



**ADDENDUM NO. 1**

**PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT  
HIGHWAY 401 WEST EXPANSION  
REGIONS OF PEEL AND HALTON, ONTARIO  
ASSIGNMENT NO. 2016-E-0004**

**Submitted to:**

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GEOCRES No.: **30M12-420**

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**ADDENDUM NO. 1**

**PART 1**

**GENERAL PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT  
HIGHWAY 401 WEST EXPANSION  
REGIONS OF PEEL AND HALTON, ONTARIO  
ASSIGNMENT NO. 2016-E-0004**

1.0 INTRODUCTION

Peto MacCallum Ltd. (PML) prepared a Preliminary Foundation Investigation and Design Report dated June 7, 2018, as sub-consultant to AECOM Canada Ltd. (AECOM) under the Ministry of Transportation, Ontario (MTO) Purchase Order No. 2016-E-0004.

Additional work tasks were requested by AECOM via e-mails dated June 19 and 22, July 23, and August 3, 2018. PML has prepared this report as an Addendum No. 1 to the original report for the additional preliminary Foundation Engineering services provided for four (4) non-structural culverts, and one (1) retaining wall under Scope Change Request No. 2. This Addendum report only includes the additional information requested under Scope Change No. 2 and shall be read in conjunction with the original Preliminary Foundation Investigation and Design Report dated June 7, 2018.

Refer to Appendix A for a Site Location Plan.

Refer to respective SITE-SPECIFIC Preliminary FIDR sheets for borehole locations plans and details of borehole locations at respective sites.

Refer to Appendix B for borehole sheets and lab test results from previous investigations.

Refer to Appendix C for borehole sheets and lab test results from the supplemental investigation carried out for this assignment.

Refer to Table 1 for a list of referenced boreholes by structural site.

TABLE 1 - REFERENCED BOREHOLES BY STRUCTURE LOCATION

Structure / Location	Site No.	Previous Borehole No.	PML Borehole No.	SITE-SPECIFIC Preliminary FIDR Sheet No.
Mullet Creek Culvert Replacement	24-253/C	11-401 11-402	MC-1 MC-2 MC-3	U
Retaining Wall at North End of Sixteen Mile Creek (W-C17)	10-368/C	-	SME-1 SME-3 SME-5	V
Non-Structural Culvert W-C18	-	-	C18-1 C18-2	W
Non-Structural Culvert W-C19	-	-	C19-1 C19-2	X
Non-Structural Culvert W-C20	-	-	C20-1 C20-2	Y

2.0 CLOSURE

This Preliminary Investigation and Design Report was prepared by Mr. Keshav Amatya, P.Eng. with assistance by Ms. Natasha Leong-Sem. EIT and reviewed by Mr. Nazibur Rahman, P.Eng. Manager Geotechnical Services and Mr. David Dundas, P.Eng., Senior Engineer, Geotechnical Services. Mr. Robert Ng, PhD, MBA, P.Eng., MTO Designated Principal Contact, conducted an independent quality review of the report.

Peto MacCallum Ltd.

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## **PART 2**

### **SITE SPECIFIC PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN SHEETS**

## **SITE U – MULLET CREEK CULVERT REPLACEMENT**

PRELIMINARY FOUNDATION INVESTIGATION

Borehole Information

A total of five (5) boreholes, including two (2) boreholes from a previous investigation, were advanced along the alignment of Mullet Creek Culvert located on Highway 401 east of Derry Road West. Proponents should review the information in this report in the context of the scope of the Mullet Creek culvert replacement to assess the sufficiency of the provided subsurface information for their purposes and to plan and implement additional foundation subsurface investigations as they deem appropriate.

Refer to

- Structure and borehole location plan, and subsurface stratigraphy (Drawing MC-1).
- Table U-1 for details of borehole location coordinates and borehole elevations/depths.
- Appendices B and C for Record of Borehole sheets and lab results showing details of the subsurface conditions at the borehole locations from previous and current investigations, respectively.

Table U-1 Mullet Creek Borehole Information

Borehole ID	Borehole Location	MTM NAD 83 Coordinates		Ground Surface Elevation (m)	Borehole Depth (m)
		Northing (m)	Easting (m)		
Current Investigation					
MC-1	Inlet	4 829 334.5	284 420.2	182.6	12.3
MC-2	Outlet	4 829 276.5	284 420.2	184.2	11.0
MC-3	Outlet	4 829 281.6	284 437.4	183.9	11.6
Previous Investigation (Geocres No. 30M12-348)					
11-401	Outlet	4 829 244.1	284 426.8	178.3	13.6
11-402	Inlet	4 829 362.5	284 412.4	178.5	10.6

Subsurface Conditions

The stratigraphy conceptually consists of approximately 1.4 m to 1.5 m of roadway pavement underlain by general fill consisting of an approximately 0.9 m to 1.9 m thickness of sandy silt to silty sand with varying proportions of gravel over 3.5 m to 5.6 m of clayey silt. The general fill is underlain by a very stiff to hard clayey silt till deposit to the maximum borehole depth of 12.3 m. Refer to the Record of Boreholes sheets for actual subsurface conditions.

The subsurface conditions at this site can be categorized into three (3) general layers as presented below.

• Pavement Fill

Pavement fill was encountered in all three boreholes drilled on the existing paved shoulders of Highway 401. The pavement structure consisted of an approximately 130 mm to 145 mm thick layer of asphalt over 1.3 m to 1.4 m of base and subbase fill consisting of silty sand with varying proportions of gravel. This pavement fill extends to Elevations 181.2 m and Elevation 182.8 m in boreholes drilled on the shoulders of westbound and eastbound lanes, respectively. A 38 mm thick asphalt was encountered within the pavement fill in the borehole drilled on the shoulder of Highway 401 eastbound. The SPT ‘N’ values of this layer ranged from 55 blows to 93 blows per 0.3 m, with the exception of one test on the asphalt layer (50 blows/ 0 cm penetration). Moisture contents of samples ranged from 2.1% to 3.9%.

• General Fill

The composition of the General Fill varied across the site from Sandy Silt /Silty Sand to Clayey Silt.

▪ Sandy Silt to Silty Sand Fill

An approximately 0.9 m to 1.9 m thick compact to very dense sandy silt to silty sand fill layer was encountered immediately below the pavement fill, extending to Elevation 180.3 m to Elevation 181.4 m below the existing surfaces of westbound and eastbound shoulders of Highway 401, respectively. The SPT ‘N’ values of this layer ranged from 19 blows to 72 blows per 0.3 m. Moisture contents of samples ranged from 2.8% to 18.5%.

▪ Clayey Silt Fill

An approximately 3.5 m to 5.6 m thick stiff to very stiff clayey silt fill was encountered in all three boreholes, immediately below the sandy silt/silty sand fill and extending to Elevation 176.8 m to Elevation 177.2 m at the westbound and eastbound shoulders of Highway 401, respectively. The SPT ‘N’ values of this layer varied widely between 3 blows and 20 blows per 0.3 m, indicating soft to very stiff consistency. Moisture contents ranged from 8.1% to 30.1%. The grain size distribution result of a selected sample from the clayey silt fill layer is provided on Figure GS-U-1 and the Atterberg limits are presented on Figure PC-U-1 in Appendix C-2.

• Clayey Silt (Till)

The very stiff to hard clayey silt (till) deposit was encountered in all three boreholes, immediately below the clayey silt fill layer, extending for thicknesses of 6.5 m, 4.0 m and 3.8 m in all BH’s MC-1, MC-2 and MC-3 respectively. The clayey silt till deposit was not fully penetrated in BH’s MC-1 and MC-2 with BH termination Elevations of 170.3 m and 173.2 m, respectively. The SPT ‘N’ values of this clayey silt deposit ranged from 24 blows to 100 blows for 0.08 m penetration (Refusal). Moisture contents of the samples ranged between 8.1% and 12.9%. The grain size distribution result of a selected sample from the clayey silt till layer is provided on Figure GS-U-2 and the Atterberg limits are presented on Figure PC-U-2 in Appendix C-2.

• Sandy Silt (Till)

The clayey silt till in Borehole MC-3 at Elevation 173.2 m is underlain by very dense sandy silt till to the termination depth of this borehole at Elevation 172.3 m.

The SPT ‘N’ values of the sandy silt till deposit were 80 blows for 0.3 m and 50 blows for 10 mm penetrations. Moisture content of a sample from this sandy silt deposit was 9.4%. The grain size distribution result of a sample from this deposit is provided on Figure GS-U-3.

Groundwater Conditions

Groundwater was not encountered in any of the boreholes during drilling. However, groundwater was measured at a depth of 10.4 m below ground surface (Elevation 172.2 m) upon completion of augering of borehole drilled on the shoulder of Highway 401 westbound. Groundwater levels are subject to seasonal fluctuations and precipitation patterns.

The groundwater levels indicated in this and referenced reports should be considered during detail design.

**PRELIMINARY FOUNDATION DESIGN RECOMMENDATIONS**

Mullet Creek Culvert (Site 24-253/C) is proposed to be replaced with a longer and wider culvert to accommodate widening of both eastbound and westbound directions of Highway 401.

The following documents are referenced:

- 1. Preliminary Foundation Investigation and Design Report–Mullet Creek Culvert Extension Highway 401 Widening from East of Credit River to Trafalgar Road, Regional Municipalities of Peel and Halton, W.O. 07-20021(GEOCRES No. 30M12-348), Submitted to URS Canada Inc. by Golder Associates Ltd., (Report Number: 10-1111-0040-4), October 2012.
- 2. Preliminary General Arrangement (GA) Drawing, dated August 2018, for Mullet Creek Culvert provided by AECOM on October 5, 2018.
- 3. Structural Design Report- Mullet Creek Culvert, Site No. 24-253/C, Submitted to Ministry of Transportation Ontario by AECOM, Project No. 60542331, Service Provider Agreement No. 2016-E-0004, dated September, 2018

**Existing Culvert**

The existing culvert consists of three different sections constructed at different times, with additions associated with widenings of EBL and WBL of Highway 401. The original rigid frame culvert (6.1 m span and a 1.5 m rise) was supported on open type footings and was built in 1957. The south end of the culvert was extended by about 5.5 m in 1977 under MTO Contract No. 77-47 with a rigid frame structure of the same size as the original and supported on open type footings. The footings of the culverts are 1.22 m deep and 2.04 m wide. The extension on the north end of the culvert was constructed with a 6.1 m span and a 2.1 m rise. The date of this extension and other details are not available. The current total length of the existing culvert is approximately 80 m. Based on the invert levels and depth of the footings, the founding level of the culvert may be estimated at Elevation 175±.

Mullet Creek culvert was originally constructed with a fill height of 1.5 m above the culvert obvert. Since the original construction, the highway has been re-graded and the existing structure supports a fill height of about 4.3 m to 6.5 m above the culvert deck. The existing inlet and outlet inverts are at Elevation 176.64 m and Elevation 176.40 m, respectively. As-built drawings were not available during the preparation of this report to confirm foundation elevations. Based on the information provided on GA drawing dated August 2018, high water level (HWL) in the 100-year event is Elevation 178.21 m.

**Proposed Culvert**

The Structural Design Report dated September 2018 (Reference 3) and the GA drawing dated August 2018 (Reference 2) indicate that a two-cell concrete box culvert, with each cell with 6.0 m span and 2.4 m rise is the preferred configuration for replacement of the Mullet Creek Culvert. The total length of the replacement culvert will be 112.0 m to accommodate the proposed widening of Highway 401. The length of the proposed culvert includes 17.3 m and 18.0 m extensions at the south and north ends, respectively. The new culvert will be constructed straight, with the exception of an 18.0 m length at the north end with a curvature to facilitate realignment of the stream into the new culvert. The replacement culvert will consist of 680 mm and 850 mm thick top and bottom slabs, respectively, with a clear cell height of 2.4 m above any bedding material placed inside the culvert.

The proposed streambed elevations at the north and south ends of the culvert are expected to be at Elevation 176.3 m and Elevation 175.5 m, respectively. Foundation depths for footings should be determined once the preferred installation method is determined.

The maximum height of fill above the culvert will be about 5.8 m over the extension area of the south end. Retaining walls are proposed for all four corners of the culvert to retain the embankments and a header wall at the south end of the culvert. Based on the Structural Design Report (reference document #3), cut-off walls are also proposed at both ends of the culvert to protect against any scour of the subgrade.

The scope of this preliminary Foundation Investigation and Design Report is limited to preliminary design level consideration of the 3 alternative construction methods identified in the Structural Design Report (Reference 3) for the replacement culvert. A comparison of these three alternatives construction methods considered in terms of advantages and disadvantages is provided in Table U-3. The methods of construction considered are as follows:

- a. Tunnelling by Pipe Roof Method
- b. Open Cut and Cover
- c. Cover and Cut

Other tunnelling methods may be considered but are beyond the scope of this preliminary Foundation Investigation and Design Report.

In the case of Alternative (a), the replacement culvert would be constructed with excavation by tunnelling along an alignment approximately 15 m east of the existing culvert and the stream flow would be maintained through the existing culvert during construction.

Alternative (b) would involve deep excavations and roadway protection system for multiple stages of construction for transfer of traffic. The replacement culvert could be constructed along the proposed alignment of Alternative (a) or along the approximate alignment of existing culvert, which would require construction of cells separately and shifting of the stream flow between the cells to permit construction in-the-dry.

Alternative (c) involves construction of secant walls and roof slabs, as well as aspects similar to that of Alternative (b) regarding staging of construction and alignment for the replacement culvert. In this method, there would be space and complexity challenges for excavation and construction in the confined space under the roof slab and between the secant walls.

The extensions at the north and south ends are expected to be constructed using conventional cut and cover construction, which may require roadway protection systems for excavation.

Detail design level foundation recommendations should be determined during the detail design phase of the project and in consultation with an expert tunnelling contractor for alternative a) or any alternate tunnelling proposals.

**Foundation Type**

The proposed founding levels of the replacement culvert at the inlet is expected to be at Elevation 176.3 m and at the outlet, it will be at Elevation 175.5 m. The subsoil conditions below the proposed founding levels is a very stiff to hard clayey silt till deposit. The ground water level was encountered at Elevation 172.2 m, which is about 3.3 m to 4.1 m below the proposed founding levels of the culvert.

The cut and cover method is expected to be employed for the construction of culvert extensions at both ends for all alternatives. The clayey silt layer at the proposed founding level will be susceptible to disturbance from construction traffic and any ponded water. In order to limit the degradation of the founding soil in the area of culvert extension, it

is recommended that 100 mm thick concrete working slab (lean concrete) be placed on the subgrade within four hours after preparation, inspection, and approval of the foundation subgrade.

**Alternative (a) – Tunnelling by Pipe Roof Method**

Refer to Reference #3 – Structural Design Report for background regarding Alternative (a) as considered during the preliminary design phase by AECOM.

For preliminary design purposes, the culvert placed at or below the proposed founding levels may be designed assuming a factored geotechnical resistance of 450 kPa at ULS and a factored geotechnical resistance of 300 kPa at SLS.

**Alternative (b) –Open Cut and Cover**

Refer to Reference #3 – Structural Design Report for background regarding Alternative (b) as considered during the preliminary design phase by AECOM.

This alternative will involve 7.0 m to 8.0 m deep excavations and require roadway protection systems with tiebacks or anchors. The design of the culvert constructed by employing the open cut and cover method may be designed using the recommendations provided for Alternative (a).

**Alternative (c) – Cover and Cut**

Refer to Reference #3 – Structural Design Report for background regarding Alternative (c) as considered during the preliminary design phase by AECOM.

The design of the concrete box culvert will be similar to that of Alternatives (a) and (b). However, this alternative will involve construction of secant walls and roof slab with greater complexity in excavation and construction under the roof slab. For preliminary design purposes, the recommendations provided for Alternative (a) may be used.

**Culvert Bedding, Backfill and Erosion Protection**

In the Structural Design Report (reference #3 above), cut-off walls have been proposed to be constructed at both ends of the replacement culvert. Cut-off walls should be in accordance with OPSD 812.010 or made of cast-in-place concrete with similar dimensions to prevent washout or scour. As indicated on the GA drawing dated August 2018, the cut-off walls should be extended to a minimum of 1.2 m below the base of the bottom slab.

Appropriate culvert inlet and outlet erosion and scour protection should be recommended during the detail design phase of the project including appropriate cut-offs to channel water through the inlet and filters to protect the outlet and erosion protection measures at both the inlet and outlet. The detail design should prescribe

- the limits of scour protection in both plan and section, for example from the high-water level to a recommended distance in front of foundations and also the lateral extent on each side of foundations
- the thickness of scour protection
- the material and minimum particle size of scour protection

The detail design Foundation Investigation and Design Report should

- state that scour design is a multi-disciplinary exercise that involves the structural and hydrology designer as well as the foundation/geotechnical designer working as a team,

- document ground conditions and provide relevant characterization related to scour design such as erodibility,
- require and document that the geotechnical foundation engineer has reviewed and endorsed the resulting scour design as meeting the minimum scour protection from a foundation perspective, with reference made to the documentation reviewed, and
- reference appropriate guidelines where applicable. Accepted design protocols are clearly prescribed in documents such as
  - HEC-18 (evaluating scour at bridges)
  - HEC-23 (bridge scour and stream instability countermeasures)

For preliminary foundation design purposes, an appropriate filter should be provided at the outlet. The filter could be appropriately sized free-draining granular material and extend from the design high water level, downstream for a distance equal to three times the culvert height and along the adjacent side slopes for a horizontal distance equal to two times the culvert height. Rock protection should be provided at the inlet and outlet, in accordance with OPSS 511 and OPSS 1004, to protect the inlet seal and outlet filter materials respectively. The dimensions of rock protection particles should be determined during the detail design phase in consideration of the flow velocity. The thickness of the rock protection should be a minimum of twice the maximum rock particle dimension.

Ontario Provincial Standard Specifications (OPSS 1010) Granular ‘A’ or ‘B Type II’ should be used as backfill material behind the wall and compacted in accordance with the requirements specified in the OPSS 902 (Excavation and Backfilling of Structures) as amended by SP 109S12 and NSSP FOUN0003. The backfill material should be placed in layers not exceeding 200 mm in thickness before compaction.

Heavy vibratory compaction equipment adjacent to retaining structures should be restricted to limit the compaction pressure described in Clause 6.12.3 of the CHBDC, 2014. Restrictions on compaction near the retaining wall should be as specified in OPSS 902 as amended by SP 109S12 and NSSP FOUN0003. The type of compaction equipment and the compaction procedure that can be used for this purpose should be in accordance with OPSS 501 (Construction Specification for Compacting).

**Retaining Walls at Inlet and Outlet**

Details of the proposed retaining walls were not available at the time of preparing this report. Refer to the section 5.3.1 of associated General Report for associated general recommendations. However, the proposed retaining walls may be designed assuming the geotechnical resistances recommended for the design of the culvert, if the walls are placed at or below the proposed subgrade levels of inlet and outlet.

**Approach Embankments**

PML understands that there will be no increase in the profile grade of the road and it will be maintained at Elevation 183.8± at the centre line of the highway. No major instability problems are anticipated for the excavated section of the embankment to be reconstructed with similar side slope as the existing. Any soft or compressible zones observed under the base of the embankment should be replaced.

Construction Considerations

• Staged Construction

Staged construction with roadway protection will be required to maintain the existing culvert and to extend the proposed new culvert extension while maintaining traffic on Highway 401 without any interruption. Surface water should be diverted away from open excavations and all excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA) and MTO Regulations for Construction Projects.

The roadway should be protected by a properly designed protection system when space limitation exists. The protection system for excavations should be in accordance with OPSS 539 as amended by SP105S09, Construction Specification for Temporary Protection Systems, OPSS 902 as amended by SP 109S12 and NSSP FOUN0003 and Construction Specifications for Excavating and Backfilling–Structures. Excavated material should not be stockpiled in the areas immediately adjacent to the top of the excavation slopes. Culvert bedding for box culverts should be in conformance with OPSS 422.

• Excavation

Based on the record of boreholes, the excavations will be advanced through existing fill material underlain by native till deposits. For OHSA classification purposes, the fill materials should be classified as Type 3 soils and clayey silt till should be classified as Type 2 soils. Soils below groundwater should be classified as Type 4. For excavations through multiple soil types, the side slope geometry is governed by the soil with the highest number designation.

Excavation should be in accordance with OPSS 902 amended by SP 109S12 and NSSP FOUN0003.

• Roadway Protection and Shoring

The Contractor is responsible for the selection, design, construction, and performance of the temporary protection systems. The protection systems should be designed to meet the Performance Level 2 as specified in OPSS 539 amended by SP 105S09.

Geotechnical parameters provided in Table U-2 may be used for the preliminary evaluation of temporary roadway protection system or shoring for excavation. The soil parameter provided in the table below may not be adequate for design of shoring system requiring anchors or tiebacks. Additional boreholes may be needed at the final design stage to establish soil parameters for anchor design.

Table U-2 Preliminary Geotechnical Design Parameters

Soil Type	Unit Weight, (kN/m <sup>3</sup> )	Design Parameters	
		Friction Angle, (Ø')	Undrained Shear Strength, Su (kPa)
Silty Sand (Fill)	20	30	-
Clayey Silt (Fill)	20	26	n/a
Clayey Silt (Till)	22	28	n/a

• Groundwater and Surface Water Control

The groundwater level was encountered at Elevation 172.2 m upon completion of drilling in borehole MC- 1 and the excavation to the founding level will have to be carried out above Elevation 172.2 m.

The surface water flow should be directed away from excavations areas to mitigate disturbance and weakening of the clayey silt till subgrade. Furthermore, depending on the creek flow at the time of the construction, the surface water flow could be passed through the construction area by means of a temporary pipe or diverted by pumping from behind a temporary cofferdam. Groundwater levels should be maintained a minimum of 0.5 m below the bases of excavations for construction in-the-dry.

The contractor should be responsible for the selection, performance and detailed design of the dewatering system including the cofferdam. The dewatering system should be designed to conform to the requirement of OPSS 517 amended by SP 517F01.

