



May 19, 2017

## PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

### Culverts - New, Replacements and Extensions Highway 401 Improvements from Brock Road to Courtice Road Regional Municipality of Durham W.O. 10-20011

**Submitted to:**

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REPORT



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**PRELIMINARY FOUNDATION REPORT  
CULVERTS - NEW, REPLACEMENTS AND EXTENSIONS**

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# **PART A**

**PRELIMINARY FOUNDATION INVESTIGATION REPORT  
CULVERTS – NEW, REPLACEMENTS AND EXTENSIONS  
HIGHWAY 401 IMPROVEMENTS FROM BROCK ROAD TO COURTICE ROAD  
REGIONAL MUNICIPALITY OF DURHAM  
W.O. 10-20011**





## PRELIMINARY FOUNDATION REPORT CULVERTS - NEW, REPLACEMENTS AND EXTENSIONS

### 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM on behalf of the Ministry of Transportation, Ontario (MTO) to provide preliminary foundation engineering services for the future improvements and widening of Highway 401 from Brock Road to Courtice Road in the Regional Municipality of Durham, Ontario.

This report addresses the rehabilitation or replacement of, or extensions to six culverts. The locations of the culverts were determined using survey plans provided by AECOM and are shown on Drawing 1. The proposed locations, dimensions, type, and invert elevation for the existing culverts that are to be rehabilitated, replaced or extended, as well as the approximate embankment height, are summarized as follows:

Culvert ID	Station	Existing Culvert Dimensions/ Type	Proposed New or Replacement Structure/ Extension Details	Proposed Culvert or Extension Length (m)
C06 Rehabilitation, Replacement and Extension	32+455 (Hwy 401)	<u>North Section</u> 6200 x 2400 x 96.5 m Concrete Box Culvert (West Cell) 4300 x 96.5 m CSP Culvert (East Cell)	6200 x 2400 x 112 m Concrete Box Culvert (Extend West Cell / Replace East Cell)**	N 15
		<u>Middle Section</u> 11000 x 4430 x 39 m Concrete Box Culvert	-	-
		<u>South Section</u> 4300 x 37 m and 3540 x 37 m Twin CSP Culverts	-	-
C22 Rehabilitation and Extension	16+213 (Hwy 401)	5000 x 3100 x 121 m* Concrete Box Culvert	5000 x 3100 x 172 m Concrete Box Culvert**	N 7 S 44
C29 Replacement (on new alignment)	15+030 (Hwy 401)	3800 x 2200 x 61 m* Concrete Box Culvert	4000 X 2200 x 93 m Concrete Box Culvert**	93
C30 Replacement (on new alignment)	15+000 (Hwy 401)	3700 x 2000 x 54 m* Concrete Box Culvert	4000 x 2200 x 70 m Concrete Box Culvert	70
C31 Rehabilitation and Extension	15+539 (Hwy 401)	5000 x 2600 x 62 m* Concrete Single Span Open Footing Arch	5000 x 2600 x 81 m* Concrete Single Span Open Footing Arch	N 8 S 12
C35 Replacement (with North Extension)	11+816 (Hwy 401)	3800 x 3050 x 120 m* Concrete Box Culvert	4500 x 3050 x 132 m Concrete Box Culvert**	132

\*Culvert size at opening. Culvert type may vary along its length and details are unknown.

\*\* Cast-in-place replacement box culvert. Dimensions vary for pre-cast box culvert.





## PRELIMINARY FOUNDATION REPORT CULVERTS - NEW, REPLACEMENTS AND EXTENSIONS

The terms of reference for the preliminary foundation engineering services are outlined in MTO's Request for Proposals (RFP) for Assignment No. 2010-E-0062, dated June 2011. The scope of work for the preliminary foundation engineering services is presented in Section 5.8 of URS's *Technical Proposal* for this assignment, as well as Golder's Scope Change for Foundations Engineering Services letter dated September 30, 2013.

Subsurface information from previous investigations associated with the Brock Road to Courtice Road culverts was obtained from the MTO Geocres library as follows:

- MTO GEOCREs No. 30M15-030: Report titled "Proposed Widening of Harmony Creek Arch Culvert at Hwy. #401, Town of Oshawa, County of Ontario District 36 (Toronto), W.P. 44-71-11," prepared by the Department of Highways – Ontario, Foundation Section, dated June 26, 1973.

## 2.0 SITE DESCRIPTION

The culvert sites addressed in this report are located across Highway 401 and adjacent ramps from about 380 m west of the Westney Road S interchange to about 1700 m west of the Highway 401 - Courtice Road interchange in the regional municipality of Durham, Ontario. It is understood that the culvert replacements and extensions will be completed using conventional open cut methods.

In general, the topography in the area of the overall project site consists of rolling terrain covered by commercial and residential facilities located along Highway 401, with agricultural fields near the east end of the site.

## 3.0 INVESTIGATION PROCEDURES

### 3.1 Previous Investigation

Culvert C31 is located approximately 150 m east of the planned Harmony Road Underpass. The field work for the previous subsurface investigation for Culvert 31 was carried out between the period of April 10 to 11, 1973 and May 29 and 30, 1974, during which time a total of four (4) boreholes with dynamic cone penetrating tests and four (4) additional dynamic cone penetration test holes (designated as BH1 through BH8) were advanced approximately at the locations shown on Drawing 5. Boreholes BH1 to BH4 were advanced on the south side of Highway 401 and Boreholes BH5 to BH8 were advanced on the north side of the Highway.

The boreholes were advanced using a continuous flight hollow stem auger drill rig adapted for soil sampling purposes, supplied and operated by Master Soil Investigation Inc. of Toronto, Ontario. The boreholes were advanced to depths ranging from about 3.2 m to 9.0 m below the existing ground surface. Dynamic cone penetration testing was carried out in all eight (8) boreholes advanced as part of this program.

The groundwater conditions were observed in the open boreholes during and immediately following the drilling operations.

The borehole locations, including MTM NAD 83 Zone 10 northing and easting coordinates and the ground surface elevations referenced to Geodetic datum, presented on the Record of Borehole sheets in Appendix C and on Drawing 5 and together with the drilled depths are summarized below.





## PRELIMINARY FOUNDATION REPORT CULVERTS - NEW, REPLACEMENTS AND EXTENSIONS

Culvert ID	Station	Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
C31	15+539 (Hwy 401)	BH1	4,860,968.6	359,055.8	78.1	9.0
		BH2	4,860,976.9	359,057.0	78.1	3.3
		BH3	4,860,965.0	359,069.5	78.2	7.6
		BH4	4,860,970.6	359,069.6	78.3	3.2
		BH5	4,861,037.0	359,072.1	78.1	3.9
		BH6	4,861,047.3	359,074.2	78.2	7.9
		BH7	4,861,043.6	359,059.2	78.2	3.7
		BH8	4,861,037.5	359,058.9	78.2	5.4

### 3.2 Current Investigation

The field work for the subsurface investigation for the culverts was carried out on May 13, 2014 and between the period of March 12 to April 12, 2015, during which time a total of seven (7) boreholes (designated as RW6-3, C22-1, C22-2, C29-1, C29-2, C30-1, and C35-1) were advanced approximately at the locations shown on Drawings 2 to 4. Borehole RW6-3 was drilled in conjunction for the proposed retaining wall under the same terms of reference, as it is applicable to both the culvert extension and the retaining wall. Boreholes C22-1 and C22-2 are located approximately 250 m west of the Thickson Road interchange on the S-W Ramp and on the W-N/S Ramp, respectively. Boreholes C29-1, C29-2 and C30-1 are located approximately 400 m west of the Harmony Road interchange near Farewell Street on the shoulder of the Highway 401 westbound lane, near the W-N/S Ramp to Bloor and Harmony Street and in the ditch near the intersection of Farewell Street and Bloor Street, respectively. Borehole C35-1 is located approximately 1700 m west of the Courtice Road interchange on the shoulder of the Highway 401 westbound lane.

The boreholes were advanced using a CME-55 or CME-75 truck-mounted auger drill rig, supplied and operated by Strong Soil Search Inc. of Claremont, Ontario. The boreholes were advanced to depths ranging from about 6.4 m to 17.2 m below the existing ground surface. The boreholes were advanced using 150 mm diameter continuous flight solid stem augers. Soil samples were obtained at 0.75 m and 1.5 m intervals of depth, using 50 mm outside diameter split-spoon samplers driven by an automatic hammer, in accordance with the Standard Penetration Test (SPT) procedure ASTM D1586-11 – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of the Soil). Field vane shear tests (ASTM D2573) were carried out in the cohesive deposit at the culvert site using MTO 'N'-size vane to assess the undrained shear strength of the deposit. Dynamic cone penetration testing was carried out in Borehole C22-2 from the bottom of the borehole at 15.7 m to 22.6 m below ground surface.





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The groundwater conditions were observed in the open borehole during and immediately following the drilling operations. The boreholes were backfilled with bentonite on completion of drilling, in accordance with Ontario Regulation 903 (as amended).

The field work was observed by members of Golder's engineering and technical staff, who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined and cared for the soil samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to Golder's Mississauga geotechnical laboratory where the samples underwent further visual examination and geotechnical laboratory testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Index and classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected samples. The results of the geotechnical laboratory testing are included in Appendix B.

The borehole locations, including MTM NAD 83 Zone 10 northing and easting coordinates and the ground surface elevations referenced to Geodetic datum; presented on the Record of Borehole sheets in Appendix A and on Drawings 2 to 5 and together with the drilled depths are summarized below.

Culvert ID	Station	Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
C06	32+455 (Hwy 401)	RW6-3	4,856,602.7	341,362.2	88.2	9.2
C22	16+213 (Hwy 401)	C22-1	4,858,945.2	352,385.9	86.0	17.2
		C22-2	4,858,864.3	352,442.6	89.2	22.6
C29	15+030 (Hwy 401)	C29-1	4,861,004.8	358,538.8	87.0	10.9
		C29-2	4,860,930.3	358,526.2	86.0	6.5
C30	15+000 (Hwy 401)	C30-1	4,860,881.3	358,595.4	84.0	6.4
C35	11+816 (Hwy 401)	C35-1	4,859,869.1	362,473.3	95.0	15.7

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

This section of Highway 401 is located within the Iroquois Plain physiographic region, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984)<sup>1</sup> and *Urban Geology of Canadian Cities*

<sup>1</sup> Chapman, L.J., and Putnam, D.F., 1984. *The Physiography of Southern Ontario*, 3rd Edition. Ontario Geological Survey, Special Volume 2. Ontario Ministry of Natural Resources.





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(Brennand, 1998)<sup>2</sup>. The Iroquois Plain extends around the western shores of Lake Ontario. The Plain is comprised of the flat to undulating lakebed and beaches of the former glacial Lake Iroquois, which occupied this area during the last glacial recession.

The surficial soils in this area of the Iroquois Plain are typically comprised of glaciolacustrine clays, silts and sands to gravelly sands, which are underlain by an extensive till deposit that is mapped in this area as the Bowmanville Till. Within the area approximately bounded by Holt Road and Morgan's Road, the surficial glaciolacustrine deposits are absent or of relatively minor thickness and the Bowmanville Till unit is frequently present immediately below the ground surface. Between these limits, an extensive surficial deposit of clayey silt to silty clay is present over the Bowmanville Till (Brennand, 1998). More recent alluvial deposits of gravel, sand, silt and/or clay are present in the creek valleys.

### 4.2 Subsurface Conditions

As part of the previous and current subsurface investigation, a total of eight (8) boreholes and seven (7) boreholes, respectively were advanced near the proposed culvert rehabilitation, replacement and extension locations. The borehole locations, ground surface elevations and interpreted stratigraphic conditions at each culvert site are shown on Drawings 2 to 6.

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are presented on the Record of Borehole sheets in Appendix A (current investigation) and Appendix C (previous investigation). The results of the insitu filed tests (i.e., SPT "N"-values and vane shear tests, as presented on the Records of Borehole sheets and in Section 4.0 are uncorrected. The results of the current geotechnical laboratory testing are also presented on Figures B1 to B8 contained in Appendix B.

The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic sections on Drawings 2 to 6 are inferred from non-continuous sampling, observations of drilling progress and the results of the insitu tests. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change and the stratigraphy shown on the culvert centreline profile on Drawings 2 to 6 are interpretations of the subsurface conditions. Variation in the stratigraphic boundaries between and beyond boreholes will exist and is to be expected, however, the factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions. For the purposes of this report the, the Highway 401 alignment is an east-west orientation. Therefore, the directions indicated in the text may differ from those shown on the drawings.

In general, the stratigraphy consists of surficial layers of topsoil underlain by native ground or asphalt underlain by fill in the Highway platform/embankment areas. The fill is generally underlain by a clayey silt to silty clay deposit, or a clayey silt till deposit in placed, and the cohesive deposit is further underlain by till deposits that vary in composition from clayey silt to silty clay with sand to silty sand. In Boreholes BH1 and C30-1, shale bedrock is inferred present below the sand and gravel and clayey silt till deposits, respectively. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

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<sup>2</sup> Brennand, T.A. 1998. *Urban Geology Note: Oshawa Ontario*. In P.F. Karrow, and O. L. White (Eds.), Geological Association of Canada, Special Paper 42: *Urban Geology of Canadian Cities*, p. 353-364.





## PRELIMINARY FOUNDATION REPORT CULVERTS - NEW, REPLACEMENTS AND EXTENSIONS

### 4.2.1 Asphalt

An approximately 80 mm to 150 mm thick layer of asphalt was encountered immediately below the existing ground surface in all boreholes, with the exceptions of Boreholes BH1 to BH8 and C30-1.

### 4.2.2 Topsoil

An approximately 150 mm thick layer of topsoil was encountered immediately below the existing ground surface in Borehole C30-1, which was advanced in the south-east ditch near the intersection of Bloor Street East and Farewell Street.

### 4.2.3 Fill

Fill was encountered in all of the boreholes immediately below the topsoil or asphalt, with the exception of Boreholes BH1 to BH8 at Culvert C31. The elevation of the base of the fill and the thickness of the fill as encountered in the boreholes is summarized below.

Culvert Location	Borehole No.	Elevation of Surface of Fill (m)	Thickness of Fill (m)	Description
C06 Station 32+455	RW6-3	88.1	0.7	Sand and Gravel
		87.4	4.7	Clayey Silt
C22 Station 16+213	C22-1	85.9	4.6	Sand and Gravel Gravelly Sand
	C22-2	89.1	7.0	Sand and Gravel Silt and Sand
C29 Station 15+030	C29-1	86.9	5.2	Sand and Gravel Silty Sand
	C29-2	85.9	1.3	Sand and Gravel Sand
C30 Station 15+000	C30-1	83.8	0.6	Silty Clay
C35 Station 11+816	C35-1	94.8	0.6	Sand and Gravel
		94.2	6.8	Silty Clay with Sand

The thickness of the sand and gravel fill encountered underlying the asphalt ranges from approximately 180 mm to 650 mm and is generally underlain by a non-cohesive fill consisting of gravelly sand, silty and sand, silty sand and sand. The non-cohesive fill contains trace clay, organic material and slag. As noted above, a deposit of cohesive fill consisting of clayey silt or silty clay to silty clay with sand was encountered underlying the topsoil or sand and gravel fill in places. The cohesive fill contains trace to some gravel and organic material.

The Standard Penetration Test (SPT) "N"-values measured within the non-cohesive fill range from 2 blows to 32 blows per 0.3 m of penetration, indicating a very loose to dense relative density. The SPT "N"-values recorded within the cohesive fill range from 7 blows to 33 blows per 0.3 m of penetration, suggesting a firm to hard consistency.





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The natural water content measured on nine selected samples of the non-cohesive fill ranged from 6 per cent to 24 per cent. The natural water measured on four samples of the cohesive fill ranged from 9 per cent to 24 per cent.

The results of grain size distribution tests carried out on four selected samples of the non-cohesive fill are presented on Figure B1 in Appendix B. The result of one grain size distribution test completed on one sample of the cohesive fill is presented on Figure B2 in Appendix B.

Atterberg limit testing was conducted on one sample of the cohesive fill and measured a plastic limit of about 16 per cent, a liquid limit of about 38 per cent, and a corresponding plasticity index of about 22 per cent. The test result, which is plotted on a plasticity chart on Figure B3 in Appendix B, confirms that the deposit consists of silty clay of intermediate plasticity.

### 4.2.4 Clayey Silt to Silty Clay

A deposit of clayey silt to silty clay was encountered in all boreholes, except Boreholes BH4 to BH8 at Culvert C31 and RW6-3 at Culvert C6. The clayey silt to silty clay deposit was encountered at ground surface or immediately below the fill in all boreholes where the material was observed. A second silty clay deposit was encountered in Borehole C35-1 immediately below the clayey silt with sand till deposit. The thickness of the silty clay to clayey silt deposit varies from about 0.8 m to 9.0 m. Borehole C35-1 was terminated within this deposit, penetrating it for a thickness of 3.5 m. The elevations of the surface and base of the deposit and the thickness as encountered in the boreholes are summarized below.

Culvert Location	Borehole No.	Depth to Surface of Deposit (m)	Deposit Surface Elevation (m)	Deposit Thickness (m)	Deposit Base Elevation (m)	Soil type
C22 Station 16+213	C22-1	4.7	81.3	9.0	72.3	Silty Clay
	C22-2	7.1	82.1	>8.6	Below 73.5	Clayey Silt to Silty Clay
C29 Station 15+030	C29-1	5.3	81.7	1.7	80.0	Clayey Silt
	C29-2	1.4	84.6	0.7	83.9	Silty Clay
C30 Station 15+000	C30-1	0.8	83.2	1.9	81.3	Silty Clay
C31 Station 15+539	BH1	0	78.1	2.4	75.7	Clayey Silt
	BH3	0	78.2	3.2	75.0	Clayey Silt
C35 Station 11+816	C35-1	12.2	82.8	>3.5	Below 79.3	Silty Clay

The cohesive deposit ranges in composition from clayey silt to silty clay, trace sand to with sand and trace to some gravel. A 0.5 m thick silty sand layer was observed within the deposit in Borehole C22-1 at a depth of 9.1 m (Elevation 76.9 m). The results of a current grain size distribution tests completed on three (3) samples of the clayey silt to silty clay deposit are shown on Figure B4 in Appendix B.





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The measured SPT “N”-values within the clayey silt to silty clay deposit from the current investigation range from 0 blows (weight of hammer) to 72 blows per 0.3 m of penetration. The measured SPT “N”-values within the clayey silt to silty clay deposit from the previous investigation range from 6 blows to 28 blows per 0.3 m of penetration. In situ vane tests carried out within the clayey silt to silty clay deposit in two boreholes measured undrained shear strengths ranging from about 7 kPa to 45 kPa and sensitivities between 2 and 4. The results of the SPT “N”-values and vane tests suggest that the clayey silt to silty clay deposit is very soft to hard in consistency.

The natural water content measured on seven (7) selected samples from the current investigation of the silty clay to clayey silt deposit range from about 16 per cent to 52 per cent. The natural water content measured on four (4) selected samples from the previous investigation of the silty clay to clayey silt deposit range from about 22 per cent to 31 per cent.

Atterberg limits testing was conducted on eight (8) selected samples from the current investigation of the cohesive deposit and measured plastic limits ranging from about 12 per cent to 19 per cent, liquid limits ranging from 26 per cent to 49 per cent, and plasticity indices ranging from 14 per cent to 31 per cent. Atterberg limits testing was conducted on three (3) selected samples from the previous investigation of the cohesive deposit and measured plastic limits ranging from about 13 per cent to 20 per cent, liquid limits ranging from 21 per cent to 28 per cent, and plasticity indices ranging from 6 per cent to 10 per cent. The test results from the current investigation, which are plotted on a plasticity chart on Figure B5 in Appendix B, confirm that the cohesive deposit is classified as clayey silt of low plasticity to silty clay of intermediate plasticity.

Laboratory consolidation tests were carried out on one sample of silty clay from the clayey silt to silty clay deposit from Borehole C22-2. The pre-consolidation stress of about 160 kPa was estimated from the Void Ratio versus logarithmic Pressure plot using the Casagrande method. The specific gravity of the samples tested is about 2.77. The consolidation test results are presented on Figures B6A to B6D in Appendix B, and summarized below.

Borehole /Sample No.	Sample Depth/EI ev.	Bulk Unit Wt. (kN/m <sup>3</sup> )	$\sigma_{vo}'$ (kPa)	$\sigma_p'$ (kPa)	$\sigma_p' - \sigma_{vo}'$ (kPa)	OCR	$C_c$	$C_r$	$e_o$	$C_v^*$ (cm <sup>2</sup> /s)
C22-2 / 8	10.4 m / 78.8 m	17.9	150	158	8	1.06	0.28	0.06	1.13	1.05x10 <sup>-3</sup>

### NOTES:

\* For stress range between effective overburden stress and final stress due to a 3 m to 5 m high embankment, that is 60 kPa  $\leq \sigma_v' \leq 100$  kPa.

$\sigma_p'$	Estimated preconsolidation stress (kPa)	$\sigma_{vo}'$	Computed existing vertical effective stress (kPa)
$C_c$	Compression index	$C_r$	Recompression index
$e_o$	Initial void ratio	OCR	Overconsolidation ratio
		$C_v$	Coefficient of Consolidation (cm <sup>2</sup> /s)

### 4.2.5 Till

A till deposit was encountered in all the boreholes except Borehole C22-2 and BH4 at Culvert C22 and C31, respectively. The till deposit was encountered immediately below the clayey silt to silty clay deposit in all boreholes where it was observed, except in Boreholes BH5 to BH8 and RW6-3 where the till deposit was encountered immediately below a surficial sand or fill layer. The thickness of the till deposit varies from about 3.1 m to 4.9 m





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and is greater than 5.8 m where not fully penetrated. The elevations of the surface and base of the till deposit and the thickness as encountered in the boreholes are summarized below.

