August 10, 2015

FOUNDATION INVESTIGATION AND DESIGN REPORT

Trenchless Sewer and Culvert Crossings Highway 410 Widening from South of Highway 401 to Queen Street Regional Municipality of Peel GWP 2144-07-00

Submitted to:
AECOM Canada Ltd.
30 Leek Crescent, 4th Floor
Richmond Hill, Ontario
L4B 4N4

GEOCRES No.

Report No.: 11-1111-0083-11

Distribution:

2 Copy - MTO Central Region
1 Copy - MTO Foundations Section
1 Copy - AECOM Canada Ltd
1 Copy - Golder Associates Ltd.

REPORT

Golder Associates

Table of Contents

PART A – FOUNDATION INVESTIGATION REPORT

PART B – FOUNDATION DESIGN REPORT

TABLES

DRAWINGS

FIGURES

APPENDICES

PART A

FOUNDATION INVESTIGATION REPORT
TRENCHLESS SEWER AND CULVERT CROSSINGS
HIGHWAY 410 WIDENING
FROM SOUTH OF HIGHWAY 401 TO QUEEN STREET
REGIONAL MUNICIPALITY OF PEEL
G.W.P. 2144-07-00

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by URS Canada Inc. (URS) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services in support of the design for the widening of Highway 410 from south of Highway 401 to Queen Street in the Cities of Mississauga and Brampton, in the Regional Municipality of Peel, Ontario.

This report presents the subsurface conditions at twenty-one sewer and culvert crossing locations that are to be installed using trenchless construction methods.

The terms of reference and scope of work for the foundation engineering services are outlined in MTO's Request for Proposal (RFP) dated November 2010, in Section 6.8 of URS's *Technical Proposal* for this assignment, and in Golder's change request letter dated April 14, 2014.

2.0 SITE DESCRIPTION

The proposed trenchless crossing locations are located within the area extending from Matheson Boulevard in Mississauga, Ontario to north of Orenda Road in Brampton, Ontario.

The topography within the project limits is relatively flat-lying, with the natural ground surface generally rising from south to north over the project limits. The Highway 410 grade also rises progressively from south to north, from about Elevation 166.5 m at Matheson Boulevard, to about Elevation 172 m to 174 m in the vicinity of Highway 401, to Elevation 194 m to 196 m in the area of Highway 407, Etobicoke Creek and Steeles Avenue, and to Elevation 221 m just north of the CN Rail line and Orenda Road. Highway 410 has been constructed near the original ground surface through much of its length, although fill embankments up to approximately 8 m to 10 m in height are present in the area of the Glidden Road, CN Rail and Orenda Road overpass/overhead structures.

3.0 INVESTIGATION PROCEDURES

3.1 Investigations by Golder

A total of thirty-two boreholes (Boreholes 14-01 to 14-32) were drilled in June 2014 as part of the site-specific geotechnical investigation program for the proposed trenchless sewer crossing locations, using truck-mounted CME-75 and CME-45 drill rigs supplied and operated by Aardvark Drilling Inc. of Guelph, Ontario. Use was also made of nine boreholes from earlier stages of Golder's investigation for the widening of Highway 410 (in order from south to north, Boreholes MB-5, 12-8, P1-3, P3-3, P4-3, 12-14, P6-2, GR-6 and CN-10). These boreholes were drilled using CME-45, CME-55 and CME-75 drill rigs supplied and operated by Geo-Environmental Drilling Inc. of Milton, Ontario, and a D-50 drill rig supplied and operated by DBW Drilling Inc. of North York, Ontario. The auger type and diameter are indicated on the borehole records that are contained in Appendices A through S, organized by crossing location.

The boreholes from the 2014 investigation were advanced to at least three tunnel diameters below the proposed trenchless crossing horizon. Soil samples were obtained in the boreholes at 0.8 m and 1.5 m intervals of depth using a 50 mm outer diameter split-spoon sampler, driven by an automatic hammer in accordance with the

Standard Penetration Test (SPT) procedure (ASTM D1586-08a Standard Test Method for Standard Penetration Test). Bedrock coring was completed in Boreholes 14-16, 14-17 and 14-18, where the proposed trenchless crossing from Structure 1105 to 1117, and from Structure 1118 to SWM Pond 4, will be within the bedrock, using NQ-sized coring equipment. Bedrock coring was also completed in some of the boreholes from Golder's 2011 and 2012 investigations, which were completed for other structure sites; the bedrock horizon in these earlier boreholes is generally below the proposed tunnel crossing locations.

The groundwater conditions were observed in the open boreholes during and immediately following the drilling operations. The water levels observed in the boreholes following completion of drilling are indicated on the borehole records contained in Appendices A through S, corresponding to the crossing locations. Standpipe piezometers were installed in Boreholes MB-5 and P6-2, drilled as part of the 2011 and 2012 stages of investigation, and these piezometers consist of 50 mm diameter slotted screens installed within a sand filter pack at a selected depth within the boreholes; the details of the piezometer installation are shown on the applicable borehole records in Appendix A and O. All of the boreholes were backfilled with bentonite upon completion, in accordance with Ontario Regulation 903 (as amended), with an asphalt patch placed at the highway surface.

The field work was supervised on a full-time basis by members of Golder's engineering staff who located the boreholes in the field, cleared all locations of underground utilities, directed the drilling, sampling and in situ testing operations, and logged the subsurface conditions. The soil and bedrock samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Mississauga for further examination and laboratory testing. Index and classification tests consisting of water content determinations, Atterberg limits testing and grain size distribution analyses were carried out on selected soil samples. Point load index and unconfined compressive strength tests were carried out on selected rock core samples. All laboratory testing was carried out according to applicable MTO LS and ASTM standards.

3.2 Previous Investigations

Two boreholes from previous investigations by others have been used in the preparation of this report, as follows:

- **MTO GEOCRES No. 30M12-122**: Report titled "Foundation Investigation and Design Report, W.P. 103-69-08, Hwy. 410 from Steeles Avenue Southerly to Derry Road, Culverts" by Ministry of Transportation and Communications, Soil Mechanics Section, Geotechnical Office, dated December 21, 1976.
- **MTO GEOCRES No. 30M12-193**: Report titled "Foundation Investigation Report for Derry Road Underpass, W.P. 103-69-15, Site 24-81-495, Hwy. 410, Toronto," by Ministry of Transportation and Communications, Soil Mechanics Section, Geotechnical Office, dated June 18, 1987.

These two boreholes have been renamed to show the MTO GEOCRES reference number followed by the original borehole designation. For example, the borehole from MTO GEOCRES Report No. 30M12-122 has been renamed as 122-X, where X is the original borehole number.

3.3 Borehole Locations

The borehole locations for the 2014 investigation were laid out by Golder personnel using a GPS (Global Positioning System), accurate to within 0.3 m horizontally. Where these borehole locations had to be modified due to the presence of underground utilities or for safety (i.e., location within the highway shoulder), the adjusted locations were measured relative to the original layout point. The borehole locations for the 2011 and 2012 investigations were measured in the field by Golder personnel relative to site features.

The ground surface elevation at each borehole location was estimated from the digital terrain model for the project as provided by URS. The borehole locations (referenced to the MTM NAD83 co-ordinate system) and ground surface elevations (referenced to geodetic datum) are summarized in the following table and are shown on Drawings 1 to 8.

Trenchless Installation	Drawing No.	Borehole No.	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)
Str. 774 – Str. 773	1	14-01	4,832,315.9	292,889.2	166.5
		MB-5	4,832,294.2	292,887.4	166.5
Culvert #5	2	14-02	4,833,393.0	291,571.3	193.3
		14-03	4,833,400.0	291,576.0	192.9
Culvert #6	2	14-04	4,833,759.0	291,444.0	179.6
		14-05	4,833,766.0	291,447.0	179.3
Str. 870 – Str. 868	2	14-06	4,833,877.3	291,318.3	179.5
		12-8	4,833,866.9	291,282.9	180.0
Str. 894 - Outlet	2	14-07	4,833,915.9	291,226.8	179.5
		P1-3	4,833,960.1	291,245.5	180.2
Str. 1326 – Median – Str. 1327	3	14-08	4,834,603.5	290,521.0	187.5
		14-09	4,834,624.0	290,542.7	186.4
		14-10	4,834,640.3	290,564.1	187.2
Str. 978 – Str. 979	3	14-11	4,835,148.3	290,035.3	183.7
		14-12	4,835,162.1	290,058.2	184.9
Str. 1018 – Str. 1019	4	14-13	4,835,772.3	289,468.3	187.1
		193-8	4,835,745.2	289,455.7	186.6
Str. 1036 – Str. 1028	4	14-14	4,835,973.1	289,230.8	187.5
		14-15	4,835,996.0	289,248.8	189.0
		P3-3	4,835,999.4	289,275.7	187.5
Str. 1105 – Str. 1117 and Str. 1118 – SWM Pond 4	5	14-16	4,836,905.8	288,367.0	192.0
		14-17	4,836,912.6	288,389.0	193.5
		14-18	4,836,918.0	288,409.1	192.6
		P4-3	4,836,878.4	288,351.3	191.6

Trenchless Installation	Drawing No.	Borehole No.	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)
Str. 1126 – Outlet	5	14-19	4,837,213.6	288,321.2	191.8
		14-20	4,837,221.0	288,342.3	192.5
Str. 1143 – Str. 1141	5	14-21	4,837,504.8	288,185.4	193.4
		122-3(1)	4,837,502.3	288,229.7	192.7
Str. 1158 – Outlet	6	14-22	4,837,916.9	288,114.2	194.7
		12-14	4,837,913.0	288,085.2	193.5
Str. 1176 – Outlet	6	14-23	4,838,170.4	287,958.2	194.8
		14-24	4,838,174.9	287,991.7	195.7
Str. 1182 – Str. 1183	6	14-25	4,838,397.1	287,914.7	197.0
		14-26	4,838,397.0	287,927.0	196.5
		P6-2	4,838,372.4	287,879.1	199.9
Str. 1247 – Str. 1249	7	14-27	4,839,042.3	287,118.8	207.9
		GR-6	4,839,053.3	287,147.6	207.7
Str. 1268 – Str. 1267	7	14-28	4,839,335.6	286,878.6	214.6
		14-29	4,839,350.9	286,899.8	214.9
Str. 1279 – Str. 1278	7	14-30	4,839,505.0	286,670.5	220.0
		CN-10	4,839,520.5	286,693.7	218.5
Str. 1301 – Str. 1303	8	14-31	4,839,901.2	286,283.9	218.4
		14-32	4,839,893.1	286,321.0	218.3

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

This section of Highway 410 is located within the Peel Plain physiographic region, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984).

The Peel Plain physiographic region covers the central portions of the Regional Municipalities of York, Peel and Halton. The general topography of this region consists of level to gently rolling terrain, sloping gradually southward toward Lake Ontario. A surficial till sheet, which generally follows the surface topography, is present throughout much of this area. The till, which is mapped in this area as Halton Till, typically consists of clayey silt to silty clay, with occasional sand to silt zones. Shallow, localized deposits of loose sand and silt and/or soft clay can overlie this uppermost till sheet, and these represent relatively recent deposits, formed in small glacial meltwater ponds scattered throughout the Peel Plain and concentrated near river valleys. The recent sand, silt and clay and uppermost till deposits in this area overlie and are interbedded with stratified deposits of sand, silt and clay. The study area, in the western portion of the Peel Plain, is underlain by grey shale of the Georgian Bay Formation.

4.2 Subsurface Conditions

The subsurface models at the trenchless crossing locations have been developed based on the results of thirty-two boreholes drilled as part of a 2014 investigation, nine boreholes completed as part of 2011 and 2012 investigations by Golder, and two boreholes advanced as part of previous studies by others.

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are given on the borehole records that are contained in Appendices A through S. These Appendices are organized by proposed crossing location, in order from south to north. The Appendix letter corresponds to the interpreted stratigraphic section label as presented for each crossing location on Drawings 1 to 8.

The stratigraphic boundaries shown on the borehole records and on the interpreted stratigraphic profile and cross-sections on Drawings 1 to 8 are inferred from observations of drilling progress and from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsurface conditions will vary between and beyond the borehole and test pit locations.

In general, the subsurface conditions at the proposed crossing locations consist of asphalt and sand and gravel to gravelly sand road base fill associated with the existing Highway 410 or ramp pavements, overlying variable embankment fill materials, in places overlying a thin surficial clayey silt to silty clay deposit. The entire alignment is underlain by a glacial till deposit, which is typically comprised of clayey silt but which grades in places to a silty clay or sand and silt till. The till deposit is underlain by shale bedrock, which is present at relatively shallow depth in the area from Matheson Boulevard to just north of Highway 401, and again at relatively shallow depth in the vicinity of the Highway 407 interchange and Etobicoke Creek.

A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Fill

Fill material associated with the embankments for Highway 410 and/or ramps was encountered in almost every borehole. Reference should be made to the interpreted stratigraphic sections on Drawings 1 to 8, and the specific borehole records in Appendices A to S for each of the proposed crossing locations, to assess the thickness of the fill material, its surface and base elevation, composition, and geotechnical properties.

The fill materials encountered in the boreholes are variable in composition, ranging from sand and gravel to gravelly sand road base materials, which are generally present immediately below the asphalt, to sand to sand and silt, to clayey silt to silty clay. The grain size distribution test results specific to any one borehole are presented in the relevant Appendix (A through S). Envelopes of grain size distribution data, demonstrating the typical range in composition of the fill materials, are provided as follows:

- The results of grain size distribution tests on 7 selected samples of the sand and gravel to gravelly sand portions of the fill are presented on Figure 1.
- The results of grain size distribution tests on 12 selected samples of the sand to sand and silt portions of the fill are presented on Figure 2.

- The results of grain size distribution tests on 13 selected samples of the clayey silt to silty clay portions of the fill are presented on Figure 3.

In addition, the fill materials should be expected to contain cobbles, boulders or other obstructions, distributed randomly throughout the fill strata. Cobbles and boulders were observed or inferred within the fill materials in some of the boreholes, based on visual observation and instances of difficult drilling and/or auger grinding, and such observations are presented on the borehole records contained in Appendices A through S. In Borehole GR-6, at Str. 1247 – 1249 (see Appendix P), a boulder was encountered within the fill at a depth of 7.0 m (approximately Elevation 200.7 m).

Atterberg limits tests were completed on 15 samples of cohesive fill material from Golder's 2011, 2012 and 2014 investigations as presented in this report, and measured liquid limits of 17 to 39 per cent, plastic limits of 10 to 20 per cent, and plasticity indices of 5 to 20 per cent. These test results, which are plotted on a plasticity chart on Figure 4, indicate that the cohesive fill materials vary in composition from clayey silt of low plasticity to silty clay of intermediate plasticity.

The measured Standard Penetration Test (SPT) "N" values in the fill material are variable, ranging from 1 to 88 blows per 0.3 m of penetration in the cohesionless fill materials, and 4 to 45 blows per 0.3 m of penetration in the cohesive fill materials. These SPT "N" values suggest that the cohesionless portions of the fill have a variable, very loose to very dense relative density, while the cohesive portions of the fill have a variable, very soft to hard consistency. Reference should be made to the borehole records for each crossing location, as contained in Appendices A to S, for more site-specific information about the relative density or consistency of the fill materials; however, fill materials by their nature can be variable, and the relative density or consistency may vary from that encountered in the boreholes at each crossing location.

4.2.2 Surficial Clayey Silt to Silty Clay

A thin surficial layer of clayey silt to silty clay was encountered immediately below the fill or existing ground surface, and on top of the till deposit, in the following boreholes:

- In Borehole P1-3 at Str. 894 – Outlet (see Drawing 2, Section E-E' and Appendix E), a 0.7 m thick layer of clayey silt was encountered immediately below the ground surface.
- In Borehole 14-09 at Str. 1326 – Median – Str. 1327 (see Drawing 3, Section F-F' and Appendix F), a 0.9 m thick layer of clayey silt was encountered below 1.4 m of fill material.
- In Borehole P3-3 at Str. 1036 – 1028 (see Drawing 4, Section I-I' and Appendix I), a 0.3 m thick layer of clayey silt was encountered below 1.5 m of fill material.
- In Borehole P4-3 at Str. 1105-1117 (see Drawing 5, Section J-J' and Appendix J), a 0.1 m thick layer of silty clay was encountered immediately below ground surface, on top of shale bedrock.

A grain size distribution test was conducted on one sample of this surficial cohesive deposit from Borehole P4-3, and the test result is included in Appendix J. Atterberg limits tests were completed on two selected samples of this surficial deposit, and measured liquid limits of 29 and 38 per cent, plastic limits of 16 and 23 per cent, and plasticity indices of 13 and 15 per cent. These results, which are plotted on a plasticity chart on Figure 5, confirm that this surficial deposit varies in composition from clayey silt of low plasticity, to silty clay of intermediate plasticity.

The measured SPT "N" values range from 6 to 22 blows per 0.3 m of penetration, suggesting that the surficial clayey silt to silty clay deposit (where present) has a variable, firm to very stiff consistency.

4.2.3 Clayey Silt to Silty Clay Till

The predominant soil deposit throughout the Highway 410 corridor is a glacial till deposit. Reference should be made to the interpreted stratigraphic sections on Drawings 1 to 8, and the specific borehole records in Appendices A to S for each of the proposed crossing locations, to assess the thickness of the till deposit, its surface and base elevation, composition, and geotechnical properties.

The till deposit is generally comprised of clayey silt with sand to some sand, and trace to some gravel. However, the till does vary in composition, and in some areas it grades to silty clay till of intermediate plasticity, or sand and silt till of slight plasticity. Grain size distribution tests were completed on 36 samples of the till from Golder's 2011, 2012 and 2014 investigations as included in this report, and an "envelope" of these results is presented on Figure 6 following the text of this report. Specific grain size distribution test results at each of the crossing locations are contained in Appendices A to S. The till deposit should be expected to contain seams and interlayers of cohesionless soil of varying thickness, which may be water-bearing.

Cobbles and boulders were observed or inferred within the till deposit in many of the boreholes, based on visual observation and instances of difficult drilling and/or auger grinding, and such observations are presented on the borehole records contained in Appendices A through S. In Borehole 12-14 at Str. 1158 – Outlet (see Appendix M), an approximately 2.3 m thick layer of cobbles and boulders was encountered at a depth of approximately 4 m below the existing ground surface (at about Elevation 189.5 m). The till deposit is glacially derived and, as such, should be expected to contain cobbles and boulders even where such obstructions were not observed in nearby boreholes.

Atterberg limits tests were completed on 42 samples of the till deposit as part of the borehole investigations presented in this report, and measured liquid limits ranging from 17 to 42 per cent, plastic limits ranging from 11 to 21 per cent, and plasticity indices ranging from 5 to 21 per cent. These test results, which are plotted on plasticity charts on Figures 7A to 7C, confirm that the till deposit is comprised predominantly of clayey silt of low plasticity, but that some portions grade to silty clay of intermediate plasticity.

The measured SPT "N" values in the till deposit vary from 9 blows to greater than 100 blows per 0.3 m of penetration, suggesting that the deposit has a stiff to hard consistency. However, the majority of the SPT "N" values exceed 30 blows per 0.3 m of penetration, indicative of a typically hard consistency.

4.2.4 Shale Bedrock

Shale bedrock was encountered within, or within 1 m to 2 m above, the proposed depth for trenchless sewer installation in boreholes at the following crossing sites:

Crossing Location	Approx. Station	Borehole No.	Depth to Bedrock Surface (m)	Bedrock Surface Elevation (m)	Thickness of Weathered Zone (m)	Elevation of Base of Weathered Zone (m)
Str. 774 - 773	2+970	14-01	4.6	161.9	Not confirmed	Not confirmed
		MB-5	3.1	163.5	1.5	Approx. 161.9
Str. 1105 – 1117 and 1118 – SWM 4	9+400	14-16	1.2	190.8	0.3	Approx. 190.5
		14-17	1.6	191.9	<0.1	Approx. 191.8
		14-18	1.2	191.4	<0.1	Approx. 191.3
		P4-3	P4-3	191.5	3.0	Approx. 188.5

The bedrock consists of slightly weathered to fresh, laminated, grey, weak to medium strong shale of the Georgian Bay Formation, which contains interbeds of stronger limestone and/or siltstone. In the above-noted boreholes, the upper 0.1 m to 3.0 m of the bedrock was penetrated by augering and split-spoon sampling (as shown on the borehole records contained in Appendices A and J), and this upper portion of the bedrock is considered to be more weathered than the underlying bedrock material. The presence within the shale of limestone layers greater than 25 mm in thickness is noted in detail on the Records of Drillholes 14-16, 14-17 and 14-18 contained in Appendix J. These drillhole records also note the relative proportion of stronger limestone (including layers less than 25 mm in thickness) within each core run, which varies from 4 to 55 per cent.

The Rock Quality Designation (RQD) measured on the recovered bedrock core samples at the Str. 1105 – 1117 and 1118 – SWM Pond 4 crossing sites is between 30 and 95 per cent, indicating a rock mass of poor to excellent quality. The Total Core Recovery (TCR) is between about 75 and 100 per cent, but generally over 85 per cent, and the Solid Core Recovery (SCR) is between about 40 and 100 per cent, but generally over 80 per cent below the upper core run.

Point Load tests were carried out on sixteen samples of the bedrock, with the results summarized in the following table and shown on the drillhole records contained in Appendix J:

Borehole No.	Sample Depth (m)	Approximate Sample Elevation (m)	Axial (A) or Diametral (D) Test	$I_{s\ (50\ mm)}$ (MPa)	Approximate Unconfined Compressive Strength (MPa)
14-16	2.6	189.4	A	1.01	20
14-16	2.9	189.1	D	0.09	2
14-16	3.1	188.9	D	0.52	10
14-16	3.2	188.8	A	0.15	3
14-16	3.5	188.5	D	0.13	3
14-16	3.6	188.4	A	0.94	19
14-17	2.3	191.2	D	1.05	21

Borehole No.	Sample Depth (m)	Approximate Sample Elevation (m)	Axial (A) or Diametral (D) Test	$I_{s\ (50\ mm)}$ (MPa)	Approximate Unconfined Compressive Strength (MPa)
14-17	2.3	191.2	A	1.70	34
14-17	3.4	190.1	D	0.39	8
14-17	3.4	190.1	A	0.54	11
14-17	3.7	189.8	D	1.94	39
14-17	3.7	189.8	A	2.33	47
14-17	4.1	189.4	D	0.26	5
14-17	4.1	189.4	A	0.81	16
14-18	3.6	189.0	A	0.48	10
14-18	3.8	188.8	A	0.73	15

The estimated uniaxial compressive strength (UCS) values for each sample tested for point load strength are based on a relationship between Is_{50} and UCS which is given by a correlation factor in accordance with ASTM D5731-08 *(Standard Test Method for Determination of the Point Load Strength Index of Rock and Application to Rock Strength Classification),* which may vary depending on the size of the core sample and the strength of the rock. For this project, the UCS values are based on an estimated average correlation factor (C) of approximately 20.

Laboratory unconfined compressive strength tests were carried out in accordance with ASTM D7012-10 *(Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens)* on three samples of the bedrock. The results of the unconfined compressive strength tests are summarized below.

Borehole No.	Sample Depth (m)	Sample Elevation (m)	Unconfined Compressive Strength – UCS (MPa)
14-16	2.8	189.2	86
14-17	3.6	189.9	33
14-18	3.3	189.3	50

Based on the point load test results and the unconfined compressive strength results, in accordance with Table 3.5 from CFEM (2006), the shale bedrock within the depth of exploration is classified as weak to medium strong (R2 to R3, 5 MPa < UCS < 50 MPa), containing typically strong (R4, 50 MPa < UCS < 100 MPa) limestone interlayers.

4.3 Groundwater Conditions

The water levels were observed in the open boreholes during drilling and immediately following completion of drilling, and these measurements are recorded on the borehole records contained in Appendices A through S. As the glacial till is over consolidated and predominantly cohesive, many of the boreholes were observed to be “dry” on completion of drilling; these dry conditions and any observed water levels do not represent the long-term stabilized groundwater level at the borehole locations. Based on measurements made in piezometers installed along the Highway 410 corridor, and observations of colour transitions from brown to grey, the groundwater level along the Highway 410 corridor is summarized below; these groundwater elevations are consistent with the interpolated conditions shown in the Foundation Investigation Report for the Median Sewer (dated June 2013) for this assignment.

Approximate Station (m)	Approximate Groundwater Elevation (m)
2+970	165
4+700	175
5+000	176.5
5+200	178
6+250	184
7+000	182
7+850	185
8+150	186
9+400	191
9+700	188
10+050	189
10+450	191
10+750	193
10+900	195
11+950	199
12+350	208
12+600	213
13+100	213

In addition to the above-noted groundwater levels, “perched” groundwater should be anticipated within granular fill materials on top of the predominantly cohesive native soils.

The groundwater and perched water levels along the Highway 410 corridor are expected to fluctuate seasonally in response to changes in precipitation and snow melt, and are expected to be higher during the spring and periods of precipitation.

5.0 CLOSURE

This Foundation Investigation Report was prepared by Lisa Coyne, P.Eng. Mr. Fin Heffernan, P.Eng., a Designated MTO Foundations Contact for Golder, conducted an independent review of this report.

GOLDER ASSOCIATES LTD.

LICENSED PROFESSIONAL ENGINEER
L. C. COYNE
10AUG/15
PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER
Aug 10/15
F. J. HEFFERNAN
PROVINCE OF ONTARIO

Lisa C. Coyne, P.Eng.
Geotechnical Engineer, Principal

Fin Heffernan, P.Eng.
Designated MTO Foundations Contact

LCC/FJH/sm

\\golder.gds\gal\mississauga\active\2011\1111\11-1111-0083 urs hwy 410 peel region\7 - reports\11 - trenchless crossings\11-1111-0083 fidr11 2015-08-10 trenchless crossings.docx

PART B

FOUNDATION DESIGN REPORT
TRENCHLESS SEWER AND CULVERT CROSSINGS
HIGHWAY 410 WIDENING
FROM SOUTH OF HIGHWAY 401 TO QUEEN STREET
REGIONAL MUNICIPALITY OF PEEL
G.W.P. 2144-07-00

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides geotechnical recommendations for the installation of sewer crossings and culverts under the Highway 410 mainline and ramps using trenchless methods. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced in the vicinity of each crossing location. The discussion and recommendations presented are intended to provide the designers with sufficient information to assess the feasible trenchless installation methods and to design the crossings.

Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project, and for which special provisions or operational constraints may be required in the Contract Documents. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.2 Pipe Materials

Installation of the sewer by either jack and bore or pipe ramming methods will require that a steel casing be installed during boring or ramming. The steel casing would remain in place, with a smaller diameter sewer or culvert pipe installed within the casing. It is recommended that grout be injected in the annular space between the culvert pipe and the steel casing, as is discussed further in Section 6.7. It has been assumed that the steel casing will, as a minimum, be one standard pipe diameter larger than the proposed sewer/culvert diameter.

If micro-tunnelling methods are selected for this project, it is likely that the pipe will be jacked into place behind the micro-tunnelling cutter head. Different pipe materials could be used from interlocking steel pipe to glass-fibre reinforced concrete (mortar) pipe specially made for micro-tunnelling. In such cases, the jacking pipe may be used for the final culvert pipe, depending on materials and installed diameter. It will be essential to specify appropriate hydraulic, joint integrity and long-term abrasion resistance performance requirements in the event that alternative pipe materials are proposed by the trenchless contractor.

The pipe must be selected to withstand the overburden and highway loads, hydrostatic pressures (if present), and the installation forces and grouting pressure. The overburden pressure may be calculated using a unit weight of 21 kN/m^3. The unit weight of water may be taken as 9.8kN/m^3.

6.3 Sewer/Culvert Tunnel Alignment

Tables 1 and 2 following the text of this report provides a summary of the proposed sewer/culvert and carrier pipe diameter, invert elevations, the cover thickness at the highway/ramp shoulders, and the corresponding range of overburden cover expressed as a function of the tunnel diameter (i.e., the number of tunnel diameters between the crown of the tunnel and the overlying ground surface). Table 2 also provides a summary of the subsurface conditions encountered in the boreholes at and above the depth through which the sewer/culvert crossings are to be advanced. Plan and interpreted stratigraphic sections for each crossing location are provided on Drawings 1 to 8 (Sections A-A' to S-S'), and the borehole records and geotechnical laboratory test results specific to each crossing location are provided in corresponding Appendices A to S.

For tunnels under 400-series highways, MTO requires that the minimum overburden cover shall not be less than two tunnel diameters or 1.5 m, whichever is greater, at any point along the entire length of the tunnel crossing. For the proposed sewer Str 774 – Str 773 carrier pipe diameter of 0.45 m, the obvert would need to be the greater of a minimum of 0.9 m or 1.5 m below the lowest point along the alignment. Based on the profile provided by URS, the proposed tunnel obvert is less than 1.5 m below the existing ground surface but greater than 0.9 m. The proposed tunnel invert would also results in the tunnel obvert being at approximately the interface of the fill and native material near the median shoulder. Typically it is recommended that the tunnel obvert be a minimum of 0.5 m below the fill/native interface so that tunnel horizon is primarily within the native deposits; however, it is understood that other constraints, such as the elevations of the median sewer and the configuration of the drainage ditches, do not allow the depth of cover to be increased at this location.

For the proposed sewer Str 1143 – Str 1141 carrier pipe diameter of 0.75 m, the obvert would need to be the greater of a minimum of 1.5 m below the lowest point along the alignment. Based on the profile provided by URS, the proposed tunnel obvert is less than 1.5 m below the existing ground surface at the outside shoulder. Typically, it would be recommended that the tunnel invert be lowered approximately 0.2 m to meet the minimum 1.5 m depth of cover requirement; however, as mentioned above, other constraints do not allow for this at this location.

Tunnels are typically mined in the direction of increasing elevation to allow for gravity drainage of groundwater seepage. Therefore the entry shafts would be at the lower elevation and the exit shafts would be at the higher elevation. It may be necessary that the shafts where the base is below the anticipated groundwater table be dewatered to maintain stability of the excavation base as discussed in Section 6.6.

6.4 Pipe Installation Methods

The Contractor will be responsible for choosing the method and equipment for culvert installation unless specific methods are otherwise prohibited. Ground behaviour will be, in part, dependent on the installation method adopted and this report provides guidance on the influence of ground behaviour on some possible culvert installation methods. It should not be construed that the Contractor is restricted to the particular methods considered herein, and in the event of alternative methods, the Contractor must make his own interpretation of the anticipated ground behaviour, based on the factual information provided in Part A, Foundation Investigation Report, of this report.

Based on the sewer and culvert profiles provided by URS, it is understood that it is preferable that the culverts be installed using trenchless methods under Highway 410. Possible trenchless methods include, jacking and boring, pipe ramming, using a mirco-tunnel boring machine (MTBM) and horizontal directional drilling (HDD).

HDD uses drilling fluid under pressure to create the pilot hole and is typically used for smaller diameter crossings below embankments or rivers, where the installed pipe is not dependant on gravity drainage as is the case for sewers and culverts. Furthermore, HDD would typically require greater amounts of cover than are present at the majority of sewer and culvert locations to minimize the risk of hydraulic fracturing of the ground and loss of drilling fluid to the surface (“frac-out”). Therefore the HDD method is not considered suitable for any of these crossings and is not considered further.

The following sections of the report will present and address the geotechnical design recommendations and construction issues for the four main types of construction: jack and bore, pipe ramming, MTBM and open-face shield tunnelling.

6.4.1 Jack and Bore

Conventional "jack and bore" is a method of forming a near horizontal bore from a jacking/drive (i.e., entry) pit. Boring is undertaken with a rotating cutter head and a continuous welded casing is jacked through reaction against a thrust block located within the jacking pit. Spoil from the tunnel excavation is transported to the jacking pit along helical auger flights and the new pipe is then installed within the casing. The casing may be lubricated to reduce the frictional forces between casing and the surrounding soil. The jack and bore method is generally suitable for penetrating cohesive soils (silt and clay) and wet but unsaturated cohesionless soils that are well-graded (i.e., broadly graded). Jack and bore methods can lead to excessive ground losses, settlement and development of sinkholes extending to the surface when passing through saturated (flowing) or dry (running) sand, silt and/or gravel. The presence of boulders and cobbles can obstruct augering operations, damage the equipment and require manual interventions that slow progress. The removal of obstructions may also result in loss of ground at the face and ground settlement at the ground surface, depending on the soil conditions. Difficulties may also be encountered in maintaining alignment control of the tunnel as it advances due to the presence of stiffer or more compact/dense soils ahead of the face, cobbles or boulders at the face or due to mixed face conditions. Because the steel casing is jacked from the rear, there is little opportunity to adjust the alignment if deviations begin to occur as a result of obstructions or variability in the ground conditions at the tunnel face.

The size of the jacking pit is controlled by the equipment size and the length of the casing sections which are being installed. Typically, a work area of about 10 m long by about 3 m to 5 m wide is required to accommodate the jacking/drive pit for jack and bore operations. The receiving pit is typically about 3 m square.

6.4.2 Pipe Ramming

Pipe ramming involves the use of a percussive hammer to advance a steel casing with a cutting shoe attached at the front end of the casing, much like horizontal pile driving. The casing is generally advanced open-ended and the soil within the casing is typically removed after the casing has been driven the entire length of the installation, thereby reducing the potential for ground loss into the casing during driving. As each casing length is installed the rammer is removed, the next casing is welded in place and the rammer replaced and restarted. On completion of the bore, compressed air or water, pressure jetting or augering is used to remove the spoils from within the casing. In some cases, depending on the ground conditions and length of the pipe, soil can be removed periodically from within the pipe to reduce the total mass being driven and the resistance to driving.

Pipe ramming is best suited for soft to firm clays and very loose to compact sands above the water table. Pipe ramming methods are also better suited for penetrating through/displacing potential obstructions such as cobbles and boulders in comparison to jack and bore installation method, though this method can still be obstructed by cobbles and boulders depending on their size and number. Difficulties in maintaining alignment control of the tunnel as it advances can still occur if cobbles and boulders are encountered. Vibrations from the pipe ramming operations may result in settlement of loose materials in the immediate vicinity of the installation. Furthermore, a “plug” of soil may form at the head of the casing inducing surficial heave as the pipe is advanced. This can be controlled by stopping the operation and removing spoil from within the pipe before advancing further. Compared to the jack and bore method the single most important advantage of pipe ramming is that the soil is typically removed from the pipe only after the pipe has fully passed beneath overlying infrastructure. Another advantage of pipe ramming is there is no need for a thrust block in the entrance pit, therefore a smaller pit size is required for pipe ramming.

6.4.3 Micro-Tunnel Boring Machines (MTBM)

Micro-tunnel boring machines (MTBM) typically use pressurized bentonite slurry to counterbalance the earth and water pressures acting at the tunnel face and to transport the cuttings to the surface. A remotely-controlled rotating cutterhead is used to excavate soil in a controlled manner at the face and together with the pressurized slurry these act to minimize loss of ground during tunnel advance. The slurry is circulated back through the tunnel to transport cuttings to a settling tank as well as cyclone and screen separators. The MTBM can also be specified and equipped to cut and/or crush cobbles and boulders that are anticipated along the proposed tunnel alignment. While many MTBMs are stated as capable of cutting or crushing cobbles and boulders, these machines can still be “choked” if there are a sufficient number of cobbles and progress can still be obstructed if boulders cannot be efficiently cut by the face tools or they move around at the face in loose soils rather than being cut. Given the machine’s ability to control soil and water pressures at the face, dewatering of cohesionless soils along the tunnel alignment is seldom necessary with this tunnelling method.

Micro-tunnelling, as described above, is typically considered to be the method that minimizes the risk of loss of ground and ground surface settlement. However, it is relatively expensive to mobilize this type of machine and the availability of machines with the suitable diameter bore and the mobilization costs for such equipment may constrain their use on this project.

In the greater Toronto area, some trenchless contractors use “small boring units” and present this system as “micro-tunnelling”. In general, the small boring units often consist of a rotating cutter head system that is temporarily welded to the lead end of a steel casing. The ground is cut using a variety of face tools (similar to MTBMs described above), but the spoil is transported to the surface using an auger system, much like conventional jack and bore systems. Face openings on the small boring units are typically much smaller than the auger opening on conventional jack and bore systems and the risk of uncontrolled ingress of ground into the lead end of the casing is lower for this system as compared to jack and bore methods. These systems do not, however, provide consistent and positive support to the ground at all face openings with any slurry or cuttings, unlike the slurry-based MTBMs described above. Therefore, while the small boring units are more suitable and advantageous for cutting through stiff to hard cohesive glacial till and weathered rock materials, they should only be used only with caution if granular soils may be encountered along the alignment.

6.4.4 Open Face Shield Tunnelling

Open face shield tunnelling involves excavating the soils using a hydraulic excavator arm, working within a full-circumference tunnelling shield. Alternatively, hand mining (i.e., manual and mechanically-assisted excavation) within the tunnelling shield could be carried out whereby the soil would be excavated using manual equipment with workers at the face. Typically, the liner would consist of a solid steel casing, jacked in sections from the launching shaft. Unlike auger jack and bore, this method allows personnel to enter the tunnel to allow more control over the operations such as for removal of obstructions or control of groundwater seepage or localized instabilities. Similar to jack and bore, however, groundwater lowering is necessary to control cohesionless soils below the groundwater level. Manual or machine-assisted excavation generally requires a tunnel diameter of about 1.2 m or more.

6.5 Anticipated Soil Behaviour and Feasibility of Tunnelling Methods

The anticipated soil and groundwater conditions within the proposed tunnel horizons are summarized in Table 2. The feasibility for installing the culvert using the jack and bore, pipe ramming, MTBM or open shield is summarized on Table 3. A summary comparison of the advantages, disadvantages, relative costs and risks associated with the culvert installation methods is presented in Table 4.

Based on the fines content, the coefficient of uniformity[1] and the SPT ‘N’ values, the soil has been classified according to the Tunnelman’s Ground Classification System by Terzaghi as reported in Heuer (1974). This system is commonly used to describe the expected behaviour of an unsupported tunnel face during excavation and uses qualitative “stand-up time” criteria to classify the ground at and above the tunnel face into the following principal categories: firm, slowly ravelling, fast ravelling, cohesive-running, running and flowing.

The soil conditions within the tunnel horizon have been classified on Table 3 and generally they range from “running” to “rapidly raveling” to “firm” to “slow ravelling” or “cohesive-running.” Soils that are classified as “flowing” or “running” are not considered suitable for the jack and bore method or the open face shield method because of the risk for uncontrolled inflows into the casing that would lead to increased settlement (and potentially sink holes) at the ground surface. These methods can be utilized if the sand and silt deposits are dewatered/depressurized such that the groundwater level is lowered to below the tunnel invert along the full alignment. In a moist, depressurized condition, the sands and silts would behave as ravelling to cohesive running ground, providing the ability to advance with minimal ground losses providing excavation is undertaken on a continuous controlled basis. Pipe ramming is suitable through the majority of the soil conditions, with the exception of very stiff to hard clays, as resistance will build up rapidly and it will be difficult to impossible to displace cobbles and boulders encountered in such soils.

6.5.1 Jack and Bore Considerations

Jack and bore operations can be carried out below the groundwater table in soils that have a high fines content and exhibit suitable “stand-up” time; however, under such conditions the specifications should require that a plug of spoil material remain in the lead end of the casing at all times. This can be achieved by maintaining the cutting head at the appropriate distance behind the leading edge of the casing or retracting it into the casing during the jacking operations through such soils. The objective is to balance the potential inflow of material into

---

[1] The coefficient of uniformity is an indicator of the degree to which the soil is well graded, and is expressed as the ratio of the particle size at which 60 per cent of the particles are finer divided by the particle size at which 10 per cent are finer.

the casing, with a plug of soil at the front of the casing to minimize ground loss and consequent settlement. Once started, the jack and bore operation should continue without interruption until complete.

If obstructions, such as a boulder or a nest of cobbles, are encountered, it would be necessary to remove the augers and soil plug. Depending on the soil conditions at the location of the obstructions, this may result in loss of ground at the face and ground settlement at the ground surface. Typically the till deposits and native cohesive deposits will have a greater “stand-up time” compared to the cohesionless soil and fill. For cohesionless soil above the water table, the greater the fines content and the more broadly graded the soil is the greater the stand-up time will be, and the greater the likelihood that the obstructions can be removed without significant ground settlement. In the event the obstructions are encountered below the groundwater table in cohesionless soils, then the risk of large ground settlements occurring is greatly increased. The contractor should have a contingency plan for such an event that includes highway closure to protect the travelling public.

The stiff to hard cohesive soils, including glacial till soils, will likely be difficult to penetrate using only jacking forces and the lead end of the casing. In such cases, contractors frequently prefer to have the lead end of the auger at or ahead of the lead edge of the casing. While in some well-known cohesive soil ground conditions this may be acceptable, this practice could lead to excessive ground losses if native saturated or dry granular soils, granular embankment fill or pavement sub-base and base course materials are encountered.

Difficulties may also be encountered in maintaining alignment control of the tunnel as it advances due to the presence of cobbles/boulders, stiffer or more compact/dense soils ahead of the face or mixed face conditions.

Ground movements should be monitored during pipeline installation to measure ground surface movements (i.e. settlement/heave) as compared to specified tolerances (see Section 6.5). Construction specifications for the installation of the sewer/culvert by jacking and boring and pipe ramming are given in NSSP, “Pipe Installation by Trenchless Method” (see Appendix T).

6.5.2 Pipe Ramming Considerations

The feasibility of pipe ramming is questionable at the culvert crossing locations where very stiff to hard cohesive soils and cohesive tills were encountered within the tunnel horizon as significant resistance to pipe advance can be expected and will increase as the pipe is advanced. Also, when the pipe is not being advanced (during welding of casing extensions) the stresses around the circumference of the pipe may increase which will further increase the friction around the pipe, making it more difficult to advance the pipe. The casing may be lubricated to reduce the frictional forces between casing and the surrounding soil and/or the Contractor may utilize a higher energy hammer and thicker wall pipe in such conditions.

As with the jack and bore method, tunnel alignment may be difficult to control due to the presence of cobbles/boulders, or mixed face conditions. Also, there is an increased risk of difficulty with alignment control for the option where the tunnelled portion is extended beyond the east shoulder of the southbound lanes into the median, owing to the increased installation length. If cobbles and boulders are encountered, the casing may be cleaned out, allowing access for equipment to break up the obstructions. Cleaning out the spoils from inside the casing may result in the loss of ground at the face of the casing. As discussed in Section 6.3.4, the till and cohesive soils will have a longer “stand-up time”, compared to the cohesionless soil and fills.

Ground movements should be monitored during pipeline installation to measure ground surface movements (i.e., settlement/heave) as compared to specified tolerances (see Section 6.5). Construction specifications for the installation of the sewer/culvert by jacking and boring and pipe ramming are given in NSSP, "Pipe Installation by Trenchless Method" (see Appendix T).

6.5.3 MTBM Considerations

The MTBM method uses bentonite slurry to counterbalance the earth and water pressures acting at the tunnel face. If the slurry pressure at the face is allowed to become too high, hydraulic fracture (typically referred to as "frac-out") of the ground can occur, allowing bentonite slurry to exit at ground surface. "Frac-out" can then result in a sudden drop in face pressure, creating face instability if tunnelling through cohesionless soils below the groundwater table. To minimize the risk of "frac-out" the MTBM method should not be used for sewer/culvert crossing locations on this project with cover of less than 2.5 m. Further, to both properly support ground at the cutting face and along the pipe if an over-cut is used, slurries should have a Marsh funnel viscosity of not less than about 70 seconds.

An advantage of the MTBM is that lowering of the groundwater level in cohesionless soils is not required. Another advantage is the MTBM can also be specified to have the capability to cut and crush boulders that are anticipated along the proposed tunnel alignments. For tunnelling in the anticipated ground conditions on this project, MTBMs should be specified to include rock disc cutters and/or roller bit cutters as well as soft-ground excavation tools on the MTBM face. Typical drag bits or carbide cutting teeth are often broken from the face of tunnel boring machines when encountering boulders or the interbedded shale and limestone and should not be solely relied upon for cutting rock on this project.

Micro-tunnelling for this project should not be undertaken on this project using a "small boring unit" where there is a risk that saturated or dry granular soils (native or highway and pavement fill materials) might be encountered. While the small boring units are often highly effective in penetrating till and the rock types in the area (depending on face tool configuration), the openings in the cutting head are not well protected against uncontrolled ingress of running or flowing ground.

Ground movements should be monitored during pipeline installation to measure ground surface movements (i.e., settlement/heave) as compared to specified tolerances (see Section 6.5).

This project includes pipe design diameters ranging from about 0.3 m to about 1.0 m. For this size range, many MTBM systems are available. Given the numbers of pipes to be installed, one or two MTBM sizes may be selected to minimize the equipment and operational costs. Consideration could be given during construction to adapting the final pipe diameter to better match proposed equipment sizes and pipe materials.

6.5.4 Open Face Shield Tunnelling Considerations

If the open face shield tunnelling method is selected, the contractor should have a means to readily secure the face if inward ground deformation is encountered or if unanticipated work stoppages are necessary (pre-fabricated breasting boards, etc.). Further, the tunnelling work should be continuous from start to finish (24 hours per day, 7 days per week). If it is necessary to stop the tunnelling operations, the contractor should be prepared to immediately support the face. Filling of the annular space between the liner and native ground should be carried out as soon as the liner is installed (bentonitic grout/lubricant in the case of jacked pipes, with cementitious grout provided at the completion of construction).

Ground movements should be monitored during pipeline installation to measure ground surface movements (i.e. settlement/heave) as related to specified tolerances (see Section 6.5). Construction specifications for the installation of the sewer/culvert by tunnelling are given in Non-Standard Special Provision, “Pipe Installation by Trenchless Method” (see Appendix T).

6.6 Instrumentation and Monitoring

An instrumentation and monitoring program is recommended at trenchless crossing locations in order to:

- document the effects of the sewer/culvert installation on the overlying roadways, adjacent structures or services lines/pipes;
- identify adverse movement trends;
- measure the Contractor’s compliance with the settlement limits specified in the Contract; and
- provide information to support adaptation of the culvert installation methods to observed behaviour and ground conditions toward compliance with the settlement limits.

Monitoring of settlement instruments on this project is constrained by the continuous and high traffic volume and the limited periods during which access to the highway can be obtained. By necessity, settlement points on the road must be read remotely and the use of electromagnetic distance measuring equipment reading reflectors installed on the highway is recommended. A specialist surveying firm should be retained to confirm the set-up and to carry out the settlement monitoring during construction; their equipment and procedures must be capable of surveying the settlement point elevation to within ± 2 mm of the actual elevation.

In addition, the installation of in-ground settlement points, consisting of a sleeved iron bars, set 0.3 m above the tunnel obvert elevation at each crossing at accessible locations (e.g. highway shoulders) should be also considered. The elevation of the top of the bar would be read using conventional precision levelling equipment. The in-ground monitoring points provide the best measure of the ground settlement effects of tunnelling, as they are unaffected by frost heave, thaw settlement or the bridging action of the pavement structure.

All monitoring points should be read at least three times (on separate days) before the start of culvert installation to establish a pre-construction baseline. All points behind the face of the excavation and those within 10 m of the front of the face should be read every 4 hours over the duration of the tunnel drives. The effectiveness of this monitoring method could be impacted by weather conditions if the work is undertaken during the winter months.

A settlement monitoring plan consistent with the requirements in the “Appendix: Settlement Monitoring Guideline – Tunnelling” of MTO’s “Guideline for Foundation Engineering – Tunnelling Speciality for Corridor Encroachment Permit Application”, should be established as part of the Contract Administration for construction.

Where concrete pavements exist, these may temporarily bridge over and mask underlying ground losses or settlements. High traffic volumes and the need to preserve the integrity of pavements further inhibit installation of monitoring points through concrete pavements. Therefore, to the extent practicable and possible, it will be important to measure the volume of ground removed from beneath paved areas as compared to the theoretical cut hole volume on a frequency of at least once per 6 m section of pipe installed. Measuring excavated ground volumes will be difficult because of bulking that occurs when excavating soils and the spoil discharge systems on some systems are not readily conducive to such measurements (e.g., jack and bore, MTBM). However, on-site observation of construction operations and measurement of grout and/or lubricant volumes should assist in identifying atypical conditions that could be indicative of unacceptable ground losses.

6.7 Grouting

After the permanent sewer/culvert pipe is installed within the jacked or rammed casing, post installation grout to fill the annular space between the pipes should be carried out. Refer to the Specification in Appendix T for sewer/culvert installation via trenchless methods.

For any installations at which the settlement monitoring indicates that pavement settlement has occurred, or where signs of ground loss have been noted, provision should be made for a program of compensation grouting above the pipe and/or repair of the pavements.

7.0 CLOSURE

This Foundation Design Report was prepared by Nikol Kochmanová, P.Eng., with technical input from Lisa Coyne, P.Eng., a Principal with Golder, and reviewed by Storer Boone, P.Eng., who is certified in MTO's RAQS system for high complexity tunnelling assignments. Mr. Fin Heffernan, P.Eng., a Designated MTO Foundations Contact for Golder, conducted an independent review of this report.

GOLDER ASSOCIATES LTD.

LICENSED PROFESSIONAL ENGINEER
S. J. BOONE
90559733
PROVINCE OF ONTARIO

Nikol Kochmanová, Ph.D., P.Eng., PMP
Geotechnical Engineer

Storer J. Boone, Ph.D., P.Eng.
Geotechnical Engineer, Principal

REGISTERED PROFESSIONAL ENGINEER
Aug 10/15
F. J. HEFFERNAN
PROVINCE OF ONTARIO

Fin Heffernan, P.Eng.
Designated MTO Foundations Contact

NK/SJB/LCC/FJH/

Golder, Golder Associates and the GA globe design are trademarks of Golder Associates Corporation.

\\golder.gds\gal\mississauga\active\2011\1111\11-1111-0083 urs hwy 410 peel region\7 - reports\11 - trenchless crossings\11-1111-0083 fdr11 2015-08-10 trenchless crossings.docx

REFERENCES

Heuer, Ronald E., 1974 “Important Ground Parameters in Soft Ground Tunneling”, Proceedings Specialty Conference on Subsurface Explorations for Underground Excavations and Heavy Construction, ASCE, NY.

Table 1: Summary of Trenchless Installations

Trenchless Crossing	Approximate Station	Drawing/ Section and Appendix	Borehole Nos.	Proposed Diameter (m)	Estimated Carrier Pipe Diameter (m)	Existing Pavement Elevation (m)		Proposed Invert Elevation (m)		Estimated Carrier Pipe Obvert Elevation (m)		Estimated Cover Thickness (m)		Minimum Cover Thickness
						Median Shoulder	Outside Shoulder	Median Shoulder	Outside Shoulder	Median Shoulder	Outside Shoulder	Median Shoulder	Outside Shoulder	
Str 774 - Str 773	2+970	1 - A-A' A	14-01 MB-5	0.375	0.450	166.76	166.39	164.87	164.40	165.32	164.85	1.44	1.54	3.2D
Culvert #5	10+394 (Ramp)	2 - B-B' B	14-02 14-03	0.800	0.900	192.93	193.40	182.11	182.85	183.01	183.75	9.92	9.65	10.7D
Culvert #6	11+516 (Ramp)	2 - C-C' C	14-04 14-05	0.800	0.900	180.11	179.75	176.52	176.73	177.42	177.63	2.69	2.12	2.4D
Str 870 - Str 868	5+180	2 - D-D' D	14-06 12-8	0.450	0.600	180.23	179.88	177.25	177.55	177.85	178.15	2.38	1.73	2.9D
Str 894 - Outlet	5+280	2 - E-E' E	14-07 P1-3	0.825	0.900	181.04	180.89	178.31	177.96	179.21	178.86	1.83	2.03	2.0D
Str 1326 - Median Median - Str. 1327	6+266	3 - F-F' F	14-08 14-09 14-10	0.825	0.900	187.29	187.38	183.68	183.49	184.58	184.39	2.71	2.99	3.0D
				0.825	0.900	187.38	187.20	183.49	183.30	184.39	184.20	2.99	3.00	3.3D
Str 978 - Str 979	7+000	3 - G-G' G	14-11 14-12	0.825	0.900	184.91	184.84	182.25	182.00	183.15	182.90	1.76	1.94	2.0D
Str 1018 - Str 1019	7+830	4 - H'H' H	14-13 193-8	0.600	0.750	187.17	187.09	184.77	184.71	185.52	185.46	1.65	1.63	2.2D
Str 1036 - Str 1028	8+140	4 - I-I' I	14-14 14-15 P3-3	0.675	0.750	188.78	188.55	185.94	185.60	186.69	186.35	2.09	2.20	2.8D
Str 1105 - Str 1117 Str 1118 – SWM 4 (410N-407 Ramp)	9+400	5 - J-J' J	14-16 14-17 14-18 P4-3	0.750	0.900	193.37	193.86	189.75	189.59	190.65	190.49	2.72	3.37	3.0D
				0.750	0.900	192.44	192.71	189.46	189.30	190.36	190.20	2.08	2.51	2.3D
Str 1126 - Outlet	9+700	5 - K-K' K	14-19 14-20	0.450	0.600	192.61	192.27	189.84	189.60	190.44	190.20	2.17	2.07	3.5D
Str 1143 - Str 1141	10+040	5 - L-L' L	14-21 122-3(1)	0.675	0.750	193.66	193.43	191.22	191.37	191.97	192.12	1.69	1.31	1.7D
Str 1158 - Outlet	10+460	6 - M-M' M	14-22 12-14	0.600	0.750	194.63	194.96	192.38	192.30	193.13	193.05	1.50	1.91	2.0D
Str 1176 - Outlet	10+750	6 - N-N' N	14-23 14-24	0.300	0.450	195.44	195.59	193.09	192.44	193.54	192.89	1.90	2.70	4.2D
Str 1182 - Str 1183	Ramp	6 - O-O' O	14-25 14-26 P6-2	0.600	0.750	197.11	196.90	192.70	192.31	193.45	193.06	3.66	3.84	4.9D
Str 1247 - Str 1249	11+950	7 - P-P' P	14-27 GR-6	0.525	0.600	208.08	207.83	205.20	204.75	205.80	205.35	2.28	2.48	3.8D
Str 1268 - Str 1267	12+330	7 - Q-Q' Q	14-28 14-29	0.525	0.600	215.10	214.85	212.03	211.81	212.63	212.41	2.47	2.44	4.1D

Trenchless Crossing	Approximate Station	Drawing/ Section and Appendix	Borehole Nos.	Proposed Diameter (m)	Estimated Carrier Pipe Diameter (m)	Existing Pavement Elevation (m)		Proposed Invert Elevation (m)		Estimated Carrier Pipe Obvert Elevation (m)		Estimated Cover Thickness (m)		Minimum Cover Thickness
						Median Shoulder	Outside Shoulder	Median Shoulder	Outside Shoulder	Median Shoulder	Outside Shoulder	Median Shoulder	Outside Shoulder	
Str 1279 - Str 1278	12+600	7 - R-R' R	14-30 CN-10	0.825	0.900	220.11	219.86	216.58	216.17	217.48	217.07	2.63	2.79	2.9D
Str 1301 - Str 1303	13+110	8 - S-S' S	14-31 14-32	0.525	0.600	218.64	218.38	216.52	216.27	217.12	216.87	1.52	1.51	2.5D

Table 2: Summary of Anticipated Subsurface Conditions

Trenchless Crossing	Approximate Station	Drawing/ Section and Appendix	Borehole Nos.	Anticipated Subsurface Conditions at Sewer/Culvert Alignment	Groundwater Elevation (m)	Distance between Groundwater and Invert of Culvert (m)	
						Median Shoulder	Outside Shoulder
Str 774 - Str 773	2+970	1 - A-A' A	14-01 MB-5	■ Compact sand and gravel fill ■ Stiff to very stiff clayey silt to silty clay fill ■ Very stiff to hard clayey silt to silty clay	165	0.1 below	0.6 below
Culvert #5	10+394 (Ramp)	2 - B-B' B	14-02 14-03	■ Compact to dense sand and gravel fill ■ Stiff to hard clayey silt fill ■ Very stiff to hard clayey silt to silty clay till	175	7.1 above	7.8 above
Culvert #6	11+516 (Ramp)	2 - C-C' C	14-04 14-05	■ Compact sand and gravel fill ■ Stiff to very stiff clayey silt fill ■ Very stiff to hard clayey silt till	176.5	At about invert elevation	0.2 above
Str 870 - Str 868	5+180	2 - D-D' D	14-06 12-8	■ Loose to compact sand and gravel fill ■ Very stiff to hard clayey silt till	178	0.8 below	0.4 below
Str 894 - Outlet	5+280	2 - E-E' E	14-07 P1-3	■ Loose to dense sand and gravel fill ■ Very stiff clayey silt ■ Firm to hard clayey silt till	178	0.3 above	At about invert elevation
Str 1326 - Median Median - Str. 1327	6+266	3 - F-F' F	14-08 14-09 14-10	■ Compact to dense sand and gravel fill ■ Compact sand fill ■ Very stiff clayey silt ■ Stiff to hard clayey silt till	184	0.3 below 0.5 below	0.5 below 0.7 below
Str 978 - Str 979	7+000	3 - G-G' G	14-11 14-12	■ Loose to dense sand and gravel fill ■ Firm clayey silt fill ■ Very stiff to hard clayey silt till	182	0.3 above	At about invert elevation
Str 1018 - Str 1019	7+830	4 - H'H' H	14-13 193-8	■ Compact sand fill ■ Stiff clayey silt fill ■ Very stiff to hard clayey silt till	185	0.2 below	0.3 below
Str 1036 - Str 1028	8+140	4 - I-I' I	14-14 14-15 P3-3	■ Loose to compact sand and gravel fill ■ Stiff clayey silt fill ■ Loose to compact silty sand fill ■ Firm to hard clayey silt to silty clay fill ■ Firm clayey silt ■ Firm to hard clayey silt till	186	0.1 below	0.4 below
Str 1105 - Str 1117 Str 1118 – SWM 4 (410N-407 Ramp)	9+400	5 - J-J' J	14-16 14-17 14-18 P4-3	■ Loose to dense sand to gravelly sand fill ■ Hard clayey silt till ■ Weak to medium strong shale bedrock	191	1.3 below 1.5 below	1.4 below 1.7 below
Str 1126 - Outlet	9+700	5 - K-K' K	14-19 14-20	■ Compact to dense sand and gravel to gravelly sand fill ■ Very stiff to hard clayey silt till	188	1.8 above	1.6 above

Trenchless Crossing	Approximate Station	Drawing/ Section and Appendix	Borehole Nos.	Anticipated Subsurface Conditions at Sewer/Culvert Alignment	Groundwater Elevation (m)	Distance between Groundwater and Invert of Culvert (m)	
						Median Shoulder	Outside Shoulder
Str 1143 - Str 1141	10+040	5 - L-L' L	14-21 122-3(1)	■ Compact sand fill ■ Hard clayey silt till	189	2.2 above	2.4 above
Str 1158 - Outlet	10+460	6 - M-M' M	14-22 12-14	■ Dense sand and gravel fill ■ Stiff to very stiff clayey silt fill	191	1.4 above	1.3 above
Str 1176 - Outlet	10+750	6 - N-N' N	14-23 14-24	■ Compact sand and gravel to gravelly sand fill ■ Very stiff clayey silt fill ■ Loose silty sand fill ■ Very stiff to hard clayey silt till	193	0.1 above	0.6 below
Str 1182 - Str 1183	Ramp	6 - O-O' O	14-25 14-26 P6-2	■ Compact to very dense sand and gravel fill ■ Firm to very stiff clayey silt fill ■ Very stiff to hard clayey silt till	195	2.3 below	2.7 below
Str 1247 - Str 1249	11+950	7 - P-P' P	14-27 GR-6	■ Dense sand and gravel fill ■ Firm to stiff clayey silt fill ■ Loose to compact sand and silt to silty sand fill	199	6.2 above	5.8 above
Str 1268 - Str 1267	12+330	7 - Q-Q' Q	14-28 14-29	■ Very loose to dense sand and gravel fill ■ Soft to stiff clayey silt fill ■ Loose to dense silty sand to sand and gravel fill	208	4.0 above	3.8 above
Str 1279 - Str 1278	12+600	7 - R-R' R	14-30 CN-10	■ Compact sand and gravel fill ■ Firm to stiff clayey silt fill ■ Very loose to compact sand and silt to silty sand fill ■ Firm to stiff clayey silt fill	213	3.6 above	3.2 above
Str 1301 - Str 1303	13+110	8 - S-S' S	14-31 14-32	■ Loose sand and gravel fill ■ Compact to very dense sand to gravelly sand fill ■ Stiff to hard clayey silt fill	213	3.5 above	3.3 above