Table U-3 Comparison of Culvert Replacement Foundation Alternatives		
Alternative (a) – Tunnelling by Pipe Roof Method	Alternative (b) – Open Cut and Cover	Alternative (c) – Cover and Cut
Advantages: <ul style="list-style-type: none"><li>Maintains all traffic lanes open during construction</li><li>Streamflow is maintained in the existing culvert during construction</li></ul>	Advantages: <ul style="list-style-type: none"><li>Low estimated initial construction cost</li><li>May be constructed on the same offset as Alternative (a) and maintain streamflow in the existing culvert</li></ul>	Advantages: <ul style="list-style-type: none"><li>Traffic maintained during excavation phase</li><li>May be constructed on the same offset as Alternative (a) and maintain streamflow in the existing culvert</li></ul>
Disadvantages: <ul style="list-style-type: none"><li>High cost and complexity of construction and specialized tunnelling equipment</li><li>Uncertainties related construction technique that could lead to construction challenges and delays</li></ul>	Disadvantages: <ul style="list-style-type: none"><li>Open cut may not be permitted by MTO policy for Highway 401 crossings in Central Region.</li><li>Requires deep excavations and roadway protection systems with piles and lagging and tie backs</li><li>Requires construction in multiple stages which will have significant impacts on Highway 401 traffic flow</li><li>If constructed along the existing culvert alignment would require shifting of the streamflow during each construction stage</li></ul>	Disadvantages: <ul style="list-style-type: none"><li>Higher estimated initial cost than Alternative (b)</li><li>Complex construction requiring construction of secant wall and roof slab</li><li>Requires construction in multiple stages, which will have potential significant impacts on Highway 401 traffic flow</li><li>To accommodate all existing travel and ramp lanes during construction may require overbuilding</li><li>If constructed along the existing culvert alignment would require shifting of the streamflow during each construction stage</li></ul>

Asgmt. No 2016-E-0004



MULLET CREEK CULVERT  
HIGHWAY 401  
TOWN OF HALTON  
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



#### LEGEND

- Borehole (Current Investigation)
- Geocres Borehole (30M12-348)  
(Refer to Record of Borehole for details)
- Blows/0.3m (Std. Pen Test, 475 J/blow)
- WL at Time of Investigation Oct. - Nov. 2017
- \* Water level could not be established

BH No	ELEVATION	NORTHINGS	EASTINGS
MC-1	182.6	4 829 334.5	284 420.2
MC-2	184.2	4 829 276.5	284 420.2
MC-3	183.9	4 829 281.6	284 437.4
Geocres Boreholes (30M12-348)			
11-401	178.3	4 829 244.1	284 426.8
11-402	178.5	4 829 362.5	284 412.4

#### NOTE

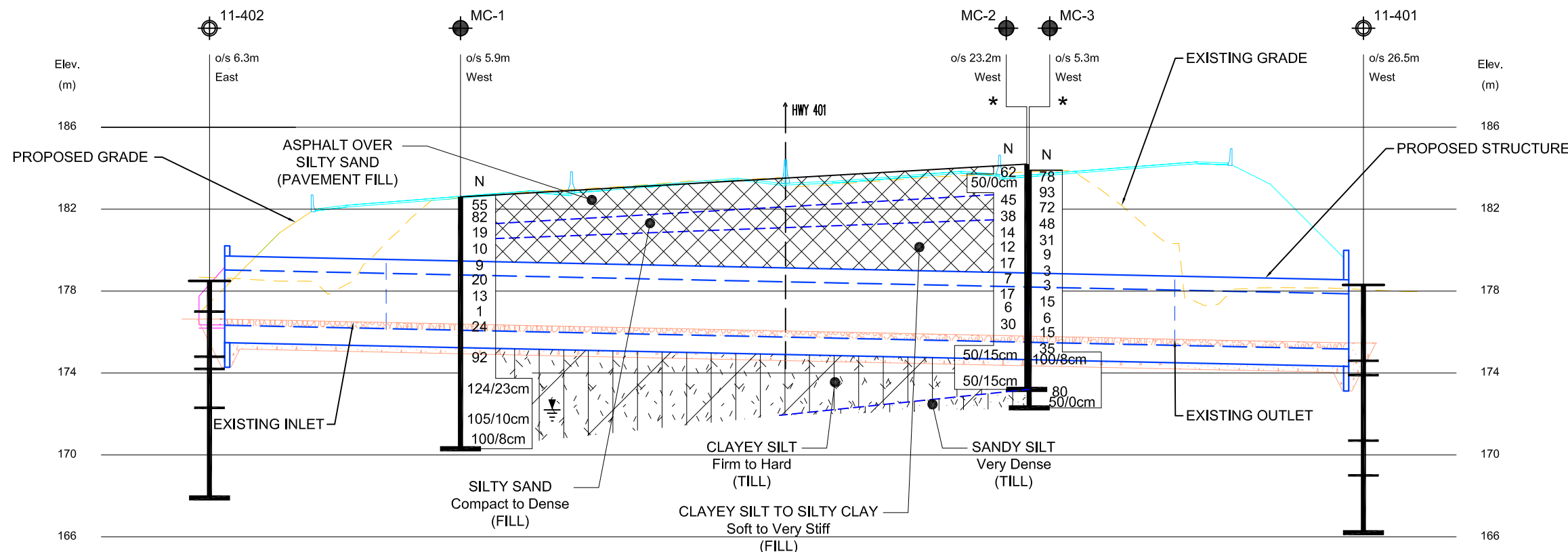
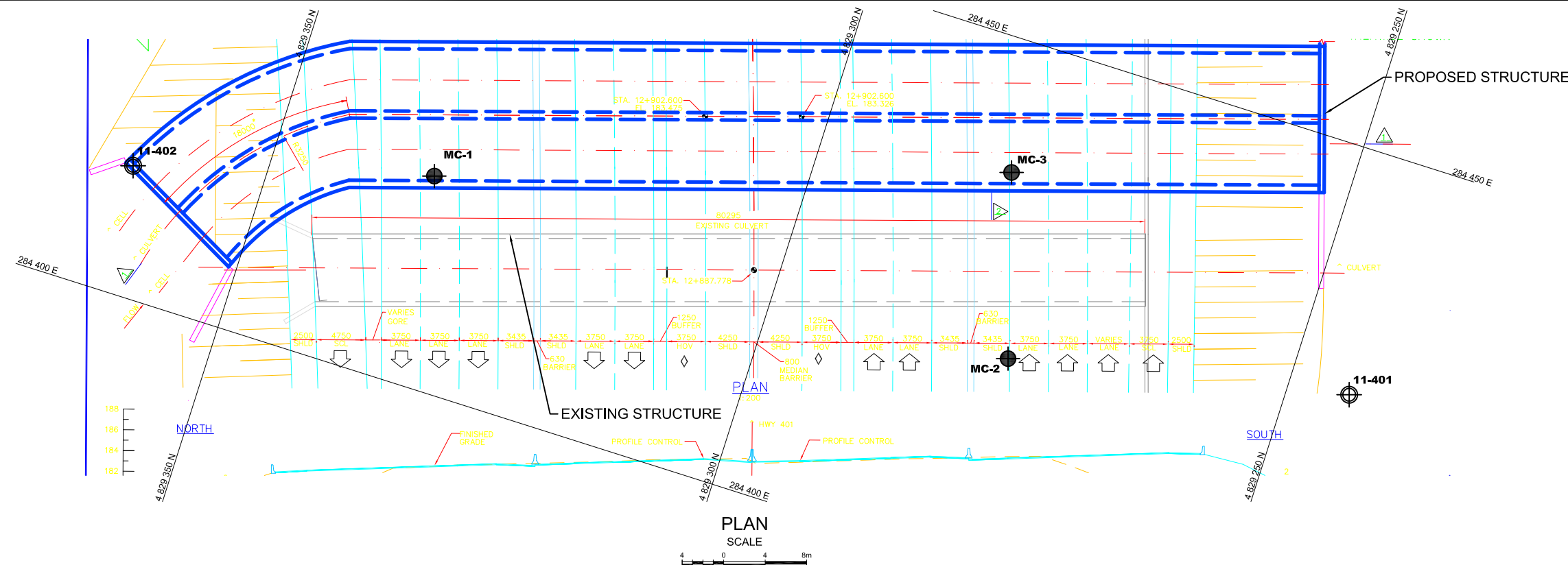
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

DATE	BY	DESCRIPTION

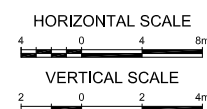
Geocres No. 30M12-420

HWY No	401	CHECKED	KA	DATE	DEC. 17, 2018	DIST	Central
SUBMD	NL	CHECKED	DD	APPROVED	RN	SITE	24-253/C
DRAWN	NL	CHECKED	DD	APPROVED	RN	DWG	MC-1

Reference AECOM Drawing: 24-253C - Mullet Creek Culvert GA dated Nov. 2017.

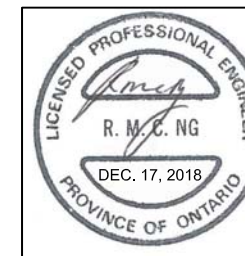


#### PROFILE ALONG Q PROPOSED MULLET CREEK CULVERT



#### NOTES:

- THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
- THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
- DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.





## **SITE V – RETAINING WALL AT NORTH END OF SIXTEEN MILE CREEK (W-C17)**

PRELIMINARY FOUNDATION INVESTIGATION

Borehole Information

A total of five (5) boreholes were advanced along the alignment of Sixteen Mile Creek Culvert at Highway 401 east of Regional Road 25 and west of the CNR, including contingency borehole SME-5, which was investigated on September 5, 2018 at the north end of the proposed culvert alignment.

Refer to

- Structure and borehole location plan, and subsurface stratigraphy (Drawing SME-2).
- Table V-1 for details of borehole location coordinates and borehole elevations/depths.
- Appendices B and C for Record of Borehole sheets and lab results showing details of the subsurface conditions at the borehole locations from previous and current investigation, respectively.

Table V- Borehole Information

Borehole ID	Borehole Location	MTM NAD 83 Coordinates		Ground Surface Elevation (m)	Borehole Depth (m)
		Northing (m)	Easting (m)		
SME-1	North End (Inlet)	4821180.4	272280.5	206.3	18.7
SME-3	North Embankment	4821166.4	272273.7	208.1	12.7
SME-5	Proposed Retaining Wall (North End)	4821182.9	272251.7	209.0	21.6

Subsurface Conditions

Subsurface soil and groundwater conditions encountered in boreholes SME-1, SME-3 and SME-5 have been considered for the proposed retaining wall north of the culvert extension.

The stratigraphy on the roadway conceptually consists of approximately 0.8 m and 1.5 m of roadway pavement then general fill consisting of approximately 1.9 m and 2.3 m of silty sand to clayey silt underlain by approximately 8.6 m to 10.7 m of clayey silt till deposit underlain by approximately 6.1 m to 8.0 m of sandy silt to silty sand over clayey silt till to the termination depth of the boreholes. Refer to the Record of Boreholes sheets for actual subsurface conditions.

The subsurface conditions at this site can be categorized into five (5) general layers as presented below from surface downwards.

• Topsoil

A 200 mm thick topsoil layer was encountered at the existing ground surface in borehole SME-1, drilled on the north end of the proposed culvert alignment.

• Pavement Fill

Approximately 0.8 m and 1.5 m thick pavement fill was encountered at the drilled boreholes SME-3 and SME-5 at the north end of the proposed culvert alignment. The pavement structure consists of an approximately 100 mm and 50 mm thick layer of asphalt over silty sand with to some gravel fill, which extends to a depth of 0.8 m and 1.5 m below the existing ground surface, corresponding to Elevations 207.3 m and 207.5 m, respectively. The SPT ‘N’ values of this layer were 15, 16 and 41 blows per 0.3 m penetration. Moisture contents of samples were between 5.3% and 12.0%.

• General Fill

The composition of the General Fill varied across the site from Silty Sand to Clayey Silt.

▪ Silty Sand Fill

Approximately 1.4 m thick compact to dense silty sand fill layer was encountered immediately below the pavement fill in borehole SME-3, extending to 2.2 m, Elevation 205.9 m, below existing ground surface. The SPT ‘N’ values of this layer ranged from 17 blows to 43 blows per 0.3 m penetration. Moisture contents of samples ranged from 5.9% to 6.0%.

▪ Clayey Silt Fill

Approximately 1.9 m and 0.9 m thick soft to very stiff clayey silt fill layer was encountered below the topsoil and silty sand fill layer in boreholes SME-1 and SME-3, extending to depths 2.1 m and 3.1 m (Elevations 204.2 m and 205.0 m), respectively. The SPT ‘N’ values of this layer varied from 3 blows to 22 blows per 0.3 m penetration. Moisture contents ranged from 11.5%to 12.4%.

• Clayey Silt (Till)

Approximately 8.6 m to 10.7 m thick stiff to hard clayey silt deposit (till) was encountered immediately below the clayey silt and silty sand fills at 1.5 m to 3.1 m below the existing ground surface ( Elevations 204.2 m to 207.5 m), extending to Elevations 195.6 m to 196.8 m in boreholes SME-1, SME-3 and SME-5. The SPT ‘N’ values ranged from 12 blows to 113 blows per 0.30 m penetration. A lower deposit of about 3.3 m thick hard clayey silt till deposit was encountered in borehole SME-5 below the silty sand to sandy silt deposit (discussed below) at 18.3 m below the existing ground surface (Elevation 190.7 m) , which extends to the termination depth 21.6 m, Elevation 187.4 m. The SPT ‘N’ values of this lower clayey silt till deposit varied between 100 blows per 0.23 m penetration and 100 blows per 0.08 m penetration. Moisture contents of the clayey silt (till) samples ranged between 7.1% and 20.3%. The results of grain size distribution test on selected samples from this deposit are provided in Figure GS-V-1 and the Atterberg limits are presented in Figure PC-V-1 in Appendix C-2.

• Sandy Silt to Silty Sand (Till)

Compact to very dense silty sand to sandy silt deposit (till) was encountered immediately below the clayey silt till at depths 10.7 m and 12.4 m below the existing ground surface in boreholes SME-1, SME-3 and SME-5 (Elevations 195.6 m and 196.8 m), extending to Elevations 187.6 m to 195.4 m. Boreholes SME-1 and SME-3 were terminated in this layer. The SPT ‘N’ values recorded in this deposit ranged between 18 blows for 0.3 m penetration and 115 blows for 0.25 m penetration. A low SPT ‘N’ value of 9 was recorded where clayey silt layer was encountered within the cohesionless till deposit. Moisture contents ranged between 9.5% and 30.1%. The grain size distribution results of selected samples from this deposit are provided in Figure GS-V2 and the Atterberg limits are presented in Figure PC-V-1 in Appendix C-2.

Groundwater Conditions

Groundwater was encountered during drilling in boreholes SME-1 and SME-3 at 10.7 m below ground surface, Elevation 195.6 m and Elevation 197.4 m, respectively. Groundwater level was measured at 9.7 m depth below the ground surface (Elevation 198.4 m) upon completion of augering in borehole SME-3 drilled on the shoulder of ramp along Highway 401 westbound.

However, groundwater was not encountered up to an Elevation 204.0 m in the investigated borehole SME-5 during and upon completion of drilling. Below this depth, groundwater reading could not be measured because mud drilling method was used for drilling. Groundwater levels are subject to seasonal fluctuations and precipitation patterns.

PRELIMINARY FOUNDATION DESIGN RECOMMENDATIONS

Introduction

At the time of the investigation, it was proposed to relocate the existing weir north of the present culvert to facilitate the extension of the culvert and widening of Highway 401. However, based on the email received from AECOM on October11, 2018, the weir relocation is no longer required and a retaining wall is proposed in the vicinity of the existing weir.

Proposed Retaining Wall

Details of the proposed retaining walls were not available at the time of preparation of this report. Refer to Section 5.3.1 of the General Report, dated June 7, 2018, pertaining to the general recommendations for retaining wall.

Evaluation of Retaining Wall Alternatives

The evaluation of retaining wall alternatives for preliminary design and planning purposes are based on the subsoil and groundwater conditions encountered, and the suitability of the site conditions.

A comparison of two alternatives considered for retaining wall, in terms of advantages, disadvantages, relative costs and risks/consequences is provided in Table V-4. The options considered are as follows:

- Retained Soil Systems (RSS) Wall
- Cast-in-Place (CIP) Reinforced Concrete Wall.

Retained Soil Systems (RSS) Wall

Considering the availability of space and subsoil conditions, a retained soil system (RSS) wall may be feasible. The RSS wall constructed at this site should be “High Performance” and “High Appearance”. The design of the RSS wall shall be the responsibility of the proprietary RSS supplier and the design should meet the MTO RSS Design Guideline, SP 599S22 and SP 599S23.

The internal stability and sliding resistance of the RSS wall will be assessed by the designer of proprietary product and the structural integrity of the wall will remain the responsibility of the supplier.

The RSS wall may be founded on clayey silt till at approximate Elevation 204.0 m and designed assuming a factored geotechnical resistance of 450 kPa at Ultimate Limit State (ULS) and a factored geotechnical resistance of 300 kPa at Serviceability Limit State (SLS). Considering the subgrade materials below the recommended founding level, global stability problems are not expected.

Per MTO policy, RSS should not be used in submerged conditions.

Cast-in-Place Reinforced Concrete Wall

Alternatively, a cast-in-place (CIP) reinforced concrete wall or gravity retaining wall placed at approximate Elevation 204.0 m may be considered. The glacial till deposit is capable of providing adequate geotechnical resistance to support the retaining wall.

The CIP reinforced concrete wall founded on clayey silt till deposit at Elevation 204.0 m or below may be designed assuming a factored geotechnical resistance of 450 kPa at Ultimate Limit State (ULS) and a geotechnical resistance of 300 kPa at Serviceability Limit State (SLS) for a spread footing.

The foundation for the CIP concrete wall should be protected against frost heave and the depth of frost penetration for the area where the site is located is 1.2 m.

Lateral Earth Pressure

Earth pressure for the concrete structure should be computed in accordance with Clause 6.12.2 (b) of Canadian Highway Bridge Design Code (CHBDC, 2014). The lateral earth and water pressure, P (kPa), may be computed using the equivalent fluid pressures presented in Section 6.12 of the CHBDC 2014 or employing the following equation assuming a triangular pressure distribution.

P = K (γh<sub>1</sub> + γ'h<sub>2</sub> + q) + γ<sub>w</sub>h<sub>2</sub> + C<sub>p</sub> + C<sub>s</sub>

Where, P = lateral earth pressure (kPa)

K = lateral earth pressure coefficient

γ = unit weight of backfill material above assumed water level (kN/m<sup>3</sup>)

γ' = unit weight of submerged backfill (γ - γ<sub>w</sub>) material below assumed water level (kN/m<sup>3</sup>)

γ<sub>w</sub> = unit weight of water (9.8 kN/m<sup>3</sup>)

h<sub>1</sub> = depth below final grade (m), above assumed water level

h<sub>2</sub> = depth below assumed water level (m)

q = surcharge load (kPa)

C<sub>p</sub> = compaction pressure (refer to clause 6.12.3 of CHBDC 2014)

C<sub>s</sub> = earth pressure induced by seismic events, kPa (refer to clause 4.6.5 of CHBDC 2014)

Where Ø = angle of internal friction of retained soil

δ = angle of friction between soil and wall

Granular ‘A’ or ‘B’ should be utilized as backfill material and should be carried out in accordance with the requirements specified in the OPSS 902 amended by SP 109S12 and NSSP FOUN0003. The following parameters are recommended for the granular backfill provided in Table V-2 below.

Table V -2 Earth Pressure Coefficients		
GEOTECHNICAL PARAMETER	OPSS Granular ‘A’ or ‘B’ Type II	OPSS Granular ‘B’ Type I
Internal Friction Angle, (degrees)	35	30
Unit weight, γ (kN/m <sup>3</sup> )	22.5± 0.3	21.5 ± 0.3
Coefficient of Active Earth Pressure, K <sub>a</sub>	0.27	0.33
Coefficient of Earth Pressure at Rest, K <sub>o</sub>	0.43	0.5
Coefficient of Passive Earth Pressure, K <sub>p</sub>	3.69	3

The coefficient of earth pressure “at rest” should be used for design of rigid and unyielding walls where sufficient movement of the structure wall is not permitted. For unrestrained structures, the active earth pressure coefficient should be employed.

A weeping tile system (OPSS 405 and OPSD 3190.100) and/or weep holes should be installed to minimize the build-up of hydrostatic pressure behind the wall. The weeping tiles should be surrounded by a properly designed granular filter or geotextile to prevent migration of fines into the system. The drainage pipe should be installed on a positive grade.

Backfilling behind the retaining structures should be carried out in conformance with OPSS 902 as amended by SP 109S12 and NSSP FOUN0003. The minimum requirement of granular backfill material behind the retaining walls should be in accordance with OPSD 3121.150. The granular material should be in accordance with OPSS.PROV 1010.

For RSS walls, the drainage behind the RSS walls should be designed by the RSS supplier.

Construction Considerations

• Excavation

For CIP walls, the depth of excavation for founding subgrade may be about 2.3 m to 5.0 m below the existing ground surface. Therefore, a properly designed shoring system may need to be employed.

According to OHSA criteria, the existing fill layers can be classified as Type 3 soil and the till layer can be considered as Type 2 soil. Open cut excavations are governed by soils with the highest soil type number. A temporary cut slope of 1H: 1V should be provided assuming adequate drainage measures are in place. Temporary shoring systems may be required if such slopes cannot be provided.

The earth fill slopes and other exposed earth surfaces should be protected against surface erosion by sodding and suitable vegetation. Refer to OPSS 803 and OPSS.PROV 804 for time constraints and the type of seed and mulch required.

All work should be carried out in accordance with the Occupational Health and Safety Act (Ontario Regulation 213/91) and with local/MTO regulations.

• Temporary Protection System

The Contractor is responsible for the selection, design, construction, and performance of the shoring system. Shoring should be designed to meet the appropriate Performance Level 2 as specified in OPSS 539 and SP105S09, Construction Specification for Temporary Protection Systems. Parameters and recommendations for design of shoring should be determined during the detail design phase of the project. It is anticipated that the geotechnical parameters will be approximately those provided in Table V-3.

Table V-3 Preliminary Geotechnical Design Parameters

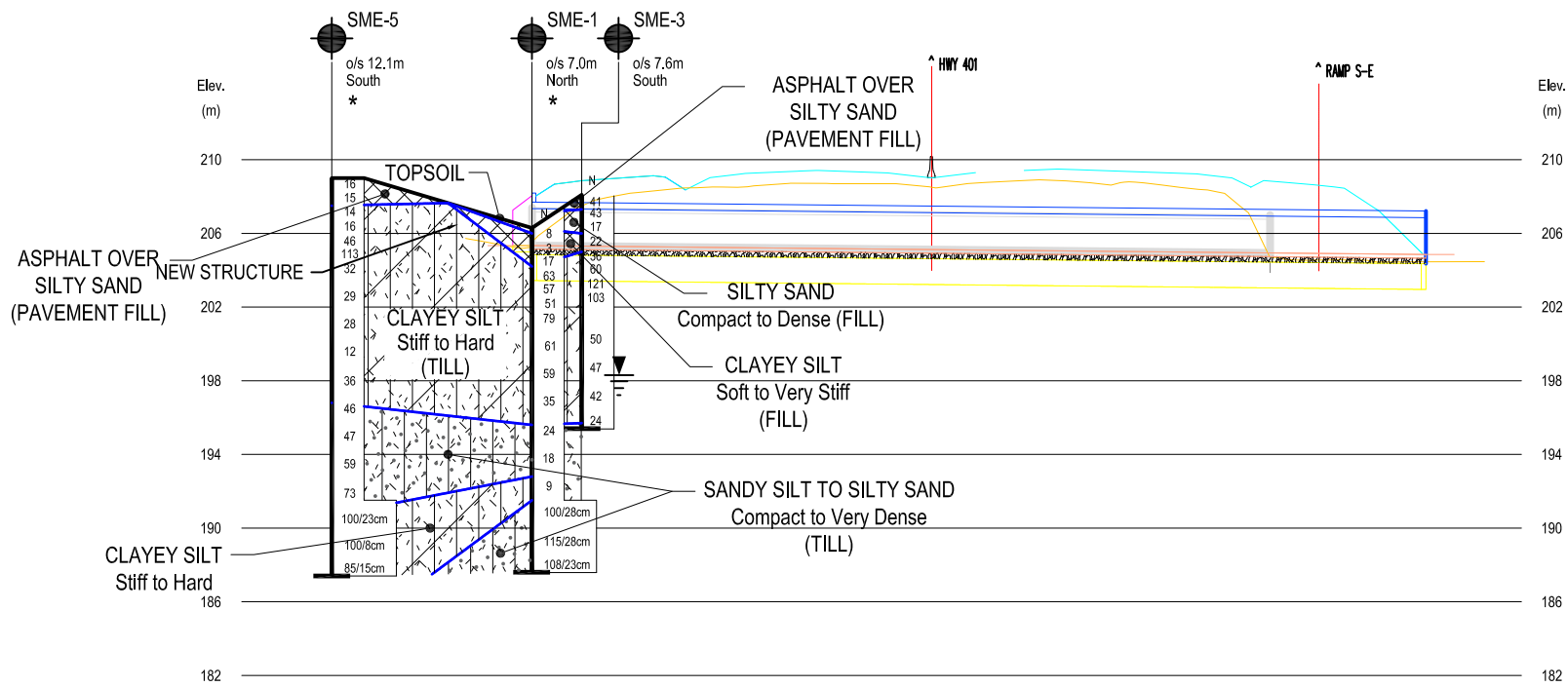
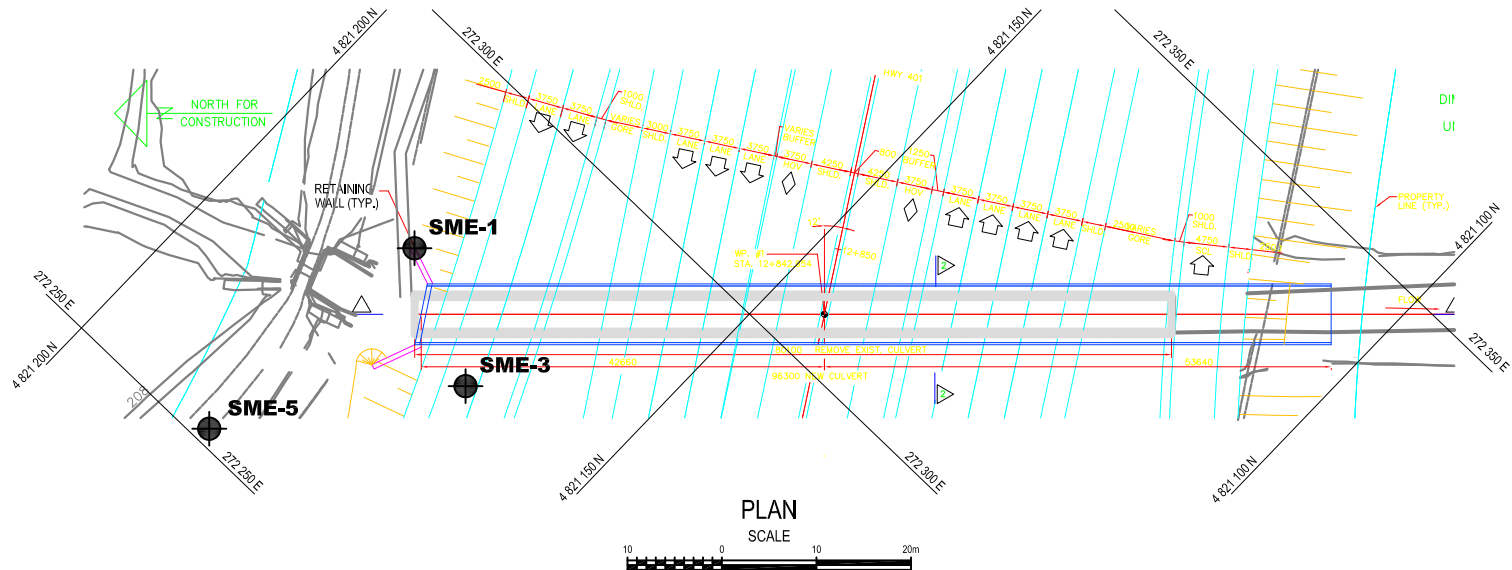
Soil Type	Unit Weight, (kN/m <sup>3</sup> )	Design Parameters	
		Effective Friction Angle, (Ø°)	Undrained Shear Strength, Su (kPa)
Silty Sand (Fill)	19	30	-
Clayey Silt (Fill)	18	22	50
Clayey Silt (Till)	20	25	150