Culvert Location	Borehole No.	Depth to Surface of Deposit (m)	Deposit Surface Elevation (m)	Deposit Thickness (m)	Deposit Base Elevation (m)	Soil Type
C06 Station 32+455	RW6-3	5.5	82.7	3.1	79.6	Clayey Silt Till
C22 Station 16+213	C22-1	13.7	72.3	>3.5	Below 68.8	Silty Clay with Sand Till
C29 Station 15+030	C29-1	7.0	80.0	>3.9	Below 76.1	Silty Sand Till
	C29-2	2.1	83.9	> 4.4	Below 79.5	Clayey Silt with Sand Till
C30 Station 15+000	C30-1	2.3	81.7	>4.1	Below 77.6	Clayey Silt with Sand Till
C31 Station 15+539	BH1	2.4	75.7	4.9	70.8	Sand and Gravel
	BH3	3.2	74.9	>4.4	Below 70.5	Sand and Gravel
	BH6	2.1	76.0	>5.8	Below 70.2	Sand and Gravel
	BH8	1.1	77.0	>4.4	Below 72.6	Sand and Gravel
C35 Station 11+816	C35-1	7.6	87.4	4.6	82.8	Clayey Silt with Sand Till

In the current investigation the till deposit varies in composition from clayey silt to silty clay, trace to with sand, and is classified as silty sand trace to some clay in one borehole. In Borehole C35-1, organic material was observed within the till deposit at a depth of 7.6 m. The presence of cobbles was also inferred in Boreholes C30-1 and C35-1 from difficulties advancing augers (auger grinding) between depths of approximately 8.2 m and 9.1 m. In the previous investigation the till deposit was comprised of sand and gravel with varying amounts of silt and clay. In Boreholes BH6 and BH8, shale fragments were observed within the deposit. The presence of cobbles and boulders was also inferred in BH6 and BH8 within the till deposit.

The SPT "N"-values recorded within the cohesive till deposits during the current investigation range from 0 blows (weight of hammer) per 0.3 m of penetration to 50 blows per 0.1 m of penetration, suggesting that the cohesive till deposit has a very soft to hard consistency. The SPT "N"-values recorded within the non-cohesive till deposit during the current investigation range from 26 blows per 0.3 m of penetration to 50 blows per 0.1 m of penetration, indicating a compact to very dense relative density. The SPT "N"-values recorded within the non-cohesive till





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deposit during the previous investigation range from 28 blows per 0.3 m of penetration to 100 blows per 0.1 m of penetration, indicating a compact to very dense relative density.

The natural water content measured on selected samples of the till deposit during the current investigation range from about 7 per cent to 35 per cent. The natural water content measured on selected samples of the till deposit during the previous investigation range from 5 per cent to 10 per cent.

The results of grain size distribution tests completed on five (5) samples of the cohesive till deposit are shown on Figure B7 in Appendix B. The results of grain size distribution tests completed on one samples of the silty sand till deposit are shown on Figure B8 in Appendix B. The results of laboratory testing completed on selected samples of the till during the previous investigation are contained in Appendix C.

Atterberg limits testing was conducted on four (4) selected samples of the till deposit during the current investigation and measured plastic limits ranging from about 11 per cent to 14 per cent, liquid limits ranging from about 18 per cent to 26 per cent, and plasticity indices ranging from about 7 per cent to 12 per cent. The test results, which are plotted on a plasticity chart on Figure B9 in Appendix B, confirm that the cohesive portions of the cohesive till deposit are classified as clayey silt of low plasticity.

### 4.2.6 Shale Bedrock

Weathered black shale was encountered underlying the clayey silt till in Borehole RW6-3. The shale was encountered at a depth of 8.6 m, corresponding to Elevation 79.6 m, and was penetrated for a depth of 0.6 m. Sound shale bedrock was also encountered in BH1 during the previous investigation. The shale was encountered at a depth of 7.6 m, corresponding to Elevation 70.4 m, and was penetrated for a depth of 1.4 m.

### 4.2.7 Groundwater Conditions

The groundwater levels in the open boreholes were measured upon completion of drilling operations. Details of the measured groundwater levels are shown on the Record of Borehole sheets in Appendix A for the current investigation and in Appendix C for the previous investigation. The groundwater levels recorded in the open boreholes are summarized below.

Borehole No.	Ground Surface Elevation (m)	Depth to Water Level (m)	Groundwater Elevation (m)	Date
RW6-3	88.2	6.1	82.1	May 13, 2014
C22-1	86.0	3.7	82.3	March 31, 2015
C22-2	89.2	6.1	83.1	April 1, 2015
C29-1	87.0	3.4	83.6	March 26, 2015
C29-2	86.0	Dry	-	April 12, 2015
C30-1	84.0	5.8	78.2	March 12, 2015
BH1	78.1	1.6	76.5	April 10, 1973
BH3	78.2	1.7	76.5	April 4, 1973
BH6	78.2	1.1	77.1	May 30, 1974
BH8	78.2	1.0	77.1	May 30, 1974





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Borehole No.	Ground Surface Elevation (m)	Depth to Water Level (m)	Groundwater Elevation (m)	Date
C35-1	95.0	9.8	85.2	March 25, 2015

The groundwater level observations at these sites are unstabilized, short term conditions and will be subject to seasonal fluctuations and precipitation events, therefore the water levels should be expected to be higher during the spring season or during any period of heavy precipitation.

### 5.0 CLOSURE

This Preliminary Foundation Investigation Report was prepared by Mr. Kevin Wallin, EIT, and reviewed by Nikol Kochmanová, P.Eng., a geotechnical engineer with Golder. Mr. Jorge Costa, P.Eng., a Senior Consultant and Designated MTO Foundations Contact for Golder, conducted an independent quality control review of this report.

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**PRELIMINARY FOUNDATION REPORT  
CULVERTS - NEW, REPLACEMENTS AND EXTENSIONS**

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## **PART B**

**PRELIMINARY FOUNDATION DESIGN REPORT  
CULVERTS – NEW, REPLACEMENTS AND EXTENSIONS  
HIGHWAY 401 IMPROVEMENTS FROM BROCK ROAD TO COURTICE ROAD  
REGIONAL MUNICIPALITY OF DURHAM  
W.O. 10-20011**





## **6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS**

### **6.1 General**

This section of the report provides foundation design recommendations for the proposed new culverts, culvert replacements, rehabilitations and culvert extensions in the general area of Highway 401 between Brock Road and Courtice Road in the Regional Municipality of Durham, Ontario. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during this subsurface investigation. This preliminary design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation to provide the designers with sufficient information to assess the feasible culvert foundation alternatives as well as the feasible trenchless installation methods/open cut excavations and to carry out the design of the culvert foundations and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor. The design-build contractor must make their own interpretation based on the factual data in Part A of the report.

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. Contractors must 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 Foundation Options**

It is understood that rehabilitation and extension of two culverts and replacement of three culverts are proposed along Highway 401 between Brock Road and Courtice Road. Details regarding the proposed culverts are provided below.





## PRELIMINARY FOUNDATION REPORT CULVERTS - NEW, REPLACEMENTS AND EXTENSIONS

Culvert ID	Station	Existing Culvert Dimensions/ Type	Proposed Culvert Replacement / Extension Details	Proposed Culvert or Extension Length (m)	Approximate Embankment Height (m)	Invert Elevation (m)	
						Inlet	Outlet
C06 Rehabilitation, Replacement and Extension	32+455 (Hwy 401)	<u>North Section</u> 6200 x 2400 x 96.5 m Concrete Box Culvert (West Cell) 4300 x 96.5 m CSP Culvert (East Cell)	6200 x 2400 x 112 m Concrete Box Culvert (Extend West Cell / Replace East Cell)**	N 15	2 to 3	81.4	-
		<u>Middle Section</u> 11000 x 4430 x 39 m Concrete Box Culvert	-	-			
		<u>South Section</u> 4300 x 37 m and 3540 x 37 m Twin CSP Culverts	-	-			
C22 Rehabilitation and Extension	16+213 (Hwy 401)	5000 x 3100 x 121 m* Concrete Box Culvert	5000 x 3100 x 172 m Concrete Box Culvert**	N 7 S 44	3.5 to 5	81.9	81.2
C29 Replacement (on new alignment)	15+000 (Hwy 401)	3800 x 2200 x 61 m* Concrete Box Culvert	4000 X 2200 x 93 m Concrete Box Culvert**	93	2 to 3	82.2	81.8
C30 Replacement (on new alignment)	15+030 (Hwy 401)	3700 x 2000 x 54 m* Concrete Box Culvert	4000 x 2200 x 70 m Concrete Box Culvert	70	4.0	81.6	81.0
C31 Rehabilitation and Extension	15+539 (Hwy 401)	5000 x 2600 x 62 m* Concrete Single Span Open Footing Arch	5000 x 2600 x 81 m* Concrete Single Span Open Footing Arch	N 8 S 12	2.8	77.6	77.3
C35 Replacement (with North Extension)	11+816 (Hwy 401)	3800 x 3050 x 120 m* Concrete Box Culvert	4500 x 3050 x 132 m Concrete Box Culvert**	132	7.5 to 8.5	85.1	83.5

\*Culvert size at opening. Culvert type may vary along its length and details are unknown.

\*\* Cast-in-place replacement box culvert. Dimensions vary for pre-cast box culvert.





## PRELIMINARY FOUNDATION REPORT CULVERTS - NEW, REPLACEMENTS AND EXTENSIONS

Although it is recognized that the culvert extensions will likely be required to match the existing culverts, this section of the report presents advantages, disadvantages and geotechnical recommendations for new box culverts, box culvert replacements or extensions and open footing culvert as replacements or extensions.

Either box culverts or “open footing” (shallow foundation) concrete culverts are feasible for replacement or extension of the existing culverts or for new structures. Associated retaining walls, if required, should be supported on shallow foundations. Deep foundations are not required at any of the culvert sites, as shallow foundations will provide sufficient bearing resistance and acceptable settlement performance. Both pre-cast concrete elements (box culvert segments or footing elements) and cast-in-place concrete elements are also feasible from a foundations perspective.

The advantages and disadvantages associated with both the pre-cast box culvert and cast-in-place open footing new culvert and culvert replacement and extension options are summarized in Table 1 following the text of this report. From a foundations perspective, pre-cast box culverts are preferred for every site over cast-in-place open footing culvert replacements and extensions based on the following:

- Pre-cast box culvert extensions minimize the depth of excavation and groundwater control requirements as compared with open footings; and are compatible with the existing box structures.
- Pre-cast box culvert segments can usually be installed more expeditiously than cast-in-place open footing culverts, resulting in shorter durations for dewatering, surface water pumping, traffic control needs.
- Pre-cast box culvert segments are more tolerant of total and differential settlement if the highway or ramp embankment is widened at the culvert extension site to accommodate construction staging requirements.

It is noted, however, that a box culvert extension may not satisfy fisheries requirements related to channel substrate, in which case an open footing culvert is geotechnically feasible (though not preferred from a geotechnical perspective).

Recommendations for both new or replacement box culverts and extensions, and open footing new/replacement culverts and extensions are provided in the following sections.

### 6.3 Founding Elevations and Sub-excavation Requirements

#### 6.3.1 Box Culvert – New, Replacements or Extensions

It is not necessary to found new box culverts or box culvert replacements or extensions sections at the standard depth for frost protection purposes, as the box structures are tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur, and differential settlement that may occur at the extension connection from loading of new embankment widening fill. Box culverts should, however, be founded below any existing fill and surficial organic materials. Table 2, following the text of the report, provides recommended founding elevations and sub-excavation requirements for new or replacement box culverts or extensions, based on an assumed base slab thickness of 250 mm. In addition, it is recommended that the box culvert segments be placed on a minimum thickness of 150 mm (or more depending on the requirements for excavation backfill and bedding as noted in Table 2) of granular bedding material meeting Ontario Provincial Standard Specification (OPSS.PROV) 1010 Granular ‘A’ (Aggregates). It is further noted that the strength of the subgrade soils at Culvert C22 decreases substantially with depth and therefore the base founding depth and depths of excavation should be restricted to the elevation(s) given in Table 2.





## PRELIMINARY FOUNDATION REPORT CULVERTS - NEW, REPLACEMENTS AND EXTENSIONS

For sites where sub-excavation is recommended below replacement or extension box culverts (as per Table 2), the width of the required sub-excavation should be defined by lines extending from 0.3 m beyond the outside edges of the proposed culvert base slab, outward and downward at 1H:1V. Depending on the depth of sub-excavation required relative to the existing culvert base or footings, temporary excavation support may be required to prevent loss of bedding material and/or native soils from below the existing culvert during sub-excavation. In wet conditions, the excavation backfill/bedding should be comprised of OPSS.PROV 1010 Granular B Type II material.

The box culvert subgrade should be inspected by a Quality Verification Engineer following sub-excavation to ensure that all existing fill, peat and surficial organic soils or other unsuitable material have been removed, in accordance with OPSS 422 (Box Culverts and Box Sewers in Open Cut) and OPSS 902 (Excavating and Backfilling Structures). Following inspection, the sub-excavated area should be backfilled with granular material meeting OPSS.PROV 1010 Granular 'A' or Granular 'B' Type II as noted above that is placed and compacted in accordance with OPSS.PROV 501 (Compaction).

Groundwater and/or surface water control will be required for excavation and construction of box culvert for many of the culvert sites.

The subgrade for the box culvert replacements and extensions will be susceptible to loosening/softening and degradation on exposure to water and construction traffic. As discussed further in Section 6.7, as an alternative to the placement of granular bedding material on the native soil below the base slab, a 100 mm thick, 20 MPa concrete working slab could be placed on the subgrade to protect it from degradation followed by the required backfill bedding to the underside of the levelling course. In any case, a 75 mm thick layer of uncompacted OPSS.PROV 1010 (Aggregates) Granular 'A' or concrete fine aggregate meeting the gradation requirements set out in OPSS.PROV 1002 (Aggregates - Concrete) should be placed on top of the bedding/backfill or concrete working slab, as applicable, to provide a "levelling pad" for the box culvert replacement or extension.

### 6.3.2 Open Footing Culvert – New, Replacements and Extensions

Strip footings for open footing culvert replacements and extensions, and for any associated concrete wing walls/retaining walls, should be founded at a minimum depth of 1.2 m below the lowest surrounding grade to provide adequate protection against frost penetration which, for these sites is estimated to be to a depth of 1.2 m, as per Ontario Provincial Standard Drawing (OPSD) 3090.101 (Foundation, Frost Penetration Depths for Southern Ontario). In addition, the footings should extend below any existing fill and surficial organic materials, where present. Table 3, following the text of the report, provides recommended founding elevations and sub-excavation requirements for strip footings for the proposed culvert replacements and extensions. It is further noted that the strength of the subgrade soils at Culvert C22 decreases substantially with depth and therefore the footing founding depth and depth of excavation should be restricted to the elevation(s) given in Table 3.

For sites where open footing culverts are to be constructed on a granular backfill pad rather than on the native subgrade at greater depth in subexcavation areas, the width of the sub-excavation should be defined by lines extending from 0.3 m beyond the outside edges of the proposed culvert footing, outward and downward at 1H:1V. Depending on the depth of sub-excavation required relative to the existing culvert base or footings, temporary excavation support may be required to prevent loss of bedding material and/or native soils from below the existing culvert during sub-excavation.





The footing subgrade should be inspected by a Quality Verification Engineer following excavation, in accordance with OPSS 902 (Excavating and Backfilling Structures) to check that all existing fill, peat and surficial organic soils or other unsuitable material have been removed. Where sub-excavation is required to remove unsuitable materials, the sub-excavated area should be backfilled with granular material meeting OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II that is placed and compacted in accordance with OPSS.PROV 501 (Compacting).

Groundwater and/or surface water control will be required for excavation and construction of open footing culverts for the majority of the culvert sites.

The footing subgrade where comprised of native material will be susceptible to loosening and degradation on exposure to water and construction traffic. As discussed further in Section 6.7, it is recommended that a 100 mm thick, 20 MPa concrete working slab be placed on the inspected and approved footing subgrade where comprised of native materials, to protect the subgrade from degradation and to form a working surface for construction of the culverts.

### 6.4 Geotechnical Resistance

Tables 2 and 3, following the text of this report, provide factored geotechnical axial resistances at Ultimate Limit State (ULS) and geotechnical reaction at Serviceability Limit State (SLS) for each of the box culvert option and open footing option at each culvert site, respectively.

#### 6.4.1 Box Culverts – New, Replacements or Extensions

Replacement box culverts or extensions placed on the properly prepared subgrade, at or below the founding elevations recommended in Table 2, should be designed based on the recommended factored geotechnical axial resistance at ULS and the geotechnical reaction at SLS (for 25 mm of settlement) as given in Table 2 for each culvert. These recommendations are based on the box culvert span as given in Table 2.

The ULS resistance and settlement are dependent on the footing size, configuration and applied loads; the geotechnical resistances should, therefore, be reviewed if the culvert span or founding elevation differs significantly from that given in Table 2.

The geotechnical resistances provided in Table 2 are based on loading applied perpendicular to the surface of the footings. Where the load is not applied perpendicular to the surface of the footing, inclination of the load should be taken into account in accordance with Section 6.7.2 of the Canadian Highway Bridge Design Code (CHBDC, 2006).

#### 6.4.2 Open Footing Culvert Replacements and Extensions

Strip footings placed on the properly prepared subgrade, at or below the founding elevations recommended in Table 3, should be designed based on the factored axial geotechnical resistance at ULS and the geotechnical reaction at SLS (for 25 mm of settlement) as given in Table 3 for each culvert. These recommendations are based on an assumed footing width of 0.6 m.

The ULS resistance and settlement are dependent on the footing size, configuration and applied loads; the geotechnical resistances should, therefore, be reviewed if the selected footing width or founding elevation differs significantly from those given in Table 3.





## PRELIMINARY FOUNDATION REPORT CULVERTS - NEW, REPLACEMENTS AND EXTENSIONS

The geotechnical resistances provided in Table 3 are given under the assumption that the loads will be applied perpendicular to the surface of the footings. Where the load is not applied perpendicular to the surface of the footing, inclination of the load should be taken into account in accordance with Section 6.7.2 of the CHBDC (2006).

### 6.5 Settlement

It is understood that Highway 401 is to be widened, or new ramps constructed, at the culvert locations, which would require placement of a vertical thickness of approximately 3 m up to approximately 5 m of additional fill atop the existing embankment side slopes or fully over a native soil subgrade. This embankment widening, and ramp construction, will induce some settlement in the foundation soils beneath the newly loaded areas.

The settlement analysis for culvert sites was carried out using both hand calculations and the commercially-available program *Settle-3D* from Rocscience, using estimated consolidation parameters and elastic deformation moduli as given below, based on correlations with the undrained shear strength, Atterberg limits and SPT "N"-values and engineering judgement from experience with similar soils in this region of Ontario.

Soil Deposit	Bulk Unit Weight	Elastic Modulus	$P_c'$	$e_o$	$C_c$	$C_r$
Embankment fill (existing and new)	21 kN/m <sup>3</sup>	—	—	—	—	—
Very soft to stiff clayey silt to silty clay	18 kN/m <sup>3</sup>	-	158 kPa	1.13	0.28	0.06
Very soft to firm silty clay to clayey silt/ clayey silt to silty clay till	20 kN/m <sup>3</sup>	-	70 - 200 kPa	0.675	0.2	0.02
Stiff to very stiff silty clay to clayey silt/ clayey silt to silty clay till	20 kN/m <sup>3</sup>	-	150 - 250 kPa	0.675	0.3	0.03
Very stiff to hard clayey silt till	21 kN/m <sup>3</sup>	50 – 75 MPa	—	—	—	-
Dense to very dense silty sand till	21 kN/m <sup>3</sup>	150 MPa	—	—	—	-

The settlement of the foundation soils under the approximately 3 m to 5 m thick layer of additional fill to be placed on the embankment side slope is estimated to be between approximately 20 mm to 35 mm under the actual widening area, decreasing to less than 10 mm under the shoulder of the existing embankment and at the toe of the widened embankment, with the exception of Culvert C22. The weak in-situ soils observed at Culvert C22 are susceptible to higher settlements. The settlement of the foundation soils at Culvert C22 under the approximate 5 m thick layer of additional fill that may be placed on the embankment side slope to facilitate construction staging is estimated to be on the order of 250 mm under the actual widened embankment, decreasing to 60 mm under the shoulder of the existing embankment and at the toe of the widened embankment. At the site of Culvert C22, preloading or other ground improvement measures and/or the utilization of lightweight fill for widening embankment construction will be required and needs to be assessed at detail design. Table 4, following the text of this report, provides estimated settlement values at each culvert site.

The connection between an existing culvert and the extension should be designed by the structural engineers to accommodate these deformations and stresses. For the relatively small predicted settlements, settlement mitigation measures are not required but settlement mitigation measures will be required at Culvert C22 as noted above. This should be reassessed at the detail design stage following completion of additional borehole investigation at that time.