Table 3: Feasibility of Jack and Bore, Pipe Ramming and MTBM

Trenchless Crossing	Approximate Station	Borehole Nos.	Soil Conditions[1] (ground surface to invert)	Fines Content[2] (%)	SPT 'N' Values (ground surface to invert) (per 0.3 m)	Coefficient of Uniformity	Behaviour	Feasibility of Jack and Bore	Feasibility of Pipe Ramming	Feasibility of MTBM	Feasibility Of Open Face Shield
Str 774 - Str 773	2+970	14-01	■ Compact sand and gravel fill ■ **Stiff silty clay fill*[a]** ■ **Very stiff to hard silty clay*[b]**	74*[a], 71*[b]	10, 20, 23	17*[a], 18*[b]	Running to firm to slow raveling	Feasible	Questionable	Feasible for Slurry Systems Only	Feasible
		MB-5	■ Compact silty sand and gravel fill ■ **Very stiff clayey silt fill** ■ **Very stiff to hard silty clay***	41*	22, 15, 60	7917*	Firm to slow raveling				
Culvert #5	10+394 (Ramp)	14-02	■ Dense sand and gravel fill ■ Crushed stone fill ■ **Stiff to hard clayey silt fill*[a]** ■ **Hard clayey silt to silty clay till*[b]**	42*[a], 53*[b]	31, 17, 13, 54, 20, 12, 22, 37	1944*[a], 375*[b]	Firm to slow raveling	Feasible	Questionable	Feasible	Feasible
		14-03	■ Compact sand and gravel fill ■ **Stiff to hard clayey silt fill** ■ **Very stiff to hard clayey silt to silty clay till***	47*	45, 23, 21, 21, 13, 13, 29, 27, 18	1750*	Firm to slow raveling				
Culvert #6	11+516 (Ramp)	14-04	■ Sand and gravel fill ■ Stiff clayey silt fill ■ **Very stiff to hard clayey silt till***	64*, 61*	8, 15, 19, 30	37*, 54*	Running to firm to slow raveling	Feasible	Questionable	Feasible for Slurry Systems Only	Feasible
		14-05	■ Compact sand and gravel fill*[a] ■ Very stiff clayey silt fill ■ **Hard clayey silt till*[b]**	11*[a], 65*[b]	11, 18, 47, 17/0.25 mm	47*[a], 42*[b]	Running to firm to slow raveling				
Str 870 - Str 868	5+180	14-06	■ Loose to compact sand and gravel fill*[a] ■ **Very stiff to hard clayey silt till*[b]**	10*[a], 61*[b]	26, 7, 16, 22, 60	324*[a], 36*[b]	Running to firm to slow raveling	Feasible	Questionable	Feasible for Slurry Systems Only	Feasible
		12-8	■ Loose to compact sand and gravel fill ■ **Very stiff to hard clayey silt till***	62*, 50*	39, 49, 29, 32, 45	43*, 57*	Running to firm to slow raveling				
Str 894 - Outlet	5+280	14-07	■ Loose to dense sand and gravel fill ■ **Firm to hard clayey silt till***	65*, 55*	32, 7, 18	39*, 121*	Running to firm to slow raveling	Feasible	Questionable	Feasible for Slurry Systems Only	Feasible
		P1-3	■ Very stiff clayey silt ■ **Very stiff to hard clayey silt till***	69*, 35*	17, 28, 25, 42	25*, 1333*	Firm to slow raveling				
Str 1326 - Median Median - Str. 1327	6+266	14-08	■ Compact to dense sand and gravel fill ■ **Stiff to hard clayey silt till***	56*	37, 12, 37, 38, 39, 26	87*	Running to firm to slow raveling	Feasible	Questionable	Feasible for Slurry Systems Only	Feasible
		14-09	■ Dense sand and gravel fill ■ Compact sand fill ■ Very stiff clayey silt ■ **Stiff to hard clayey silt till***	60*	46, 10, 22, 37, 21	50*	Running to firm to slow raveling				

Trenchless Crossing	Approximate Station	Borehole Nos.	Soil Conditions[1] (ground surface to invert)	Fines Content[2] (%)	SPT 'N' Values (ground surface to invert) (per 0.3 m)	Coefficient of Uniformity	Behaviour	Feasibility of Jack and Bore	Feasibility of Pipe Ramming	Feasibility of MTBM	Feasibility Of Open Face Shield
		14-10	■ Sand and gravel fill ■ Compact sand fill*[a] ■ **Stiff to hard clayey silt till*[b]**	16*[a], 62*[b]	13, 12, 37, 41, 27	8*[a], 44*[b]	Running rapidly raveling to firm to slow raveling				
Str 978 - Str 979	7+000	14-11	■ Loose to dense sand and gravel fill*[a] ■ Firm clayey silt fill ■ **Very stiff to hard clayey silt till*[b]**	13*[a], 59*[b]	42, 6, 26	85*[a], 21*[b]	Running to firm to slow raveling	Feasible	Questionable	Feasible for Slurry Systems Only	Feasible
		14-12	■ Compact sand and gravel fill ■ **Very stiff clayey silt till***	77*	12, 24, 20	12*	Running to firm to slow raveling				
Str 1018 - Str 1019	7+830	14-13	■ Compact sand fill*[a] ■ Stiff clayey silt fill ■ **Very stiff to hard clayey silt till*[b]**	10*[a], 65*[b]	12, 22, 25, 33	5*[a], 28*[b]	Rapidly raveling to firm to slow raveling	Feasible	Questionable	Feasible for Slurry Systems Only	Feasible
		193-8	■ **Very stiff to hard clayey silt till**	62, 54	8, 28, 45, 68	-	Firm to slow raveling				
Str 1036 - Str 1028	8+140	14-14	■ **Compact sand fill*[a]** ■ **Stiff to hard clayey silt fill*[b]**	10*[a], 66*[b]	11, 39, 10	100*[a], 32*[b]	Rapidly raveling to firm to slow raveling	Not feasible	Questionable to feasible but requires dewatering	Feasible for Slurry Systems Only	Not feasible
		14-15	■ Loose sand and gravel fill ■ **Firm to stiff clayey silt to silty clay fill***	47*, 71*	7, 4, 7, 10	85*, 21*	Running to firm to slow raveling				
		P3-3	■ Stiff clayey silt fill ■ **Loose to compact silty sand fill** ■ **Firm clayey silt** ■ **Firm to hard clayey silt till***	72*	12, 8, 6, 17	25*	Rapidly raveling to firm to slow raveling				
Str 1105 - Str 1117 Str 1118 – SWM 4 (410N-407 Ramp)	9+400	14-16	■ Sand to gravel fill ■ Hard clayey silt till ■ **Weak to medium strong shale bedrock**	-	50/0.025 m RQD = 30%	-	Running to firm to slow raveling	Not feasible	Not feasible	Feasible for Slurry Systems Only	Not feasible
		14-17	■ Loose to dense sand fill ■ Hard clayey silt fill ■ Hard clayey silt till* ■ **Weak to medium strong shale bedrock**	45*	89, 100/0.13 m RQD = 33%, 95%	2267*	Running to firm to slow raveling				
		14-18	■ Gravelly sand fill ■ Hard clayey silt till* ■ **Weak to medium strong shale bedrock**	59*	100/0.1 m, 100/0.08 m, 100/0.08 m RQD = 33%, 78%	73*	Running to firm to slow raveling				
		P4-3	■ Firm clayey silt* ■ **Weak to medium strong shale bedrock**	85*	85/0.2 m, 50/0.15 m, 50/0.05 m	11*	Firm to slow raveling				

Trenchless Crossing	Approximate Station	Borehole Nos.	Soil Conditions[1] (ground surface to invert)	Fines Content[2] (%)	SPT 'N' Values (ground surface to invert) (per 0.3 m)	Coefficient of Uniformity	Behaviour	Feasibility of Jack and Bore	Feasibility of Pipe Ramming	Feasibility of MTBM	Feasibility Of Open Face Shield
Str 1126 - Outlet	9+700	14-19	■ Dense gravelly sand fill ■ **Very stiff to hard clayey silt till***	41*	48, 30, 151	275*	Running to firm to slow raveling	Feasible	Questionable	Feasible for Slurry Systems Only	Feasible
		14-20	■ Compact sand and gravel fill ■ Very still clayey silt fill ■ **Hard clayey silt till***	48*	15, 38, 79, 63	157*	Running to firm to slow raveling				
Str 1143 - Str 1141	10+040	14-21	■ Compact sand fill*[a] ■ **Hard clayey silt till*[b]**	16*[a], 66*[b]	14, 32	96*[a], 30*[b]	Rapidly raveling to firm to slow raveling	Feasible	Questionable	Feasible for Slurry Systems Only	Feasible
		122-3(1)	■ **Hard clayey silt till**	77, 67, 53, 73	34, 70	-	Firm to slow raveling				
Str 1158 - Outlet	10+460	14-22	■ Dense sand and gravel fill ■ **Stiff to very stiff clayey silt fill***	63*	32, 11, 24, 28	37*	Running to firm to slow raveling	Feasible	Feasible	Feasible for Slurry Systems Only	Feasible
		12-14	■ Dense sand and gravel fill ■ **Stiff to very stiff clayey silt fill**	-	9, 23	-	Running to firm to slow raveling				
Str 1176 - Outlet	10+750	14-23	■ Sand and gravel fill ■ **Very stiff clayey silt fill** ■ **Very stiff to hard clayey silt till***	71*	19, 22, 19	19*	Running to firm to slow raveling	Not feasible	Feasible but requires dewatering	Feasible for Slurry Systems Only	Not feasible
		14-24	■ Compact gravelly sand fill ■ Very stiff clayey silt fill ■ **Loose silty sand fill*[a]** ■ **Firm clayey silt fill** ■ **Hard clayey silt till*[b]**	27*[a], 60*[b]	24, 16, 17, 7, 32	8*[a], 54*[b]	Running to rapidly raveling to firm to slow raveling				
Str 1182 - Str 1183	Ramp	14-25	■ Compact sand and gravel fill ■ Firm to very stiff clayey silt fill ■ **Very stiff to hard clayey silt till***	62*	21, 16, 7, 9, 26, 43, 37	44*	Firm to slow raveling	Feasible	Questionable	Feasible	Feasible
		14-26	■ Very dense sand and gravel fill ■ **Firm to very stiff clayey silt fill*[a]** ■ **Hard clayey silt till*[b]**	65*[a], 65*[b]	88, 13, 7, 25, 25, 52	30*[a], 36*[b]	Firm to slow raveling				
		P6-2	■ Stiff to very stiff clayey silt fill*[a] ■ **Hard clayey silt till*[b]**	44*[a], 71*[b], 62*[b]	20, 17, 9, 10, 18, 39, 50, 61, 73	307*[a], 33*[b], 50*[b]	Firm to slow raveling				
Str 1247 - Str 1249	11+950	14-27	■ Dense sand and gravel fill ■ **Loose to compact sand and silt to silty sand fill***	48*, 51*	9, 8, 10, 10	93*, 86*	Running to cohesive running	Questionable	Feasible	Feasible for Slurry Systems Only	Feasible
		GR-6	■ Firm to stiff clayey silt fill ■ Compact sand and silt fill* ■ **Firm to stiff clayey silt fill**	43*	5, 11, 18, 9	93*	Rapidly raveling to firm to slow raveling				

Trenchless Crossing	Approximate Station	Borehole Nos.	Soil Conditions[1] (ground surface to invert)	Fines Content[2] (%)	SPT 'N' Values (ground surface to invert) (per 0.3 m)	Coefficient of Uniformity	Behaviour	Feasibility of Jack and Bore	Feasibility of Pipe Ramming	Feasibility of MTBM	Feasibility Of Open Face Shield
Str 1268 - Str 1267	12+330	14-28	■ Very loose to dense sand and gravel fill ■ Soft to firm clayey silt fill ■ **Loose to dense sand fill***	40*	32, 3, 8, 19	47*	Running to firm to slow raveling to rapidly raveling	Feasible	Feasible	Feasible for Slurry Systems Only	Questionable
		14-29	■ Compact to dense sand and gravel fill ■ Stiff clayey silt fill ■ **Loose to compact sand and gravel fill***	8*, 52*	38, 12, 6, 6, 10	40*, 62*	Running to firm to slow raveling				
Str 1279 - Str 1278	12+600	14-30	■ Compact sand and gravel fill ■ **Loose to compact sand and fill*[a]** ■ **Firm to stiff clayey silt fill*[b]**	58*[a], 64*[b]	14, 8, 24, 6, 8	57*[a], 40*[b]	Running to rapidly raveling to firm to slow raveling	Feasible	Feasible	Feasible for Slurry Systems Only	Questionable
		CN-10	■ Firm to stiff clayey silt fill ■ **Very loose to compact sandy silt fill***	73*	5, 8, 19, 6	38*	Firm to slow raveling to rapidly raveling				
Str 1301 - Str 1303	13+110	14-31	■ Loose sand and gravel fill ■ **Very dense gravelly sand fill*[a]** ■ **Stiff to very stiff clayey silt fill*[b]**	16*[a], 55*[b]	100/0.13 m, 14	1357*[a], 80*[b]	Running to firm to slow raveling	Feasible	Questionable	Not feasible	Feasible
		14-32	■ Sand and gravel fill ■ **Compact sand fill*[a]** ■ **Stiff to hard clayey silt fill*[b]**	17*[a], 53*[b]	17, 9	1400*[a], 114*[b]	Running to rapidly raveling to firm to slow raveling				

Notes:

1. Soil conditions from ground surface to invert, bold soil condition indicates soil conditions at tunnel horizon.
2. Fines content is the percentage by weight passing the number 200 sieve.

*[a] and *[b] Fines content marked with '*[a]' coincide with soil material marked with an '*[a]'and Fines content marked with '*[b]' coincide with soil material marked with an '*[b]'

Table 4: Evaluation of Trenchless Sewer/Culvert Installation Methods

Installation Method	Advantages	Disadvantages	Estimated Costs/m of Culvert Installation	Risk/Consequences
Jack and Bore Installation	■ Sewers/culverts can be installed without lane closures resulting in minimal traffic disruption.	■ Large work area required for jacking pit. ■ Obstructions (e.g., cobbles and boulders) may deflect and/or halt bore. Greatest risk of ground subsidence of highway particularly if obstructions that slow installation procedures or if unanticipated granular soils encountered. ■ May require groundwater lowering.	\$900^2/m to \$1,800^3/m	■ Risk of encountering refusal on obstructions within native deposits, particularly till, where man entry to remove obstructions is not possible. ■ Obstructions can result in deflection of the casing resulting in misalignment of culvert. ■ Potential for loss of ground into casing particularly if cohesionless materials are encountered. ■ Risk of ground surface subsidence increases with decreasing cover.
Pipe Ramming Installation	■ Minimal traffic disruption. ■ Less risk of subsidence above culvert alignment than jack and bore installation methods. ■ Better suited for penetrating through potential obstructions such as cobbles and boulders than jack and bore methods.	■ Large work area required for ramming pit. ■ Large obstructions can deflect casing. Potential for heaving at ground surface. May require groundwater lowering. ■ Potential noise objections in urban areas.	\$1,800^2/m to \$3,600^3/m	■ Obstructions can cause deflection of casing resulting in misalignment of culvert. ■ Nests of cobbles and/or boulders can stop penetration of casing requiring hand mining. ■ Vibration from pipe ramming may be experienced by the users of the highway.
MTBM	■ Minimal traffic disruption. ■ Typically does not require groundwater lowering except for use of “small boring units” without slurry face pressure and cuttings transport systems. ■ Slurry machines able to counterbalance earth and water pressures in a controlled manner, thereby reducing the risk of ground losses during tunneling. ■ Machine can also be specified to have the capability to cut and crush boulders and/or bedrock.	■ Relatively expensive. High mobilization cost for short crossings. ■ Slurry processing systems required along with additional working area at shaft/pit locations for some systems. ■ “Small boring unit” systems are not capable of fully controlling saturated granular soils. ■ Susceptible to hydraulic fracture depending on slurry viscosity and pressure.	\$7,500/m	■ Hydraulic fracture is possible at culvert locations with cover less than 2.5 m and any slurry exiting onto the pavements could be a significant hazard to the travelling public ■ Use of small boring units or low viscosity slurries could contribute to excessive ground losses when cutting through granular soils that result in pavement damage and a significant hazard to the travelling public
Open Face Shield Tunnelling	■ Minimal traffic disruption. ■ Better suited for penetrating through potential obstructions such as cobbles and boulders than jack and bore methods.	■ Risk of ground subsidence of highway but more control than jack and bore methods. ■ Requires groundwater lowering if saturated granular soils might be encountered. ■ Requires diameter sufficient for person entry (>1 m) ■ Additional health and safety concerns	\$1,800^2/m to \$3,600^3/m	■ Potential for loss of ground into shield particularly if cohesionless materials are encountered. ■ Risk of ground surface subsidence increases with decreasing cover.

DRAWINGS

MINISTRY OF TRANSPORTATION, ONTARIO

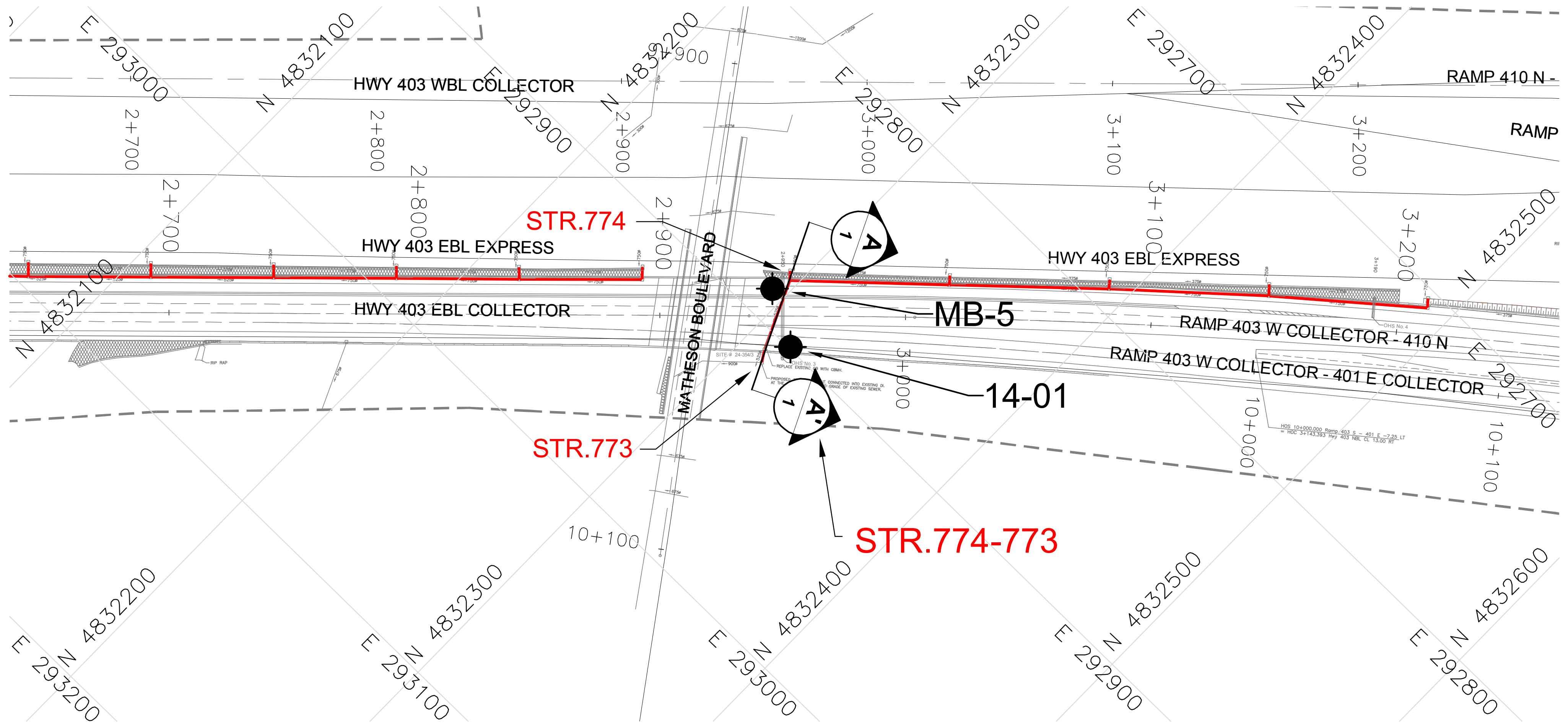
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No. 2014–2026
GWP No. 2144–07–00

SHEET

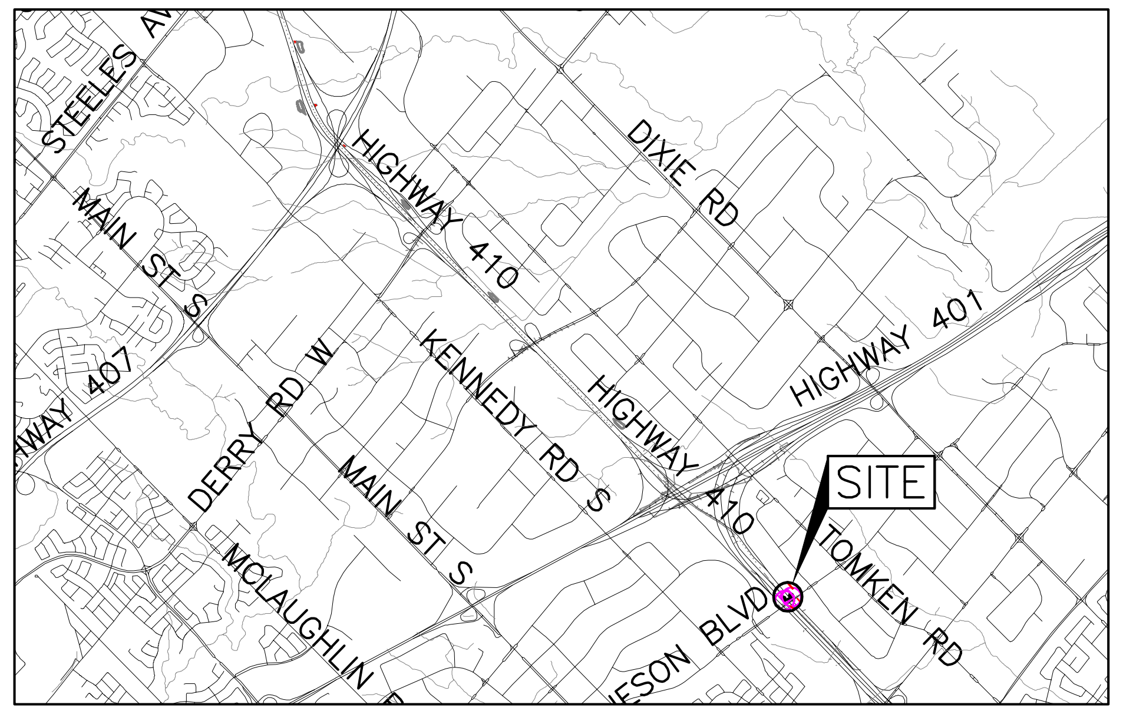
STATION 2+650 to 3+300
HIGHWAY 410 WIDENING
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN

SCALE
40 0 40 80 m



KEY PLAN

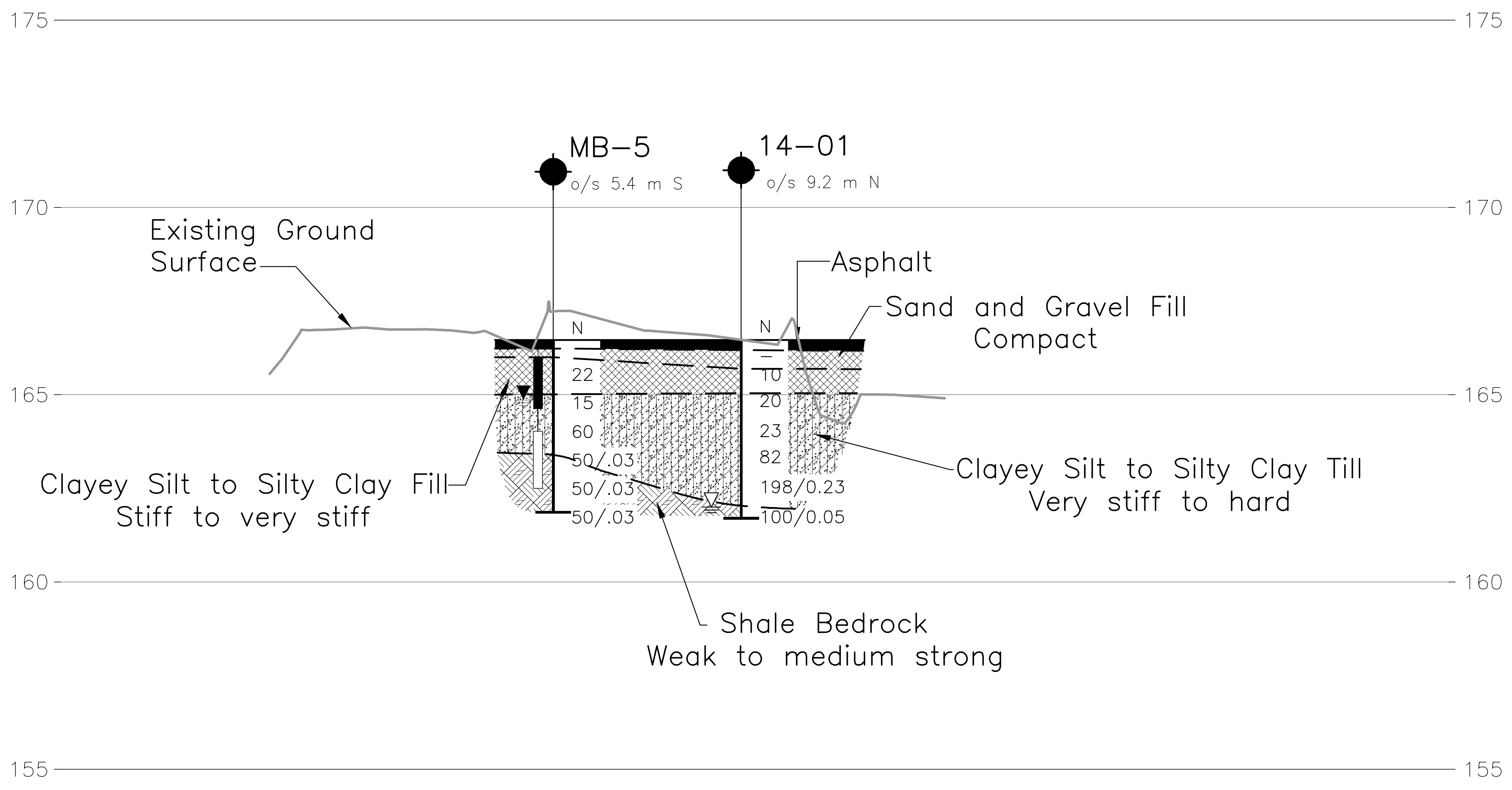
SCALE
2 0 2 4 km

LEGEND

●	Borehole – Golder Investigation
▮	Seal
▯	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
▼	WL in piezometer, measured on November 13, 2011
▽	WL upon completion of drilling

BOREHOLE CO–ORDINATES

No.	ELEVATION	NORTHING	EASTING
14–01	166.5	4832315.9	292899.2
MB–5	166.5	4832294.2	292887.4



A-A' 1 CROSS–SECTION A–A'
STR. 774–773

HORIZONTAL SCALE
10 0 10 20 m
2.5 0 2.5 5 m
VERTICAL SCALE

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS Canada Inc., (Drawing Files "Hwy410_Utilities.dwg", received Sept. 19, 2012, "2013 02 07 – Hwy410_Profile (sewers).dwg", received Feb. 07, 2013 and "2013 12 17 – Hwy410_Plan – For FDN.dwg", received Dec. 19, 2013).

L.C. COYNE
Aug. 10, 2015

F. J. HEFFERNAN
Aug. 10, 2015

Geocres No.

HWY. 410		PROJECT NO. 11–1111–0083	DIST. CENTRAL
SUBM'D. AV	CHKD. LCC	DATE: Aug. 29, 2014	SITE:
DRAWN: JFC	CHKD. LCC	APPD. LCC	DWG. 1

MINISTRY OF TRANSPORTATION, ONTARIO

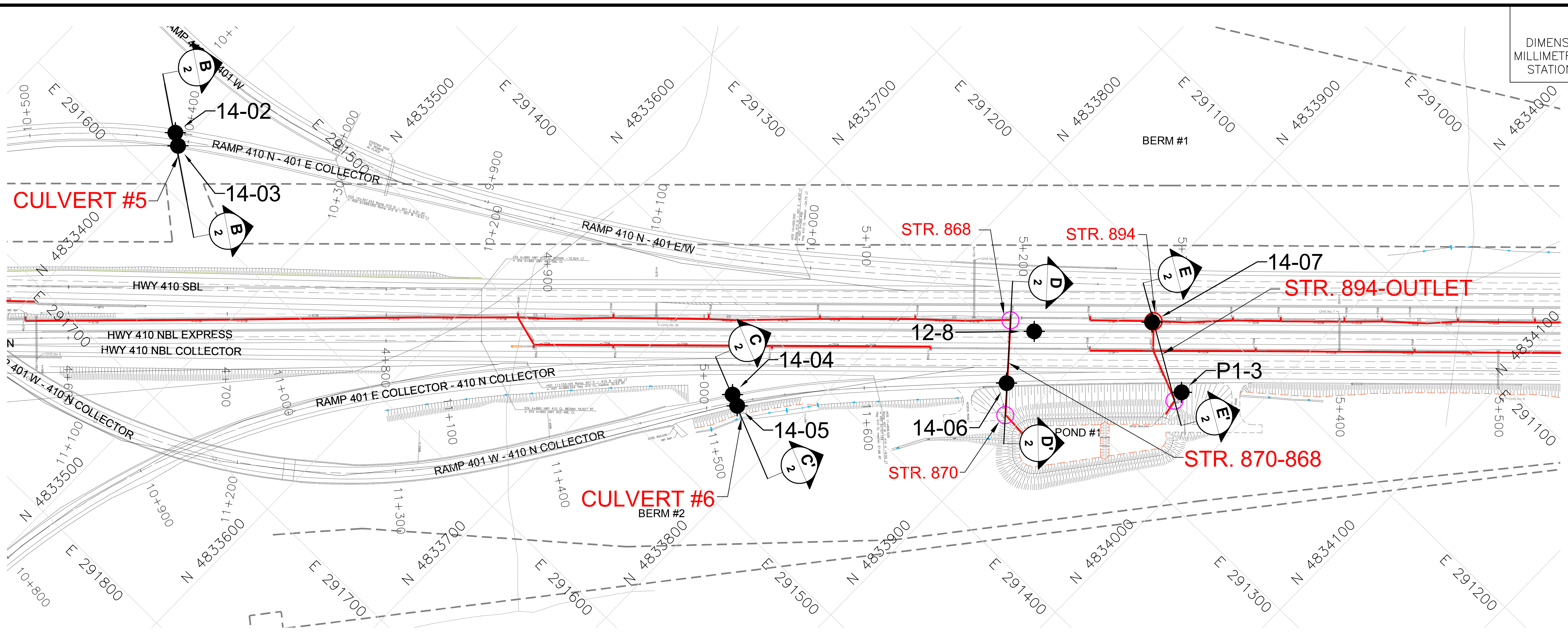
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No. 2014–2026
GWP No. 2144–07–00

STATION 4+550 to 5+525
HIGHWAY 410 WIDENING
BOREHOLE LOCATIONS AND SOIL STRATA

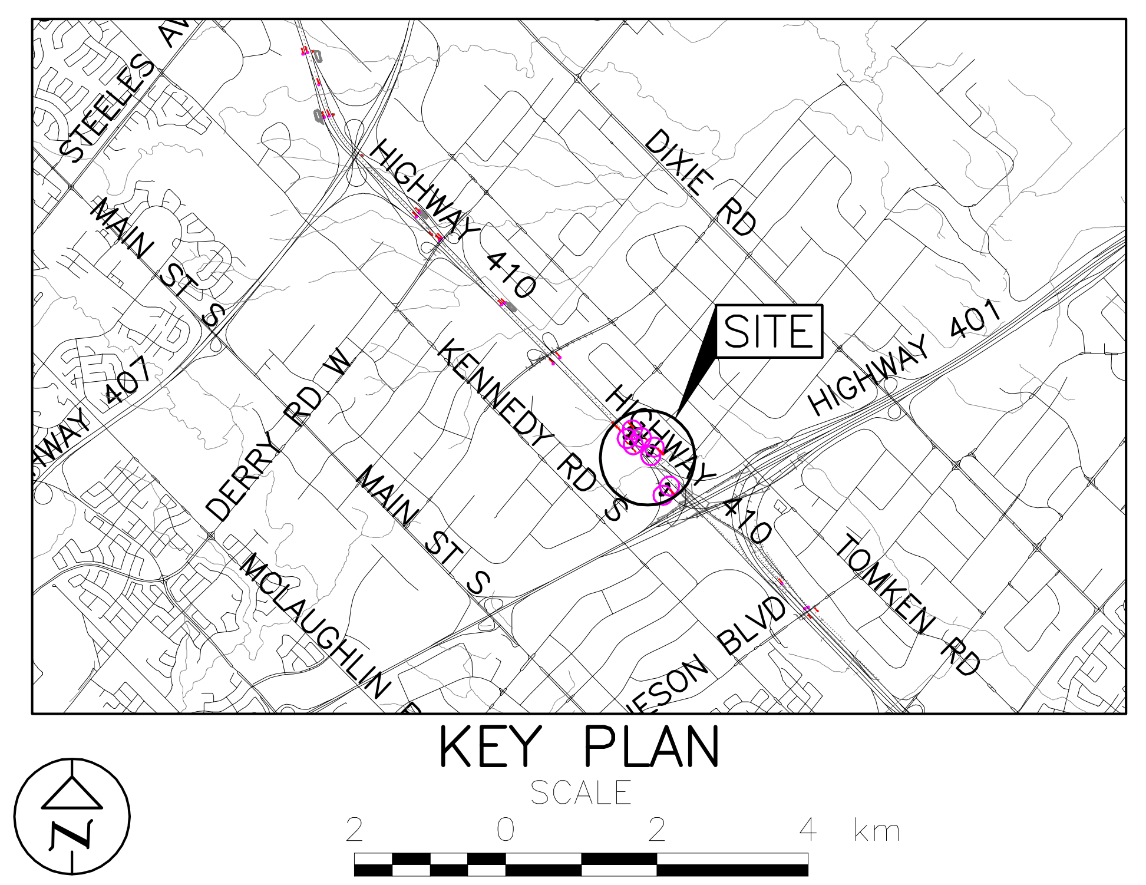
SHEET

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN

SCALE
40 0 40 80 m



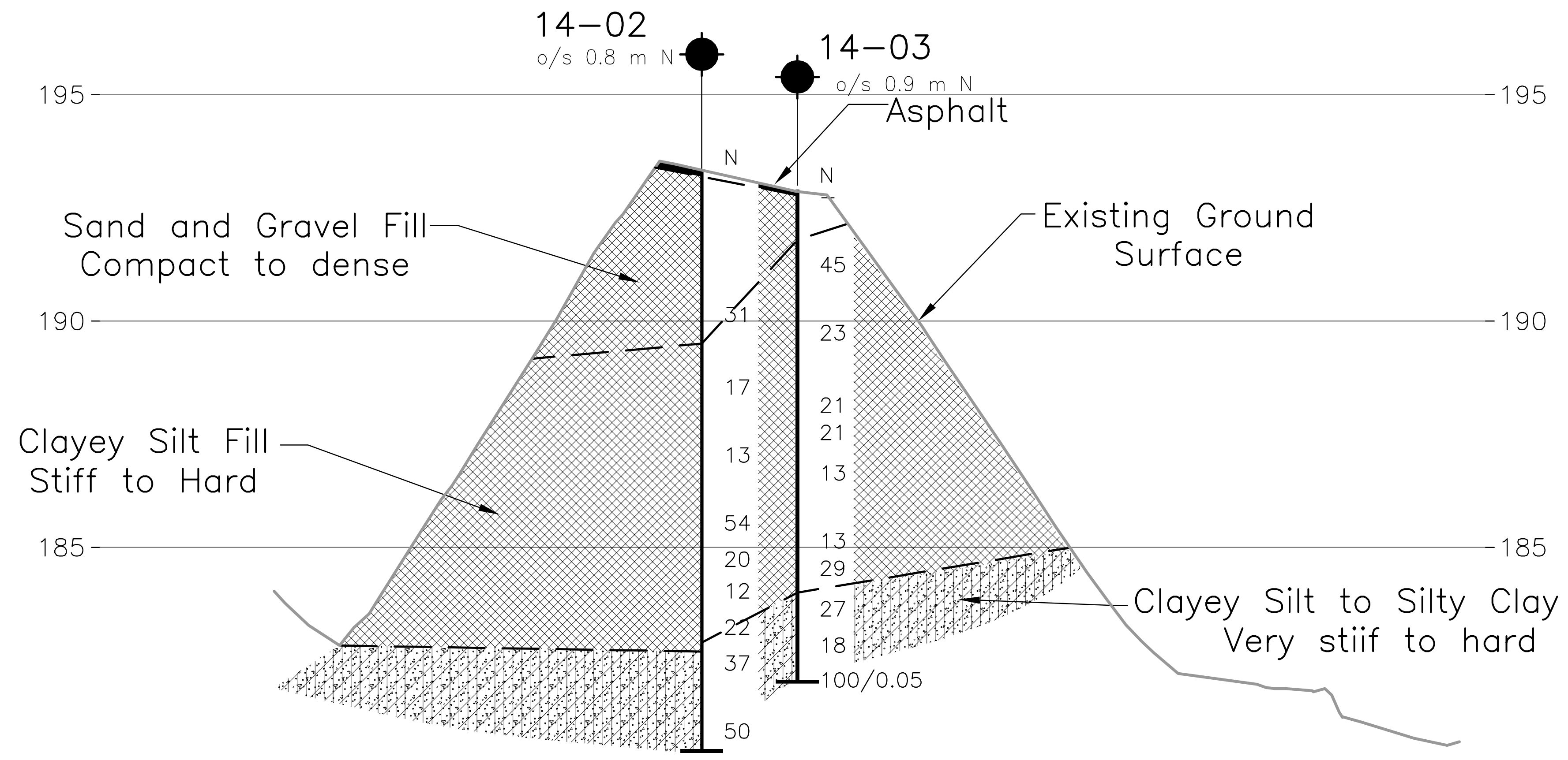
KEY PLAN
SCALE
2 0 2 4 km

LEGEND

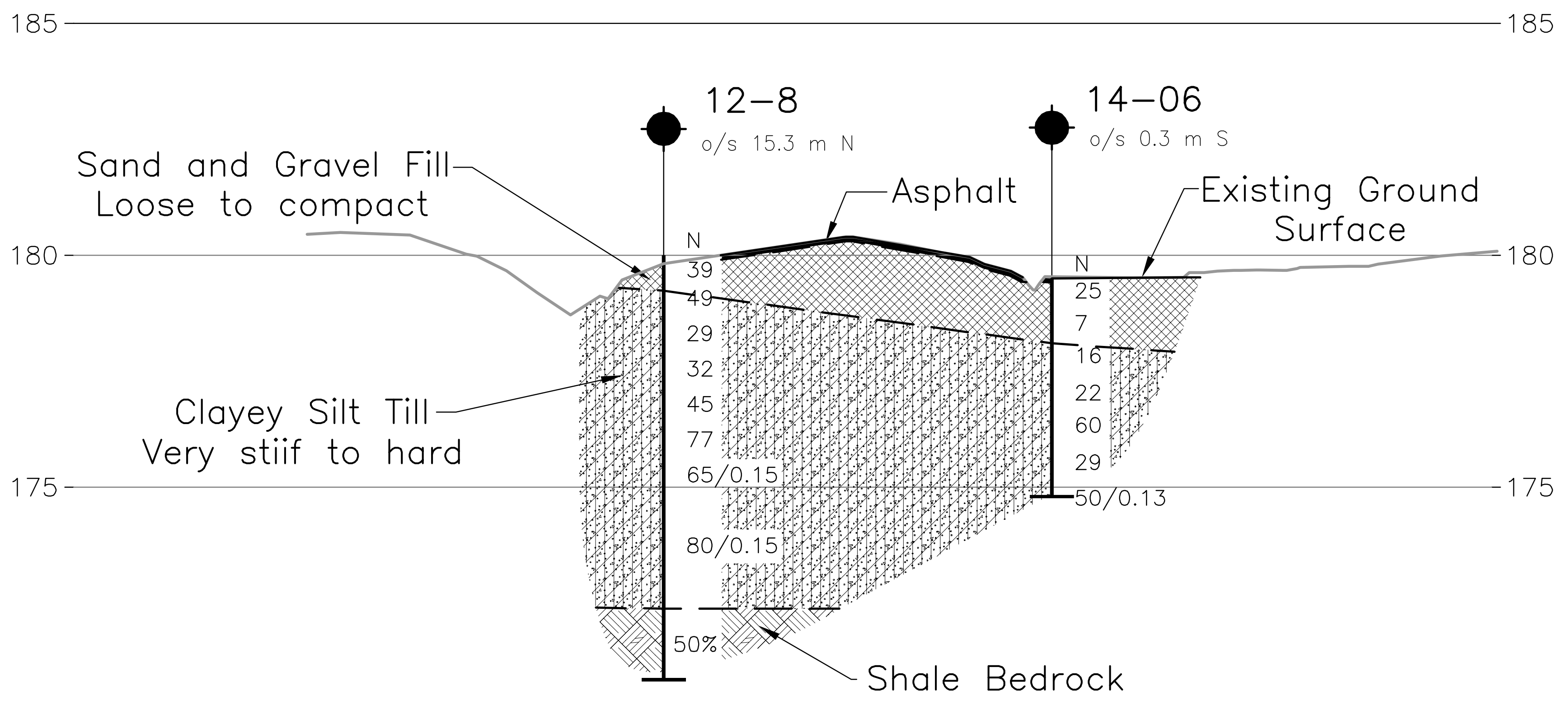
●	Borehole – Golder Investigation
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
⊽	WL upon completion of drilling

BOREHOLE CO–ORDINATES

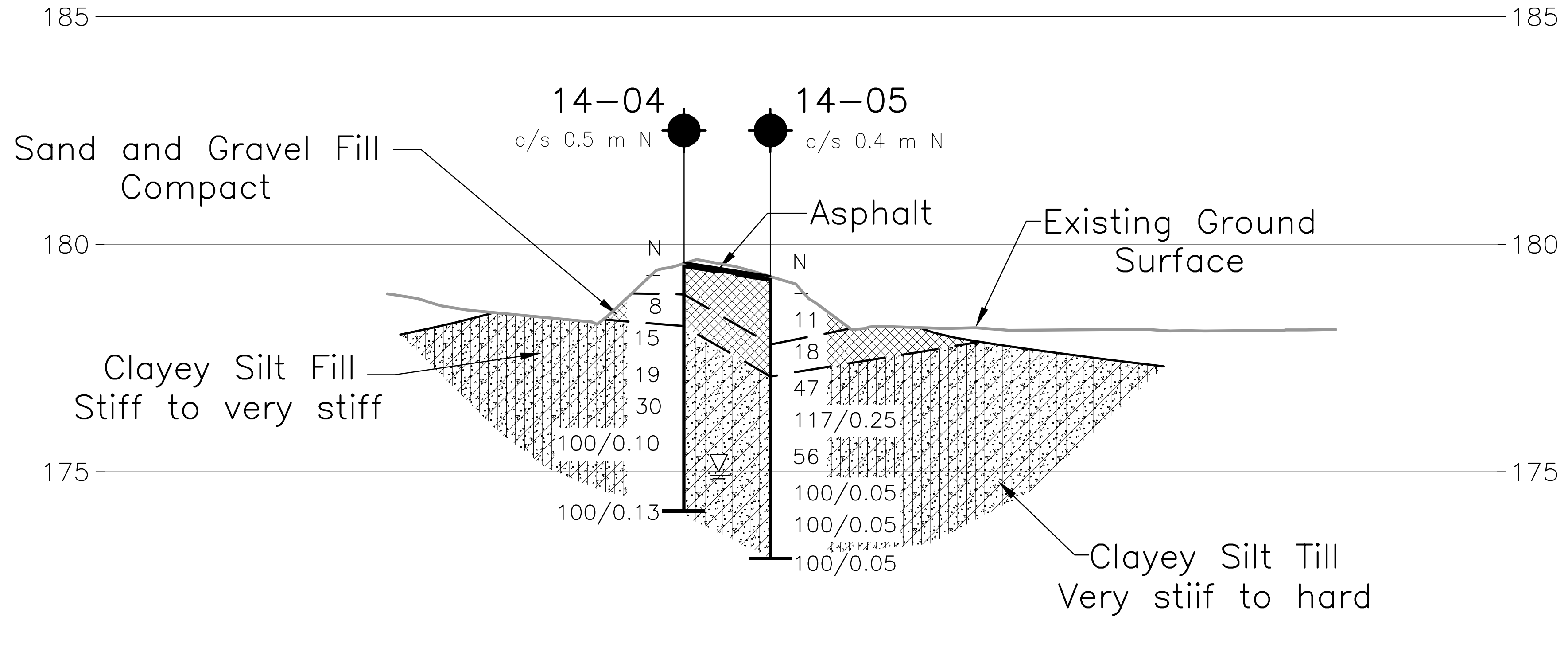
No.	ELEVATION	NORTHING	EASTING
12–8	180.0	4833866.9	291282.9
14–02	193.3	4833393.0	291571.3
14–03	192.9	4833400.0	291576.0
14–04	179.6	4833759.0	291444.0
14–05	179.3	4833766.0	291447.0
14–06	179.5	4833877.3	291318.3
14–07	179.5	4833915.9	291226.8
P1–3	180.2	4833960.1	291245.5



B-B' 2 CROSS–SECTION B–B'
CULVERT #5

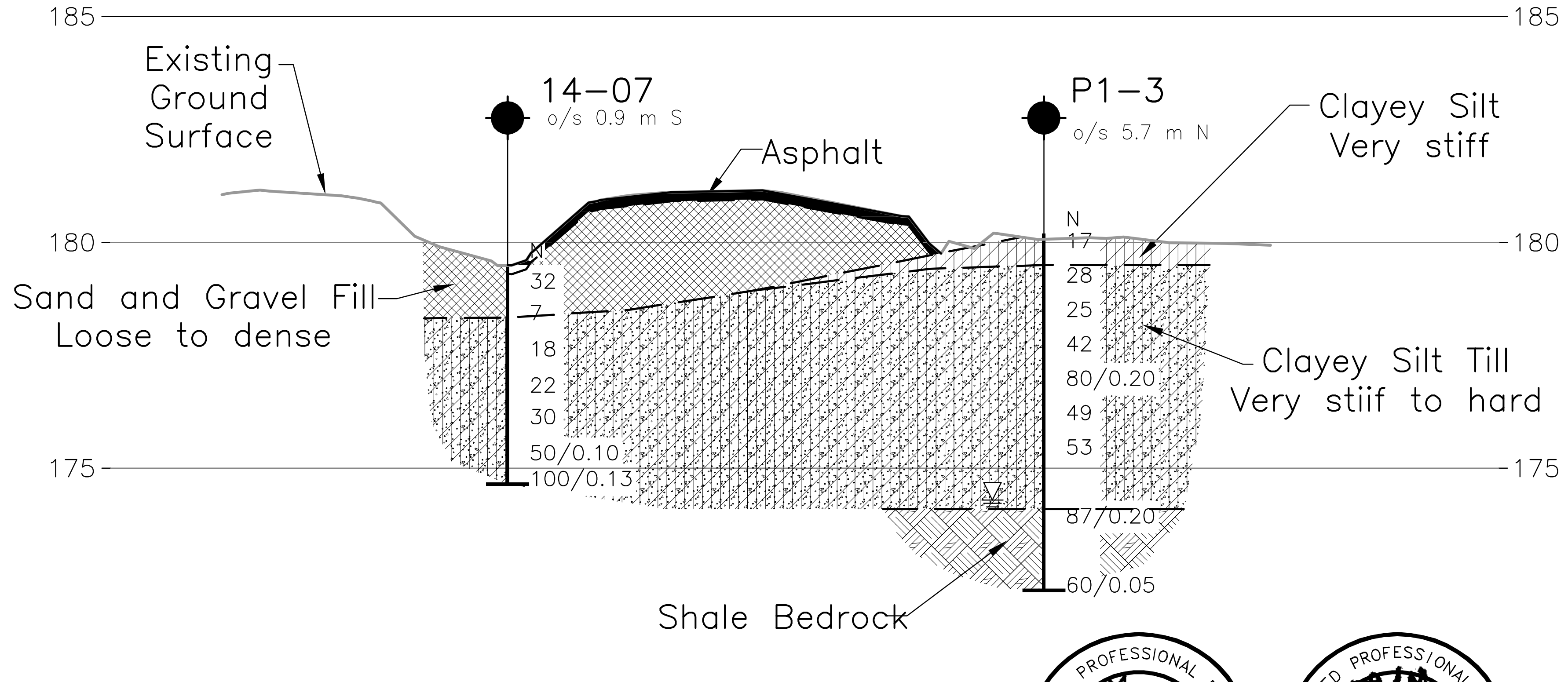


D-D' 2 CROSS–SECTION D–D'
STR. 870–868



C-C' 2 CROSS–SECTION C–C'
CULVERT #6

HORIZONTAL SCALE
10 0 10 20 m
2.5 0 2.5 5 m
VERTICAL SCALE



E-E' 2 CROSS–SECTION E–E'
STR. 894–OUTLET

L.C. COYNE
Aug. 10, 2015

F. J. HEFFERNAN
Aug. 10, 2015

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS Canada Inc., (Drawing Files "2013 12 17 – Hwy410_Plan – For FDN.dwg"and 2013 12 17 – Hwy410_Profile – for FDN.dwg", received Dec. 19, 2013).

Geocres No.

HWY. 410		PROJECT NO. 11–1111–0083	DIST. CENTRAL
SUBM'D. AV	CHKD. LCC	DATE: Aug. 29, 2014	SITE:
DRAWN: JFC	CHKD. LCC	APPD. LCC	DWG. 2

MINISTRY OF TRANSPORTATION, ONTARIO

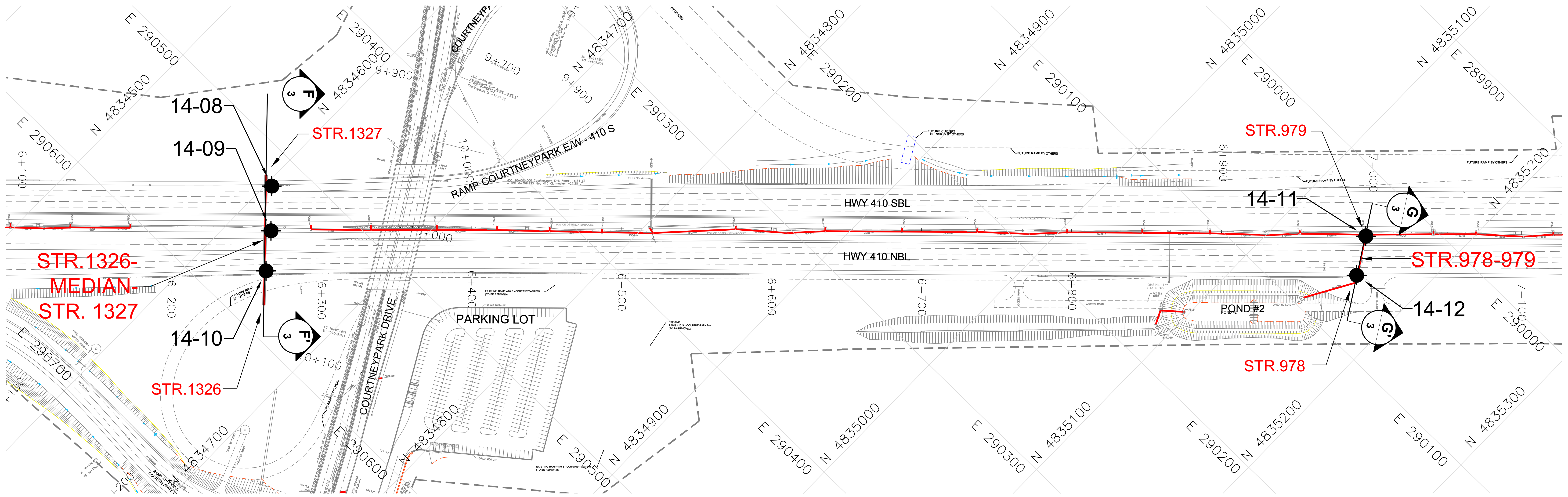
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No. 2014–2026
GWP No. 2144–07–00

STATION 6+100 to 7+100
HIGHWAY 410 WIDENING
BOREHOLE LOCATIONS AND SOIL STRATA

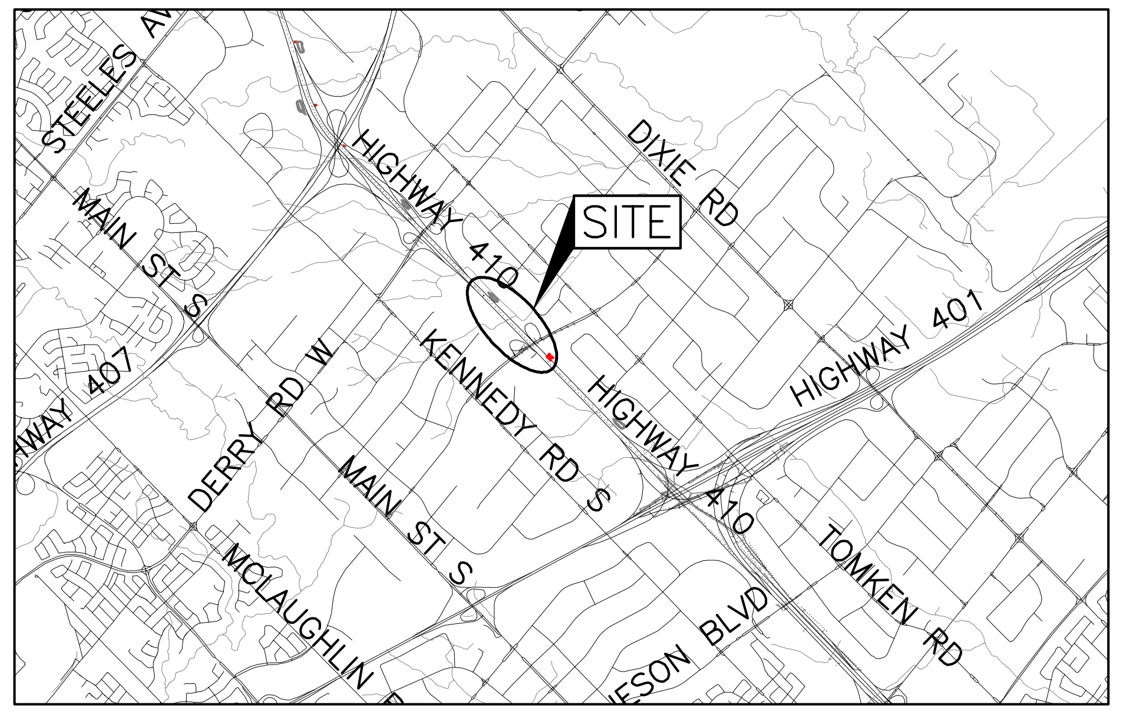
SHEET

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN

SCALE
40 0 40 80 m



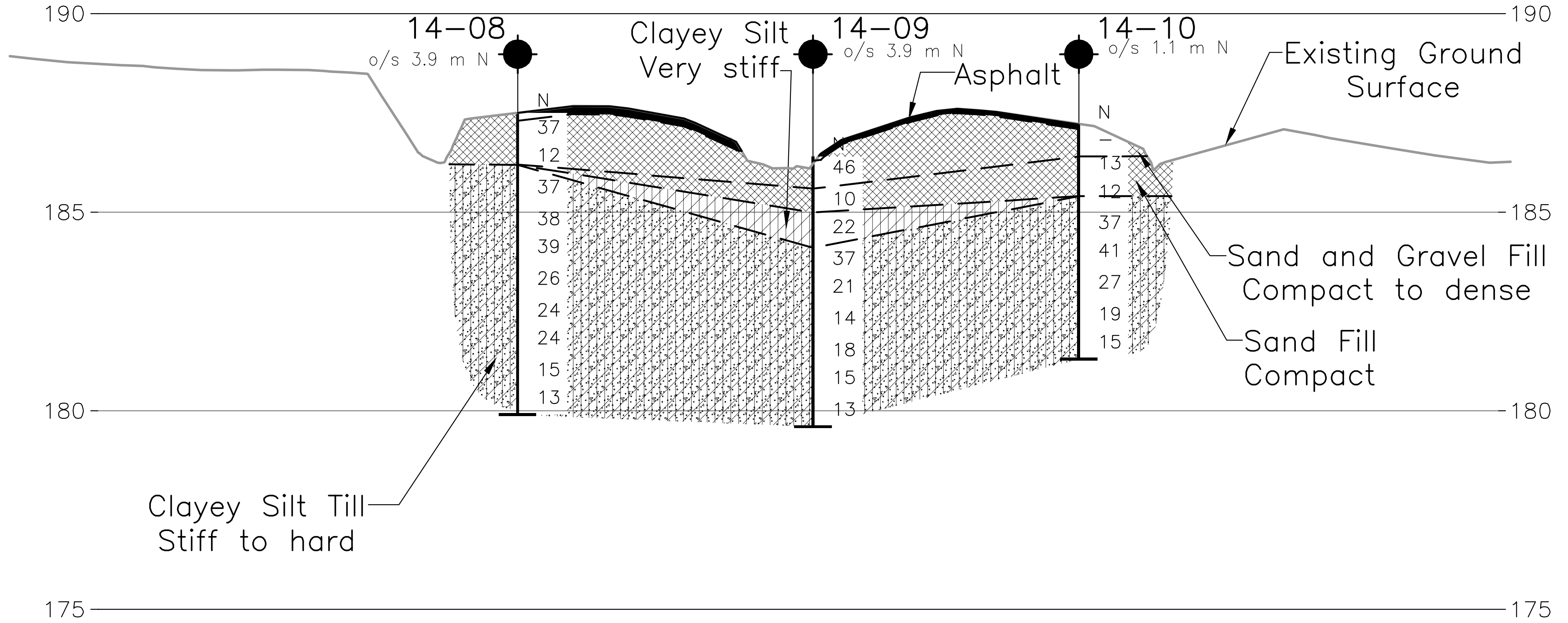
KEY PLAN
SCALE
2 0 2 4 km

LEGEND

●	Borehole – Golder Investigation
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
⊽	WL upon completion of drilling

BOREHOLE CO–ORDINATES

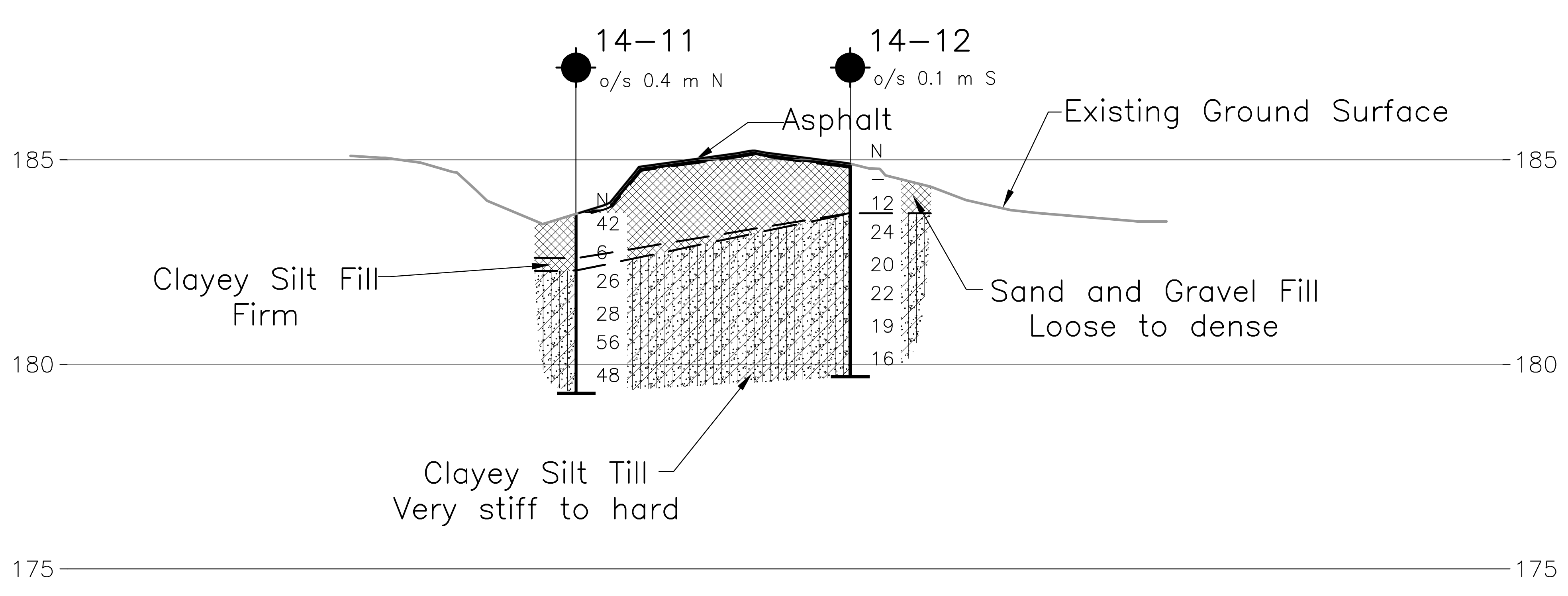
No.	ELEVATION	NORTHING	EASTING
14–08	187.5	4834603.5	290521.0
14–09	186.4	4834624.0	290542.7
14–10	187.2	4834640.3	290564.1
14–11	183.7	4835148.3	290035.3
14–12	184.9	4835162.1	290058.2



F-F' 3

CROSS–SECTION F–F'
STR. 1326–MEDIAN–STR. 1327

HORIZONTAL SCALE
10 0 10 20 m
2.5 0 2.5 5 m
VERTICAL SCALE



G-G' 3

CROSS–SECTION G–G'
STR. 978–979

HORIZONTAL SCALE
10 0 10 20 m
2.5 0 2.5 5 m
VERTICAL SCALE

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS Canada Inc., (Drawing Files "2013 12 17 – Hwy410_Plan – For FDN.dwg"and 2013 12 17 – Hwy410_Profile – for FDN.dwg", received Dec. 19, 2013).