• Groundwater Control

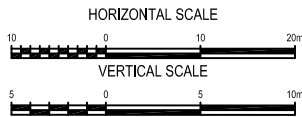
No major dewatering problems are anticipated based on groundwater observations for the anticipated depths of excavation for construction of the proposed retaining wall. However, it is considered that seepage from soil fissures or surface run-off that enters the excavations may be handled by conventional sump pumping techniques. The groundwater level should be lowered to a minimum of 0.5 m below the base of excavation. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

Table V-4 – Comparison of Retaining Wall Alternatives

ALTERNATIVE	ADVANTAGES	DISADVANTAGES	RISKS / CONSEQUENCES	RELATIVE COST
Retained Soil Systems (RSS) Wall	<ul style="list-style-type: none"><li>• Fast and efficient design and construction</li><li>• Require less depth of excavation for frost protection of footings</li></ul>	<ul style="list-style-type: none"><li>• Shorter service life than CIP Reinforced Concrete walls</li><li>• Susceptible to mobilize large deformation than expected</li><li>• Not accepted for MTO projects in submerged conditions.</li></ul>	Requires contracting protocol to specify particular design	Less expensive than cast-in-place reinforced concrete walls on spread footings
Cast-in-Place Reinforced Concrete Wall on Spread Footings	<ul style="list-style-type: none"><li>• Longer service life than RSS walls</li><li>• Superior appearance</li></ul>	<ul style="list-style-type: none"><li>• Requires site specific design</li><li>• Requires deeper excavations to construct footings</li></ul>	Requires deeper excavation for foundations	More expensive than RSS wall



PROFILE ALONG Q SIXTEEN MILE CREEK CULVERT



NOTES:

- THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
- THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
- DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.

LEGEND

- Borehole (Current Investigation)
- N Blows/0.3m (Std. Pen Test, 475 J/blow)
- WL at Time of Investigation Nov. 2017 - Mar. 2018
- \* Water level could not be established
- Head
- ARTESIAN WATER Encountered
- Piezometer

BH No	ELEVATION	NORTHINGS	EASTINGS
SME-1	206.3	4 821 180.4	272 280.5
SME-3	208.1	4 821 166.4	272 273.7
SME-5	209.0	4 821 182.9	272 251.7

NOTE

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



REVISIONS	DATE	BY	DESCRIPTION

Geocres No. 30M12-420

HWY No	401	DIST	Central
SUBM'D	NL	CHECKED	NR
DATE	DEC. 17, 2018	APPROVED	RN
DRAWN	NL	CHECKED	DD
SITE	10-368C	DWG	SME-2

Reference AECOM Drawing: 10-0368\_East of RR25 Culvert GA.dwg, dated Aug.2018.

## **SITE W – NON-STRUCTURAL CULVERT (W-C18)**

PRELIMINARY FOUNDATION INVESTIGATION

Borehole Information

A total of two (2) contingency boreholes were advanced along the alignment of proposed Culvert WC-18 at Highway 401 west of Regional Road 25.

Refer to

- Structure and borehole location plan, and subsurface stratigraphy (Drawing WC18-1)
- Table W-1 for details of borehole location coordinates and borehole elevations/depths
- Appendices B and C for Record of Borehole sheets and lab results showing details of the subsurface conditions at the borehole locations from the current investigation.

Table W-1 Culvert WC-18 Borehole Information

Borehole ID	Borehole Location	MTM NAD 83 Coordinates		Ground Surface Elevation (m)	Borehole Depth (m)
		Northing (m)	Easting (m)		
C18-1	North End (Inlet)	4820869.6	271790.1	207.7	17.4
C18-2	South End (Outlet)	4820817.4	271845.4	207.1	17.4

Subsurface Conditions

The stratigraphy conceptually consists of an approximately 0.6 m thick roadway pavement and related fill over an approximately 1.2 m to 1.7 m thick clayey silt fill underlain by an approximately 15.3 m to 15.6 m thick clayey silt till deposit, which is underlain by a silt deposit. Refer to the Record of Boreholes for actual conditions at the borehole locations.

The subsurface conditions at this site can be categorized into five (5) general layers, presented below from surface downwards.

• Topsoil

A topsoil layer of 100 m thickness was encountered at the existing ground surface in borehole C18-2, drilled on the south end of the proposed culvert alignment.

• Pavement Fill

Roadway pavement and related fill was encountered in borehole C18-1, drilled on the right shoulder of Highway 401 westbound. The pavement fill layer consisted of an approximately 125 mm thick layer of asphalt over silty sand with gravel fill extending to 0.6 m below ground surface (Elevation 207.1 m). The SPT ‘N’ value of this layer was 13 blows per 0.3 m penetration. Moisture content of a typical sample was 3.4 %.

• Clayey Silt Fill

An approximately 1.2 m and 1.7 m thick firm to stiff clayey silt fill layer was encountered below the Topsoil in BH 18-2 and the Pavement Fill in BH 18-1, extending 1.8 m below the existing ground surface (Elevation 205.9 m in BH 18-1 and Elevation 205.3 m in BH 18-2). The SPT ‘N’ values of this layer varied from 5 blows to 9 blows per 0.3 m penetration. Moisture contents of samples ranged from 9.5% to 41.6%.

• Clayey Silt (Till)

An approximately 15.3 m to 15.6 m thick stiff to hard clayey silt (till) deposit was encountered immediately below the clayey silt fill in both boreholes, extending to at least a depth of 17.4 m (Elevation 190.3 m) and to a depth of 17.1 m (Elevation 190.0 m) below ground surface in BH’s 18-1 and 18-2, respectively. The SPT ‘N’ values of the

clayey silt till layer ranged from 8 blows to 72 blows for 0.3 m penetration. A 0.6 m thick clayey sand interlayer was encountered at a depth of 5.3 m (Elevation 201.8 m) in borehole C18-2. Moisture contents of the samples ranged between 11.2% and 22.4%. The results of grain size distribution test on selected samples are provided in Figure GS-W-1 and the Atterberg limits are presented in Figure PC-W-1 in Appendix C-2. The result of grain size distribution test on clayey sand till sample is provided in Figure GS-W-2 and the Atterberg limits are presented in Figure PC-W-2 in Appendix C-2.

• Silt (Till)

An approximate 0.3 m thick very dense silt (till) deposit was encountered immediately below the clayey silt till in Borehole C18-2 at a depth 17.1 m (Elevation 190.0 m). BH 18-2 was terminated within this deposit. The SPT ‘N’ value of this layer was 66 blows per 0.3 m penetration. Moisture content of a sample was 13.5%. The result of grain size distribution test on a selected sample from this deposit is provided in Figure GS-W-3 in Appendix C-2.

Groundwater Conditions

Groundwater was not encountered during or upon completion of drilling in borehole C18-2. Groundwater was recorded at 11.3 m below the existing ground surface (Elevation 196.4 m) upon completion of drilling in borehole C18-1. Groundwater levels are subject to seasonal fluctuations and precipitation patterns.



PRELIMINARY FOUNDATION DESIGN RECOMMENDATIONS

Introduction

The existing non-structural culvert located approximately at Sta. 12+280 is proposed to be replaced and extended with a culvert along the existing alignment to accommodate the Highway 401 widening in both eastbound and westbound directions.

The following document is referenced:

- Preliminary Design Report, Highway 401 Improvements from Trafalgar Road to Regional Road 25, in the Regional Municipality of Halton, Town of Milton and Town of Halton Hills, W.O. 07-20024, Volume I, URS, September 2013.

Existing Structure

Based on the above-referenced document, the existing culvert is a non-structural Corrugated Steel Pipe (CSP) culvert with diameter of 800 mm and slope of 0.45%. The length of the culvert is about 68.4 m. The upstream and downstream invert levels of the existing culvert are approximately at Elevations 205.8 m and 205.5 m, respectively.

Proposed Structure

It is proposed to replace the existing CSP culvert with a new non-structural culvert. The length of the proposed culvert is anticipated to be 102.6 m. The upstream and downstream invert levels of the proposed culvert will be approximately at Elevations 206.0 m and 205.5 m, respectively. It is assumed that the span of the proposed culvert will be less than 3.0 m.

New embankment fills will be placed over the widened portion of the replacement culvert to facilitate the widening of the existing Highway 401 WBL and EBL. The grade of Highway 401 is expected to be maintained at the existing elevation.

Evaluation of Foundation Alternatives

The evaluation of foundation alternatives for preliminary design and planning purposes has been based on the subsoil conditions and the environmental considerations. A comparison of various alternatives considered in terms of advantages and disadvantages is provided in Table W-4.

The following options have been considered for culvert replacement to match the vertical and horizontal alignments of the existing culvert:

- Open footing concrete culvert
- Precast concrete box culvert

Option 1: Open Footing Culvert on Strip Footing

An open footing culvert founded on strip footings is feasible at this site. The strip footings may be founded on clayey silt till at or below a plane defined by Elevation 205.5 m at the inlet and by Elevation 205.0 m at the outlet.

Temporary roadway protection may be required to facilitate construction where temporary slopes can not be maintained at stable slope geometry.

For preliminary design purposes, a factored geotechnical resistance at ULS of 300 kPa and a factored geotechnical resistance of 200 kPa at SLS may be used for a strip footing with a minimum width of 0.5 m. The total settlement is expected to be less than 25 mm.

Option 2: CIP or Precast Concrete Box Culvert

A box culvert may be founded at or below the Box Culvert Foundation Elevations provided in Table W-2. The fill material below these elevations should be removed and replaced with compacted backfill meeting the requirements of OPSS 422.07.06. Bedding for the concrete box culvert should be in accordance with OPSS 422.07.08, and may consist of 300 mm thick granular material, including the 75 mm leveling course required by OPSS 422.07.07. Bedding should be as specified in OPSS 422.05.13 and should be placed in accordance with OPSS 422.07.07.

Table W-2 Box Culvert Founding Elevations			
Foundation Location	Proposed Culvert Invert Elevation	Box Culvert Foundation Elevation	Founding Stratum
North End (Inlet)	206.0 m	205.5 m	Stiff to hard clayey silt till
South End (Outlet)	205.5 m	205.0 m	

Note 1: The bottom thickness of the precast concrete box culvert is assumed to be 0.25 m.

For preliminary design purposes, a factored geotechnical resistance at ULS of 300 kPa and a factored geotechnical resistance at SLS of 200 kPa may be utilized. The total settlement is expected to be less than 25 mm.

Recommended Option for Replacement Culvert

Both options are feasible. The box culvert provides less complex construction requirements. The open footings culvert may present fewer complex requirements to re-establish a natural stream bed.

Approach Embankments

The profile grade of the approach at the location of new culvert on the widening of Highway 401 was not known at the time of the preparation of this report. Assuming the elevation of the widened Highway 401 embankments match the existing Highway 401 embankment, no slope stability problems are anticipated for permanent embankments constructed with a minimum slope of 2H: 1V or flatter. Any compressible material under the plan limits of the immediate approaches to the proposed culvert new embankments should be identified and replaced with compacted suitable fill. New embankments should be benched into the existing embankment according to the requirement of OPSD 208.010. It is anticipated that the settlement of approach embankments will be less than 50 mm and probably in the order of 25 mm.

Construction Considerations

• Excavation

Based on the record of boreholes, the excavations for the culvert replacement will be advanced through existing fill material underlain by native till deposits. For OHSA classification purposes, the fill materials should be classified as Type 3 soils and clayey silt till should be classified as Type 2 soils. For excavations through multiple soil types, the side slope geometry is governed by the soil with the highest number designation.

All work should be carried out in accordance with the Occupational Health and Safety Act (Ontario Regulation 213/91) and with local/MTO regulations.

• Culvert Bedding, Backfill and Erosion Protection

Cut-offs are required at the culvert inlet. Consideration could be given to structural vertical cut-offs or horizontal apron cut-offs. Vertical cut-offs should be in accordance with OPSD 812.010. Alternatively, a horizontal apron consisting of a clay seal blanket may be implemented extending from the design high water level, upstream for a distance in the order of three times the culvert height and along the adjacent side slopes for a horizontal distance equal to two times the culvert height.

An appropriate filter should be provided at the outlet. The filter could be appropriately sized free-draining granular material and extend from the design high water level, downstream for a distance equal to three times the culvert height and along the adjacent side slopes for a horizontal distance equal to two times the culvert height.

Rock protection may be provided at the inlet and outlet, in accordance with OPSS 511 and OPSS 1004, to protect the inlet seal and outlet filter materials, respectively. The dimensions of rock protection particles should be determined during the detail design phase in consideration of the flow velocity. The thickness of the rock protection should be a minimum of twice the maximum rock particle dimension.

Ontario Provincial Standard Specifications (OPSS 1010) Granular ‘A’ or ‘B Type II’ should be used as backfill material behind the wall and compacted in accordance with the requirements specified in the OPSS 902 (Excavation and Backfilling of Structures) as amended by SP 109S12 and NSSP FOUN0003. The backfill material should be placed in layers not exceeding 200 mm in thickness before compaction.

• Cover and Backfill

Backfill materials should meet the requirements of Group I, or Group II specified in OPSS 422.05.14, and placed according to the procedures described in Section 422.07.11. It should be placed in layers not exceeding 200 mm in thickness before compaction and compacted in accordance with OPSS 501. Backfill on each side of the culvert should be completed simultaneously so that at no time, the levels on each side of the culvert vary by more than 400 mm.

Restrictions on compaction near the culvert should be as specified in OPSS 902.07.06.02. Heavy vibratory compaction equipment adjacent to retaining structures should be restricted to limit the compaction pressure described in Clause 6.12.3 of the CHBDC, 2014. The type of compaction equipment and the compaction procedure that can be used for this purpose should be in accordance with OPSS 501 (Construction Specification for Compacting).

The cover material should meet the requirements of OPSS 422.05.14 and placed in accordance with OPSS 422.07.12.

• Roadway Protection and Shoring

The roadway should be protected by a properly designed protection system when space limitation exists. The protection system for excavations should be in accordance with OPSS 539 as amended by SP105S09, Construction Specification for Temporary Protection Systems, OPSS 902 as amended by SP 109S12 and NSSP FOUN00003, Construction Specifications for Excavating and Backfilling–Structures. Excavated material should not be stockpiled in the areas immediately adjacent to the top of the excavation slopes.

The Contractor is responsible for the selection, design, construction, and performance of the temporary protection systems. The protection systems should be designed to meet the Performance Level 2 as specified in OPSS 539 as amended by SP 105S09, Construction Specification for Temporary Protection Systems.

Geotechnical parameters provided in Table W-3 may be used for the preliminary evaluation of temporary protection system.

Table W-3 Preliminary Geotechnical Design Parameters

Soil Type	Approximate Unit Weight, (kN/m <sup>3</sup> )	Design Parameters	
		Effective Friction Angle, (Ø’)	Undrained Shear Strength, Su (kPa)
Clayey Silt (Fill)	18	22	30
Clayey Silt (Till)	20	25	150
Silt (Till)	20	34	-

• Groundwater and Surface Water Control

Surface water should be diverted away from open excavations and all excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA) and MTO Regulations for Construction Projects. The surface water flow should be directed away from the excavation areas to mitigate disturbance and weakening of the clayey silt till subgrade. Furthermore, depending on the surface water flow at the time of the construction, the water flow could be passed through the construction area by means of a temporary pipe or diverted by pumping from behind a temporary cofferdam.

Groundwater levels should be maintained a minimum of 0.5 m below the bases of excavations for construction in-the-dry.

The contractor should be responsible for the selection, performance and detailed design of the dewatering system including the cofferdam. The dewatering system should be designed to conform to the requirement of OPSS 517 as amended 517F01.

Table W-4 - Comparison of Culvert Options

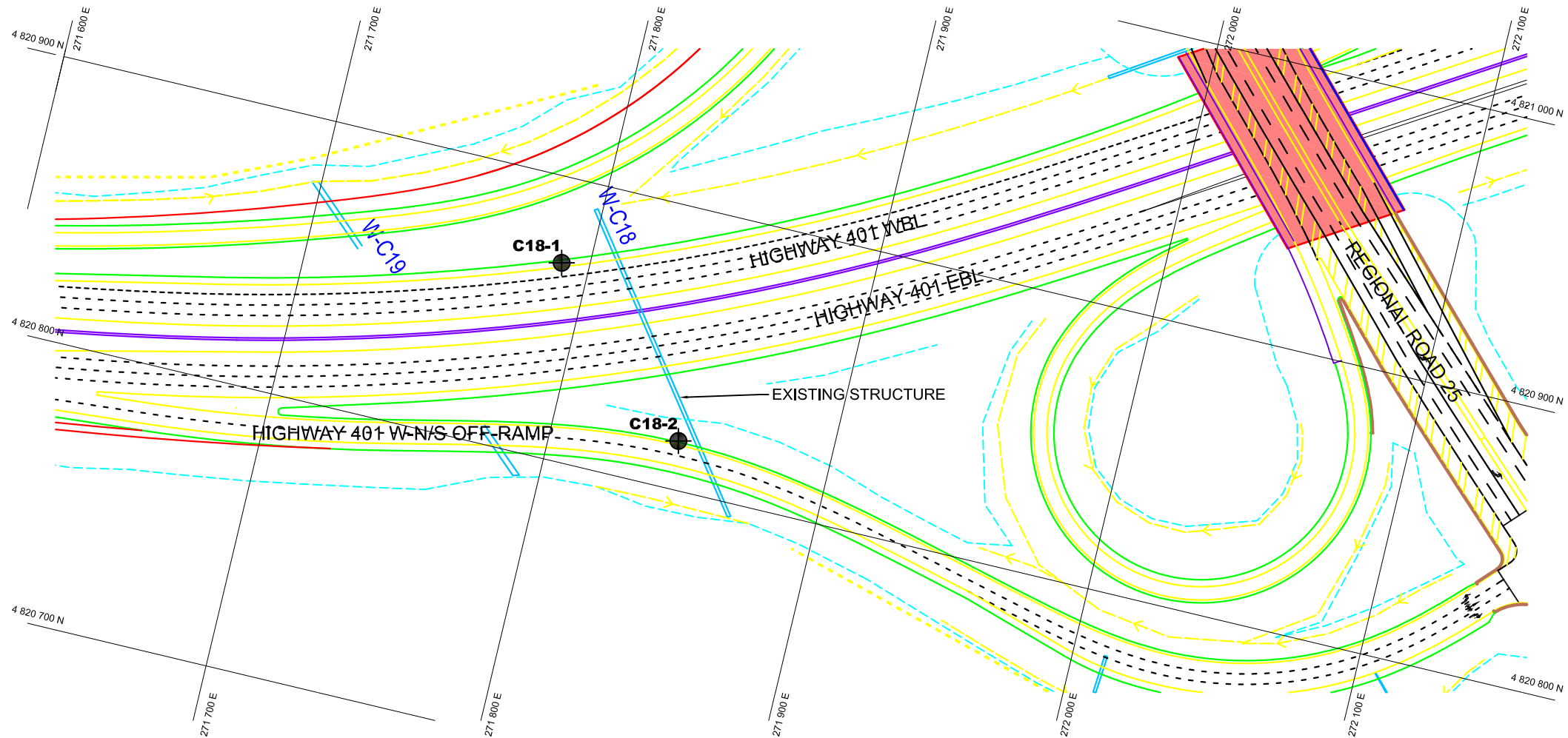
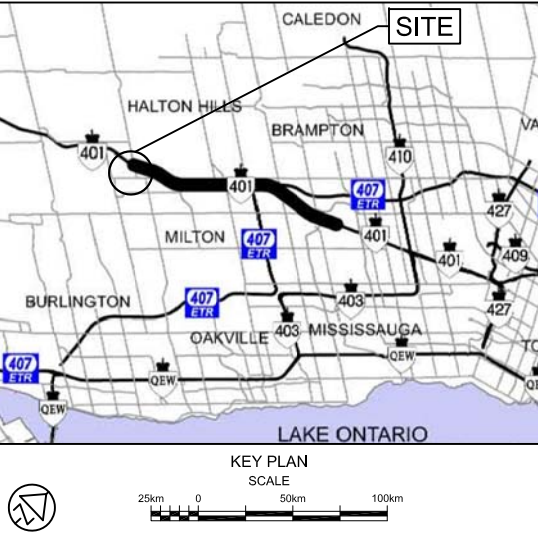
Option 1: Open Footing Concrete Culvert	Option 2: Precast Concrete Box Culvert
Advantages: <ul style="list-style-type: none"><li>Generally, allows for natural streambed to remain intact</li><li>Adequate geotechnical resistance available at founding level</li></ul>	Advantages: <ul style="list-style-type: none"><li>Ease and speed of construction</li><li>Installation in wet conditions is possible</li><li>The joints provide flexibility to accommodate more differential settlements than open footings</li></ul>
Disadvantages: <ul style="list-style-type: none"><li>Limited tolerance to differential settlements</li></ul>	Disadvantages: <ul style="list-style-type: none"><li>Provision may be required to re-establish natural stream bed</li></ul>
Feasibility: Technically feasible	Feasibility: Technically feasible, but may not be feasible at this environmentally sensitive site

Asgmt. No 2016-E-0004

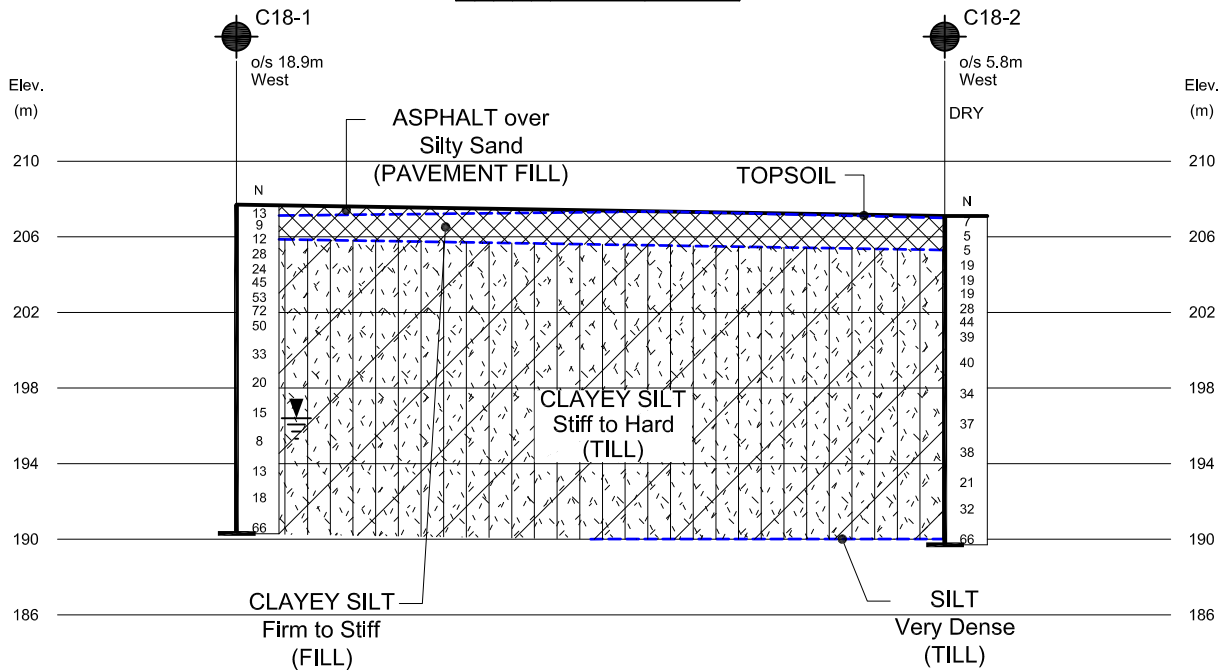
NON-STRUCTURAL CULVERT W-C18  
HIGHWAY 401  
CITY OF MISSISSAUGA  
BOREHOLE LOCATIONS AND SOIL STRATA



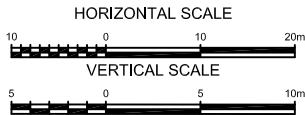
SHEET



PLAN  
SCALE  
0 25 50m



PROFILE ALONG C EXISTING CULVERT



NOTES:

- THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
- THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
- DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.