## **6.6 Culvert Bedding, Backfill and Erosion Protection**

For the replacement box culverts or extensions, the levelling pad / bedding and backfill requirements should be in accordance with OPSS 422 (Box Culverts and Box Sewers in Open Cut) for pre-cast rigid frame culverts. The culverts should be provided with at least 150 mm of OPSS.PROV 1010 Granular 'A' material for bedding purposes, or alternatively a 100 mm thick concrete working slab, and a 75 mm thick levelling course of Granular 'A' or concrete fine aggregate material.

Backfill and cover for the culverts should be of similar construction as per OPSD 803.010 (Backfill and Cover for Concrete Culverts). Backfill to culvert walls should consist of granular fill meeting the requirements of OPSS.PROV 1010 Granular 'A' or Granular 'B' Type II. The backfill and bedding should be placed and compacted in accordance with OPSS.PROV 501 (Compacting). The fill depth during placement should be maintained equal on both sides of the culvert walls, with one side not exceeding the other by more than 400 mm. The culvert replacements or extensions should be designed for the full overburden and hydrostatic pressures, and live load, assuming that the embankment fill has a unit weight of 22 kN/m<sup>3</sup> for Granular A, and 21 kN/m<sup>3</sup> for Granular B Type II or select earth fill above and/or surrounding the culvert.

Backfill placement for reconstruction of the roadway embankment and for widening embankments over and along the culverts should be carried out as per OPSD 208.010 (Benching of Earth Slopes) to integrate the new fill into the existing embankment fill along the cut faces and existing embankment side slopes.

To prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring) or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a concrete or clay cut-off wall should be provided at the upstream end of box culvert, while a clay seal should be provided at the upstream end of open footing culvert. Clay seals should also be placed adjacent to the culvert inlet opening for both box culvert and open footing structure types. The clay material should meet the requirements of OPSS.PROV 1205 (Clay Seal). The clay seal should have a thickness of 1 m, and the seal should extend from a depth of 1 m below the scour level to a minimum horizontal distance of 2 m on either side of the culvert inlet opening, and a minimum vertical height equivalent to the high water level including treatment of the adjacent side slopes.

Provision should be made for scour and erosion protection (suitable non-woven geotextiles and/or rip-rap) at the culvert inlet and outlet, including in front of any wing walls/retaining walls adjacent to the creek channel. The requirements for and design of erosion protection measures for the culvert inlet should be assessed by the hydraulic design engineer. As a minimum, rip-rap treatment for the culvert outlet should be consistent with the standard Treatment Type A presented in OPSD 810.010 (Rip-Rap Layout for Sewer and Culvert Outlets), with the rip-rap placed up to the toe of slope level, in combination with the cut-off measures noted above. Similarly, rip-rap should be provided at the culvert inlet end similar to that at the outlet end.

Excavation, bedding and backfilling operations should be inspected by a Quality Verification Engineer in accordance with OPSS 902 (Excavating and Backfilling Structures).





## **6.7 Construction Considerations**

The following subsections identify future construction considerations that should be considered at this stage as they may impact the planning and preliminary design. Where applicable, Non-Standard Special Provisions (NSSP) should be developed during detail design for incorporation in the Contract Documents.

### **6.7.1 Excavations and Temporary Roadway Protection**

The existing CSP extension at Culvert C06 is to be replaced with a box culvert, and Culverts C29 and C30 are to be replaced along new alignments. The proposed invert of the existing CSP Culvert C06 is about the same as that of the proposed invert of the box culvert replacement. The recommendations for excavation and protections systems provided below may be used for the removal of the existing culverts.

Temporary excavations for the new culverts, culvert extensions and replacements will be made through the existing embankment fill and native soils, which generally vary from very loose to compact/stiff to very stiff sand and gravel/silt and sand fill and clayey silt fill, and soft to stiff clayey silt to silty clay soils and clayey silt to silty clay till. Excavation works must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act and Regulations for Construction Projects. The existing fill and the soft portions of the clayey silt to silty clay soils would be classified as Type 3 soil, according to the Occupation Health and Safety Act, assuming that proper groundwater control is in place to dewater non-cohesive soil deposits prior to excavation, where necessary. The firm to hard native cohesive materials and till deposits would be classified as a Type 2 soil. Where space permits, and provided that proper groundwater control is in place, temporary open-cut excavations through these materials should be made with side slopes formed no steeper than 1H:1V in Type 3 soils and excavation walls sloped at 1H:1V to within 1.2 m of the bottom of the excavation in Type 2 soil. In wet ground conditions, the excavations should be made at side slopes no steeper than 3H:1V.

Temporary protection systems will be required to facilitate construction staging to maintain traffic on Highway 401 and the ramps during the culvert replacement works and for the new culvert construction. Temporary protection systems may be required for the culvert extension work. The temporary excavation support systems for the culvert construction should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems). The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS.PROV 539, provided that any adjacent utilities can tolerate this magnitude of deformation.

The protection system will be required for excavation depth of approximately 3 m and up to 6 m. Although the selection and design of the protection system will be the responsibility of the Contractor, it is considered that either a driven, interlocking sheetpile system or a soldier pile and timber lagging system would be suitable for the roadway protection at these culvert sites, based on the subsurface soil and groundwater conditions. An interlocking sheetpile system would contribute to both ground and groundwater control. For the soldier pile and lagging system, it would be necessary to lower the groundwater level to control seepage from the non-cohesive fill or native soils, or include measures to mitigate loss of soil particles through the lagging boards.

The sheetpiles or soldier piles would have to be socketted to sufficient depth to provide the necessary passive resistance for the retained soil height of up to 6 m. Lateral support to the sheetpiles or soldier piles could be provided in the form of rakers or temporary anchors.





### 6.7.2 Groundwater and Surface Water Control

As discussed in Section 6.3, the culvert foundation excavations will extend below the groundwater level at this site, and groundwater control will be required to handle seepage from the water-bearing non-cohesive soil layers and existing fill. Based on the water levels and soil conditions observed in the previous and current boreholes, it is expected that active dewatering will be required to maintain the water level below the founding level throughout the excavating and culvert construction operations; the dewatering system would likely consist of a vacuum well-point system given the fine-grained (clayey silt or clayey silt till) soils at or near the proposed founding level. Further assessment of the potential dewatering volumes should be completed at the detail design stage to confirm the requirements for an Environmental Activity Section Registry (EASR) a Permit to Take Water (PTTW) from the Ontario Ministry of the Environment and Climate Change (MOECC).

Control of surface water and groundwater will be necessary for the construction of the new or replacement culverts and extensions, to allow excavation and foundation construction to be carried out in dry conditions.

Depending on the creek flow at the time of construction, the surface water flow could be passed through the culvert area by means of a temporary pipe, or diverted by pumping from behind a temporary cofferdam. Surface water should be directed away from the excavation areas, to prevent ponding of water that could result in disturbance and weakening of the subgrade soils.

### 6.7.3 Subgrade Protection

The subgrade soils that will be exposed at the foundation subgrade level will be susceptible to disturbance from construction traffic and/or ponded water. To limit this degradation, it is recommended that a concrete working slab be placed on the subgrade within four hours after preparation, inspection and approval of the footing subgrade. This requirement can be addressed with a note on the General Arrangement drawing and/or with an NSSP, which can be developed during the detail design stage.

## 6.8 Recommendations for Further Work During Detail Design

Additional boreholes are recommended as close as practicable to the alignment of the proposed new culverts, culvert replacement and extension areas during the future detail design stage of investigation, to further assess and/or confirm the subsurface conditions and the preliminary recommendations provided herein, as follows:

- Assessment of the depth and extent of stripping of organics, fill materials and/or any soft/loose surficial materials within the footprint of the new culverts and culvert replacement and extensions.
- Confirmation of the groundwater elevation at the sites and further assessment of dewatering requirements during construction.
- Additional oedometer testing of samples of the very soft silty clay and clayey silt to silty clay till strata from the boreholes at the Culvert C22 site.
- Further assessment of the estimated magnitude of settlement under the widened Highway embankment, especially at the site of Culvert C22.





## PRELIMINARY FOUNDATION REPORT CULVERTS - NEW, REPLACEMENTS AND EXTENSIONS

### 7.0 CLOSURE

This Foundation Design Report was prepared by Ms. Nikol Kochmanová, P.Eng. Mr. Jorge Costa, P.Eng., a Senior Consultant and Designated MTO Foundations Contact for Golder, conducted an independent quality control review of this report.

#### GOLDER ASSOCIATES LTD.



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



Jorge M. A. Costa, P.Eng.  
Designated MTO Foundations Contact, Senior Consultant

NK/JMAC/sm

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## PRELIMINARY FOUNDATION REPORT CULVERTS - NEW, REPLACEMENTS AND EXTENSIONS

### REFERENCES

- Brennand, T.A. 1998. *Urban Geology Note: Oshawa Ontario*. In P.F. Karrow, and O. L. White (Eds.), Geological Association of Canada, Special Paper 42: *Urban Geology of Canadian Cities*, p. 353-364.
- Canadian Standards Association (CSA), 2006. *Canadian Highway Bridge Design Code and Commentary on CAN/CSA S6 06*. CSA Special Publication, S6.1 06.
- Chapman, L.J., and Putnam, D.F., 1984. *The Physiography of Southern Ontario*, 3rd Edition. Ontario Geological Survey, Special Volume 2. Ontario Ministry of Natural Resources.

### ASTM International

- ASTM D1586 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils
- ASM D2573 Standard Test Method for Field Vane Shear Test in Saturated Fine Grained Soils

### Ontario Provincial Standard Specifications

- OPSS 422 Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
- OPSS.PROV 501 Construction Specification for Compacting
- OPSS.PROV 539 Construction Specification for Temporary Protection Systems
- OPSS 902 Construction Specification for Excavating and Backfilling Structures
- OPSS.PROV 1002 Material Specification for Aggregates - Concrete
- OPSS.PROV 1010 Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material
- OPSS.PROV 1205 Material Specification for Clay Seal

### Ontario Provincial Standard Drawings

- OPSD 208.010 Benching of Earth Slopes
- OPSD 803.010 Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m
- OPSD 810.010 Granular Rip-Rap Layout for Sewer and Culvert Outlets
- OPSD 3090.101 Foundation Frost Penetration Depths for Southern Ontario

### Ontario Water Resources Act

- Ontario Regulation 903/90 Wells: O. Reg. 468/10 Amendment to Ontario Regulation 903

### Ontario Occupational Health and Safety Act

- Ontario Regulation 213 (Construction Projects)

### Commercial Software

- Settle 3D (Version 2.016) by Rocscience Inc.





## PRELIMINARY FOUNDATION REPORT CULVERTS - NEW, REPLACEMENTS AND EXTENSIONS

**Table 1: Comparison of Foundation Alternatives for Culvert Replacements and Extensions**

Option	Advantages	Disadvantages	Risks/Consequences
Box culvert: replacement; or extension	<ul style="list-style-type: none"> <li>■ Minimizes depth of excavation, excavation support and dewatering requirements compared to open footing option.</li> <li>■ In some cases, avoids the need for a Permit to Take Water associated with construction dewatering when compared with an open footing culvert option.</li> <li>■ Pre-cast box sections expected to allow for faster construction than cast-in-place open footings, with shorter duration for dewatering and surface water pumping, traffic control needs.</li> <li>■ More tolerant of differential settlement than open footing culvert; not required to be founded below the frost penetration depth.</li> <li>■ Box-type extensions are compatible with existing structures.</li> <li>■ Potentially suitable for replacement (on adjacent alignment to existing) by trenchless installation methods.</li> </ul>	<ul style="list-style-type: none"> <li>■ Where excavation extends below the groundwater level, dewatering may still be required, although backfill could consist of fill draining, non-frost susceptible granular fill.</li> <li>■ Transportation of large box sections in the case of pre-cast units.</li> <li>■ Requires soil substrate to address material habitat requirements.</li> </ul>	<ul style="list-style-type: none"> <li>■ Some risk of disturbance of the subgrade; can be mitigated with appropriate groundwater control and use of a concrete working slab or subgrade protection bedding.</li> <li>■ Limited risk related to settlement performance</li> </ul>





## PRELIMINARY FOUNDATION REPORT CULVERTS - NEW, REPLACEMENTS AND EXTENSIONS

Option	Advantages	Disadvantages	Risks/Consequences
Open footing culvert: replacement; or extension	<ul style="list-style-type: none"><li>■ Would satisfy fisheries requirements related to natural channel substrate, if applicable</li><li>■ May be feasible to build culvert replacement on pre-cast footing sections, to accelerate construction schedule and reduce time for dewatering and surface water pumping</li><li>■ No need for highway transportation of the culvert units (i.e., no off-site construction)</li></ul>	<ul style="list-style-type: none"><li>■ Excavation depths are greater than for box culvert option, resulting in increased excavation support and dewatering requirements, including need for Permit to Take Water at some sites</li><li>■ Cast-in-place footings may require a longer duration for construction, including traffic control, dewatering and surface water pumping, as compared with pre-cast culvert segments or footing elements</li><li>■ Excavations for strip footings for small span culverts would likely require excavation of most of the substrate</li><li>■ Footings have to be founded below the depth of frost penetration.</li><li>■ Culvert extensions would not be compatible with existing box structures.</li></ul>	<ul style="list-style-type: none"><li>■ Some risk of disturbance of the subgrade during construction; can be mitigated with appropriate groundwater control and use of a concrete working slab</li></ul>





## PRELIMINARY FOUNDATION REPORT CULVERTS - NEW, REPLACEMENTS AND EXTENSIONS

**Table 2: Box Culvert Replacement or Extension Option  
Founding Elevations, Sub-Excavation Requirements and Geotechnical Resistances**

Culvert ID	Culvert Location	Reference Boreholes	Proposed Culvert Invert Elevation <sup>1</sup> Inlet/Outlet	Sub-excavation Required?	Culvert Span	Highest Base Slab Founding Elevation <sup>3</sup> Inlet/Outlet	Factored Geotechnical Resistance at ULS <sup>3</sup>	Geotechnical Resistance at SLS <sup>4</sup>
C06	32+455 (Hwy 401)	RW6-3	81.4 m <sup>2</sup> (North End)	No	6.2 m	81.15 m	375 kPa	200 kPa
C22	16+213 (Hwy 401)	C22-1 and C22-2	81.9 m / 81.2 m (North End / South End)	Yes, to Elevation 81.3 m on North Side and to Elevation 81.0 m on South Side	5.0 m	81.65 m / 80.95 m	65 kPa*	25 kPa**
C29	15+000 (Hwy 401)	C29-1 and C29-2	82.2 m / 81.8 m (North End / South End)	Yes, to Elevation 81.0 m on North Side	4.0 m	81.95 m / 81.55 m	250 kPa	125 kPa
C30	15+030 (Hwy 401)	C30-1	81.6 m / 81.0 m (North End / South End)	No	4.0 m	81.35 m / 80.75 m	350 kPa	200 kPa
C31	15+359 (Hwy 401)	BH1 to BH8	77.6 m / 77.3 m (South End / North End)	Yes, to Elevation 76.0 m on North Side and to Elevation 75.0 m on South side	5.0 m	77.35 m / 77.05 m	400 kPa	250 kPa
C35	11+816 (Hwy 401)	C35-1	85.1 m / 83.5 m (North End / South End)	Yes, to Elevation 84.0 m	4.5 m	84.85 m / 83.25	350 kPa	200 kPa

**NOTES:**

1. Proposed culvert invert elevations provided by AECOM.
  2. No change to invert at culvert outlet
  3. Highest founding elevation based on an assumed base slab thickness of 250 mm. As per Section 6.2, it is recommended that the base slab be founded on either a 150 mm thick layer of compacted OPSS.PROV Granular 'A' (including a 75 mm levelling course) or a 100 mm thick concrete working slab overlain by 75 mm of OPSS.PROV 1010 Granular A or OPSS.PROV 1002 concrete fine aggregate levelling course.
  4. The geotechnical resistances given above are based on the culvert span (width) as listed for each culvert. The recommended geotechnical resistances should be reviewed if the founding elevation and/or culvert span (width) differ significantly from those given above. SLS resistance for 25 mm settlement.
- \* Assuming no ground improvement is utilized.
- \*\* The settlement performance of the culvert extensions must be re-assessed at detail design in conjunction with the selected settlement and stability mitigation measures (e.g., pre-loading, ground improvement, lightweight fill) for the immediately adjacent embankment widening.

Reviewed by: JMAG





## PRELIMINARY FOUNDATION REPORT CULVERTS - NEW, REPLACEMENTS AND EXTENSIONS

**Table 3: Open Footing Culvert Replacement or Extension Option  
Founding Elevations, Sub-Excavation Requirements and Geotechnical Resistances**

Culvert ID	Culvert Location	Reference Boreholes	Proposed Culvert Invert Elevation <sup>1</sup> Inlet/Outlet	Sub-excavation Required?	Highest Footing Founding Elevation <sup>2</sup> Inlet/Outlet	Factored Geotechnical Resistance at ULS <sup>3</sup>	Geotechnical Resistance at SLS <sup>3</sup>
C06	32+455 (Hwy 401)	RW6-3	81.4 m (North End)	No	80.0 m	300 kPa	200 kPa
C22	16+213 (Hwy 401)	C22-1 and C22-2	81.9 m / 81.2 m (North End / South End)	Yes, to Elevation 81.3 m on North Side and to Elevation 81.0 m on South Side	80.7 m / 80.0 m	65 kPa*	25 kPa**
C29	15+000 (Hwy 401)	C29-1 and C29-2	82.2 m / 81.8 m (North End / South End)	No	81.0 m / 80.6 m	400 kPa	275 kPa
C30	15+030 (Hwy 401)	C30-1	81.6 m / 81.0 m (North End / South End)	No	80.4 m / 79.8 m	400 kPa	275 kPa
C31	15+539 (Hwy 401)	BH1 to BH8	77.6 m / 77.3 m (South End / North End)	Yes, to Elevation 76.0 m on North Side and to Elevation 75.0 m on South side	76.4 m / 76.1 m	400 kPa	275 kPa
C35	11+816 (Hwy 401)	C35-1	85.1 m / 83.5 m (North End / South End)	No	83.9 m / 82.3 m	375 kPa	250 kPa

Reviewed by: JMAC

**NOTES:**

5. Proposed culvert invert elevations provided by AECOM.
6. Highest founding elevation based on minimum footing depth of 1.2 m below lowest surrounding grade, for frost protection purposes.
7. The geotechnical resistances given above are based on an assumed footing width of 0.6 m. The recommended geotechnical resistances should be reviewed if the footing founding elevation and/or footing width differ significantly from those given above.

\* Assuming no ground improvement is utilized.

\*\* The settlement performance of the culvert extensions must be re-assessed at detail design in conjunction with the selected settlement and stability mitigation measures (e.g., pre-loading, ground improvement, lightweight fill) for the immediately adjacent embankment widening.





## PRELIMINARY FOUNDATION REPORT CULVERTS - NEW, REPLACEMENTS AND EXTENSIONS

Table 4: Predicted Magnitude of Settlement Under Embankment Widening At Culvert Locations

Culvert ID	Culvert Location	Reference Boreholes	Approximate Embankment Height	Settlement at Existing Embankment Crest	Settlement at New Embankment Toe
C06	32+455 (Hwy 401)	RW6-3	3.0	< 20mm	< 10 mm
C22	16+213 (Hwy 401)	C22-1 and C22-2	5.0	250 mm*	60 mm*
C29	15+000 (Hwy 401)	C29-1 and C29-2	3.0	< 35 mm	< 10 mm
C30	15+030 (Hwy 401)	C30-1	4.0	< 20 mm	< 10 mm
C31	15+539 (Hwy 401)	BH1 to BH8	3.0	<20 mm	<10 mm
C35	11+816 (Hwy 401)	C35-1	8.5	< 20 mm	< 10 mm

\*Assuming no ground improvement is utilized and lightweight fill is used in construction of the immediately adjacent embankment widening.