L.C. COYNE
Aug. 10, 2015

F. J. HEFFERNAN
Aug. 10, 2015

Geocres No.

HWY. 410		PROJECT NO. 11–1111–0083	DIST. CENTRAL
SUBM'D. AV	CHKD. LCC	DATE:Aug. 29, 2014	SITE:
DRAWN: JFC	CHKD. LCC	APPD. LCC	DWG. 3

PLOT DATE: August 27, 2015
FILENAME: T:\Projects\2011\11-1111-0083 (URS, Peel Region)\-MA- Storm Sewer Structures\1111110083MA003.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

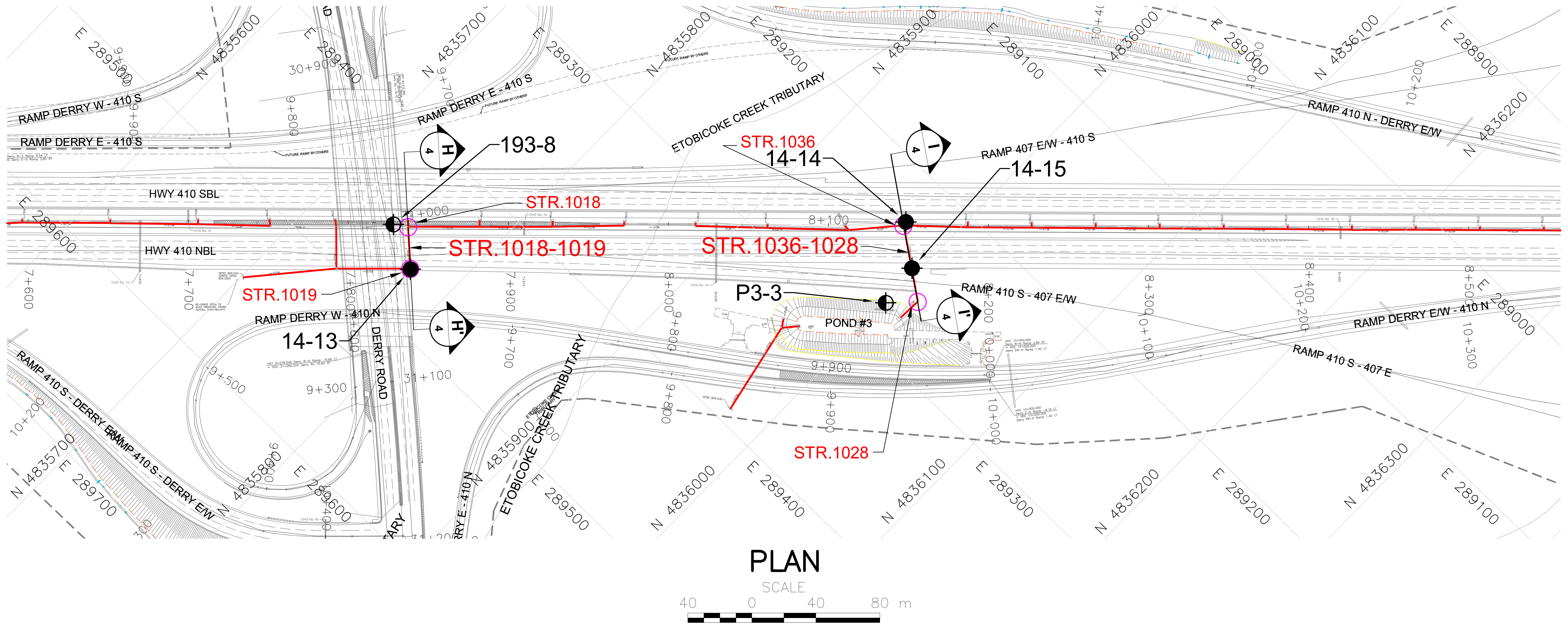
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No. 2014–2026
GWP No. 2144–07–00

STATION 7+600 to 8+550
HIGHWAY 410 WIDENING
BOREHOLE LOCATIONS AND SOIL STRATA

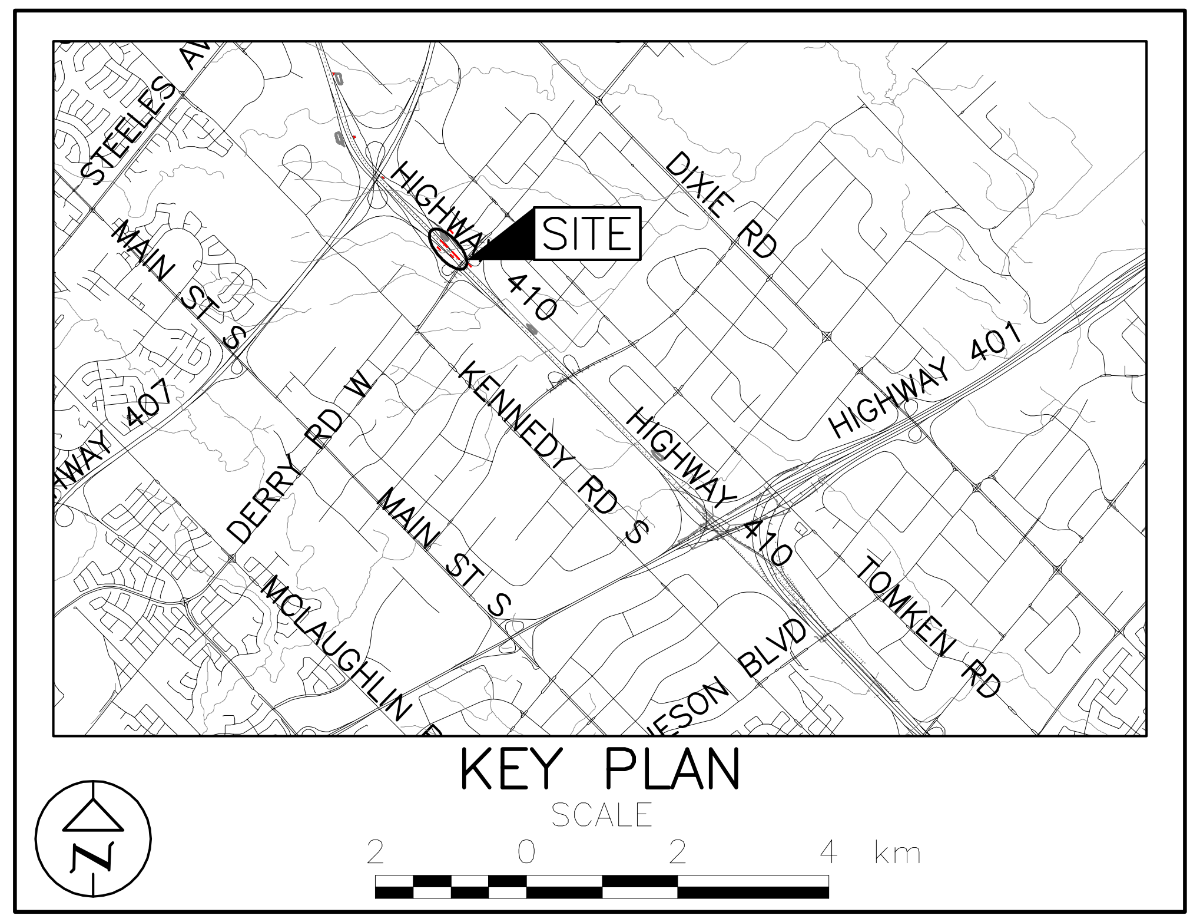
SHEET

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN

SCALE
40 0 40 80 m



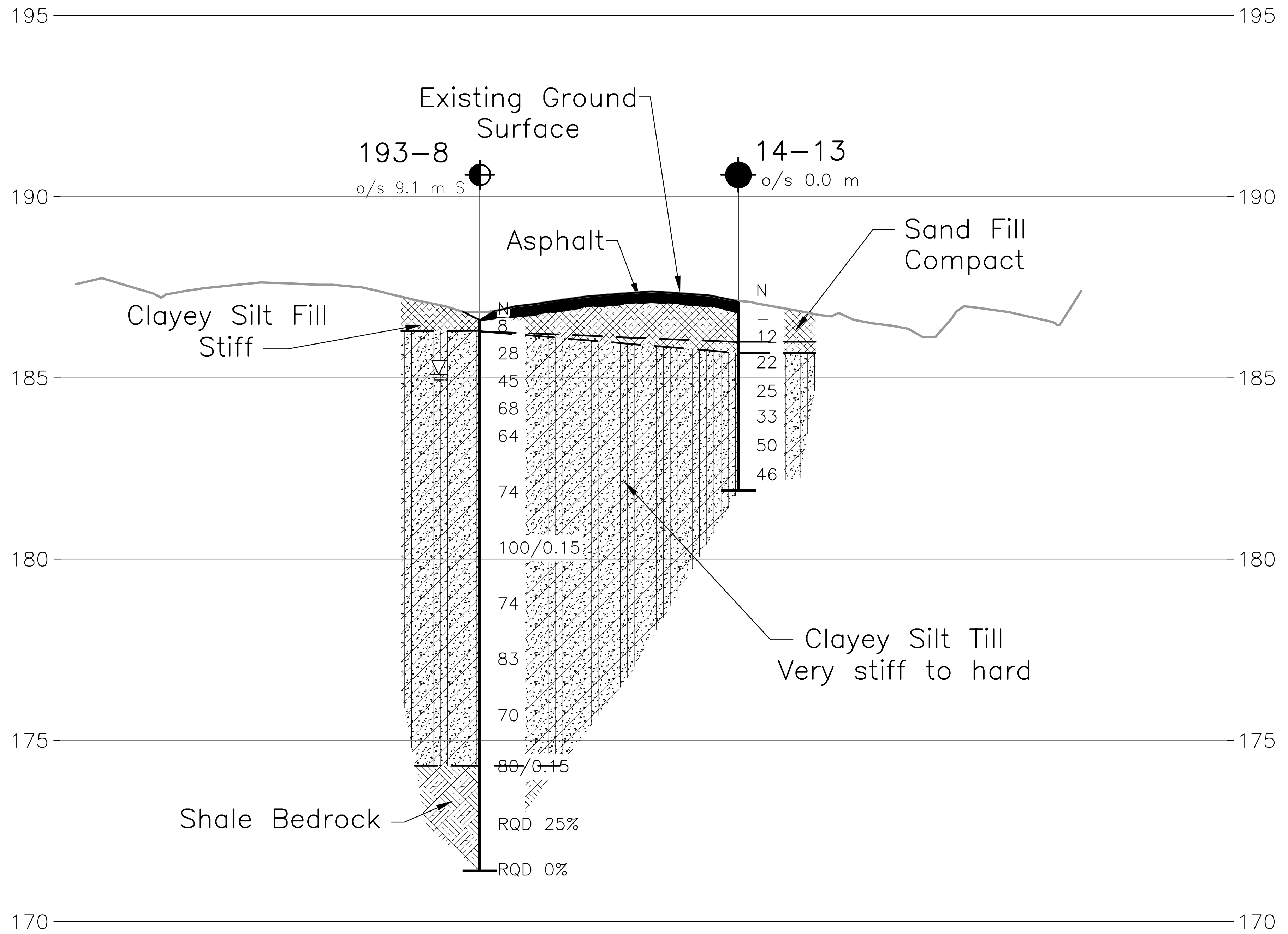
KEY PLAN
SCALE
2 0 2 4 km

LEGEND

●	Borehole – Current Investigation
◐	Borehole – Previous Investigation
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
▽	WL upon completion of drilling

BOREHOLE CO-ORDINATES

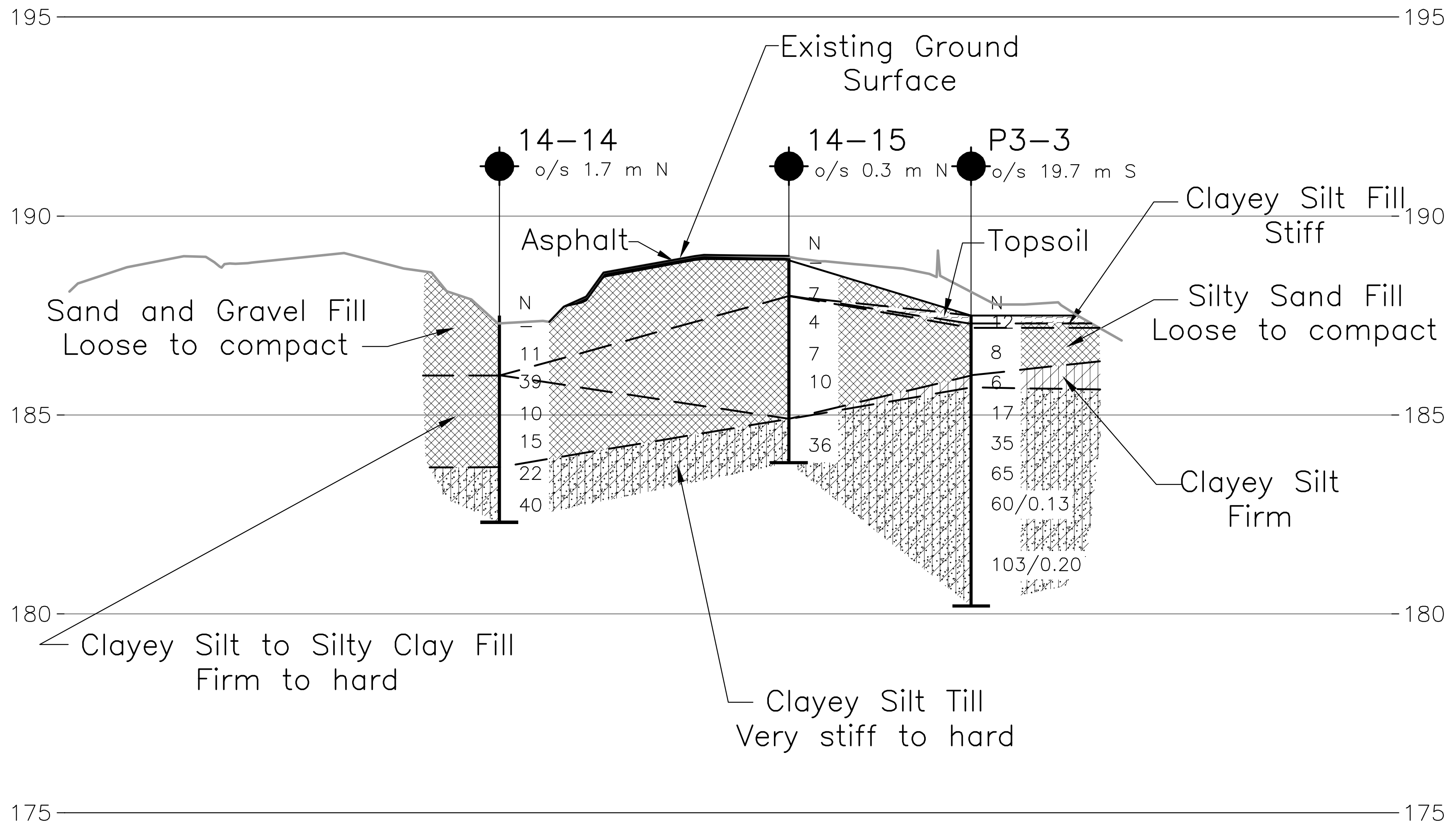
No.	ELEVATION	NORTHING	EASTING
14–13	187.1	4835772.3	289468.3
14–14	187.5	4835973.1	289230.8
14–15	189.0	4835996.0	289248.8
193–8	186.6	4835745.2	289455.7
P3–3	187.5	4835999.4	289275.7



CROSS–SECTION H–H’
STR. 1018–1019

H-H
4

HORIZONTAL SCALE
10 0 10 20 m
2.5 0 2.5 5 m
VERTICAL SCALE



CROSS–SECTION I–I’
STR. 1036–1028

I-I'
3

HORIZONTAL SCALE
10 0 10 20 m
2.5 0 2.5 5 m
VERTICAL SCALE

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS Canada Inc., (Drawing Files ”2013 12 17 – Hwy410_Plan – For FDN.dwg”and 2013 12 17 – Hwy410_Profile – for FDN.dwg”, received Dec. 19, 2013).

L.C. COYNE
Aug. 10, 2015

F. J. HEFFERNAN
Aug. 10, 2015

Geocres No.

HWY. 410		PROJECT NO. 11–1111–0083	DIST. CENTRAL
SUBM'D. AV	CHKD. LCC	DATE: Aug. 29, 2014	SITE:
DRAWN: JFC	CHKD. LCC	APPD. LCC	DWG. 4

MINISTRY OF TRANSPORTATION, ONTARIO

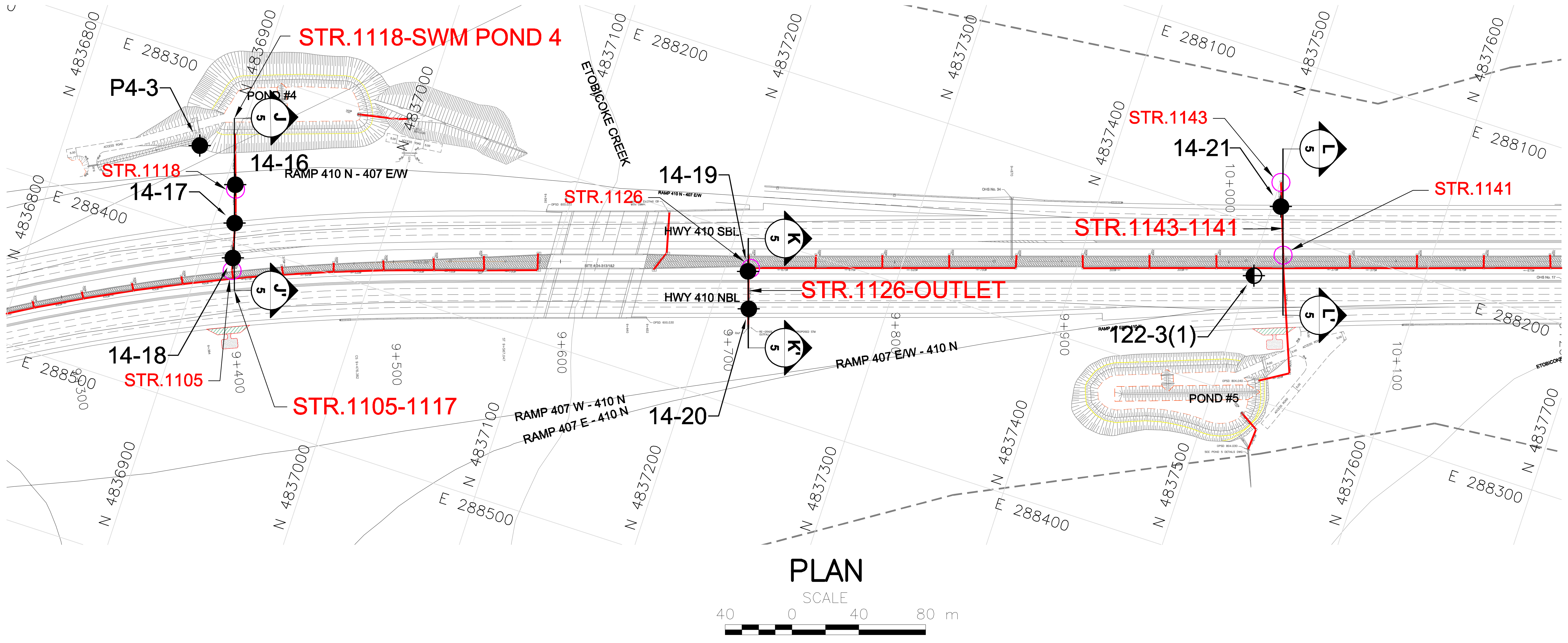
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

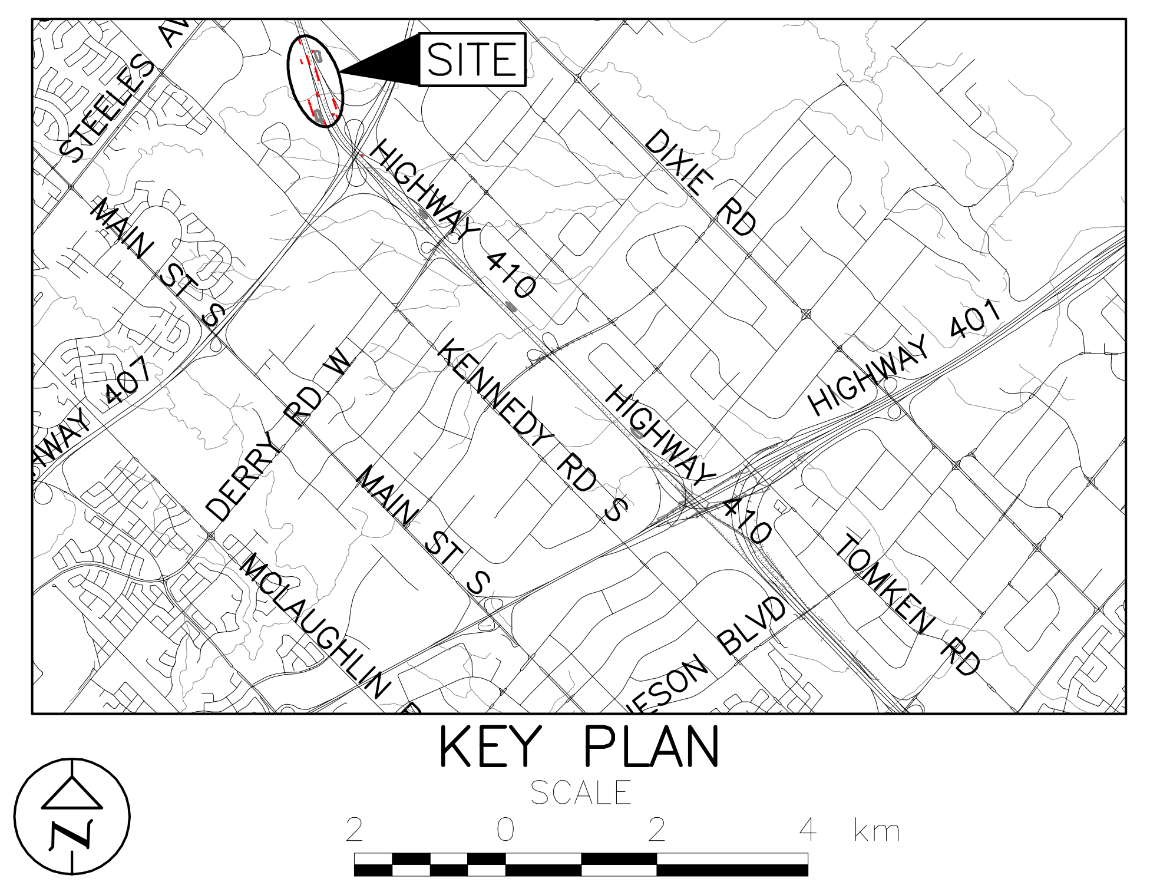
CONT No. 2014–2026
GWP No. 2144–07–00

STATION 9+300 to 10+200
HIGHWAY 410 WIDENING
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



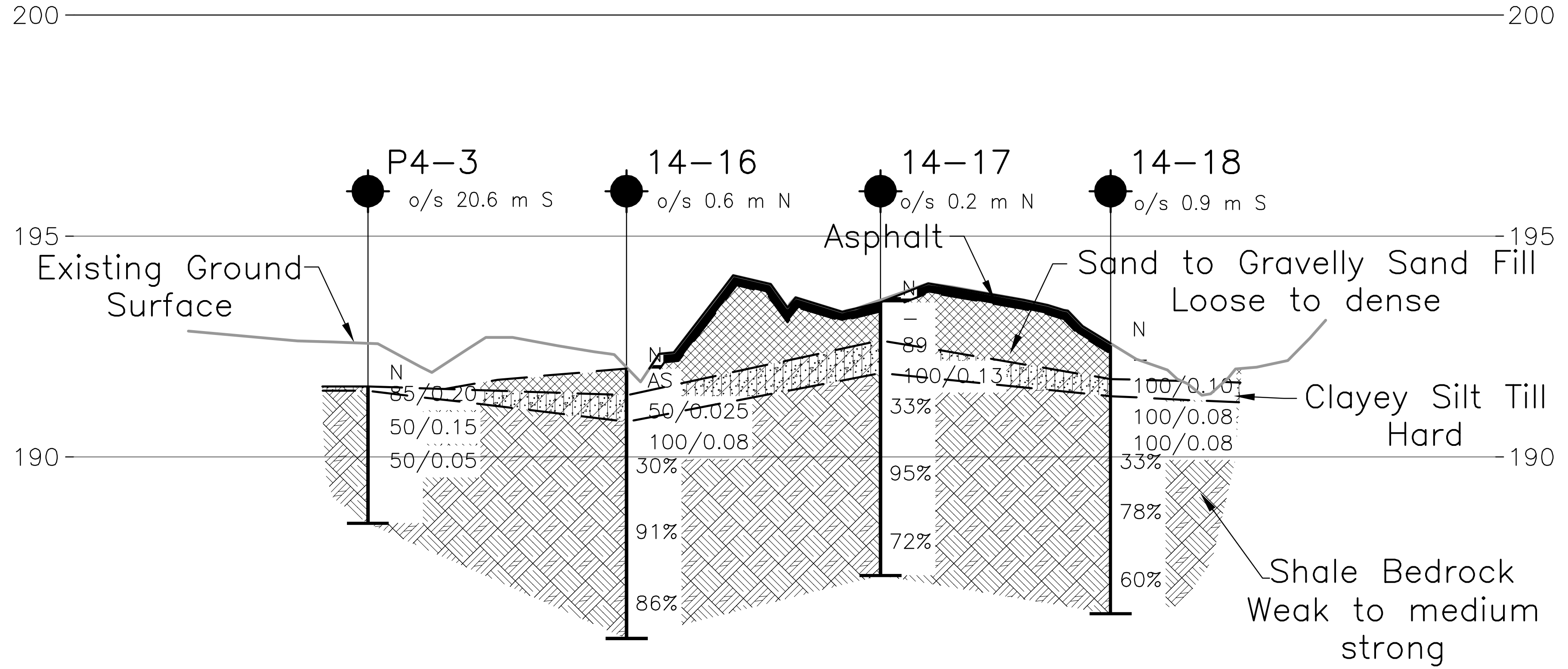


LEGEND

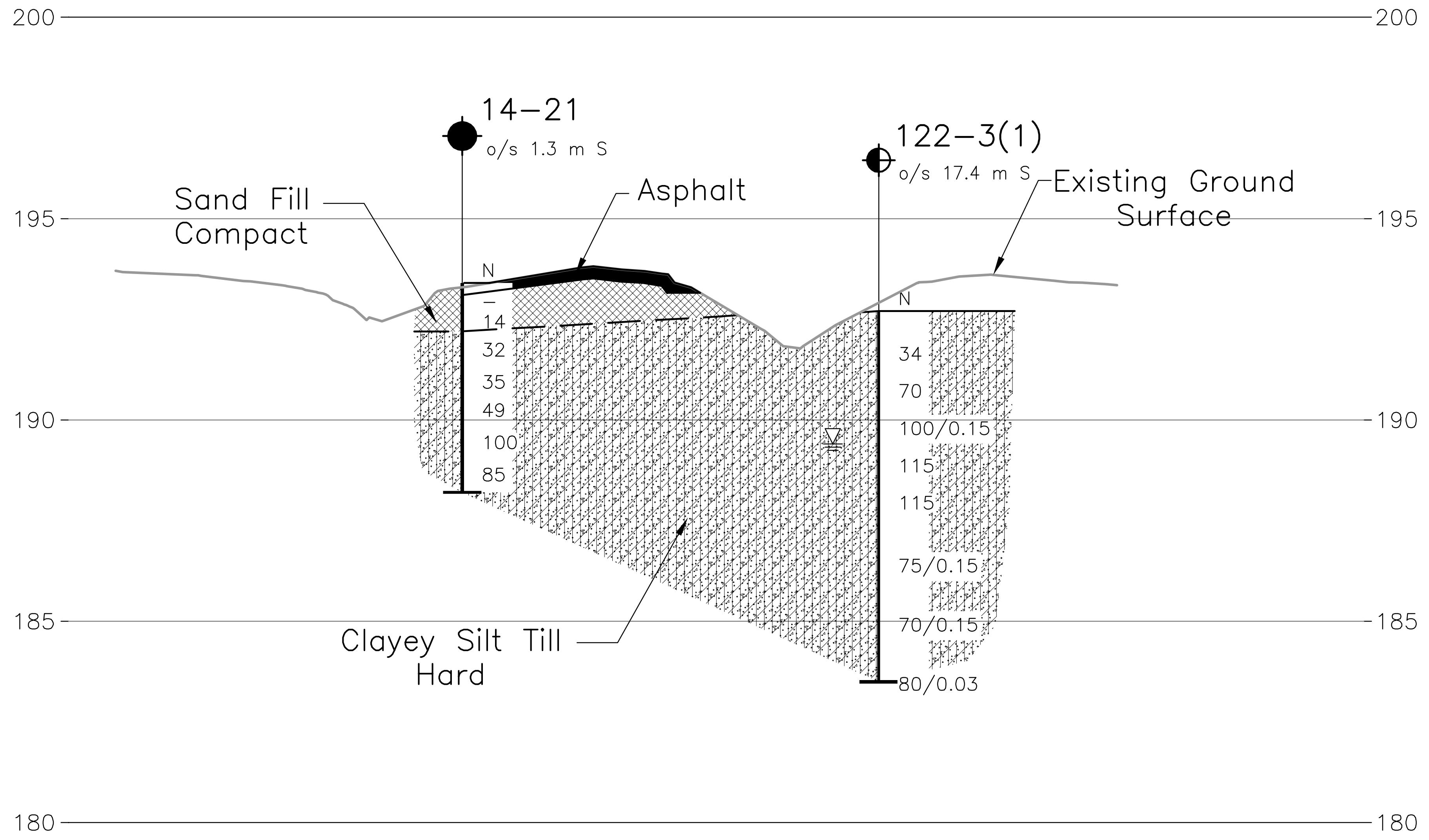
●	Borehole – Golder Investigation
◐	Borehole – Previous Investigation by Others
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
▽	WL upon completion of drilling

BOREHOLE CO–ORDINATES

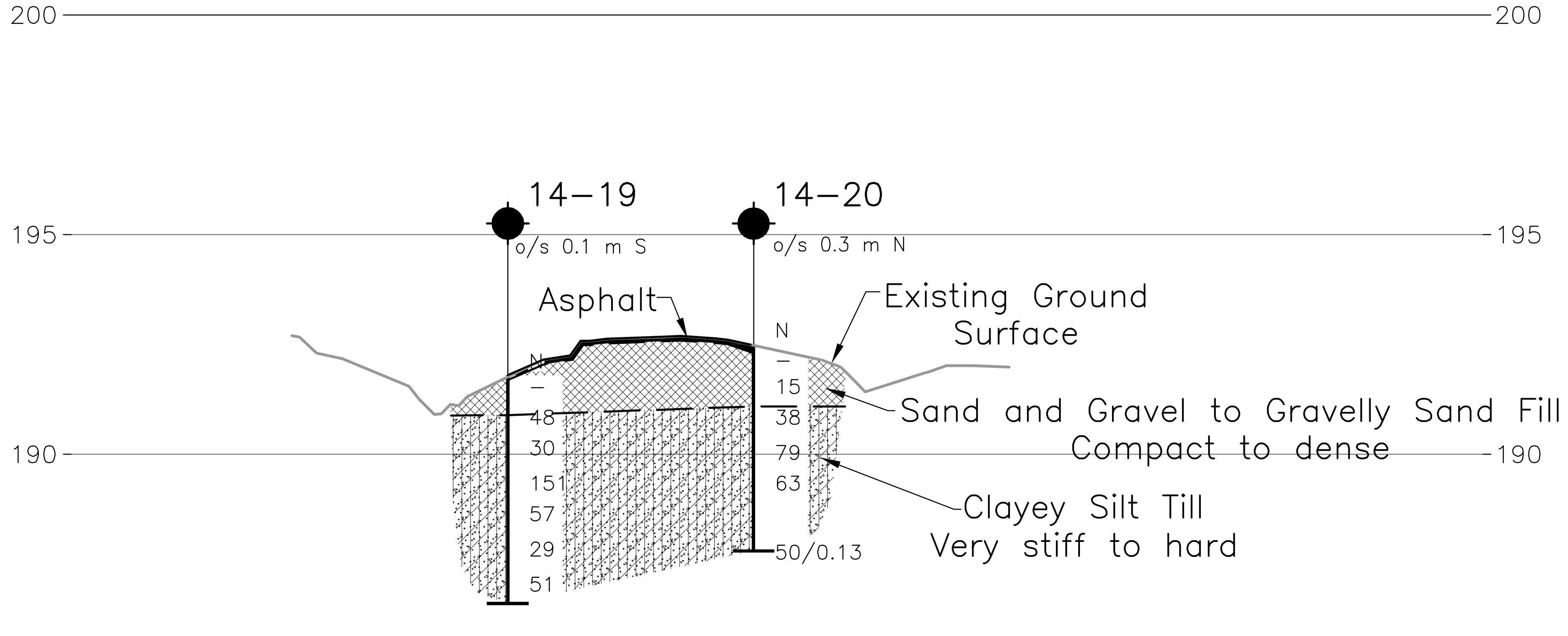
No.	ELEVATION	NORTHING	EASTING
14–16	192.0	4836905.8	288367.0
14–17	193.5	4836912.6	288389.0
14–18	192.6	4836918.0	288409.1
14–19	191.8	4837213.6	288321.2
14–20	192.5	4837221.0	288342.3
14–21	193.4	4837504.8	288185.4
122–3(1)	192.7	4837502.3	288229.7
P4–3	191.6	4836878.4	288351.3



J-J'
5
CROSS–SECTION J–J'
STR. 1105–1117 AND 1118–SWM POND4



L-L'
5
CROSS–SECTION L–L'
STR. 1143–1141



K-K'
5
CROSS–SECTION K–K'
STR. 1126–OUTLET

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS Canada Inc., (Drawing Files "2013 12 17 – Hwy410_Plan – For FDN.dwg"and 2013 12 17 – Hwy410_Profile – for FDN.dwg", received Dec. 19, 2013).

L.C. COYNE
Aug. 10, 2015

F. J. HEFFERNAN
Aug. 10, 2015

HORIZONTAL SCALE
10 0 10 20 m
2.5 0 2.5 5 m
VERTICAL SCALE

Geocres No.

HWY. 410		PROJECT NO. 11–1111–0083	DIST. CENTRAL
SUBM'D. AV	CHKD. LCC	DATE: Aug. 29, 2014	SITE:
DRAWN: JFC	CHKD. LCC	APPD. LCC	DWG. 5

MINISTRY OF TRANSPORTATION, ONTARIO

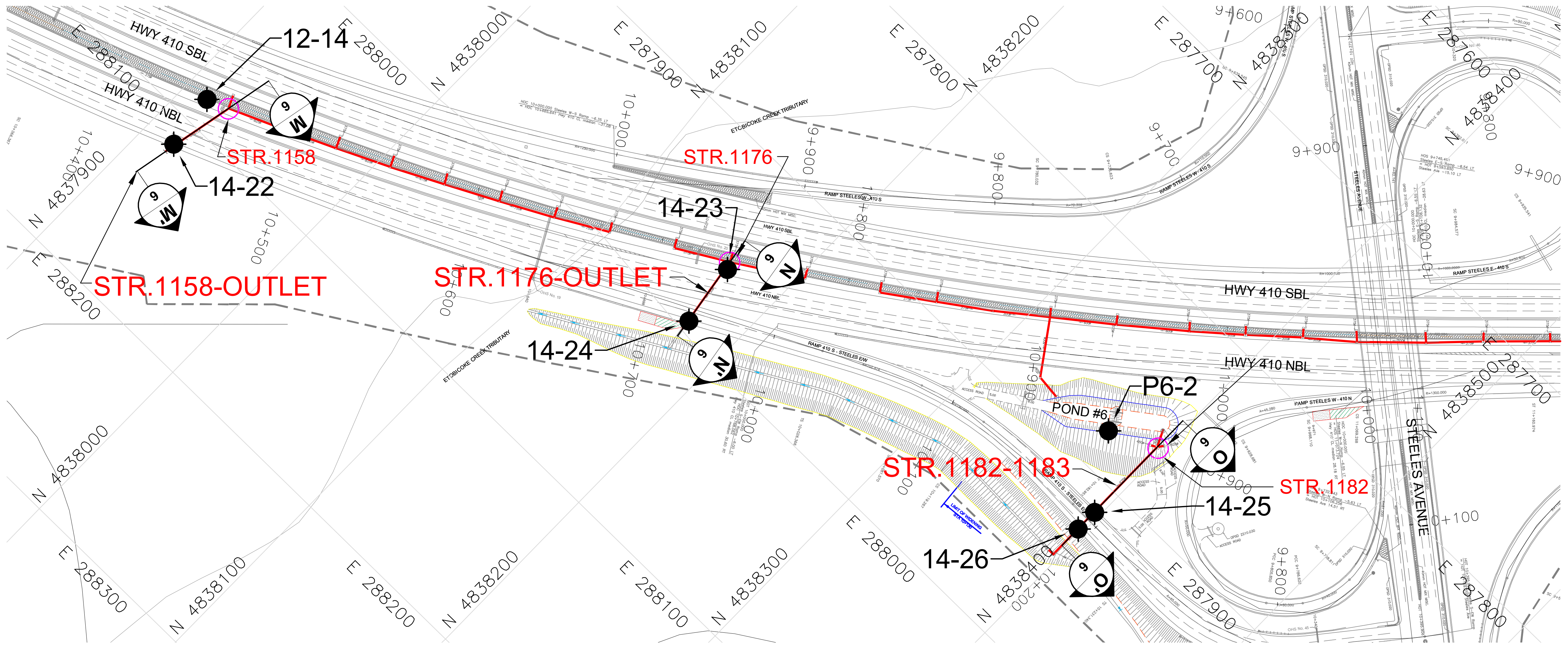
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No. 2014–2026
GWP No. 2144–07–00

SHEET

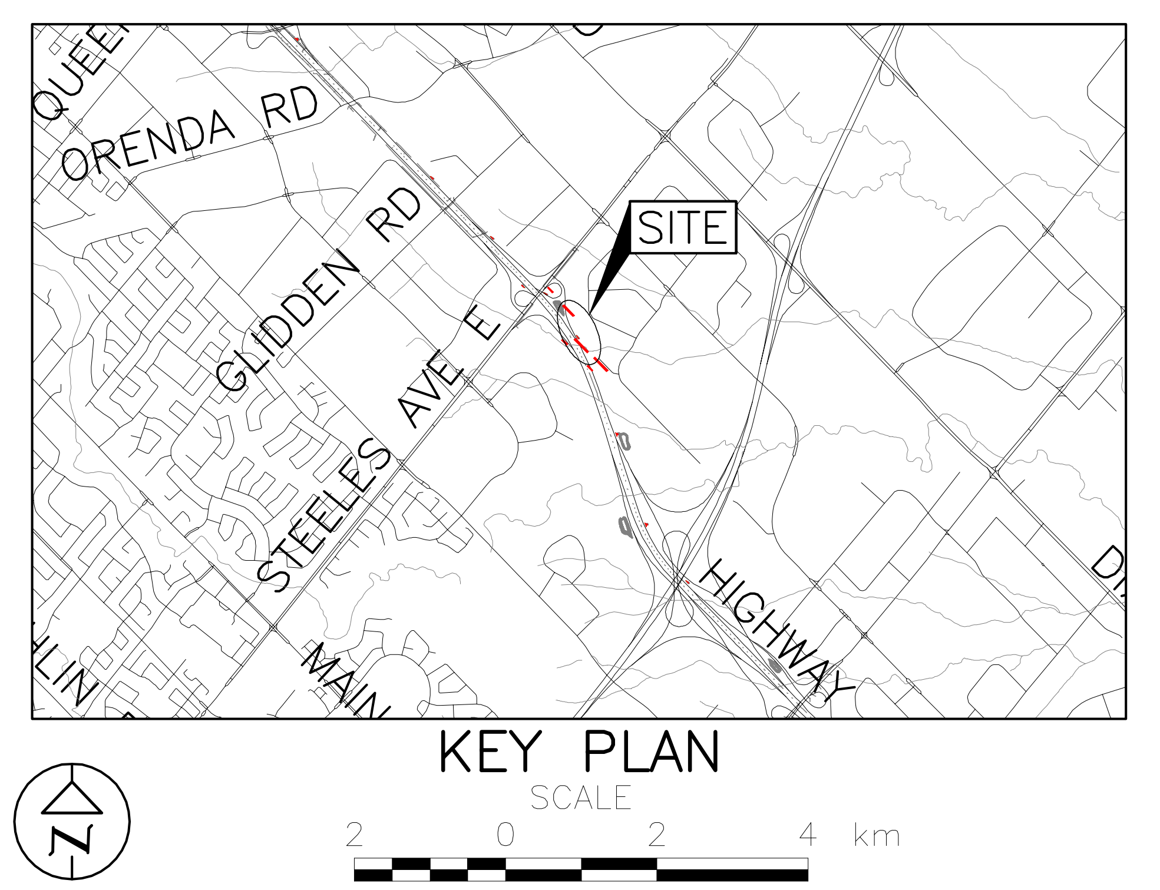
STATION 10+350 to 11+150
HIGHWAY 410 WIDENING
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN

SCALE
40 0 40 80 m



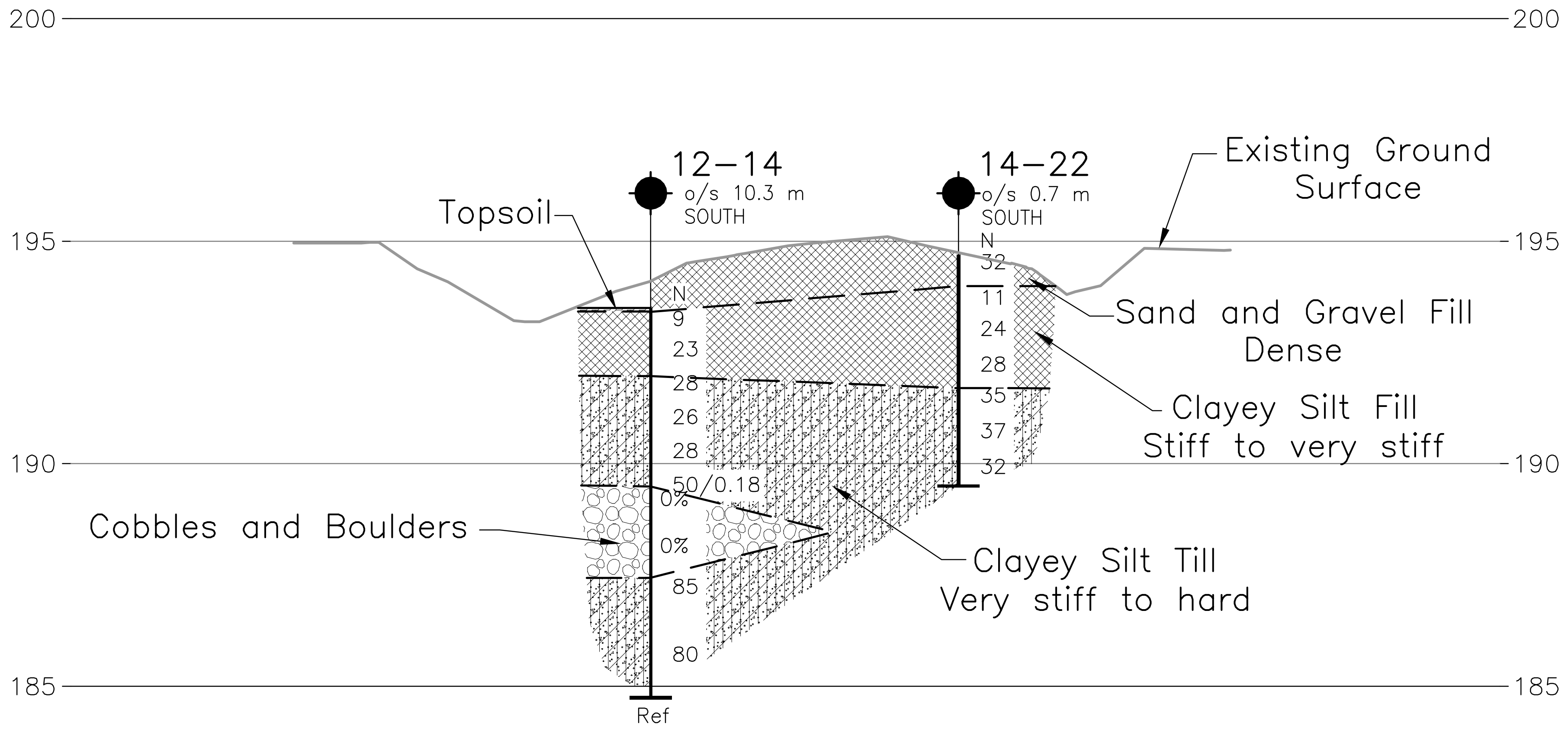
KEY PLAN
SCALE
2 0 2 4 km

LEGEND

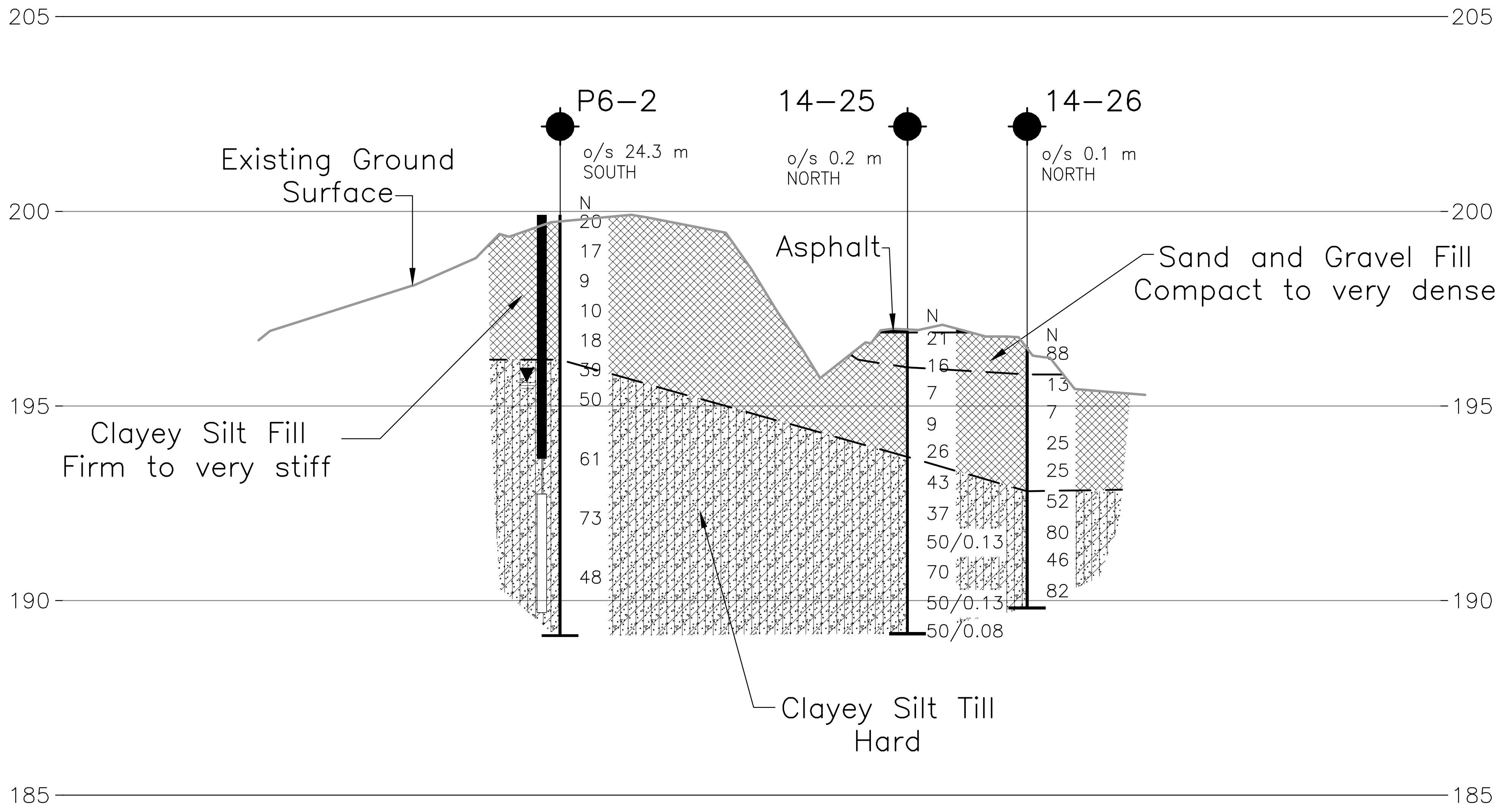
●	Borehole – Golder Investigation
▮	Seal
▯	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
▼	WL in piezometer, measured on Sep. 24, 2014
▽	WL upon completion of drilling
Ref	Refusal

BOREHOLE CO-ORDINATES

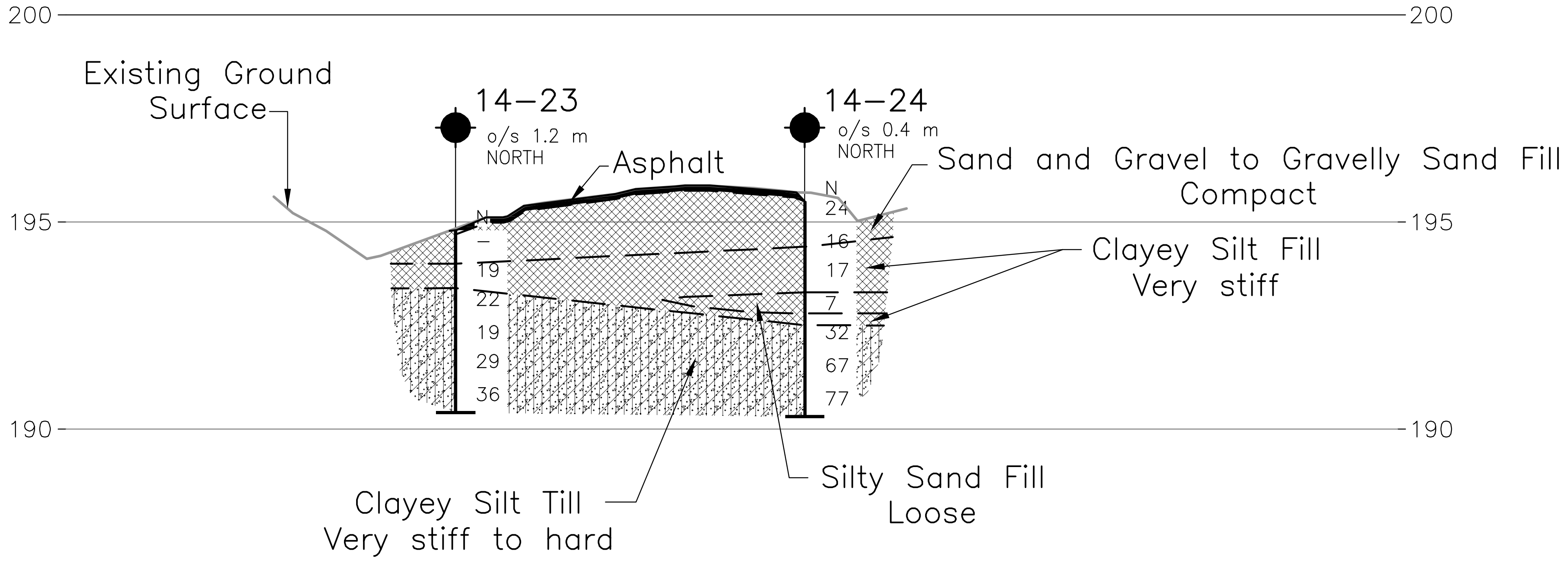
No.	ELEVATION	NORTHING	EASTING
12–14	193.5	4837913.0	288085.2
14–22	194.7	4837916.9	288114.2
14–23	194.8	4838170.4	287958.2
14–24	195.7	4838174.9	287991.7
14–25	197.0	4838397.1	287914.7
14–26	196.5	4838397.0	287927.0
P6–2	199.9	4838372.4	287879.1



M-M' 6 CROSS–SECTION M–M'
STR. 1158–OUTLET



O-O' 6 CROSS–SECTION O–O'
STR. 1182–1183



N-N' 6 CROSS–SECTION N–N'
STR. 1176–OUTLET

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS Canada Inc., (Drawing Files "2013 12 17 – Hwy410_Plan – For FDN.dwg" and 2013 12 17 – Hwy410_Profile – for FDN.dwg", received Dec. 19, 2013).

L.C. COYNE
Aug. 10, 2015

F. J. HEFFERNAN
Aug. 10, 2015

HORIZONTAL SCALE
10 0 10 20 m
2.5 0 2.5 5 m
VERTICAL SCALE

Geocres No.