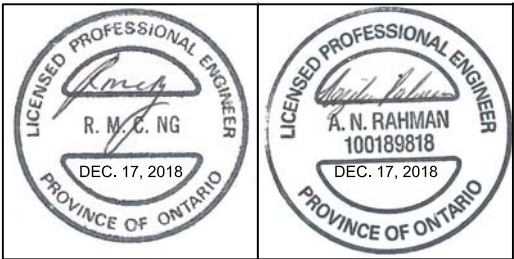
LEGEND

- Borehole (Current Investigation)
- Blows/0.3m (Std. Pen Test, 475 J/blow)
- WL at Time of Investigation September 2018

BH No	ELEVATION	NORTHINGS	EASTINGS
C18-1	207.7	4 820 869.6	271 790.1
C18-2	207.1	4 820 817.4	271 845.4

NOTE

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



Reference AECOM Drawing: X-Design\_Traf to RR25.dwg.

REVISIONS	DATE	BY	DESCRIPTION

Geocres No. 30M12-420

HWY No	401	DIST	Central
SUBM'D	NL	CHECKED	KA
DATE	DEC. 17, 2018	SITE	
DRAWN	NL	CHECKED	DD
APPROVED	RN	DWG	WC18-1

## **SITE X – NON-STRUCTURAL CULVERT (W-C19)**

PRELIMINARY FOUNDATION INVESTIGATION

Borehole Information

A total of two (2) contingency boreholes were advanced along the alignment of proposed Culvert WC-19 at Highway 401 west of Regional Road 25.

Refer to

- Structure and borehole location plan, and subsurface stratigraphy (Drawing WC19-1)
- Table X-1 for details of borehole location coordinates and borehole elevations/depths
- Appendices B and C for Record of Borehole sheets and lab results showing details of the subsurface conditions at the borehole locations from current investigation.

Table X-1 Culvert WC-19 Borehole Information

Borehole ID	Borehole Location	MTM NAD 83 Coordinates		Ground Surface Elevation (m)	Borehole Depth (m)
		Northing (m)	Easting (m)		
C19-1	North End (Inlet)	4820842.2	271655.2	207.4	17.2
C19-2	South End (Outlet)	4820773.5	271689.4	207.2	17.4

Subsurface Conditions

The stratigraphy conceptually consists of an approximately 0.1 m to 0.2 m thick topsoil underlain by approximately 0.9 m to 1.0 m thick clayey silt fill underlain by an approximately 12.7 m to 16.3 m clayey silt till deposit. Borehole C19-2 was terminated in the clayey silt till deposit. In borehole C19-1, the clayey silt till layer was underlain by an approximately 3.4 m thick silt deposit to the termination depth. Refer to the Record of Boreholes for actual conditions.

The subsurface conditions at this site can be categorized into four (4) general layers as presented below from surface downwards.

• Topsoil

A topsoil layer of 100 mm and 200 mm thickness was encountered at the existing ground surface in the boreholes, which were drilled on the north and south ends of the proposed culvert alignment.

• Clayey Silt Fill

An approximately 0.9 m and 1.0 m thick firm to very stiff clayey silt fill layer was encountered below the topsoil layer in both boreholes, extending to Elevations 206.3 m and 206.1 m in BH’s 19-1 and 19-2, respectively. The SPT ‘N’ values of this layer varied between 7 blows and 26 blows per 0.3 m penetration. Moisture contents ranged from 9.2% to 13.6%.

• Clayey Silt (Till)

An approximately 12.7 m and 16.3 m thick stiff to hard clayey silt (till) deposit was encountered immediately below the clayey silt fill layer in the BH’s 19-1 and 19-2, respectively, extending to Elevation 193.6 m in BH 19-1 and to Elevation 189.8 m in BH-2. In BH C19-2, a 1.3 m thick interlayer of silt was encountered within this deposit at a depth of 13.7 m, (Elevation 193.5 m) and extending to a depth of 15.0 m (Elevation 192.2 m). A localized firm zone was encountered in borehole C19-1 at a depth of 6.1 m (Elevation 201.3) and extending to a depth of 6.7 m (Elevation 200.7 m). The SPT ‘N’ values of this layer ranged from 5 blows to 62 blows per 0.30 m penetration. Moisture contents of the samples ranged between 10.9% and 29.4%. The results of grain size distribution test on selected

samples from this deposit are provided in Figure GS-X-1 and the Atterberg limits are presented in Figure PC-X-1 in Appendix C-2. BH 19-2 terminated within this deposit.

• Silt (Till)

An approximately 3.4 m thick compact to very dense silt (till) deposit was encountered in borehole C19-1 immediately below the clayey silt till layer at a depth of 13.8 m (Elevation 193.6 m) and extending to the termination depth of 17.2 m (Elevation 190.2 m). The SPT ‘N’ values of this layer ranged from 12 blows to 104 blows per 0.30 m penetration. Moisture contents of the samples ranged between 8.5% and 25.5%. The results of grain size distribution test on selected samples from this deposit are provided in Figure GS-X-2 in Appendix C-2.

Groundwater Conditions

Groundwater was not encountered during drilling at to depths of 3.1 m and 3.7 m (Elevations 204.3 m to 203.5 m) in BH’s 19-1 and 19-2, respectively. Below these depths, groundwater level could not be established due to the mud drilling method utilized for drilling. It is inferred that the groundwater level is approximately at Elevation 201.0 m or below based on observations during drilling, the moisture contents and visual examinations of the recovered soils. Groundwater levels are subject to seasonal fluctuations and precipitation patterns.

PRELIMINARY FOUNDATION DESIGN RECOMMENDATIONS

Introduction

A new culvert (WC-19) to replace the existing culvert is proposed to be constructed approximately at Sta. 12+100, about 100 m west of the existing culvert alignment to accommodate the Highway 401 widening in both eastbound and westbound directions.

The following document is referenced:

- Preliminary Design Report, Highway 401 Improvements from Trafalgar Road to Regional Road 25, in the Regional Municipality of Halton, Town of Milton and Town of Halton Hills, W.O. 07-20024, Volume I URS, September, 2013.

Existing Structure

Based on the above referenced document, the existing non-structural concrete box culvert is located at Sta. 12+200. The length of the culvert is about 76.2 m with 1520 mm span and 950 mm rise and sloped at 0.30%. The upstream and downstream invert levels of the existing culvert are approximately at Elevations 206.3 m and 206.1 m, respectively.

Proposed Structure

It is proposed to construct a new culvert approximately 100 m west of the existing culvert. The details of the proposed culvert were not available at the time of the preparation of this report. It is assumed that the span of the proposed culvert will be less than 3.0 m and the invert levels will be similar to the existing culvert.

New embankment fills will be placed over the replaced culvert to facilitate the widening of the existing Highway 401 WBL and EBL. The grade of Highway 401 is expected to be maintained at the existing elevation.

Evaluation of Foundation Alternatives

The evaluation of foundation alternatives for preliminary design and planning purposes has been based on the subsoil conditions and the environmental considerations. A comparison of various alternatives considered in terms of advantages and disadvantages is provided in Table X-4.

The following options have been considered for culvert replacement to match the vertical and horizontal alignments of the existing culvert:

- Open footing concrete culvert
- Precast concrete box culvert

Option 1: Open Footing Culvert on Strip Footing

An open footing culvert founded on strip footings is feasible at this site. The strip footings may be founded on clayey silt till at or below a plane defined by Elevation 206.0 m at the inlet and by Elevation 205.5 m at the outlet. The frost cover requirement is 1.2 m.

Temporary roadway protection may be required to facilitate construction where temporary slopes can not be maintained at stable slope geometry.

For preliminary design purposes, a factored geotechnical resistance at ULS of 225 kPa and factored geotechnical resistance of 150 kPa at SLS may be used for a strip footing with a minimum of 0.5 m wide. The total settlement is expected less than 25 mm for a strip footing.

Option 2: Precast Concrete Box Culvert

A box culvert may be founded at or below the Box Culvert Foundation Elevations provided in Table X-2. The fill material below these elevations should be removed and replaced with compacted backfill meeting the requirements of OPSS 422.07.06. Bedding for the concrete box culvert should be in accordance with OPSS 422.07.08, and may consist of 300 mm thick granular material, including the 75 mm leveling course required by OPSS 422.07.07. Bedding should be as specified in OPSS 422.05.13 and should be placed in accordance with OPSS 422.07.07.

Table X-2 Box Culvert Founding Elevations

Foundation Location	Proposed Culvert Invert Elevation	Box Culvert Founding Elevation	Subgrade Elevation for Granular Bedding	Founding Stratum
North End (Inlet)	206.3 m	206.0 m	205.7 m	Very stiff clayey silt till
South End (Outlet)	206.1 m	205.5 m	205.2 m	

Note 1: The bottom thickness of the precast concrete box culvert is assumed 0.25 m.

For preliminary design purposes, a factored geotechnical resistance at ULS of 225 kPa and a factored geotechnical resistance of 150 kPa at SLS may be utilized. The total settlement is expected less than 25 mm.

Recommended Option for New Culvert Construction

Both options are feasible. The box culvert provides less complex construction requirements.

Approach Embankments

The profile grade of the approach at the location of new culvert on the widening of Highway 401 was not known at the time of the preparation of this report. Assuming the elevation of the widened Highway 401 embankments match the existing Highway 401 embankment, no slope stability problems are anticipated for permanent embankments constructed with a minimum slope of 2H: 1V or flatter. Any compressible material under the plan limits of the immediate approaches to the proposed culvert new embankments should be identified and replaced with compacted suitable fill. New embankments should be benched into the existing embankment according to the requirement of OPSD 208.010. It is anticipated that the settlement of approach embankments will be less than 50 mm and probably in the order of 25 mm.

Construction Considerations

• Excavation

Based on the record of boreholes, the excavations for the culvert replacement will be advanced through existing fill material underlain by native till deposits. For OHSA classification purposes, the fill materials should be classified as Type 3 soils and clayey silt till should be classified as Type 2 soils. For excavations through multiple soil types, the side slope geometry is governed by the soil with the highest number designation.

All work should be carried out in accordance with the Occupational Health and Safety Act (Ontario Regulation 213/91) and with local/MTO regulations.

• Culvert Bedding, Backfill and Erosion Protection

Cut-offs are required at the culvert inlet. Consideration could be given to structural vertical cut-offs or horizontal apron cut-offs. Vertical cut-offs should be in accordance with OPSD 812.010. Alternatively, a horizontal apron consisting of a clay seal blanket may be implemented extending from the design high water level, upstream for a

distance in the order of three times the culvert height and along the adjacent side slopes for a horizontal distance equal to two times the culvert height.

An appropriate filter should be provided at the outlet. The filter could be appropriately sized free-draining granular material and extend from the design high water level, downstream for a distance equal to three times the culvert height and along the adjacent side slopes for a horizontal distance equal to two times the culvert height.

Rock protection may be provided at the inlet and outlet, in accordance with OPSS 511 and OPSS 1004, to protect the inlet seal and outlet filter materials, respectively. The dimensions of rock protection particles should be determined during the detail design phase in consideration of the flow velocity. The thickness of the rock protection should be a minimum of twice the maximum rock particle dimension.

Ontario Provincial Standard Specifications (OPSS 1010) Granular ‘A’ or ‘B Type II’ should be used as backfill material behind the wall and compacted in accordance with the requirements specified in the OPSS 902 (Excavation and Backfilling of Structures) as amended by SP 109S12 and NSSP FOUN0003. The backfill material should be placed in layers not exceeding 200 mm in thickness before compaction.

• **Cover and Backfill**

Backfill materials should meet the requirements of Group I, or Group II specified in OPSS 422.05.14, and placed according to the procedures described in Section 422.07.11. It should be placed in layers not exceeding 200 mm in thickness before compaction and compacted in accordance with OPSS 501. Backfill on each side of the culvert should be completed simultaneously so that at no time, the levels on each side of the culvert vary by more than 400 mm.

Restrictions on compaction near the culvert should be as specified in OPSS 902.07.06.02. Heavy vibratory compaction equipment adjacent to retaining structures should be restricted to limit the compaction pressure described in Clause 6.12.3 of the CHBDC, 2014. The type of compaction equipment and the compaction procedure that can be used for this purpose should be in accordance with OPSS 501 (Construction Specification for Compacting).

The cover material should meet the requirements of OPSS 422.05.14 and placed in accordance with OPSS 422.07.12.

• **Roadway Protection and Shoring**

The roadway should be protected by a properly designed protection system when space limitation exists. The protection system for excavations should be in accordance with OPSS 539 as amended by SP 105S09, Construction Specification for Temporary Protection Systems, and OPSS 902 as amended by SP 109S12 and NSSP FOUN00003, Construction Specifications for Excavating and Backfilling–Structures. Excavated material should not be stockpiled in the areas immediately adjacent to the top of the excavation slopes.

The Contractor is responsible for the selection, design, construction, and performance of the temporary protection systems. The protection systems should be designed to meet the Performance Level 2 as specified in OPSS 539 as amended by SP 105S09 , Construction Specification for Temporary Protection Systems.

Geotechnical parameters provided in Table X-3 may be used for the preliminary evaluation of temporary protection system.

Table X-3 Preliminary Geotechnical Design Parameters

Soil Type	Unit Weight, (kN/m <sup>3</sup> )	Design Parameters	
		Effective Friction Angle, (Ø’)	Undrained Shear Strength, Su (kPa)
Clayey Silt (Fill)	18	22	30
Clayey Silt (Till) – Stiff to Hard	20	25	150
Silt (Till)	20	34	-

• **Groundwater and Surface Water Control**

Surface water should be diverted away from open excavations and all excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA) and MTO Regulations for Construction Projects. The surface water flow should be directed away from the excavation areas to mitigate disturbance and weakening of the clayey silt till subgrade. Furthermore, depending on the surface water flow at the time of the construction, the water flow could be passed through the construction area by means of a temporary pipe or diverted by pumping from behind a temporary cofferdam.

Groundwater levels should be maintained a minimum of 0.5 m below the bases of excavations for construction in-the-dry.

The contractor should be responsible for the selection, performance and detailed design of the dewatering system including the cofferdam. The dewatering system should be designed to conform to the requirement of OPSS 517 as amended 517F01.



Table X-4 - Comparison of Culvert Options

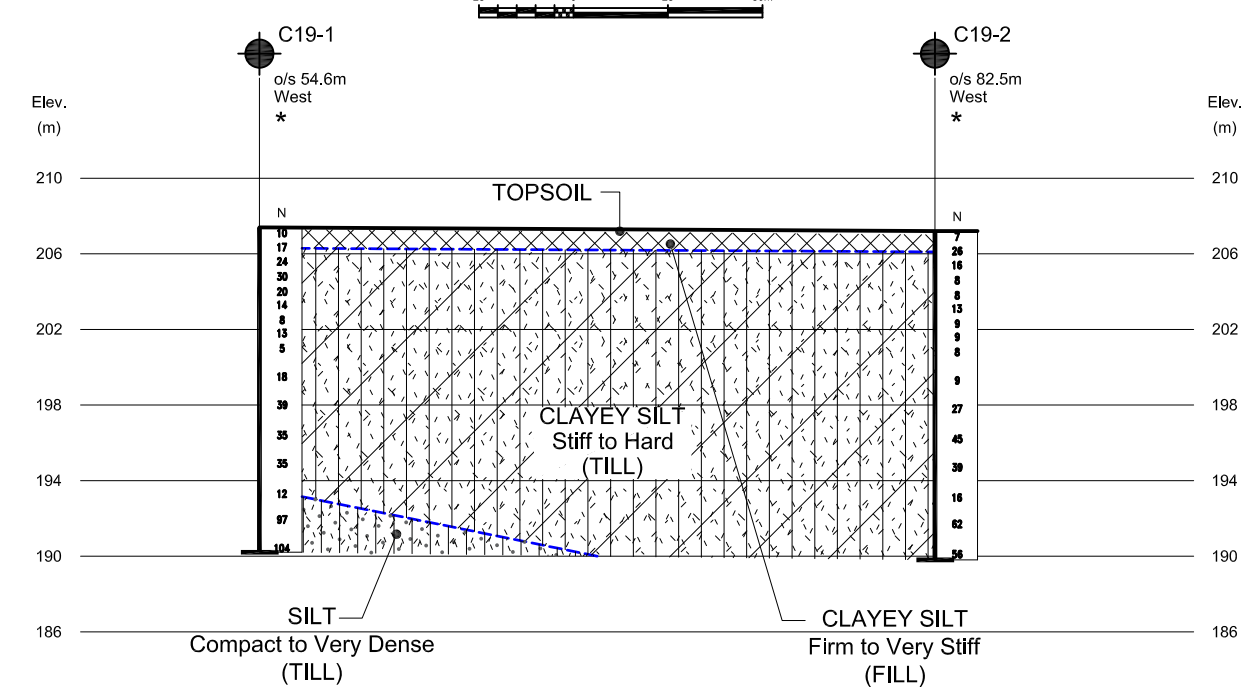
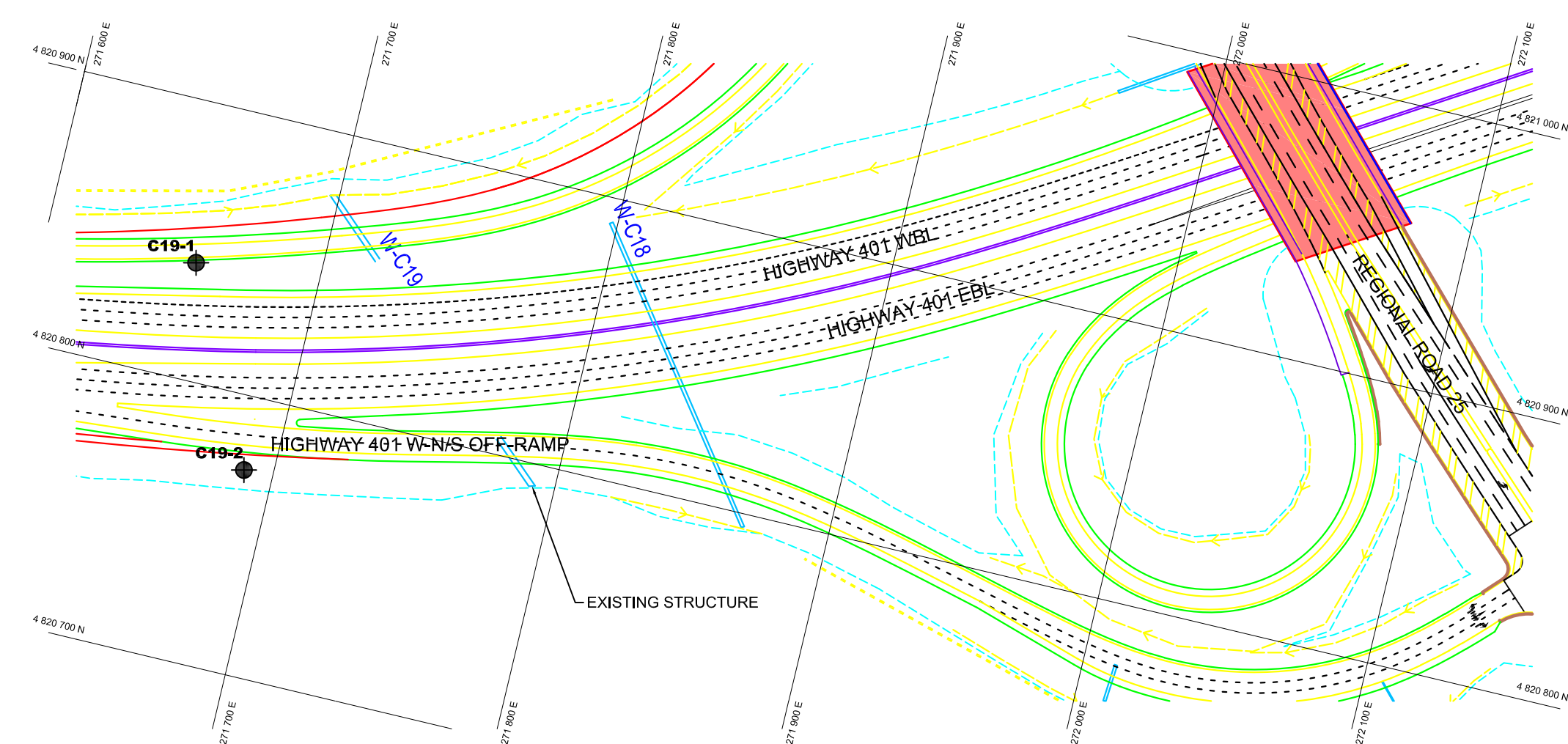
Option 1: Open Footing Concrete Culvert	Option 2: Precast Concrete Box Culvert
Advantages: <ul style="list-style-type: none"><li>• Generally, allows for natural streambed to remain intact</li><li>• Adequate geotechnical resistance available at founding level</li></ul>	Advantages: <ul style="list-style-type: none"><li>• Ease and speed of construction</li><li>• Installation in wet conditions is possible</li><li>• The joints provide flexibility to accommodate more differential settlements than open footings</li></ul>
Disadvantages: <ul style="list-style-type: none"><li>• Limited tolerance to differential settlements</li></ul>	Disadvantages: <ul style="list-style-type: none"><li>• Provision may be required to re-establish natural stream bed</li></ul>
Feasibility: Technically feasible	Feasibility: Technically feasible, but may not be feasible at this environmentally sensitive site

Asgmt. No 2016-E-0004

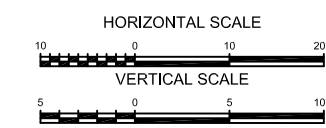
NON-STRUCTURAL CULVERT W-C19  
HIGHWAY 401  
CITY OF MISSISSAUGA  
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



PROFILE ALONG C EXISTING CULVERT



- NOTES:
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  - THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
  - DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.