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

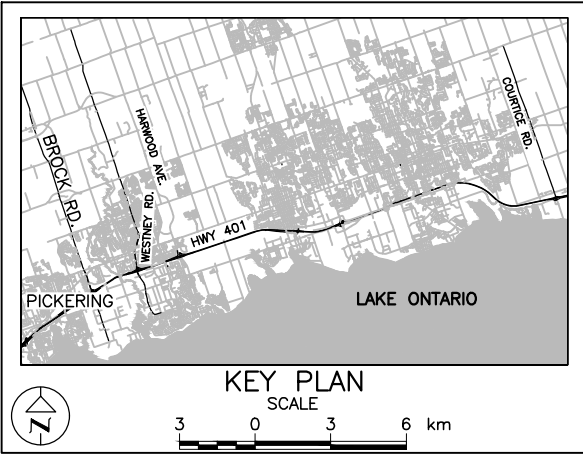
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WO No.10-20011

HIGHWAY 401 BROCK RD TO COURTICE RD  
CULVERT LOCATIONS

INDEX PLAN



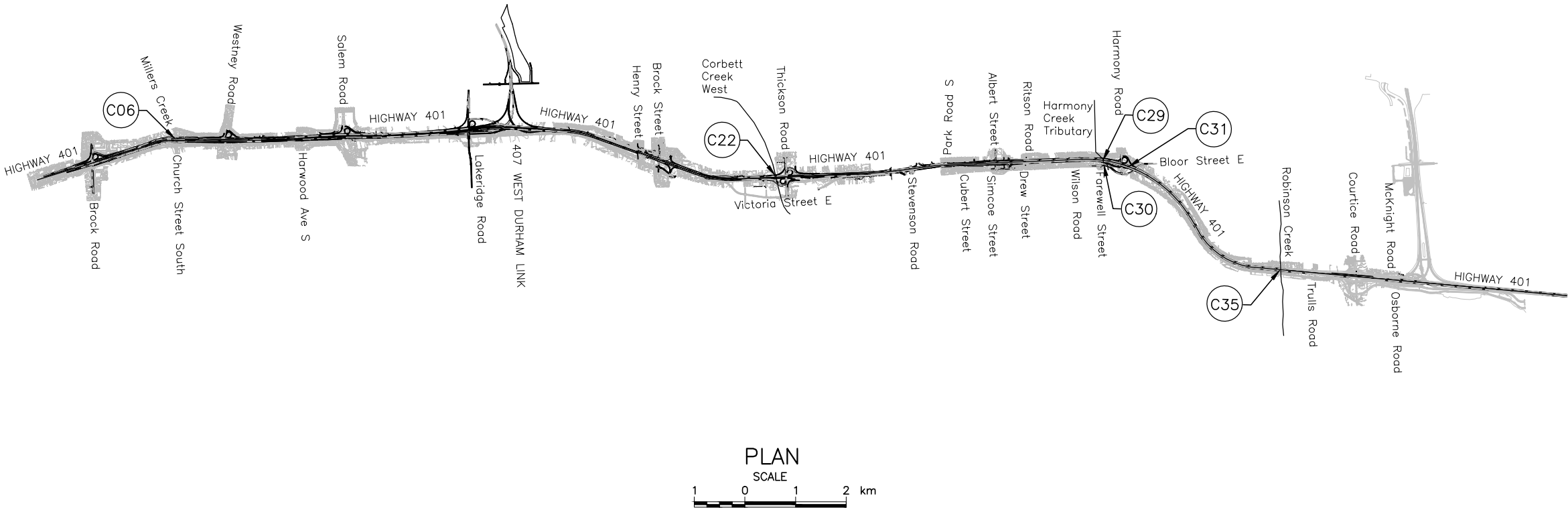
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LEGEND

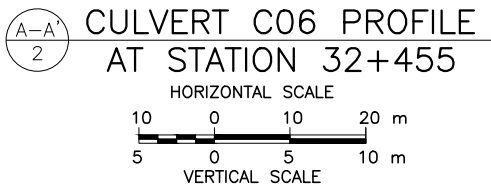
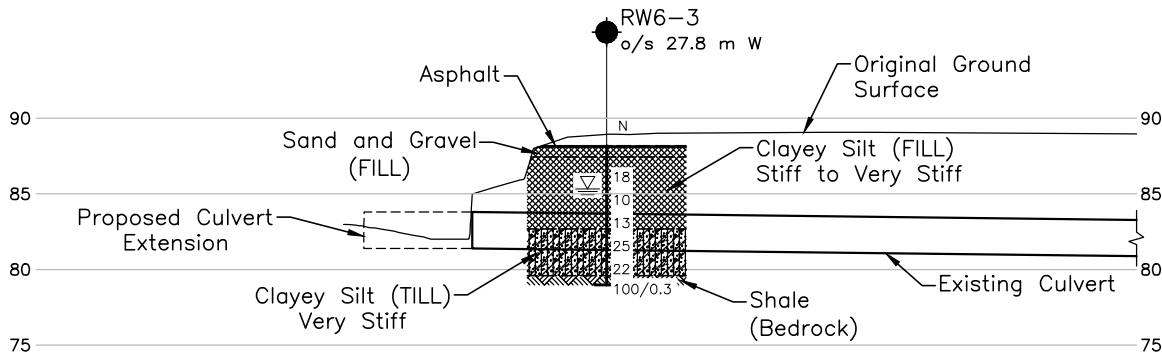
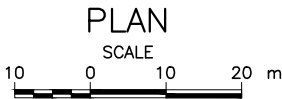
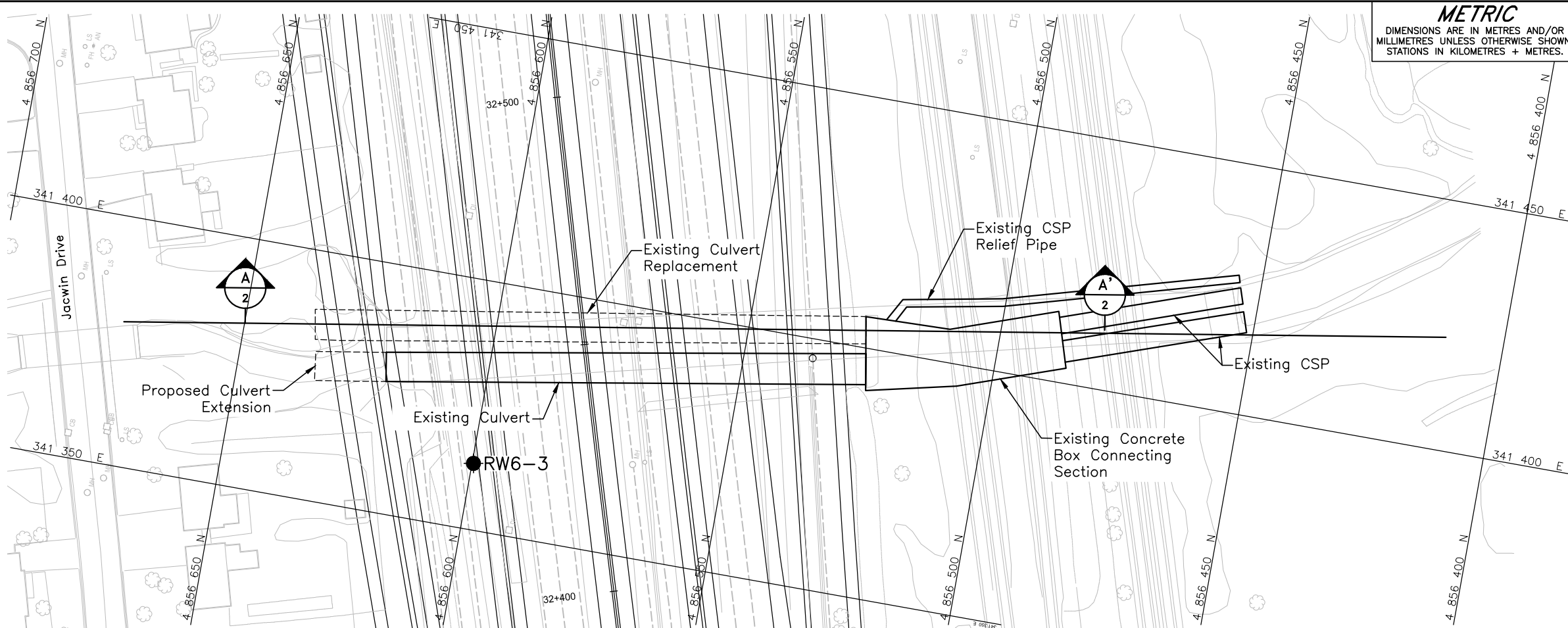
C35

Culvert location



NO.	DATE	BY	REVISION
Geocres No. 30M15-295			
HWY. 401		PROJECT NO. 11-1184-0143	DIST. CENTRAL
SUBM'D. KW	CHKD. KW	DATE: 4/5/2017	SITE: .
DRAWN: TB	CHKD. NK	APPD. JMAC	DWG. 1





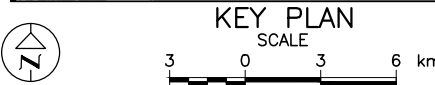
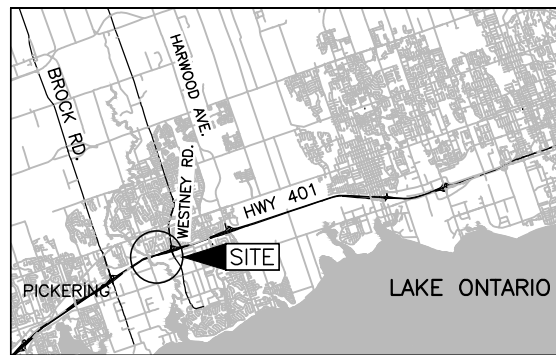
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DIMENSIONS ARE IN METRES AND/OR  
MILLIMETRES UNLESS OTHERWISE SHOWN.  
STATIONS IN KILOMETRES + METRES.

CONT No.  
WO No.10-20011

HIGHWAY 401 BROCK RD TO COURTICE RD  
C06 CULVERT AT STATION 32+455  
BOREHOLE LOCATION AND SOIL  
STRATA



SHEET



#### LEGEND

- Borehole - Current Investigation
- Standard Penetration Test Value
- Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL upon completion of drilling

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
RW6-3	88.2	4856599.7	341363.3

#### 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 Preliminary Design Report.

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

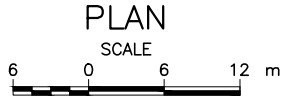
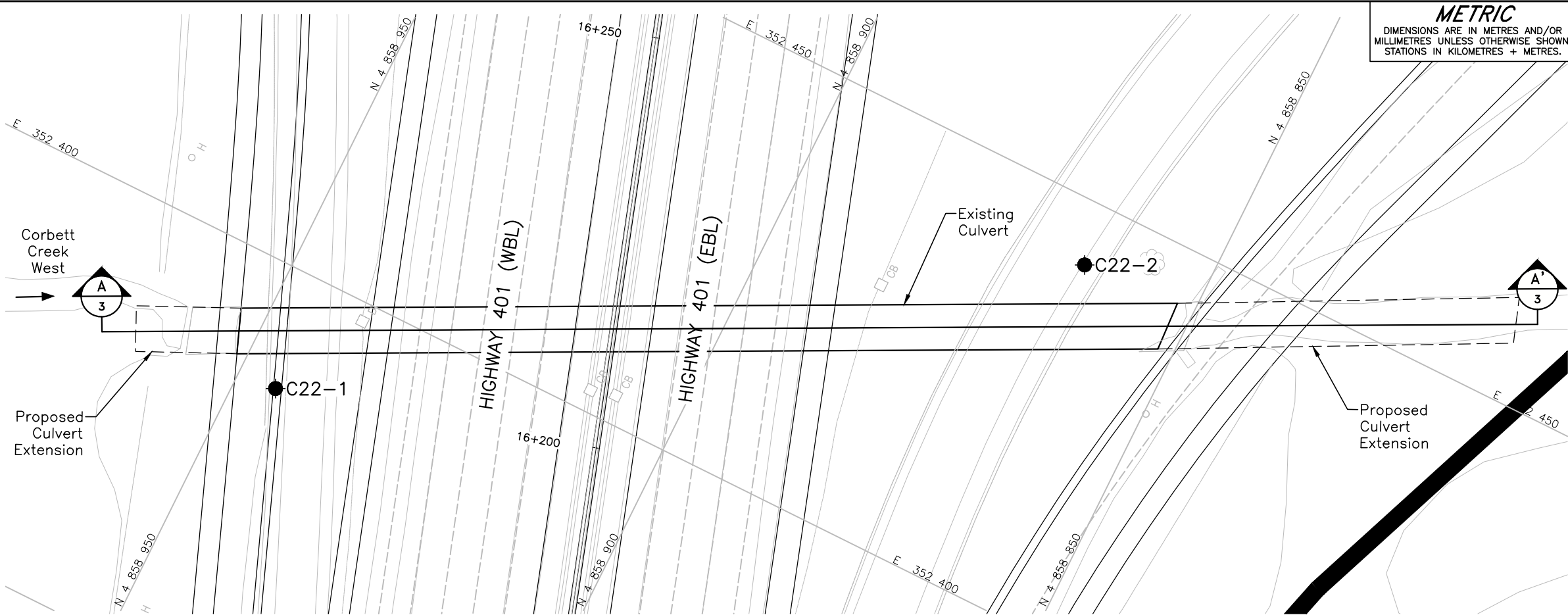
#### REFERENCE

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HWY. 401	PROJECT NO. 11-1184-0143	DIST. .	
SUBM'D. KW	CHKD. KW	DATE: 4/5/2017	SITE: .
DRAWN: TB	CHKD. NK	APPD. JMAC	DWG. 2





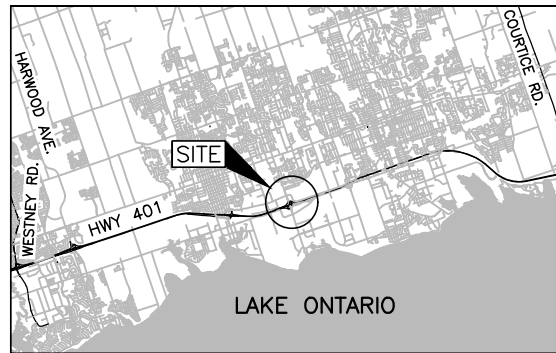
**METRIC**  
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No. WO No.10-20011

HIGHWAY 401 BROCK RD TO COURTICE RD  
CULVERT C22 EXTENSION AT STATION 16+213  
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



KEY PLAN

SCALE



LEGEND

- Borehole - Current Investigation
- Standard Penetration Test Value
- Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL upon completion of drilling

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
C22-1	86.0	4858945.2	352385.9
C22-2	89.2	4858864.3	352442.6

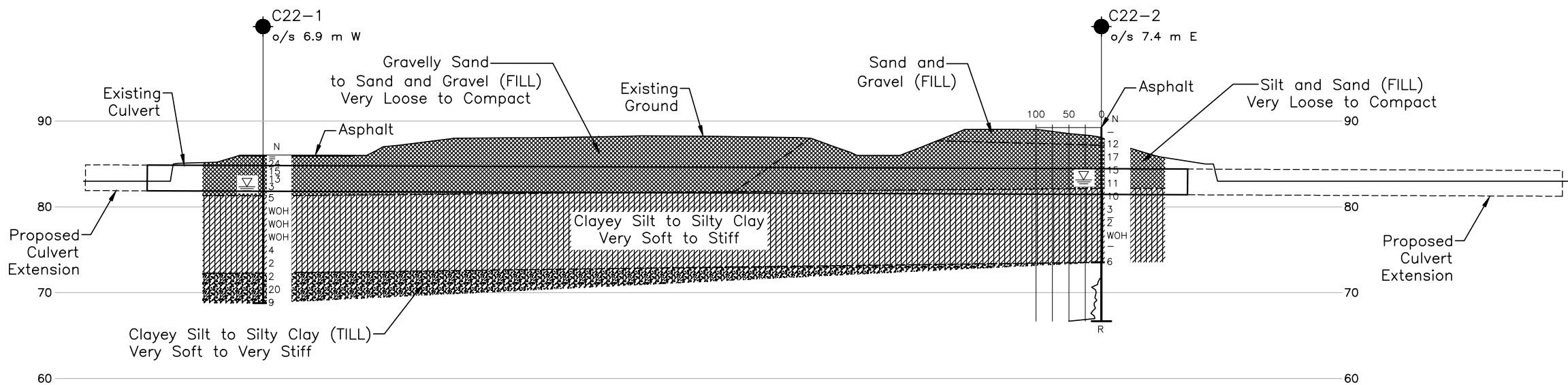
NOTES

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REFERENCE

Base plans provided in digital format by URS, drawing file no. Design (UR, 20130708).dwg, dated JUL 8, 2013.



CULVERT C22 PROFILE AT  
STATION 16+213

HORIZONTAL SCALE

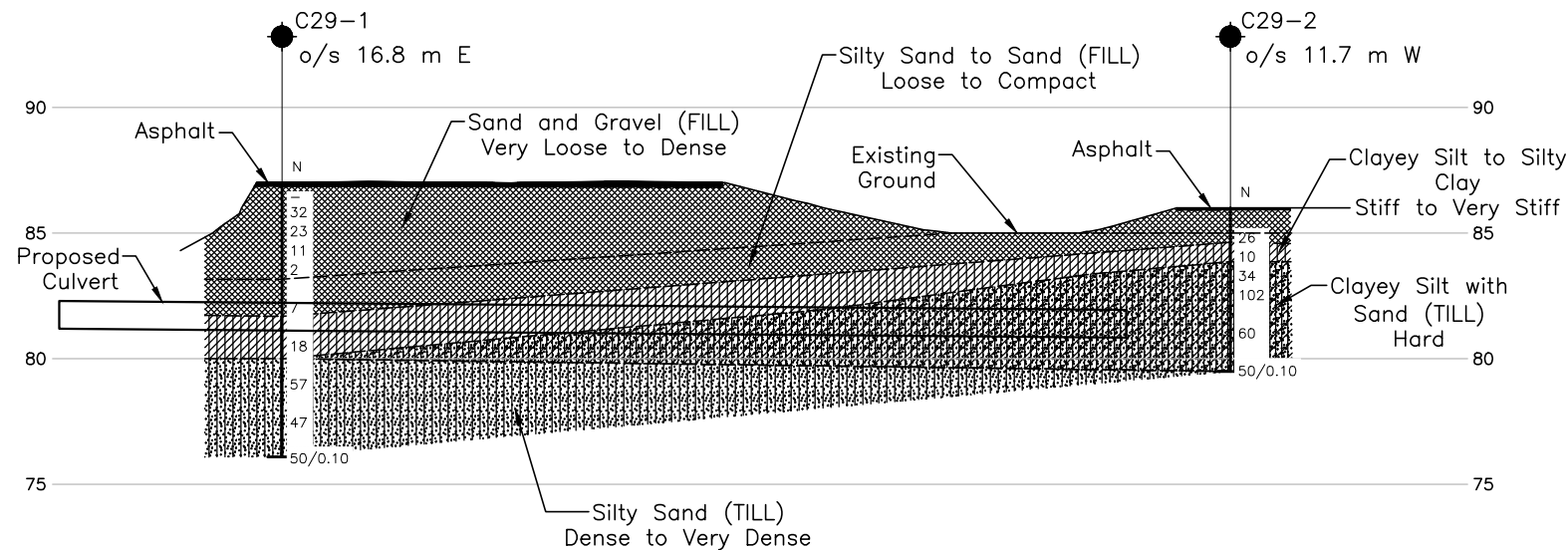
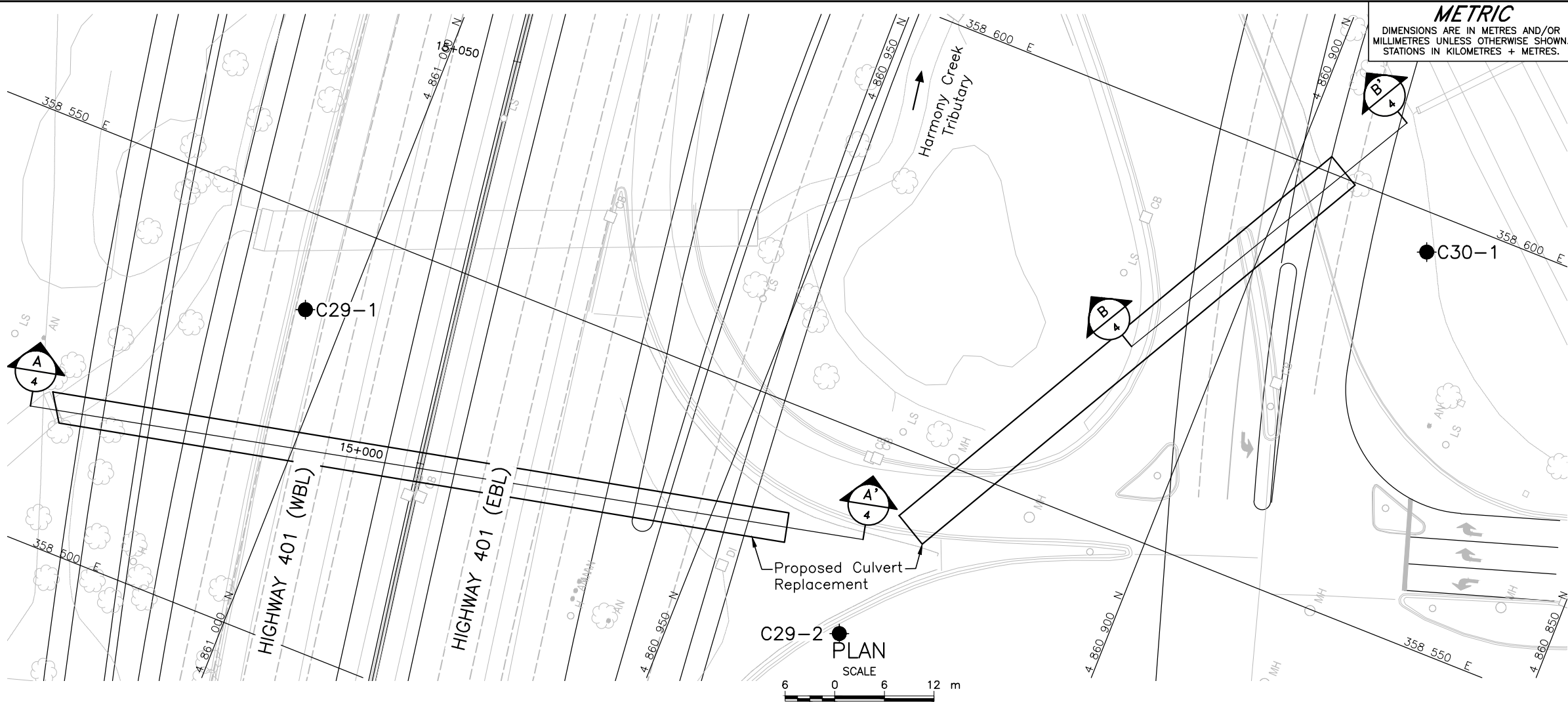