HWY. 410		PROJECT NO. 11–1111–0083	DIST. CENTRAL
SUBM'D. AV	CHKD. LCC	DATE: Aug. 29, 2014	SITE:
DRAWN: JFC	CHKD. LCC	APPD. LCC	DWG. 6

MINISTRY OF TRANSPORTATION, ONTARIO

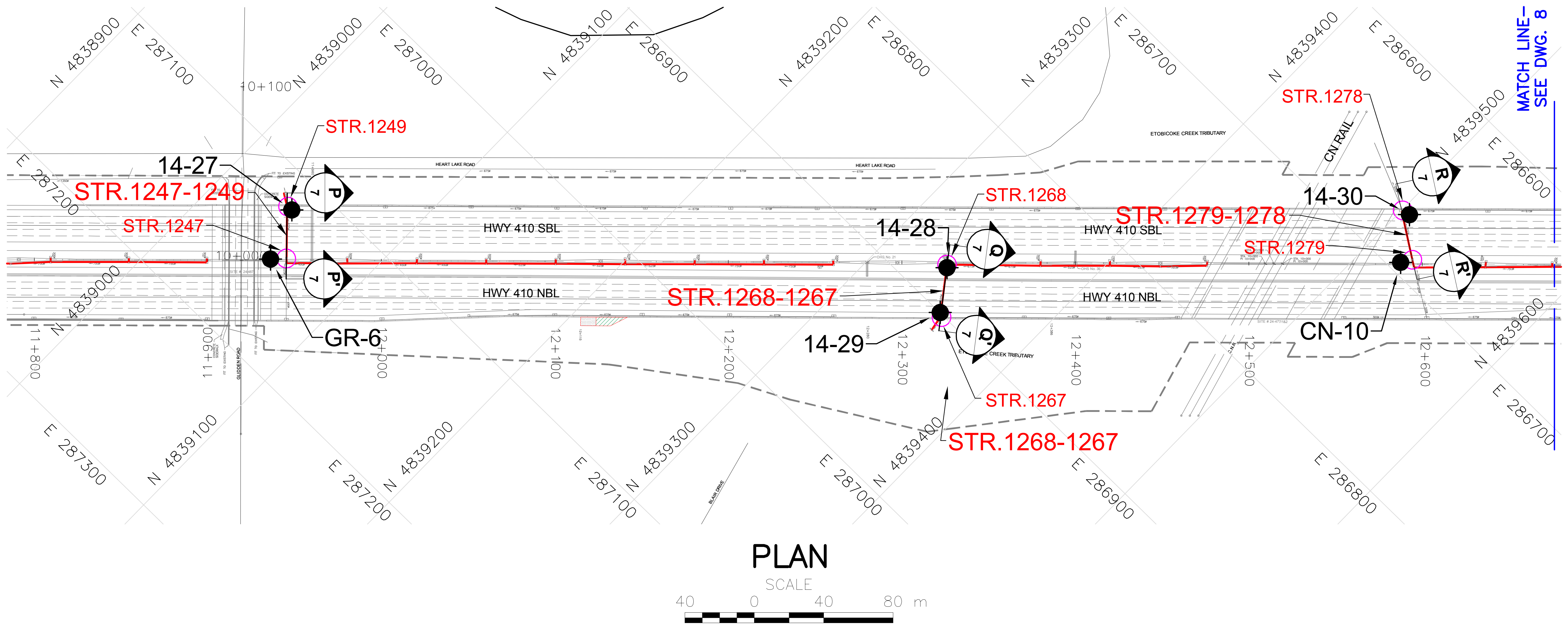
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No. 2014–2026
GWP No. 2144–07–00

SHEET

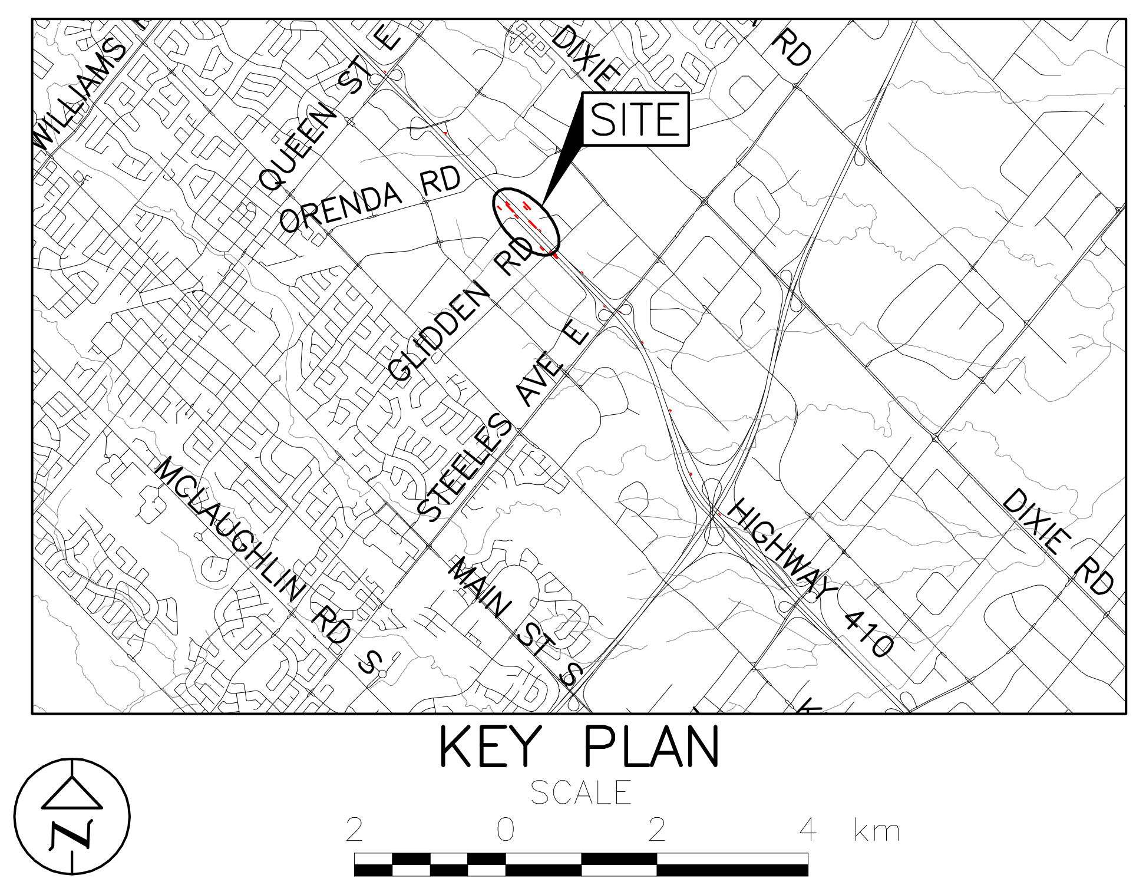
STATION 11+800 to 12+650
HIGHWAY 410 WIDENING
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN

SCALE
40 0 40 80 m



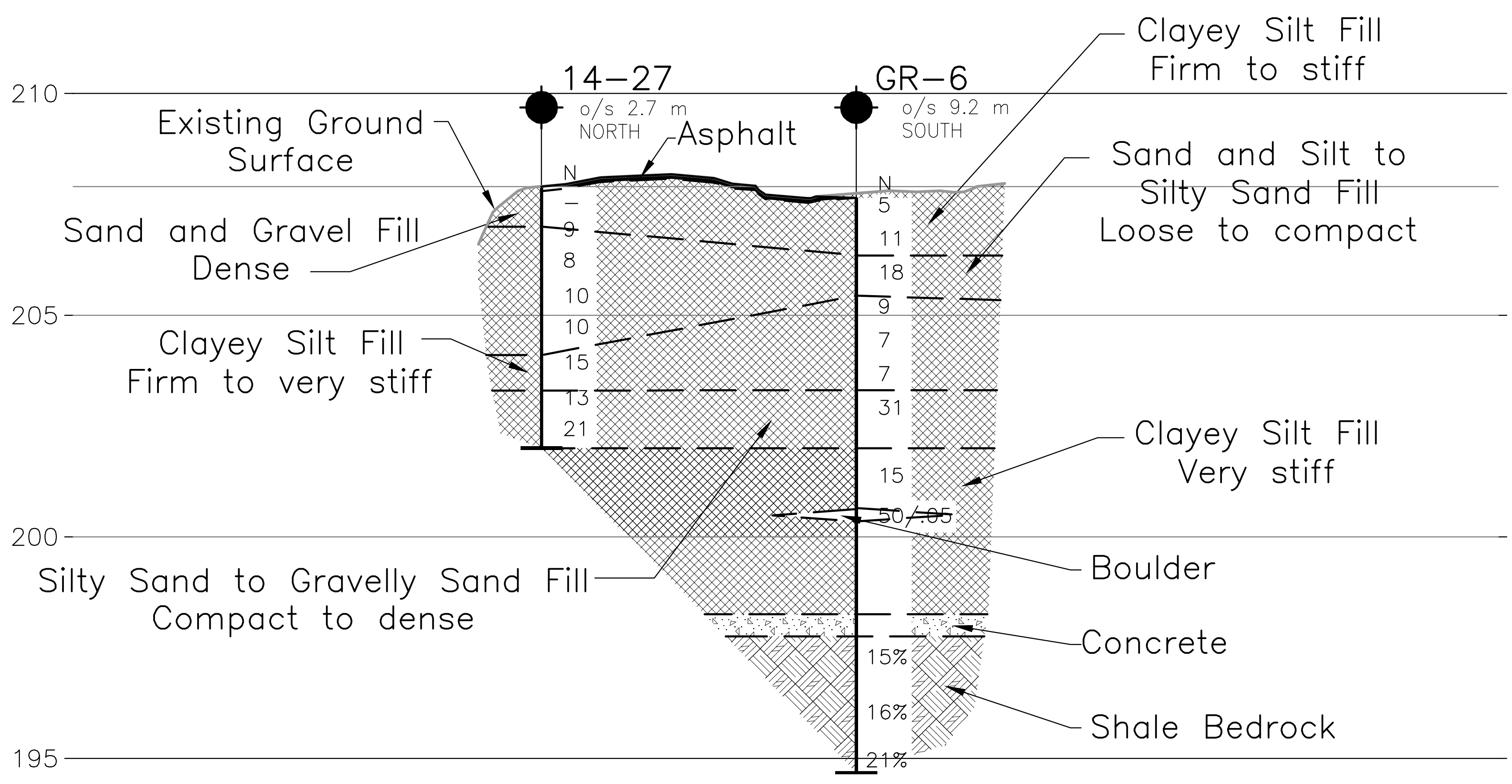
KEY PLAN
SCALE
2 0 2 4 km

LEGEND

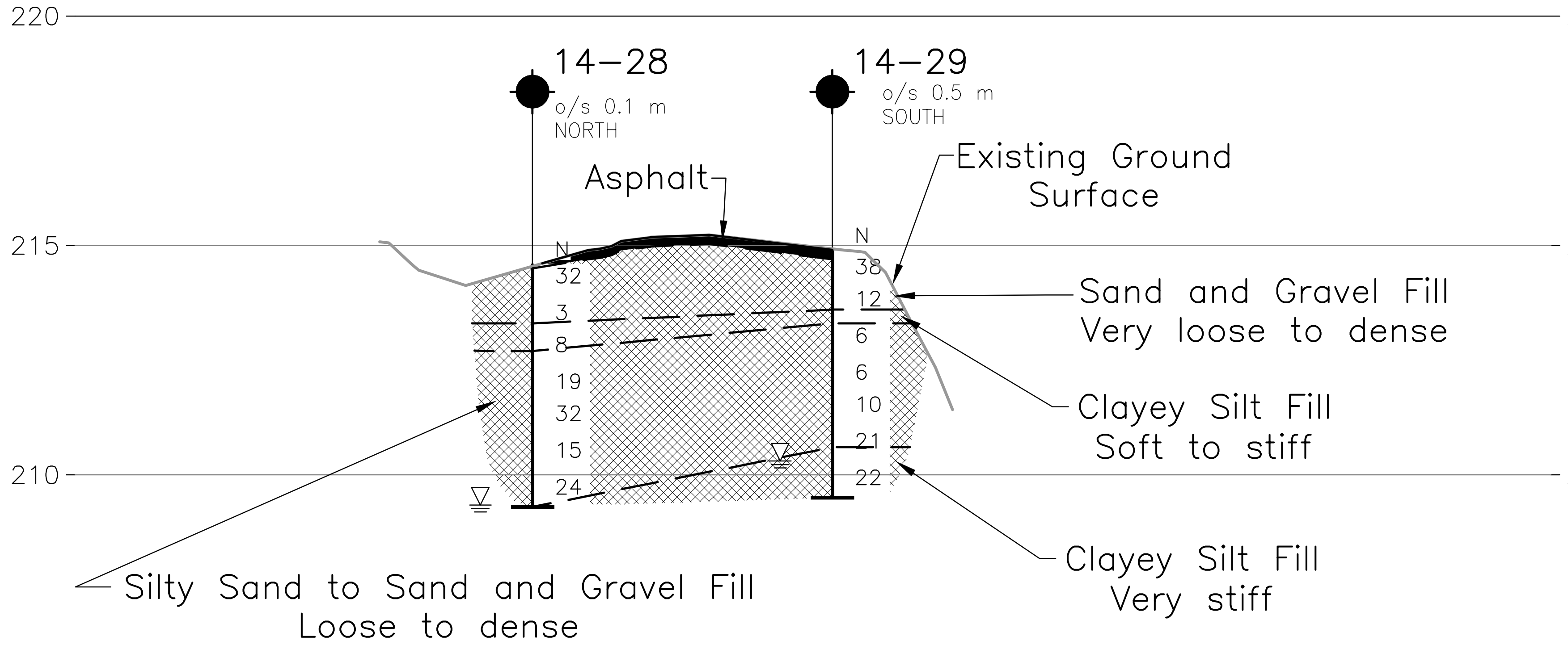
●	Borehole – Golder Investigation
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
▽	WL upon completion of drilling

BOREHOLE CO-ORDINATES

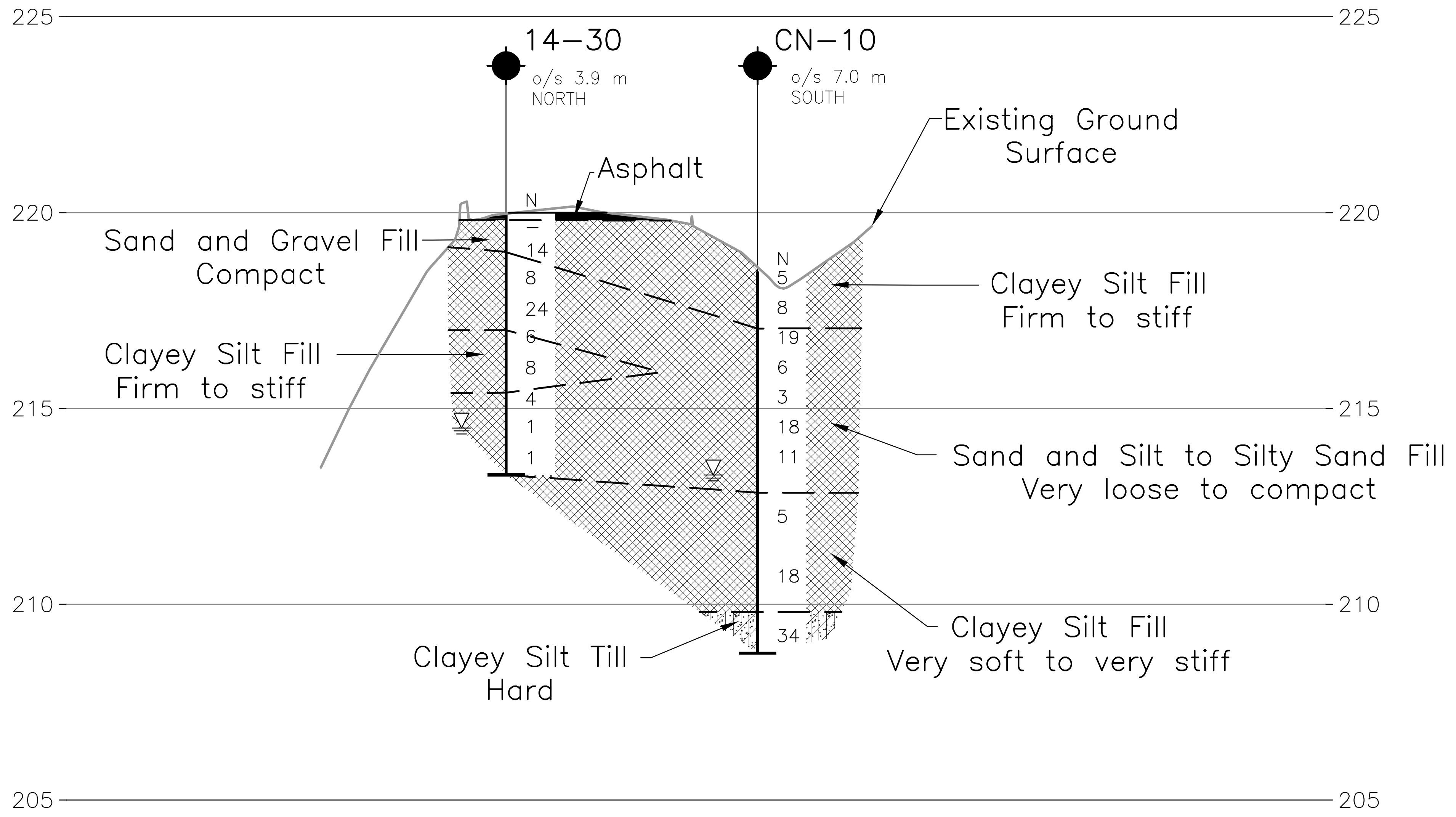
No.	ELEVATION	NORTHING	EASTING
14–27	207.9	4839042.3	287118.8
14–28	214.6	4839335.6	286878.6
14–29	214.9	4839350.9	286899.8
14–30	220.0	4839505.0	286670.5
CN–10	218.5	4839520.5	286693.7
GR–6	207.7	4839053.3	287147.6



CROSS–SECTION P–P'
P-P'
7
STR. 1247–1249



CROSS–SECTION Q–Q'
Q-Q'
7
STR. 1268–1267



CROSS–SECTION R–R'
R-R'
7
STR. 1279–1278

L.C. COYNE
Aug. 10, 2015

F. J. HEFFERNAN
Aug. 10, 2015

HORIZONTAL SCALE
10 0 10 20 m
2.5 0 2.5 5 m
VERTICAL SCALE

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS Canada Inc., (Drawing Files "2013 12 17 – Hwy410_Plan – For FDN.dwg"and 2013 12 17 – Hwy410_Profile – for FDN.dwg", received Dec. 19, 2013).

Geocres No.

HWY. 410		PROJECT NO. 11–1111–0083	DIST. CENTRAL
SUBM'D. AV	CHKD. LCC	DATE: Aug. 29, 2014	SITE:
DRAWN: JFC	CHKD. LCC	APPD. LCC	DWG. 7

PLOT DATE: August 27, 2015
FILENAME: T:\Projects\2011\11-1111-0083 (URS, Peel Region)\-MA- Storm Sewer Structures\1111110083MA007.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

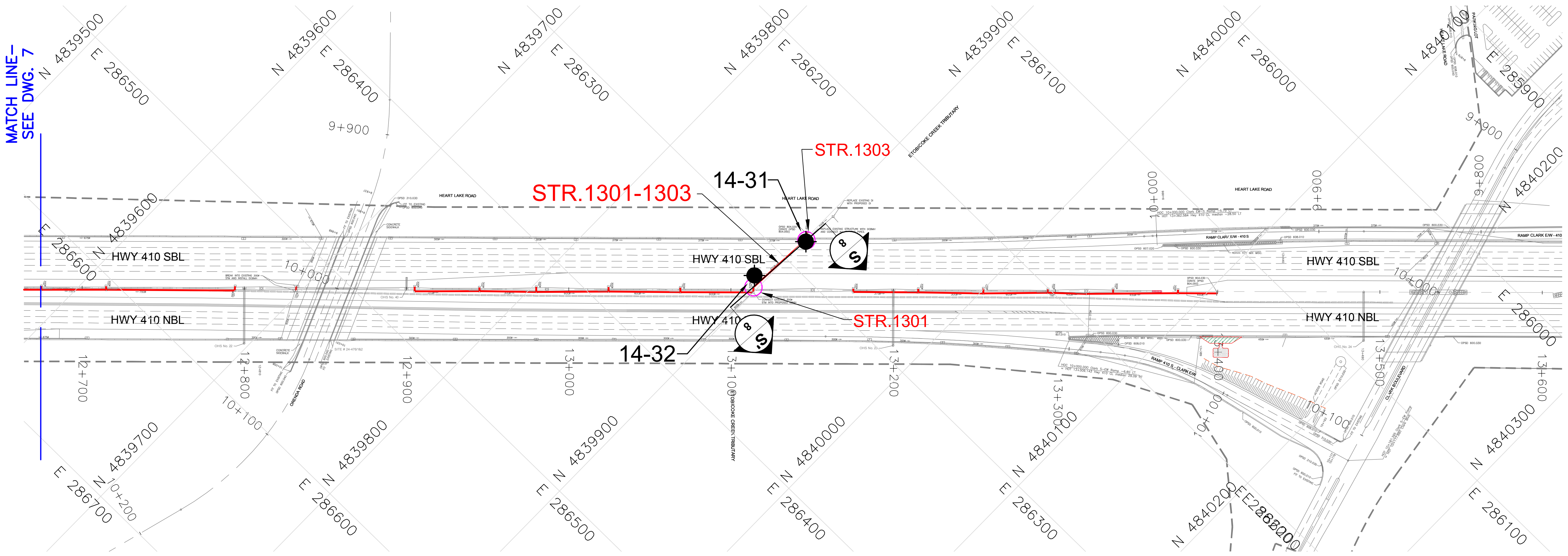
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No. 2014–2026
GWP No. 2144–07–00

SHEET

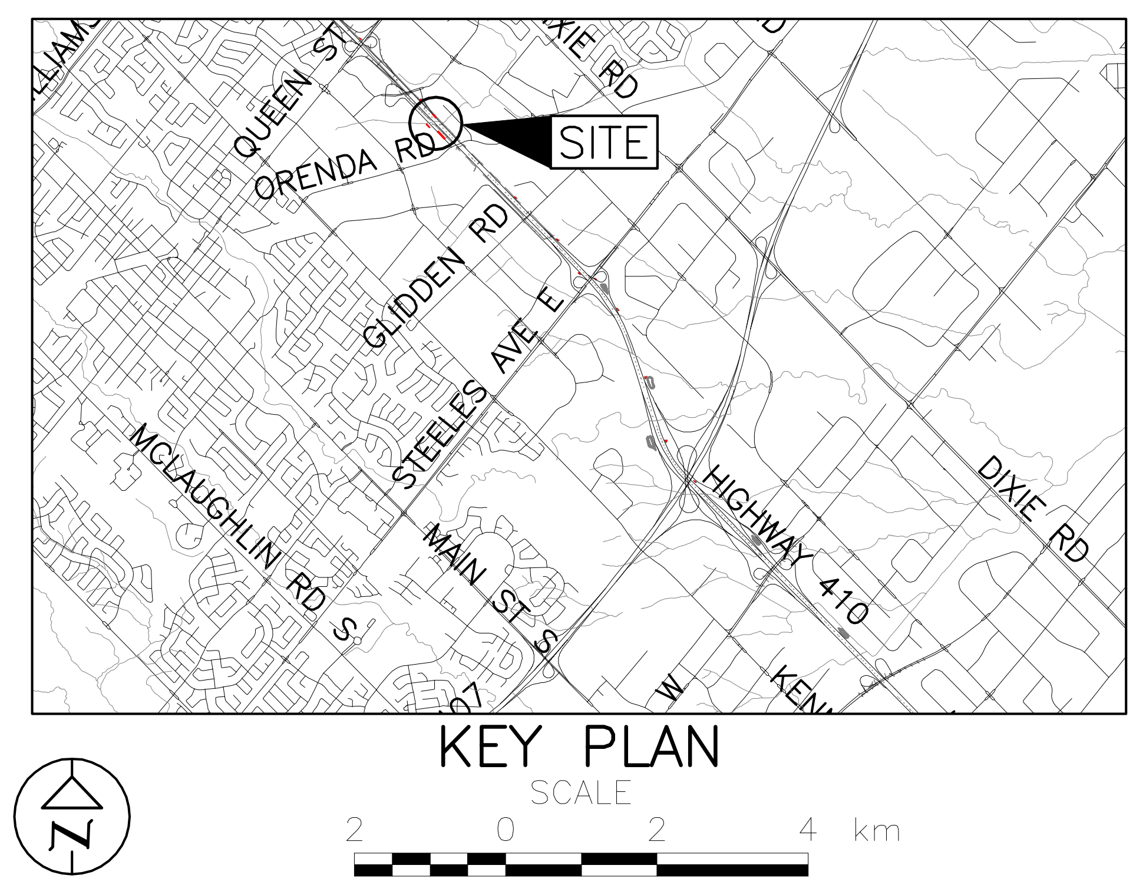
STATION 12+700 to 13+600
HIGHWAY 410 WIDENING
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN

SCALE
40 0 40 80 m



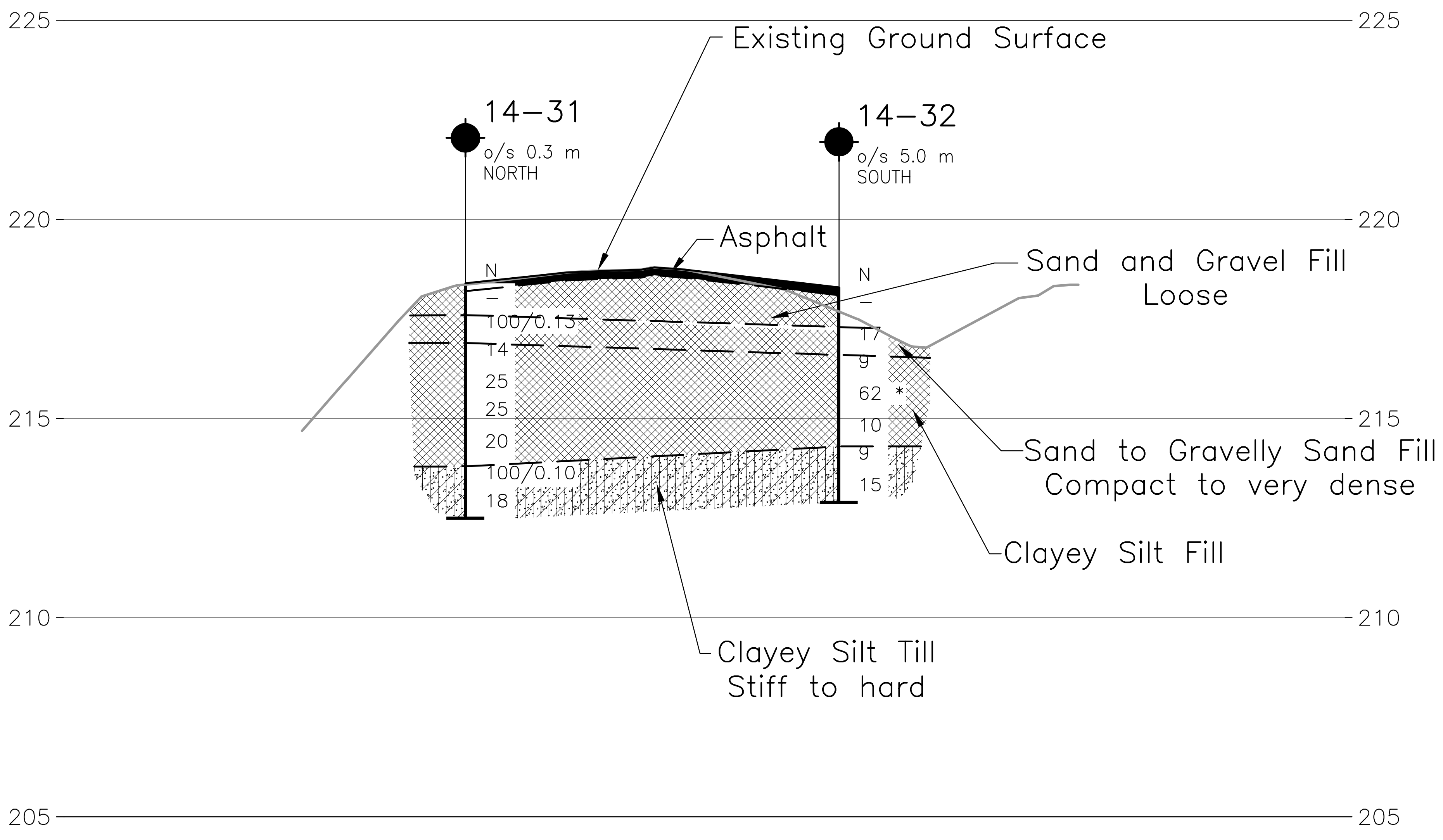
KEY PLAN
SCALE
2 0 2 4 km

LEGEND

●	Borehole – Current Investigation
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
⊻	WL upon completion of drilling

BOREHOLE CO–ORDINATES

No.	ELEVATION	NORTHING	EASTING
14–31	218.4	4839901.2	286283.9
14–32	218.3	4839893.1	286321.0



CROSS–SECTION S–S'
STR. 1301–1303

S-S' 8

HORIZONTAL SCALE
10 0 10 20 m
2.5 0 2.5 5 m
VERTICAL SCALE

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS Canada Inc., (Drawing Files "2013 12 17 – Hwy410_Plan – For FDN.dwg"and 2013 12 17 – Hwy410_Profile – for FDN.dwg", received Dec. 19, 2013).

L.C. COYNE
Aug. 10, 2015

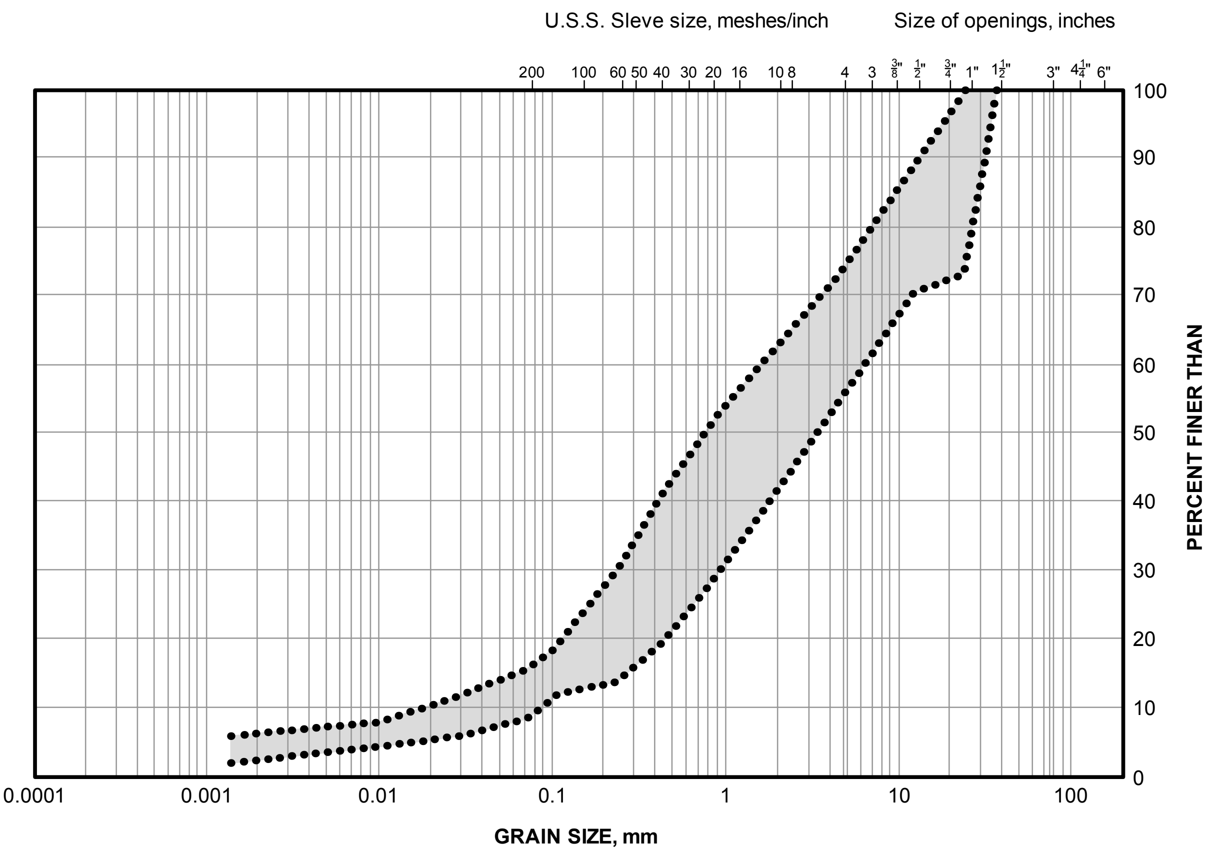
F. J. HEFFERNAN
Aug. 10, 2015

Geocres No.

HWY. 410		PROJECT NO. 11–1111–0083	DIST. CENTRAL
SUBM'D. AV	CHKD. LCC	DATE: Aug. 29, 2014	SITE:
DRAWN: JFC	CHKD. LCC	APPD. LCC	DWG. 8

PLOT DATE: August 27, 2015
FILENAME: T:\Projects\2011\11-1111-0083 (URS, Peel Region)\-MA- Storm Sewer Structures\1111110083MA008.dwg

FIGURES



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		

NOTES:

THE GRAIN SIZE DISTRIBUTION ENVELOPE SHOWN ON THIS FIGURE IS BASED ON THE TEST RESULTS FOR 7 SAMPLES.

FOR INDIVIDUAL TEST RESULTS, REFER TO APPENDICES A TO S.

THE SAMPLERS USED IN THE GEOTECHNICAL INVESTIGATIONS LIMIT THE MAXIMUM PARTICLE SIZE THAT CAN BE SAMPLED AND TESTED TO ABOUT 40mm. LARGER PARTICLE SIZES PRESENT WITHIN THE DEPOSIT, INCLUDING COBBLES AND BOULDERS, ARE NOT REPRESENTED ON THE ABOVE ENVELOPE AND ARE DISCUSSED WITHIN THE TEXT OF THE REPORT.

Golder Associates
Mississauga, Ontario, Canada

SCALE	AS SHOWN
DATE	Aug. 27, 2014
DESIGN	
CAD	FC
CHECK	LCC
REVIEW	LCC
FILE No.	1111110083MAF01.dwg
PROJECT No.	11-1111-0083
REV.	A

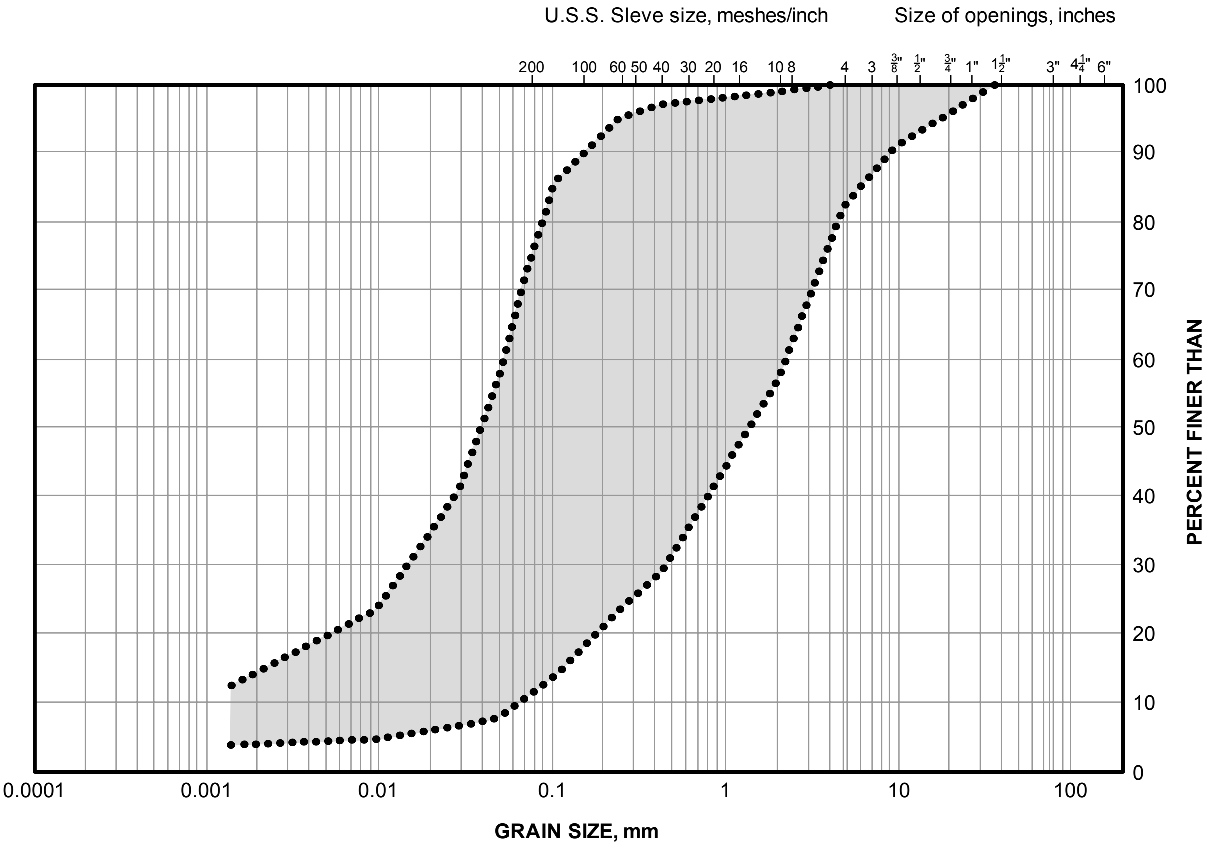
TITLE

GRAIN SIZE DISTRIBUTION ENVELOPE
SAND AND GRAVEL TO GRAVELLY SAND FILL

TRENCHLESS CROSSINGS
HIGHWAY 410 WIDENING

FIGURE
1

PLOT DATE: August 27, 2014
FILENAME: T:\Projects\2011\11-1111-0083 (URS, Peel Region)\-MA- Storm Sewer Structures\1111110083MAF01.dwg



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		

NOTES:

THE GRAIN SIZE DISTRIBUTION ENVELOPE SHOWN ON THIS FIGURE IS BASED ON THE TEST RESULTS FOR 12 SAMPLES.

FOR INDIVIDUAL TEST RESULTS, REFER TO APPENDICES A TO S.

THE SAMPLERS USED IN THE GEOTECHNICAL INVESTIGATIONS LIMIT THE MAXIMUM PARTICLE SIZE THAT CAN BE SAMPLED AND TESTED TO ABOUT 40mm. LARGER PARTICLE SIZES PRESENT WITHIN THE DEPOSIT, INCLUDING COBBLES AND BOULDERS, ARE NOT REPRESENTED ON THE ABOVE ENVELOPE AND ARE DISCUSSED WITHIN THE TEXT OF THE REPORT.

Golder Associates
Mississauga, Ontario, Canada

SCALE AS SHOWN
DATE Aug. 27, 2014
DESIGN
CAD FC
CHECK LCC
REVIEW LCC

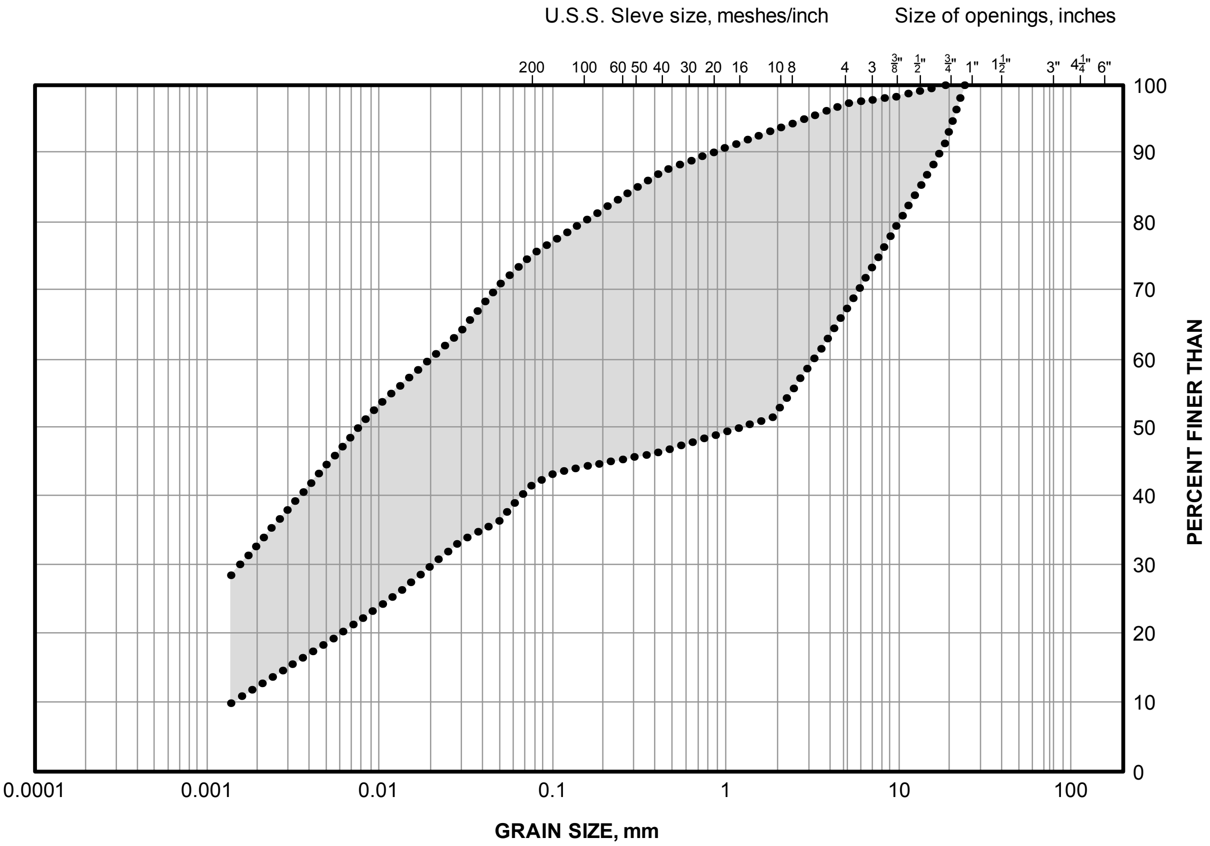
FILE No. 1111110083MAF02.dwg
PROJECT No. 11-1111-0083
REV. A

TITLE
GRAIN SIZE DISTRIBUTION ENVELOPE
SAND TO SAND AND SILT FILL

TRENCHLESS CROSSINGS
HIGHWAY 410 WIDENING

FIGURE 2

PLOT DATE: August 27, 2014
FILENAME: T:\Projects\2011\11-1111-0083 (URS, Peel Region)\-MA- Storm Sewer Structures\1111110083MAF02.dwg



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	**COBBLE SIZE**
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		

NOTES:

THE GRAIN SIZE DISTRIBUTION ENVELOPE SHOWN ON THIS FIGURE IS BASED ON THE TEST RESULTS FOR 13 SAMPLES.

FOR INDIVIDUAL TEST RESULTS, REFER TO APPENDICES A TO S.

THE SAMPLERS USED IN THE GEOTECHNICAL INVESTIGATIONS LIMIT THE MAXIMUM PARTICLE SIZE THAT CAN BE SAMPLED AND TESTED TO ABOUT 40mm. LARGER PARTICLE SIZES PRESENT WITHIN THE DEPOSIT, INCLUDING COBBLES AND BOULDERS, ARE NOT REPRESENTED ON THE ABOVE ENVELOPE AND ARE DISCUSSED WITHIN THE TEXT OF THE REPORT.

Golder Associates
Mississauga, Ontario, Canada

SCALE	AS SHOWN
DATE	Aug. 27, 2014
DESIGN	
CAD	FC
CHECK	LCC
REVIEW	LCC
FILE No.	1111110083MAF03.dwg
PROJECT No.	11-1111-0083
REV.	A

TITLE

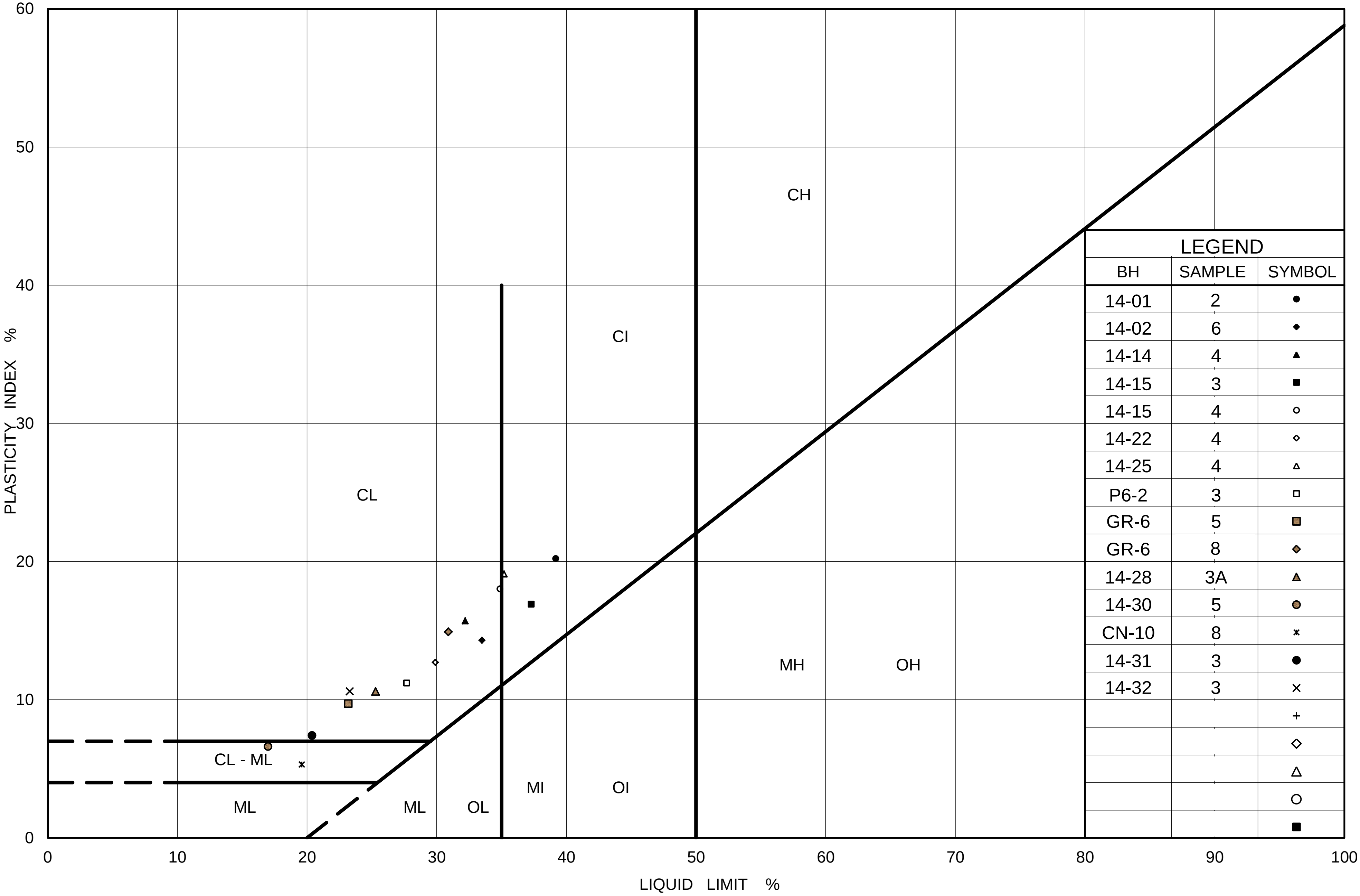
GRAIN SIZE DISTRIBUTION ENVELOPE
CLAYEY SILT TO SILTY CLAY FILL

TRENCHLESS CROSSINGS
HIGHWAY 410 WIDENING

FIGURE 3

PLOT DATE: August 27, 2014
FILENAME: T:\Projects\2011\11-1111-0083 (URS, Peel Region)\-MA- Storm Sewer Structures\1111110083MAF03.dwg

Oct 75, FF-S-21



LEGEND

BH	SAMPLE	SYMBOL
14-01	2	●
14-02	6	◆
14-14	4	▲
14-15	3	■
14-15	4	○
14-22	4	◇
14-25	4	△
P6-2	3	□
GR-6	5	■
GR-6	8	◆
14-28	3A	▲
14-30	5	●
CN-10	8	×
14-31	3	●
14-32	3	×
		+
		◇
		△
		○
		■

Ministry of Transportation

Ontario

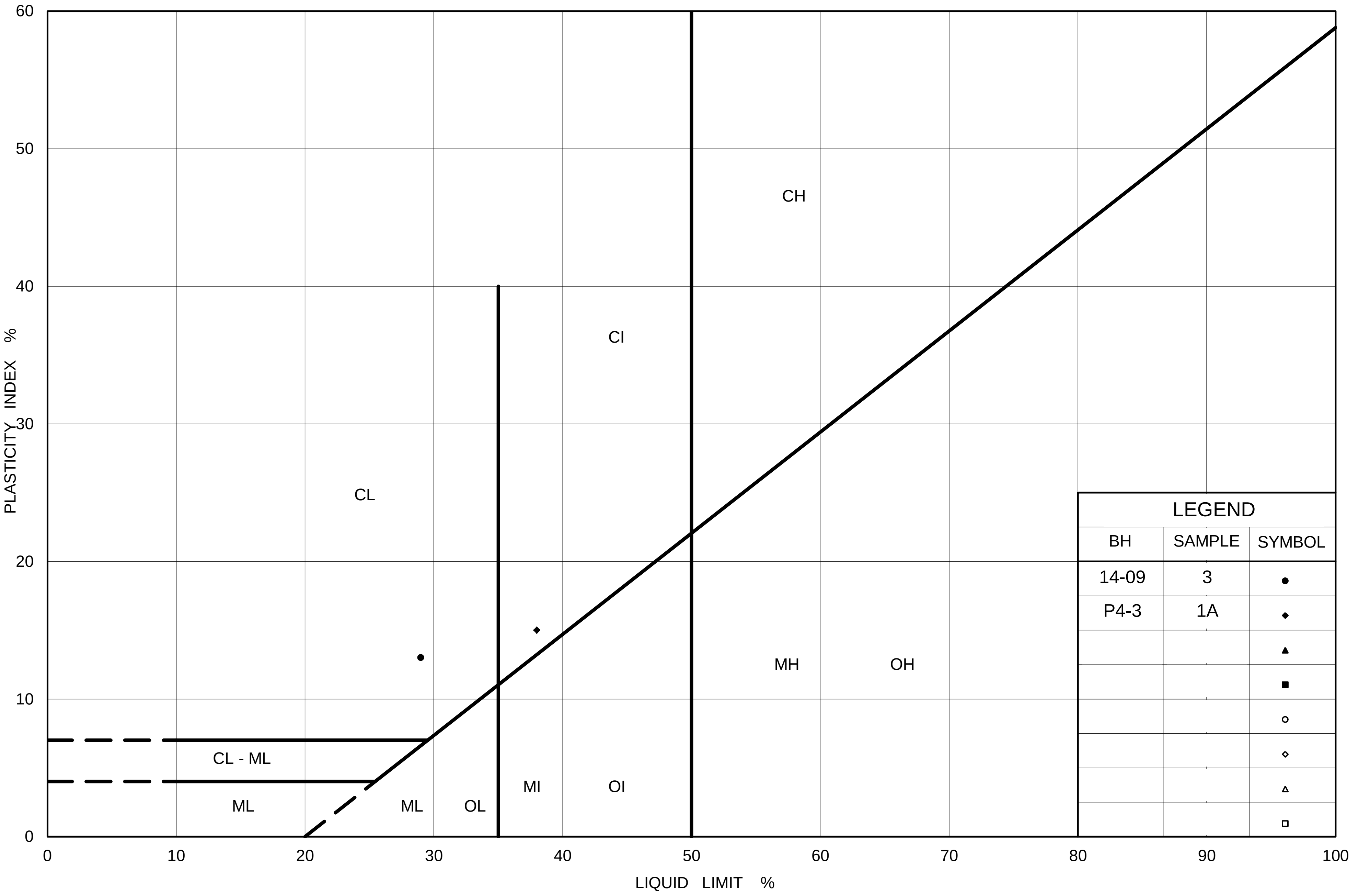
PLASTICITY CHART
Clayey Silt to Silty Clay Fill

Figure No.4

Project No. 11-1111-0083-11

Checked By: LCC

Oct 75, FF-S-21



LEGEND

BH	SAMPLE	SYMBOL
14-09	3	●
P4-3	1A	◆
		▲
		■
		○
		◇
		△
		□

Ministry of Transportation

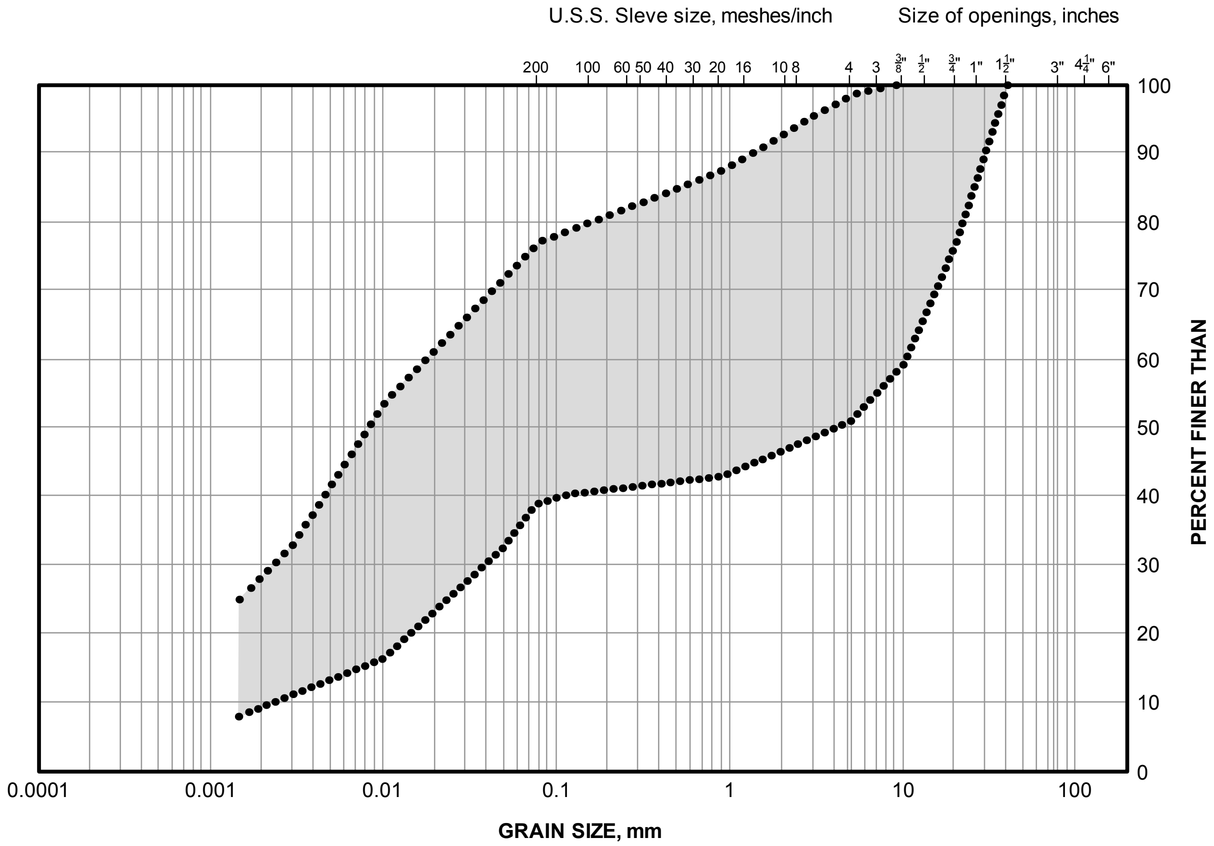
Ontario

PLASTICITY CHART
Surficial Clayey Silt to Silty Clay

Figure No. 5

Project No. 11-1111-0083-11

Checked By: LCC



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		

NOTES:

THE GRAIN SIZE DISTRIBUTION ENVELOPE SHOWN ON THIS FIGURE IS BASED ON THE TEST RESULTS FOR 36 SAMPLES.

FOR INDIVIDUAL TEST RESULTS, REFER TO APPENDICES A TO S.

THE SAMPLERS USED IN THE GEOTECHNICAL INVESTIGATIONS LIMIT THE MAXIMUM PARTICLE SIZE THAT CAN BE SAMPLED AND TESTED TO ABOUT 40mm. LARGER PARTICLE SIZES PRESENT WITHIN THE DEPOSIT, INCLUDING COBBLES AND BOULDERS, ARE NOT REPRESENTED ON THE ABOVE ENVELOPE AND ARE DISCUSSED WITHIN THE TEXT OF THE REPORT.

Golder Associates
Mississauga, Ontario, Canada

SCALE AS SHOWN
DATE Aug. 27, 2014
DESIGN
CAD FC
CHECK LCC
REVIEW LCC

FILE No. 1111110083MAF06.dwg
PROJECT No. 11-1111-0083 REV. A

TITLE

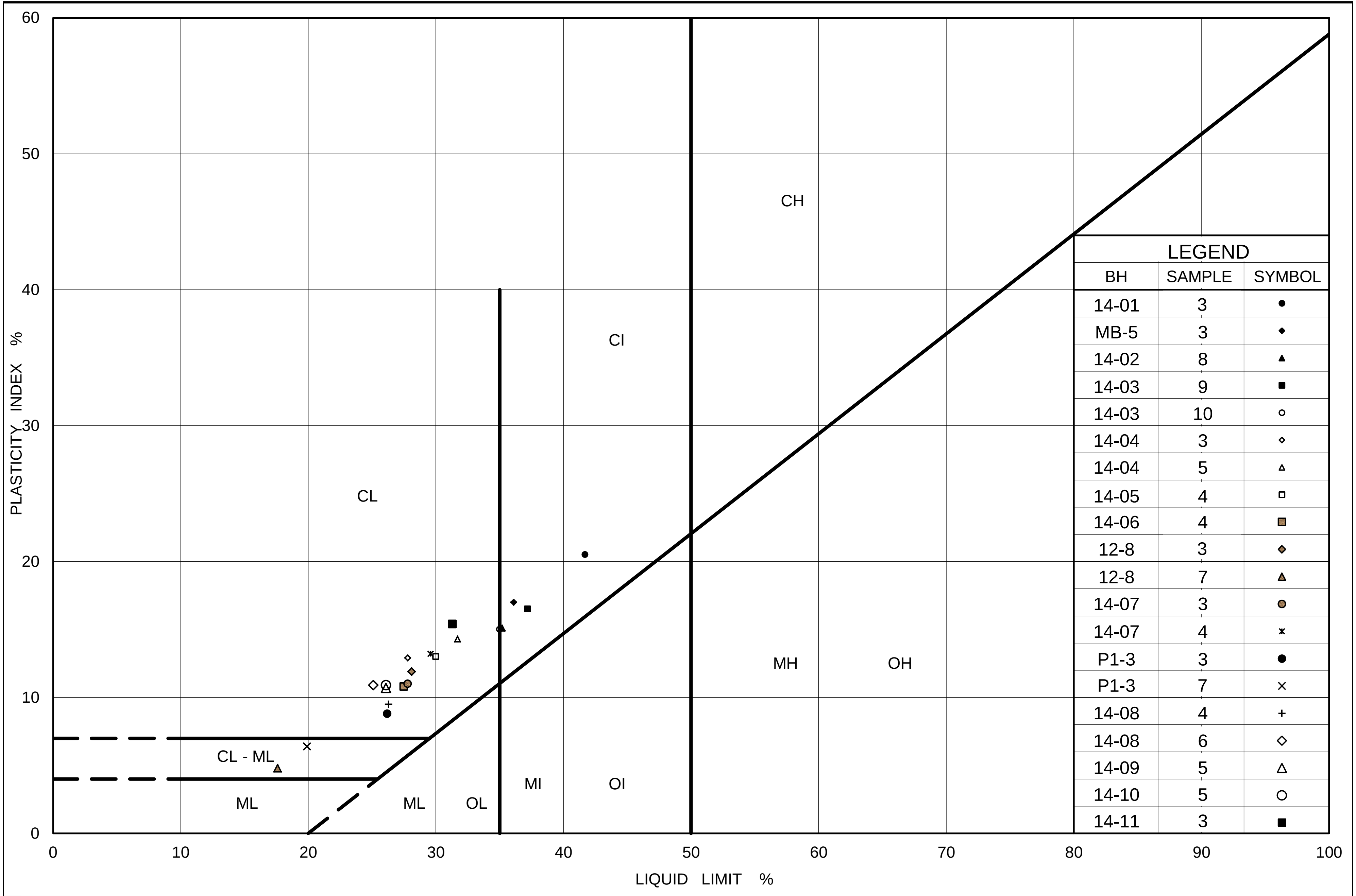
GRAIN SIZE DISTRIBUTION ENVELOPE
CLAYEY SILT TO SILTY CLAY TILL

TRENCHLESS CROSSINGS
HIGHWAY 410 WIDENING

FIGURE 6

PLOT DATE: August 27, 2014
FILENAME: T:\Projects\2011\11-1111-0083 (URS, Peel Region)\-MA- Storm Sewer Structures\1111110083MAF06.dwg

Oct 75, FF-S-21



Ministry of Transportation

Ontario

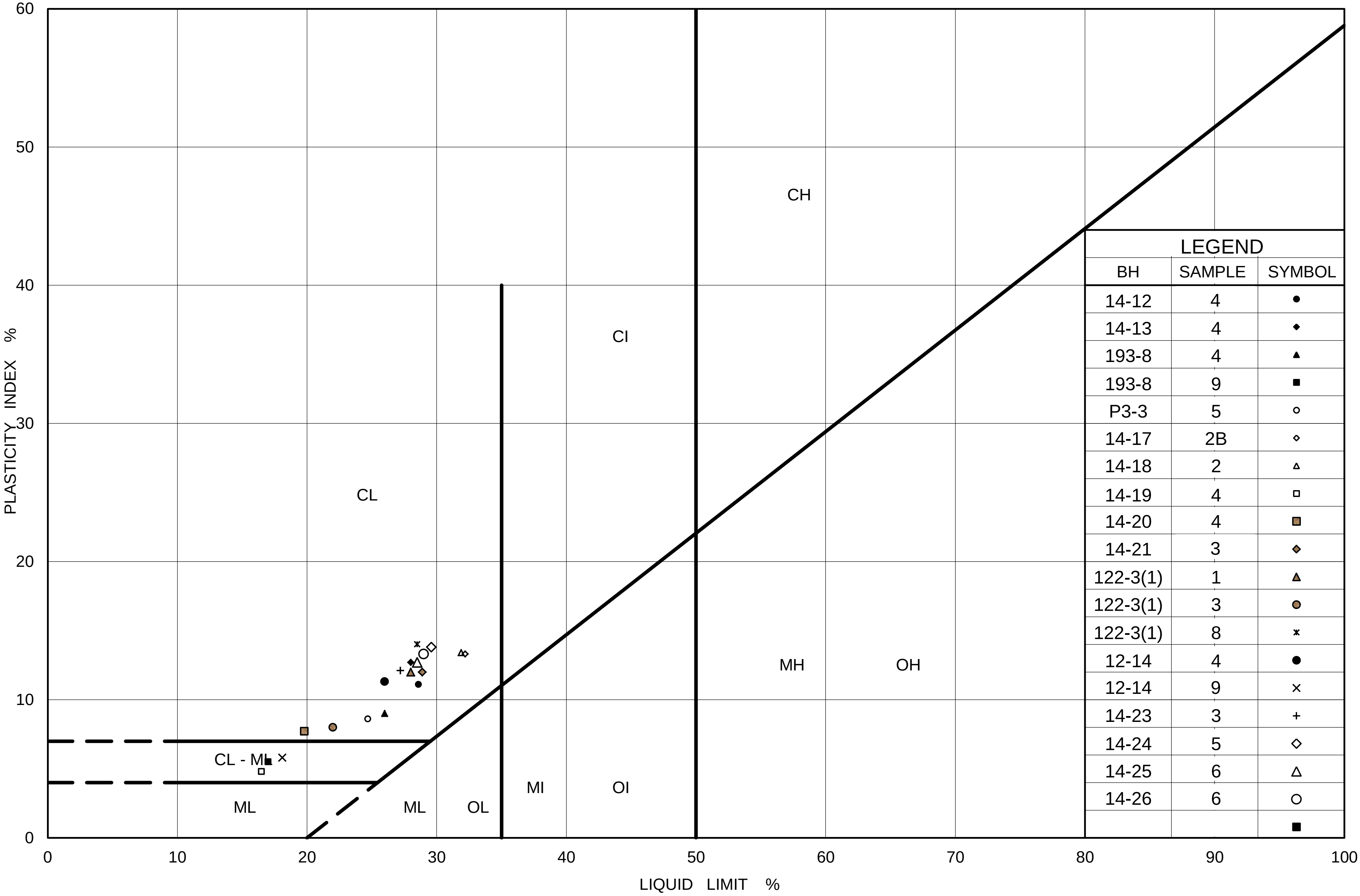
PLASTICITY CHART
Clayey Silt to Silty Clay Till

Figure No. 7A

Project No. 11-1111-0083 -11

Checked By: LCC

Oct 75, FF-S-21



BH	SAMPLE	SYMBOL
14-12	4	●
14-13	4	◆
193-8	4	▲
193-8	9	■
P3-3	5	○
14-17	2B	◇
14-18	2	△
14-19	4	□
14-20	4	🟫
14-21	3	◆
122-3(1)	1	▲
122-3(1)	3	●
122-3(1)	8	✱
12-14	4	●
12-14	9	×
14-23	3	+
14-24	5	◇
14-25	6	△
14-26	6	○
		■

Ministry of
Transportation

Ontario

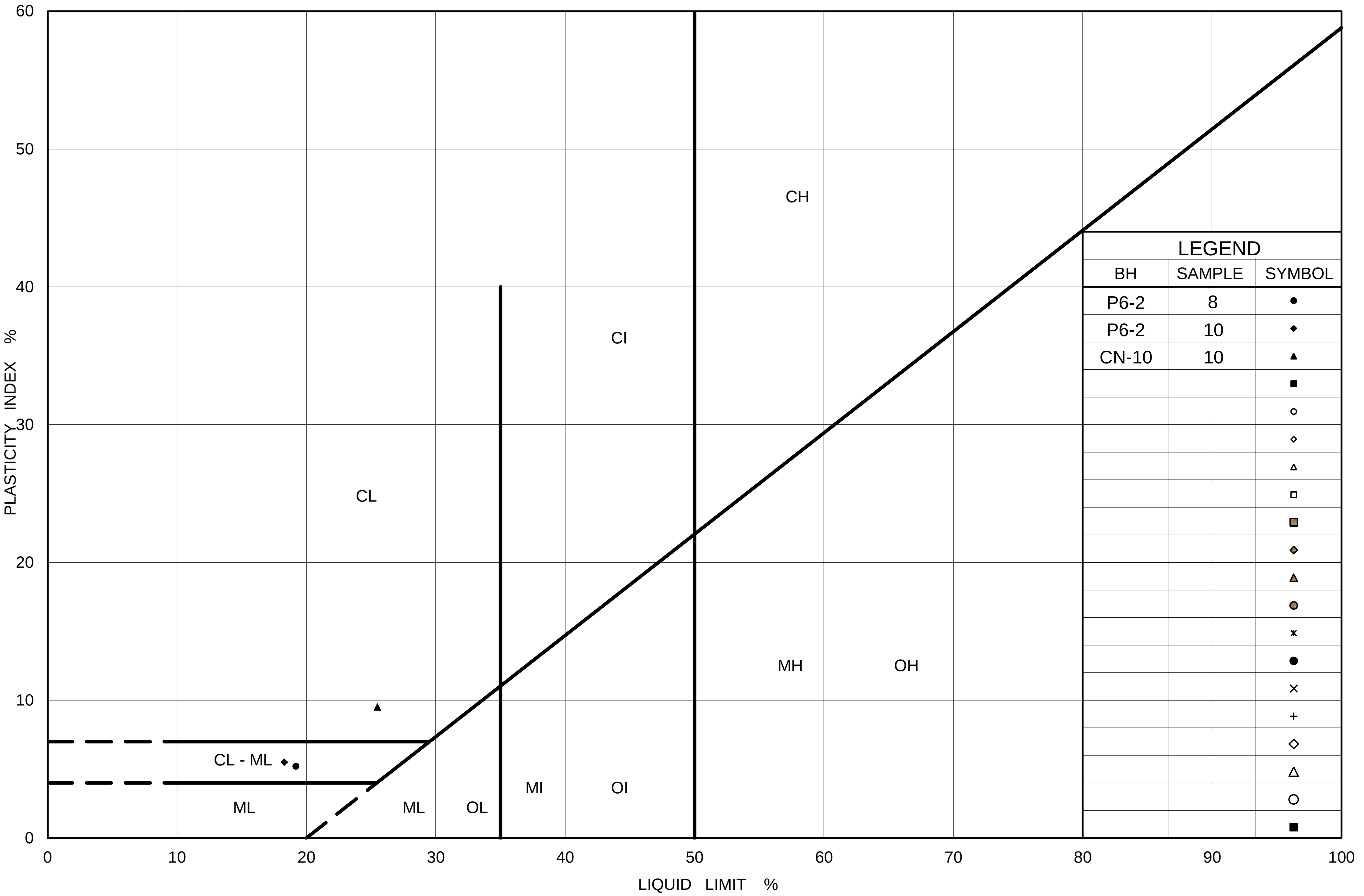
PLASTICITY CHART
Clayey Silt to Silty Clay Till