LEGEND

- Borehole (Current Investigation)
- N Blows/0.3m (Std. Pen Test, 475 J/blow)
- \* Water level could not be established

BH No	ELEVATION	NORTHINGS	EASTINGS
C19-1	207.4	4 820 842.2	271 655.2
C19-2	207.2	4 820 773.5	271 689.4

NOTE

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



Reference AECOM Drawing: X-Design\_Traf to RR25.dwg.

DATE	BY	DESCRIPTION

Geocres No. 30M12-420			
HWY No 401		CHECKED KA	DATE NOV. 17, 2018
SUBM'D NL			SITE
DRAWN NL		CHECKED DD	APPROVED RN
			DWG WC19-1

## **SITE Y – NON-STRUCTURAL CULVERT (W-C20)**

PRELIMINARY FOUNDATION INVESTIGATION

Borehole Information

A total of two (2) contingency boreholes were advanced along the alignment of proposed Culvert WC-20 at Highway 401 west of Regional Road 25.

Refer to

- Structure and borehole location plan, and subsurface stratigraphy (Drawing WC20-1)
- Table Y-1 for details of borehole location coordinates and borehole elevations/depths
- Appendices B and C for Record of Borehole sheets and lab results showing details of the subsurface conditions at the borehole locations from current investigation.

Table Y-1 Culvert WC-20 Borehole Information

Borehole ID	Borehole Location	MTM NAD 83 Coordinates		Ground Surface Elevation (m)	Borehole Depth (m)
		Northing (m)	Easting (m)		
C20-1	North End (Inlet)	4820791.3	271344.9	210.0	28.0
C20-2	South End (Outlet)	4820739.5	271364.8	210.6	17.4

Subsurface Conditions

The stratigraphy conceptually consists of approximately 0.1 m to 0.2 m thickness of topsoil underlain by an approximately 0.6 m to 1.0 m thick fill underlain by an approximately 16.3 m to 23.6 m thick clayey silt till deposit. Borehole C20-2 was terminated in the clayey silt till deposit. In borehole C20-1, the clayey silt till layer is underlain by a silt deposit. BH C20-1 was terminated at a depth of 3.6 m into the silt deposit. Refer to the Record of Boreholes for actual conditions.

The subsurface conditions at this site can be categorized into four (4) general layers as presented below from surface downwards.

• Topsoil

A topsoil layer of 100 mm to 200 mm thickness was encountered at the existing ground surface in the boreholes drilled on the north and south ends of the proposed culvert alignment.

• Fill

The composition of the fill varied consisted of Clayey Silt with Silty Sand zones.

An approximately 0.6 m (extending to Elevation 209.2 m) to 1.0 m (extending to Elevation 209.5 m) thick, firm to stiff clayey silt fill layer was encountered below the topsoil in boreholes 20-1 and 20-2. The SPT ‘N’ values of this layer were 4 blows and 14 blows per 0.3 m penetration. Moisture contents of sample were 14.5% and 24.2%. In BH C20-2, an approximately 0.5 m thick compact silty sand fill layer was encountered immediately below the topsoil, extending to Elevation 210.0 m.

• Clayey Silt (Till)

An approximately 23.6 m to 16.3 m thick stiff to hard clayey silt (till) deposit was encountered immediately below the clayey silt fill layer in BH’s C20-1 and C20-2, extending to Elevations 193.2 m and 185.6 m, respectively. Firm to soft localized zones in the order of 1 to m thick were encountered in BH’s C20-1 and C20-2 at depths of 7.6 m and 9.1 m (Elevation 202.4 m and 201.5 m), respectively. Borehole C20-2 was terminated within this deposit at a depth of

17.4 m (Elevation 193.2 m). The SPT ‘N’ values of this layer ranged from 2 blows to 73 blows per 0.30 m penetration. Moisture contents of the samples ranged between 9.7% and 38.4%. The results of grain size distribution test on selected samples from this deposit are provided in Figure GS-Y-1 and the Atterberg limits are presented in Figure PC-Y-1 in Appendix C-2.

• Silt (Till)

An approximately 3.6 m thick compact to dense silt (till) deposit was encountered below the clayey silt till layer at 24.4 m below the existing ground surface (Elevation 185.6 m) in borehole C20-1, extending to the termination depth 28.0 m below ground surface (Elevation 182.0 m). Cobbles were encountered in this deposit. The SPT ‘N’ values of this layer were 29 blows and 74 blows per 0.30 m penetration. One moisture content determination of a sample was 22.0%. The result of grain size distribution test on a selected sample from this deposit is provided in Figure GS-Y-2 in Appendix C-2.

Groundwater Conditions

Groundwater was not encountered up to a depth of 3.1 m below the existing ground surface in the investigated boreholes (Elevations 207.5 m to 206.9 m) during drilling. Below these depths, the groundwater level could not be established due to the mud drilling method utilized for drilling. It is inferred that the groundwater level is approximately at Elevation 201.0 m or below based on observations during drilling, the moisture contents and visual examinations of the recovered soils. Groundwater levels are subject to seasonal fluctuations and precipitation patterns.

PRELIMINARY FOUNDATION DESIGN RECOMMENDATIONS

Introduction

The existing culvert approximately at Station 11+ 800 is to be replaced to accommodate the Highway 401 widening in both eastbound and westbound directions.

The following document is referenced:

- Preliminary Design Report, Highway 401 Improvements from Trafalgar Road to Regional Road 25, in the Regional Municipality of Halton, Town of Milton and Town of Halton Hills, W.O. 07-20024, Volume I URS, September, 2013.

Existing Structure

The existing culvert is a non-structural culvert and its details were not known at the time of writing this report.

Proposed Structure

It is proposed to replace the existing culvert with a new non-structural culvert. The details of the proposed culvert were not available at the time of the preparation of this report. It is assumed that the span of the proposed culvert will be less than 3.0 m.

New embankment fills will be placed over the replacement portion of the culvert to facilitate the widening of the existing Highway 401 WBL and EBL. The grade of Highway 401 is expected to be maintained at the existing elevation.

Evaluation of Foundation Alternatives

The evaluation of foundation alternatives for preliminary design and planning purposes has been based on the subsoil conditions and the environmental considerations. A comparison of various alternatives considered in terms of advantages and disadvantages is provided in Table Y-4.

Following options have been discussed for culvert replacement to match along the same vertical and horizontal alignments are as follows:

- Open footing concrete culvert, and
- Precast concrete box culvert

Option 1: Open Footing Culvert on Strip Footing

Open footing culvert founded on strip footings are feasible at this site. The strip footings may be founded on very stiff to hard clayey silt till at or below Elevation 209.0 m. The frost cover requirement is 1.2 m.

Temporary roadway protection may be required to facilitate construction where temporary slopes can not be maintained at stable slope geometry.

For preliminary design purposes, the factored geotechnical resistance at ULS of 300 kPa and factored geotechnical resistance of 200 kPa at SLS may be used for a strip footing with a minimum of 0.5 m wide. The total settlement is expected less than 25 mm for a strip footing.

Option 2: CIP or Precast Concrete Box Culvert

A box culvert may be placed at or below the Elevation 209 m. Reference is made to the proposed founding levels in Table Y-2. The fill material below these elevations should be removed and replaced with compacted backfill meeting the requirements of OPSS 422.07.06. Bedding for the concrete box culvert should be in accordance with

OPSS 422.07.08, and may consist of 300 mm thick granular material, including the 75 mm leveling course required by OPSS 422.07.07. Bedding should be as specified in OPSS 422.05.13 and should be placed in accordance with OPSS 422.07.07.

Table Y-2 Box Culvert Founding Elevations

Foundation Location	Proposed Culvert Invert Elevation	Box Culvert Founding Elevation	Founding Stratum
North End (Inlet)	208.5 m	208.2m	Very stiff to hard clayey silt till
South End (Outlet)	208.0 m	207.7 m	

Note 1: The bottom thickness of the precast concrete box culvert is assumed 0.25 m.

For preliminary design purposes, a factored geotechnical resistance at ULS of 300 kPa and a factored geotechnical resistance of 200 kPa at SLS may be utilized. The total settlement is expected less than 25 mm.

Recommended Option for New Culvert Construction

Both options are feasible. The box culvert provides less complex construction requirements. The open footings culvert may present fewer complex requirements to re-establish a natural stream bed.

Approach Embankments

The profile grade of the approach at the location of new culvert on the widening of Highway 401 was not known at the time of the preparation of this report. Assuming the elevation of the widened Highway 401 embankments match the existing Highway 401 embankment, no slope stability problems are anticipated for permanent embankments constructed with a minimum slope of 2H: 1V or flatter. Any compressible material under the plan limits of the immediate approaches to the proposed culvert new embankments should be identified and replaced with compacted suitable fill. New embankments should be benched into the existing embankment according to the requirement of OPSD 208.010. It is anticipated that the settlement of approach embankments will be less than 50 mm and probably in the order of 25 mm.

Construction Considerations

• Excavation

Based on the record of boreholes, the excavations for the construction of new culvert will be advanced through existing fill material underlain by native till deposits. For OHSA classification purposes, the fill materials should be classified as Type 3 soils and clayey silt till should be classified as Type 2 soils. For excavations through multiple soil types, the side slope geometry is governed by the soil with the highest number designation.

All work should be carried out in accordance with the Occupational Health and Safety Act (Ontario Regulation 213/91) and with local/MTO regulations.

• Culvert Bedding, Backfill and Erosion Protection

Cut-offs are required at the culvert inlet. Consideration could be given to structural vertical cut-offs or horizontal apron cut-offs. Vertical cut-offs should be in accordance with OPSD 812.010. Alternatively, a horizontal apron consisting of a clay seal blanket may be implemented extending from the design high water level, upstream for a distance in the order of three times the culvert height and along the adjacent side slopes for a horizontal distance equal to two times the culvert height.

An appropriate filter should be provided at the outlet. The filter could be appropriately sized free-draining granular material and extend from the design high water level, downstream for a distance equal to three times the culvert height and along the adjacent side slopes for a horizontal distance equal to two times the culvert height.

Rock protection may be provided at the inlet and outlet, in accordance with OPSS 511 and OPSS 1004, to protect the inlet seal and outlet filter materials, respectively. The dimensions of rock protection particles should be determined during the detail design phase in consideration of the flow velocity. The thickness of the rock protection should be a minimum of twice the maximum rock particle dimension.

Ontario Provincial Standard Specifications (OPSS 1010) Granular ‘A’ or ‘B Type II’ should be used as backfill material behind the wall and compacted in accordance with the requirements specified in the OPSS 902 (Excavation and Backfilling of Structures) as amended by SP 109S12 and NSSP FOUN0003. The backfill material should be placed in layers not exceeding 200 mm in thickness before compaction.

• **Cover and Backfill**

Backfill materials should meet the requirements of Group I, or Group II specified in OPSS 422.05.14, and placed according to the procedures described in Section 422.07.11. It should be placed in layers not exceeding 200 mm in thickness before compaction and compacted in accordance with OPSS 501. Backfill on each side of the culvert should be completed simultaneously so that at no time, the levels on each side of the culvert vary by more than 400 mm.

Restrictions on compaction near the culvert should be as specified in OPSS 902.07.06.02. Heavy vibratory compaction equipment adjacent to retaining structures should be restricted to limit the compaction pressure described in Clause 6.12.3 of the CHBDC, 2014. The type of compaction equipment and the compaction procedure that can be used for this purpose should be in accordance with OPSS 501 (Construction Specification for Compacting).

The cover material should meet the requirements of OPSS 422.05.14 and placed in accordance with OPSS 422.07.12.

• **Roadway Protection and Shoring**

The roadway should be protected by a properly designed protection system when space limitation exists. The protection system for excavations should be in accordance with OPSS 539 as amended by SP 105S09, Construction Specification for Temporary Protection Systems, and OPSS 902 as amended by SP 109S12 and NSSP FOUN00003, Construction Specifications for Excavating and Backfilling–Structures. Excavated material should not be stockpiled in the areas immediately adjacent to the top of the excavation slopes.

The Contractor is responsible for the selection, design, construction, and performance of the temporary protection systems. The protection systems should be designed to meet the Performance Level 2 as specified in OPSS 539 as amended by SP 105S09, Construction Specification for Temporary Protection Systems.

Geotechnical parameters provided in Table Y-3 may be used for the preliminary evaluation of temporary protection system.

Table Y-3 Preliminary Geotechnical Design Parameters

Soil Type	Unit Weight, (kN/m <sup>3</sup> )	Design Parameters	
		Effective Friction Angle, (Ø’)	Undrained Shear Strength, Su (kPa)
Silty Sand (Fill)	18	30	-
Clayey Silt (Fill)	18	22	50
Clayey Silt (Till)	20	25	150
Silt (Till)	19	30	-

• **Groundwater and Surface Water Control**

Surface water should be diverted away from open excavations and all excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA) and MTO Regulations for Construction Projects. The surface water flow should be directed away from the excavation areas to mitigate disturbance and weakening of the clayey silt till subgrade. Furthermore, depending on the surface water flow at the time of the construction, the water flow could be passed through the construction area by means of a temporary pipe or diverted by pumping from behind a temporary cofferdam.

Groundwater levels should be maintained a minimum of 0.5 m below the bases of excavations for construction in-the-dry.

The contractor should be responsible for the selection, performance and detailed design of the dewatering system including the cofferdam. The dewatering system should be designed to conform to the requirement of OPSS 517 as amended by 517F01.

Table Y-4 - Comparison of Culvert Options

Option 1: Precast Concrete Box Culvert	Option 2: Open Footing Concrete Culvert
Advantages: <ul style="list-style-type: none"><li>Ease and speed of construction</li><li>Installation in wet conditions is possible</li><li>The joints provide flexibility to accommodate more differential settlements than open footings</li></ul>	Advantages: <ul style="list-style-type: none"><li>Generally, allows for natural streambed to remain intact</li><li>Adequate geotechnical resistance available at founding level</li></ul>
Disadvantages: <ul style="list-style-type: none"><li>Provision may be required to re-establish natural stream bed</li></ul>	Disadvantages: <ul style="list-style-type: none"><li>Limited tolerance to differential settlements</li></ul>
Feasibility: Technically feasible	Feasibility: Technically feasible

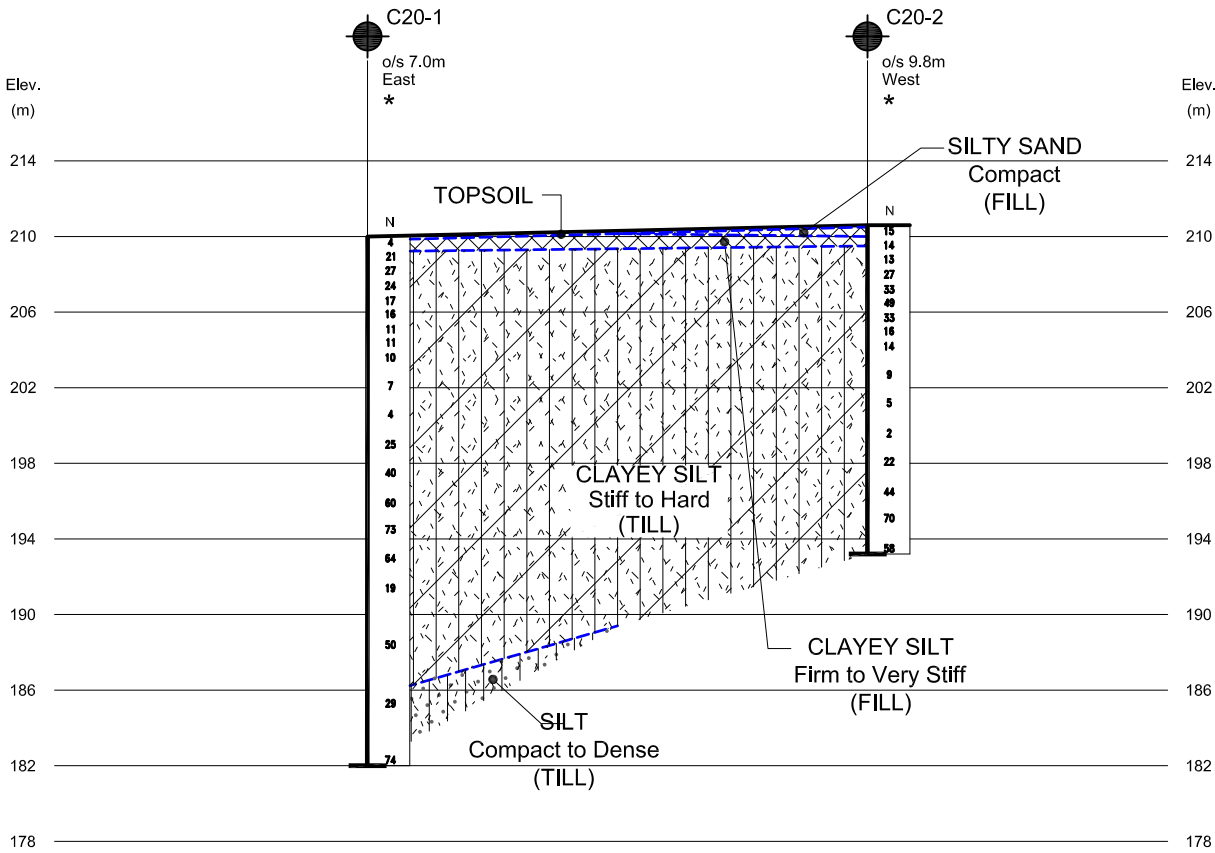
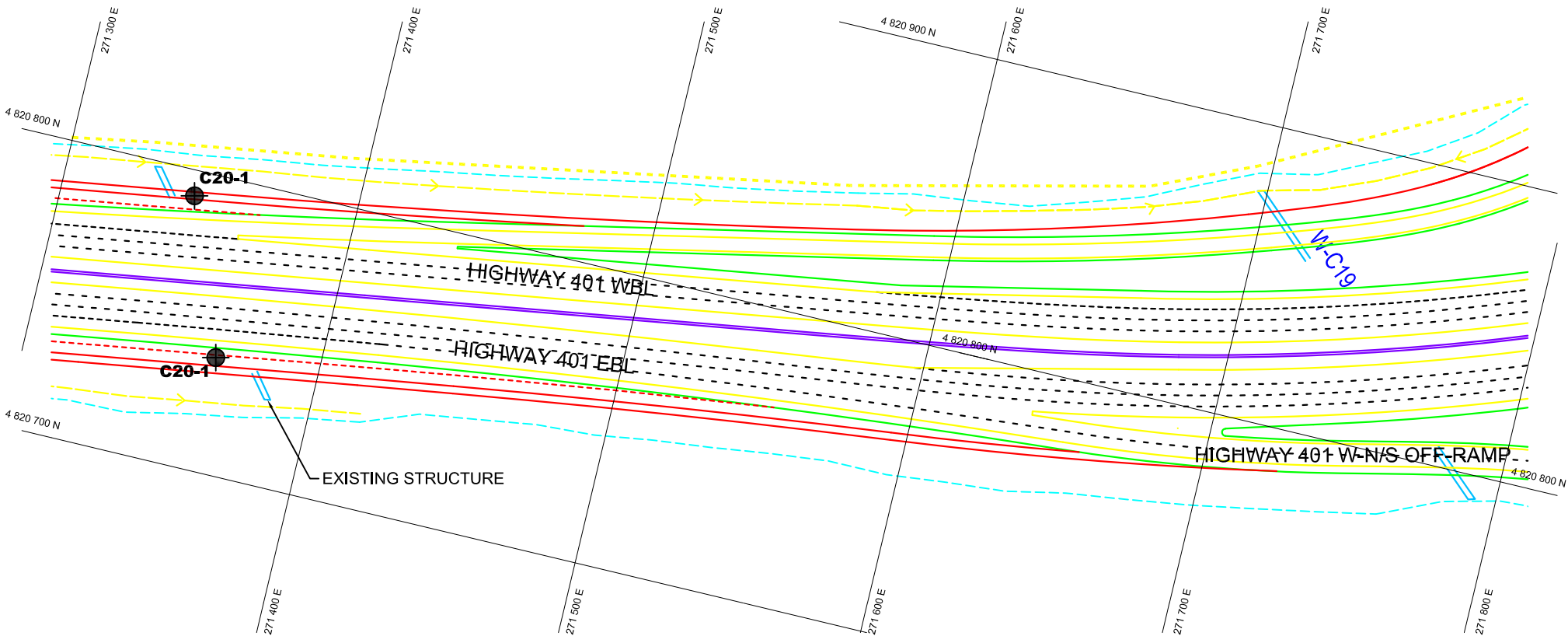
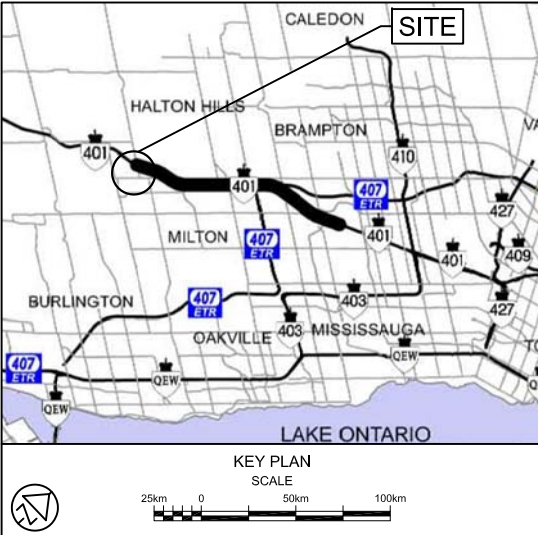


Asgmt. No 2016-E-0004

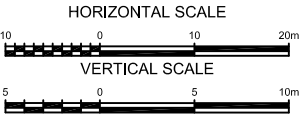
NON-STRUCTURAL CULVERT W-C20  
HIGHWAY 401  
CITY OF MISSISSAUGA  
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



PROFILE ALONG C<sub>q</sub> EXISTING CULVERT



NOTES:

- THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
- THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
- DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.