VERTICAL SCALE

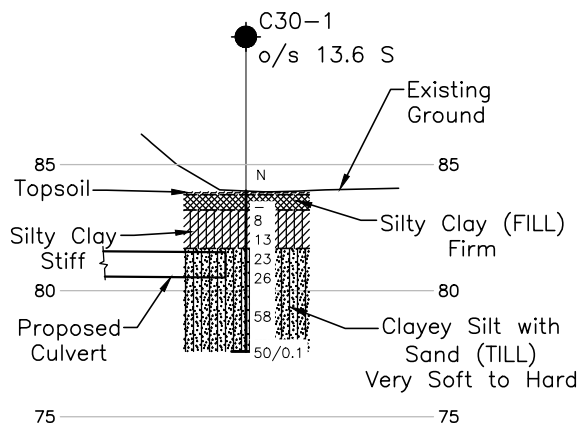


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HWY. 401	PROJECT NO. 11-1184-0143	DIST. CENTRAL	
SUBM'D. KW	CHKD. KW	DATE: 4/5/2017	SITE: .
DRAWN: TB	CHKD. NK	APPD. JMAC	DWG. 3





**CULVERT C29 PROFILE AT STATION 15+000**  
HORIZONTAL SCALE  
VERTICAL SCALE



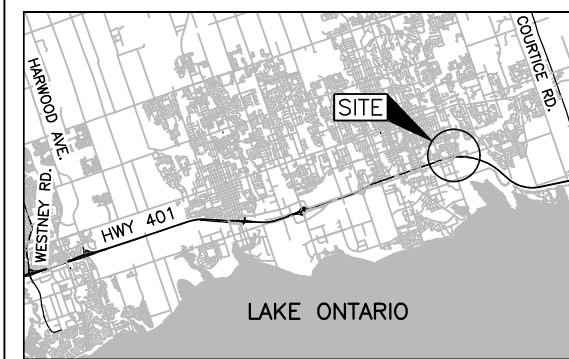
**CULVERT C30 PROFILE AT STATION 15+030**  
HORIZONTAL SCALE  
VERTICAL SCALE

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

CONT No.  
WO No.10-20011

HIGHWAY 401 BROCK RD TO COURTICE RD  
CULVERTS C29 AND C30 REPLACEMENT/REALIGNMENT  
AT STA 15+000 AND 15+030  
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



**KEY PLAN**  
SCALE  
3 0 3 6 km

LEGEND

Borehole - Current Investigation  
 Standard Penetration Test Value  
16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)  
 WL upon completion of drilling

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
C29-1	87.0	4861004.8	358538.8
C29-2	86.0	4860930.3	358526.2
C30-1	84.0	4860881.3	358595.4

NOTES

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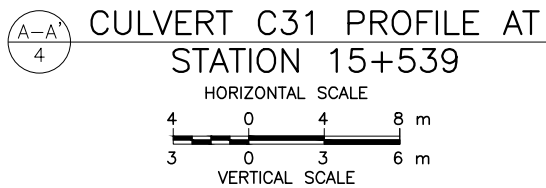
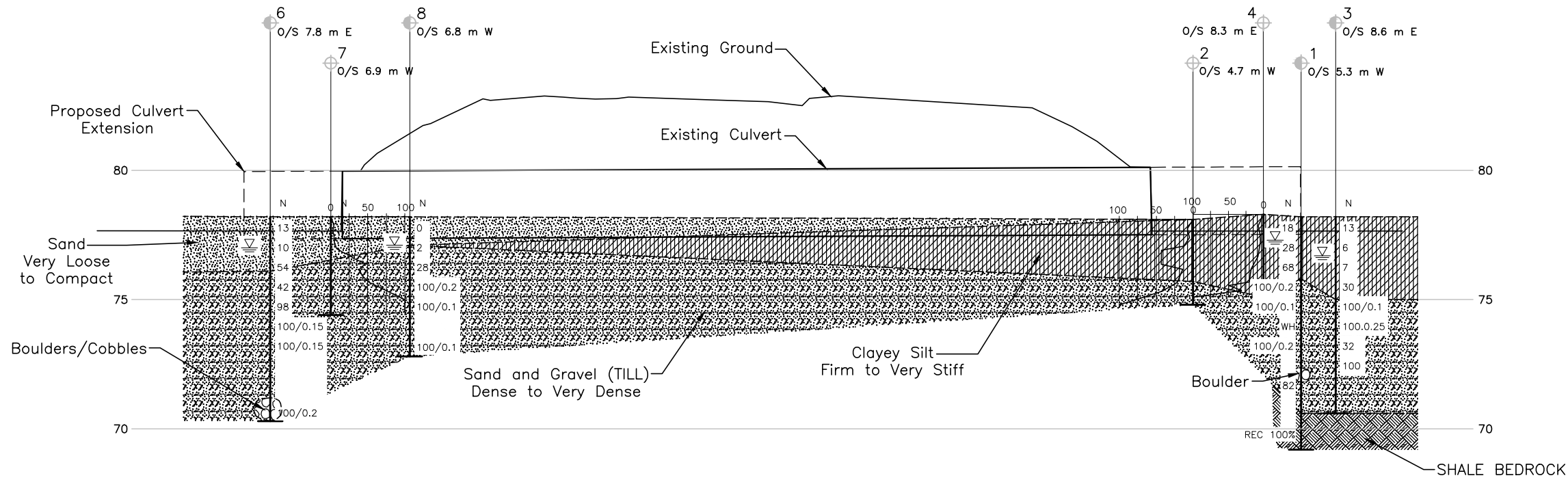
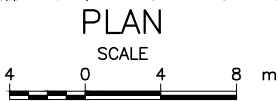
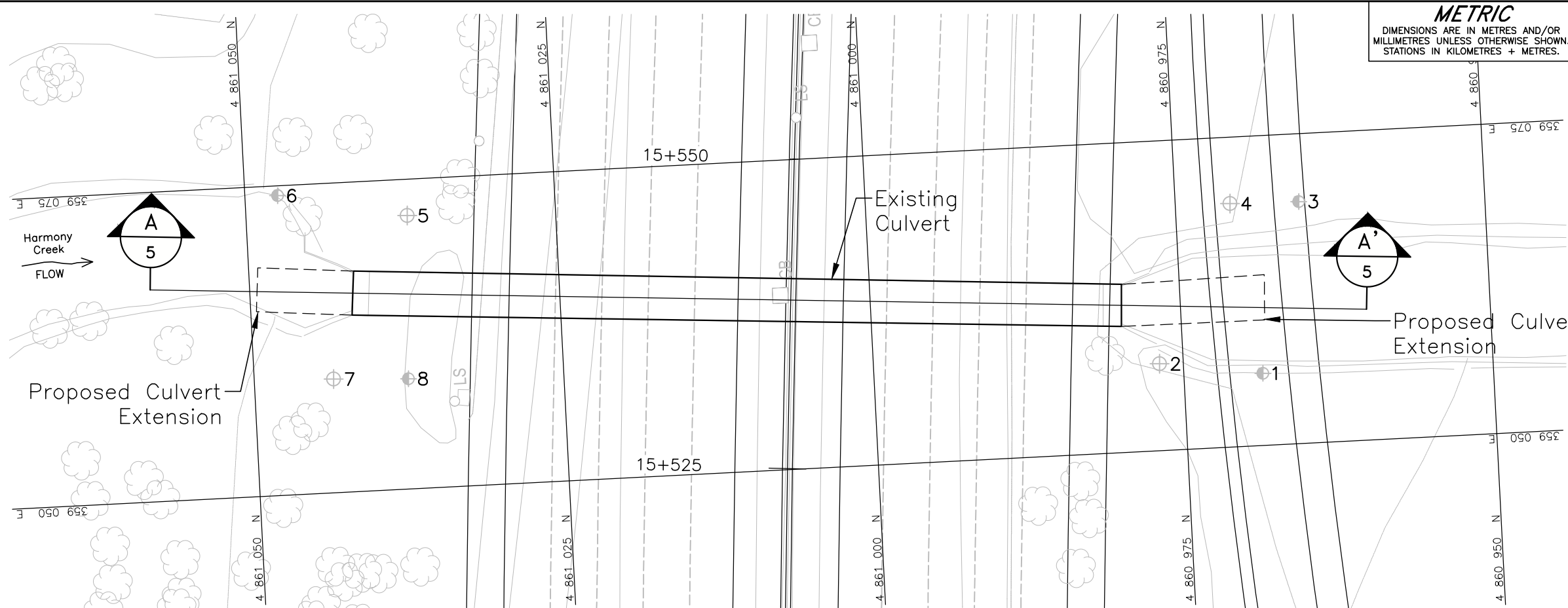
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NO.	DATE	BY	REVISION
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HWY. 401		PROJECT NO. 11-1184-0143	DIST. CENTRAL
SUBM'D. KW	CHKD. KW	DATE: 4/5/2017	SITE: .
DRAWN: TB	CHKD. NK	APPD. JMAC	DWG. 4





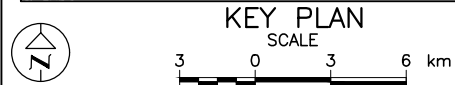
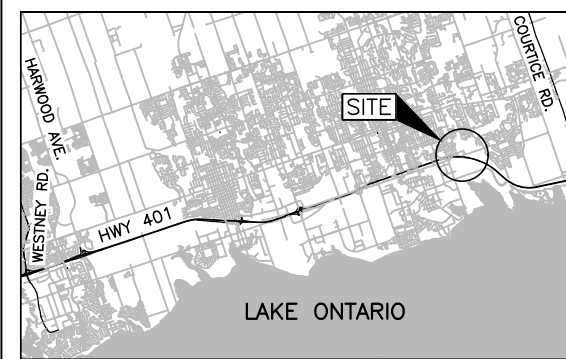
**METRIC**  
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STATIONS IN KILOMETRES + METRES.

CONT No.  
WP No.10-20011

HIGHWAY 401  
CULVERT C31 EXTENSION AT STATION 15+539

BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



### LEGEND

- Borehole - Previous Inv. (Geocres No.: 30M15-030)
- DCPT - Previous Inv. (Geocres No.: 30M15-030)
- 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
- REC % Recovery

### BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
1	78.2	4860968.6	359055.8
2	78.1	4860976.9	359057.0
3	78.2	4860965.0	359069.5
4	78.3	4860970.6	359069.6
5	78.1	4861037.0	359072.1
6	78.2	4861047.3	359074.2
7	78.2	4861043.6	359059.2
8	78.2	4861037.5	359058.9

### 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 Preliminary Design Report.

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

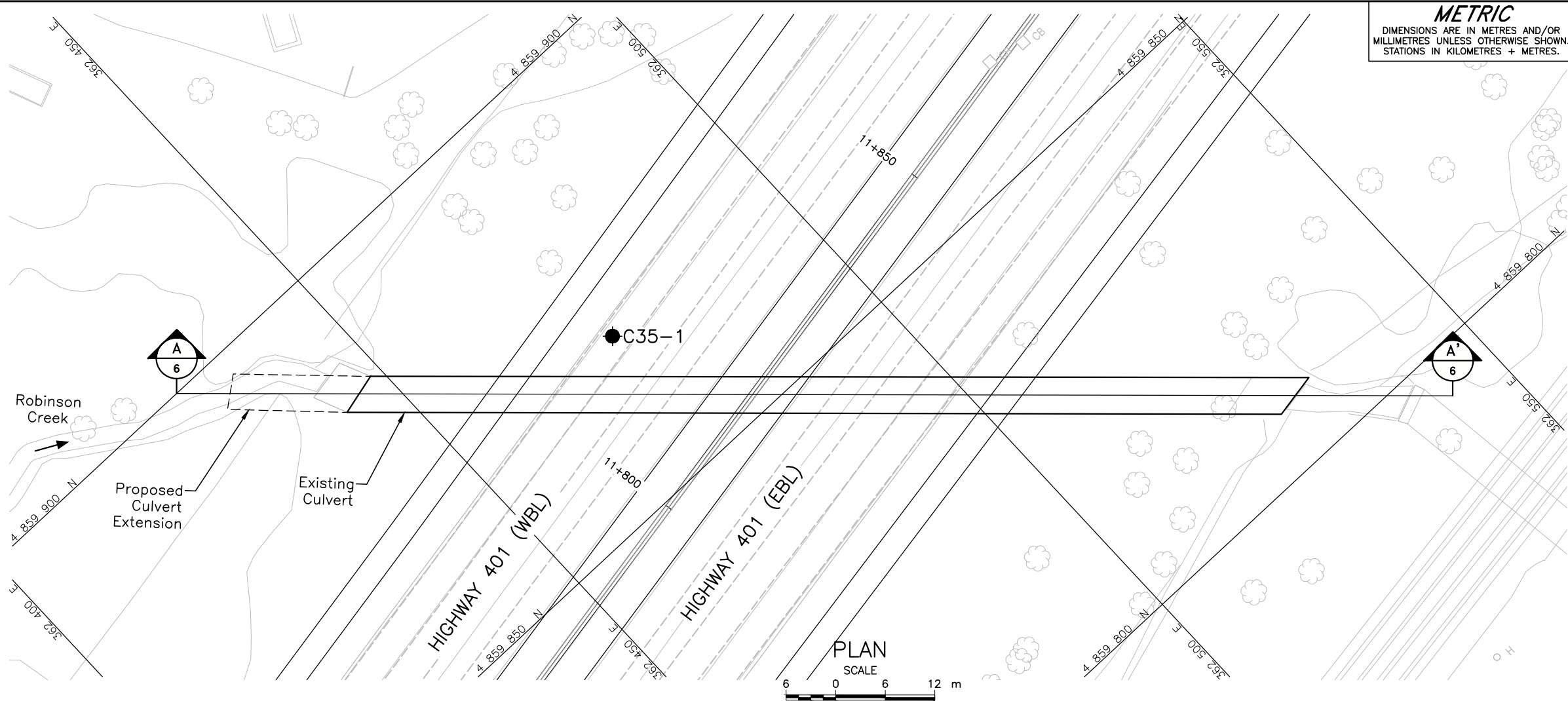
### REFERENCE

Base plans provided in digital format by URS, drawing file no. Design (UR, 20130708).dwg, dated JUL 8, 2013.

NO.	DATE	BY	REVISION
1	4/5/2017	N. KOCHMAN	PROJECT NO. 11-1184-0143
2	4/5/2017	N. KOCHMAN	DIST.
3	4/5/2017	N. KOCHMAN	SUBM'D.
4	4/5/2017	N. KOCHMAN	CHKD. KW
5	4/5/2017	N. KOCHMAN	DATE: 4/5/2017
6	4/5/2017	N. KOCHMAN	SITE:
7	4/5/2017	N. KOCHMAN	APPD.
8	4/5/2017	N. KOCHMAN	DWG. 5





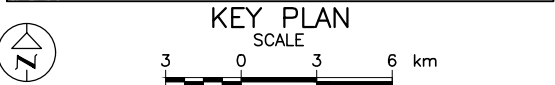
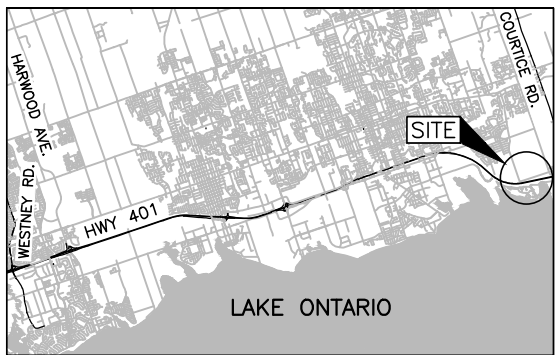


**METRIC**  
DIMENSIONS ARE IN METRES AND/OR  
MILLIMETRES UNLESS OTHERWISE SHOWN.  
STATIONS IN KILOMETRES + METRES.

CONT No.  
WO No.10-20011

HIGHWAY 401 BROCK RD TO COURTICE RD  
C35 CULVERT EXTENSION AT STATION 11+816  
BOREHOLE LOCATION AND SOIL  
STRATA

SHEET



- LEGEND**
- Borehole - Current Investigation
  - N Standard Penetration Test Value
  - 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
  - ≡ WL upon completion of drilling

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
C35-1	95.0	4859869.1	362473.3

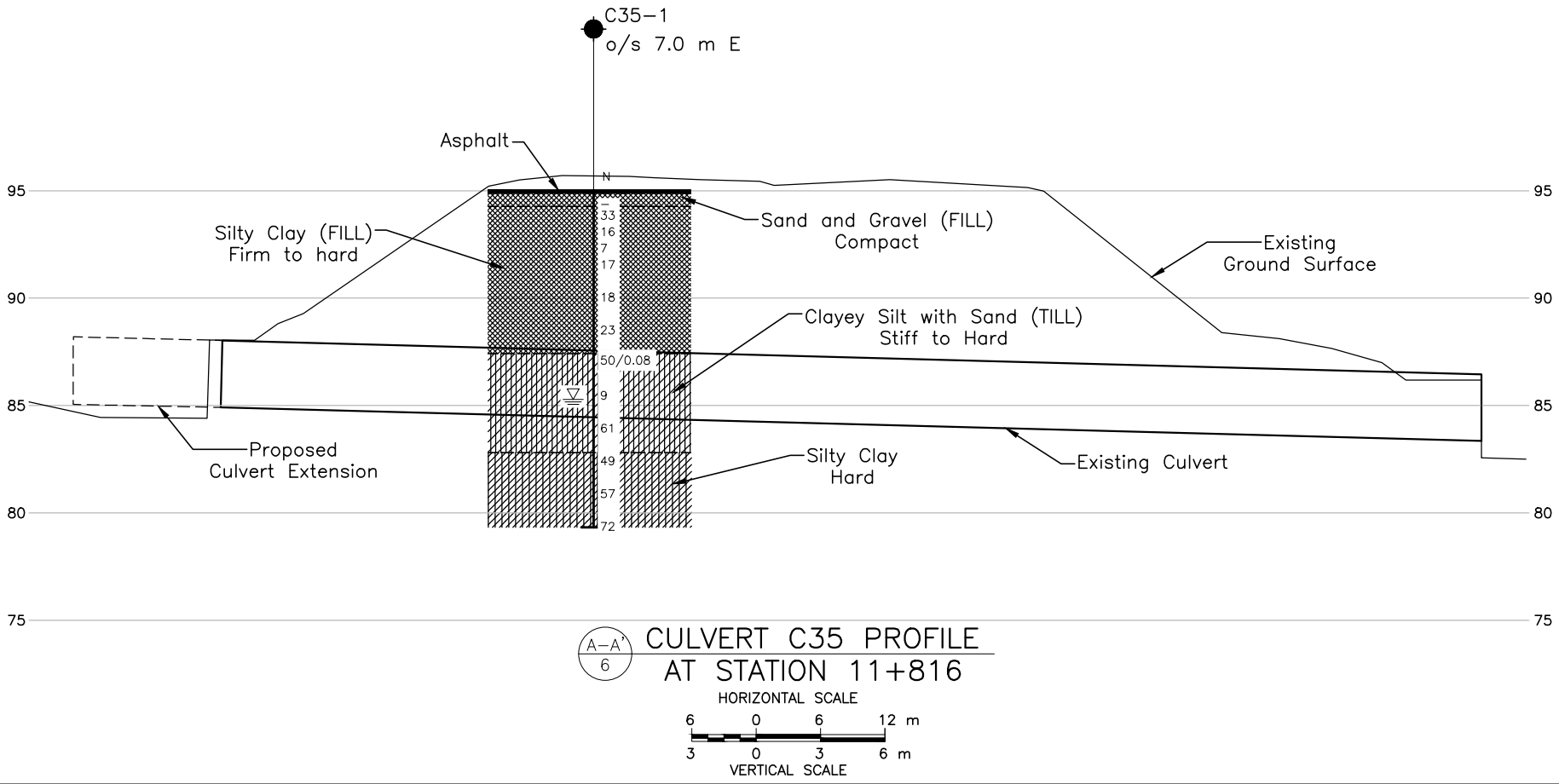
**NOTES**

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

**REFERENCE**

Base plans provided in digital format by URS, drawing file no. Design (UR, 20130708).dwg, dated JUL 8, 2013.