Figure No. 7B

Project No. 11-1111-0083-11

Checked By: LCC

Oct 75, FF-S-21



Ministry of
Transportation

Ontario

PLASTICITY CHART
Clayey Silt to Silty Clay Till

Figure No. 7C

Project No. 11-1111-0083-11

Checked By: LCC

APPENDIX A

Borehole Records and Laboratory Test Results
Str. 774 – Str. 773, Approximate Station 2+970

Golder Associates

RECORD OF BOREHOLE No 14-01

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083			
G.W.P. 2144-07-00	LOCATION N 4832315.9 ;E 292899.2		ORIGINATED BY OS
DIST Central	HWY 410	BOREHOLE TYPE CME 75 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers	COMPILED BY AV
DATUM Geodetic		DATE June 13, 2014	CHECKED BY LCC

ELEV DEPTH	DESCRIPTION
166.5	GROUND SURFACE
0.0	ASPHALT
166.2 0.3	Sand and gravel (FILL) Compact Brown Moist
165.7 0.8	Silty clay with sand to some sand, trace gravel, containing trace organic material and rootlets (FILL) Stiff Brown Moist
165.1 1.5	SILTY CLAY, some sand, trace to some gravel, containing trace organic material and rootlets (TILL) Very stiff to hard Brown becoming grey below a depth of 3.1 m Moist
161.9 4.8	SHALE (BEDROCK) Weathered Grey
	END OF BOREHOLE

NOTE:

1. Water level measured inside hollow stem augers at a depth of 4.5 m (Elev. 162.0 m) upon completion of drilling.

SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
1	AS	-		166					
2	SS	10				4	22	41	33
3	SS	20		165	42	10	19	41	30
4	SS	23		164					
5	SS	82		163					
6	SS	98/0.23							
			∇	162					
7	SS	100/0.05							

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × REMOULDED
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 (%)

GTA-MTO 001 T:\PROJECTS\2011\11-1111-0083 (URS, PEEL REGION)\LOG\1111110083.GPJ GAL-GTA.GDT 9/4/14

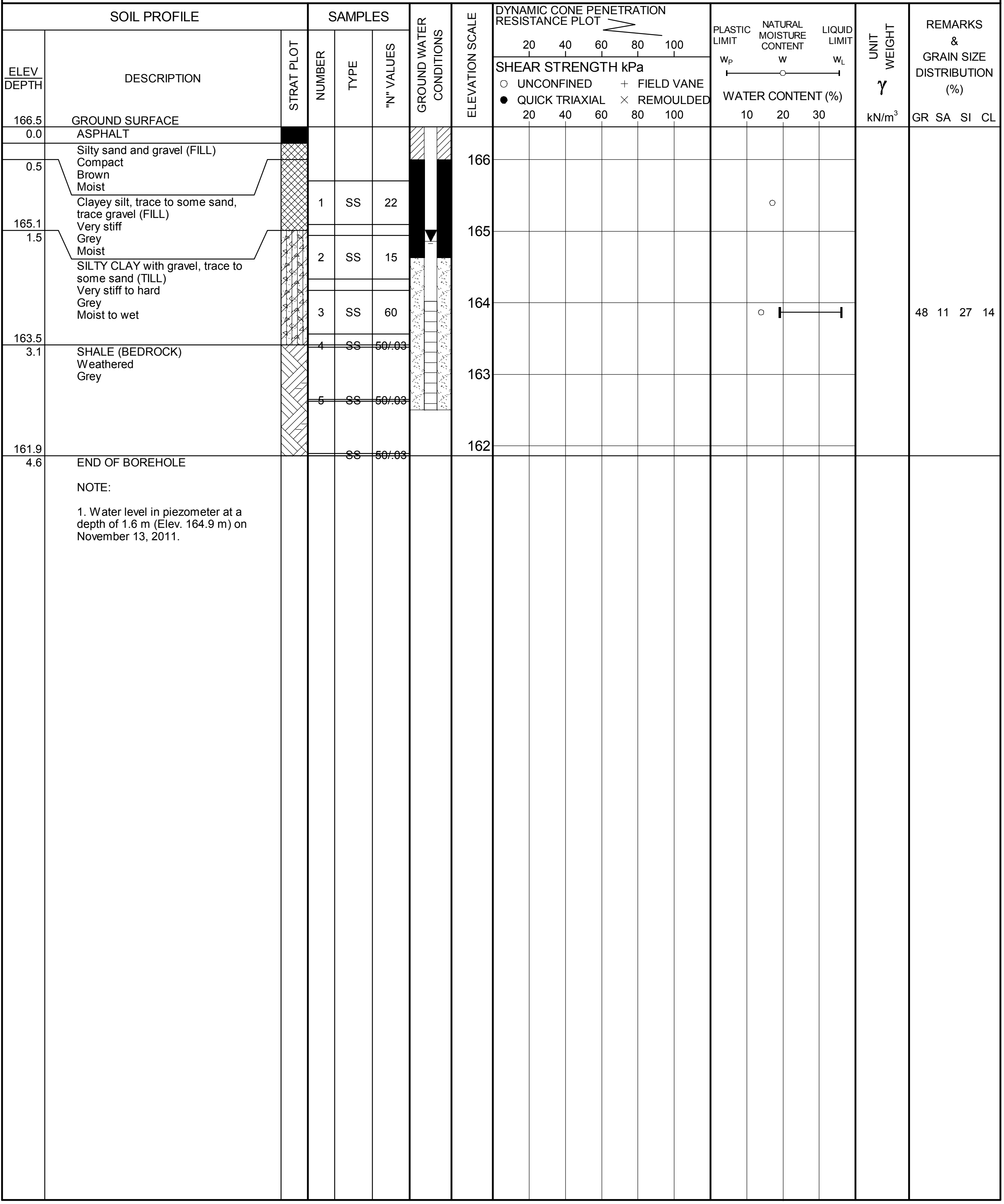
$+^3, \times^3$: Numbers refer to Sensitivity ○$^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No MB-5

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
DIST Central HWY 410
DATUM Geodetic
LOCATION N 4832294.2 ;E 292887.4
BOREHOLE TYPE CME-55 Track-mount, 108 mm Inner Diameter Hollow Stem Augers
DATE November 13, 2011
ORIGINATED BY MS
COMPILED BY NK
CHECKED BY LCC



ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
166.5	GROUND SURFACE								
0.0	ASPHALT								
0.5	Silty sand and gravel (FILL) Compact Brown Moist								
	Clayey silt, trace to some sand, trace gravel (FILL) Very stiff Grey Moist	1	SS	22					
165.1 1.5	SILTY CLAY with gravel, trace to some sand (TILL) Very stiff to hard Grey Moist to wet	2	SS	15					
		3	SS	60		48	11	27	14
163.5 3.1	SHALE (BEDROCK) Weathered Grey	4	SS	50/.03					
		5	SS	50/.03					
161.9 4.6	END OF BOREHOLE		SS	50/.03					

NOTE:

1. Water level in piezometer at a depth of 1.6 m (Elev. 164.9 m) on November 13, 2011.

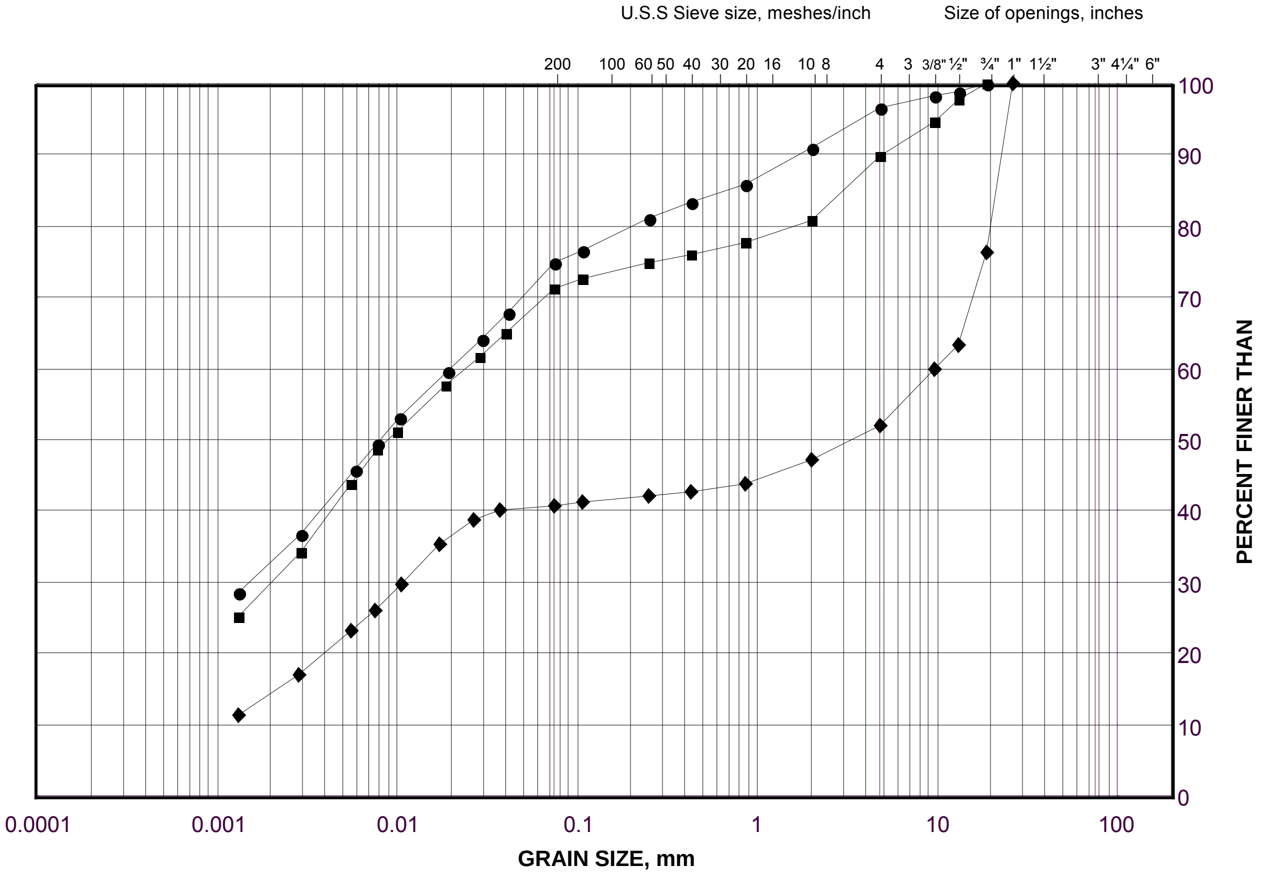
GTA-MTO 001 T:\PROJECTS\2011\11-1111-0083 (URS, PEEL REGION)\LOG\1111110083.GPJ GAL-GTA.GDT 08/21/14

$+^3, \times^3$: Numbers refer to Sensitivity ○ $^{3\%}$ STRAIN AT FAILURE

GRAIN SIZE DISTRIBUTION TEST RESULTS

Str. 774 - Str. 773
Approximate Station 2+970

FIGURE A



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	**COBBLE**
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	14-01	2	165.4
■	14-01	3	164.7
◆	MB-5	3	163.8

Project Number: 11-1111-0083

Checked By: LC, 27-Aug-14

Golder Associates

Date: 25-Aug-14

APPENDIX B

Borehole Records and Laboratory Test Results
Culvert #5, Approximate Station 10+394, 410N-401E Ramp

Golder Associates

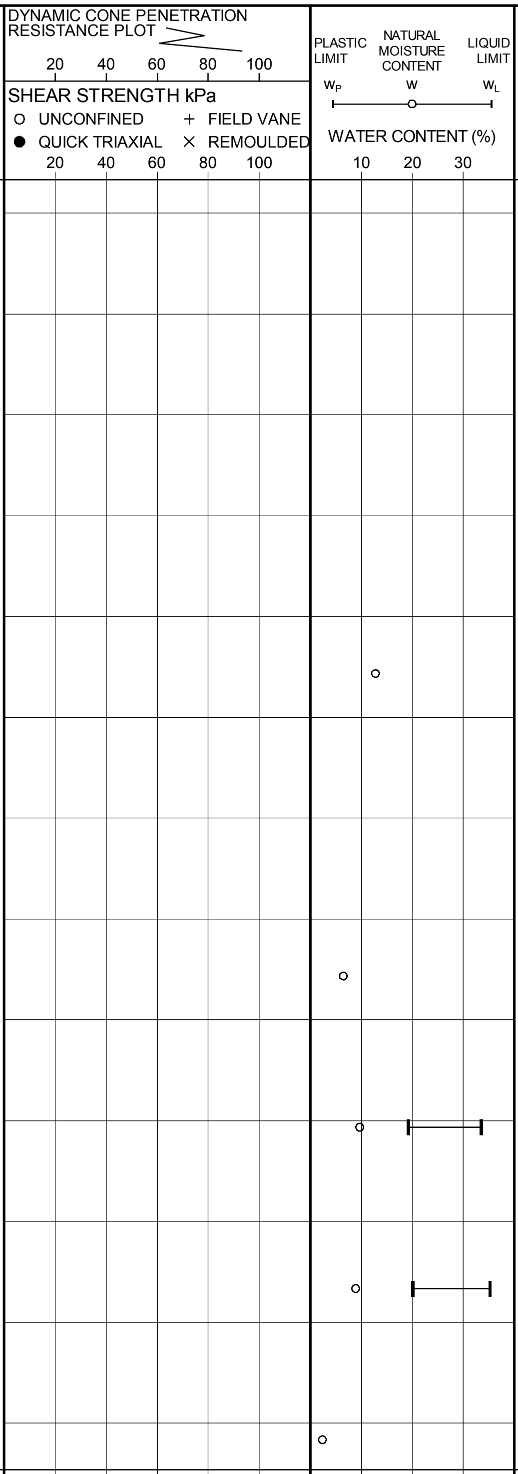
RECORD OF BOREHOLE No 14-02

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
DIST Central HWY 410
DATUM Geodetic
LOCATION N 4833393.0 ;E 291571.3
BOREHOLE TYPE CME 75 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
DATE June 4, 2014
ORIGINATED BY OS
COMPILED BY AV
CHECKED BY LCC

SOIL PROFILE		SAMPLES			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
193.3	GROUND SURFACE							
0.0	ASPHALT							
0.1	Sand and gravel, trace silt, containing cobbles (FILL) Dense Light grey to brown Dry to moist Auger grinding between 1.2 m and 1.7 m Auger grinding between 2.4 m and 3.0 m							
190.3 3.0	Crushed stone (FILL) Dense Light grey Dry	1	SS	31				
189.5 3.8	CLAYEY SILT with sand to some sand, some gravel, containing cobbles (FILL) Stiff to hard Brown and grey to black with oxidation staining Moist Auger grinding at a depth of 4.3 m	2	SS	17				
		3	SS	13				
	Auger grinding at a depth of 7.5 m	4	SS	54				
	Auger grinding at a depth of 8.2 m	5	SS	20				
		6	SS	12	35	23	31	11
	Auger grinding at a depth of 9.8 m	7	SS	22				
182.7 10.6	CLAYEY SILT to SILTY CLAY with sand, some gravel, containing rootlets and organic material (TILL) Hard Grey and dark brown Moist	8	SS	37	21	26	37	16
		9	SS	50				
180.5 12.8	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.							



GROUND WATER CONDITIONS

UNIT WEIGHT γ kN/m³

$+^3, \times^3$: Numbers refer to Sensitivity $\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No 14-03

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083

G.W.P. 2144-07-00

DIST Central HWY 410

DATUM Geodetic

LOCATION N 4833400.0 ;E 291576.0

BOREHOLE TYPE CME 75 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers

DATE June 3, 2014

ORIGINATED BY EG

COMPILED BY AV

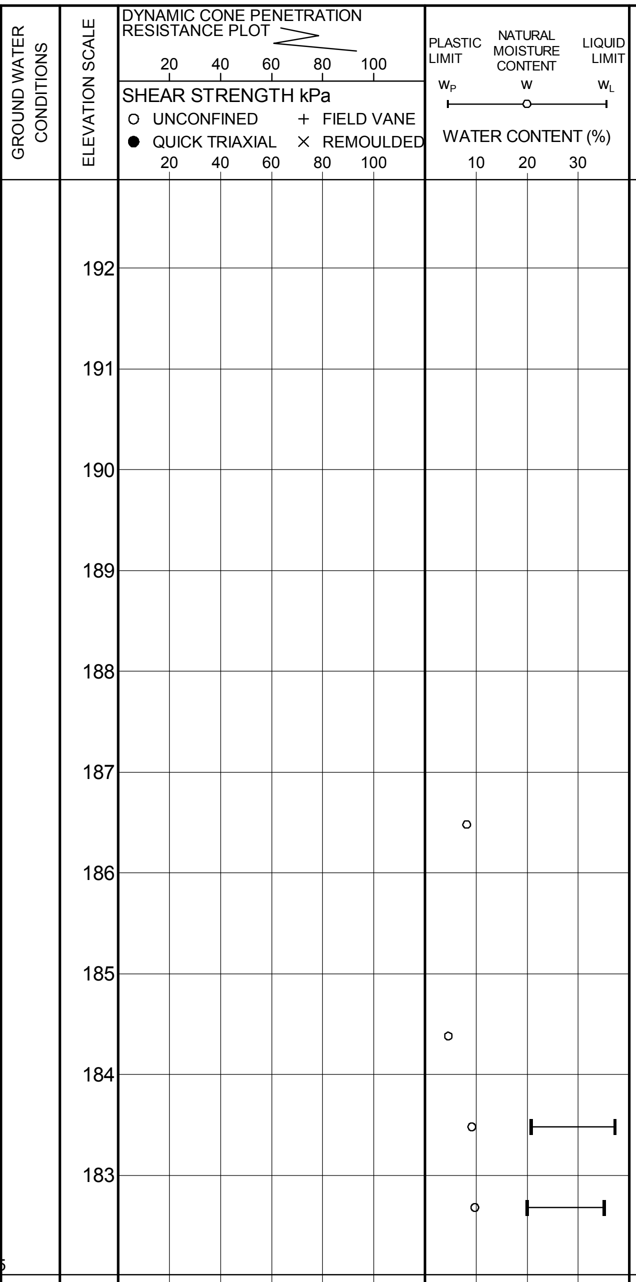
CHECKED BY LCC

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
192.9	GROUND SURFACE
0.0	ASPHALT
0.1	Sand and gravel, some silt (FILL) Compact Brown and grey Moist Auger grinding at 0.8 m
191.8 1.1	Clayey silt with sand to some sand, trace to some gravel, containing cobbles (FILL) Stiff to hard Brown and grey with oxidation staining Moist Auger grinding while drilling through fill material
183.9 9.0	CLAYEY SILT to SILTY CLAY with sand, some gravel, containing cobbles (TILL) Very stiff to hard Grey-brown to grey Moist
182.0 10.9	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	AS	-				
2	SS	45				
3A 3B	SS	23				
4	SS	21				
5	SS	21				
6	SS	13				
7	SS	13				
8	SS	29				
9	SS	27	32	21	32	15
10	SS	18				
11	SS	100/0.05				



UNIT WEIGHT γ kN/m³

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

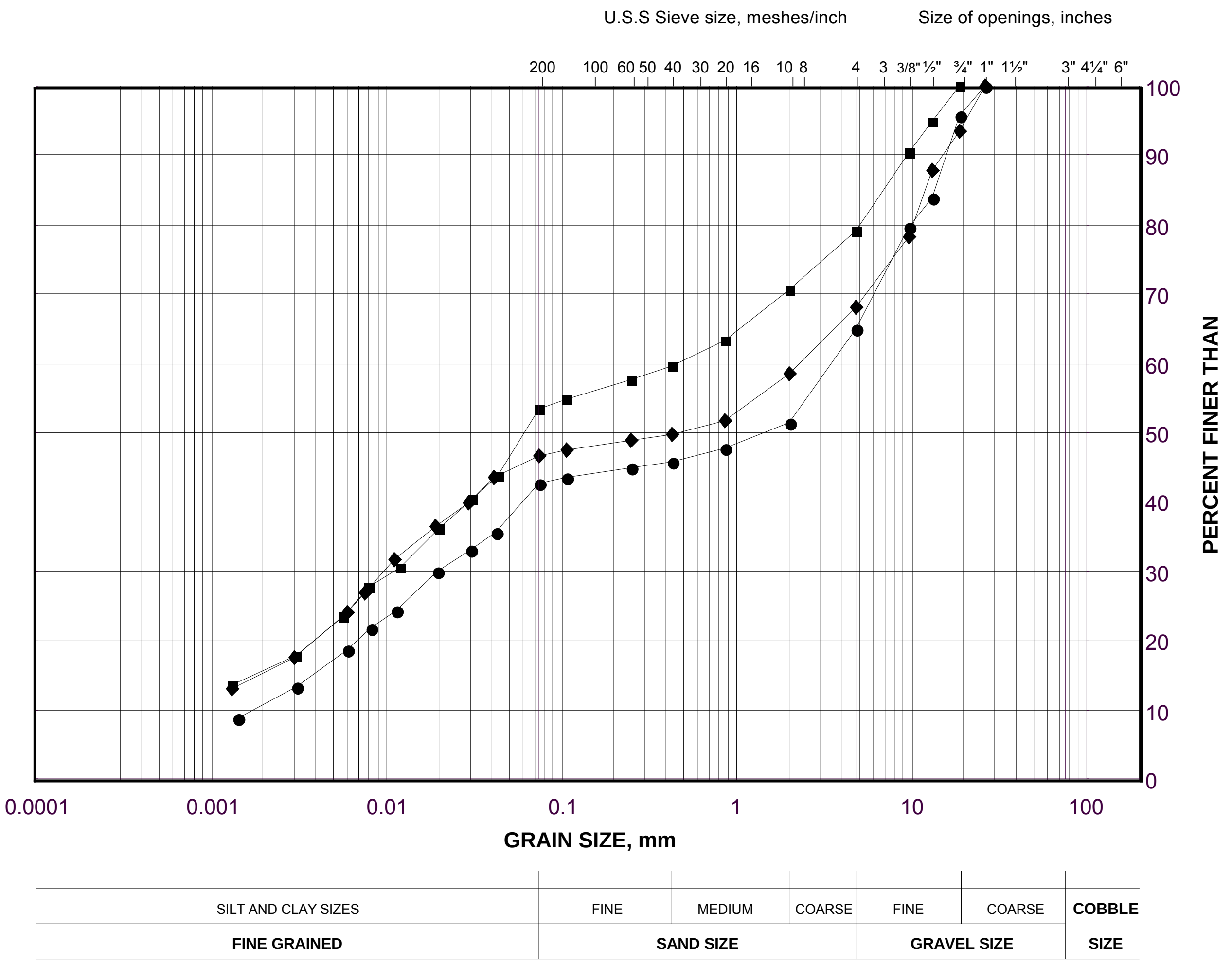
O 3% STRAIN AT FAILURE

GRAIN SIZE DISTRIBUTION TEST RESULTS

Culvert #5

Approximate Station 10+394 - 410N-401E Ramp

FIGURE B



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	14-02	6	183.9
■	14-02	8	182.4
◆	14-03	9	183.5

Project Number: 11-1111-0083

Checked By: LC, 27-Aug-14

Golder Associates

Date: 25-Aug-14

APPENDIX C

Borehole Records and Laboratory Test Results
Culvert #6, Approximate Station 11+516, 410W-410N Ramp

RECORD OF BOREHOLE No 14-04

SHEET 1 OF 1

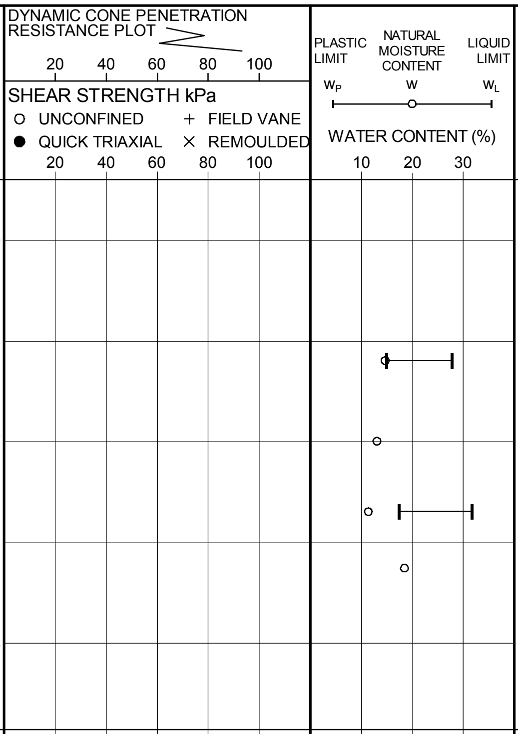
METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
DIST Central HWY 410
DATUM Geodetic
LOCATION N 4833759.0 ;E 291444.0
BOREHOLE TYPE CME 45 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
DATE June 9, 2014
ORIGINATED BY EG
COMPILED BY AV
CHECKED BY LCC

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
179.6	GROUND SURFACE							
0.0	ASPHALT							
0.1	Sand and gravel (FILL) Brown Dry	1	AS	-				
178.9 0.7	Clayey silt, some sand, trace gravel (FILL) Stiff Brown with oxidation staining Moist	2	SS	8				
178.2 1.4	CLAYEY SILT with sand to some sand, trace to some gravel, containing cobbles (TILL) Very stiff to hard Brown becoming grey below a depth of 3.8 m Moist	3	SS	15	7	29	41	23
		4	SS	19				
	Auger grinding below a depth of 3.4 m	5	SS	30	18	21	39	22
		6	SS	100/0.10				
		7	SS	100/0.13				
174.1 5.5	END OF BOREHOLE							

NOTE:

1. Open borehole dry upon completion of drilling.



GROUND WATER CONDITIONS

UNIT WEIGHT γ kN/m³

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

O $^{3\%}$ STRAIN AT FAILURE

GTA-MTO 001 T:\PROJECTS\2011\11-1111-0083 (URS, PEEL REGION)\LOG\1111110083.GPJ GAL-GTA.GDT 9/4/14

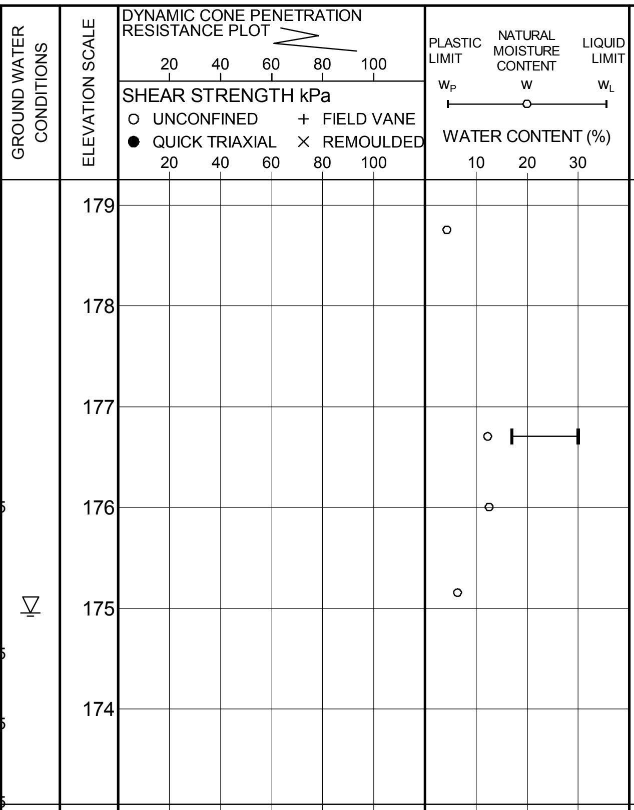
RECORD OF BOREHOLE No 14-05

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
DIST Central HWY 410
DATUM Geodetic
LOCATION N 4833766.0 ;E 291447.0
BOREHOLE TYPE CME 75 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
DATE June 6, 2014
ORIGINATED BY OS
COMPILED BY AV
CHECKED BY LCC

SOIL PROFILE		SAMPLES			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
179.3	GROUND SURFACE							
~~0.0~~ 0.1	ASPHALT							
	Sand and gravel (FILL) Compact Brown Moist	1	AS	-	35	54	8	3
		2	SS	11				
177.8 1.5	Clayey silt, some sand, trace to some gravel (FILL) Very stiff Brown with oxidation staining Moist	3	SS	18				
177.1 2.2	CLAYEY SILT with sand to some sand, trace to some gravel (TILL) Hard Brown becoming grey below a depth of 4.4 m Moist Cobbles and boulders encountered at depths of 2.8 m and 3.5 m	4	SS	47	10	25	42	23
		5	SS	117/0.25				
		6	SS	56				
		7	SS	100/0.05				
		8	SS	100/0.05				
173.1		9	SS	100/0.05				
6.2	END OF BOREHOLE NOTE: 1. Water level measured in open borehole at a depth of 4.3 m (Elev. 175.0 m) upon completion of drilling.							



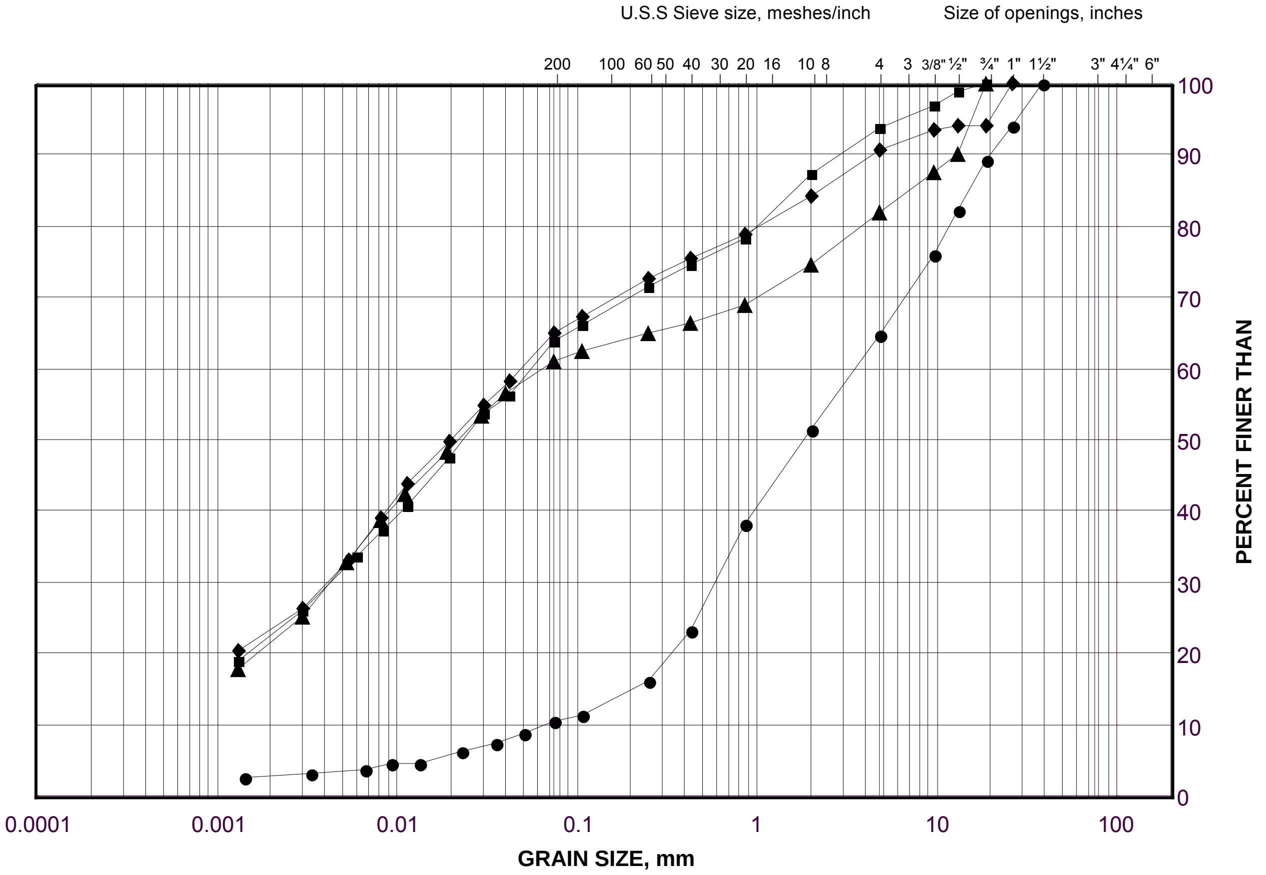
+3, ×3: Numbers refer to Sensitivity ○3% STRAIN AT FAILURE

GRAIN SIZE DISTRIBUTION TEST RESULTS

Culvert #6

Approximate Station 11+516 - 410W-410N Ramp

FIGURE C



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	**COBBLE**
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	14-05	1	178.8
■	14-04	3	177.8
◆	14-05	4	176.7
▲	14-04	5	176.3

Project Number: 11-1111-0083

Checked By: LC, 27-Aug-14

Golder Associates

Date: 25-Aug-14

APPENDIX D

Borehole Records and Laboratory Test Results
Str. 870 – Str. 868, Approximate Station 5+180

Golder Associates

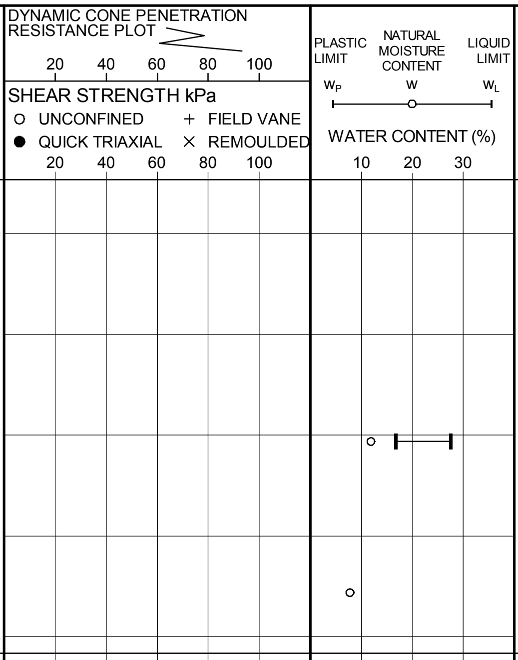
RECORD OF BOREHOLE No 14-06

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
DIST Central HWY 410
DATUM Geodetic
LOCATION N 4833877.3 ;E 291318.3
BOREHOLE TYPE CME 45 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
DATE June 9, 2014
ORIGINATED BY EG
COMPILED BY AV
CHECKED BY LCC

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES				GR	SA	SI	CL
179.5	GROUND SURFACE										
0.0	ASPHALT										
0.1	Sand and gravel (FILL) Loose to compact Brown Dry to moist	1	SS	25		179					
		2	SS	7				43	47	7	3
178.1 1.4	CLAYEY SILT with sand to some sand, trace to some gravel, containing cobbles (TILL) Very stiff to hard Brown becoming grey below a depth of 3.1 m Moist	3	SS	16		178					
		4	SS	22		177		7	32	40	21
	Auger grinding below a depth of 3.1 m	5	SS	60		176					
		6	SS	29							
174.8		7	SS	50/0.13		175					
4.7	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.										



$+^3, \times^3$: Numbers refer to Sensitivity ○ $^{3\%}$ STRAIN AT FAILURE

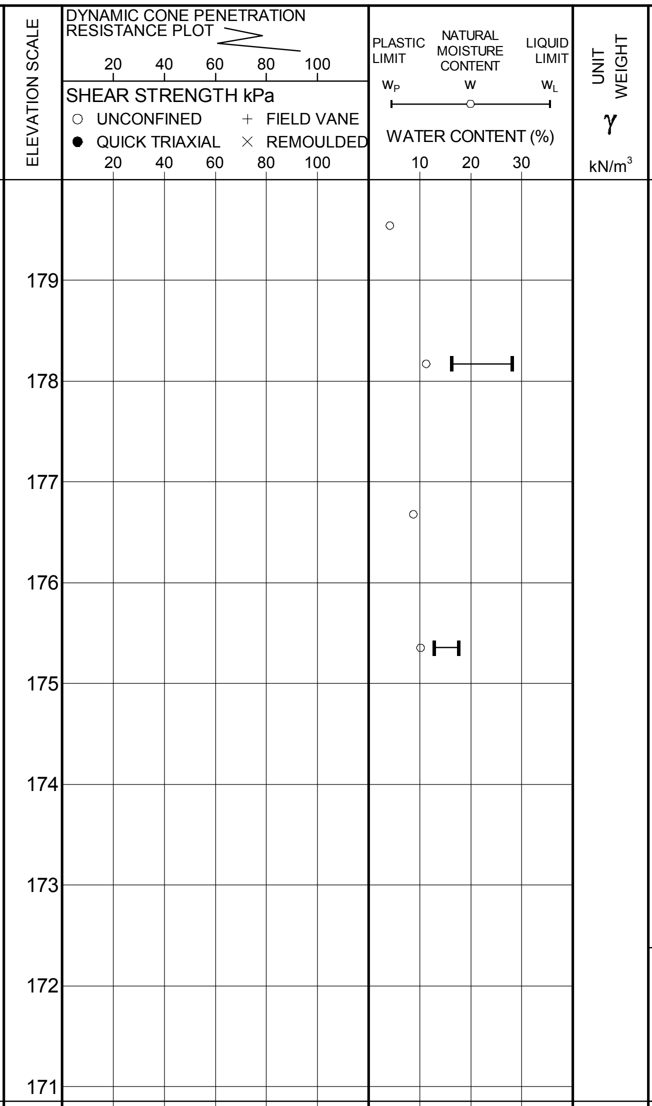
RECORD OF BOREHOLE No 12-8

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
DIST Central HWY 410
DATUM Geodetic
LOCATION N 4833866.9 ;E 291282.9
BOREHOLE TYPE CME 75 Truck-mount, 101 mm Diameter Solid Stem Augers
DATE November 19, 2012
ORIGINATED BY SB
COMPILED BY AV/GL
CHECKED BY GDS

SOIL PROFILE			SAMPLES				REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
180.0	GROUND SURFACE									
0.0	ASPHALT									
0.2	Sand and gravel (FILL) Dense Brown Moist		1	SS	39					
179.2 0.8	CLAYEY SILT with SAND, trace to some gravel (TILL) Very stiff to hard Grey Moist		2	SS	49					
			3	SS	29		12	26	42	20
			4	SS	32					
	Containing cobbles below 3.0 m		5	SS	45					
			6	SS	77					
			7	SS	65/0.15		15	35	41	9
	Shale fragments below 6.1 m		8	SS	80/0.15					
172.4 7.6	SHALE (BEDROCK) Bedrock cored from 7.6 m to 9.1 m Refer to Record of Drillhole 12-8 for rock coring details		1	RC	REC 87%		RQD = 50%			
170.9 9.1	END OF BOREHOLE NOTES: 1. Open borehole dry prior to rock coring. 2. Borehole backfilled with bentonite.									

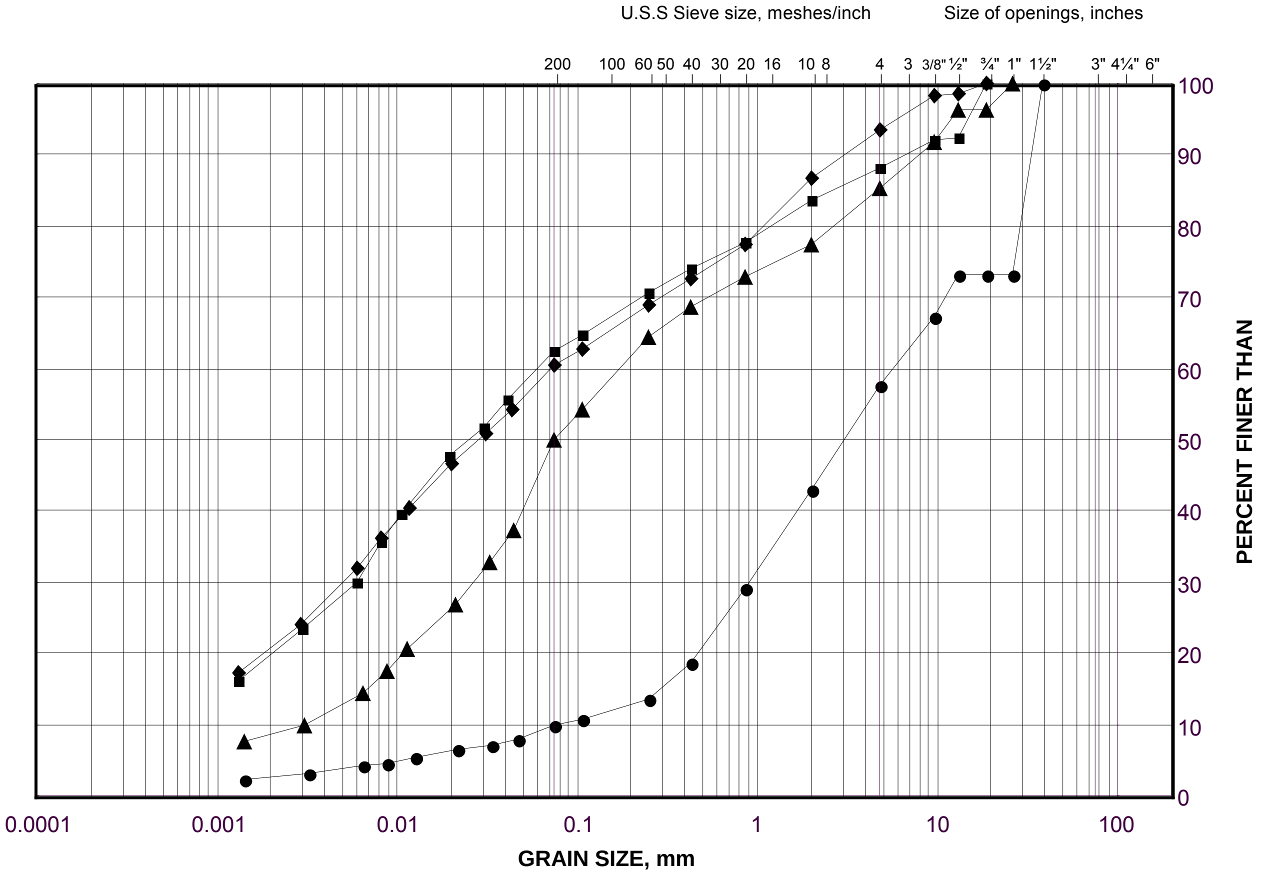


$+^3, \times^3$: Numbers refer to Sensitivity

$\bigcirc^{3\%}$ STRAIN AT FAILURE

GRAIN SIZE DISTRIBUTION TEST RESULTS
Str. 870 - Str. 868
Approxiamte Station 5+180

FIGURE D



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	**COBBLE**
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	14-06	2	177.9
■	12-8	3	178.2
◆	14-06	4	176.4
▲	12-8	7	175.4

Project Number: 11-1111-0083

Checked By: LC, 27-Aug-14

Golder Associates

Date: 25-Aug-14

APPENDIX E

Borehole Records and Laboratory Test Results
Str. 894 – Outlet, Approximate Station 5+280

Golder Associates

RECORD OF BOREHOLE No 14-07

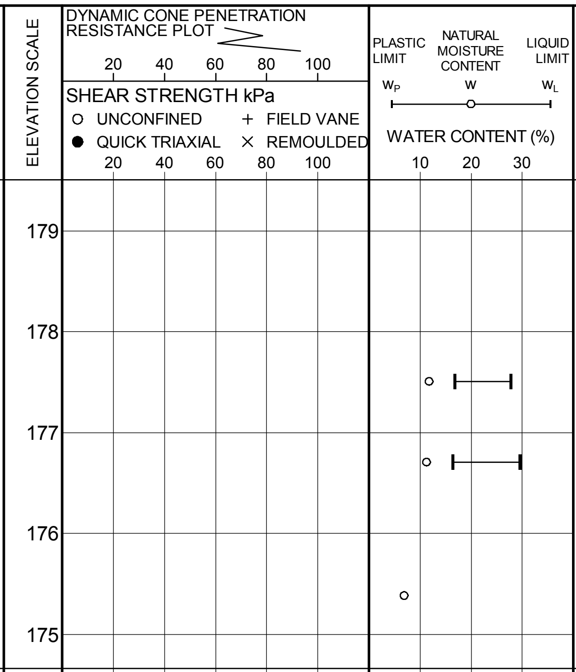
SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
LOCATION N 4833915.9 ;E 291226.8
ORIGINATED BY EG
DIST Central HWY 410
BOREHOLE TYPE CME 45 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
COMPILED BY AV
DATUM Geodetic
DATE June 8, 2014
CHECKED BY LCC

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLES – NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
179.5	GROUND SURFACE									
0.0	ASPHALT									
0.2	Sand and gravel (FILL) Loose to dense Brown Moist	1	SS	32						
178.3 1.2	CLAYEY SILT with sand to some sand, trace to some gravel, containing cobbles (TILL) Firm to hard Brown becoming grey below a depth of 3.0 m Moist	2A 2B	SS	7						
		3	SS	18			5	30	43	22
		4	SS	22			22	23	36	19
		5	SS	30						
		6	SS	50/0.10						
		7	SS	100/0.13						
174.7 4.9	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.									

REMARKS & GRAIN SIZE DISTRIBUTION (%)



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

$○^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No P1-3

SHEET 1 OF 1

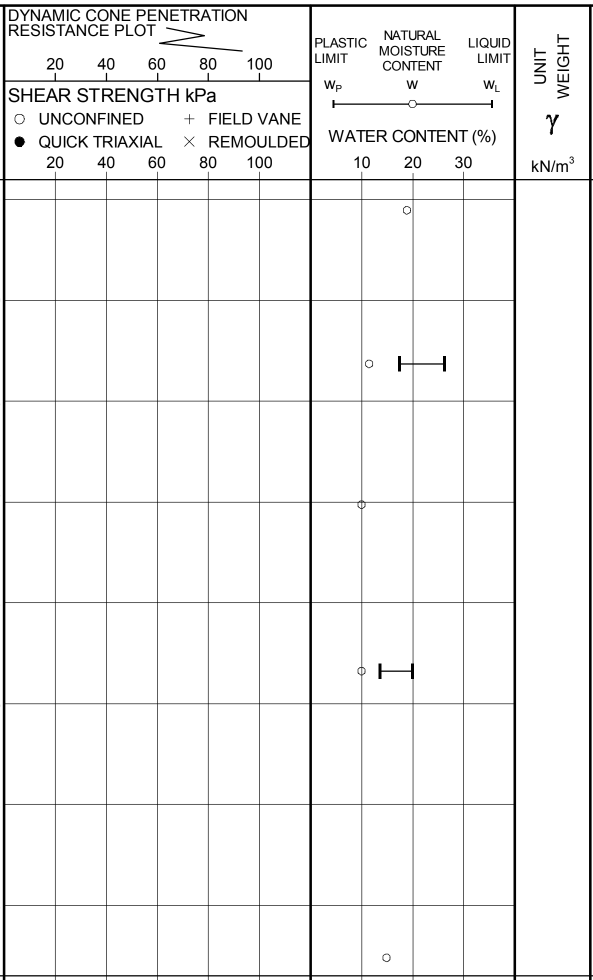
METRIC

PROJECT 11-1111-0083			
G.W.P. 2144-07-00	LOCATION N 4833960.1 ;E 291245.5	ORIGINATED BY TWB
DIST Central HWY 410	BOREHOLE TYPE CME-55 Track-mount, 152 mm Solid Stem Augers	COMPILED BY MAS
DATUM Geodetic	DATE August 23, 2012	CHECKED BY LCC

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
180.2	GROUND SURFACE									
0.0	CLAYEY SILT, some sand Very stiff Brown Moist	1	SS	17		180				
179.5 0.7	CLAYEY SILT with sand, trace to some gravel, containing cobbles and boulders below 3.0 m (TILL) Very stiff to hard Brown becoming grey below a depth of 3.7 m Moist	2	SS	28		179				
		3	SS	25			7	24	45	24
		4	SS	42		178				
		5	SS	80/0.20		177				
		6	SS	49		176				
		7	SS	53		175	40	25	27	8
					▽					
174.1 6.1	SHALE (BEDROCK / RESIDUAL SOIL) Highly weathered Grey	8	SS	87/0.20		174				
173.0 7.2	SHALE (BEDROCK) Weathered Grey	9	SS	60/0.05		173				
172.3 7.9	END OF BOREHOLE AUGER REFUSAL									

NOTE:

1. Water level in open borehole at a depth of 5.9 m (Elev. 174.3 m) on completion of drilling.



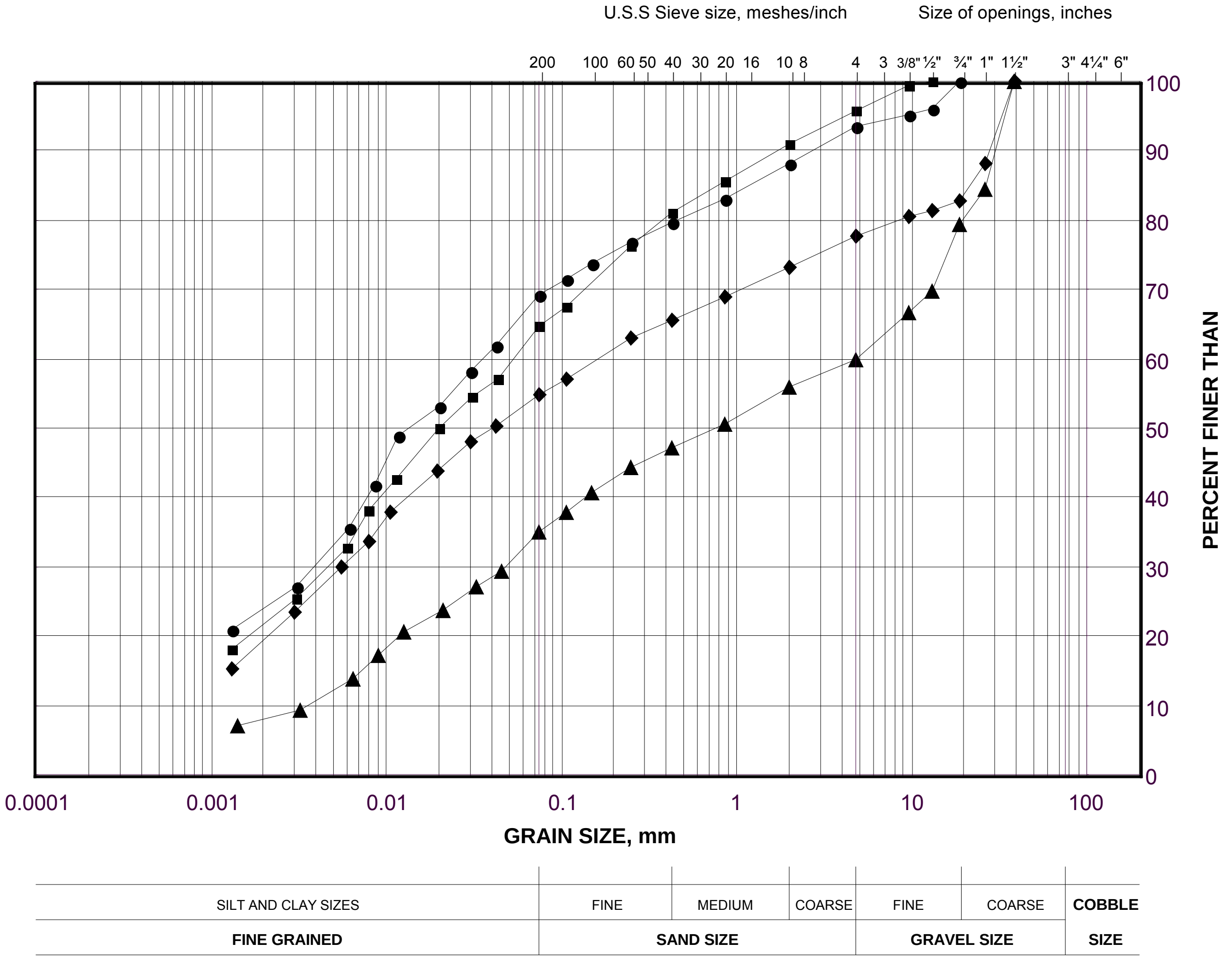
+3, ×3: Numbers refer to Sensitivity ○3% STRAIN AT FAILURE

GRAIN SIZE DISTRIBUTION TEST RESULTS

Str. 894 - Outlet

Approximate Station 5+280

FIGURE E



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	P1-3	3	178.4
■	14-07	3	177.5
◆	14-07	4	176.7
▲	P1-3	7	175.3

Project Number: 11-1111-0083

Checked By: LC, 27-Aug-14

Golder Associates

Date: 25-Aug-14

APPENDIX F

Borehole Records and Laboratory Test Results
Str. 1326 – Median – Str. 1327, Approximate Station 6+266

RECORD OF BOREHOLE No 14-08

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083

G.W.P. 2144-07-00

DIST Central HWY 410

DATUM Geodetic

LOCATION N 4834603.5 ;E 290521.0

BOREHOLE TYPE CME 45 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers

DATE June 4, 2014

ORIGINATED BY EG

COMPILED BY AV

CHECKED BY LCC

SOIL PROFILE		SAMPLES			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
187.5	GROUND SURFACE							
0.0	ASPHALT							
0.2	Sand and gravel (FILL) Dense to compact Brown Moist	1	SS	37				
		2A 2B	SS	12				
186.2 1.3	CLAYEY SILT with sand to some sand, trace to some gravel, containing cobbles (TILL) Stiff to hard Brown becoming grey below a depth of 3.0 m Moist Auger grinding at a depth of 2.3 m	3	SS	37				
		4	SS	38	7	37	39	17
		5A 5B	SS	39				
		6	SS	26				
		7	SS	24				
		8	SS	24				
		9	SS	15				
		10	SS	13				
179.9 7.6	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.							

STRAT PLOT

GROUND WATER CONDITIONS

ELEVATION SCALE

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa

○ UNCONFINED + FIELD VANE

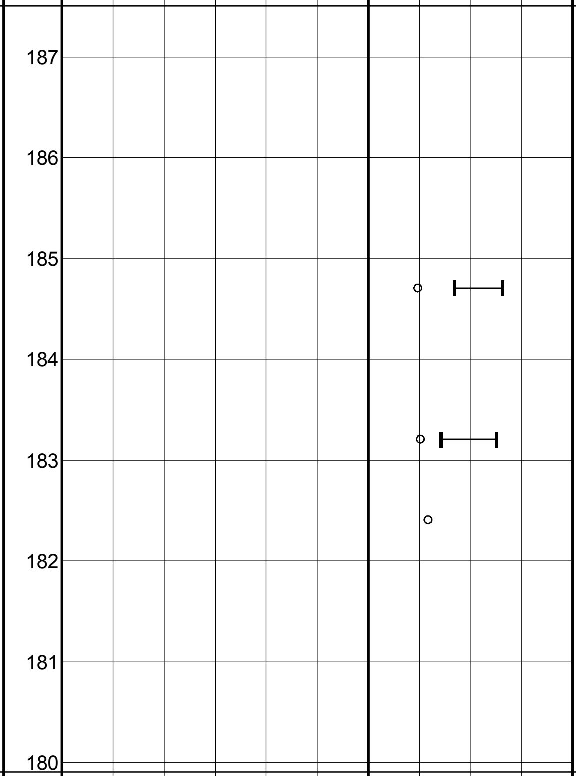
● QUICK TRIAXIAL × REMOULDED

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 ○ $^{3\%}$ STRAIN AT FAILURE

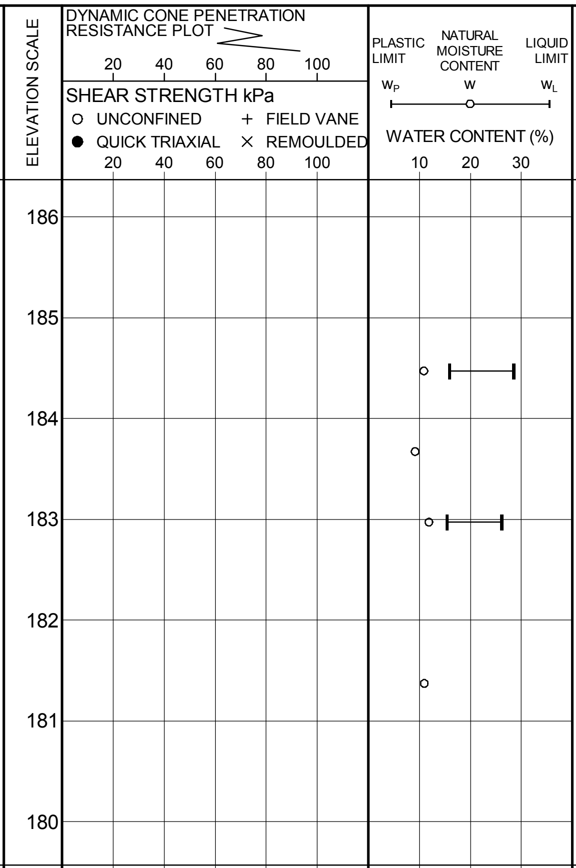
RECORD OF BOREHOLE No 14-09

SHEET 1 OF 1

METRIC

PROJECT	11-1111-0083		
G.W.P.	2144-07-00	LOCATION	N 4834624.0 ;E 290542.7
DIST	Central HWY 410	BOREHOLE TYPE	CME 45 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
DATUM	Geodetic	DATE	June 8, 2014
ORIGINATED BY	EG	COMPILED BY	AV
CHECKED BY	LCC		

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES		GR	SA	SI	CL
186.4	GROUND SURFACE								
0.0	ASPHALT								
0.1	Sand and gravel (FILL) Dense Brown Moist	1	SS	46					
185.6 0.8	Sand (FILL) Compact Brown Moist	2	SS	10					
185.0 1.4	CLAYEY SILT, some sand, trace to some gravel, containing rootlets Very stiff Brown Moist	3	SS	22					
184.1 2.3	CLAYEY SILT with sand to some sand, trace to some gravel (TILL) Stiff to hard Brown becoming grey below a depth of 3.4 m Moist	4	SS	37					
		5	SS	21		10	30	40	20
		6	SS	14					
		7	SS	18					
		8	SS	15					
		9	SS	13					
179.6 6.8	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.								