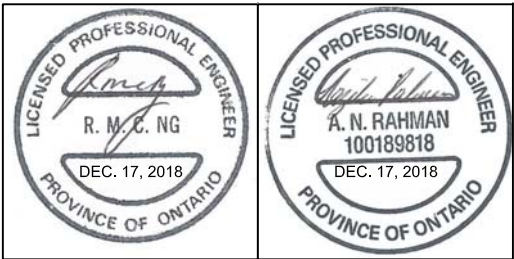
LEGEND

- Borehole (Current Investigation)
- N Blows/0.3m (Std. Pen Test, 475 J/blow)
- \* Water level could not be established

BH No	ELEVATION	NORTHINGS	EASTINGS
C20-1	210.0	4 820 791.3	271 344.9
C20-2	210.6	4 820 739.5	271 364.8

NOTE

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



DATE	BY	DESCRIPTION

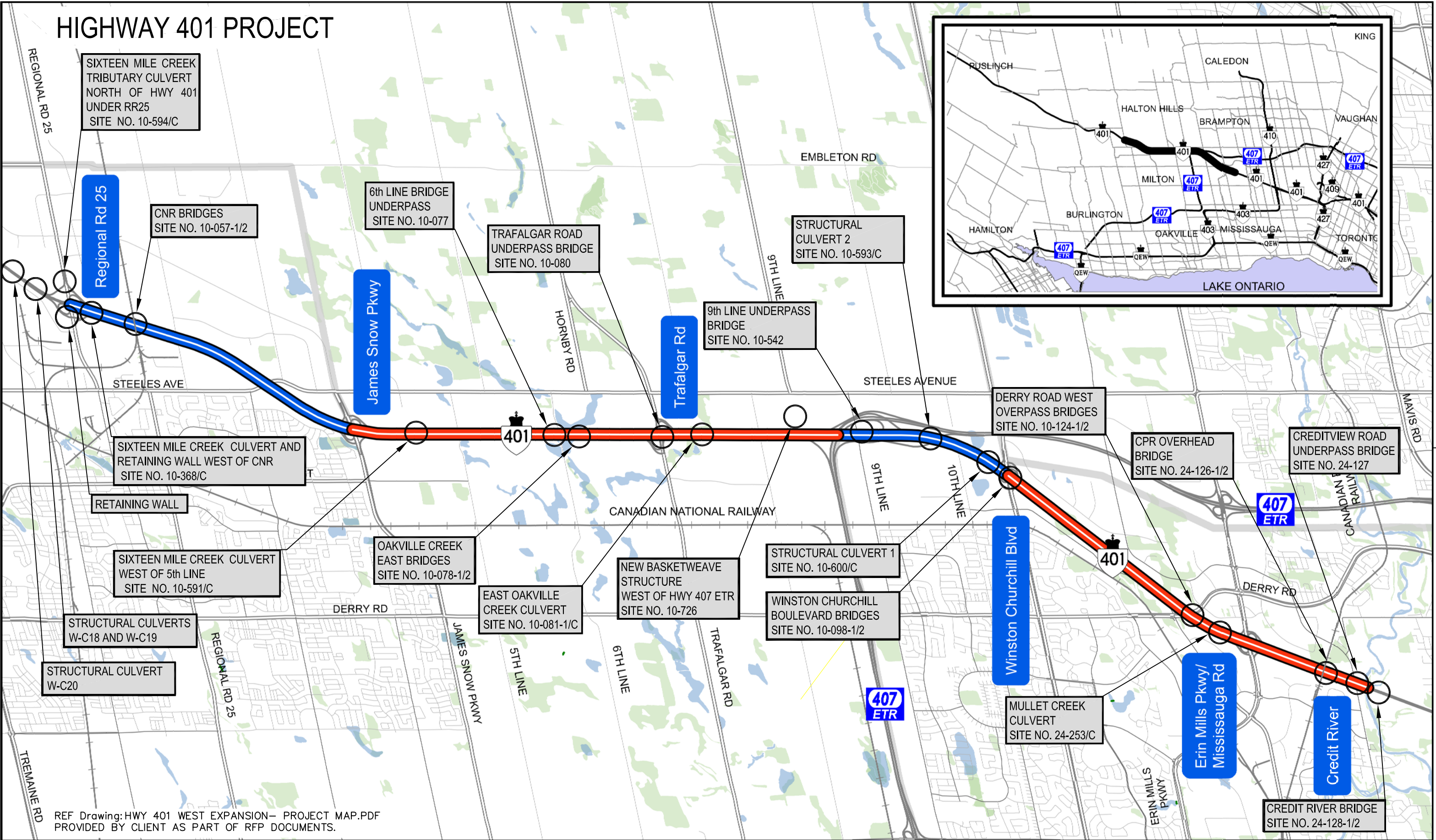
HWY No	401	DIST	Central
SUBM'D	NL	CHECKED	KA
DATE	DEC. 17, 2018	SITE	
DRAWN	NL	CHECKED	DD
APPROVED	RN	DWG	WC20-1

Reference AECOM Drawing: X-Design\_Traf to RR25.dwg.



## APPENDIX A – SITE LOCATION PLAN

# HIGHWAY 401 PROJECT



REF Drawing: HWY 401 WEST EXPANSION- PROJECT MAP.PDF  
PROVIDED BY CLIENT AS PART OF RFP DOCUMENTS.



APPENDIX A  
SITE LOCATION PLAN



## **APPENDIX B – PREVIOUS INVESTIGATIONS**

### **Record of Borehole Sheets and Laboratory Test Results**

## MULLET CREEK CULVERT (SITE NO. 24-253/C)



October 2012

PRELIMINARY FOUNDATION  
INVESTIGATION AND DESIGN REPORT

Mullet Creek Culvert Extension  
Highway 401 Widening from East of Credit River  
to Trafalgar Road, Regional Municipalities of  
Peel and Halton  
W.O. 07-20021

Submitted to:  
URS Canada Inc.  
75 Commerce Valley Drive East  
Markham, Ontario  
L3T 7N9



GEOCRES No. 30M12-348

Report Number: 10-1111-0040-4  
Distribution:  
3 Copies - MTO - Central Region  
1 Copy - MTO Foundations Section  
2 Copy - URS Canada Inc.  
2 Copies - Golder Associates Ltd.



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		III. SOIL DESCRIPTION	
AS	Auger sample	(a)	Cohesionless Soils
BS	Block sample		Density Index
CS	Chunk sample		Relative Density
SS	Split-spoon		N
DS	Denison type sample		Blows/300 mm or Blows/ft
FS	Foil sample		
RC	Rock core		
SC	Soil core		
ST	Slotted tube		
TO	Thin-walled, open		
TP	Thin-walled, piston		
WS	Wash sample		
II. PENETRATION RESISTANCE		(b) Cohesive Soils	
Standard Penetration Resistance (SPT), N:		Consistency	
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 <sub>d</sub> :			
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 <sub>t</sub> ), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.			
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 <sub>s</sub> )		
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)		
γ	unit weight		
		Note: 1	Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.
V. MINOR SOIL CONSTITUENTS			
Percent 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 (cohesionless) or With (cohesive)	Sand and Gravel	
		Silty Clay with sand / Clayey Silt with sand	





LIST OF SYMBOLS

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

I. GENERAL		(a)	Index Properties (continued)
$\pi$	3.1416	w	water content
$\ln x$	natural logarithm of x	$w_l$ or LL	liquid limit
$\log_{10}$	x or log x, logarithm of x to base 10	$w_p$ or PL	plastic limit
g	acceleration due to gravity	$I_p$ or PI	plasticity index = $(w_l - w_p)$
t	time	$w_s$	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)
II. STRESS AND STRAIN		(b)	Hydraulic Properties
$\gamma$	shear strain	h	hydraulic head or potential
$\Delta$	change in, e.g. in stress: $\Delta \sigma$	q	rate of flow
$\epsilon$	linear strain	v	velocity of flow
$\epsilon_v$	volumetric strain	i	hydraulic gradient
$\eta$	coefficient of viscosity	k	hydraulic conductivity (coefficient of permeability)
$\nu$	Poisson's ratio	j	seepage force per unit volume
$\sigma$	total stress		
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )	(c)	Consolidation (one-dimensional)
$\sigma'_{vo}$	initial effective overburden stress	$C_c$	compression index (normally consolidated range)
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)	$C_r$	recompression index (over-consolidated range)
$\sigma_{oct}$	mean stress or octahedral stress = $(\sigma_1 + \sigma_2 + \sigma_3)/3$	$C_s$	swelling index
$\tau$	shear stress	$C_a$	secondary compression index
u	porewater pressure	$m_v$	coefficient of volume change
E	modulus of deformation	$c_v$	coefficient of consolidation (vertical direction)
G	shear modulus of deformation	$c_h$	coefficient of consolidation (horizontal direction)
K	bulk modulus of compressibility	$T_v$	time factor (vertical direction)
		U	degree of consolidation
		$\sigma'_p$	pre-consolidation stress
		OCR	over-consolidation ratio = $\sigma'_p / \sigma'_{vo}$
III. SOIL PROPERTIES		(d)	Shear Strength
(a)	Index Properties	$\tau_p, \tau_r$	peak and residual shear strength
$\rho(\gamma)$	bulk density (bulk unit weight)*	$\phi'$	effective angle of internal friction
$\rho_d(\gamma_d)$	dry density (dry unit weight)	$\delta$	angle of interface friction
$\rho_w(\gamma_w)$	density (unit weight) of water	$\mu$	coefficient of friction = $\tan \delta$
$\rho_s(\gamma_s)$	density (unit weight) of solid particles	$c'$	effective cohesion
$\gamma'$	unit weight of submerged soil ( $\gamma' = \gamma - \gamma_w$ )	$c_u, s_u$	undrained shear strength ( $\phi = 0$ analysis)
$D_R$	relative density (specific gravity) of solid particles ( $D_R = \rho_s / \rho_w$ ) (formerly $G_s$ )	p	mean total stress $(\sigma_1 + \sigma_3)/2$
e	void ratio	$p'$	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
n	porosity	q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
S	degree of saturation	$q_u$	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	$\tau = c' + \sigma' \tan \phi'$
		2	shear strength = (compressive strength)/2



LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERINGS STATE

**Fresh:** no visible sign of weathering

**Faintly weathered:** weathering limited to the surface of major discontinuities.

**Slightly weathered:** penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

**Moderately weathered:** weathering extends throughout the rock mass but the rock material is not friable.

**Highly weathered:** weathering extends throughout rock mass and the rock material is partly friable.

**Completely weathered:** rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

BEDDING THICKNESS

Description	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 m to 2 m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	Less than 6 mm

JOINT OR FOLIATION SPACING

Description	Spacing
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

GRAIN SIZE

Term	Size*
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: \* Grains greater than 60 microns diameter are visible to the naked eye.

CORE CONDITION

**Total Core Recovery (TCR)**  
The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

**Solid Core Recovery (SCR)**  
The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

**Rock Quality Designation (RQD)**  
The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

DISCONTINUITY DATA

**Fracture Index**  
A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

**Dip with Respect to Core Axis**  
The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.

**Description and Notes**  
An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

Abbreviations	
JN Joint	PL Planar
FLT Fault	CU Curved
SH Shear	UN Undulating
VN Vein	IR Irregular
FR Fracture	K Slickensided
SY Stylolite	PO Polished
BD Bedding	SM Smooth
FO Foliation	SR Slightly Rough
CO Contact	RO Rough
AXJ Axial Joint	VR Very Rough
KV Karstic Void	
MB Mechanical Break	



PROJECT10-1111-0040

G.W.P.07-20021

DISTCentral

DATUMNAD83, Geodetic

LOCATIONN 4829244.1 ; E 284426.8

BOREHOLE TYPETrack-Mounted CME55, 108 mm I.D. Hollow Stem Augers

DATESeptember 6, 2011

ORIGINATED BYSB/BM

COMPILED BYMM

CHECKED BYLCC

RECORD OF BOREHOLE No 11-401

SHEET 1 OF 2

METRIC

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT			UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa				WATER CONTENT (%)			
						20 40 60 80 100				Wp W WL					
						o UNCONFINED + FIELD VANE									
						● QUICK TRIAXIAL x REMOULDED									
						20 40 60 80 100				10 20 30					
178.3	GROUND SURFACE														
0.0	CLAYEY SILT with sand, trace gravel (TILL) Stiff to hard Brown and grey Moist		1	SS	14										
			2	SS	23										
			3	SS	21										
	Becoming grey at a depth of 2.3 m		4	SS	21										
			5	SS	31										
174.6	Gravelly SAND, some silt, trace clay Dense Brown Wet		6	SS	31										
173.9	CLAYEY SILT with sand, some gravel (TILL) Hard Brown Moist		7	SS	31										
170.7	Shale (BEDROCK) Weathered Reddish brown		9	SS	50/0.15										
169.0	Shale (BEDROCK) containing limestone interbeds  Bedrock cored between 9.3 m and 13.6 m. For bedrock coring details, refer to Record of Drillhole 11-401		10	SS	70/0.15										
			1	RC	REC 75%										
			2	RC	REC 73%										
			3	RC	REC 100%										
164.7	END OF BOREHOLE														
13.6	NOTE:  1. Wet soils encountered at 3.7 m (Elev. 174.6 m), but borehole dry on completion of overburden drilling.														

+ 3, x 3: Numbers refer to Sensitivity      o 3% STRAIN AT FAILURE

GTA-MTO 001 1011110040.GPJ GAL-GTA.GDT 10/22/12 DD

PROJECT: 10-1111-0040

LOCATION: N 4829244.1 ; E 284426.8

INCLINATION: -90°      AZIMUTH: —

RECORD OF DRILLHOLE: 11-401

DRILLING DATE: September 6, 2011

DRILL RIG: Track-Mounted CME 55

DRILLING CONTRACTOR: Geo-Environmental Drilling Inc.

SHEET 2 OF 2

DATUM: NAD83, Geodetic

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR FLUSH	JN - Joint FLT - Fault SH - Shear VN - Vein CJ - Conjugate	BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage	PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular	PO - Polished K - Stickensided SM - Smooth RO - Rough VR - Very Rough	MB - Mechanical Break BR - Broken Rock NOTE: For additional abbreviations refer to list of abbreviations & symbols.	DISCONTINUITY DATA		HYDRAULIC CONDUCTIVITY		Diameter (mm)	MC - J2 AVG.	NOTES	
												RECOVERY TOTAL CORE %	SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 0.3 m				TYPE AND SURFACE DESCRIPTION
		Continued from Record of Borehole BH11-401		168.99															
		SHALE (BEDROCK) with fossiliferous limestone beds Slightly to moderately weathered Laminated Reddish-brown to grey Weak to medium strong		9.32															(Axial)
10					1														
11					2														
12					3														
13																			
14		END OF DRILLHOLE		164.72															
				13.59															
15																			
16																			
17																			
18																			
19																			

DEPTH SCALE

1 : 50

LOGGED: SB/BM  
CHECKED: MS

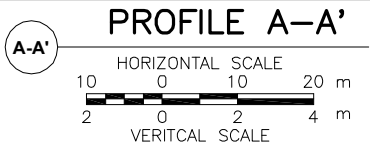
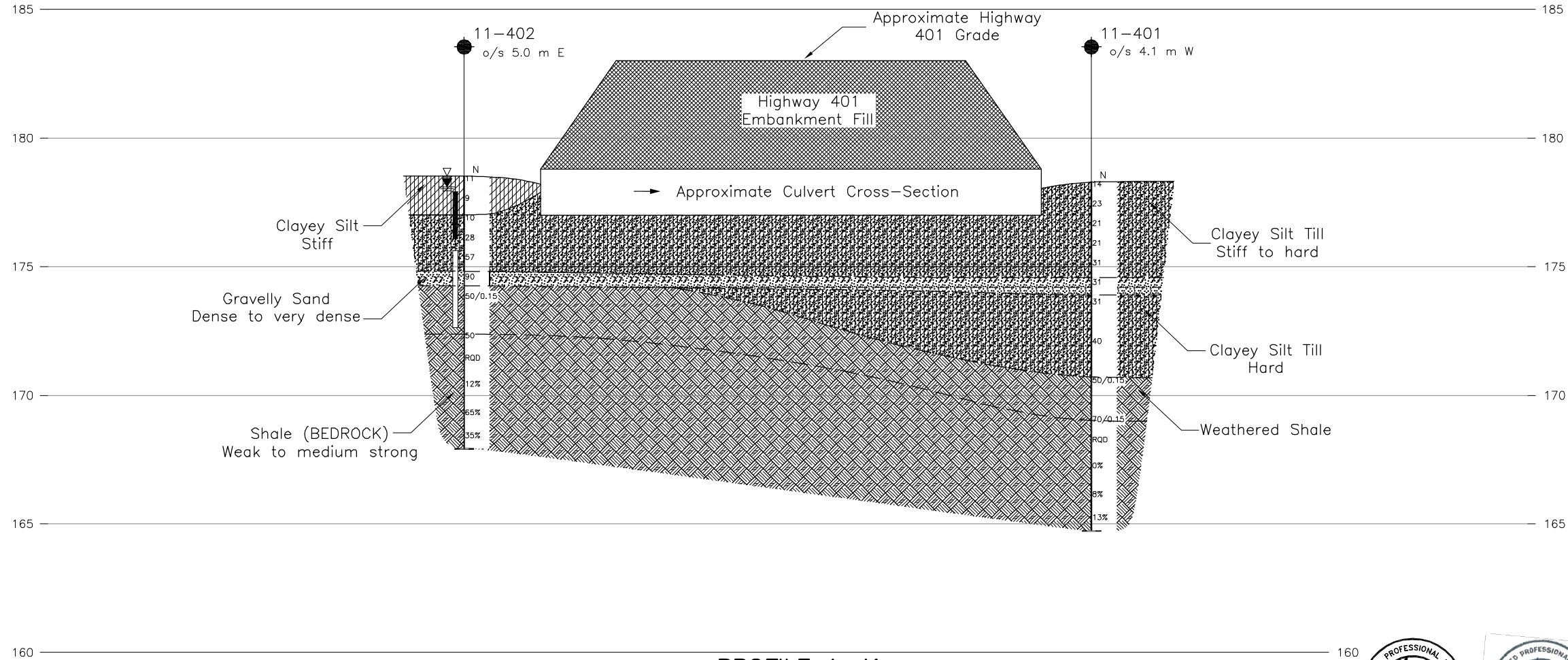
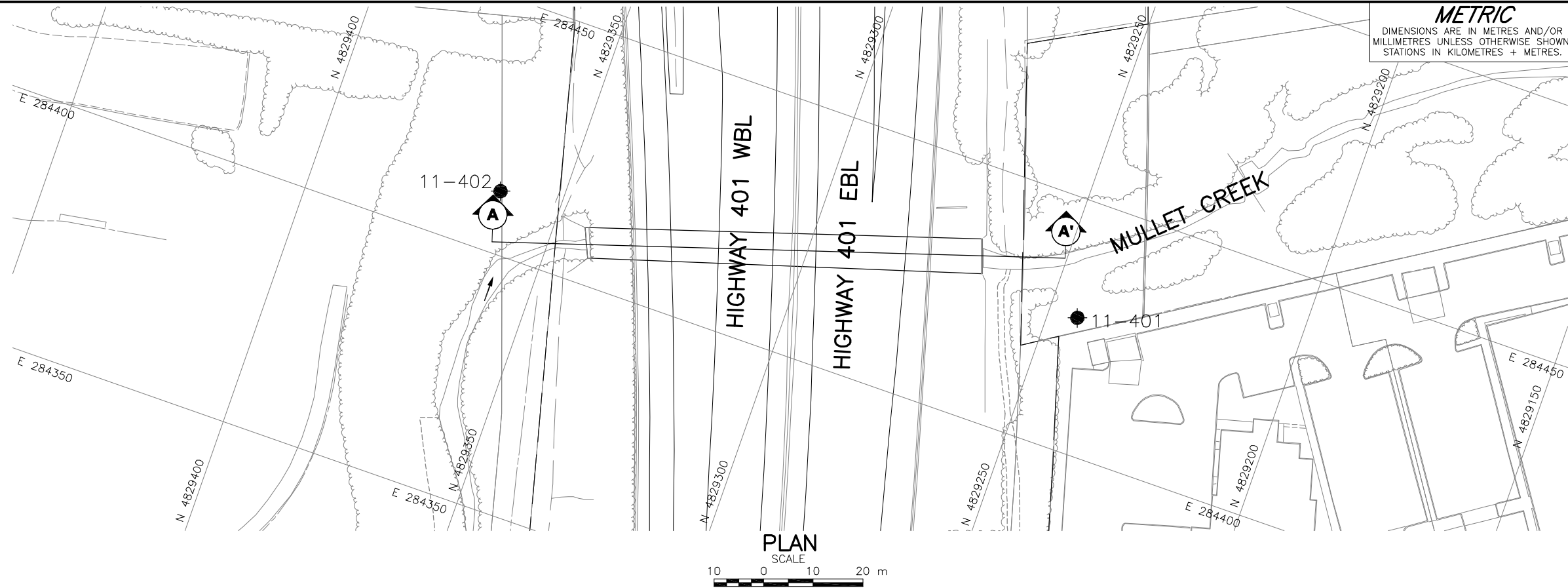
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GTA-RCK 018 1011110040.GPJ GAL-MISS.GDT 10/22/12 DD

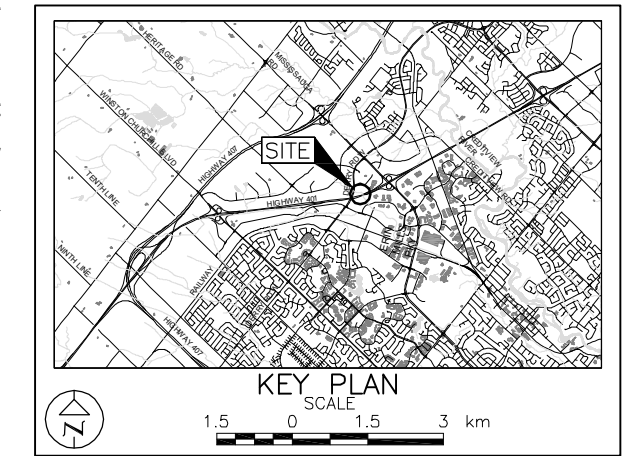




CONT No. WO No. 07-20021

MULLET CREEK CULVERT  
HIGHWAY 401 WIDENING  
BOREHOLE LOCATIONS AND SOIL STRATA

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



**LEGEND**

- Borehole - Current Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- WL in piezometer, measured on November 2, 2011
- WL upon completion of drilling
- Direction of flow

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
11-401	178.3	4829244.1	284426.8
11-402	178.5	4829362.5	284412.4

**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 design configuration as shown elsewhere in the Preliminary Design Report.

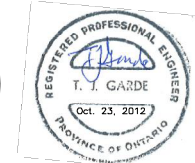
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

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

**REFERENCE**

Base plans provided in digital format by URS, Drawing File Nos. ACAD-X-base1\_to\_Trafalgar.dwg and ACAD-Aerials\_MTO ROW\_Property Boundaries.dwg, received August 17, 2011 and August 29, 2011.