CULVERT C35 PROFILE  
AT STATION 11+816  
HORIZONTAL SCALE  
6 0 6 12 m  
VERTICAL SCALE  
3 0 3 6 m



NO.	DATE	BY	REVISION
Geocres No. 30M15-295			
HWY. 401		PROJECT NO. 11-1184-0143	DIST. CENTRAL
SUBM'D. KW	CHKD. KW	DATE: 4/5/2017	SITE: .
DRAWN: TB	CHKD. NK	APPD. JMAC	DWG. 6





# **APPENDIX A**

## **Record of Borehole Sheets from Current Investigation**





## LIST OF SYMBOLS

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

### I. GENERAL

$\pi$	3.1416
$\ln x$ ,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

### II. STRESS AND STRAIN

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\varepsilon$	linear strain
$\varepsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

### III. SOIL PROPERTIES

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

### (a) Index Properties (continued)

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

### (b) Hydraulic Properties

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

### (c) Consolidation (one-dimensional)

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

### (d) Shear Strength

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

\* Density symbol is  $\rho$ . Unit weight symbol is  $\gamma$  where  $\gamma = \rho g$  (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1  
2

$$\tau = c' + \sigma' \tan \phi'$$
$$\text{shear strength} = (\text{compressive strength})/2$$





## LIST OF ABBREVIATIONS

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

### I. SAMPLE TYPE

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

### II. PENETRATION RESISTANCE

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

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

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

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

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

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

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

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

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

### III. SOIL DESCRIPTION

#### (a) Non-Cohesive (Cohesionless) Soils

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

#### (b) Cohesive Soils Consistency

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

### IV. SOIL TESTS

w	water content
w <sub>p</sub>	plastic limit
w <sub>l</sub>	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
D <sub>R</sub>	relative density (specific gravity, $G_s$ )
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO <sub>4</sub>	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
$\gamma$	unit weight

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

### V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand



PROJECT <u>11-1184-0143</u>		<b>RECORD OF BOREHOLE No C22-1</b>		1 OF 2 <b>METRIC</b>	
WO <u>10-20011</u>		LOCATION <u>N 4858945.2 ; E 352385.9</u>		ORIGINATED BY <u>TD</u>	
DIST <u>Central</u> HWY <u>401</u>		BOREHOLE TYPE <u>CME-75 Truck-Mount, 150 mm O.D. Continuous Flight Solid Stem Augers</u>		COMPILED BY <u>PKS</u>	
DATUM <u>Geodetic</u>		DATE <u>March 31, 2015</u>		CHECKED BY <u>LCC</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)				
								○ UNCONFINED		+ FIELD VANE		● QUICK TRIAXIAL			× REMOULDED		w <sub>p</sub>	w	w <sub>L</sub>
							20	40	60	80	100	10	20	30	GR	SA	SI	CL	
86.0	GROUND SURFACE																		
0.0	ASPHALT (90 mm)		1	AS	-														
0.3	Sand and gravel, trace silt (FILL)		2	AS	-														
	Brown																		
	Moist																		
	Gravelly sand, trace to some silt, trace clay, trace organic material and slag (FILL)		3	SS	24							○							
	Very loose to compact																		
	Black		4	SS	15							○							
	Moist to wet																		
			5	SS	13														
			6	SS	3														

Continued Next Page

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

MIS-MTO 001 11-1184-0143.GPJ GAL-MISS.GDT 07/18/16 KD



PROJECT <u>11-1184-0143</u>				<b>RECORD OF BOREHOLE No C22-1</b>				2 OF 2 <b>METRIC</b>									
<u>WO 10-20011</u>				LOCATION <u>N 4858945.2 ; E 352385.9</u>				ORIGINATED BY <u>TD</u>									
DIST <u>Central</u> HWY <u>401</u>				BOREHOLE TYPE <u>CME-75 Truck-Mount, 150 mm O.D. Continuous Flight Solid Stem Augers</u>				COMPILED BY <u>PKS</u>									
DATUM <u>Geodetic</u>				DATE <u>March 31, 2015</u>				CHECKED BY <u>LCC</u>									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	--- CONTINUED FROM PREVIOUS PAGE ---																
	SILTY CLAY with SAND, some gravel (TILL) Very soft to very stiff Grey Wet		14	SS	20												
68.8			15	SS	9												
17.2	END OF BOREHOLE																
	NOTES:  1. Borehole caved to a depth of 4.0 m below ground surface (Elev. 82.0 m) upon completion of drilling.  2. Water level measured in open borehole at a depth of 3.7 m below ground surface (Elev. 82.3 m) upon completion of drilling.																



Continued Next Page

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

MIS-MTO 001 11-1184-0143.GPJ GAL-MISS.GDT 07/18/16 KD



<b>PROJECT</b> 11-1184-0143		<b>RECORD OF BOREHOLE No C22-2</b>		2 OF 2 <b>METRIC</b>	
WO 10-20011		LOCATION N 4858864.3 ; E 352442.6		ORIGINATED BY TD	
DIST Central HWY 401		BOREHOLE TYPE CME-75 Truck-Mount, 150 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY PKS	
DATUM Geodetic		DATE April 1, 2015		CHECKED BY LCC	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL LIMIT   MOISTURE   LIQUID CONTENT   LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W <sub>p</sub>	W	W <sub>L</sub>		GR	SA	SI	CL
--- CONTINUED FROM PREVIOUS PAGE ---								20	40	60	80	100	WATER CONTENT (%)							
							○ UNCONFINED	+ FIELD VANE												
							● QUICK TRIAXIAL	× REMOULDED												
							20	40	60	80	100	10	20	30						
73.5			12	SS	6		74													
15.7	END OF BOREHOLE (Start of DCPT)																			
66.6																				
22.6	END OF DCPT. DCPT REFUSAL																			
NOTES:																				
1. Borehole caved to a depth of 14.3 m below ground surface (Elev. 74.9 m) upon removal of augers.																				
2. Water level measured in open borehole at a depth of 6.1 m below ground surface (Elev. 83.1 m) upon removal of augers.																				



PROJECT		11-1184-0143		<b>RECORD OF BOREHOLE No C29-1</b>		1 OF 1 <b>METRIC</b>								
WO 10-20011		LOCATION		N 4861004.8 ; E 358538.8		ORIGINATED BY TD								
DIST Central HWY 401		BOREHOLE TYPE		CME-75 Truck-Mount, 150 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY PKS								
DATUM Geodetic		DATE		March 26, 2015		CHECKED BY LCC								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
87.0	GROUND SURFACE													
0.0	ASPHALT (140 mm)													
0.1	Sand and gravel, trace to some silt, trace clay, trace organic material (FILL) Very loose to dense Brown Moist		1	AS										
			2	SS	32									44 35 16 5
			3	SS	23									
			4	SS	11									
			5	SS	2									
83.0	SILTY SAND, some gravel, trace clay (FILL) Loose Brown Moist		6	SS	7									11 60 25 4
81.7	CLAYEY SILT, trace sand, trace gravel Very stiff Brown Moist		7	SS	18									
80.0	SILTY SAND, trace to some clay, trace gravel (TILL) Dense to very dense Grey Moist		8	SS	57									0 69 22 9
76.1			9	SS	47									
10.9	END OF BOREHOLE		10	SS	50/0.10									
NOTE: 1. Borehole caved to a depth of 3.4 m below ground surface (Elev. 83.6 m) upon completion of drilling. 2. Water level measured in open borehole at a depth of 3.4 m below ground surface (Elev. 83.6 m) upon completion of drilling.														



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

MIS-MTO 001 11-1184-0143.GPJ GAL-MISS.GDT 07/18/16 KD



PROJECT 11-1184-0143			RECORD OF BOREHOLE No C30-1			1 OF 1 METRIC										
WO 10-20011			LOCATION N 4860881.3 ; E 358595.4			ORIGINATED BY TD										
DIST Central HWY 401			BOREHOLE TYPE CME-75 Truck-Mount, 150 mm O.D. Continuous Flight Solid Stem Augers			COMPILED BY PKS										
DATUM Geodetic			DATE March 12, 2015			CHECKED BY LCC										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
84.0	GROUND SURFACE															
0.0	TOPSOIL															
0.2	Silty clay, trace sand, trace organic material (FILL)		1	AS	-											
83.2	Firm Brown Moist		2	SS	8											
0.8	SILTY CLAY, trace to some sand, trace gravel															
	Stiff Grey Moist		3	SS	13											
			4A	SS	23											
81.3	CLAYEY SILT with SAND, some gravel (TILL)															
2.7	Very stiff to hard Grey Moist		5	SS	26											
	- auger grinding on inferred cobbles between depths of 3.1 m to 6.1 m															
			6	SS	58											
77.6	END OF BOREHOLE		7	SS	50/0.1											
6.4	NOTES:  1. Borehole open upon completion of drilling.  2. Water level measured in open borehole at a depth of 5.8 m below ground surface (Elev. 78.2 m) upon completion of drilling.															



<b>PROJECT</b> 11-1184-0143		<b>RECORD OF BOREHOLE No C35-1</b>		1 OF 2 <b>METRIC</b>	
WO 10-20011		LOCATION N 4859869.1 ; E 362473.3		ORIGINATED BY TD	
DIST Central HWY 401		BOREHOLE TYPE CME-75 Truck-Mount, 150 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY PKS	
DATUM Geodetic		DATE March 25, 2015		CHECKED BY LCC	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W <sub>p</sub>	W	W <sub>L</sub>		
95.0	GROUND SURFACE													
0.0	ASPHALT (150 mm)													
0.2	Sand and gravel (FILL)		1	AS	-									
94.2	Compact Brown Moist		2	SS	33									
0.8	Silty clay with sand, trace to some gravel (FILL) Firm to hard Brown to grey		3	SS	16									
			4	SS	7									
			5	SS	17									
			6	SS	18									
			7	SS	23									
	- contains organic material and rootlets at depth of 6.6 m													
87.4	CLAYEY SILT with SAND, trace to some gravel (TILL) Stiff to hard Brown to grey Moist - trace organic material and rootlets at depth of 7.6 m - auger grinding on inferred cobbles between depths of 8.2 m and 9.1 m		8	SS	50/0.08									
7.6			9	SS	9									
			10	SS	61									
82.8	SILTY CLAY, trace sand Hard Grey Moist		11	SS	49									
12.2			12	SS	57									

Continued Next Page

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

MIS-MTO 001 11-1184-0143.GPJ GAL-MISS.GDT 07/18/16 KD



PROJECT <u>11-1184-0143</u>				<b>RECORD OF BOREHOLE No C35-1</b>				2 OF 2 <b>METRIC</b>								
WO <u>10-20011</u>				LOCATION <u>N 4859869.1 ; E 362473.3</u>				ORIGINATED BY <u>TD</u>								
DIST <u>Central</u> HWY <u>401</u>				BOREHOLE TYPE <u>CME-75 Truck-Mount, 150 mm O.D. Continuous Flight Solid Stem Augers</u>				COMPILED BY <u>PKS</u>								
DATUM <u>Geodetic</u>				DATE <u>March 25, 2015</u>				CHECKED BY <u>LCC</u>								
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)			
	--- CONTINUED FROM PREVIOUS PAGE ---															
79.3		13	SS	72									o			
15.7	END OF BOREHOLE  NOTES:  1. Borehole caved to a depth of 13.9 m below ground surface (Elev. 81.1 m) upon completion of drilling.  2. Water level measured in open borehole at a depth of 9.8 m below ground surface (Elev. 85.2 m) upon completion of drilling.															



PROJECT 11-1184-0143		<b>RECORD OF BOREHOLE No RW6-3</b>				1 OF 1 <b>METRIC</b>										
WO 10-20011		LOCATION N 4856602.7 ; E 341362.2				ORIGINATED BY JL										
DIST Central HWY 401		BOREHOLE TYPE CME-55 Truck-Mount, 150 mm O.D. Continuous Flight Solid Stem Augers				COMPILED BY PKS										
DATUM Geodetic		DATE May 13, 2014				CHECKED BY LCC										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
88.2	GROUND SURFACE															
88.0	ASPHALT (110 mm)															
87.5	Sand and gravel, trace silt (FILL) Brown Moist															
87.0	Clayey silt, some sand, trace gravel, contains organic material and rootlets (FILL) Stiff to very stiff Grey to brown Moist		1	SS	18											
86.0																
85.0			2	SS	10											
84.0																
83.0			3	SS	13											
82.7																
82.0	CLAYEY SILT, some sand, trace gravel (TILL) Very stiff Brown to grey Moist		4	SS	25											
81.0																
80.0			5	SS	22											
79.6																
79.0	SHALE (BEDROCK) Weathered Black		6	SS	100/0.3											
78.0	END OF BOREHOLE															
Note: 1. Borehole open upon completion of drilling. 2. Water level measured in open borehole at a depth of 6.1 m below ground surface (Elev. 82.1 m) upon completion of drilling.																





# **APPENDIX B**

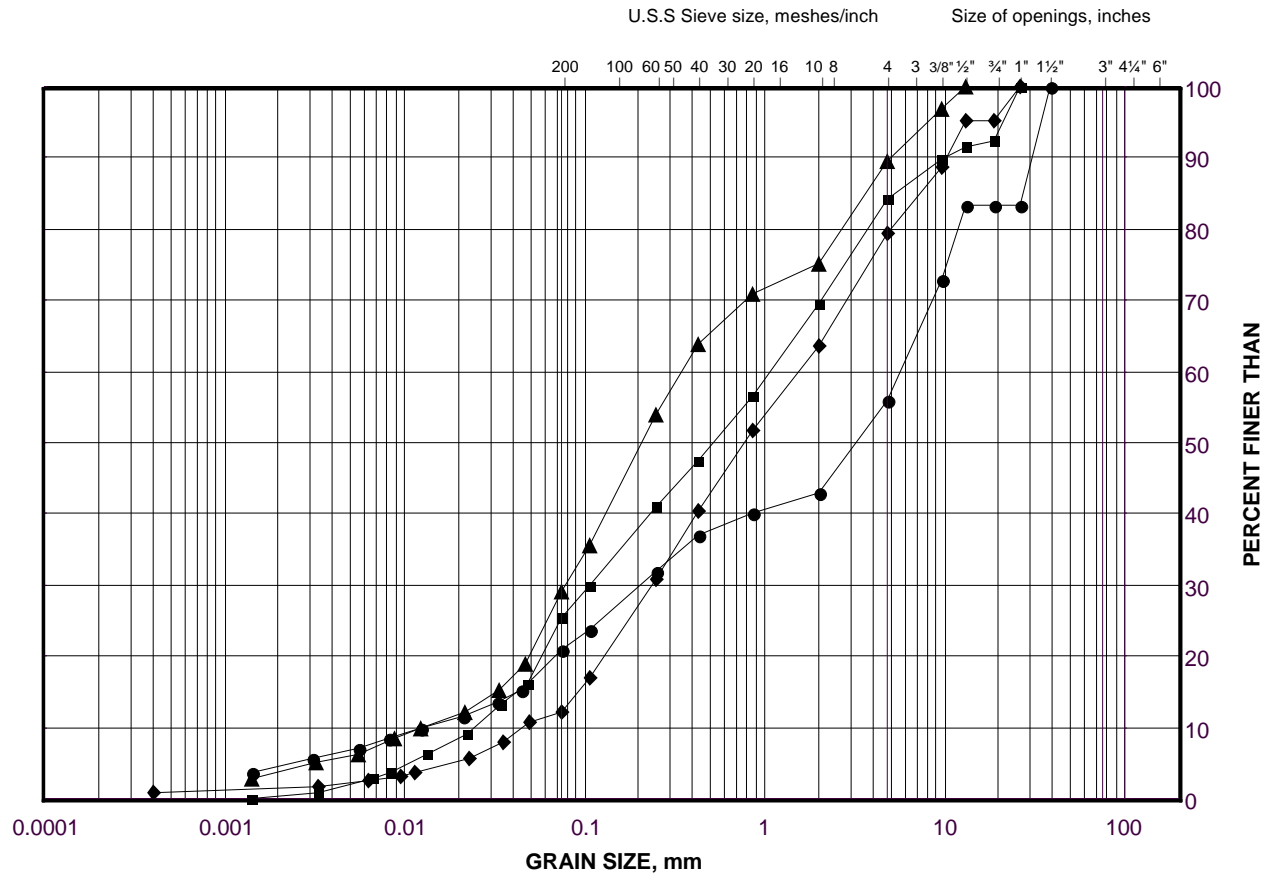
## **Laboratory Test Results from Current Investigation**



# GRAIN SIZE DISTRIBUTION

Silt and Sand to Sand (Fill)

FIGURE B1



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

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C29-1	2	86.0
■	C22-2	2	87.5
◆	C22-1	4	84.3
▲	C29-1	6	82.2

Project Number: 11-1184-0143

Checked By: NK

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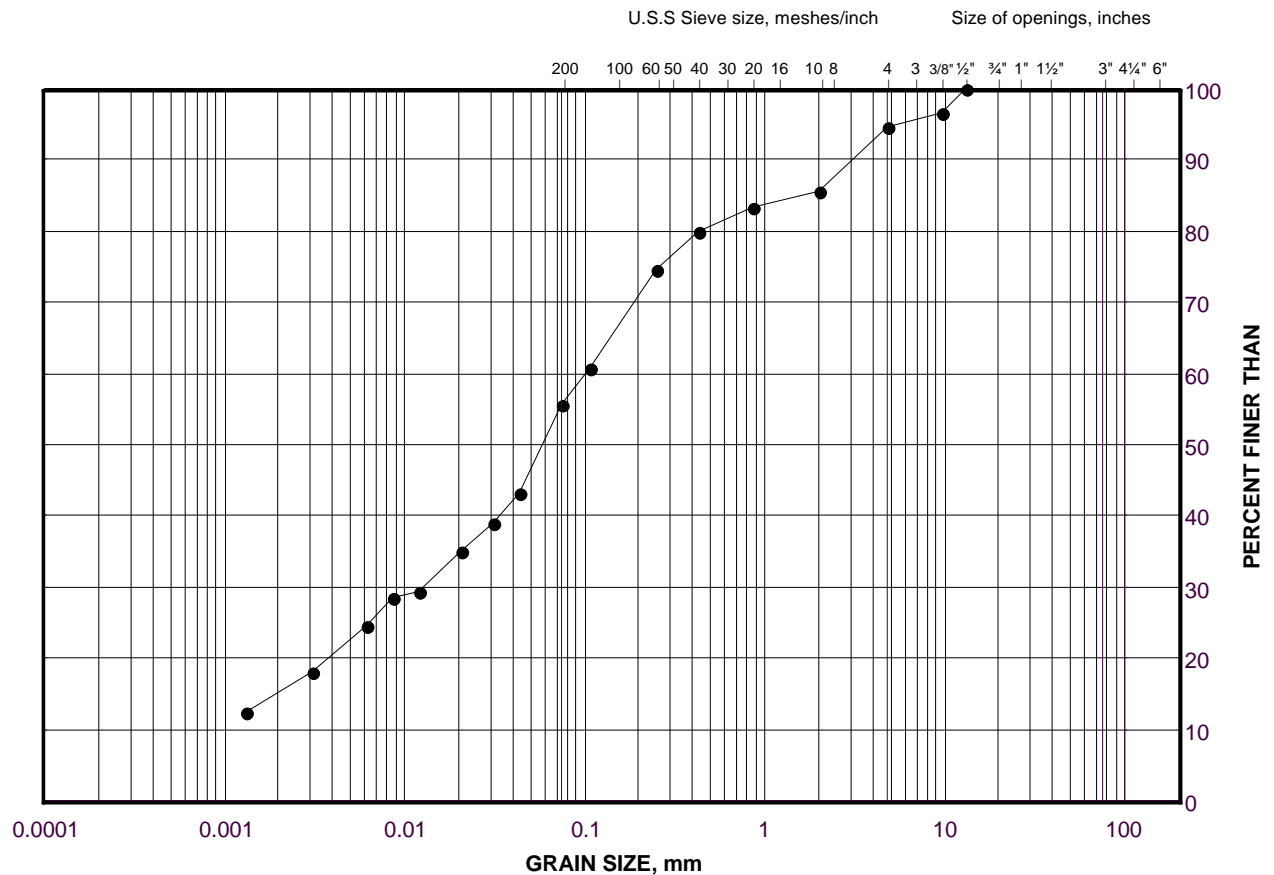
Date: 04-Jul-16



# GRAIN SIZE DISTRIBUTION

Silty Clay with Sand (Fill)

FIGURE B2



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

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	C35-1	4	92.5

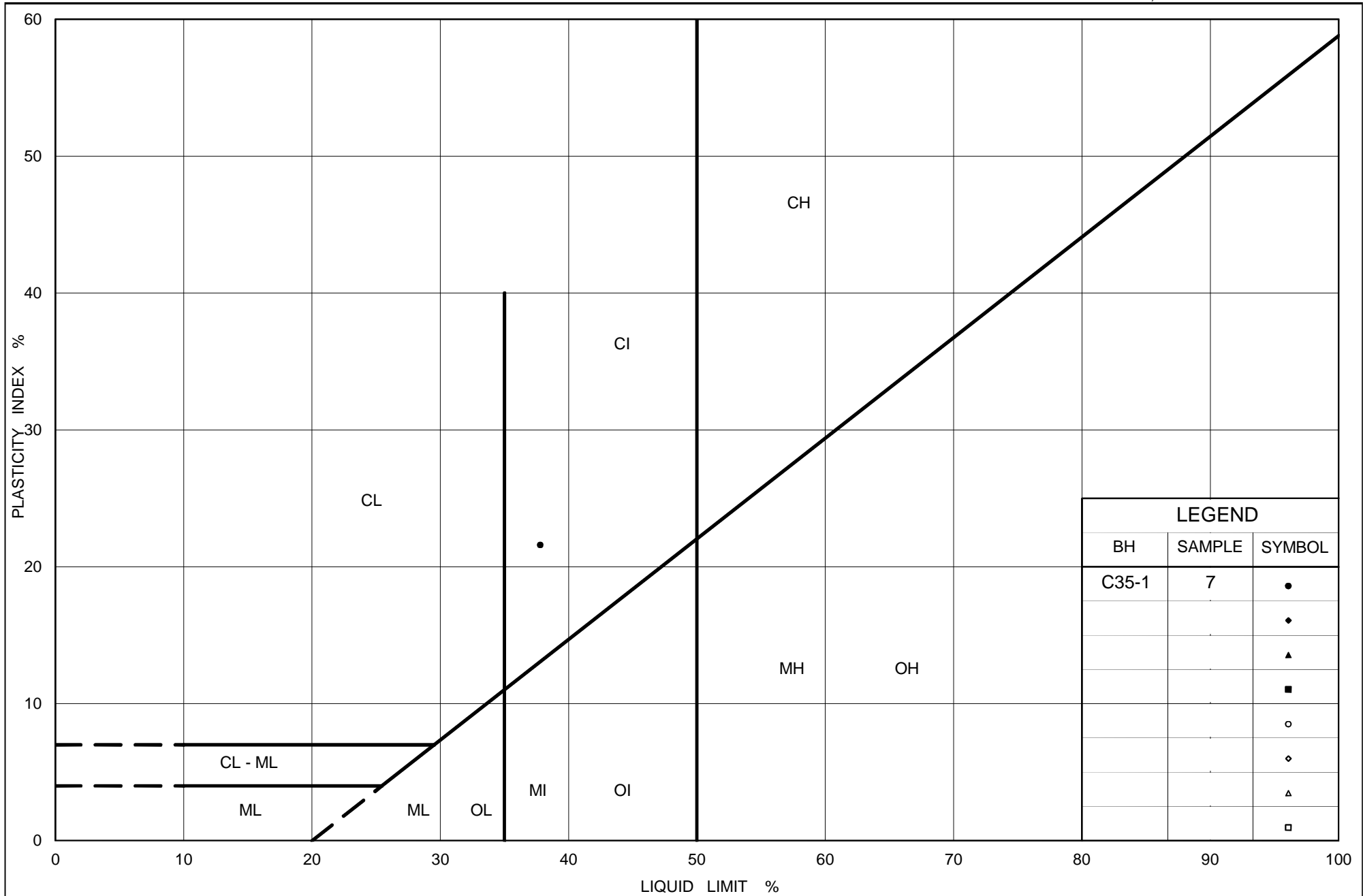
Project Number: 11-1184-0143

Checked By: NK

**Golder Associates**

Date: 05-Jul-16





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# PLASTICITY CHART Silty Clay with Sand (Fill)

