granular soils below the groundwater and to reduce the risk of caving in. Temporary liners will also enable the bases to be properly cleaned of any disturbed soils and to enable the inspection and approval of the base by the engineer, where necessary. The casing would then be carefully withdrawn as the concrete is poured, keeping a sufficient head of concrete in the casing to prevent 'necking'. Alternatively, tremie concrete method can be used for concreting of caissons installed below the groundwater.

The clayey silt deposit can be expected to be self-supporting and should not yield significant amounts of water in the short term, in the caisson holes, even below the groundwater table. However, water bearing layers may cause instability problems during the installation of the caissons. Where these layers are rather thin and the soil is relatively fine grained, it may be possible to effect construction by pouring the concrete rapidly upon the completion of the excavation of the caisson hole. In other cases, however, the sandy layers may cause cave-ins or excessive groundwater seepage in unlined caisson holes and will necessitate special precautions.

The use of dewatering techniques to lower the groundwater table during construction is unlikely to be economically viable due to the limited construction effort required and space limitations on Highway 401.

Within the till and/or sandy layers below the water table, the soil is susceptible to disturbance due to the unbalanced hydrostatic head and seepage and may become unstable, especially with increased depth of excavation below the water table. The contractor should maintain the stability of the soil at the sides and bases of the holes for the concrete footings, at all times from the commencement of excavation to the completion of the pouring of the concrete.

In view of these, we recommend that the following special provisions be included in the contract documents:

- The contractor shall install concrete foundations in earth for noise barrier wall foundations. At the various foundation locations, strata may consist of fill, silty sand to sandy silt, clayey silt, and sandy till deposits. Groundwater is likely to be encountered above the base of the excavations at most locations.
- At the various foundation locations, soil deposits may consist of basically granular (i.e. non-cohesive) soils such as silt sand to sandy silt, and sandy till. In such cases where the soil is susceptible to conditions of unbalanced hydrostatic head and seepage forces, "boiling" or a quick condition may occur and the soil may become unstable.
- The contractor shall maintain the stability of the soil along the side and at the base of the holes for the concrete caissons at all times, from the commencement of their construction to the placing of the concrete.
- Dewatering may be required to maintain a sufficiently dry condition for proper installation of the caisson hole and the placement of concrete.

We recommend that the Contractor be advised that the presence of cobbles and boulders can be expected, especially within the till deposit which can cause problems during the installation of the caissons, such as increasing the time required for drilling, the employment of special equipment, etc. An NSSP should be issued to alert the Contractor of these aspects, as well as possible dewatering requirements, as presented in Appendix E.

6 CLOSURE

The "Limitations of Report" as presented in Appendix F are integral part of the report.

For and on behalf of Coffey Geotechnics Inc.

for

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Appendix E

NSSP

CAISSON PILES

Special Provision

The requirements of OPSS 903, November 2009 shall govern this specification with the following amendments:

903.07.03 Caisson Piles

903.07.03.01 General

Subsection 903.07.03.01 is amended by the addition of the following paragraphs:

The Contractor is alerted that there is a possibility of the presence of cobbles and boulders in the till where caisson piles are to be installed. If cobbles and boulders are encountered, the Contractor shall employ the necessary measures to comply with the requirements of OPSS 903.

The Contractor is alerted that dewatering may be required to facilitate the installation of the caisson units due to the presence of granular soil layers below the groundwater table. The Contractor shall be prepared to employ adequate dewatering procedure if the flow into the hole becomes a problem. Temporary steel liner will be required during the construction of the caisson holes to prevent caving. The liner shall be withdrawn as the concrete is poured, ensuring a sufficient head of concrete in the liner to prevent 'necking'. Concrete must be poured expeditiously after the preparation and approval of the base of the caisson to prevent its disturbance due to hydrostatic uplift.

903.10 BASIS FOR PAYMENT

903.10.02 Caisson Piles - Item

Subsection 903.10.02 is amended by the addition of the following paragraphs:

If cobbles and boulders are encountered and/or dewatering is required for the installation of the caisson piles, there will be no additional cost to the Contractor.

Appendix F

Limitations of Report

LIMITATIONS OF REPORT

This report is intended solely for the Client named. The material in it reflects our best judgment in light of the information available to Coffey Geotechnics Inc. (Coffey) at the time of preparation. Unless otherwise agreed in writing by Coffey, it shall not be used to express or imply warranty as to the fitness of the property for a particular purpose. No portion of this report may be used as a separate entity, it is written to be read in its entirety.

The conclusions and recommendations given in this report are based on information determined at the testhole locations. The information contained herein in no way reflects on the environment aspects of the project, unless otherwise stated. Subsurface and groundwater conditions between and beyond the testholes may differ from those encountered at the testhole locations, and conditions may become apparent during construction, which could not be detected or anticipated at the time of the site investigation. The benchmark and elevations used in this report are primarily to establish relative elevation differences between the testhole locations and should not be used for other purposes, such as grading, excavating, planning, development, etc.

The design recommendations given in this report are applicable only to the project described in the text and then only if constructed substantially in accordance with the details stated in this report.

The comments made in this report on potential construction problems and possible methods are intended only for the guidance of the designer. The number of testholes may not be sufficient to determine all the factors that may affect construction methods and costs. For example, the thickness of surficial topsoil or fill layers may vary markedly and unpredictably. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusions as to how the subsurface conditions may affect their work. This work has been undertaken in accordance with normally accepted geotechnical engineering practices.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Coffey accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.