NO.	DATE	BY	REVISION
Geocres No.	30M12-348		
HWY. 401		PROJECT NO. 10-1111-0040	DIST.
SUBM'D. MM	CHKD. LCC	DATE: 10/23/2012	SITE:
DRAWN: JFC	CHKD. MM	APPD. LCC	DWG. 1



October 2012

PRELIMINARY FOUNDATION  
INVESTIGATION AND DESIGN REPORT

Mullet Creek Culvert Extension  
Highway 401 Widening from East of Credit River  
to Trafalgar Road, Regional Municipalities of  
Peel and Halton  
W.O. 07-20021

Submitted to:  
URS Canada Inc.  
75 Commerce Valley Drive East  
Markham, Ontario  
L3T 7N9



GEOCRES No. 30M12-348

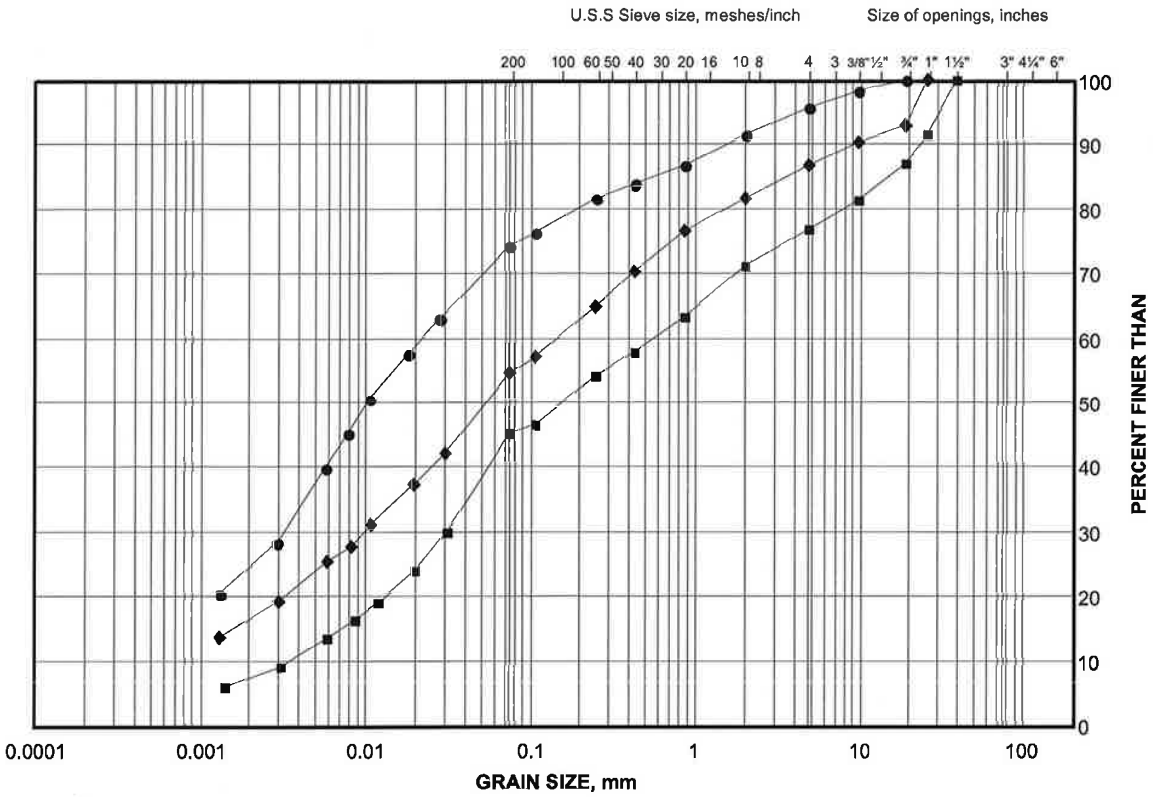
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GRAIN SIZE DISTRIBUTION TEST RESULTS  
Clayey Silt Till

FIGURE B1



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	11-401	2	177.2
■	11-402	5	175.1
◆	11-401	8	171.9

Project Number: 10-1111-0040

Checked By: 

Golder Associates

Date: 09-Jul-12

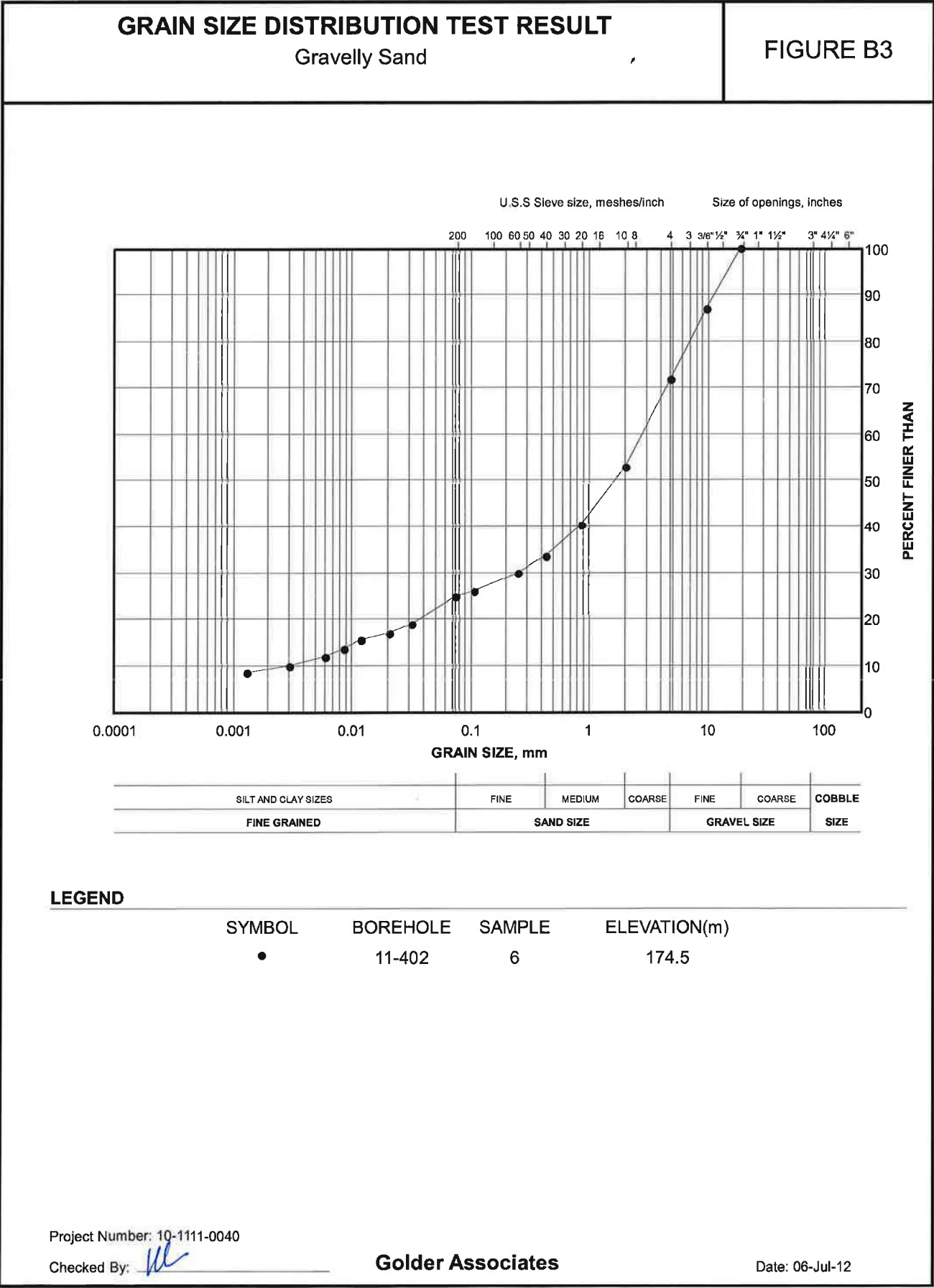
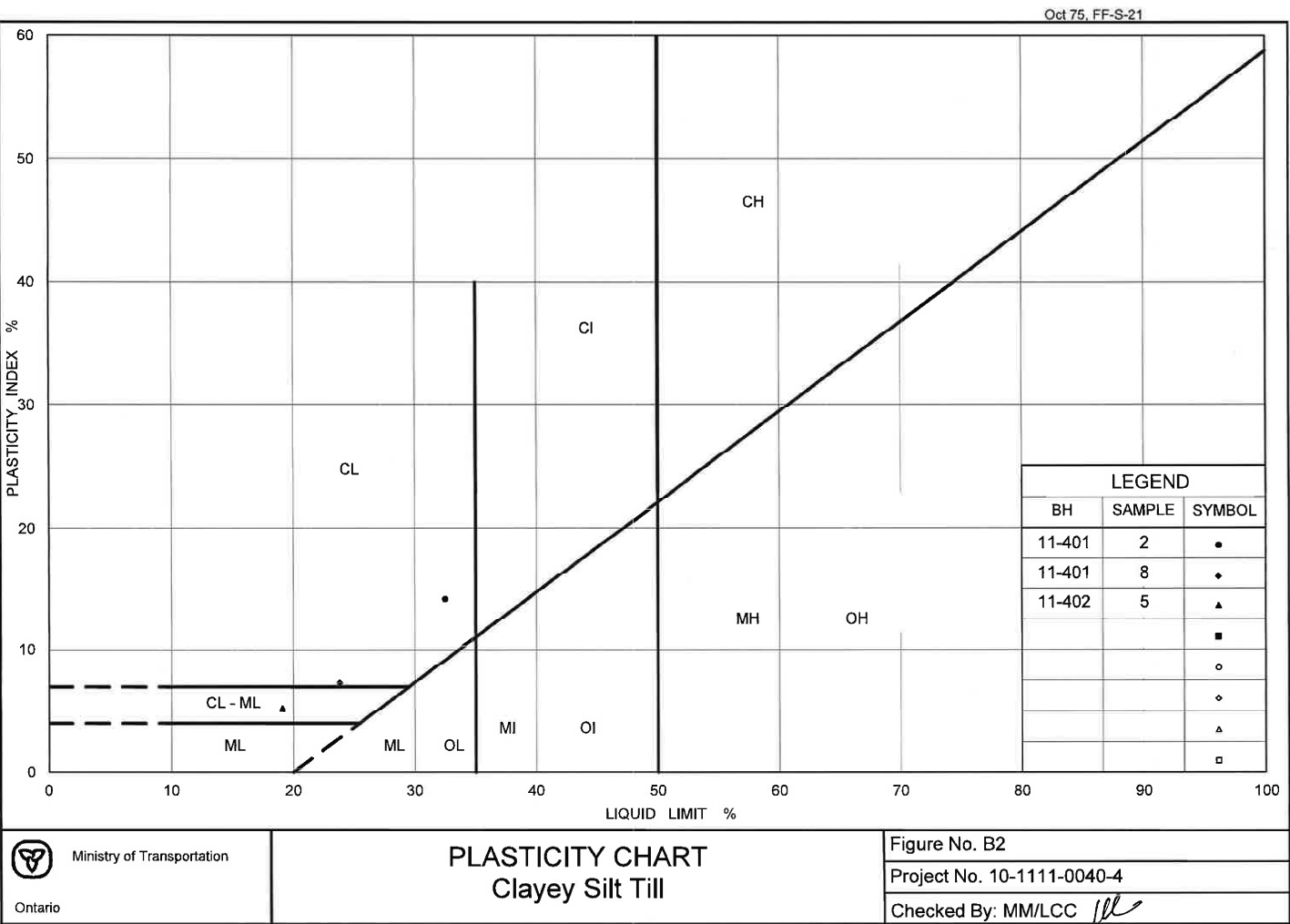


TABLE B1 - POINT LOAD TEST ON ROCK SAMPLES

PROJECT NO. 10-1111-0040-4											
TITLE URS / Hwy 401 Widening / Halton Peel											
DATE October, 2011											
Borehole Number	Sample Depth (m)	Test Type	Core Length (mm)	Core <sup>(2)</sup> Diameter (mm)	Equivalent Diameter (mm)	Ram Pressure (kPa)	Load (P) (kN)	Is Axial (MPa)	Is Diametral (MPa)	Is (50mm) (MPa)	Approx. <sup>(1)</sup> UCS (MPa)
11-401	9.98-10.05	A	15.01	46.10	29.68	3,360.00	3.19	3,616	-	2.859	66
11-401	12.75-12.79	D	36.61	45.63	-	1,030.00	0.98	-	0.469	0.450	9
11-402	6.76-6.83	A	20.50	46.69	34.91	2,880.00	2.73	2,240	-	1.906	44
11-402	8.16-8.23	D	41.88	46.85	-	660.00	0.63	-	0.285	0.277	6
<div><div><sup>(1)</sup> Is<sub>50</sub> x C (actual value will have to be confirmed by UCS testing), from ISRM ("Suggested Methods for Determining Point Load Strength", International Society for Rock Mechanics Commission on Testing Methods, Int. J. Rock. Mech. Min. Sci. and Geomechanical Abstr., Vol 22, No. 2 1985, pp. 51-60.</div><div><sup>(2)</sup> Actual distance between point load cones at time of failure.</div></div>											

## **APPENDIX C – CURRENT INVESTIGATIONS**

**C-1 Record of Borehole Sheets**

**C-2 Geotechnical Laboratory Test Results**

**C-4 Chemical Test Results**

**C-1   Record of Borehole Sheets**



## **SITE U – MULLET CREEK CULVERT REPLACEMENT**



EXPLANATION OF TERMS USED IN REPORT

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

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

COMPOSITION: SECONDARY SOIL COMPONENTS ARE DESCRIBED ON THE BASIS OF PERCENTAGE BY MASS OF THE WHOLE SAMPLE AS FOLLOWS:

PERCENT BY MASS	0 - 10	10 - 20	20 - 30	30 - 40	> 40
	TRACE	SOME	WITH	ADJECTIVE (SLTY)	AND (AND SLT)

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH [ $c_u$ ] AS FOLLOWS:

$c_u$ (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

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

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

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

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

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

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S SPLIT SPOON	T P THINWALL PISTON
W S WASH SAMPLE	O S OSTERBERG SAMPLE
S T SLOTTED TUBE SAMPLE	R C ROCK CORE
B S BLOCK SAMPLE	P H T W ADVANCED HYDRAULICALLY
C S CHUNK SAMPLE	P M T W ADVANCED MANUALLY
T W THINWALL OPEN	F S FOIL SAMPLE
F V FIELD VANE	

STRESS AND STRAIN

$u_w$ kPa	PORE WATER PRESSURE
$i$	PORE PRESSURE RATIO
$\sigma$ kPa	TOTAL NORMAL STRESS
$\sigma'$ kPa	EFFECTIVE NORMAL STRESS
$\tau$ kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$ kPa	PRINCIPAL STRESSES
$\epsilon$ %	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$ %	PRINCIPAL STRAINS
$E$ kPa	MODULUS OF LINEAR DEFORMATION
$G$ kPa	MODULUS OF SHEAR DEFORMATION
$\mu$	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

$m_v$ kPa <sup>-1</sup>	COEFFICIENT OF VOLUME CHANGE
$C_c$	COMPRESSION INDEX
$C_s$	SWELLING INDEX
$C_{\alpha}$	RATE OF SECONDARY CONSOLIDATION
$c_v$ m <sup>2</sup> /s	COEFFICIENT OF CONSOLIDATION
$H$ m	DRAINAGE PATH
$t_v$ t	TIME FACTOR
$U$ %	DEGREE OF CONSOLIDATION
$\sigma'_{vo}$ kPa	EFFECTIVE OVERBURDEN PRESSURE
$\sigma'_p$ kPa	PRECONSOLIDATION PRESSURE
$\tau_f$ kPa	SHEAR STRENGTH
$c'$ kPa	EFFECTIVE COHESION INTERCEPT
$\phi'$ °	EFFECTIVE ANGLE OF INTERNAL FRICTION
$c_u$ kPa	APPARENT COHESION INTERCEPT
$\phi_u$ °	APPARENT ANGLE OF INTERNAL FRICTION
$\tau_R$ kPa	RESIDUAL SHEAR STRENGTH
$\tau_r$ kPa	REMOULDED SHEAR STRENGTH
$S_r$	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL


$\rho_s$ kg/m <sup>3</sup>	DENSITY OF SOLID PARTICLES	$n$ %	POROSITY	$e_{max}$ %	VOID RATIO IN LOOSEST STATE
$\gamma_s$ kN/m <sup>3</sup>	UNIT WEIGHT OF SOLID PARTICLES	$w$ %	WATER CONTENT	$e_{min}$ %	VOID RATIO IN DENSEST STATE
$\rho_w$ kg/m <sup>3</sup>	DENSITY OF WATER	$S_r$ %	DEGREE OF SATURATION	$I_D$	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
$\gamma_w$ kN/m <sup>3</sup>	UNIT WEIGHT OF WATER	$w_L$ %	LIQUID LIMIT	$D$ mm	GRAIN DIAMETER
$\rho$ kg/m <sup>3</sup>	DENSITY OF SOIL	$w_p$ %	PLASTIC LIMIT	$D_n$ mm	n PERCENT - DIAMETER
$\gamma$ kN/m <sup>3</sup>	UNIT WEIGHT OF SOIL	$w_s$ %	SHRINKAGE LIMIT	$C_u$	UNIFORMITY COEFFICIENT
$\rho_d$ kg/m <sup>3</sup>	DENSITY OF DRY SOIL	$I_p$ %	PLASTICITY INDEX = $w_L - w_p$	$h$ m	HYDRAULIC HEAD OR POTENTIAL
$\gamma_d$ kN/m <sup>3</sup>	UNIT WEIGHT OF DRY SOIL	$I_L$	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	$q$ m <sup>3</sup> /s	RATE OF DISCHARGE
$\rho_{sat}$ kg/m <sup>3</sup>	DENSITY OF SATURATED SOIL	$I_C$	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	$v$ m/s	DISCHARGE VELOCITY
$\gamma_{sat}$ kN/m <sup>3</sup>	UNIT WEIGHT OF SATURATED SOIL	DTPL	DRIER THAN PLASTIC LIMIT	$i$	HYDRAULIC GRADIENT
$\rho'$ kg/m <sup>3</sup>	DENSITY OF SUBMERGED SOIL	APL	ABOUT PLASTIC LIMIT	$k$ m/s	HYDRAULIC CONDUCTIVITY
$\gamma'$ kN/m <sup>3</sup>	UNIT WEIGHT OF SUBMERGED SOIL	WTPL	WETTER THAN PLASTIC LIMIT	$j$ kN/m <sup>3</sup>	SEEPAGE FORCE
$e$ %	VOID RATIO				

RECORD OF BOREHOLE No MC-1

1 OF 1

METRIC

G.W.P. 2016-E-0004 LOCATION Coords: 4 829 334.5 N; 284 420.2 E ORIGINATED BY A.H.  
DIST Central HWY 401 BOREHOLE TYPE Hollow Stem Auger COMPILED BY N.R.  
DATUM Geodetic DATE 2017.11.14 LATITUDE 43.60367 LONGITUDE -79.75244 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE					
182.6	GROUND SURFACE															
0.0	130 mm ASPHALT over silty sand, with gravel		1	SS	55											
	(PAVEMENT FILL)		2	SS	82											
181.2	SANDY SILT, some gravel															
1.4	Compact, Brown, Dry		3	SS	19											
	CLAYEY SILT some sand, trace gravel asphalt debris		4	SS	10											
	Stiff to very stiff, Brown/grey, Moist		5	SS	9											
			6	SS	20											
			7	SS	13											
	(FILL)		8	SS	1											
176.8	CLAYEY SILT, with sand, some gravel															
5.8	Very stiff to hard, Grey, Moist to dry		9	SS	24											
			10	SS	92											
			11	SS	124/23cm											
			12	SS	105/10cm											
	(TILL)															
170.3	End of borehole		13	SS	100/8cm											
12.3	Refusal on probable bedrock															
	 Water level measured upon completion of drilling															
	NOTES: Upon extraction of hollow stem augers, borehole caved in at a depth of 11.0 m.															

ONTARIO MTO 17TF008A.GPJ ONTARIO MTO.GDT 5/17/18

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



RECORD OF BOREHOLE No MC-2												1 OF 1		METRIC		
G.W.P. 2016-E-0004			LOCATION Coords: 4 829 276.5 N; 284 420.2 E					ORIGINATED BY K.P.								
DIST Central HWY 401			BOREHOLE TYPE Solid Stem Auger					COMPILED BY N.R.								
DATUM Geodetic			DATE 2017.11.01		LATITUDE 43.60315		LONGITUDE -79.75244		CHECKED BY M.V.							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
184.2	GROUND SURFACE															
0.0	140 mm ASPHALT over silty sand, some gravel		1	SS	62											
	38 mm asphalt layer		2	SS	50/0cm											
	(PAVEMENT FILL)															
182.8	SILTY SAND, some gravel asphalt debris		3	SS	45											
1.4	Dense, Brown, Dry		4	SS	38											
	CLAYEY SILT TO SILTY CLAY some sand, trace gravel		5	SS	14											
	Stiff to very stiff, Brown/grey, Moist		6	SS	12											
	(FILL)		7	SS	17											
			8	SS	7											
			9	SS	17											
177.2	CLAYEY SILT, with sand, some gravel		10	SS	6											
7.0	Hard, Grey/reddish brown, Dry		11	SS	30											
	(TILL)		12	SS	50/15cm											
173.2	End of borehole		13	SS	50/15cm											
11.0																
NOTES: 1. Groundwater was not encountered during and upon completion of drilling 2. No cave-in was noted in the borehole upon extraction of solid stem augers.																

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

RECORD OF BOREHOLE No MC-3												1 OF 1		METRIC		
G.W.P. 2016-E-0004			LOCATION Coords: 4 829 281.6 N; 284 437.4 E					ORIGINATED BY A.H.								
DIST Central HWY 401			BOREHOLE TYPE Hollow Stem Auger					COMPILED BY K.A.								
DATUM Geodetic			DATE 2018.09.13 - 2018.09.14		LATITUDE 43.60319		LONGITUDE -79.75222		CHECKED BY M.V.							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
183.9	GROUND SURFACE															
0.0	145mm ASPHALT over Silty Sand, with gravel		1	SS	78											
	Very dense, Grey, Moist		2	SS	93											
	(PAVEMENT FILL)															
182.4	SILTY SAND, with gravel, concrete and asphalt debris		3	SS	72											
1.5	Dense to very dense, Grey, Moist		4	SS	48											
	CLAYEY SILT, some/with sand, trace gravel		5	SS	31											
	Stiff to soft, Brown to grey, Moist		6	SS	9											
	(FILL)		7	SS	3											
			8	SS	3											
			9	SS	15											
177.0	CLAYEY SILT, with sand		9A	SS	6											
6.9	Firm to hard, Grey, Moist		10	SS	15											
	(TILL)		10A	SS	35											
			11	SS	100/8cm											
173.2	SILTY SAND, with gravel, cobble fragments		12	SS	80											
10.7	Very dense, Brown, Moist		13	SS	50/0cm											
172.3	End of borehole															
11.6																
NOTES: 1. Groundwater was not encountered during and upon completion of drilling 2. Upon extraction of hollow stem augers, borehole caved-in at a depth of 7.9 m.																

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

## **SITE V – RETAINING WALL AT NORTH END OF SIXTEEN MILE CREEK (W-C17)**

EXPLANATION OF TERMS USED IN REPORT

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

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

COMPOSITION: SECONDARY SOIL COMPONENTS ARE DESCRIBED ON THE BASIS OF PERCENTAGE BY MASS OF THE WHOLE SAMPLE AS FOLLOWS:

PERCENT BY MASS	0 - 10	10 - 20	20 - 30	30 - 40	> 40
	TRACE	SOME	WITH	ADJECTIVE (SLTY)	AND (AND SLT)

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH [ $c_u$ ] AS FOLLOWS:

$c_u$ (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

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

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

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

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

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

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S SPLIT SPOON	T P THINWALL PISTON
W S WASH SAMPLE	O S OSTERBERG SAMPLE
S T SLOTTED TUBE SAMPLE	R C ROCK CORE
B S BLOCK SAMPLE	P H T W ADVANCED HYDRAULICALLY
C S CHUNK SAMPLE	P M T W ADVANCED MANUALLY
T W THINWALL OPEN	F S FOIL SAMPLE
F V FIELD VANE	

STRESS AND STRAIN

$u_w$ kPa	PORE WATER PRESSURE
$u$ kPa	PORE PRESSURE RATIO
$\sigma$ kPa	TOTAL NORMAL STRESS
$\sigma'$ kPa	EFFECTIVE NORMAL STRESS
$\tau$ kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$ kPa	PRINCIPAL STRESSES
$\epsilon$ %	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$ %	PRINCIPAL STRAINS
E kPa	MODULUS OF LINEAR DEFORMATION
G kPa	MODULUS OF SHEAR DEFORMATION
$\mu$	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

$m_v$ kPa <sup>-1</sup>	COEFFICIENT OF VOLUME CHANGE
$c_c$	COMPRESSION INDEX
$c_s$	SWELLING INDEX
$c_{\alpha}$	RATE OF SECONDARY CONSOLIDATION
$c_v$ m <sup>2</sup> /s	COEFFICIENT OF CONSOLIDATION
H m	DRAINAGE PATH
$t_v$ s	TIME FACTOR
U %	DEGREE OF CONSOLIDATION
$\sigma'_{vo}$ kPa	EFFECTIVE OVERBURDEN PRESSURE
$\sigma'_p$ kPa	PRECONSOLIDATION PRESSURE
$\tau_f$ kPa	SHEAR STRENGTH
$c'$ kPa	EFFECTIVE COHESION INTERCEPT
$\phi'$ °	EFFECTIVE ANGLE OF INTERNAL FRICTION
$c_u$ kPa	APPARENT COHESION INTERCEPT
$\phi_u$ °	APPARENT ANGLE OF INTERNAL FRICTION
$\tau_R$ kPa	RESIDUAL SHEAR STRENGTH
$\tau_r$ kPa	REMOULDED SHEAR STRENGTH
$S_r$	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

$\rho_s$ kg/m <sup>3</sup>	DENSITY OF SOLID PARTICLES	n %	POROSITY	$e_{max}$ %	VOID RATIO IN LOOSEST STATE
$\gamma_s$ kN/m <sup>3</sup>	UNIT WEIGHT OF SOLID PARTICLES	w %	WATER CONTENT	$e_{min}$ %	VOID RATIO IN DENSEST STATE
$\rho_w$ kg/m <sup>3</sup>	DENSITY OF WATER	$S_r$ %	DEGREE OF SATURATION	$I_D$	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
$\gamma_w$ kN/m <sup>3</sup>	UNIT WEIGHT OF WATER	$w_L$ %	LIQUID LIMIT	D mm	GRAIN DIAMETER
$\rho$ kg/m <sup>3</sup>	DENSITY OF SOIL	$w_p$ %	PLASTIC LIMIT	$D_n$ mm	n PERCENT - DIAMETER
$\gamma$ kN/m <sup>3</sup>	UNIT WEIGHT OF SOIL	$w_s$ %	SHRINKAGE LIMIT	$C_u$	UNIFORMITY COEFFICIENT
$\rho_d$ kg/m <sup>3</sup>	DENSITY OF DRY SOIL	$I_p$ %	PLASTICITY INDEX = $w_L - w_p$	h m	HYDRAULIC HEAD OR POTENTIAL
$\gamma_d$ kN/m <sup>3</sup>	UNIT WEIGHT OF DRY SOIL	$I_L$	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	q m <sup>3</sup> /s	RATE OF DISCHARGE
$\rho_{sat}$ kg/m <sup>3</sup>	DENSITY OF SATURATED SOIL	$I_C$	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	v m/s	DISCHARGE VELOCITY
$\gamma_{sat}$ kN/m <sup>3</sup>	UNIT WEIGHT OF SATURATED SOIL	DTPL	DRIER THAN PLASTIC LIMIT	i	HYDRAULIC GRADIENT
$\rho'$ kg/m <sup>3</sup>	DENSITY OF SUBMERGED SOIL	APL	ABOUT PLASTIC LIMIT	k m/s	HYDRAULIC CONDUCTIVITY
$\gamma'$ kN/m <sup>3</sup>	UNIT WEIGHT OF SUBMERGED SOIL	WTPL	WETTER THAN PLASTIC LIMIT	j kN/m <sup>3</sup>	SEEPAGE FORCE
e %	VOID RATIO				

RECORD OF BOREHOLE No SME-1

1 OF 2

METRIC

G.W.P. 2016-E-0004 LOCATION Coords: 4 821 180.4 N; 272 280.5 E ORIGINATED BY S.A.  
DIST Central HWY 401 BOREHOLE TYPE Hollow Stem Auger + Mud Rotary COMPILED BY A.G.  
DATUM Geodetic DATE 2018.03.14 LATITUDE 43.52984 LONGITUDE -79.90233 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT $w_p$	NATURAL MOISTURE CONTENT W	LIQUID LIMIT $w_L$	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED      + FIELD VANE									
								● QUICK TRIAXIAL      × LAB VANE									
					20   40   60   80   100					20   40   60							
206.3	GROUND SURFACE																
206.1	TOPSOIL																
0.2	CLAYEY SILT, with sand, trace/some gravel		1	SS	8		206										
	Soft to very stiff, Brown, Moist																
			2	SS	3		205										
	(FILL)																
			3	SS	17												
204.2	CLAYEY SILT, with/some sand, trace gravel						204										
2.1	Hard, Grey to reddish brown, Moist to wet		4	SS	63												
			5	SS	57		203										
			6	SS	51		202										
			7	SS	79		201										
			8	SS	61		200										
			9	SS	59		199										
			10	SS	35		197										
	(TILL)						196										
195.6	SANDY SILT TO SILTY SAND, trace gravel		11	SS	24		195										
10.7	Compact to very dense, Grey, Moist to wet		12	SS	18		194										
							193										
	(TILL)																
	clayey silt		13	SS	9		192										

Continued Next Page

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

RECORD OF BOREHOLE No SME-1												2 OF 2		METRIC		
G.W.P. 2016-E-0004				LOCATION Coords: 4 821 180.4 N; 272 280.5 E				ORIGINATED BY S.A.								
DIST Central HWY 401				BOREHOLE TYPE Hollow Stem Auger + Mud Rotary				COMPILED BY A.G.								
DATUM Geodetic				DATE 2018.03.14		LATITUDE 43.52984		LONGITUDE -79.90233		CHECKED BY M.V.						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
191.3	Continued															
	SANDY SILT TO SILTY SAND, trace gravel															
	Compact to very dense, Grey, Moist to wet (Cont.d)		14	SS	100/28cm											
	clayey silt															
			15	SS	115/28cm											
	(TILL)															
187.6	End of borehole		16	SS	108/23cm											
18.7																
	Water level observed during drilling															
	NOTES:															
	1. Upon extraction of hollow stem augers, the borehole caved in at a depth of 18.3 m.															
	2. Borehole charged with drilling mud, thus groundwater level could not be established upon completion of drilling.															