Figure No. B3

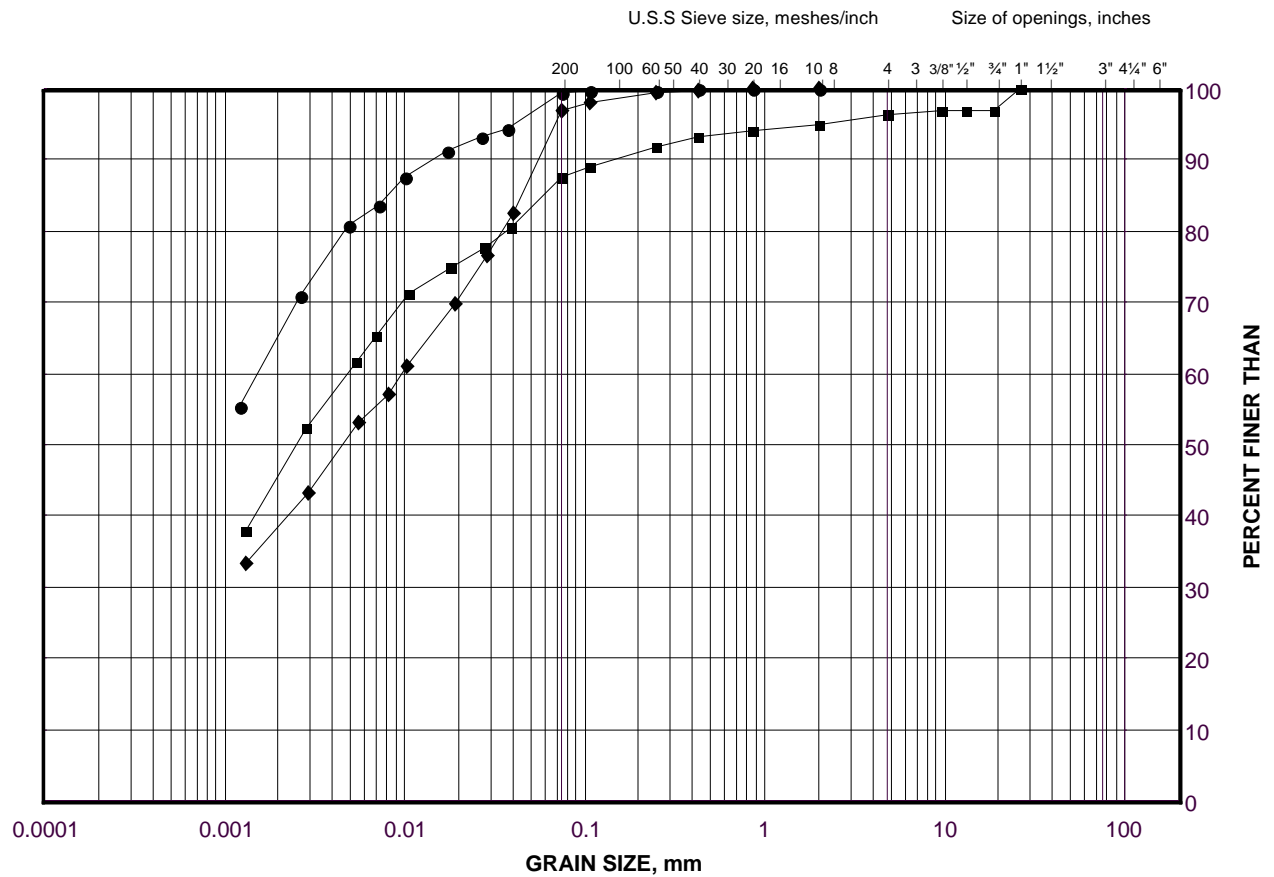
Project No. 11-1184-0143

Checked By: NK



## Clayey Silt to Silty Clay

FIGURE B4



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

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C35-1	11	82.6
■	C30-1	3	82.3
◆	C22-2	6	81.4

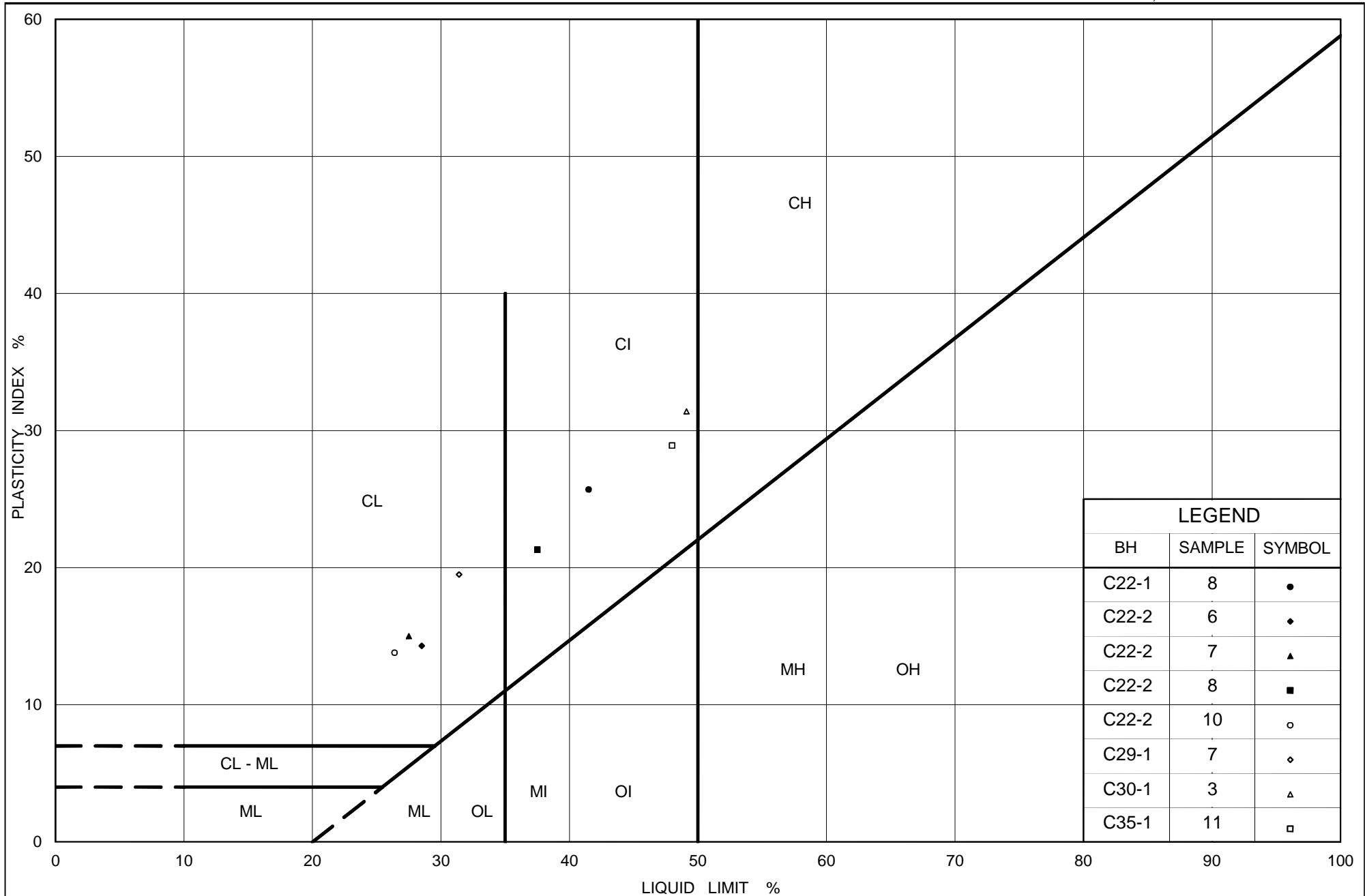
Project Number: 11-1184-0143

Checked By: NK

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Date: 05-Jul-16





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# PLASTICITY CHART Clayey Silt to Silty Clay

Figure No. B5

Project No. 11-1184-0143

Checked By: NK



**CONSOLIDATION TEST SUMMARY****ASTM D2435/D2435M****FIGURE 6A****Silty Clay****SAMPLE IDENTIFICATION**

Project Number	11-1184-0143	Sample Number	8
Borehole Number	C22-2	Sample Depth, m	10.06-10.67

**TEST CONDITIONS**

Test Type	Laboratory Standard	Load Duration, hr	24
Oedometer Number	4		
Date Started	6/01/2015		
Date Completed	6/17/2015		

**SAMPLE DIMENSIONS AND PROPERTIES - INITIAL**

Sample Height, cm	2.54	Unit Weight, kN/m <sup>3</sup>	17.94
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m <sup>3</sup>	12.74
Area, cm <sup>2</sup>	31.60	Specific Gravity, measured	2.77
Volume, cm <sup>3</sup>	80.20	Solids Height, cm	1.190
Water Content, %	40.90	Volume of Solids, cm <sup>3</sup>	37.60
Wet Mass, g	146.75	Volume of Voids, cm <sup>3</sup>	42.60
Dry Mass, g	104.15	Degree of Saturation, %	100.0

**TEST COMPUTATIONS**

Stress	Corr. Height	Void Ratio	Average Height	t <sub>90</sub> sec	cv. cm <sup>2</sup> /s	mv m <sup>2</sup> /kN	k cm/s
kPa	cm		cm				
0.00	2.538	1.133	2.538				
6.28	2.533	1.129	2.536				
10.94	2.530	1.126	2.532	406	3.35E-03	2.54E-04	0.00E+00
20.86	2.523	1.120	2.527	785	1.72E-03	2.78E-04	0.00E+00
40.13	2.507	1.107	2.515	1116	1.20E-03	3.27E-04	0.00E+00
79.08	2.478	1.083	2.493	1307	1.01E-03	2.93E-04	0.00E+00
156.50	2.433	1.045	2.456	1329	9.62E-04	2.29E-04	0.00E+00
311.48	2.264	0.903	2.349	2756	4.24E-04	4.30E-04	0.00E+00
621.27	2.062	0.733	2.163	2362	4.20E-04	2.57E-04	0.00E+00
1241.57	1.920	0.614	1.991	1808	4.65E-04	9.02E-05	0.00E+00
2480.76	1.801	0.514	1.861	1185	6.19E-04	3.78E-05	0.00E+00
1241.57	1.808	0.519	1.805				
311.48	1.843	0.549	1.826				
79.08	1.891	0.589	1.867				
20.86	1.937	0.628	1.914				
6.28	1.973	0.658	1.955				

Note:

Consolidation loading and unloading schedule assigned by the client.

Specimen taken 32-40 cm from top of the tube.

k calculated using cv based on t<sub>90</sub> values.**SAMPLE DIMENSIONS AND PROPERTIES - FINAL**

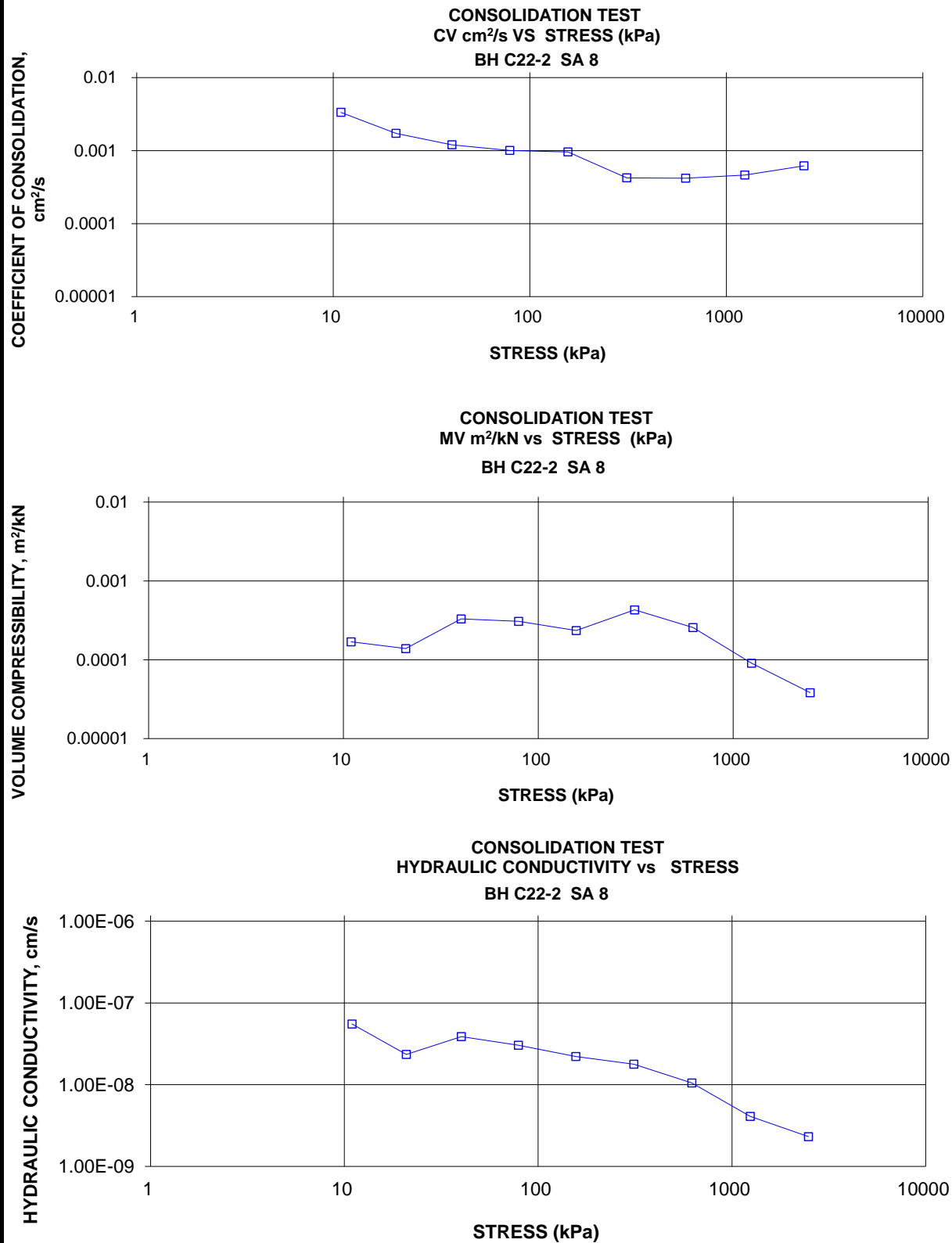
Sample Height, cm	1.97	Unit Weight, kN/m <sup>3</sup>	20.51
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m <sup>3</sup>	16.38
Area, cm <sup>2</sup>	31.60	Specific Gravity, measured	2.77
Volume, cm <sup>3</sup>	62.35	Solids Height, cm	1.190
Water Content, %	25.18	Volume of Solids, cm <sup>3</sup>	37.60
Wet Mass, g	130.37	Volume of Voids, cm <sup>3</sup>	24.75
Dry Mass, g	104.15		