UNIT WEIGHT γ kN/m³

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

$\circ^{3\%}$ STRAIN AT FAILURE

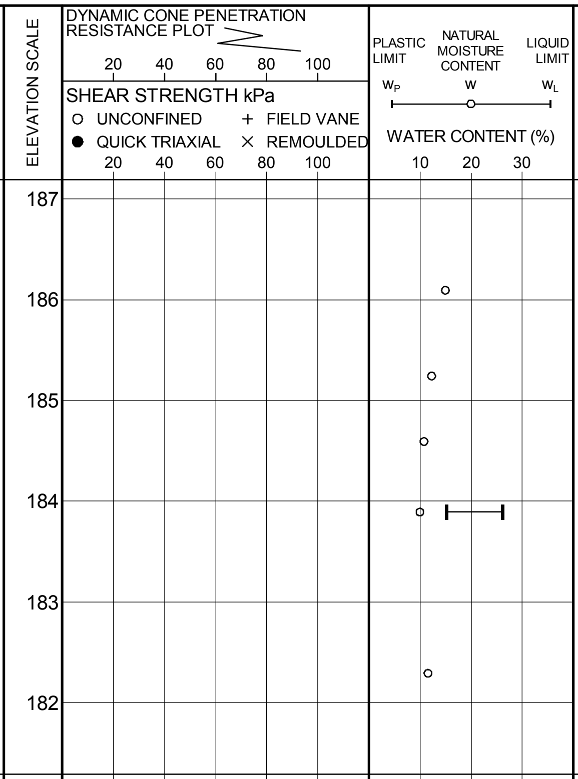
RECORD OF BOREHOLE No 14-10

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
DIST Central HWY 410
DATUM Geodetic
LOCATION N 4834640.3 ;E 290564.1
BOREHOLE TYPE CME 75 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
DATE June 6, 2014
ORIGINATED BY OS
COMPILED BY AV
CHECKED BY LCC

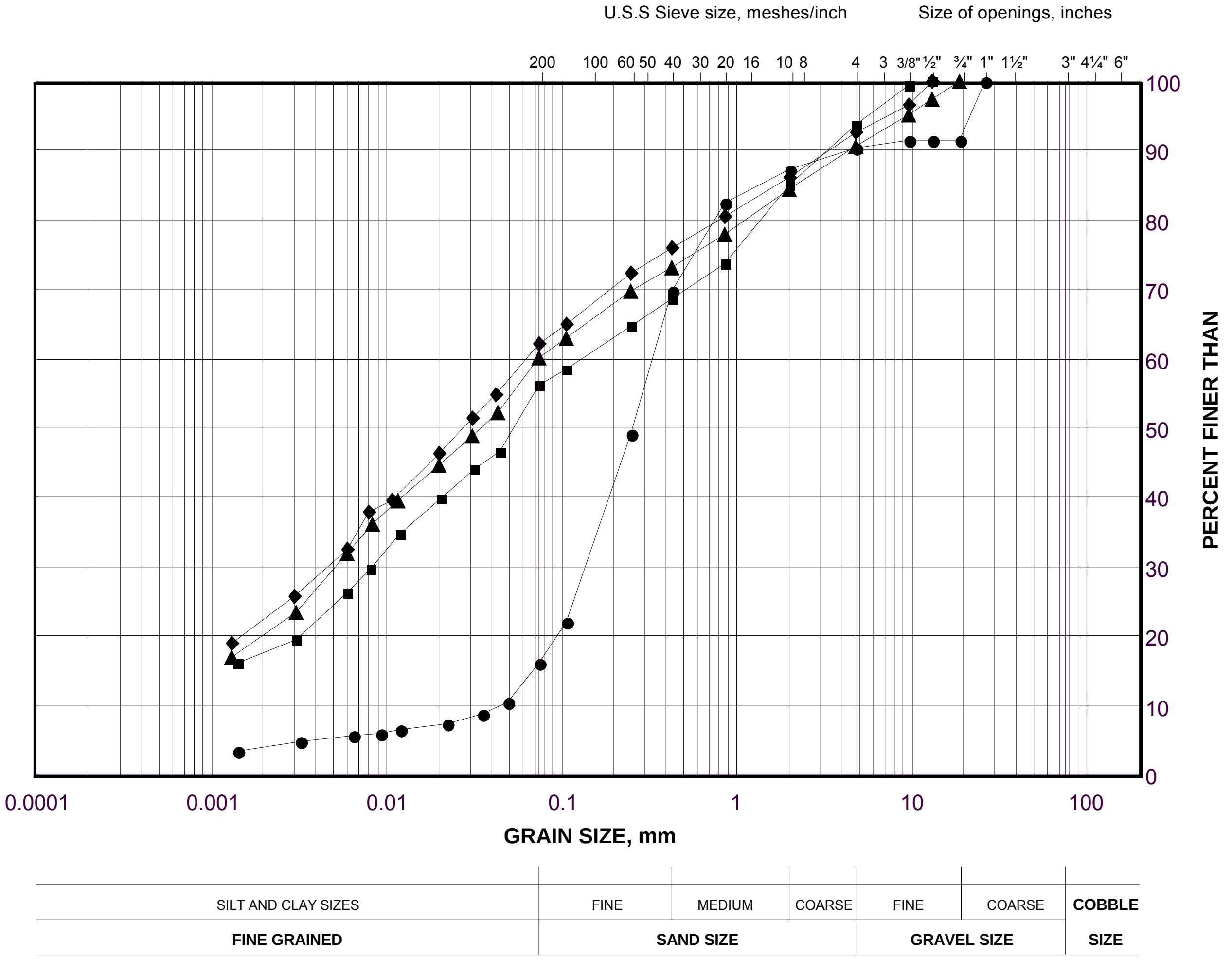
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			GR	SA	SI	CL
187.2	GROUND SURFACE										
0.0	ASPHALT										
0.2	Sand and gravel, containing asphalt fragments and clayey silt pockets (FILL) Brown to grey Moist		1	AS	-						
186.4 0.8	Sand, trace to some silt, trace to some gravel (FILL) Compact Brown Wet		2	SS	13			10	74	12	4
			3A 3B	SS	12						
185.4 1.8	CLAYEY SILT with sand to some sand, trace to some gravel (TILL) Stiff to hard Brown becoming grey below a depth of 3.8 m Moist		4	SS	37						
			5	SS	41			8	30	40	22
			6	SS	27						
			7	SS	19						
			8	SS	15						
181.3 5.9	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.										



$+^3, \times^3$: Numbers refer to Sensitivity $O^{3\%}$ STRAIN AT FAILURE

GRAIN SIZE DISTRIBUTION TEST RESULTS
Str. 1326 - Median - Str. 1327
Approximate Station 6+266

FIGURE F



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	14-10	2	186.1
■	14-08	4	184.7
◆	14-10	5	183.9
▲	14-09	5	182.9

Project Number: 11-1111-0083

Checked By: LC, 27-Aug-14

Golder Associates

Date: 25-Aug-14

APPENDIX G

Borehole Records and Laboratory Test Results
Str. 978 – Str. 979, Approximate Station 7+000

Golder Associates

RECORD OF BOREHOLE No 14-11

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
LOCATION N 4835148.3 ;E 290035.3
ORIGINATED BY EG
DIST Central HWY 410
BOREHOLE TYPE CME 45 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
COMPILED BY AV
DATUM Geodetic
DATE June 9, 2014
CHECKED BY LCC

SOIL PROFILE			SAMPLES								REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 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
183.7	GROUND SURFACE													
0.0	ASPHALT													
0.1	Sand and gravel, containing cobbles (FILL) Loose to dense Brown Moist		1	SS	42		183		○		36	51	9	4
182.6	Clayey silt, some sand, trace gravel (FILL) Firm Mottled dark grey and brown Moist		2A 2B	SS	6									
182.3 1.4	CLAYEY SILT with sand to some sand, some gravel, containing cobbles (TILL) Very stiff to hard Brown becoming grey below a depth of 3.1 m Moist		3	SS	26		182		○ ⊢——⊣		6	25	43	26
			4	SS	28		181		○					
	Auger grinding at a depth of 2.7 m		5	SS	56		180							
	Auger grinding at a depth of 3.8 m		6	SS	48									
179.3 4.4	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.													

$+^3, \times^3$: Numbers refer to Sensitivity $○^{3\%}$ STRAIN AT FAILURE

Golder Associates

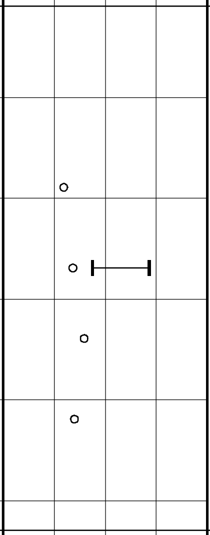
RECORD OF BOREHOLE No 14-12

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
LOCATION N 4835162.1 ;E 290058.2
ORIGINATED BY OS
DIST Central HWY 410
BOREHOLE TYPE CME 75 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
COMPILED BY AV
DATUM Geodetic
DATE June 5, 2014
CHECKED BY LCC

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 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 (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				GR	SA	SI	CL
184.9	GROUND SURFACE													
0.0	ASPHALT													
0.2	Sand and gravel (FILL) Compact Brown Moist		1	AS	-									
			2A 2B	SS	12		184							
183.7 1.2	CLAYEY SILT with sand to some sand, trace to some gravel (TILL) Very stiff Brown becoming grey below a depth of 3.8 m Moist		3	SS	24		183							
			4	SS	20		182				3	20	51	26
			5	SS	22		181							
			6	SS	19									
			7	SS	16		180							
179.7 5.2	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.													



GTA-MTO 001 T:\PROJECTS\2011\11-1111-0083 (URS, PEEL REGION)\LOG\1111110083.GPJ GAL-GTA.GDT 9/4/14

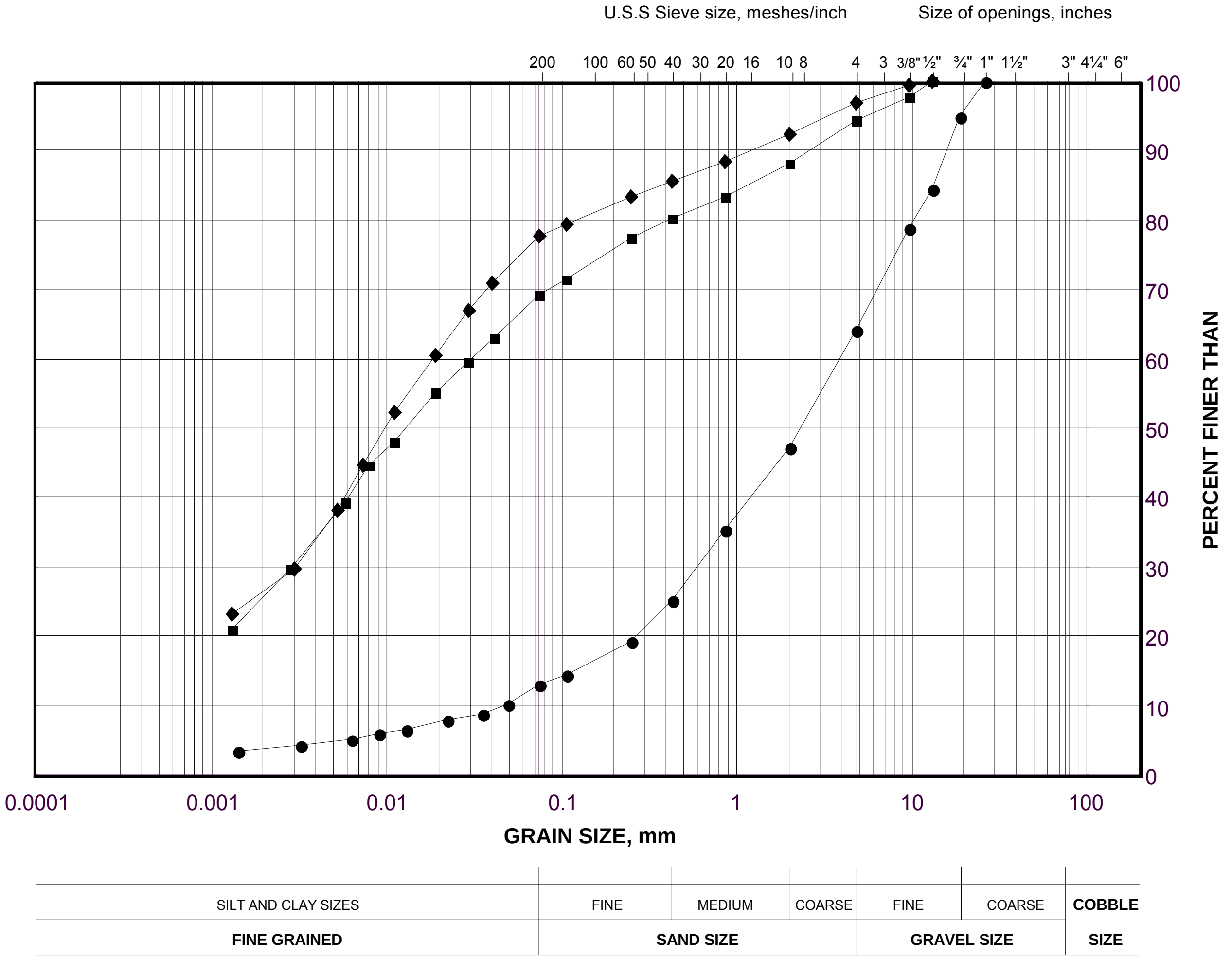
$+^3, \times^3$: Numbers refer to Sensitivity

$\circ^{3\%}$ STRAIN AT FAILURE

GRAIN SIZE DISTRIBUTION TEST RESULTS

Str. 978 - Str. 979
Approxiamte Station 7+000

FIGURE G



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	14-11	1	183.3
■	14-11	3	181.9
◆	14-12	4	182.3

Project Number: 11-1111-0083

Checked By: LC, 27-Aug-14

Golder Associates

Date: 25-Aug-14

APPENDIX H

Borehole Records and Laboratory Test Results
Str. 1018 – Str. 1019, Approximate Station 7+830

RECORD OF BOREHOLE No 14-13

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
DIST Central HWY 410
DATUM Geodetic
LOCATION N 4835772.3 ;E 289468.3
BOREHOLE TYPE CME 75 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
DATE June 5, 2014
ORIGINATED BY OS
COMPILED BY AV
CHECKED BY LCC

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
187.1	GROUND SURFACE
0.0 186.8	ASPHALT
0.3	Sand, some gravel (FILL) Compact Brown and grey Moist
186.0	Clayey silt with sand, trace to some gravel (FILL) Stiff Brown Moist
185.7 1.4	CLAYEY SILT with sand to some sand, trace to some gravel, containing cobbles (TILL) Very stiff to hard Brown becoming grey below a depth of 4.6 m Moist to dry Auger grinding at a depth of 3.5 m
181.9 5.2	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.

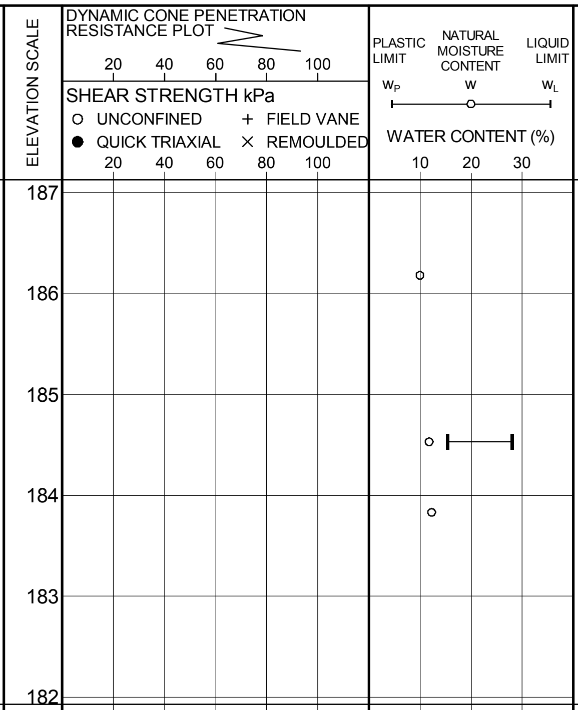
SAMPLES

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	AS	-				
2A	SS	12	10	80	7	3
2B						
3	SS	22				
4	SS	25	3	32	42	23
5	SS	33				
6	SS	50				
7	SS	46				

GROUND WATER CONDITIONS

UNIT WEIGHT γ kN/m^3

REMARKS & GRAIN SIZE DISTRIBUTION (%)



+3, ×3: Numbers refer to Sensitivity

O 3% STRAIN AT FAILURE

OFFICE REPORT ON SOIL EXPLORATION

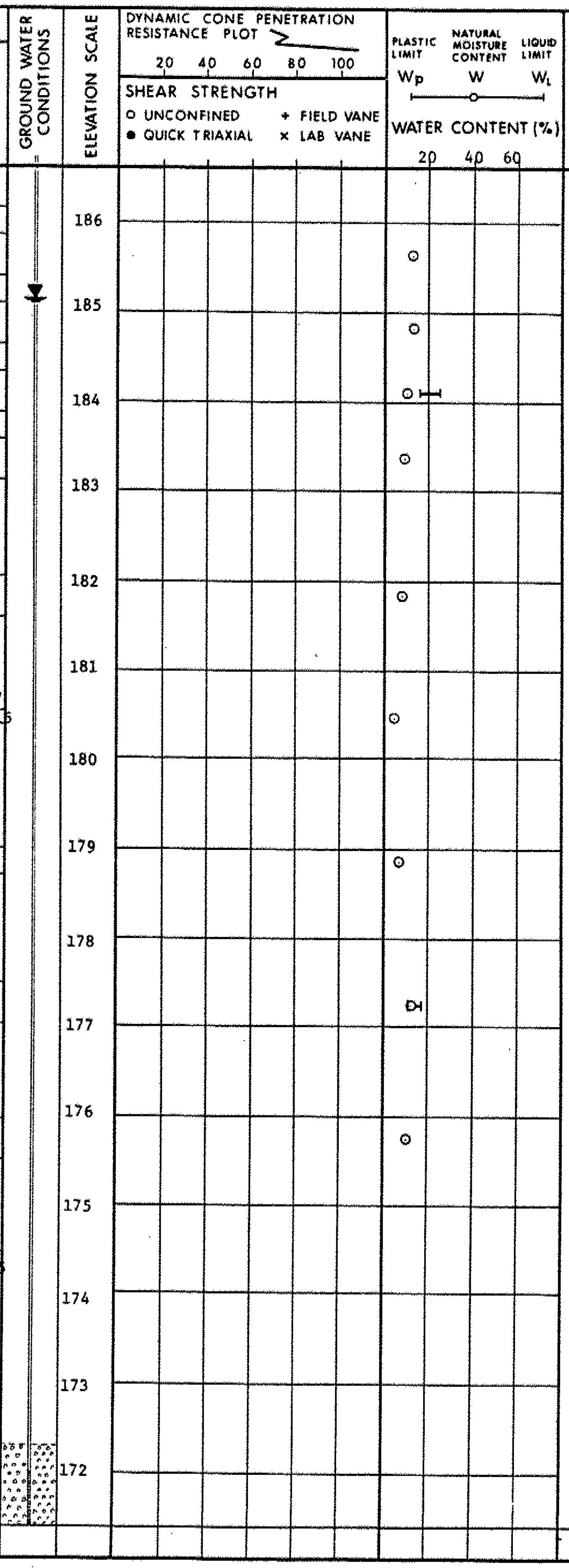
RECORD OF BOREHOLE No 8

METRIC

W P 103-69-15
DIST 6 HWY 410
DATUM Geodetic
LOCATION Co-ords. 4 835 522.5 N; 289 437.5 E.
BOREHOLE TYPE Hollow Stem Augers; BX Rock Core
DATE 1985 12 06-09
ORIGINATED BY IW
COMPILED BY AEL
CHECKED BY

ELEV / DEPTH	SOIL PROFILE DESCRIPTION
186.6	Ground Level
0.0 186.3	Topsoil
0.3	Very stiff Hard Heterogeneous mixture of silty clay, sand & gravel (Glacial Till) Brown Grey
174.3 12.3	Shale bedrock Weathered Dark Grey
171.4	
15.2	End of Borehole

SAMPLES NUMBER	TYPE	'N' VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	8	
2	SS	28	
3	SS	45	
4	SS	68	
5	SS	64	5 33 44 18
6	SS	74	
7	SS	100/ 0.15	
8	SS	74	7 39 50 4
9	SS	83	
10	SS	70	
11	SS	80/ 0.15	
12	RC BX	94%	RQD 25%
13	RC BX	92%	0%



$+^3$, $\times^5$: Numbers refer to Sensitivity

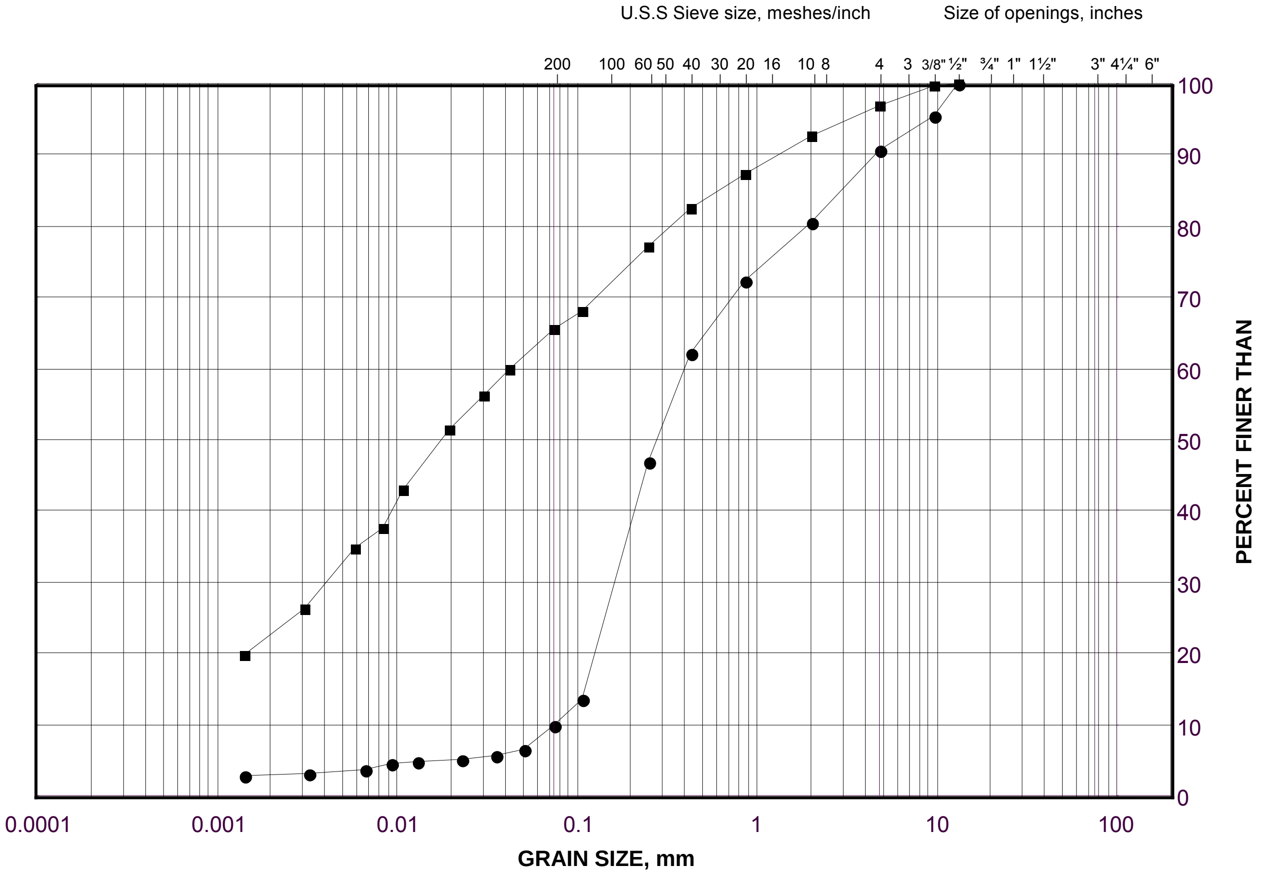
$15 \overset{20}{\underset{10}{\diamond}} 5$ (%) STRAIN AT FAILURE

GRAIN SIZE DISTRIBUTION TEST RESULTS

Str. 1018 - Str. 1019

Approxiamte Station 7+830

FIGURE H



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	14-13	2A	186.2
■	14-13	4	184.5

Project Number: 11-1111-0083

Checked By: LC, 27-Aug-14

Golder Associates

Date: 25-Aug-14

APPENDIX I

Borehole Records and Laboratory Test Results
Str. 1036 – Str. 1038, Approximate Station 8+140

Golder Associates

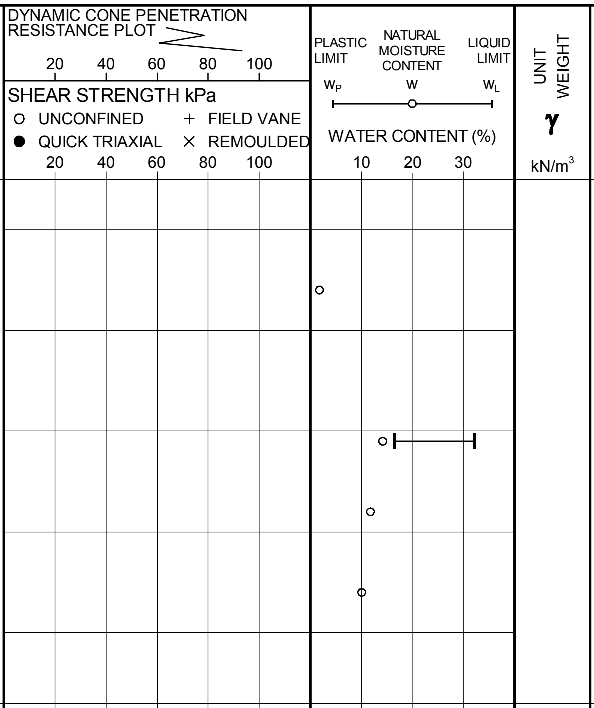
RECORD OF BOREHOLE No 14-14

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
DIST Central HWY 410
DATUM Geodetic
LOCATION N 4835973.1 ;E 289230.8
BOREHOLE TYPE CME 75 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
DATE June 11, 2014
ORIGINATED BY OS
COMPILED BY AV
CHECKED BY LCC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			GR	SA	SI	CL
187.5	GROUND SURFACE										
0.0	ASPHALT										
0.1	Sand, some gravel to sand and gravel (FILL) Compact Brown Moist		1	AS	-		187				
			2	SS	11			46	44	7	3
186.0 1.5	Auger grinding at 1.4 m Clayey silt with sand to some sand, trace to some gravel, containing trace organic material (FILL) Stiff to hard Grey to dark grey Moist to wet		3	SS	39		186				
			4	SS	10		185	5	29	42	24
			5	SS	15		184				
183.7 3.8	CLAYEY SILT, some sand, some gravel (TILL) Very stiff to hard Brown Moist		6	SS	22						
			7	SS	40		183				
182.3 5.2	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.										



$+^3$, $\times^3$: Numbers refer to Sensitivity   O $^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No 14-15

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083

G.W.P. 2144-07-00

DIST Central HWY 410

DATUM Geodetic

LOCATION N 4835996.0 ;E 289248.8

BOREHOLE TYPE CME 75 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers

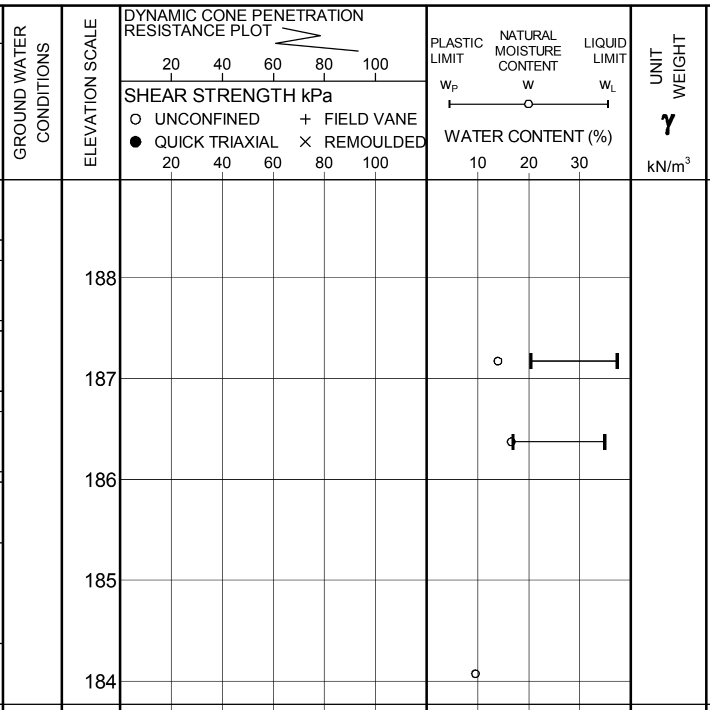
DATE June 10, 2014

ORIGINATED BY OS

COMPILED BY AV

CHECKED BY LCC

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
189.0	GROUND SURFACE							
0.0	ASPHALT							
0.1	Sand and gravel, containing asphalt fragments (FILL) Loose Dark brown to brown Dry to moist	1	AS	-				
188.0 1.0	Clayey silt to silty clay with sand to some sand, trace to some gravel, containing rootlets (FILL) Firm to stiff Brown to dark grey Moist	2A 2B	SS	7				
		3	SS	4	18	25	39	18
		4	SS	7	8	21	42	29
		5	SS	10				
184.9 4.1	CLAYEY SILT, some sand, some gravel, containing cobbles (TILL) Hard Grey Moist Auger grinding at a depth of 4.4 m	6	SS	36				
183.8 5.2	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.							



REMARKS & GRAIN SIZE DISTRIBUTION (%)

+³, ×³: Numbers refer to Sensitivity

O ³% STRAIN AT FAILURE

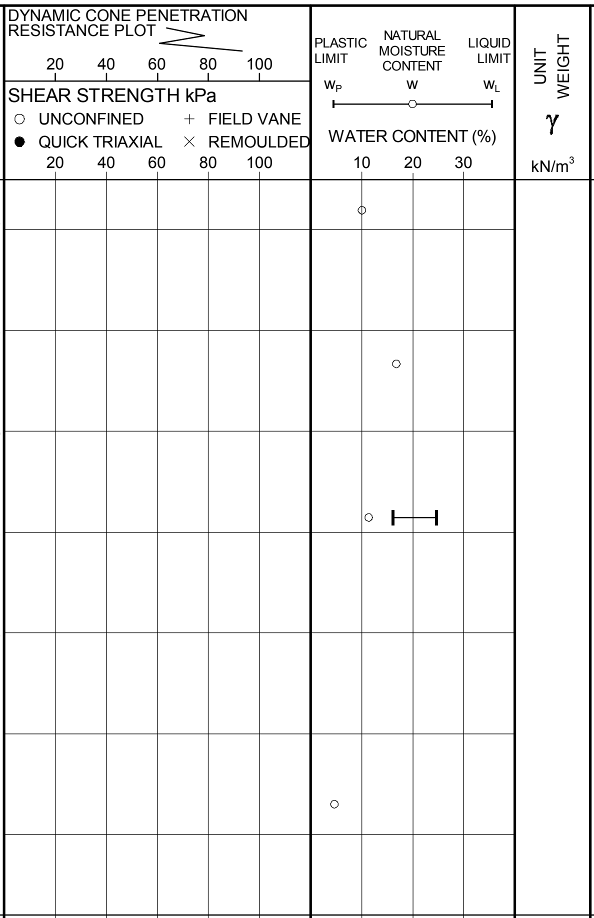
RECORD OF BOREHOLE No P3-3

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083			
G.W.P. 2144-07-00	LOCATION N 4835999.4 ;E 289275.7		ORIGINATED BY TWB
DIST Central HWY 410	BOREHOLE TYPE CME-55 Track-mount, 152 mm Solid Stem Augers		COMPILED BY MAS
DATUM Geodetic	DATE August 21, 2012		CHECKED BY LCC

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	GR	SA	SI	CL
187.5	GROUND SURFACE									
0.0	TOPSOIL									
0.3	Clayey silt, some sand, trace gravel (FILL) Stiff Brown Moist	1	SS	12		187				
	Silty SAND, trace clay, containing organic matter and rootlets (FILL) Loose to compact Brown Moist	2	SS	8		186				
186.0										
185.7 1.8	CLAYEY SILT, some sand, trace gravel, containing rootlets Firm Dark brown Moist	3	SS	6						
		4	SS	17		185				
	CLAYEY SILT with sand, trace to some gravel, containing cobbles and boulders below 3.8 m (TILL) Firm to hard Brown becoming grey below a depth of 3.7 m Moist	5	SS	35		184	7	21	46	26
		6	SS	65		183				
		7	SS	60/0.13						
182.0 5.5	SAND and SILT, trace to some clay, trace gravel, containing cobbles and boulders (TILL) Very dense Grey Moist	8	SS	103/0.20		182 181	1	37	48	14
180.2 7.3	END OF BOREHOLE AUGER REFUSAL NOTE: 1. Open borehole dry upon completion of drilling.									



REMARKS & GRAIN SIZE DISTRIBUTION (%)

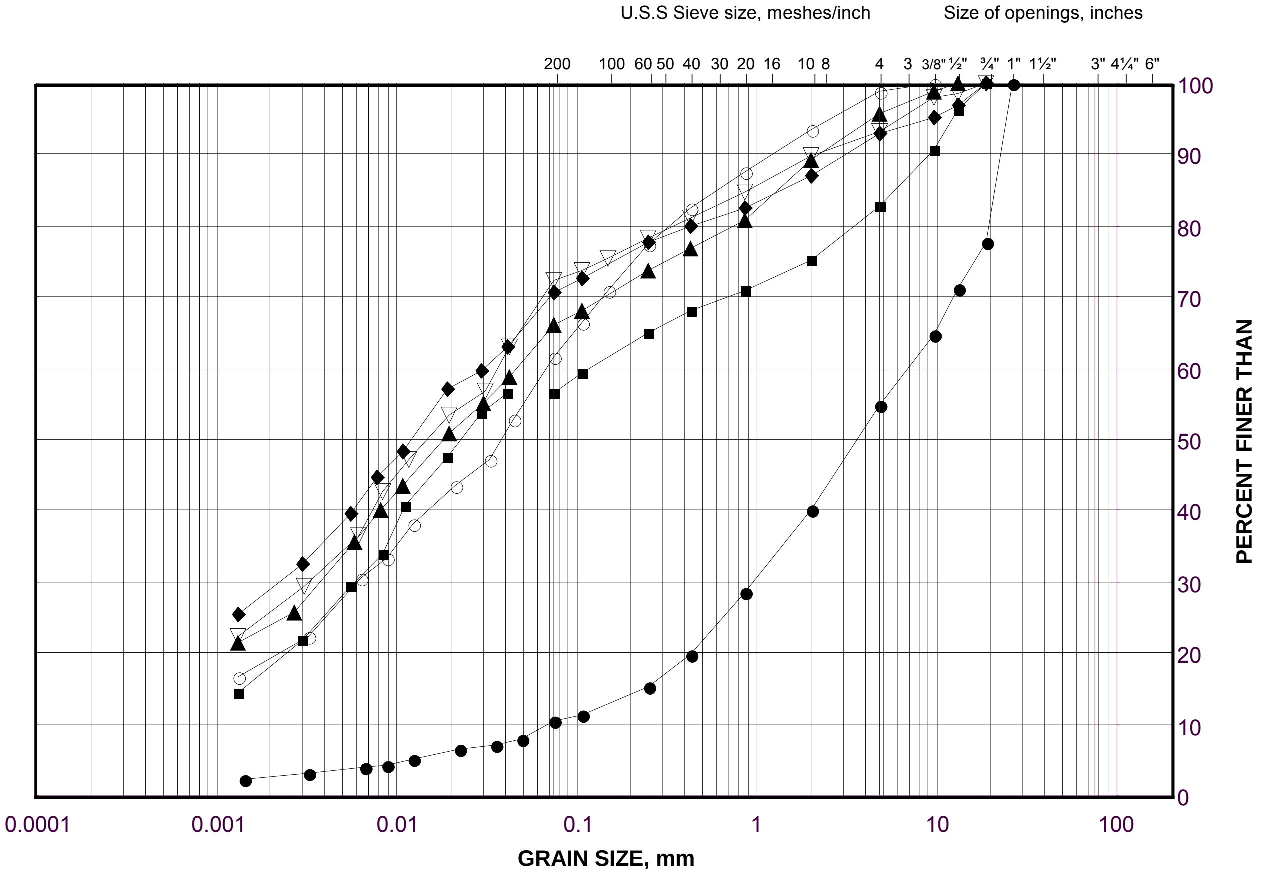
+3, ×3: Numbers refer to Sensitivity ○3% STRAIN AT FAILURE

GRAIN SIZE DISTRIBUTION TEST RESULTS

Str. 1036 - Str. 1028

Approximate Station 8+140

FIGURE I



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	**COBBLE**
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	14-14	2	186.4
■	14-15	3	187.2
◆	14-15	4	186.4
▲	14-14	4	184.9
▽	P3-3	5	184.1
○	P3-3	8	181.3

Project Number: 11-1111-0083

Checked By: LC, 27-Aug-14

Golder Associates

Date: 25-Aug-14

APPENDIX J

Borehole Records and Laboratory Test Results Str. 1105 – Str. 1117 and Str. 1118 – SWM Pond 4, Approximate Station 9+400

RECORD OF BOREHOLE No 14-16

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
DIST Central HWY 410
DATUM Geodetic
LOCATION N 4836905.8 ;E 288367.0
BOREHOLE TYPE CME 75 Track-mount; 152 mm I.D. & 203 mm O.D. Hollow Stem Augers
DATE June 10, 2014
ORIGINATED BY OS
COMPILED BY AV
CHECKED BY LCC

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 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
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES						
192.0	GROUND SURFACE									
0.0	ASPHALT									
0.1	Sand and gravel (FILL) Brown Moist	1	AS	AS						
191.4 0.6	CLAYEY SILT, some sand, some gravel (TILL) Hard Grey Moist	2	SS	50/0.025		191		○		
190.8 1.2	SHALE (BEDROCK) Bedrock cored between depths of 1.5 m and 6.1 m Refer to Record of Drillhole 14-16 for rock coring details.	3	SS	100/0.08						
		1	RC	REC 87%		190				RQD = 30%
		2	RC	REC 100%		189 188				RQD = 91%
		3	RC	REC 100%		187				RQD = 86%
185.9 6.1	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of overburden drilling.					186				

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

$\circ^{3\%}$ STRAIN AT FAILURE

PROJECT: 11-1111-0083

RECORD OF DRILLHOLE: 14-16

SHEET 1 OF 1

LOCATION: N 4836905.8 ;E 288367.0

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: June 10, 2014

DRILL RIG: CME 75 Trackmount

DRILLING CONTRACTOR: Aardvark Drilling

DATUM: Geodetic

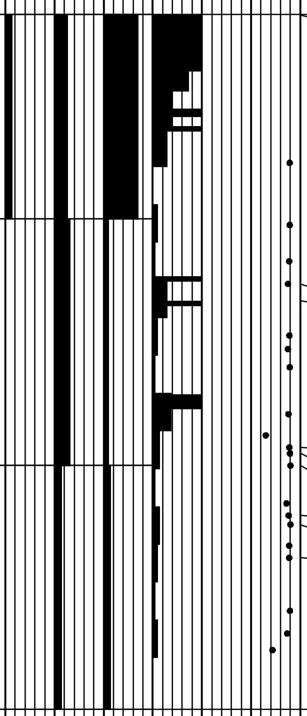
JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate
BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Cleavage
PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular
PO - Polished
K - Slickensided
SM - Smooth
RO - Rough
VR - Very Rough
MB - Mechanical Break
BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.
		Continued from Record of Borehole 14-16	190.48	
1.52 – 6.11	NW Casing NQRC June 10, 2014	Slightly weathered to fresh, thinly bedded, light to dark grey, fine grained, weak to medium strong, SHALE interbedded with LIMESTONE (GEORGIAN BAY FORMATION) Limestone intervals > 2.5 cm (m): 1.89 - 1.94 2.09 - 1.14 2.68 - 2.78 3.82 - 3.85 4.11 - 4.50 4.51 - 4.78 4.91 - 5.11 5.15 - 5.19 5.46 - 5.61 Total limestone in Run No. 1 = 15% Total limestone in Run No. 2 = 26% Total limestone in Run No. 3 = 41%	1.52	1 2 3
		END OF DRILLHOLE	185.89 6.11	

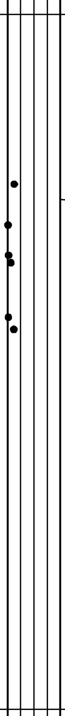
COLOUR % RETURN / FLUSH

RECOVERY: TOTAL CORE % / SOLID CORE % (80 60 40 20); R.Q.D. % (80 60 40 20); FRACT. INDEX PER 0.25 (5 10 15 20); DISCONTINUITY DATA: B Angle (0 90 180 270), DIP w.r.t. CORE AXIS (0 30 60 90)



TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn
LC,,			
BC,,			2
BC,,			
BD,PL,SM	1	1	
BD,PL,RO	1.5	1	
BD,PL,RO	1.5	1	
BC,,			
BD,PL,RO	1.5	1	
BC,,			
BD,PL,RO	1.5	1	4
BD,PL,RO	1	10	
BD,PL,RO	1	6	
BC,,			
BD,CU,RO	1	10	
JN,UN,RO	3	1	
BD,PL,RO	1.5	1	
BD,PL,RO	1.5	1	
BD,PL,RO	1.5	1	
BD,CU,RO	3	1	
BD,PL,SM	1	1	
BD,PL,RO	1	10	
BD,IR,RO	3	1	
BD,PL,RO	1	5	
			4
BD,PL,RO	1	5	
BD,PL,RO	1	5	
JN,PL,RO	1.5	1	

HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-6} 10^{-5} 10^{-4} 10^{-3}); Diametral Point Load Index (MPa) (2 4 6); RMC -Q' AVG.



NOTES

(Axial)
UC = 86 MPa

(Axial)

(Axial)

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: NAS
CHECKED: LCC

RECORD OF BOREHOLE No 14-17

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083

G.W.P. 2144-07-00

LOCATION N 4836912.6 ;E 288389.0

ORIGINATED BY OS

DIST Central HWY 410

BOREHOLE TYPE CME 75 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers

COMPILED BY AV

DATUM Geodetic

DATE June 11, 2014

CHECKED BY LCC

SOIL PROFILE			SAMPLES								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 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
193.5	GROUND SURFACE										
0.0	ASPHALT										
0.2	Sand, some gravel, some silt (FILL) Loose to dense Brown Moist		1	AS	-		193				
192.7 0.9	Clayey silt, trace sand, trace gravel (FILL) Hard Brown Moist		2A 2B	SS	89						36 19 36 9
			3	SS	100/0.13		192				
191.9 1.6	CLAYEY SILT with gravel, some sand (TILL) Hard Grey Dry to moist		1	RC	REC 75%		191				RQD = 33%
	SHALE (BEDROCK) Bedrock cored between depths of 1.6 m and 6.2 m Refer to Record of Drillhole 14-17 for rock coring details.		2	RC	REC 100%		190 189				RQD = 95%
			3	RC	REC 100%		188				RQD = 72%
187.3 6.2	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of overburden drilling.										

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

$\bigcirc^{3\%}$ STRAIN AT FAILURE

PROJECT: 11-1111-0083

RECORD OF DRILLHOLE: 14-17

SHEET 1 OF 1

LOCATION: N 4836912.6 ;E 288389.0

INCLINATION: -90°   AZIMUTH: ---

DRILLING DATE: June 11, 2014

DRILL RIG: CME 75 Truck-mount

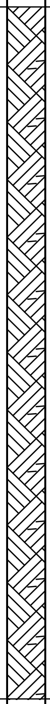
DRILLING CONTRACTOR: Aardvark Drilling

DATUM: Geodetic

JN - Joint	BD - Bedding	PL - Planar	PO - Polished	MB - Mechanical Break
FLT - Fault	FO - Foliation	CU - Curved	K - Slickensided	BR - Broken Rock
SH - Shear	CO - Contact	UN - Undulating	SM - Smooth	**NOTE:** For additional abbreviations refer to list of abbreviations & symbols.
VN - Vein	OR - Orthogonal	ST - Stepped	RO - Rough	
CJ - Conjugate	CL - Cleavage	IR - Irregular	VR - Very Rough	

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	NOTES
		Continued from Record of Borehole 14-17	191.95		
2	NW Casing	Slightly weathered to fresh, thinly bedded, light to dark grey, fine grained, weak to medium strong, SHALE interbedded with limestone (GEORGIAN BAY FORMATION) Limestone intervals > 2.5 cm (m): 1.98 - 2.39 2.47 - 2.77 3.13 - 3.18 4.09 - 4.12 5.32 - 6.18 Total limestone in Run No. 1 = 47% Total limestone in Run No. 2 = 5% Total limestone in Run No. 3 = 55%	1.60	1	(Axial)
3					
4	NQRC June 11, 2014			2	(Axial) UC = 33 MPa (Axial) (Axial)
5				3	
6			187.37 6.18		
		END OF DRILLHOLE			
7					
8					
9					
10					
11					

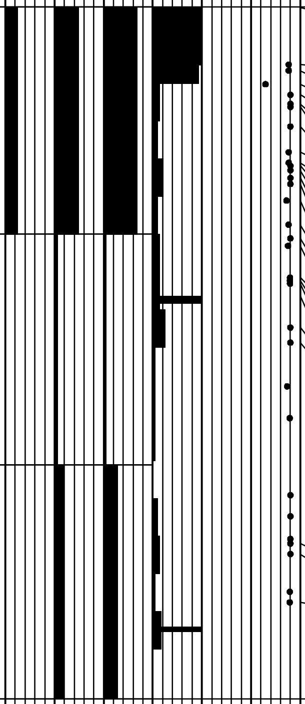
SYMBOLIC LOG



COLOUR % RETURN / FLUSH

RECOVERY: TOTAL CORE % / SOLID CORE % (80 60 40 20); R.Q.D. % (80 60 40 20); FRACT. INDEX PER 0.25 (5 10 15 20)

DISCONTINUITY DATA: B Angle (0 90 180 270); DIP w.r.t. CORE AXIS (0 30 60 90)



TYPE AND SURFACE DESCRIPTION

LC,,
BC,,
BD,PL,RO
BD,UN,RO
JN,PL,RO
BD,PL,RO
BD,PL,RO
BD,PL,RO
BD,PL,SM
BD,PL,RO
BD,PL,RO
BD,PL,RO
BD,PL,RO
BD,PL,RO
BD,PL,RO
BD,PL,RO
BD,PL,RO
BD,CU,RO
BD,PL,SM
BD,PL,RO
BD,PL,RO
BD,PL,RO
BC,,
BD,PL,RO
BD,PL,RO
BD,CU,SM
BD,PL,RO
BD,PL,RO
BD,PL,RO
BD,PL,RO
BD,PL,RO
BD,PL,RO
BD,PL,RO
BD,PL,RO
BC,,

Jr	Ja	Jn
1.5	20	
1.5	20	
3	22	
1.5	20	
1.5	20	
1.5	20	4
1	0	
1.5	20	
1.5	20	
1	0	
1.5	20	
1.5	20	
1.5	20	
1	0	
1.5	20	
1	6	
2	20	
1.5	20	
1.5	20	
1.5	20	
1.5	20	
1.5	20	2
2	20	
1.5	20	
1	0	
1.5	20	
1.5	20	
1.5	20	
1	0	
		2
1.5	20	
1	0	

HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-6} 10^{-5} 10^{-4} 10^{-3})

Diametral Point Load Index (MPa) (2 4 6)

RMC -Q' AVG.

GTA-RCK 018 T:\PROJECTS\2011\11-1111-0083 (URS, PEEL REGION)\LOG\1111110083.GPJ GAL-MISS.GDT 9/4/14

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: NAS

CHECKED: LCC

RECORD OF BOREHOLE No 14-18

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
DIST Central HWY 410
DATUM Geodetic
LOCATION N 4836918.0 ;E 288409.1
BOREHOLE TYPE CME 75 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
DATE June 9, 2014
ORIGINATED BY OS
COMPILED BY AV
CHECKED BY LCC

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 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
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
192.6	GROUND SURFACE										
0.0	ASPHALT										
0.2	Gravelly sand, some silt (FILL) Brown Moist to wet		1	AS	-		192				
191.8	CLAYEY SILT, some sand, some gravel (TILL) Hard Grey Moist		2	SS	100/0.10						20 21 42 17
191.4 1.2	SHALE (BEDROCK) Bedrock augered from 1.2 m to 2.2 m. Auger grinding throughout. Auger refusal at 2.2 m Bedrock cored between depths of 2.3 m and 6.1 m Refer to Record of Drillhole 14-18 for rock coring details.		3	SS	100/0.08		191				
			4	SS	100/0.08						
			1	RC	REC 100%		190				RQD = 33%
			2	RC	REC 100%		189				RQD = 78%
			3	RC	REC 100%		188 187				RQD = 60%
186.5 6.1	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of overburden drilling.										

GTA-MTO 001 T:\PROJECTS\2011\11-1111-0083 (URS, PEEL REGION)\LOG\1111110083.GPJ GAL-GTA.GDT 9/4/14

$+^3, \times^3$: Numbers refer to Sensitivity $\circ^{3\%}$ STRAIN AT FAILURE

PROJECT: 11-1111-0083

RECORD OF DRILLHOLE: 14-18

SHEET 1 OF 1

LOCATION: N 4836918.0 ;E 288409.1

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: June 9, 2014

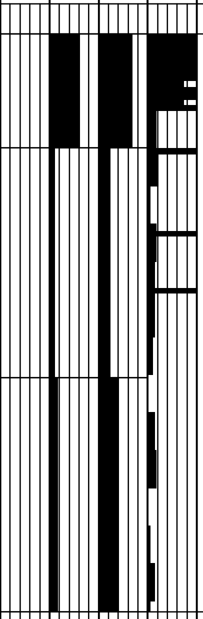
DRILL RIG: CME 75 Truck-mount

DRILLING CONTRACTOR: Aardvark Drilling

DATUM: Geodetic

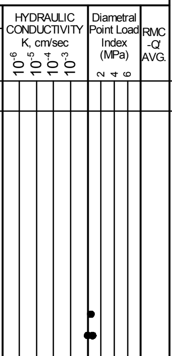
JN - Joint	BD - Bedding	PL - Planar	PO - Polished	MB - Mechanical Break
FLT - Fault	FO - Foliation	CU - Curved	K - Slickensided	BR - Broken Rock
SH - Shear	CO - Contact	UN - Undulating	SM - Smooth	**NOTE:** For additional abbreviations refer to list of abbreviations & symbols.
VN - Vein	OR - Orthogonal	ST - Stepped	RO - Rough	
CJ - Conjugate	CL - Cleavage	IR - Irregular	VR - Very Rough	

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	NOTES
		Continued from Record of Borehole 14-18	190.28		
3	NW Casing NQRC June 9, 2014	Slightly weathered, thinly bedded, light to dark grey, fine grained, weak to medium strong, SHALE with interbedded limestone (GEORGIAN BAY FORMATION) Limestone intervals > 2.5 cm (m): 2.83 - 2.86 3.19 - 3.30 3.93 - 3.98 4.34 - 4.43 4.78 - 4.81 5.04 - 5.76 CLAYEY SILT seams (m) 4.57 - 4.70 4.74 - 4.76 4.93 - 4.94 5.77 - 5.78 Total limestone in Run No. 1 = 4% Total limestone in Run No. 2 = 16% Total limestone in Run No. 3 = 48%	2.30	1 2 3	UC = 50 MPa (Axial) (Axial)
4					
5					
6			186.46 6.12		
		END OF DRILLHOLE			
7					
8					
9					
10					
11					
12					



DISCONTINUITY DATA

B Angle (0 90 180 270)	DIP w.r.t. CORE AXIS (0 30 60 90)	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn
		BC,,			
		BC,,			2
		BC,,			
		BD,PL,RO	1.5	1	
		BC,,			
		BD,CU,RO	3	1	
		BD,PL,SM	1	1	
		BD,CU,SM	2	1	
		BC,,			
					2
		BD,PL,SM	2	1	
		BC,,			
		BD,PL,RO	1.5	1	
		BD,PL,SM	1	1	
		BD,PL,RO	1	10	
		BD,PL,SM	1	4	
		BD,PL,RO	1.5	1	
		BD,PL,SM	1	4	
		BD,PL,SM	1	1	
		BD,PL,SM	1	10	
		BD,PL,SM	1	10	
		BD,PL,SM	1	4	
		BD,PL,SM	1	4	
		BD,PL,RO	1	1	
		BD,PL,SM			3
		BD,PL,RO	1	6	
		BD,PL,RO	1	4	
		BD,PL,RO	1.5	1	
		BD,PL,RO	1	10	
		JN,PL,RO	1.5	3	



GTA-RCK 018 T:\PROJECTS\2011\11-1111-0083 (URS, PEEL REGION)\LOG\1111110083.GPJ GAL-MISS.GDT 9/4/14

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: NAS
CHECKED: LCC

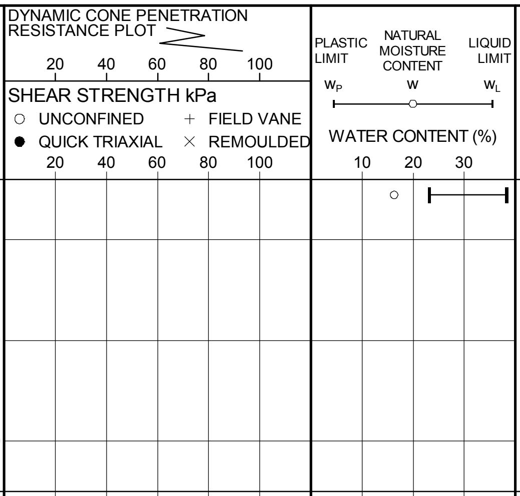
RECORD OF BOREHOLE No P4-3

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
LOCATION N 4836878.4 ;E 288351.3
ORIGINATED BY CS
DIST Central HWY 410
BOREHOLE TYPE D-50 Track-mount, 152 mm Solid Stem Augers
COMPILED BY MAS
DATUM Geodetic
DATE August 28, 2012
CHECKED BY LCC

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
191.6	GROUND SURFACE										
0.0 0.1	SILTY CLAY, some sand, trace gravel, containing rootlets Firm Brown Moist	1	SS	85/0.20				1	14	50	35
						191					
	SHALE (BEDROCK) Weathered Grey	2	SS	50/0.15							
		3	SS	50/0.05		190					
						189					
188.5 3.1	END OF BOREHOLE SPLIT-SPOON BOUNCING NOTE: 1. Open borehole dry upon completion of drilling.										

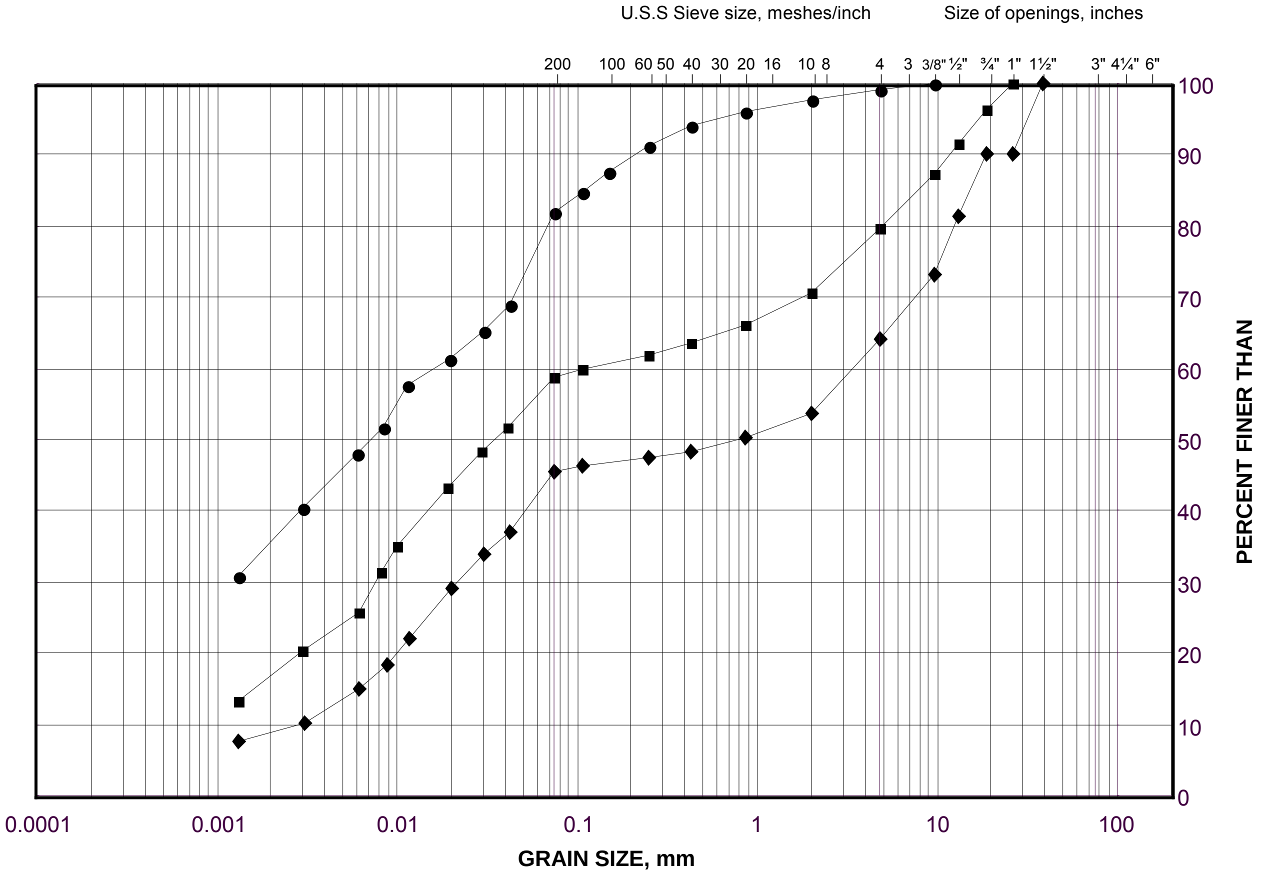


+3, ×3: Numbers refer to Sensitivity ○3% STRAIN AT FAILURE

GRAIN SIZE DISTRIBUTION TEST RESULTS

Str. 1105 - Str. 1117 and Str. 1118 - SWM Pond 4
Approximate Station 9+400

FIGURE J



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	**COBBLE**
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	P4-3	1A	191.4
■	14-18	2	191.7
◆	14-17	2B	192.4

Project Number: 11-1111-0083

Checked By: LC, 27-Aug-14

Golder Associates

Date: 25-Aug-14

APPENDIX K

Borehole Records and Laboratory Test Results
Str. 1126 – Outlet, Approximate Station 9+700

RECORD OF BOREHOLE No 14-19

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083

G.W.P. 2144-07-00

LOCATION N 4837213.6 ;E 288321.2

ORIGINATED BY OS

DIST Central HWY 410

BOREHOLE TYPE CME 75 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers

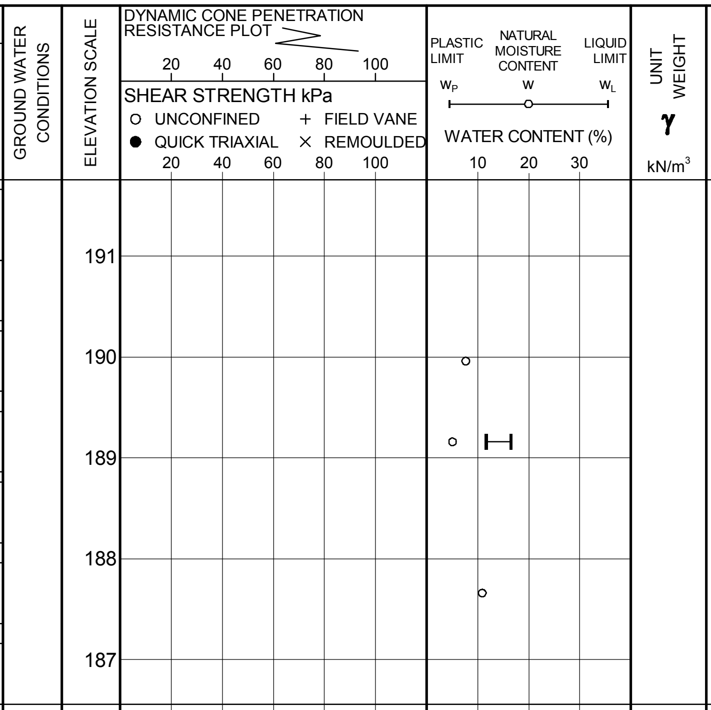
COMPILED BY AV

DATUM Geodetic

DATE June 10, 2014

CHECKED BY LCC

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
191.8	GROUND SURFACE							
0.0	ASPHALT							
0.1	Gravelly sand, some silt (FILL) Dense Brown Moist	1	AS	-				
190.9 0.9	CLAYEY SILT with sand to some sand, some gravel, containing cobbles (TILL) Very stiff to hard Grey Dry to moist Auger grinding at 1.2 m Auger grinding from 2.0 m to 2.3 m Auger grinding from 2.4 m to 3.0 m	2A 2B	SS	48				
		3	SS	30				
		4	SS	151	20	39	32	9
		5	SS	57				
		6	SS	29				
		7	SS	51				
186.6 5.2	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.							



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

$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No 14-20

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
DIST Central HWY 410
DATUM Geodetic
LOCATION N 4837221.0 ;E 288342.3
BOREHOLE TYPE CME 45 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
DATE June 10, 2014
ORIGINATED BY EG
COMPILED BY AV
CHECKED BY LCC

SOIL PROFILE		SAMPLES			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
192.5	GROUND SURFACE							
0.0	ASPHALT							
0.2	Sand and gravel (FILL) Compact Dark brown Moist	1	AS	-				
191.5	Clayey silt with sand, trace gravel, containing roootlets (FILL) Very stiff Grey Moist	2A 2B	SS	15				
191.1 1.4	CLAYEY SILT with sand to some sand, trace to some gravel, containing cobbles (TILL) Hard Grey Moist Auger grinding throughout deposit	3	SS	38				
		4	SS	79	18	34	35	13
		5A 5B	SS	63				
		6	SS	50/0.13				
187.8 4.7	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.							