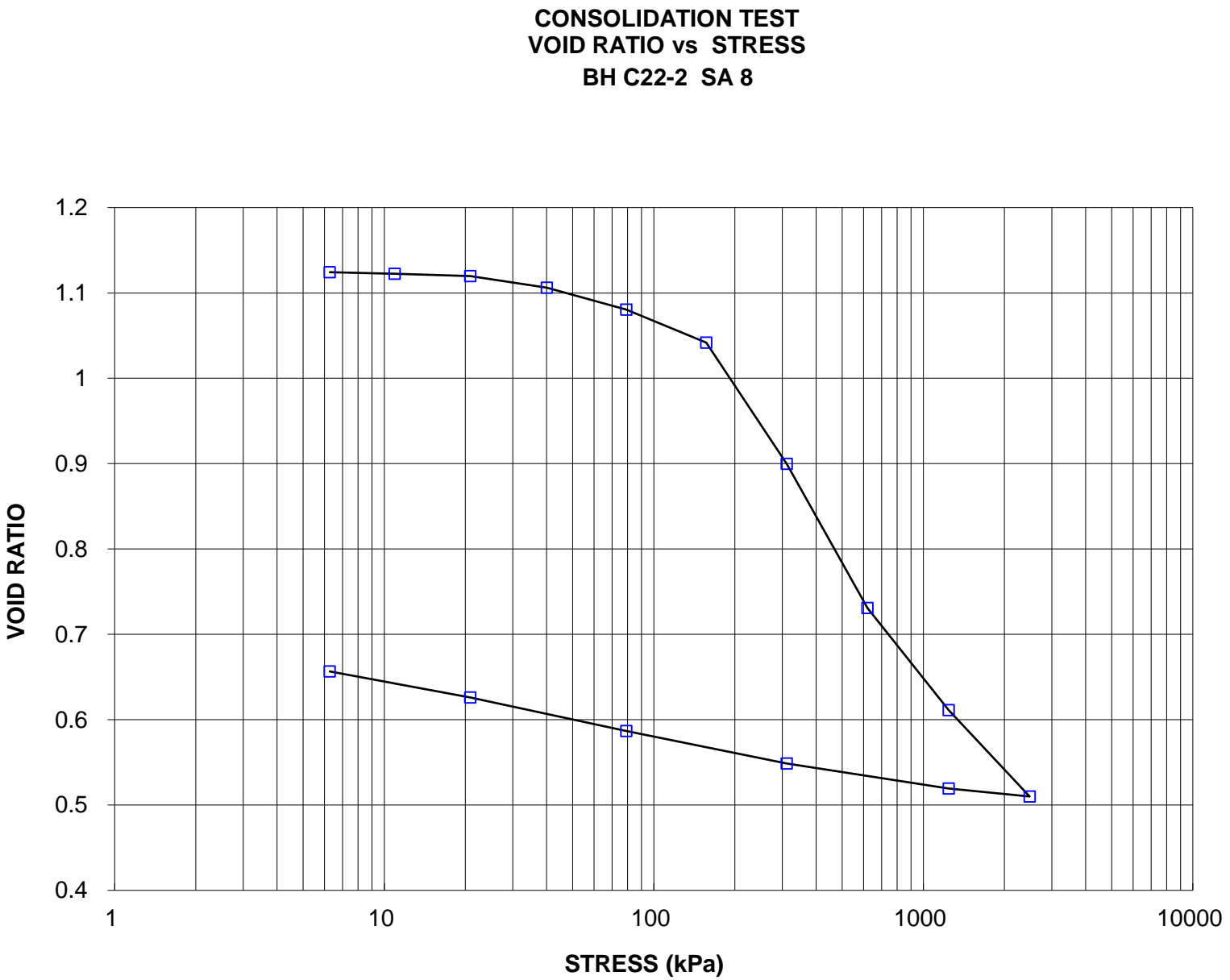
# CONSOLIDATION TEST SUMMARY

FIGURE 6B

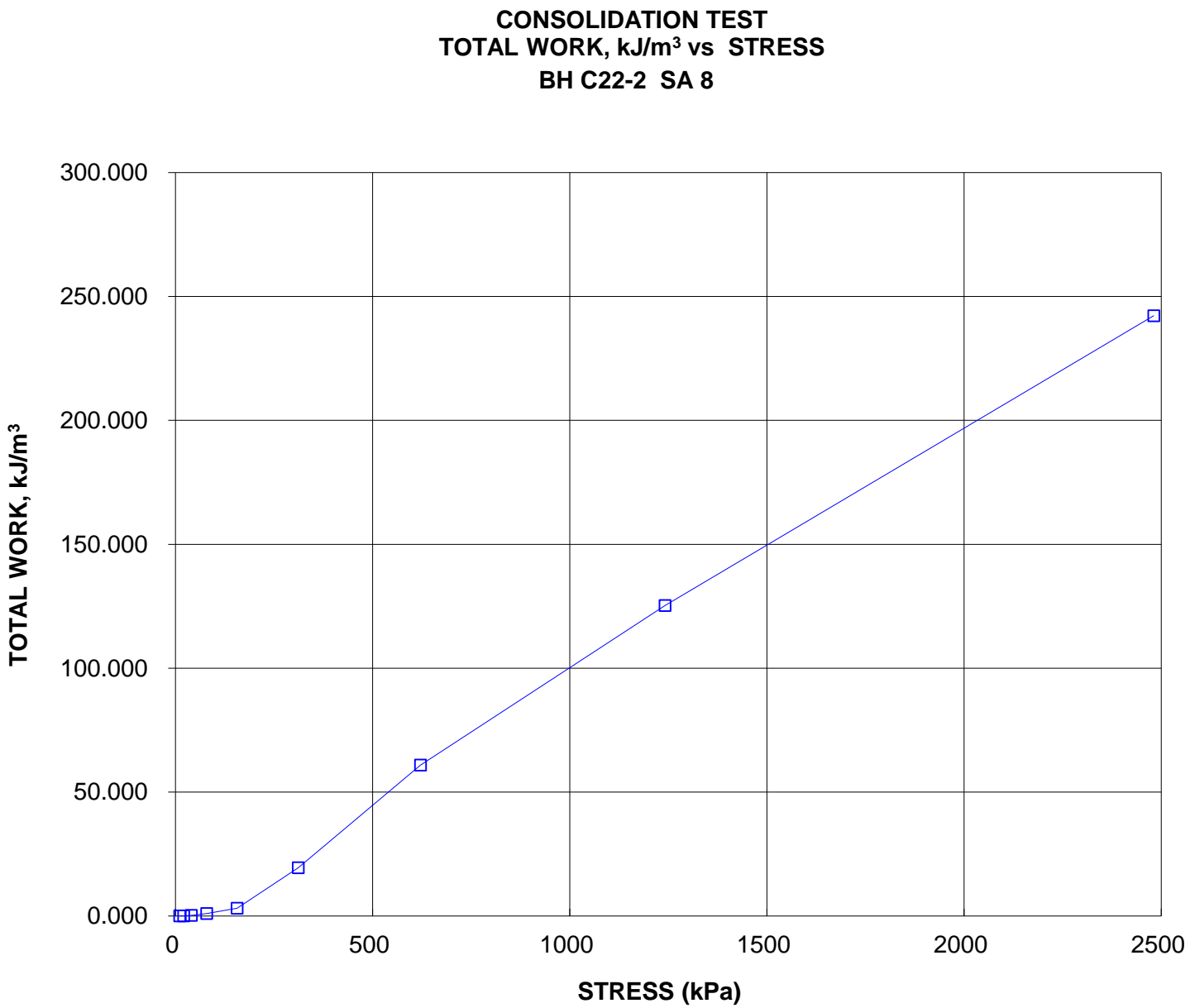
Silty Clay









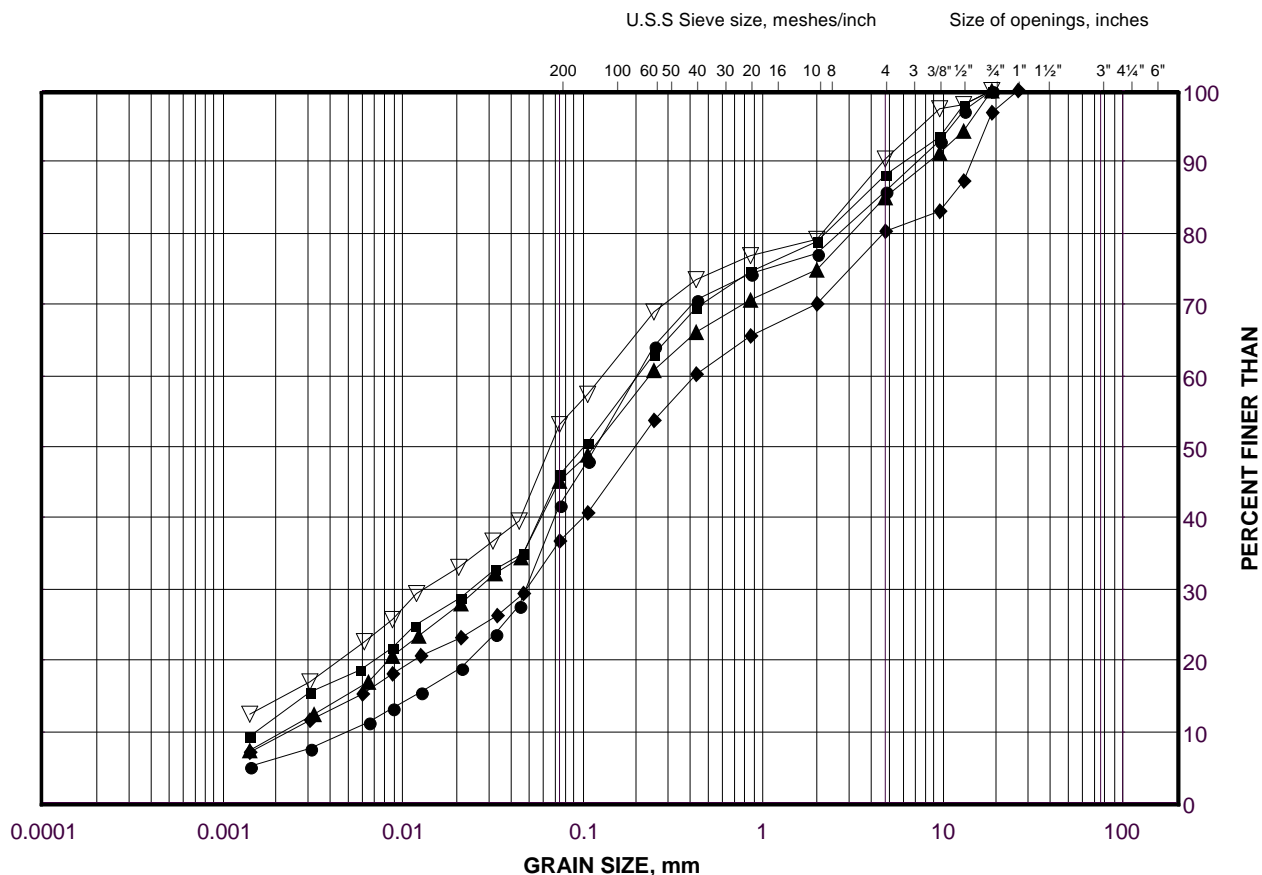




# GRAIN SIZE DISTRIBUTION

Clayey Silt with Sand to Silty Clay with Sand (Till)

FIGURE B7



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

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C22-1	13	72.1
■	C29-2	4	83.5
◆	C30-1	4B	81.5
▲	C29-2	5B	82.6
▽	C35-1	9	85.6

Project Number: 11-1184-0143

Checked By: NK

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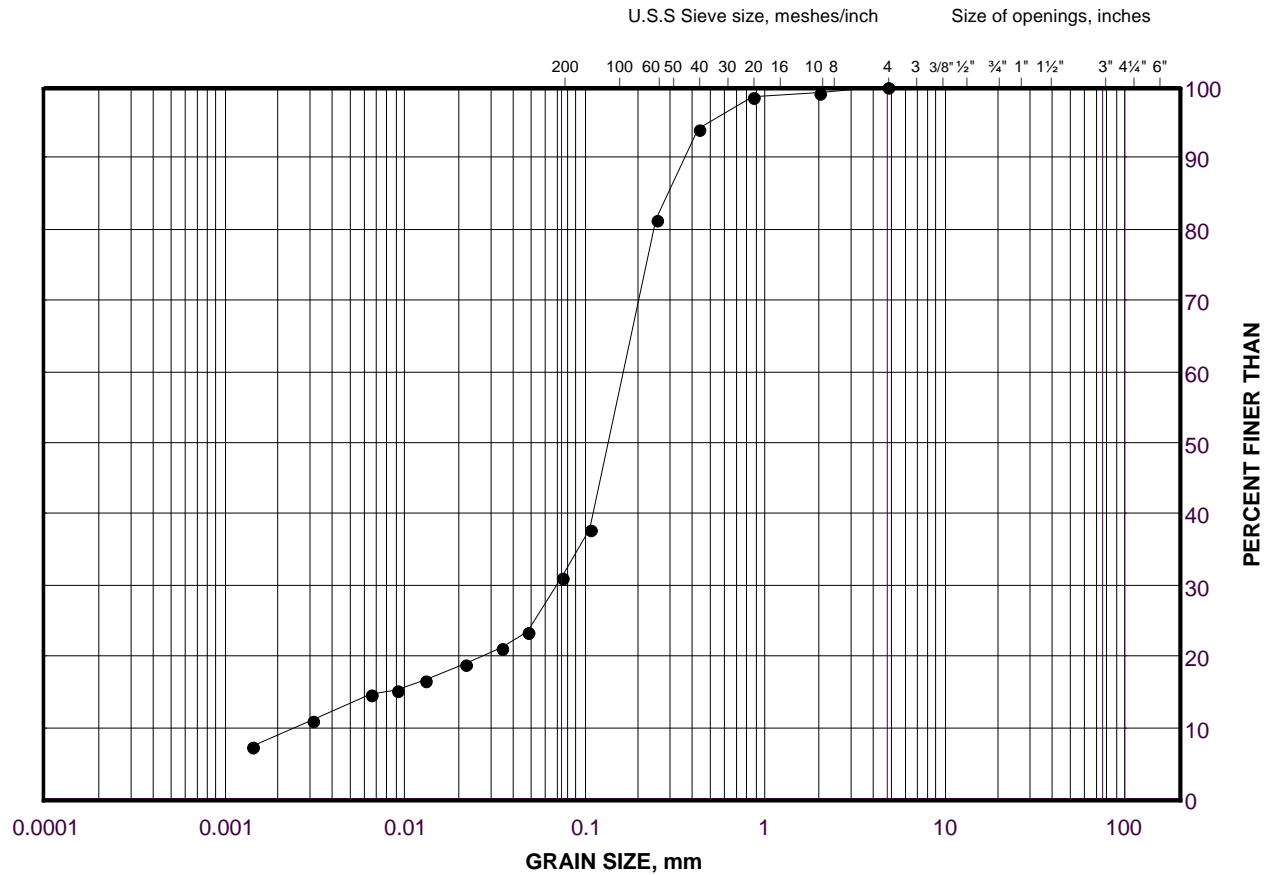
Date: 05-Jul-16



# GRAIN SIZE DISTRIBUTION

Silty Sand (Till)

FIGURE B8



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

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	C29-1	8	79.2

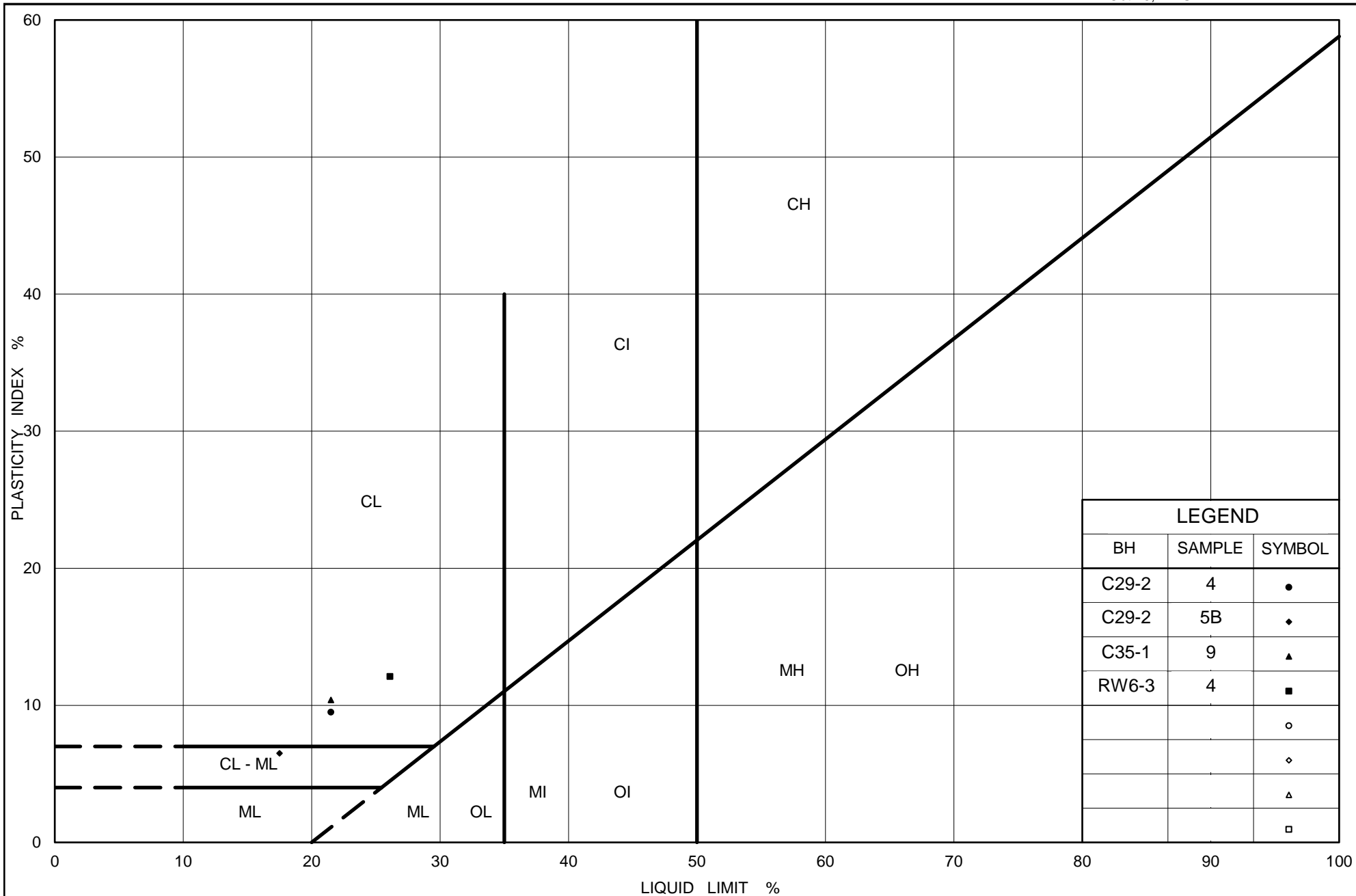
Project Number: 11-1184-0143

Checked By: NK

**Golder Associates**

Date: 05-Jul-16





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# PLASTICITY CHART Clayey Silt with Sand to Silty Clay with Sand (Till)

Figure No. B9

Project No. 11-1184-0143

Checked By: NK





# **APPENDIX C**

## **Record of Boreholes from Previous Investigation**



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## RECORD OF BOREHOLE NO 1

JOB 73-11004 LOCATION Co-ords. 15,947,336 N; 1,177,950 E.  
 W.P. 44-71-11 BORING DATE April 10, 1973  
 DATUM Geodetic BOREHOLE TYPE Hollow Stem Auger and Cone

ORIGINATED BY MY  
 COMPILED BY MY  
 CHECKED BY MY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT	LIQUID LIMIT $W_L$ PLASTIC LIMIT $W_P$ WATER CONTENT $W$ $W_p \quad W \quad W_L$ WATER CONTENT %	BULK DENSITY $\gamma$	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT					
256.4	Ground Level									
0.0	Clayey silt with sand, traces of gravel.		1	SS	18					0 57 37 6
248.4	Stiff to Very Stiff		2	SS	28					9 40 40 13
8.0	Sand and gravel with some silt & clay. (Glacial Till)		3	SS	68					33 45 (22)
			4	SS	100/8"					26 49 (25)
			5	SS	100/4"					
			6	SS	100/4"					
			7	SS	100/8"					59 37 (4)
	Very Dense		8	SS	82					
232.4	Boulder									
231.4	Shale Bedrock		9	RC	100%					
25.0	Sound									
226.9	End of Borehole									
29.5										







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## RECORD OF BOREHOLE NO 3

JOB 73-11004

LOCATION Co-ords. 15,947,324 N; 1,177,995 E.

ORIGINATED BY MY

W.P. 44-71-11

BORING DATE April 4, 1973

COMPILED BY MY

DATUM Geodetic

BOREHOLE TYPE Hollow Stem Auger and Cone

CHECKED BY *OM*

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100	LIQUID LIMIT ——— PLASTIC LIMIT ——— WATER CONTENT ——— W <sub>p</sub> ——— W <sub>L</sub> ——— WATER CONTENT % 10 20 30	BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT					
256.5	Ground Level									
0.0	Clayey silt with sand, traces to some gravel. Firm to Very Stiff		1	SS	1					2 44 47 7
			2	SS	6					0 66 29 5
246.0			3	SS	7					35 33 22 10
10.5	Sand & gravel with some silt & traces of clay. (Glacial Till) Dense to Very Dense		4	SS	30					18 47 31 1
			5	SS	100/3"					30 50 (20)
			6	SS	100/11"					
			7	SS	32					
			8	SS	100					
231.5										
25.0	Probable boulder or bedrock End of Borehole					230				



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FOUNDATIONS OFFICE

## RECORD OF BOREHOLE NO 4

JOB 73-11004 LOCATION Co-ords. 15,947,343 N; 1,177,995 E. ORIGINATED BY MY  
 W.P. 44-71-11 BORING DATE April 11, 1973 COMPILED BY MY  
 DATUM Geodetic BOREHOLE TYPE Cone Test CHECKED BY AK

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100	LIQUID LIMIT $W_L$ PLASTIC LIMIT $W_P$ WATER CONTENT $W$ $W_P \quad W \quad W_L$	BULK DENSITY $\gamma$	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT					
256.9	Ground Level									P.C.F. GR.SA.SI.CL.
0.0	Probably clayey silt sith sand.					250				
246.4										
10.5	End of Cone Test						150/6"			



FOUNDATIONS OFFICE

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

15  $\frac{20}{10}$  5 % STRAIN AT FAILURE



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FOUNDATIONS OFFICE

## RECORD OF BOREHOLE NO 6

JOB 73-11004B LOCATION Co-ords. 15,947,584 N; 1,178,013 E. ORIGINATED BY PK  
 W.P. 44-71-11 BORING DATE May 29-30, 1974 COMPILED BY WG  
 DATUM Geodetic BOREHOLE TYPE Hollow Stem Auger & Cone CHECKED BY \_\_\_\_\_

SOIL PROFILE		STRAT. PLOT	SAMPLES		ft/m	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE					LIQUID LIMIT — $w_L$			BULK DENSITY	REMARKS
ELEV. DEPTH	DESCRIPTION		NUMBER	TYPE			BLOWS/FOOT	BLOWS / FOOT	(0.3 m)	20	40	60	80	100		
m.	ft.						SHEAR STRENGTH P.S.F. kPa					WATER CONTENT %				
							○ UNCONFINED + FIELD VANE					$w_p$ — $w$ — $w_L$				
							● QUICK TRIAXIAL × LAB VANE					20 40 60				
78.18	256.5	Ground Level														
0.0	0.0	Sand, traces of organics		1	SS	13										Elev. 252.8
76.05	249.5	Compact		2	SS	10	250									77.05
2.13	7.0	Sand & gravel with some silt — dense		3	SS	54	76.20									42 34 17 7
		and traces of clay v. dense		4	SS	42										30 47 18 5
		shale fragments (Glacial Till)		5	SS	98	240									8 42 41 9
				6	SS	107	73.15									
				7	SS	100										
70.26	230.5	Boulders, cobbles		8	SS	107	230									22 47 24 7
7.92	26.0	End of Borehole					70.10									



## RECORD OF BOREHOLE NO 7

JOB 73-11004B LOCATION Co-ords. 15,947,572 N; 1,177,964 E.  
W.P. 44-71-11 BORING DATE May 30, 1974  
DATUM \_\_\_\_\_ BOREHOLE TYPE Cone Test

ORIGINATED BY PK  
COMPILED BY WG  
CHECKED BY \_\_\_\_\_

SOIL PROFILE		SAMPLES			ELEV. SCALE ft./m	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT (0.3 m) 20 40 60 80 100	LIQUID LIMIT — $w_L$ PLASTIC LIMIT — $w_p$ WATER CONTENT — $w$ $w_p$ — $w$ — $w_L$ WATER CONTENT %	BULK DENSITY $\gamma$ P.C.F. GR. SA. SI. CL.	REMARKS
ELEV. DEPTH ft.	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE					
m. 78.18	256.5	Ground Level							
0.0	0.0	Probable sand and silt some gravel				250 76.2			
74.4	244.2								
3.8	12.3	End of Cone Test				240 73.2	140/142		

15  $\frac{20}{\phi}$  5 % STRAIN AT FAILURE  
10



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## RECORD OF BOREHOLE NO 8

JOB 73-11004B

LOCATION Co-ords. 15,947,552 N; 1,177,963 E.

ORIGINATED BY PK

W.P. 44-71-11

BORING DATE May 30, 1974

COMPILED BY WG

DATUM

BOREHOLE TYPE Hollow Stem Auger and Cone Test

CHECKED BY

SOIL PROFILE			SAMPLES			ft/m	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT (0.3 m)	LIQUID LIMIT $w_L$			BULK DENSITY	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT (0.3 m)			PLASTIC LIMIT $w_p$	WATER CONTENT $w$	WATER CONTENT %		
m. 78.15 0.0 77.08 1.07	ft. 256.4 0.0 252.9 3.5											
	Ground Level											
	Sand		1	SS	0							
	Very loose		2	SS	2	250						Elev. 253.1
	Sand & gravel loose		3	SS	20	76.2						77.14
	silt & clay coarser		4	SS	100	8"						9 57 27 7
	shale fragments - (Glacial Till)		5	SS	100	3"						22 44 27 7
	cobbles very					240						
	boulders dense		6	SS	100	4"						
72.72	238.6					73.15						12 37 39 12
5.43	17.8											
	End of Borehole											
						230						
						70.1						



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