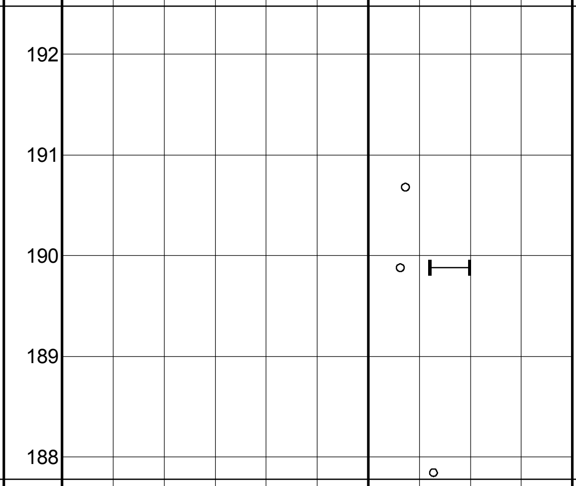
STRAT PLOT — GROUND WATER CONDITIONS — ELEVATION SCALE

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × REMOULDED
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



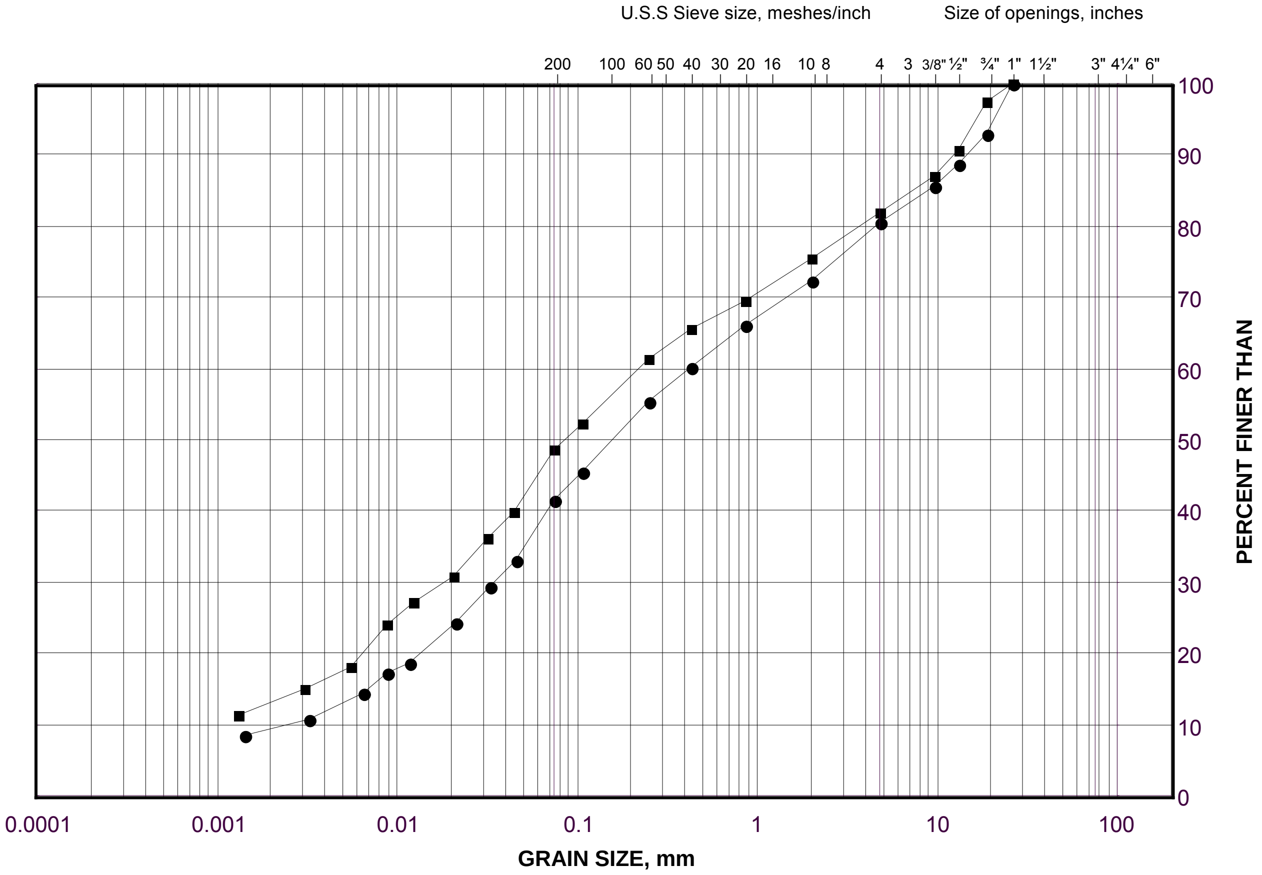
$+^3, \times^3$: Numbers refer to Sensitivity ○ $^{3\%}$ STRAIN AT FAILURE

GRAIN SIZE DISTRIBUTION TEST RESULTS

Str. 1126 - Outlet

Approximate Station 9+700

FIGURE K



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	**COBBLE**
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	14-19	4	189.2
■	14-20	4	189.9

Project Number: 11-1111-0083

Checked By: LC, 27-Aug-14

Golder Associates

Date: 25-Aug-14

APPENDIX L

Borehole Records and Laboratory Test Results
Str. 1143 – Str. 1141, Approximate Station 10+040

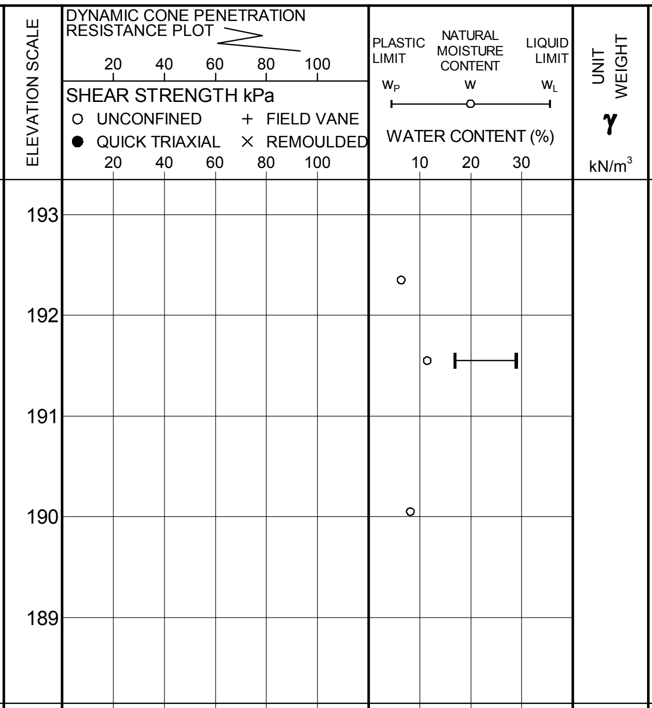
RECORD OF BOREHOLE No 14-21

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
LOCATION N 4837504.8 ;E 288185.4
ORIGINATED BY OS
DIST Central HWY 410
BOREHOLE TYPE CME 75 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
COMPILED BY AV
DATUM Geodetic
DATE June 3, 2014
CHECKED BY LCC

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
193.4	GROUND SURFACE								
193.1 0.0	ASPHALT								
0.3	Sand, some gravel (FILL) Compact Brown Moist	1	AS	-					
192.2		2A	SS	14		18	66	13	3
1.2	CLAYEY SILT with sand to some sand, trace to some gravel, containing cobbles (TILL) Hard Brown becoming grey below a depth of 3.1 m Moist Auger grinding at a depth of 1.8 m Auger grinding at a depth of 2.7 m	2B							
		3	SS	32		6	28	42	24
		4	SS	35					
		5	SS	49					
		6	SS	100					
188.2		7	SS	85					
5.2	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.								



REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

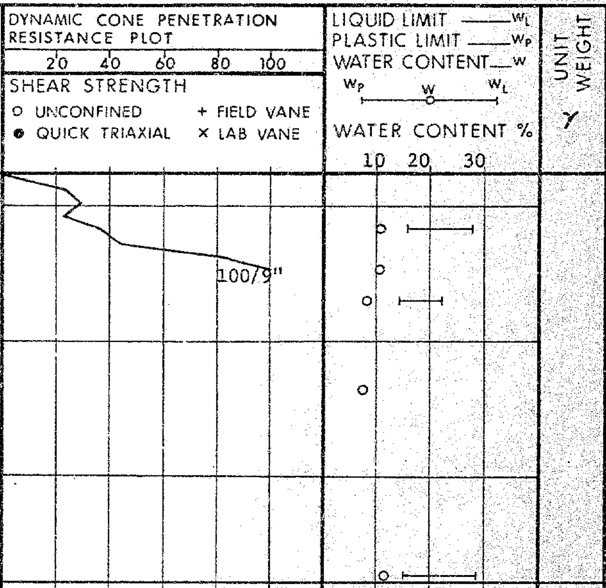
MINISTRY OF TRANSPORTATION AND COMMUNICATIONS-ONTARIO

ENGINEERING SERVICES BRANCH-GEOTECHNICAL OFFICE-SOIL MECHANICS SECTION

RECORD OF BOREHOLE Nº 3(1) (Culvert 3)

WP 103-69-08
DIST 6 HWY 410
DATUM Geodetic
LOCATION Co-ords. N 15,870,340 E 945,576
BORING DATE July 21, 1976
BOREHOLE TYPE C.M.E. 5.1 (1) M.V.H.S.
ORIGINATED BY VK
COMPILED BY VK
CHECKED BY

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER ELEV	REMARKS % GR SA SI CL
632.2	Ground Level					
0.0					630	
		1	SS	34		5 18 47 30
	Brown	2	SS	70		
	Grey	3	SS	100/6"		5 28 48 19
	Het. mix. of clayey silt, sand and gravel (Glacial Till)	4	SS	115	620	
		5	SS	115		13 34 52 1
	Hard	6	SS	75/6"	610	
		7	SS	70/6"		
602.1		8	SS	80/1"		4 23 47 26
30.1	End of Borehole					

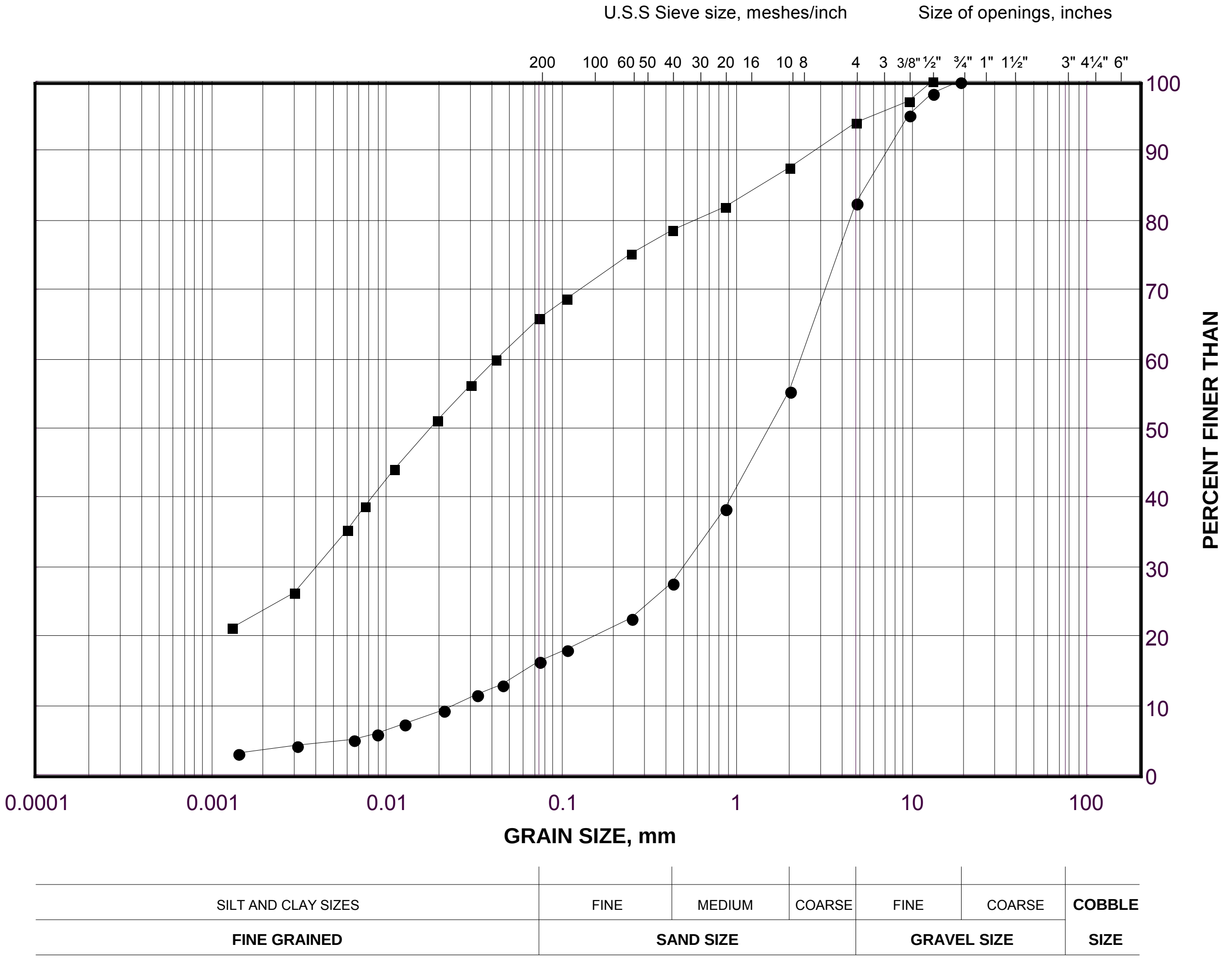


20
15 ◇ 5 % STRAIN AT FAILURE
10

OFFICE REPORT ON SOIL EXPLORATION

GRAIN SIZE DISTRIBUTION TEST RESULTS
Str. 1143 - Str. 1141
Approximate Station 10+040

FIGURE L



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	14-21	2A	192.4
■	14-21	3	191.6

Project Number: 11-1111-0083

Checked By: LC, 27-Aug-14

Golder Associates

Date: 25-Aug-14

APPENDIX M

Borehole Records and Laboratory Test Results
Str. 1158 – Outlet, Approximate Station 10+460

RECORD OF BOREHOLE No 14-22

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083

G.W.P. 2144-07-00

DIST Central HWY 410

DATUM Geodetic

LOCATION N 4837916.9 ;E 288114.2

BOREHOLE TYPE CME 45 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers

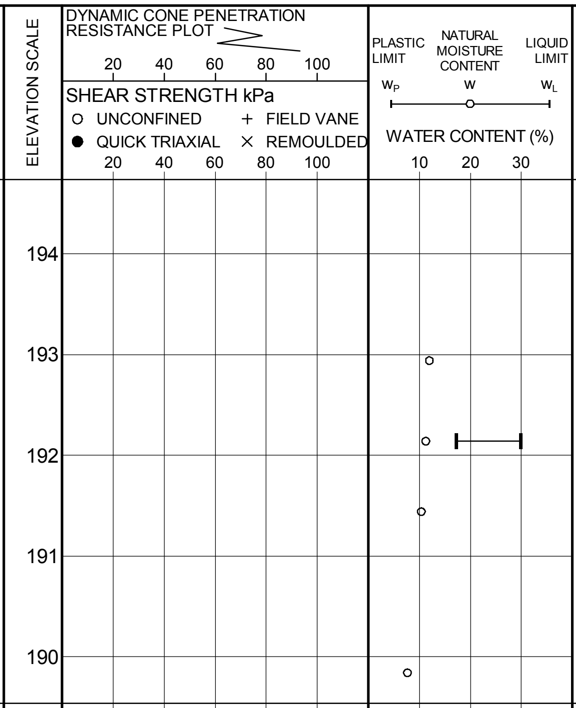
DATE June 1, 2014

ORIGINATED BY EG

COMPILED BY AV

CHECKED BY LCC

ELEV DEPTH	SOIL PROFILE: DESCRIPTION	SAMPLES: NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
194.7	GROUND SURFACE							
0.0	Sand and gravel (FILL) Dense Brown Moist	1	SS	32				
194.0 0.7	Clayey silt with sand to some sand, trace to some gravel (FILL) Stiff to very stiff Brown with oxidation staining Moist	2	SS	11				
		3	SS	24				
		4	SS	28	12	25	40	23
191.7 3.0	CLAYEY SILT, some sand, trace to some gravel, containing cobbles (TILL) Hard Brown becoming grey below a depth of 4.6 m Moist	5	SS	35				
		6	SS	37				
	Auger grinding at a depth of 4.6 m	7	SS	32				
189.5 5.2	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.							



+3, ×3: Numbers refer to Sensitivity

○3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 12-14

SHEET 1 OF 1

METRIC

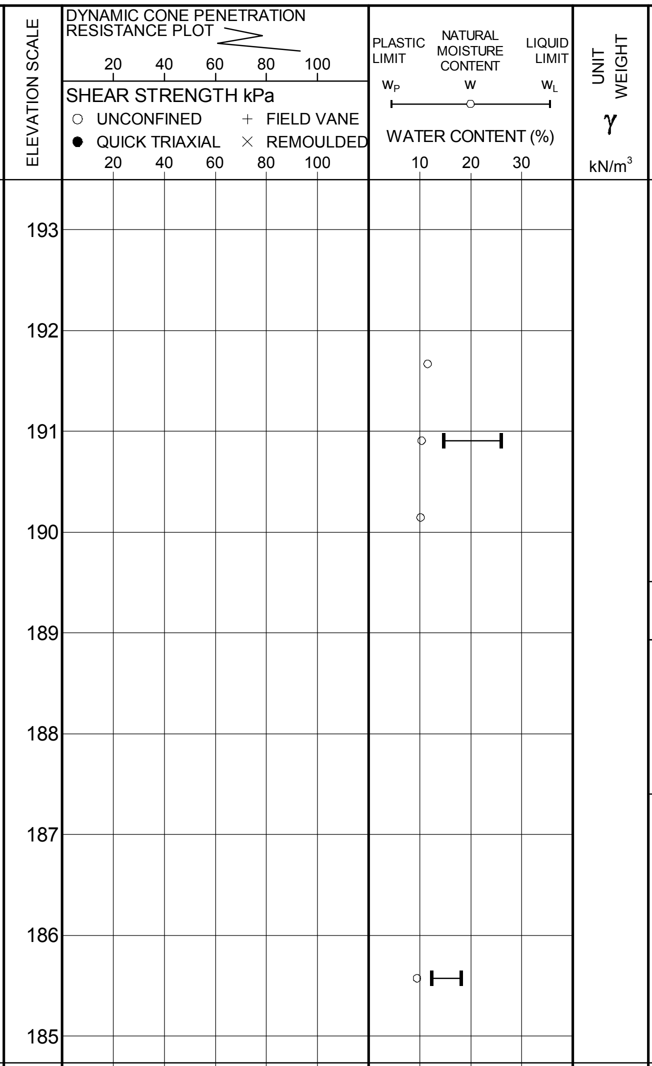
PROJECT 11-1111-0083
G.W.P. 2144-07-00
DIST Central HWY 410
DATUM Geodetic
LOCATION N 4837913.0 ;E 288085.2
BOREHOLE TYPE CME 75 Track-mount, 108 mm I.D. Hollow Stem Augers
DATE October 21, 2012
ORIGINATED BY PC
COMPILED BY AV/GL
CHECKED BY GDS

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
193.5	GROUND SURFACE								
0.0	TOPSOIL								
0.1	Clayey silt, some sand, some gravel, trace rootlets (FILL) Stiff to very stiff Brown Moist	1	SS	9					
		2	SS	23					
192.0 1.5	CLAYEY SILT with SAND, trace to some gravel (TILL) Very stiff Brown to gery Moist	3	SS	28					
		4	SS	26		6	33	43	18
		5	SS	28					
		6	SS	50/0.18					
189.5 4.0	COBBLES and BOULDERS	1	RC	REC 70%		RQD = 0%			
		2	RC	REC 24%		RQD = 0%			
187.2	SAND and GRAVEL	7	SS	85					
6.5	CLAYEY SILT with SAND, trace to some gravel (TILL) Hard Grey Moist	8	SS	80		8	38	44	10
184.7 8.8	END OF BOREHOLE PRACTICAL AUGER REFUSAL								

NOTES:

1. Borehole dry upon completion of drilling.

2. Borehole backfilled with bentonite.



+3, ×3: Numbers refer to Sensitivity

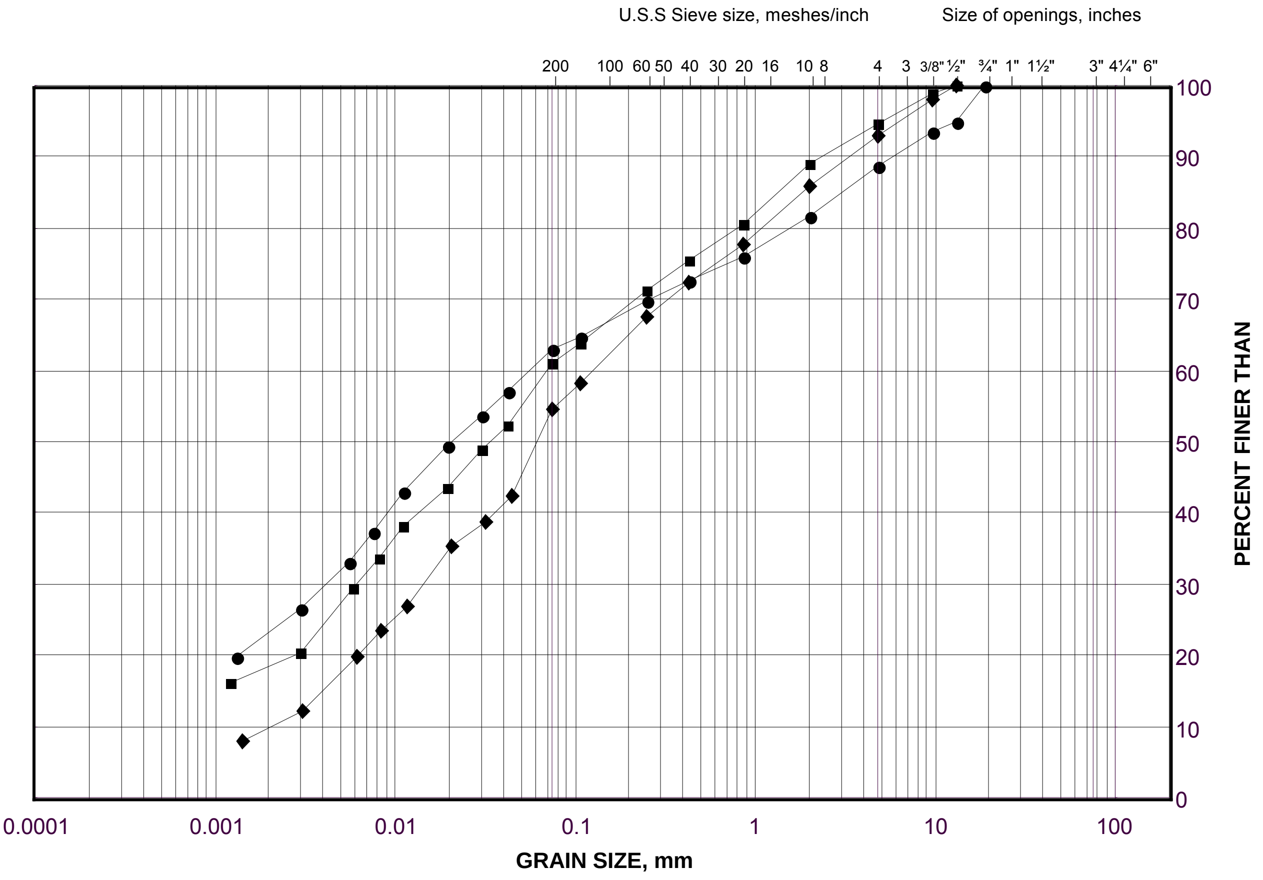
○3% STRAIN AT FAILURE

GRAIN SIZE DISTRIBUTION TEST RESULTS

Str. 1158 - Outlet

Approximate Station 10+460

FIGURE M



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	**COBBLE**
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	14-22	4	192.1
■	12-14	4	190.9
◆	12-14	8	185.6

Project Number: 11-1111-0083

Checked By: LC, 27-Aug-14

Golder Associates

Date: 25-Aug-14

APPENDIX N

Borehole Records and Laboratory Test Results
Str. 1176 – Outlet, Approximate Station 10+750

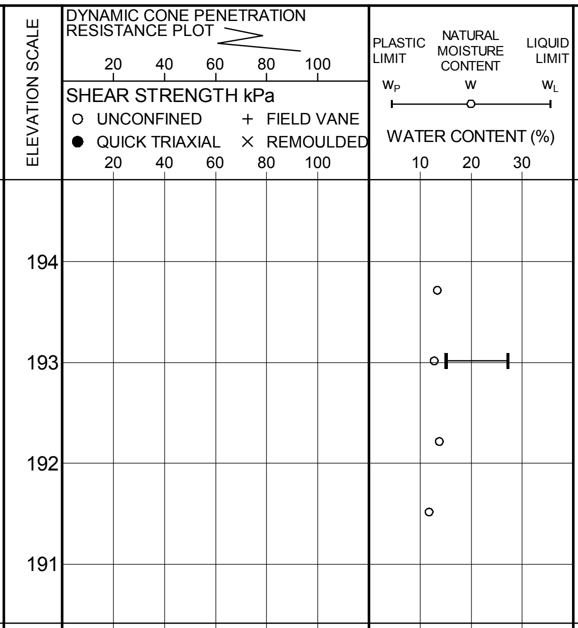
RECORD OF BOREHOLE No 14-23

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
LOCATION N 4838170.4 ;E 287958.2
ORIGINATED BY EG
DIST Central HWY 410
BOREHOLE TYPE CME 45 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
COMPILED BY AV
DATUM Geodetic
DATE June 10, 2014
CHECKED BY LCC

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	SAMPLES TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
194.8	GROUND SURFACE									
0.0	ASPHALT									
0.1	Sand and gravel, containing asphalt fragments (FILL) Dark brown Dry	1	AS	-						
194.0 0.8	Clayey silt, some sand, some gravel (FILL) Very stiff Mottled grey and brown Moist	2	SS	19						
193.4 1.4	CLAYEY SILT with sand to some sand, trace to some gravel (TILL) Very stiff to hard Brown Moist	3	SS	22			4	25	46	25
		4	SS	19						
		5	SS	29						
		6	SS	36						
190.4 4.4	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.									



REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

$\circ^{3\%}$ STRAIN AT FAILURE

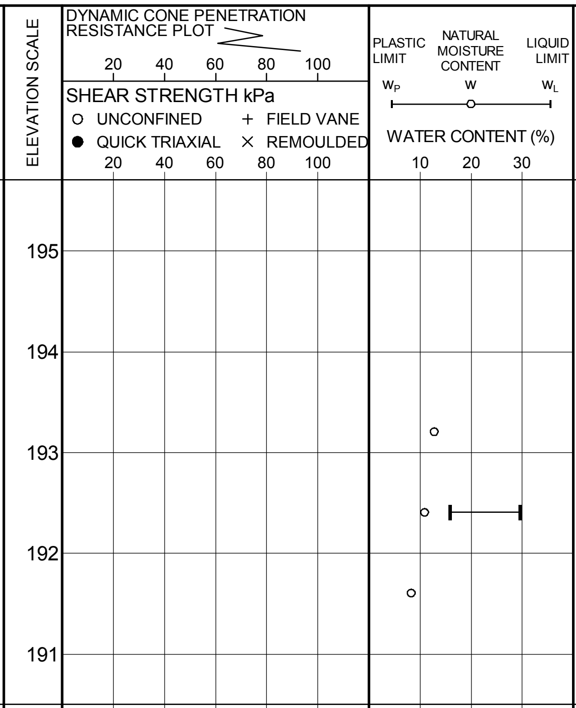
RECORD OF BOREHOLE No 14-24

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
DIST Central HWY 410
DATUM Geodetic
LOCATION N 4838174.9 ;E 287991.7
BOREHOLE TYPE CME 45 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
DATE June 1, 2014
ORIGINATED BY EG
COMPILED BY AV
CHECKED BY LCC

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
195.7	GROUND SURFACE								
0.0	Gravelly sand (FILL) Compact Brown to dark brown Moist	1	SS	24					
194.6 1.1	Clayey silt with sand, some gravel, containing sand seams (FILL) Very stiff Brown Moist	2A 2B	SS	16					
		3	SS	17					
193.5 2.2	Silty sand, trace gravel (FILL) Loose Brown Moist	4A 4B	SS	7		6	67	22	5
193.0	Clayey silt with sand, some gravel, containing cobbles (FILL) Firm Mottled grey brown to grey Moist								
192.7 3.0	CLAYEY SILT with sand to some sand, some gravel (TILL) Hard Brown becoming grey below a depth of 3.8 m Moist	5	SS	32		10	30	39	21
		6	SS	67					
		7	SS	77					
190.5 5.2	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.								



UNIT WEIGHT γ kN/m³

+³, ×³: Numbers refer to Sensitivity

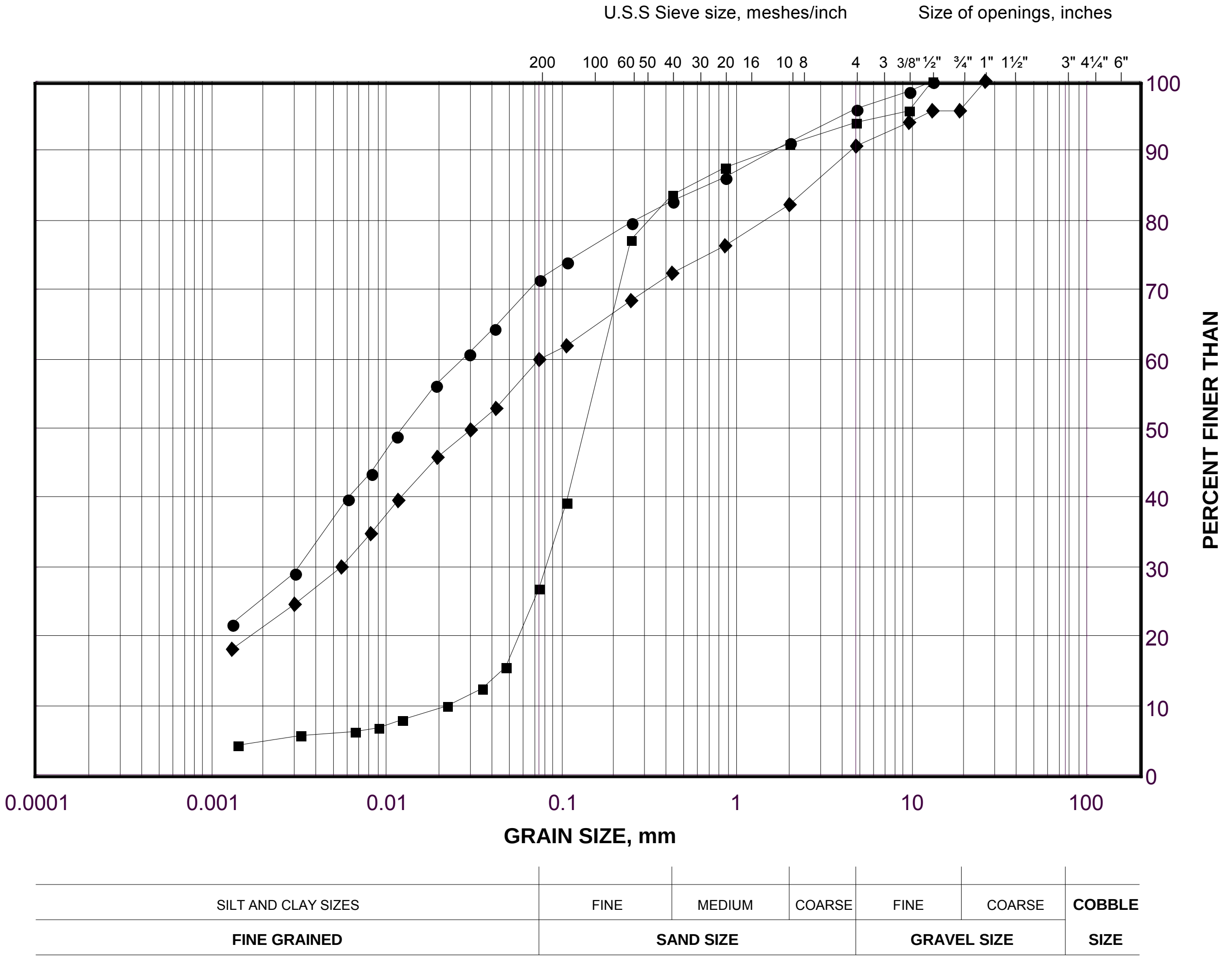
○ 3% STRAIN AT FAILURE

GRAIN SIZE DISTRIBUTION TEST RESULTS

Str. 1176 - Outlet

Approximate Station 10+750

FIGURE N



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	14-23	3	193.0
■	14-24	4A	193.2
◆	14-24	5	192.4

Project Number: 11-1111-0083

Checked By: LC, 27-Aug-14

Golder Associates

Date: 25-Aug-14

APPENDIX O

Borehole Records and Laboratory Test Results
Str. 1182 – Str. 1183, S-E/W Ramp at Steeles Avenue

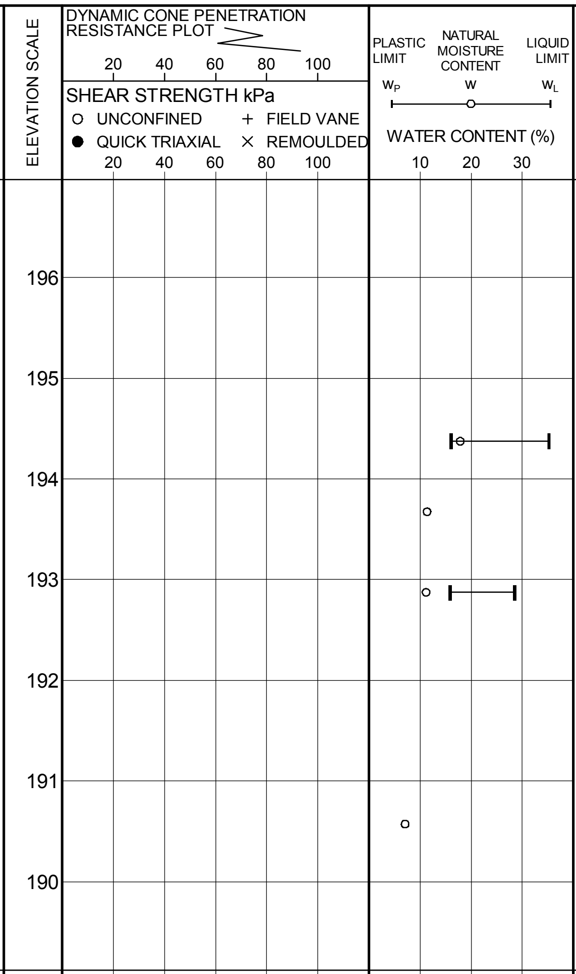
RECORD OF BOREHOLE No 14-25

SHEET 1 OF 1

METRIC

PROJECT	11-1111-0083		
G.W.P.	2144-07-00	LOCATION	N 4838397.1 ;E 287914.7
DIST	Central HWY 410	BOREHOLE TYPE	CME 45 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
DATUM	Geodetic	DATE	June 10, 2014
ORIGINATED BY	EG		
COMPILED BY	AV		
CHECKED BY	LCC		

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
197.0	GROUND SURFACE									
0.0	ASPHALT									
0.1	Sand and gravel (FILL) Compact Brown Moist	1	SS	21						
196.0 1.0	Clayey silt to silty clay with sand to some sand, trace gravel (FILL) Firm to very stiff Mottled grey and brown with oxidation staining Moist	2A 2B	SS	16						
		3A 3B	SS	7						
		4	SS	9						
193.7 3.3	CLAYEY SILT with sand to some sand, trace to some gravel, containing cobbles (TILL) Very stiff to hard Mottled brown becoming grey below a depth of 4.6 m Moist	5	SS	26						
		6	SS	43			9	29	39	23
		7	SS	37						
	Auger grinding between 5.2 m and 6.9 m	8	SS	50/0.13						
		9	SS	70						
		10	SS	50/0.13						
189.2		11	SS	50/0.08						
7.9	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.									



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

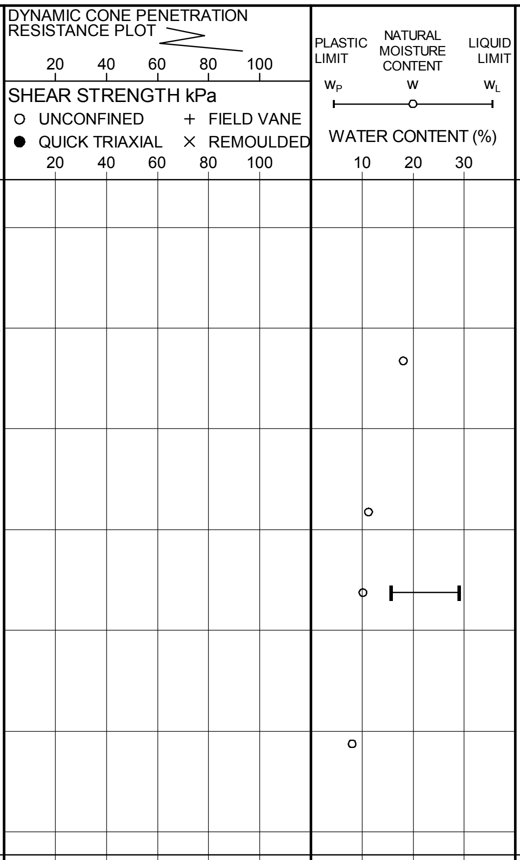
RECORD OF BOREHOLE No 14-26

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
DIST Central HWY 410
DATUM Geodetic
LOCATION N 4838397.0 ;E 287927.0
BOREHOLE TYPE CME 45 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
DATE June 1, 2014
ORIGINATED BY EG
COMPILED BY AV
CHECKED BY LCC

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
196.5	GROUND SURFACE									
0.0	Sand and gravel (FILL) Very dense Brown Moist	1	SS	88	196					
195.8 0.7	Clayey silt with sand to some sand, trace to some gravel (FILL) Firm to very stiff Mottled grey brown with oxidation staining Moist	2	SS	13	195					
		3	SS	7						
		4	SS	25	194					
		5	SS	25	193		5	30	41	24
192.8 3.7	CLAYEY SILT with sand to some sand, trace to some gravel, containing cobbles (TILL) Hard Brown becoming grey below a depth of 5.3 m Moist Auger grinding between 4.4 m and 5.3 m	6	SS	52	192		3	32	41	24
		7	SS	80						
		8	SS	46	191					
		9	SS	82	190					
189.8 6.7	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.									



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

RECORD OF BOREHOLE No P6-2

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083

G.W.P. 2144-07-00

LOCATION N 4838372.4 ;E 287879.1

ORIGINATED BY CS

DIST Central HWY 410

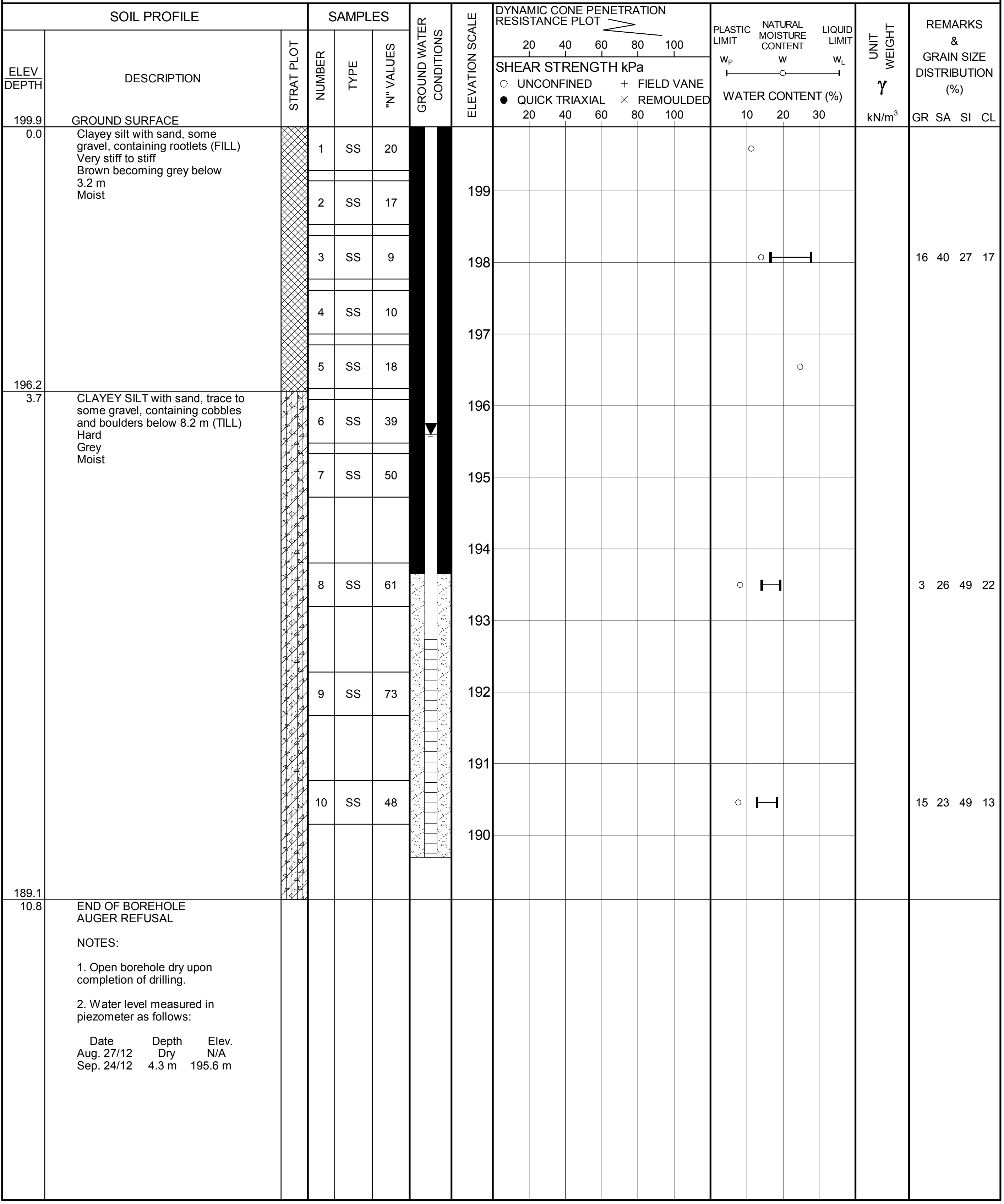
BOREHOLE TYPE D-50 Track-mount, 152 mm Solid Stem Augers

COMPILED BY MAS

DATUM Geodetic

DATE August 26 and 27, 2012

CHECKED BY LCC



ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
199.9	GROUND SURFACE							
0.0	Clayey silt with sand, some gravel, containing rootlets (FILL) Very stiff to stiff Brown becoming grey below 3.2 m Moist	1	SS	20				
		2	SS	17				
		3	SS	9	16	40	27	17
		4	SS	10				
		5	SS	18				
196.2 3.7	CLAYEY SILT with sand, trace to some gravel, containing cobbles and boulders below 8.2 m (TILL) Hard Grey Moist	6	SS	39				
		7	SS	50				
		8	SS	61	3	26	49	22
		9	SS	73				
		10	SS	48	15	23	49	13
189.1 10.8	END OF BOREHOLE AUGER REFUSAL							

NOTES:

1. Open borehole dry upon completion of drilling.

2. Water level measured in piezometer as follows:

Date	Depth	Elev.
Aug. 27/12	Dry	N/A
Sep. 24/12	4.3 m	195.6 m

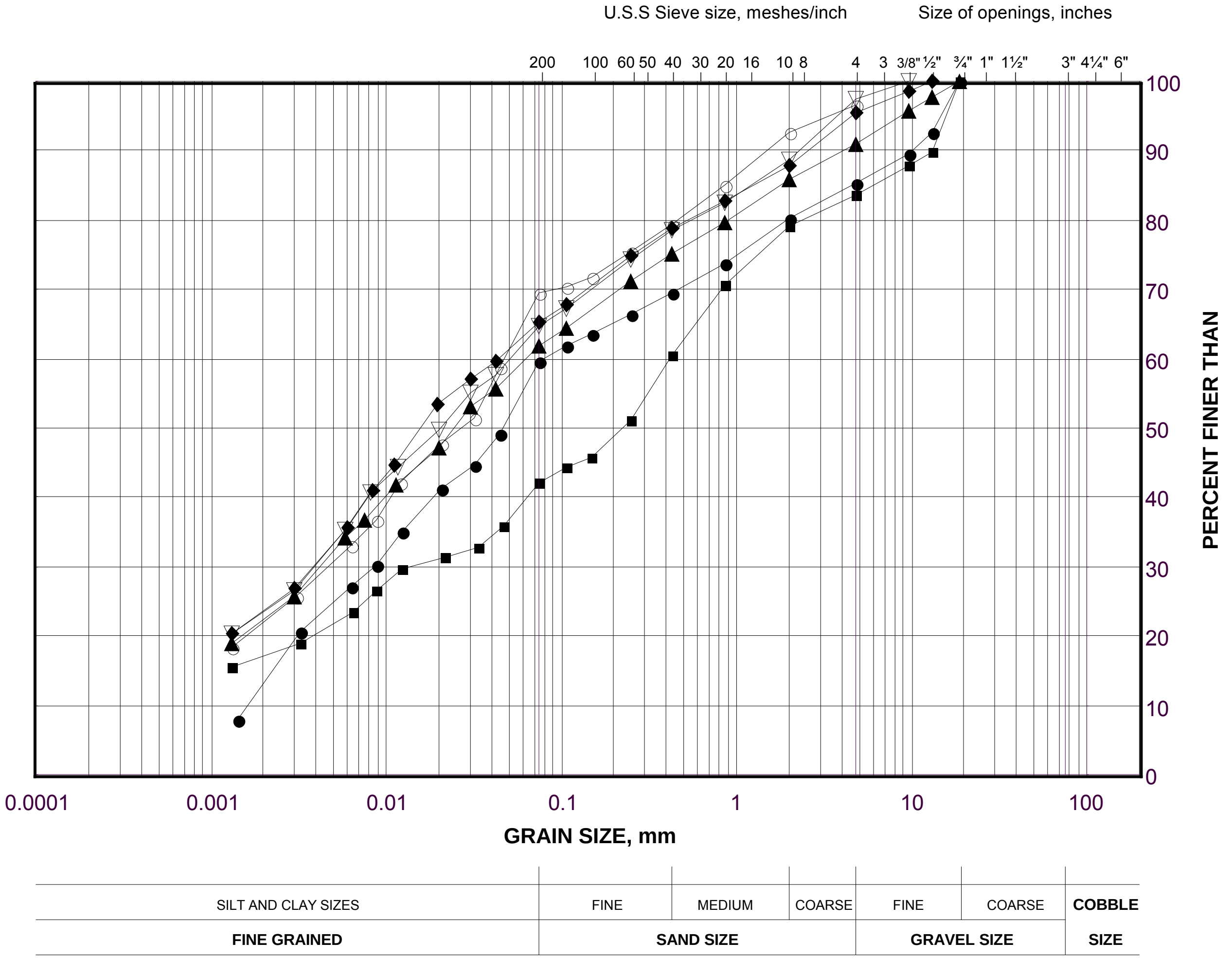
$+^3, \times^3$: Numbers refer to Sensitivity

$\bigcirc^{3\%}$ STRAIN AT FAILURE

GRAIN SIZE DISTRIBUTION TEST RESULTS

Str. 1182 - Str. 1183
S-E/W Ramp at Steeles Avenue

FIGURE O



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	P6-2	10	190.5
■	P6-2	3	198.1
◆	14-26	5	193.2
▲	14-25	6	192.9
▽	14-26	6	192.4
○	P6-2	8	193.5

Project Number: 11-1111-0083

Checked By: LC, 27-Aug-14

Golder Associates

Date: 25-Aug-14

APPENDIX P

Borehole Records and Laboratory Test Results
Str. 1247 – Str. 1249, Approximate Station 11+950

RECORD OF BOREHOLE No 14-27

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083

G.W.P. 2144-07-00

LOCATION N 4839042.3 ;E 287118.8

ORIGINATED BY OS

DIST Central HWY 410

BOREHOLE TYPE CME 75 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers

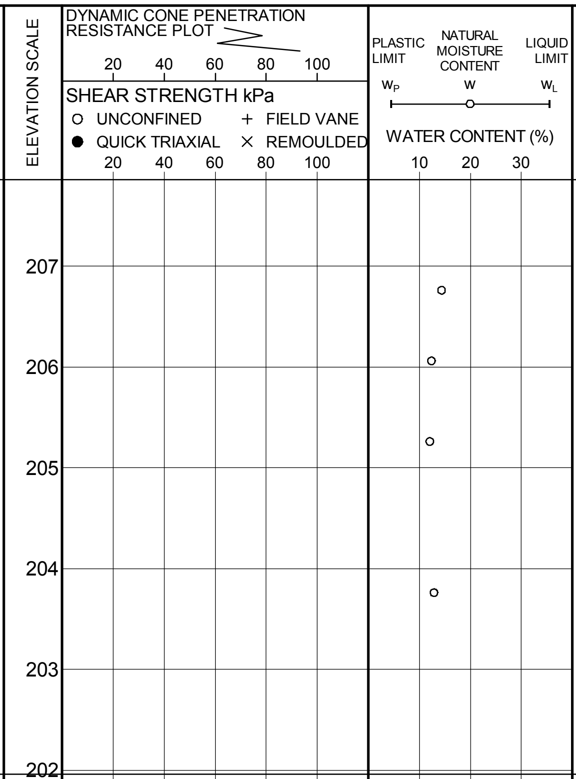
COMPILED BY AV

DATUM Geodetic

DATE June 2, 2014

CHECKED BY LCC

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
207.9	GROUND SURFACE										
0.0	ASPHALT	■									
0.1	Sand and gravel, trace silt (FILL) Dense Brown Moist	▨	1	AS	-						
207.0 0.9	Sand and silt to silty sand, trace to some gravel (FILL) Loose to compact Brown to grey Moist	▨	2	SS	9						
		▨	3	SS	8			5	47	39	9
	Containing clayey silt pockets, rootlets and trace organic material at a depth of 2.3 m	▨	4	SS	10			5	44	38	13
		▨	5	SS	10						
204.1 3.8	Clayey silt, some sand, trace gravel (FILL) Very stiff Brown Moist	▨	6	SS	15						
203.3 4.6	Silty sand, some gravel, trace clay and trace organic material, containing clayey silt lenses (FILL) Compact Brown to grey Moist	▨	7	SS	13						
		▨	8	SS	21						
202.0 5.9	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.										



REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

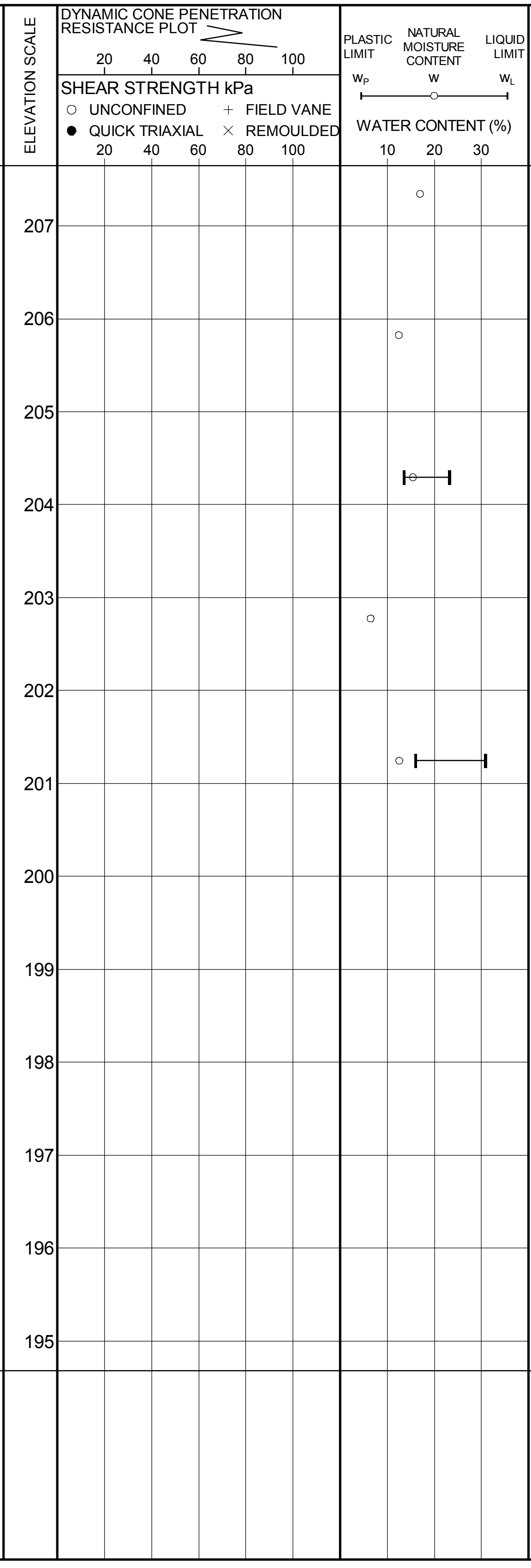
$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No GR-6

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
DIST Central HWY 410
DATUM Geodetic
LOCATION N 4839053.3 ;E 287147.6
BOREHOLE TYPE CME-55 Track-mount, 108 mm Inner Diameter Hollow Stem Augers
DATE November 7, 2011
ORIGINATED BY MS
COMPILED BY NK
CHECKED BY LCC



ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	SAMPLES TYPE	"N" VALUES	GR	SA	SI	CL
207.7	GROUND SURFACE							
0.0	Clayey silt, trace to some sand, trace gravel (FILL) Firm to stiff Brown Moist	1	SS	5				
		2	SS	11				
206.4 1.3	Sand and silt, trace clay, trace gravel (FILL) Compact Brown Moist	3	SS	18	4	53	36	7
205.5 2.2	Clayey silt, trace to some sand, trace gravel, containing pockets of sandy silt (FILL) Firm to stiff Brown Moist	4	SS	9				
		5	SS	7				
		6	SS	7				
203.4 4.3	Gravelly sand, some silt, trace clay (FILL) Dense Brown Moist	7	SS	31	27	58	13	2
202.1 5.6	Clayey silt, with to some sand, some gravel, containing rootlets (FILL) Very stiff Grey Moist	8	SS	15	16	23	34	27
200.7	Boulder	9	SS	50/.05				
200.4 7.3	Clayey silt, with to some sand, some gravel (FILL) Very stiff Grey Moist							
198.3 9.4	Concrete							
197.8 9.9	SHALE (BEDROCK)	1	RC	REC 90%	RQD = 15%			
	Bedrock cored from 9.9 m to 13.0 m Refer to Record of Drillhole GR-6 for rock coring details.	2	RC	REC 94%	RQD = 16%			
		3	RC	REC 91%	RQD = 21%			
194.7 13.0	END OF BOREHOLE NOTE: 1. Borehole dry on completion of overburden drilling.							

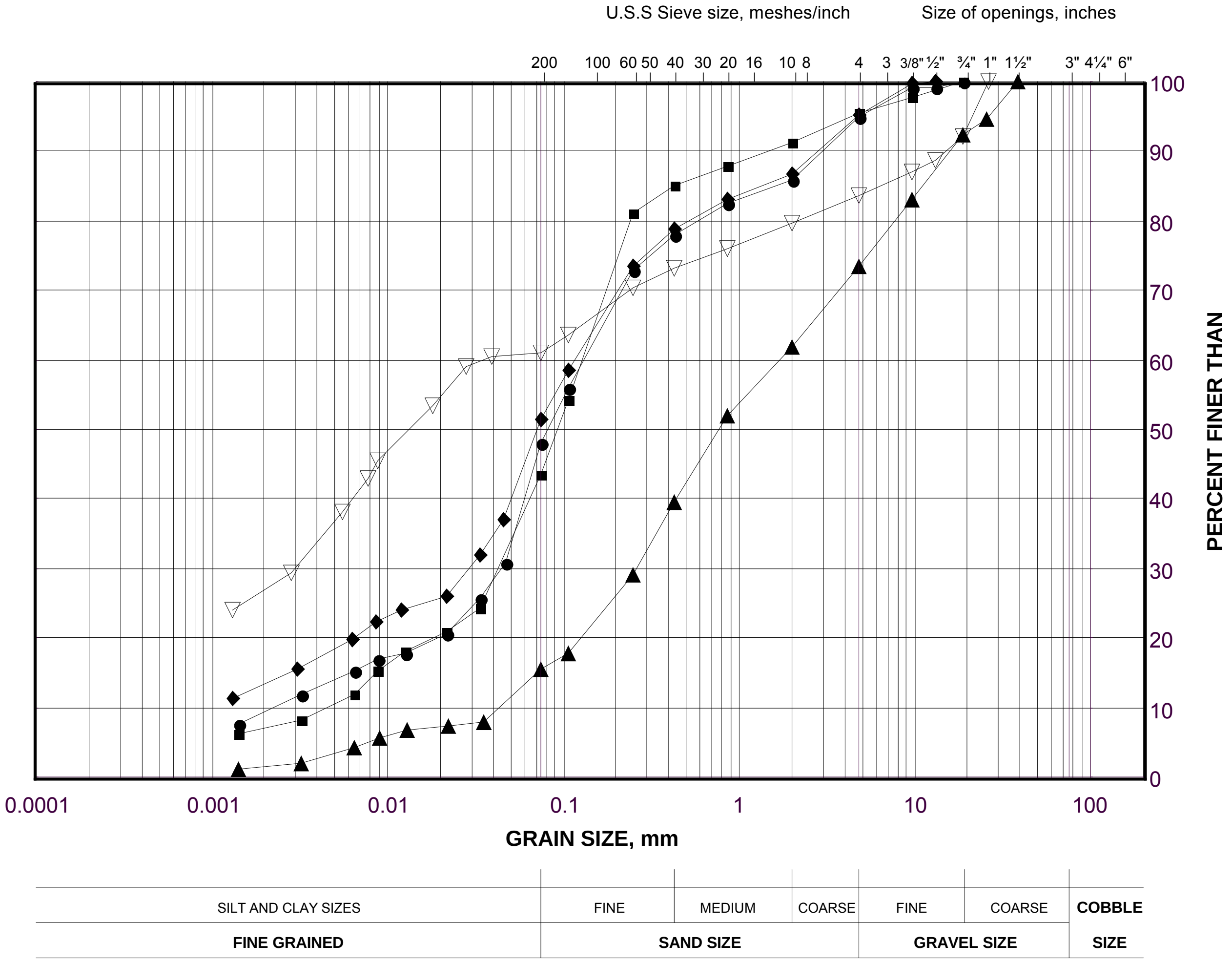
+3, ×3: Numbers refer to Sensitivity ○3% STRAIN AT FAILURE

GRAIN SIZE DISTRIBUTION TEST RESULTS

Str. 1247 - Str. 1249

Approximate Station 11+950

FIGURE P



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	14-27	3	206.1
■	GR-6	3	205.8
◆	14-27	4	205.3
▲	GR-6	7	202.8
▽	GR-6	8	201.3

Project Number: 11-1111-0083

Checked By: LC, 27-Aug-14

Golder Associates

Date: 25-Aug-14

APPENDIX Q

Borehole Records and Laboratory Test Results
Str. 1268 – Str. 1267, Approximate Station 12+330

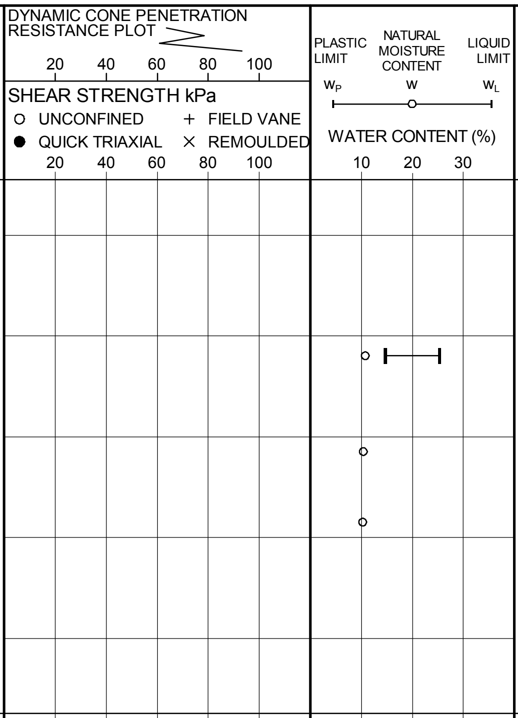
RECORD OF BOREHOLE No 14-28

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
DIST Central HWY 410
DATUM Geodetic
LOCATION N 4839335.6 ;E 286878.6
BOREHOLE TYPE CME 75 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
DATE June 8, 2014
ORIGINATED BY EG
COMPILED BY AV
CHECKED BY LCC

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
214.6	GROUND SURFACE								
0.0	ASPHALT								
0.1	Sand and gravel (FILL) Very loose to dense Brown Moist	1	SS	32					
		2A 2B	SS	3					
213.3 1.3	Clayey silt, some sand, some gravel (FILL) Soft to firm Brown Moist	3A 3B	SS	8					
212.7 1.9	Sand, some silt to silty sand, trace to some gravel (FILL) Loose to dense Brown Moist	4	SS	19		0	60	30	10
		5	SS	32					
		6	SS	15					
		7	SS	24	▽				
209.3 5.3	END OF BOREHOLE								



UNIT WEIGHT γ kN/m³

NOTE:

1. Water level in open borehole measured at a depth of 5.3 m (Elev. 209.3 m) upon completion of drilling.

$+^3, \times^3$: Numbers refer to Sensitivity   ○ $^{3\%}$ STRAIN AT FAILURE

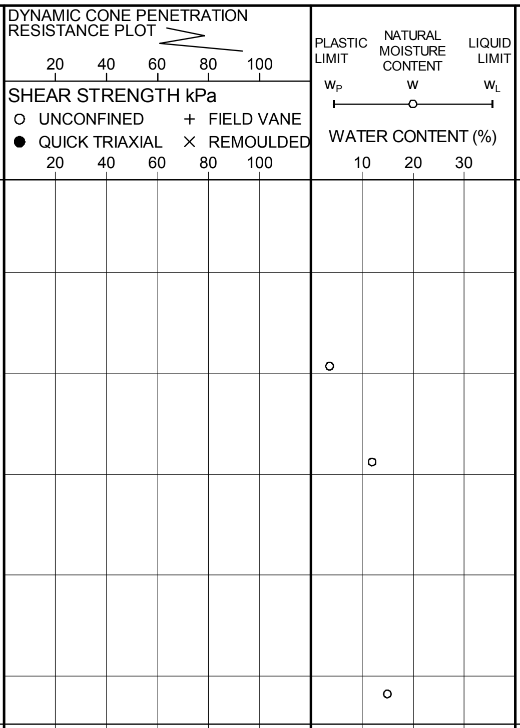
RECORD OF BOREHOLE No 14-29

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
LOCATION N 4839350.9 ;E 286899.8
ORIGINATED BY OS
DIST Central HWY 410
BOREHOLE TYPE CME 75 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
COMPILED BY AV
DATUM Geodetic
DATE June 4, 2014
CHECKED BY LCC

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES				GR	SA	SI	CL
214.9	GROUND SURFACE										
0.0	ASPHALT										
0.2	Sand and gravel (FILL) Compact to dense Brown Moist	1	SS	38							
						214					
213.6	Clayey silt with sand, some gravel (FILL) Stiff Brown Moist	2A 2B	SS	12							
213.3 1.6	Sand and gravel, trace silt to sand and silt, trace gravel (FILL) Loose to compact Brown Moist Containing clayey silt layers between depths of 2.4 m and 4.0 m	3A 3B	SS	6		213		37	55	5	3
		4	SS	6		212		7	41	40	12
		5	SS	10		211					
210.6 4.3	Clayey silt, some sand (FILL) Very stiff Brown Moist to wet	6A 6B	SS	21	∇						
		7	SS	22		210					
209.5 5.4	END OF BOREHOLE NOTE: 1. Water level in open borehole measured at a depth of 4.6 m (Elev. 210.3 m) upon completion of drilling.										

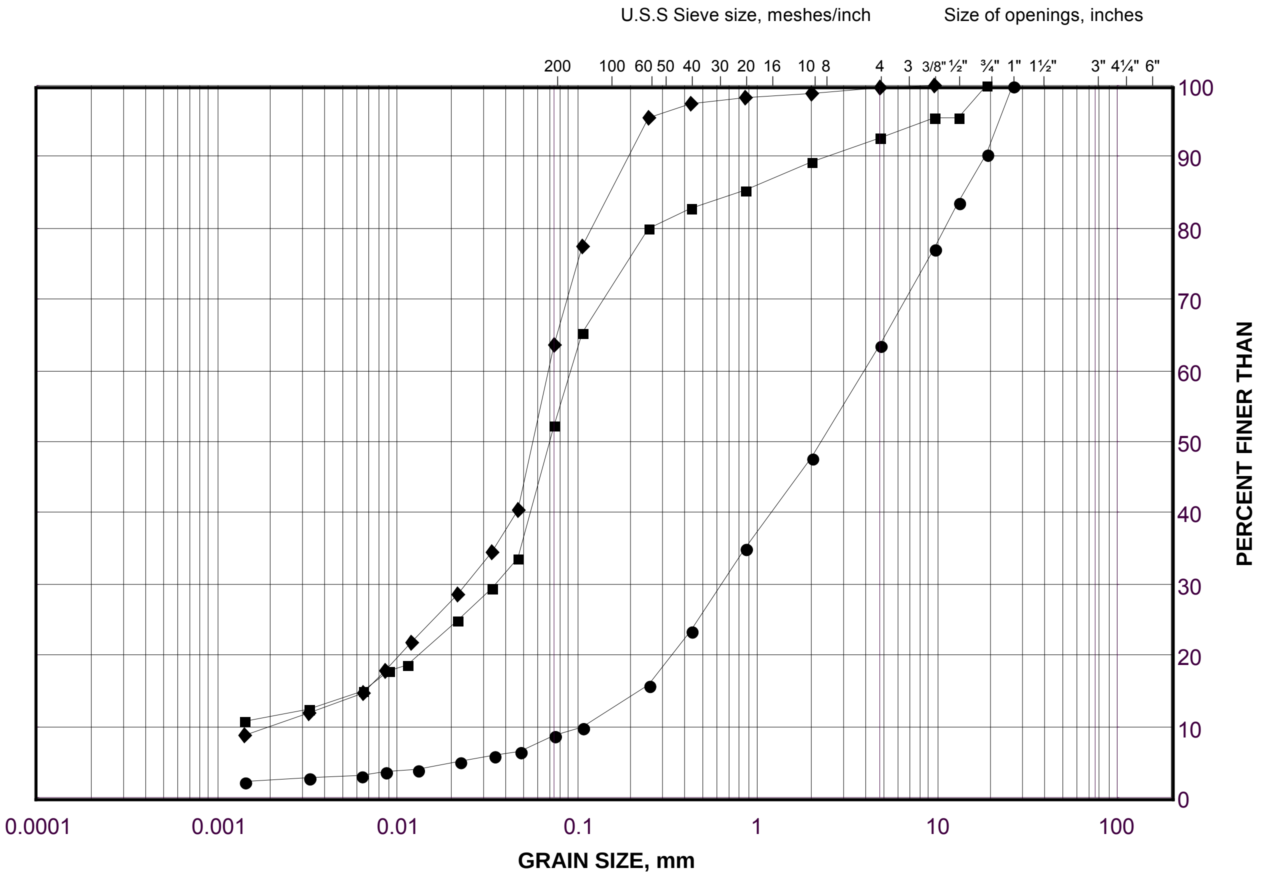


$+^3, \times^3$: Numbers refer to Sensitivity $\circ^{3\%}$ STRAIN AT FAILURE

GRAIN SIZE DISTRIBUTION TEST RESULTS

Str. 1268 - Str. 1267
Approximate Station 12+330

FIGURE Q



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	**COBBLE**
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	14-29	3A	213.1
■	14-29	4	212.1
◆	14-28	4	211.8

Project Number: 11-1111-0083

Checked By: LC, 27-Aug-14

Golder Associates

Date: 25-Aug-14

APPENDIX R

Borehole Records and Laboratory Test Results
Str. 1279 – Str. 1278, Approximate Station 12+600

Golder Associates

RECORD OF BOREHOLE No 14-30

SHEET 1 OF 1

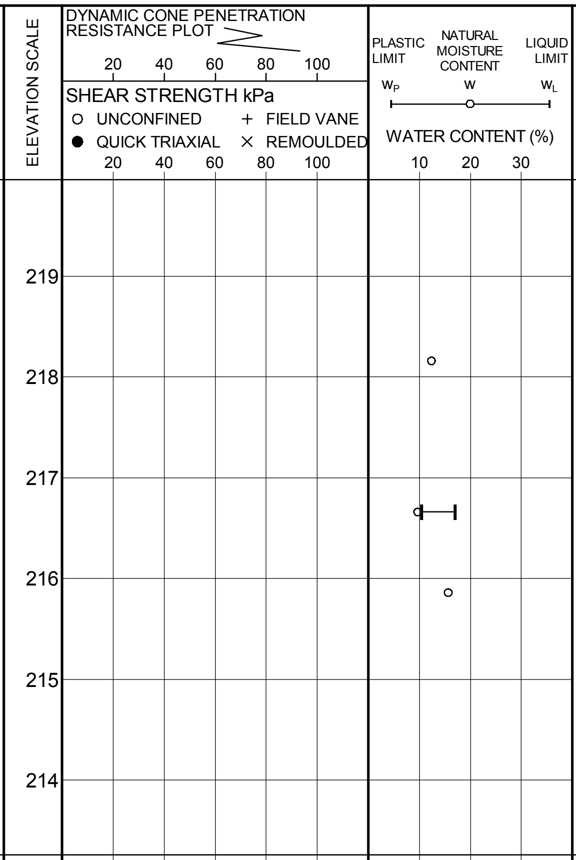
METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
DIST Central HWY 410
DATUM Geodetic
LOCATION N 4839505.0 ;E 286670.5
BOREHOLE TYPE CME 75 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
DATE June 2, 2014
ORIGINATED BY OS
COMPILED BY AV
CHECKED BY LCC

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
220.0	GROUND SURFACE										
0.0	ASPHALT										
0.2	Sand and gravel, trace silt (FILL) Compact Brown to light grey Moist		1	AS	-						
219.0 1.0	Sand and silt, trace to some gravel, trace to some clay (FILL) Loose to compact Brown Moist		2A 2B	SS	14						
			3	SS	8			9	33	46	12
			4	SS	24						
217.0 3.0	Clayey silt with sand to some sand, trace to some gravel, trace organic material (FILL) Firm to stiff Brown to dark brown Moist		5	SS	6			3	33	47	17
			6	SS	8						
215.4 4.6	Silt and sand, trace to some gravel (FILL) Very loose to loose Brown Moist to wet		7	SS	4						
			8	SS	1	∇					
214.0 6.0	Clayey silt with sand, trace to some gravel (FILL) Very soft Brown Wet		9A 9B	SS	1						
213.3 6.7	END OF BOREHOLE										

NOTE:

1. Water level in open borehole measured at a depth of 5.5 m (Elev. 214.5 m) upon completion of drilling.



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

RECORD OF BOREHOLE No CN-10

SHEET 1 OF 1

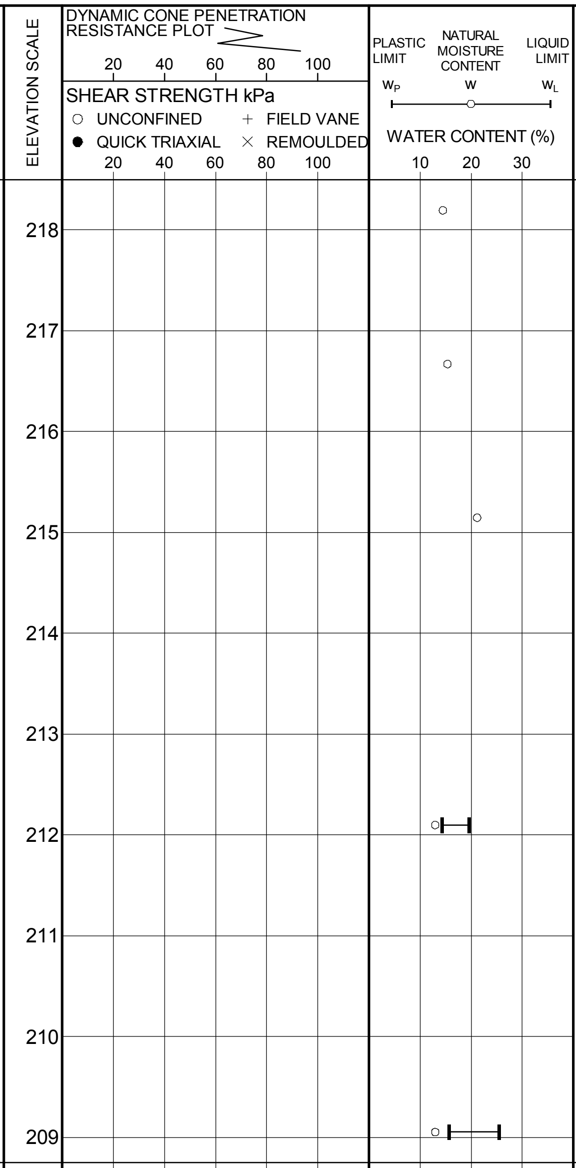
METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
DIST Central HWY 410
DATUM Geodetic
LOCATION N 4839520.5 ;E 286693.7
BOREHOLE TYPE CME-55 Track-mount, 57 mm Inner Diameter Hollow Stem Augers
DATE March 26, 2012
ORIGINATED BY SB
COMPILED BY NK
CHECKED BY LCC

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
218.5	GROUND SURFACE								
0.0	Clayey silt, some sand, trace gravel, containing rootlets and pockets of silty sand (FILL) Firm to stiff Brown Moist	1	SS	5					
		2	SS	8					
217.1 1.5	Sandy silt, trace clay, trace gravel, containing pockets of clayey silt (FILL) Very loose to compact Brown Moist becoming wet below a depth of 3.0 m	3	SS	19					
		4	SS	6					
		5	SS	3		1	26	61	12
		6	SS	18					
		7	SS	11	▽				
212.9 5.6	Clayey silt with sand, some gravel (FILL) Firm to very stiff Moist Brown	8	SS	5		13	39	34	14
		9	SS	18					
209.8 8.7	CLAYEY SILT, some to with sand, trace gravel (TILL) Hard Brown Moist	10	SS	34		4	21	46	29
208.8 9.8	END OF BOREHOLE								

NOTE:

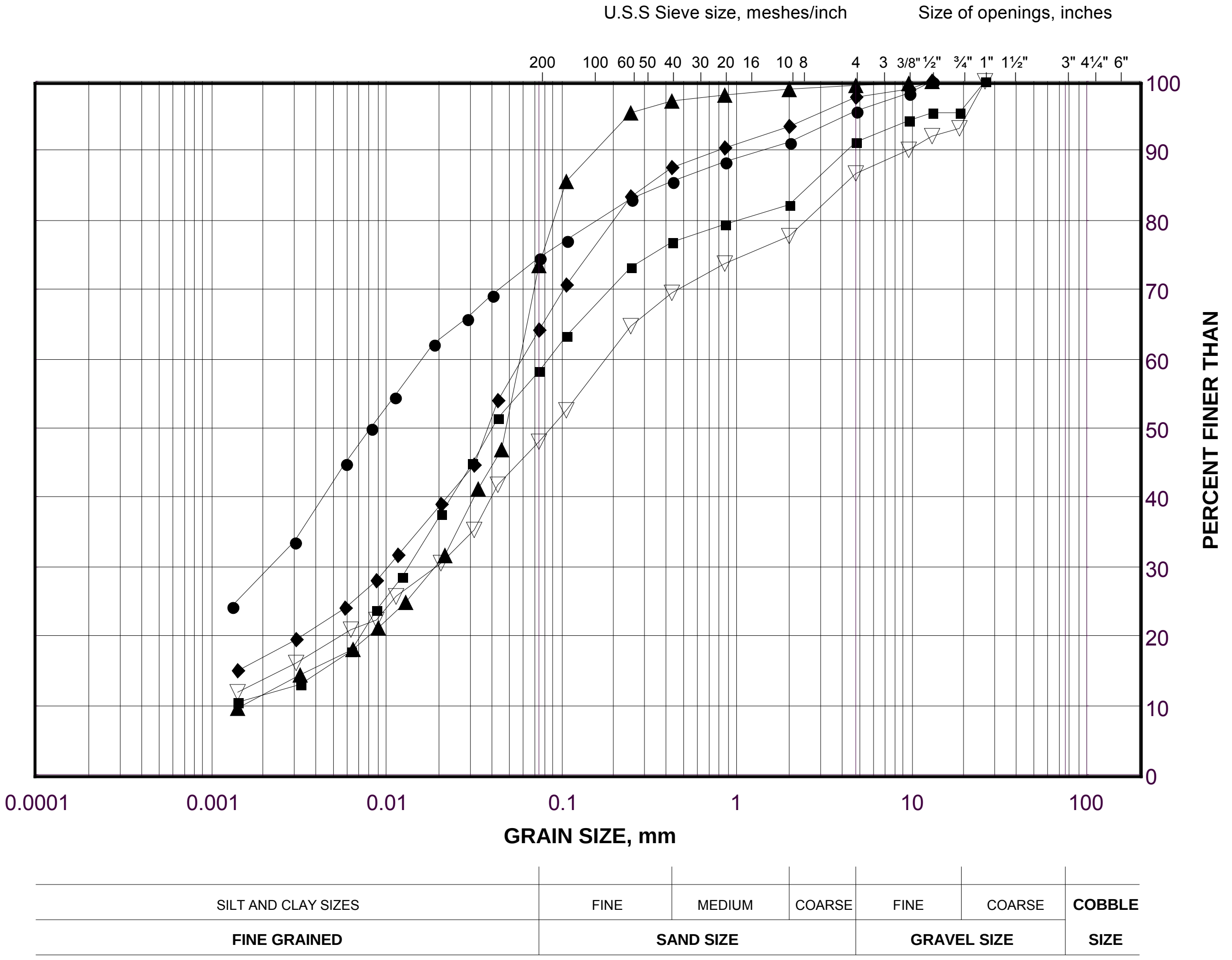
1. Water level in open borehole at a depth of 5.2 m (Elev. 213.3 m) on completion of drilling.



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

GRAIN SIZE DISTRIBUTION TEST RESULTS
Str. 1279 - Str. 1278
Approximate Station 12+600

FIGURE R



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	CN-10	10	209.1
■	14-30	3	218.2
◆	14-30	5	216.6
▲	CN-10	5	215.1
▽	CN-10	8	212.1

Project Number: 11-1111-0083

Checked By: LC, 27-Aug-14

Golder Associates

Date: 25-Aug-14

APPENDIX S

Borehole Records and Laboratory Test Results
Str. 1301 – Str. 1303, Approximate Station 13+110

Golder Associates

Foundation Design

RECORD OF BOREHOLE No 14-31

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083
G.W.P. 2144-07-00
DIST Central HWY 410
DATUM Geodetic
LOCATION N 4839901.2 ;E 286283.9
BOREHOLE TYPE CME 75 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers
DATE June 3, 2014
ORIGINATED BY OS
COMPILED BY AV
CHECKED BY LCC

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 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 (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				GR	SA	SI	CL
218.4	GROUND SURFACE													
0.0	ASPHALT													
0.2	Sand and gravel (FILL) Loose Brown Moist		1	AS	-		218							
217.6 0.8	Gravelly sand, some silt, containing cobbles (FILL) Very dense Brown Moist		2	SS	100/0.13				○		26	58	12	4
							217							
216.9 1.5	Clayey silt with sand, trace to some gravel (FILL) Stiff to very stiff Brown to light grey Moist		3	SS	14				○ ├──┤		14	31	38	17
			4	SS	25		216							
			5	SS	25		215							
			6	SS	20				○					
							214							
213.8 4.6	CLAYEY SILT, some sand, trace to some gravel, containing organic material (TILL) Very stiff to hard Grey Moist		7	SS	100/0.10									
			8	SS	18		213							
212.5 5.9	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.													

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

RECORD OF BOREHOLE No 14-32

SHEET 1 OF 1

METRIC

PROJECT 11-1111-0083

G.W.P. 2144-07-00

DIST Central HWY 410

DATUM Geodetic

LOCATION N 4839893.1 ;E 286321.0

BOREHOLE TYPE CME 75 Truck-mount, 80 mm I.D. and 203 mm O.D. Hollow Stem Augers

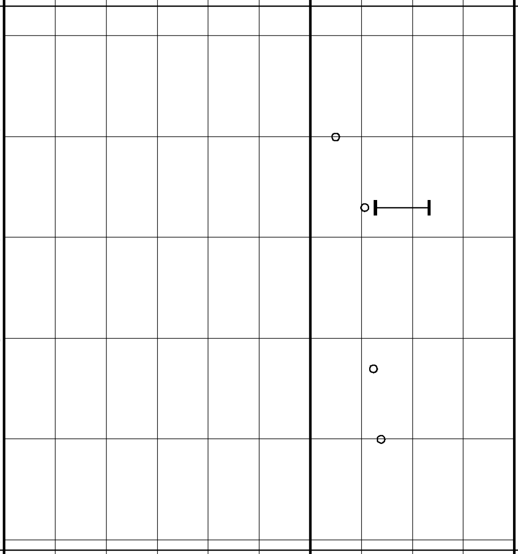
DATE June 9, 2014

ORIGINATED BY EG

COMPILED BY AV

CHECKED BY LCC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 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 (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR	SA	SI	CL
218.3	GROUND SURFACE													
0.0	ASPHALT													
0.2 217.3	Sand and gravel, trace silt (FILL) Brown Moist		1	AS	-		218							
1.0 216.6	Sand, containing layers of silt (FILL) Compact Brown Moist		2	SS	17		217				7	76	12	5
1.7	Clayey silt with sand to some sand, some gravel, trace organic material, containing cobbles (FILL) Stiff to hard Brown to grey Moist to dry		3	SS	9		216				16	31	35	18
			4	SS	62 *		215							
214.3			5	SS	10									
4.0	CLAYEY SILT, some sand, trace gravel (TILL) Stiff to very stiff Brown Moist		6	SS	9		214							
212.9			7	SS	15		213							
5.4	END OF BOREHOLE													



NOTES:

* Spoon bouncing during driving, on assumed cobble.

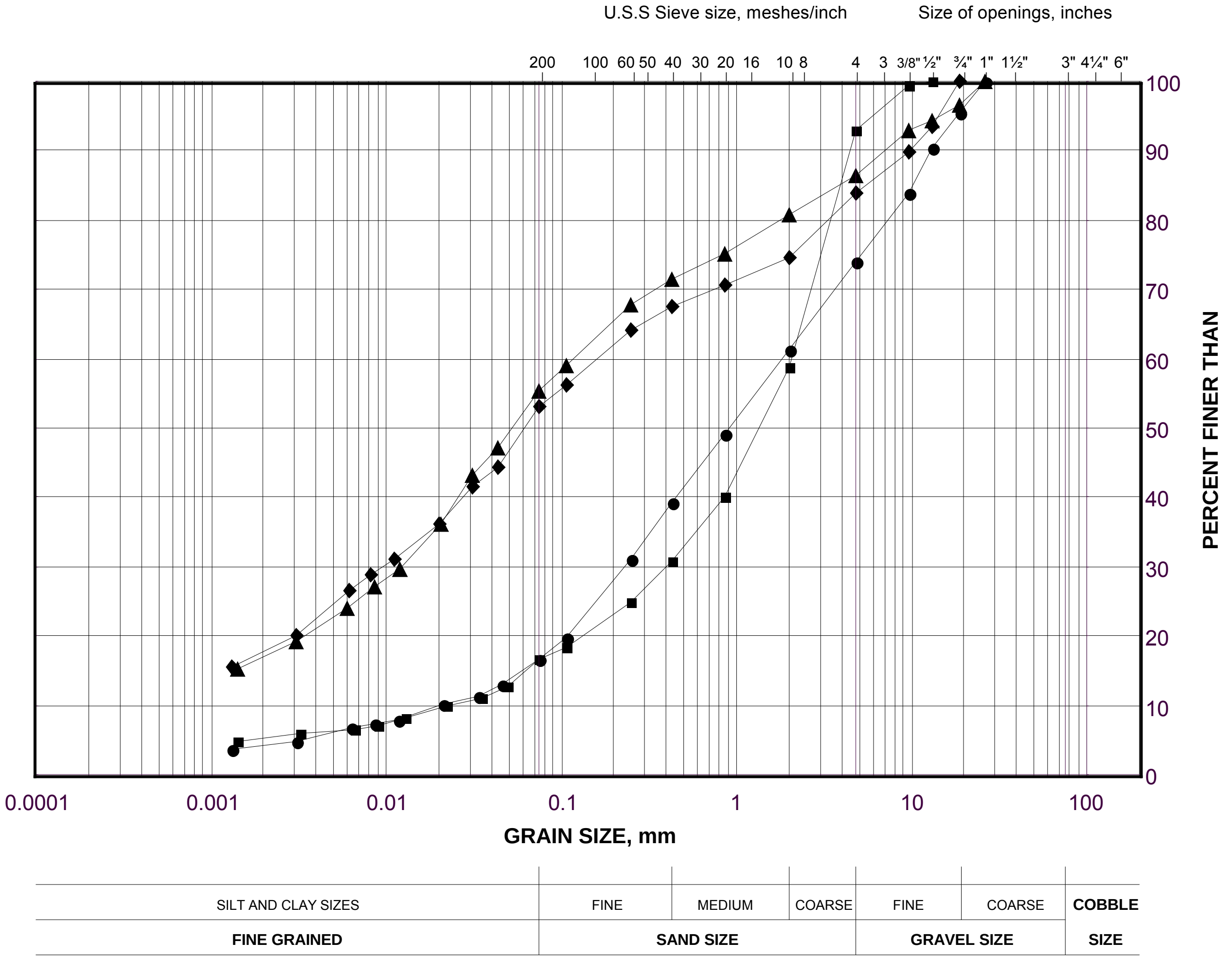
1. Open borehole dry upon completion of drilling.

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

$\circ^{3\%}$ STRAIN AT FAILURE

GRAIN SIZE DISTRIBUTION TEST RESULTS
Str. 1301 - Str. 1303
Approximate Station 13+110

FIGURE S



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	14-31	2	217.4
■	14-32	2	217.0
◆	14-32	3	216.3
▲	14-31	3	216.5

Project Number: 11-1111-0083

Checked By: LC, 27-Aug-14

Golder Associates

Date: 25-Aug-14

APPENDIX T

Non-Standard Special Provisions

PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.

Special Provision

1. SCOPE

This specification covers the general requirements for the installation of pipes by trenchless methods, including Jack & Bore, Pipe Ramming, Directional Drilling, and Tunnelling. The Contractor shall determine the most appropriate method of installation for each of the crossing locations.

This specification shall supercede OPSS 415 (Construction Specification for Pipeline and Utility Installation by Tunneling), OPSS 416 (Construction Specification for Pipeline and Utility Installation by Jacking and Boring) and OPSS 450 (Construction Specification for Pipeline and Utility Installation in Soil by Horizontal Directional Drilling).

The Contractor's attention is drawn to the following:

- Mixed face conditions will be encountered along the proposed pipe alignments. The Contractor shall select equipment that is capable of excavating the different material types while minimizing loss of ground.

- The clayey silt till deposit may contain cobbles, boulders and slabs of bedrock, including strong to very strong limestone.

- The pipe installation will be done partially through cohesive till and shale bedrock. The Contractor shall select equipment capable of drilling through these cohesive deposits.

- The shale bedrock is bedded horizontally to sub-horizontally and contains strong to very strong limestone and siltstone layers, which may tend to deflect tunnelling/boring equipment when contacted. Trenchless methods and equipment that can penetrate weathered to sound shale, and strong to very strong limestone and siltstone layers, shall be provided where required. The Contractor shall also select equipment capable of maintaining the alignment where harder layers are encountered in the bedrock.

2. REFERENCES

This specification refers to the following standards, specifications, or publications:

Ontario Provincial Standard Specifications, General

OPSS 180	Management and Disposal of Excess Material

Ontario Provincial Standard Specifications, Construction

OPSS 401	Trenching, Backfilling, and Compacting
OPSS 404	Support Systems
OPSS 491	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492	Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 517	Dewatering of Pipeline, Utility, and Associated Structure Excavations
OPSS 539	Temporary Protection Systems

Ontario Provincial Standard Specifications, Material

OPSS 1004	Aggregates - Miscellaneous
OPSS 1350	Concrete - Materials and Production
OPSS 1440	Steel Reinforcement for Concrete
OPSS 1802	Smooth Walled Steel Pipe
OPSS 1820	Circular and Elliptical Concrete Pipe
OPSS 1840	Non-Pressure Polyethylene Plastic Pipe Products

American Society for Testing and Materials (ASTM) International Standards

ASTM A252-93	Welding and Seamless Steel Pipe Piles
ASTM D2657-03	Standard Practice for Heat Fusion Joining of Polyelofin Pipe and Fittings
ASTM D3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
ASTM F894	Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

Canadian Standards Association Standards:

CSA B182.6	Profile Polyethylene Sewer Pipe and Fittings.
CAN/CSA A5-93	Portland Cement
CSA W59	Welded Steel Construction (Metal Arc Welding)

3. DEFINITIONS

For the purpose of this specification, the following definitions apply:

Auger Jack & Bore: a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead and rotating a cutter head, followed by removal of material from inside the bore by using an auger.

Backreamer: a cutting head suitably designed for the subsurface conditions that is attached to the end of a drill string to enlarge the pilot bore during a pullback operation.

Bore Path: a drilled path according to the grade and alignment tolerances specified in the Contract Documents.

Design Engineer: means the Engineer retained by the Contractor who produces the original design and working drawings. The design engineer shall be licensed to practice in the Province of Ontario.

Design Checking Engineer: means the Engineer retained by the Contractor who checks the original design and working drawings. The design checking engineer shall be licensed to practice in the Province of Ontario.

Digger Shield/Hand Mining: a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead while tunnelling advances using hand–mining (man-entry operation or “Jack and Mine) or a “digger” type shield with a hydraulic excavator arm to remove materials from inside the liner pipe.

Drilling Fluids: a mixture of water and additives, such as bentonite, polymers, surfactants, and soda ash, designed to block the pore space on a bore wall, reduce friction in the bore, and to suspend and carry cuttings to the surface.

Drilling Fluid Fracture or Frac Out: a condition where the drilling fluid's pressure in the bore is sufficient to overcome the in situ confining stress, thereby fracturing the soil and/or rock materials and allowing the drilling fluids to migrate to the surface at an unplanned location.

Engineer: a Professional Engineer licensed by the Professional Engineers of Ontario to practice in the Province of Ontario.

Excavation: includes all materials encountered regardless of type and extent. Excavation shall include removal of natural soil, large boulders, cobbles, wood and fill regardless of means necessary to break consolidated materials for removal.

Environmentally Sensitive Area (ESA): areas adjacent to construction that are off limits to the Contractor as specified elsewhere in the Contract.

Fill: man-made mixture of previously placed/handled materials such as sand, clay, silt, gravel, broken rock, sometimes containing organic and/or deleterious materials, placed in an excavation or other area to raise the surface elevation.

Grouting: injection of grout into voids.

Guidance System: an electronic system capable of locating the position, depth and orientation of the drill head during the directional drilling process.

Directional Drilling (DD): directional boring or guided boring.

HDPE: high density polyethylene.

Inadvertent Returns: the flow of unexpected fluids, saturated materials (or running soil) towards the drilling rig that typically originated from an artesian aquifer encountered during the drilling process.

Loss of Circulation: the discontinuation of the flow of drilling fluid in the bore back to the entry or exit point or other planned recovery points.

Pilot Bore: the initial bore to set directional controlled horizontal and vertical alignment between the connecting points.

Pipe Jacking: a method for installing steel casing or concrete pipe in the subsurface utilizing hydraulically operated jacks of adequate number and capacity to ensure smooth and uniform advancement without overstressing the liner/pipe.

Pipe Ramming: a method for installing steel casings utilizing the energy from a percussion hammer to advance a steel casing with a cutting shoe attached at the front end of the casing.

Primary Liner (Support): system installed prior to or concurrent with excavation, to maintain stability of an excavation and to support earth or rock and any structure utilities or other facilities in or on the supported earth or rock mass, until the excavation is completed.

Product: pipe culverts, pipe sewers, watermain pipe and sanitary pipe.

Pullback: that part of the DD method in which the drill string is pulled back through the bore path to the entry point.

Quality Verification Engineer (QVE): an Engineer who has a minimum of five (5) years experience in the field of pipe installation using trenchless methods or alternatively has demonstrated expertise by providing satisfactory quality verification services for the work at a minimum of two (2) projects of similar scope to the contract. The Quality Verification Engineer shall be retained by the Contractor to certify that the work is in general conformance with the contract documents and to issue Certificate(s) of Conformance.

Reaming: a process for pulling a tool attached to the end of the drill string through the bore path to enlarge the bore and mix the cuttings with the drilling fluid. This typically includes multiple passes.

Rock: natural beds or massive fragments, or the hard, stable, cemented part of the earth's crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered and includes boulders having a size equivalent to 0.3 m in diameter or greater.

Secondary Liner: concrete pipe, HDPE pipe or un-reinforced cast-in-place concrete, installed subsequent to tunnel excavation.

Shaft: vertically sided excavation used as entry and/or exit points from which the trenchless method is initiated or directed for the installation of product.

Strike Alert: a system that is intended to alert and protect the operator in the case of inadvertent drilling into an electrical utility cable. The strike alert system consists of a sensor and an alarm connected to the drill rig and a grounding stake. The alarm may be audio or visual or both.

Slurry: a mixture of soil and/or rock cuttings, and drilling fluid.

Soil: all materials except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials; includes rock fragments having an equivalent size less than 0.3 m in diameter.

Tunnelling: an underground method of constructing a passage open at both ends that involves installing a pipe. For the purpose of this specification, the pipe may be installed by any of the various methods defined above such as Auger Jack & Boring, Pipe Ramming, Directional Drilling or using hand mining methods.

4. DESIGN AND SUBMISSION REQUIREMENTS

4.01 General

The Contractor’s documentation, submission requirements and installation methods shall specifically consider and address the subsurface conditions at each pipe crossing as identified in the Foundation Investigation Report or elsewhere in the Contract Documents.

4.02 Working Drawings

Three copies of stamped working drawings for portal or shaft construction, primary liner, excavation, secondary lining, dewatering and groundwater control and grouting shall be submitted to the Contract Administrator (CA) at least one week prior to the commencement of the work for information purposes. All submissions shall bear the seal and signature of the Design Engineer and Design Checking Engineer. The Contractor shall have a copy of the stamped working drawings at the site during construction.

As a minimum, working drawings/details pertaining to the tunnel design and construction shall include the following (as appropriate):

a) Plans, Elevations and Details:

- A work plan outlining the materials, procedures, methods and schedule to be used to execute the work;
- A list of personnel, including backup personnel, and their qualifications and experience;
- A safety plan including the company safety manual and emergency procedures;
- The work area layout;
- An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail;
- A drilling fluid management plan, if applicable, that addresses control of frac-out pressures, any potential environmental impacts and includes a contingency plan detailing emergency procedures in the event that the fluid management plan fails;
- Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations; and
- Excavated materials disposal plan.

b) Design Criteria:

- Primary liner design details, if applicable;
- Design assumption and material data when materials other than those specified are proposed for use; and
- Drill path design, details of alignment and alignment control, maximum curvature and reaming stages.

c) Materials:

- Certification from the manufacturer that the product furnished on the contract meets the specifications cited in the manufacturer’s product specification and that the materials supplied are suitable for the application; and
- Material mixture for filling voids and installation procedures.

d) Upstream/Downstream Portal Installation Procedure:

- The access shaft or entry/exit pit details designed and stamped/signed by the Design Engineer, as applicable; and
- Face support and other temporary support details, if applicable.

e) Primary Liner/Secondary Liner Installation and Grouting Procedure:

- Excavation and pipe installation procedures, including methods to handle obstructions and prevent soil cave-in; and
- Details of tunnelling equipment/methods to be used for the works.

f) Excavation and Dewatering:

- Ground control/dewatering details, as applicable, describing the proposed method for control, handling, treatment, and disposal of water.

g) Monitoring Method

- The methods to be employed to monitor and maintain the alignment of the installation;

4.03 Site Survey

Prior to commencing the work, the Contractor shall, at each pipe location, layout the alignment and install settlement monitoring points.

4.04 Certificate of Conformance

The Contractor shall submit details of the sequence and method of construction to the Quality Verification Engineer for review, prepared and stamped by the Design Engineer. The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer a minimum of one week prior to commencement of work under this item. The Certificate shall state that the construction procedures are in conformance with the requirements and specifications of the contract documents.

The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer upon completion of each of the following operations and prior to commencement of each subsequent operation for each pipe installation:

Site Surveying (as noted in Section 4.02)
Excavation for pits including dewatering of excavations
Jacking/Ramming/Directional Drilling of Casing/Liner
Installation of the Product
Grouting Operations

Each Certificate of Conformance shall state that the work has been carried out in general conformance with the contract documents, specifications and/or stamped working drawings.

In addition, upon completion of the installation of the pipe at each location, the Contractor shall submit to the Contract Administrator a **final** Certificate of Conformance sealed and signed by the Quality Verification Engineer. The Certificate shall state that the pipe has been installed in general conformance with the Contractor's Submission and Design Requirements, stamped working drawings and contract documents.

The Design Engineer will not be permitted to carry out the work of the Quality Verification Engineer.

5. MATERIALS

5.01 Product

The product shall be concrete pipe or high density polyethylene pipe as specified.

5.02 Concrete

Concrete shall be according to OPSS 1350. The concrete strength shall be as specified in the Contractor's design submission.

5.03 Concrete Reinforcement

Steel reinforcing for concrete work shall be according to OPSS 1440.

5.04 Timber

Timber shall be sound, straight, and free from cracks, shakes and large or loose knots.

5.05 Grout

The Contractor shall submit the proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces. Purging grout shall consist of a mixture of one part Portland cement conforming to the requirements of CAN/CSA A5-93 and two parts mortar sand conforming to OPSS 1004 wetted with only sufficient water to make the mixture plastic.

5.06 Auger Jack & Bore Materials

5.06.01 Pipe Materials

Steel pipe shall conform with ASTM A252-95 welded joints suitable for jacking operations. The Contractor shall select pipe class for pipe jacking.

Concrete pipe as per OPSS 1820.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

5.07 Pipe Ramming Materials

5.07.01 Pipe Materials

Steel pipe shall conform with ASTM A 252-93 welded joints.

New steel casing when specified shall be smooth wall carbon steel pipe according to ASTM A252-93 Grade 2.

Used steel casing can be used provided that the steel casing can resist the applicable static and dynamic loadings.

Pipe wall thickness shall be determined by the Contractor based on static and dynamic loads from traffic loading and anticipated ramming forces for selected pipe and driven pipe lengths. The wall thickness shall be increased as required to ensure the casing is not damaged during handling and installation. A minimum wall thickness of 50 mm and minimum yield strength of 240 MPa is required.

Pipe segments shall be determined by the Contractor.

Steel pipe joints shall be pressure fit type or welded.

All steel casing pipe shall be square cut.

Steel casing pipe shall have roundness such that the difference between the major and minor outside diameters shall not exceed 1% of the specified nominal outside diameter or 6 mm, whichever is less.

Steel casing pipe shall have a minimum allowable straightness of 1.5 mm maximum per meter of length.

5.07.02 Mill Certificates

For permanent casing, the Contractor shall submit to the Contract Administrator at the time of delivery one copy of the mill certificate, indicating that the steel meets the requirements for the appropriate standards for casings.

Where mill test certificates originate from a mill outside Canada or the United States of America the Contractor shall have the information on the mill certificate verified by testing by a Canadian laboratory. The laboratory shall be accredited by a Canadian National Accreditation Body to comply with the requirements of ISO/IEC Guide 25 for the specific tests or type of tests required by the material standard specified on the mill test certificate. The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date and the signature of an authorized officer of the Canadian testing laboratory.

5.08 Directional Drilling Materials

5.08.01 Drilling Fluids

The drilling fluids shall be mixed according to the manufacturer's recommendations and be appropriate for the anticipated subsurface conditions.

5.08.02 Pipe Materials

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.

The requirements for fittings shall be suitable for and compatible with the class and type of pipe with which they will be used and in according to CAN/CSA-B182.6 or ASTM F894.

The Contractor shall determine the required dimensional ratio (DR) of the HDPE pipe to support all subsurface conditions and hydrostatic pressures, and to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

The Contractor's submission shall demonstrate, in conjunction with the manufacturer's specifications, that the heat resistance of the pipe material is sufficient to tolerate without damage the heat of hydration generated by grout curing.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

Jointing of HDPE piping to other piping materials or appurtenances shall be completed using flanged connections.

5.09 Tunnelling Materials

5.09.01 Primary Liner

Tunnelling methods will require installation of a primary liner. The primary liner shall be designed by the

Contractor and the design/drawings shall be stamped/signed by the Design Engineer. The design shall be submitted to the Contract Administrator as specified herein.

5.09.02 Secondary Liner

Concrete or High Density Polyethylene Pipe shall be used according to the following requirements.

5.09.02.01 Concrete Pipe

Concrete pipe as per OPSS 1820 shall be used. The Contractor shall select the pipe class to withstand grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

5.09.02.02 High Density Polyethylene (HDPE)

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.

The requirements for fittings shall be according to CAN/CSA-B182.6 or ASTM F894.

The Contractor shall determine the required dimensional ratio (DR) to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

Jointing of HDPE piping to other piping materials shall be completed using flanged connections.

6. EQUIPMENT

6.01 Auger Jack & Bore Equipment

Pipe auger jack & bore equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.02 Pipe Ramming Equipment

Pipe ramming equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

The pipe ramming hammer(s) shall be capable of driving the pipe casing from the drive pit through the existing subsurface conditions at the site.

Specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the pipe shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.03 Directional Drilling Equipment

6.03.01 General

The directional drilling equipment shall consist of a directional drilling rig and a drilling fluid mixing and delivery system of sufficient capacity to successfully complete the product installation without exceeding the maximum tensile strength of the product being installed.

6.03.02 Drilling Rig

The directional drilling rig shall:

- consist of a leak free hydraulically powered boring system to rotate, push, and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head;
- contain a guidance system to accurately guide boring operations;
- be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation; and
- be grounded during all operations unless otherwise specified by the drilling rig manufacturer.

6.03.03 Drill Head

The drill head shall be steerable by changing its rotation, be equipped with the necessary cutting surfaces and drilling fluid jets, and be of the type for the anticipated subsurface conditions,

6.03.04 Guidance System

The guidance system shall be setup, installed, and operated by trained and experienced personnel. The operator shall be aware of any magnetic or electromagnetic anomalies and shall consider such influences in the operation of the guidance system when a magnetic or electromagnetic system is used.

6.03.05 Drilling Fluid Mixing System

The drilling fluid mixing system shall be of sufficient size to thoroughly and uniformly mix the required drilling fluid.

6.03.06 Drilling Fluid Delivery System

The delivery system shall have a means of measuring and controlling fluid pressures and be of sufficient flow capacity to ensure that all slurry volumes are adequate for the length and diameter of the final bore and the anticipated subsurface conditions. Connections between the delivery pump and drill pipe shall be leak-free.

6.04 Tunnelling Equipment

Tunnelling equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the manner in which rock or boulders will be broken and removed from the tunnel face shall be submitted to the Contract Administrator information purposes. Use of rock fracturing chemicals shall only be considered subject to a field demonstration satisfactory to the Ministry prior to its use.
Use of explosives is prohibited.

7. CONSTRUCTION

7.01 General

The Contractor shall notify the Contract Administrator at least 48 hours in advance of starting work. The proposed method of pipe installation to be used by the Contractor shall be submitted to the Contract Administrator for information purposes prior to commencing the work and shall be subject to the limitations presented in the following subsections.

7.01.01 Layout, Alignment and Depth Control

The location of the installation shall be established from the lines, elevations and tolerances specified in the Contract Documents. The pipe installation shall be to the horizontal and vertical alignments specified in the Contract Drawings. Deviations from location, alignment, grades and/or invert levels shall be corrected by the Contractor at no cost to the Ministry.

All reference points necessary to construct the pipe installation and appurtenances shall be laid out.

The Contractor shall calibrate tracking and locating equipment at the beginning of each work day, and shall monitor and record the alignment and depth readings provided by the tracking system at every 5 m in normal conditions and every 2 m where precise alignment control is necessary;

The Contract Administrator shall be provided with the assistance and access necessary to check the layout of the pipe installation and associated appurtenances.

All excavations shall be carried out in accordance with the Occupational Health and Safety Act (OHSA) of Ontario.

For directional drilling, the contractor shall ensure that during pilot hole drilling the maximum degree of deviation or “dog-leg” shall be 2.5 degrees per 9m drill pipe length. Any deviation exceeding 2.5 degrees will necessitate a pull-back and straightening of the alignment at the Contractor’s sole expense. The pilot hole exit location shall be within 0.5m of the target location.

7.01.02 Construction Shafts

Construction shafts shall be specified in the Contractor's submission. The boundaries and protection of these shall be as required to contain all disturbances to areas outside of the ESA limits.

Shafts shall be maintained in a drained condition.

A minimum 2.4 m high secure fence shall be installed around the perimeter of the construction shaft area with gates and truck entrances. The fence shall be removed on completion of the work.

7.01.03 Protection Schemes

The construction of all protection schemes shall be according to OPSS 539. Where the stability, safety, or function of an existing roadway, watercourse, other works, proposed works or ESA's may be impaired due to the method of operation, protection shall be provided. Protection may include sheathing, shoring, and piles where necessary to prevent damage to such works or proposed works.

7.01.04 Settlement or Heave

Any disturbance to the ground surface (settlement or heave) as a result of the pipe installation shall be immediately corrected by the Contract, at no additional cost to the Ministry.

7.01.05 Stability of Excavation

The construction methods, plant, procedures, and precautions employed shall ensure that excavations are stable, free from disturbance, and maintained in a drained condition.

The construction methods, plant, and materials employed shall prevent the migration of soil and/or rock material into the excavation from adjacent ground.

7.01.06 Preservation and Protection of Existing Facilities

Preservation and protection of existing facilities shall be according to OPSS 491.

Minimum horizontal and vertical clearances to existing facilities as specified in the Contract Documents shall be maintained. Clearances shall be measured from the nearest edge of the largest cut diameter required to the nearest edge of the facility being paralleled or crossed.

Existing underground facilities shall be exposed to verify its horizontal and vertical locations when the outlet pipe path comes within 1.0 m horizontally or vertically of the existing facility. Existing facilities shall be exposed by non-destructive methods. The number of exposures required to monitor work progress shall be as specified in the Contract Documents.

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer's handling and storage recommendations shall be followed.

7.01.08 Trenching, Backfilling and Compacting

Trenching, backfilling, and compacting for entry and exit points or other locations along the pipe path shall be according to OPSS 401.

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

If any open excavation will encroach into the highway embankment the protection system shall satisfy the requirements for Performance Level 2 as specified in SP105S19.

7.01.10 Dewatering

The work of this Section includes control, handling, treatment, and disposal of groundwater. The Contractor shall review the foundation investigation report for reference to soil and groundwater conditions on the project site and plan a dewatering scheme accordingly.

The Contractor shall control groundwater inflows to excavations to maintain stability of surrounding ground, to prevent erosion of soil, to prevent softening of ground exposed in the excavation, and to avoid interfering with execution of the work.

The Contractor shall maintain excavations free of standing water at all times during excavation, including while concrete is curing.

Should water enter the excavation in amounts that could adversely affect the performance of the work or could cause loss of ground, the Contractor shall take immediate steps to control the inflow.

The Contractor is alerted that seepage zones of perched water within the fill materials should be expected, particularly where granular materials are excavated.

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Boulders

The Contractor is alerted that cobbles and boulders should be anticipated in the soil deposits at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

7.01.12 Record Keeping

Verification record requirements of the alignment and depth of the installation shall be as specified in the Contract Documents. A copy of the verification records shall be given to the Contract Administrator at the completion of the installation.

7.01.13 Testing

Testing of the product installation shall consist of verifying the specified grade between the two ends of the pipe and passing of water from the median end of the pipe to the outlet end to confirm gravity flow conditions.

7.01.14 Management and Disposal of Excess Material

Management and disposal of excess material shall be according to OPSS 180. Satisfactory re-usable excavated material required for backfill shall be separated from unsuitable excavated material.

7.01.15 Site Restoration

Site restoration shall be according to OPSS 492.

7.01.16 Supervision

A qualified individual, who is experienced in the pipe installation by trenchless methods shall supervise the work at all times.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

The installation procedure to be used shall be subject to the following limitations:

- Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.
- A suitably padded jacking head or collar shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.
- Selection of the excavation method and jacking equipment shall take into consideration the conditions at each pipe crossing.

7.02.02 Pipe Installation

Concrete pipe joints shall be water tight and according to OPSS 1820 and must withstand jacking forces, determined by the Contractor.

During the jacking of the liner the space between the liner and the wall of the excavation shall be kept filled with bentonite slurry. Upon completion of jacking, the space between the liner and the wall of the excavation shall be filled with grout.

The annular space between the liner and the product shall be fully grouted with a water tight, expandable and stable grout.

7.03 Pipe Ramming Installation

For pipe ramming installation the following requirements apply:

Only smooth walled steel pipe shall be used. But welding of pipe joints shall conform to CAS W59.

Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement without overstressing of the pipe. Delays shall be avoided between ramming operations.

A ramming head shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.

Two or more lubricated guide rails or sills shall be provided of sufficient length to fully support the pipe at the specified line and grade in the ramming pit. Pipe shall be installed to the line and grade specified.

Following installation of the liner pipe, all material shall be removed from the pipe to the satisfaction of the Contract Administrator. Any voids remaining between the pipe and the excavation wall shall be grouted as soon as the pipe is rammed. The annular space between the liner pipe and the product shall be fully grouted with a water tight, expandable and stable grout.

7.04 Directional Drilling Installation

7.04.01 General

When strike alerts are provided on a drilling rig, they shall be activated during drilling and maintained at all times.

7.04.02 Site Preparation

The work site shall be graded or filled to provide a level working area for the drilling rig. No alterations beyond what is required for DD operations are to be made. All activities shall be confined to designated work areas.

7.04.03 Pilot Bore

The pilot bore shall be drilled along the bore path in accordance with the grade, alignment, and tolerances as indicated on the Contractor's submitted drilling plan to ensure that the product is installed to the line and grade shown on the Contract Drawings. The Contractor's methods shall take into consideration the conditions at each crossing within the pipe alignment and shall be suitable to advance through such obstructions such as cobbles and boulders and address the potential for deflection off these obstruction and/or soil conditions.

In the event the pilot bore deviates from the submitted path, the Contract Administrator shall be notified. The Contract Administrator may require the Contractor to pullback and re-drill from the location along the bore path before the deviation.

In the event that a drilling fluid fracture, inadvertent returns, or loss of circulation occurs during pilot bore drilling operations, the Contract Administrator shall be advised of the event and action shall be taken in accordance with the Contractor's submitted contingency plan.

At the entry and exit points, there is potential for ravelling of the existing soil, fill and or weathered rock areas along the alignment. This is conventionally addressed by the use of drilling fluid. However, casing may be required. The Contractor's methods shall take into consideration the potential need to install sections of casing to manage ravelling at or near ground surface.

If a drill hole beneath the highway must be abandoned, the hole shall be backfilled with grout or bentonite to prevent future subsidence.

The Contractor shall maintain drilling fluid pressure and circulation throughout the DD process, including during the initial pilot bore and during the reaming process.

The Contractor shall at all times and for the entire length of the installation alignment be able to demonstrate the horizontal and vertical position of the alignment, the fluid volume used, return rates and pressures.

7.04.04 Drilling Fluid Fracture (Frac-Out)

In order to reduce the potential for hydraulic fracturing of the hole during directional drilling, a minimum depth of cover of 5m is normally maintained between the pipe and the ground surface. Sections of the pipe close to the exit pit with less than 5m cover shall be cased. The Contractor shall ensure that drilling fluid pressures are properly set and controlled to prevent frac-out, for the depth of cover available between the bottom of the pavement structure (bottom of the subbase material) and the top of the bore.

Since fluid loss normally occurs in fault zones, fracture zones, or seams of coarse material, fluid migration does not always gravitate to the surface, thus making detection difficult. Once a fluid loss is detected, the Contractor shall halt operations immediately and conduct a detailed examination of the drill path and implement measures to mitigate fluid loss. If no surface migration is evident, resume operation while paying particular attention to fluid monitoring.

In the event of a fluid migration to the surface occurring, the Contractor shall halt all operations immediately, isolate the migration site, and recover fluids. Once the fracture is controlled, continue drilling operations with the operator paying particular attention to the fracture points

7.04.05 Reaming

The bore shall be reamed using the appropriate tools to a diameter at least 50% greater than the outside diameter of the product.

7.04.06 Product Installation

7.04.06.0 General

The product shall be jointed according to manufacturer's recommendations. The length of the product to be pulled shall be jointed as one length before commencement of the continuous pulling operation.

The product shall be protected from damage during the pullback operation.

The minimum allowable bending radius for the product shall not be exceeded.

Product shall be allowed to recover before connections to new or existing facility are made. Product recovery time shall be according to manufacturers recommendations.

7.04.06.02 Pullback and Grouting

After successfully reaming the bore to the required diameter, the product shall be pulled through the bore path. Once the pullback operation has commenced, it shall continue without interruption until the product is completely pulled into bore unless otherwise approved by the Contract Administrator.

A swivel shall be used between the reamer and the product being installed to prevent rotational forces from being transferred to the product. When specified in the Contract Documents, a weak link or breakaway connector shall be used to prevent excess pulling force from damaging the product.

The product shall be inspected for damage where visible at excavation pits and where it exits the bore. Any damage noted shall be rectified to the satisfaction of the Contract Administrator,

The pull back and reaming operations shall not exceed the fluid circulation rate capabilities. Reaming and back pulling operations shall be planned to insure that, once started, all reaming and back pulling operations are completed without stopping and within the permitted work hours.

The space between the pipe and the excavation walls shall be filled with grout.

7. 05 Tunnelling Installation

7.05.01 General

The method of tunnelling shall be selected by the Contractor and shall be submitted to the Contract Administrator prior to commencement of the work for information purposes.

Excavation of native soil and fill shall be done in a manner to control groundwater inflow to the excavation and to prevent loss of ground into the excavation.

Methods of excavating the tunnel shall be capable of fully supporting the face and shall accommodate the removal of boulders and other oversize objects from the face. Continuous ground support shall be maintained during excavation.

As the excavation progresses, the Contractor shall continuously monitor (every 2m) indications of support distress, such as cracking, deflection or failure of support system and subsidence of ground near the excavation.

The Contractor shall advance the ventilation system as a regular part of the normal excavation cycle.

The Contractor shall provide lighting in accordance with OHSA requirements for the entire length of the tunnel.

The tunnel is to be kept sufficiently dry at all times to permit work to be performed in a safe and satisfactory manner.

The Contractor shall maintain clean working conditions at all times in tunnels.

In the event that excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation. The Contractor shall then evaluate methods of construction and revise as necessary to ensure the safe continuation of the work.

The Contractor shall maintain tunnel excavation line and grade to provide for construction of final lining within specified tolerances.

7.05.01 Tunnelling Method

The tunnelling method shall be suitable to provide face support in changing ground conditions that may be encountered during the progress of the work. The selection of the tunnelling method should consider the soil conditions at each pipe crossing and the presence of obstructions, such as cobbles and boulders, with respect to the tunnel alignment.

7.05.02 Primary Liner (Support System)

Primary support systems shall prevent deterioration, loosening, or unravelling of ground surfaces exposed by excavation.

The primary liner support system shall be designed and installed to achieve the intended performance requirements.

Primary liner support system shall maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the excavation.

The primary liner shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting, and shall ensure that no ground loading or other loading will be placed on the new work until after design strength has been reached.

The primary liner shall be installed so that the exterior is as tight as possible to the excavated surface of the tunnel and allows the placement of the full design thickness of the secondary lining.

Primary support systems shall be compatible with the encountered ground conditions, with the method of excavation, with methods for control of water, and with placement of the permanent lining.

All voids between the primary lining and the surface of the excavation shall be filled with cement grout. If an unexpanded liner is used, the space outside the liner plates shall be grouted at least daily.

7.05.03 Secondary Liner

7.05.03.01 Placing of Grout

The void outside the finished secondary liner shall be filled with cement grout according to the Contractor's submission.

Grout shall not be placed until the lining has achieved 85% of its specified strength or 30 MPa. Grouting shall be limited to such sequences and programs as are necessary to avoid damaging any part of the works or any other structure or property.

7.06 Instrumentation Monitoring

The work specified in this Section includes furnishing and installing instruments for monitoring of settlement and ground stability.

Surface settlement markers for monitoring ground stability shall be installed at the pavement/ground surface level on the shoulder, side slope and pavement at not greater than 5 m intervals along the tunnel alignment and as an array of three in-ground (1.5 m depth) measurement points on the shoulder of the highway perpendicular to the alignment. The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within ± 1 mm of the actual elevation.

Surface settlement markers shall be hardened steel markers treated or coated to resist corrosion, with an exposed convex head having a minimum diameter of 12 mm and similar to surveyor's PK nails. Markers shall be rigidly affixed so as not to move relative to the surface to which it is attached. Traffic shall be managed by the contractor using short-term lane closures in accordance with the Ontario Traffic Manual (OTM).

In general, settlement monitoring points shall be 12-18 mm rebar encased in a 50-70 mm, SCH40 PVC pipe, set to a depth of 1.5 m below ground surface. The assembly shall be placed in a drill hole and backfilled with uniform sand.

The Contractor shall install all surface settlement instruments a minimum of one week prior to the start of works.

The surface settlement instruments shall be clearly labelled for easy identification.

The Contractor shall submit to the Contract Administrator a site plan showing the locations of the monitoring points, a geodetic survey of the settlement monitoring points including station, offset and elevation recorded at the following time intervals:

- Three consecutive readings at least one week prior to commencement of the work (Baseline Reading);
- Once per shift during tunnelling operations period; and

- Weekly after completion of the work for one month, or until such time at which all parties agree that further movement has stopped.

All readings shall be submitted to the Contract Administrative for information purposes on a weekly basis. Each report shall include all survey data collected in tabular and graphical format as plots of time versus settlement in comparison to survey data collected prior to commencement of the work.

7.07 Criteria for Assessment of Roadway Subsidence/Heave

Based on the monitoring of ground movement as specified in Subsections 4.02 and 7.06, the following represents trigger levels that define magnitude of movement and corresponding action:

- Review Level: If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate or sequence of construction or ground stabilization measures to mitigate further ground displacement. If this Review Level is exceeded, the Contractor shall immediately notify the CA and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.
- Alert Level: If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic. No construction shall take place until all of the following conditions are satisfied:
    - The cause of the settlement has been identified.
    - The Contractor submits a corrective/preventive plan.
    - Any corrective and/or preventive measure deemed necessary by the Contractor is implemented.
    - The CA deems it is safe to proceed.

The Contractor shall avoid damaging instrumentation during construction. Instrumentation that is damaged as a result of the Contractor's operation shall be repaired or replaced by the Contractor within one business day. The costs for replacement/repair shall be borne by the Contractor.

At the completion of the job, the Contractor shall abandon all instrumentations installed during the course of the Work.

9. MEASUREMENT FOR PAYMENT

Measurement shall be by Plan Quantity Payment as may be revised by Adjusted Plan Quantity Payment in metres, following along the centre line of the pipes from centre to centre of maintenance holes or chambers (catch basins) or from/to the end of the pipe where no maintenance hole or chamber is installed, of the actual length of pipe installed by trenchless methods.

10. BASIS OF PAYMENT

Payment at the contract price shall be full compensation for all labour, equipment and materials required for excavation (regardless of material encountered), dewatering, sheathing and shoring, supply and installation of pipe liners, settlement instrumentation and monitoring, site restoration, and all other work necessary to complete the installation as specified.

Payment for the rigid or flexible pipe conduits installed inside the pipe liners shall be paid separately under the appropriate tender items.

Where a protection system is made necessary because of the Contractor’s operations (e.g. choice of trenchless installation method), the cost shall be included in this item and shall be full compensation for all labour, equipment and materials required to carry out the work including subsequently removing the temporary protection system and performing any necessary restoration work.

Payment for connecting intercepted drains and service connections shall be made on the following basis:

(a) Where such drains and service connections are shown on the contract drawings the cost of connections shall be included in the contract price for pipe installation.

(b) Where such drains and service connections are not shown on the contract drawings, the cost of connections will be considered an allowable extra to the contract.

Payment for removal of boulders/obstructions greater than an equivalent 0.3 m in diameter shall be on a time and materials basis. The Contractor shall inform the Contract Administrator when boulders/obstructions are encountered and prior to removal to allow for proper and accurate tracking of time and material charges.

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

For more information, visit golder.com

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 44 1628 851851
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

solutions@golder.com
www.golder.com

Golder Associates Ltd.
6925 Century Avenue, Suite #100
Mississauga, Ontario, L5N 7K2
Canada
T: +1 (905) 567 4444

Golder Associates