RECORD OF BOREHOLE No SME-3												1 OF 1		METRIC		
G.W.P. 2016-E-0004				LOCATION Coords: 4 821 166.4 N; 272 273.7 E				ORIGINATED BY A.H.								
DIST Central HWY 401				BOREHOLE TYPE Hollow Stem Auger				COMPILED BY A.G.								
DATUM Geodetic				DATE 2017.11.05 - 2017.11.06		LATITUDE 43.52971		LONGITUDE -79.90241		CHECKED BY M.V.						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
208.1	GROUND SURFACE															
0.0	100 mm ASPHALT over silty sand, with gravel (PAVEMENT FILL)		1	SS	41											
207.3	SILTY SAND, with gravel		2	SS	43											
0.8	Compact to dense, Brown, Moist		3	SS	17											
	CLAYEY SILT, with sand, trace gravel		4	SS	22											
	Very stiff, Brown, Moist (FILL)															
205.0	CLAYEY SILT, with/some sand, trace gravel		5	SS	36											
3.1	Hard, Grey, Dry to moist		6	SS	60											
			7	SS	121											
			8	SS	103											
			9	SS	50											
			10	SS	47											
			11	SS	42											
	(TILL)		12	SS	24											
195.7	SANDY SILT TO SILTY SAND															
12.4	Compact, Grey, Wet (TILL)															
195.4	End of borehole															
12.7																
	Water level observed during drilling															
	Water level measured after completion of drilling															
	NOTE: Upon extraction of hollow stem augers, the borehole caved in at a depth of 10.7 m															

RECORD OF BOREHOLE No SME-5										1 OF 2		METRIC					
G.W.P. 2016-E-0004			LOCATION Coords: 4 821 182.9 N; 272 251.7 E				ORIGINATED BY A.H.										
DIST Central HWY 401			BOREHOLE TYPE Hollow Stem Auger + Mud Rotary				COMPILED BY K.A.										
DATUM Geodetic			DATE 2018.09.05		LATITUDE 43.52986		LONGITUDE -79.902683		CHECKED BY M.V.								
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>	WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
209.0	GROUND SURFACE																
0.0	50mm ASPHALT over Silty Sand, some gravel, clayey silt inclusions		1	SS	16												
	Compact, Brown, Dry to moist (PAVEMENT FILL)		2	SS	15												
207.5	CLAYEY SILT, some sand, trace gravel		3	SS	14												
1.5	Stiff to hard, Brown, Moist (TILL)		4	SS	16												
			5	SS	46												
			6	SS	113												
			7	SS	32												
			8	SS	29												
			9	SS	28												
			10	SS	12												
			11	SS	36												
196.8	SILTY SAND TO SANDY SILT, trace/some clay, trace gravel		12	SS	46												
12.2	Dense, Grey, Moist to wet (TILL)		13	SS	47												
194.0																	

Continued Next Page

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

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RECORD OF BOREHOLE No SME-5										2 OF 2		METRIC					
G.W.P. 2016-E-0004			LOCATION Coords: 4 821 182.9 N; 272 251.7 E				ORIGINATED BY A.H.										
DIST Central HWY 401			BOREHOLE TYPE Hollow Stem Auger + Mud Rotary				COMPILED BY K.A.										
DATUM Geodetic			DATE 2018.09.05		LATITUDE 43.52986		LONGITUDE -79.902683		CHECKED BY M.V.								
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>	WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
194.0	Continued																
15.0	SILTY SAND TO SANDY SILT, trace clay, trace gravel		14	SS	59												
	Very dense, Grey, Moist to wet (TILL)																
			15	SS	73												
190.7	CLAYEY SILT, some/with sand, trace/some gravel		16	SS	100/23cm												
18.3	Hard, Brown, Moist to wet (TILL)																
			17	SS	100/8cm												
187.4	End of borehole		18	SS	85/15cm												
21.6																	
	NOTES: 1. Borehole charged with drilling mud a depth of 3.1 m, thus groundwater level could not be established upon completion of drilling. 2. No cave-in was noted in the borehole upon extraction of hollow stem augers.																

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

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## **SITE W – NON-STRUCTURAL CULVERT (W-C18)**

## Foundation Design

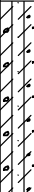

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○<sup>3%</sup> STRAIN AT FAILURE

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

Continued Next Page

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RECORD OF BOREHOLE No C18-2										2 OF 2		METRIC																						
G.W.P. 2016-E-0004			LOCATION Coords: 4 820 817.4 N; 271 845.4 E					ORIGINATED BY A.H.																										
DIST Central HWY 401			BOREHOLE TYPE Hollow Stem Auger					COMPILED BY K.A.																										
DATUM Geodetic			DATE 2018.09.12		LATITUDE 43.52655		LONGITUDE -79.9075		CHECKED BY M.V.																									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT CONTENT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL																	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%) w <sub>p</sub> w w <sub>L</sub>																					
192.1	Continued						192																											
15.0	CLAYEY SILT, some/trace sand, trace gravel		15A																															
	Hard, Brown/grey, Moist		15B	SS	32																													
	(TILL)																																	
190.0			16A																															
17.1	SILT, some sand, trace gravel						190																											
189.7	Very dense, Grey/brown, Wet		16B	SS	66																													
17.4	(TILL)																																	
	End of borehole																																	
<div>NOTES:</div> <div>1. Groundwater was not encountered during or upon completion of drilling</div> <div>2. No cave-in was noted in the borehole upon extraction of hollow stem augers.</div>																																		

## **SITE X – NON-STRUCTURAL CULVERT (W-C19)**

EXPLANATION OF TERMS USED IN REPORT

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

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

**COMPOSITION:** SECONDARY SOIL COMPONENTS ARE DESCRIBED ON THE BASIS OF PERCENTAGE BY MASS OF THE WHOLE SAMPLE AS FOLLOWS:

PERCENT BY MASS	0 - 10	10 - 20	20 - 30	30 - 40	> 40
	TRACE	SOME	WITH	ADJECTIVE (SLTY)	AND (AND SLT)

**CONSISTENCY:** COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH [ $c_u$ ] AS FOLLOWS:

$c_u$ (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

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

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

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

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

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

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

**JOINTING AND BEDDING:**

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S SPLIT SPOON	T P THINWALL PISTON
W S WASH SAMPLE	O S OSTERBERG SAMPLE
S T SLOTTED TUBE SAMPLE	R C ROCK CORE
B S BLOCK SAMPLE	P H T W ADVANCED HYDRAULICALLY
C S CHUNK SAMPLE	P M T W ADVANCED MANUALLY
T W THINWALL OPEN	F S FOIL SAMPLE
F V FIELD VANE	

STRESS AND STRAIN

$u_w$ kPa	PORE WATER PRESSURE
$u$ kPa	PORE PRESSURE RATIO
$\sigma$ kPa	TOTAL NORMAL STRESS
$\sigma'$ kPa	EFFECTIVE NORMAL STRESS
$\tau$ kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$ kPa	PRINCIPAL STRESSES
$\epsilon$ %	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$ %	PRINCIPAL STRAINS
$E$ kPa	MODULUS OF LINEAR DEFORMATION
$G$ kPa	MODULUS OF SHEAR DEFORMATION
$\mu$	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

$m_v$ kPa <sup>-1</sup>	COEFFICIENT OF VOLUME CHANGE
$C_c$	COMPRESSION INDEX
$C_s$	SWELLING INDEX
$C_{\alpha}$	RATE OF SECONDARY CONSOLIDATION
$c_v$ m <sup>2</sup> /s	COEFFICIENT OF CONSOLIDATION
$H$ m	DRAINAGE PATH
$t_v$ s	TIME FACTOR
$U$ %	DEGREE OF CONSOLIDATION
$\sigma'_{vo}$ kPa	EFFECTIVE OVERBURDEN PRESSURE
$\sigma'_p$ kPa	PRECONSOLIDATION PRESSURE
$\tau_f$ kPa	SHEAR STRENGTH
$c'$ kPa	EFFECTIVE COHESION INTERCEPT
$\phi'$ °	EFFECTIVE ANGLE OF INTERNAL FRICTION
$c_u$ kPa	APPARENT COHESION INTERCEPT
$\phi_u$ °	APPARENT ANGLE OF INTERNAL FRICTION
$\tau_R$ kPa	RESIDUAL SHEAR STRENGTH
$\tau_r$ kPa	REMOULDED SHEAR STRENGTH
$S_r$	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

$\rho_s$ kg/m <sup>3</sup>	DENSITY OF SOLID PARTICLES	$n$ %	POROSITY	$e_{max}$ %	VOID RATIO IN LOOSEST STATE
$\gamma_s$ kN/m <sup>3</sup>	UNIT WEIGHT OF SOLID PARTICLES	$w$ %	WATER CONTENT	$e_{min}$ %	VOID RATIO IN DENSEST STATE
$\rho_w$ kg/m <sup>3</sup>	DENSITY OF WATER	$S_r$ %	DEGREE OF SATURATION	$I_D$	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
$\gamma_w$ kN/m <sup>3</sup>	UNIT WEIGHT OF WATER	$w_L$ %	LIQUID LIMIT	$D$ mm	GRAIN DIAMETER
$\rho$ kg/m <sup>3</sup>	DENSITY OF SOIL	$w_p$ %	PLASTIC LIMIT	$D_n$ mm	n PERCENT - DIAMETER
$\gamma$ kN/m <sup>3</sup>	UNIT WEIGHT OF SOIL	$w_s$ %	SHRINKAGE LIMIT	$C_u$	UNIFORMITY COEFFICIENT
$\rho_d$ kg/m <sup>3</sup>	DENSITY OF DRY SOIL	$I_p$ %	PLASTICITY INDEX = $w_L - w_p$	$h$ m	HYDRAULIC HEAD OR POTENTIAL
$\gamma_d$ kN/m <sup>3</sup>	UNIT WEIGHT OF DRY SOIL	$I_L$	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	$q$ m <sup>3</sup> /s	RATE OF DISCHARGE
$\rho_{sat}$ kg/m <sup>3</sup>	DENSITY OF SATURATED SOIL	$I_C$	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	$v$ m/s	DISCHARGE VELOCITY
$\gamma_{sat}$ kN/m <sup>3</sup>	UNIT WEIGHT OF SATURATED SOIL	DTPL	DRIER THAN PLASTIC LIMIT	$i$ l	HYDRAULIC GRADIENT
$\rho'$ kg/m <sup>3</sup>	DENSITY OF SUBMERGED SOIL	APL	ABOUT PLASTIC LIMIT	$k$ m/s	HYDRAULIC CONDUCTIVITY
$\gamma'$ kN/m <sup>3</sup>	UNIT WEIGHT OF SUBMERGED SOIL	WTPL	WETTER THAN PLASTIC LIMIT	$j$ kN/m <sup>3</sup>	SEEPAGE FORCE
$e$ %	VOID RATIO				

RECORD OF BOREHOLE No C19-1										1 OF 2		METRIC			
G.W.P. 2016-E-0004				LOCATION Coords: 4 820 842.2 N; 271 655.2 E				ORIGINATED BY A.H.							
DIST Central HWY 401				BOREHOLE TYPE Hollow Stem Auger + Mud Rotary				COMPILED BY K.A.							
DATUM Geodetic				DATE 2018.09.06 - 2018.09.07				LATITUDE 43.52676		LONGITUDE -79.91		CHECKED BY M.V.			
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT $w_p$	NATURAL MOISTURE CONTENT $w$	LIQUID LIMIT $w_L$	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE							
207.4	GROUND SURFACE														
207.3 0.1	TOPSOIL CLAYEY SILT, some sand, trace gravel Stiff to very stiff, Brown to grey, Moist		1	SS	10										
206.3 1.1	(FILL) CLAYEY SILT, trace/some sand, trace gravel Stiff to hard, Brown to grey, Moist to wet		2	SS	17										
	(TILL)		3	SS	24										
			4	SS	30										
			5	SS	20										
			6	SS	14										
			7	SS	8										
			8	SS	13										
			9	SS	5										
				VANE											
			10	SS	18										
			11	SS	39										
			12	SS	35										
			13	SS	35										
193.6 13.8	SILT, trace sand Compact, Grey, Wet		14	SS	12										
192.4	(TILL)														


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

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

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RECORD OF BOREHOLE No C19-2										2 OF 2		METRIC							
G.W.P. 2016-E-0004			LOCATION Coords: 4 820 773.5 N; 271 689.4 E					ORIGINATED BY A.H.											
DIST Central HWY 401			BOREHOLE TYPE Hollow Stem Auger + Mud Rotary					COMPILED BY K.A.											
DATUM Geodetic			DATE 2018.09.11 - 2018.09.12		LATITUDE 43.52615		LONGITUDE -79.90944		CHECKED BY M.V.										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT CONTENT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%) w <sub>p</sub> w w <sub>L</sub>						
192.2	Continued						192												
15.0	CLAYEY SILT, some sand, trace gravel Hard, Grey, Moist (TILL)		15	SS	62		191												
189.8			16	SS	56		190												
17.4	End of borehole																		
<div>NOTES: 1. Borehole charged with drilling mud below a depth of 3.7 m, thus groundwater level could not be established upon completion of drilling. 2. No cave-in was noted in the borehole upon extraction of hollow stem augers.</div>																			

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## **SITE Y – NON-STRUCTURAL CULVERT (W-C20)**

EXPLANATION OF TERMS USED IN REPORT

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

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

COMPOSITION: SECONDARY SOIL COMPONENTS ARE DESCRIBED ON THE BASIS OF PERCENTAGE BY MASS OF THE WHOLE SAMPLE AS FOLLOWS:

PERCENT BY MASS	0 - 10	10 - 20	20 - 30	30 - 40	> 40
	TRACE	SOME	WITH	ADJECTIVE (SLTY)	AND (AND SLT)

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

$c_u$ (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

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

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

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

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

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

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S SPLIT SPOON	T P THINWALL PISTON
W S WASH SAMPLE	O S OSTERBERG SAMPLE
S T SLOTTED TUBE SAMPLE	R C ROCK CORE
B S BLOCK SAMPLE	P H T W ADVANCED HYDRAULICALLY
C S CHUNK SAMPLE	P M T W ADVANCED MANUALLY
T W THINWALL OPEN	F S FOIL SAMPLE
F V FIELD VANE	

STRESS AND STRAIN

$u_w$ kPa	PORE WATER PRESSURE
$\sigma_u$ kPa	PORE PRESSURE RATIO
$\sigma$ kPa	TOTAL NORMAL STRESS
$\sigma'$ kPa	EFFECTIVE NORMAL STRESS
$\tau$ kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$ kPa	PRINCIPAL STRESSES
$\epsilon$ %	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$ %	PRINCIPAL STRAINS
E kPa	MODULUS OF LINEAR DEFORMATION
G kPa	MODULUS OF SHEAR DEFORMATION
$\mu$	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

$m_v$ kPa <sup>-1</sup>	COEFFICIENT OF VOLUME CHANGE
$c_c$	COMPRESSION INDEX
$c_s$	SWELLING INDEX
$c_{\alpha}$	RATE OF SECONDARY CONSOLIDATION
$c_v$ m <sup>2</sup> /s	COEFFICIENT OF CONSOLIDATION
H m	DRAINAGE PATH
$t_v$ s	TIME FACTOR
U %	DEGREE OF CONSOLIDATION
$\sigma'_{vo}$ kPa	EFFECTIVE OVERBURDEN PRESSURE
$\sigma'_p$ kPa	PRECONSOLIDATION PRESSURE
$\tau_f$ kPa	SHEAR STRENGTH
$c'$ kPa	EFFECTIVE COHESION INTERCEPT
$\phi'$ °	EFFECTIVE ANGLE OF INTERNAL FRICTION
$c_u$ kPa	APPARENT COHESION INTERCEPT
$\phi_u$ °	APPARENT ANGLE OF INTERNAL FRICTION
$\tau_R$ kPa	RESIDUAL SHEAR STRENGTH
$\tau_r$ kPa	REMOULDED SHEAR STRENGTH
$S_r$	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

$\rho_s$ kg/m <sup>3</sup>	DENSITY OF SOLID PARTICLES	n %	POROSITY	$e_{max}$ %	VOID RATIO IN LOOSEST STATE
$\gamma_s$ kN/m <sup>3</sup>	UNIT WEIGHT OF SOLID PARTICLES	w %	WATER CONTENT	$e_{min}$ %	VOID RATIO IN DENSEST STATE
$\rho_w$ kg/m <sup>3</sup>	DENSITY OF WATER	$S_r$ %	DEGREE OF SATURATION	$I_D$	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
$\gamma_w$ kN/m <sup>3</sup>	UNIT WEIGHT OF WATER	$w_L$ %	LIQUID LIMIT	D mm	GRAIN DIAMETER
$\rho$ kg/m <sup>3</sup>	DENSITY OF SOIL	$w_p$ %	PLASTIC LIMIT	$D_n$ mm	n PERCENT - DIAMETER
$\gamma$ kN/m <sup>3</sup>	UNIT WEIGHT OF SOIL	$w_s$ %	SHRINKAGE LIMIT	$C_u$	UNIFORMITY COEFFICIENT
$\rho_d$ kg/m <sup>3</sup>	DENSITY OF DRY SOIL	$I_p$ %	PLASTICITY INDEX = $w_L - w_p$	h m	HYDRAULIC HEAD OR POTENTIAL
$\gamma_d$ kN/m <sup>3</sup>	UNIT WEIGHT OF DRY SOIL	$I_L$	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	q m <sup>3</sup> /s	RATE OF DISCHARGE
$\rho_{sat}$ kg/m <sup>3</sup>	DENSITY OF SATURATED SOIL	$I_C$	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	v m/s	DISCHARGE VELOCITY
$\gamma_{sat}$ kN/m <sup>3</sup>	UNIT WEIGHT OF SATURATED SOIL	DTPL	DRIER THAN PLASTIC LIMIT	i	HYDRAULIC GRADIENT
$\rho'$ kg/m <sup>3</sup>	DENSITY OF SUBMERGED SOIL	APL	ABOUT PLASTIC LIMIT	k m/s	HYDRAULIC CONDUCTIVITY
$\gamma'$ kN/m <sup>3</sup>	UNIT WEIGHT OF SUBMERGED SOIL	WTPL	WETTER THAN PLASTIC LIMIT	j kN/m <sup>3</sup>	SEEPAGE FORCE
e %	VOID RATIO				

RECORD OF BOREHOLE No C20-1

1 OF 2

METRIC

G.W.P. 2016-E-0004 LOCATION Coords: 4 820 791.3 N; 271 344.9 E ORIGINATED BY A.H.  
DIST Central HWY 401 BOREHOLE TYPE Hollow Stem Auger + Mud Rotary COMPILED BY K.A.  
DATUM Geodetic DATE 2018.09.06 LATITUDE 43.52629 LONGITUDE -79.91388 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								○ UNCONFINED	+ FIELD VANE					
								● QUICK TRIAXIAL	× LAB VANE					
210.0	GROUND SURFACE													
209.8	TOPSOIL													
0.2	CLAYEY SILT, some sand, trace gravel Firm, Brown, Moist (FILL)		1	SS	4									
209.2	CLAYEY SILT, some sand, trace gravel Stiff to hard, Brown to grey, Moist to wet (TILL)		2	SS	21									
0.8			3	SS	27									
			4	SS	24									
			5	SS	17									
			6	SS	16									
			7	SS	11									
			8	SS	11									
			9	SS	10									
			10	SS	7									
			11	SS	4									
				VANE										
			12	SS	25									
			13	SS	40									
			14	SS	60									
195.0														

ONTARIO MTO 17TF008A.GPJ ONTARIO MTO.GDT 11/5/18


Continued Next Page

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

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

Continued Next Page



RECORD OF BOREHOLE No C20-2										2 OF 2		METRIC				
G.W.P. 2016-E-0004			LOCATION Coords: 4 820 739.5 N; 271 364.8 E					ORIGINATED BY A.H.								
DIST Central HWY 401			BOREHOLE TYPE Hollow Stem Auger + Mud Rotary					COMPILED BY K.A.								
DATUM Geodetic			DATE 2018.09.11		LATITUDE 43.52583		LONGITUDE -79.91361		CHECKED BY M.V.							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT CONTENT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) w <sub>p</sub> w w <sub>L</sub>				
195.6	Continued						195									15 22 47 16
15.0	CLAYEY SILT, with sand, some gravel		15	SS	70											
	Hard, Brown, Wet															
	(TILL)															
193.2			16	SS	58		194									
17.4	End of borehole															
<div>NOTES:</div> <div>1. Borehole charged with drilling mud below a depth of 3.1 m, thus groundwater level could not be established upon completion of drilling.</div> <div>2. No cave-in was noted in the borehole upon extraction of hollow stem augers.</div>																

ONTARIO MTO 17TF008A.GPJ ONTARIO MTO.GDT 10/24/18

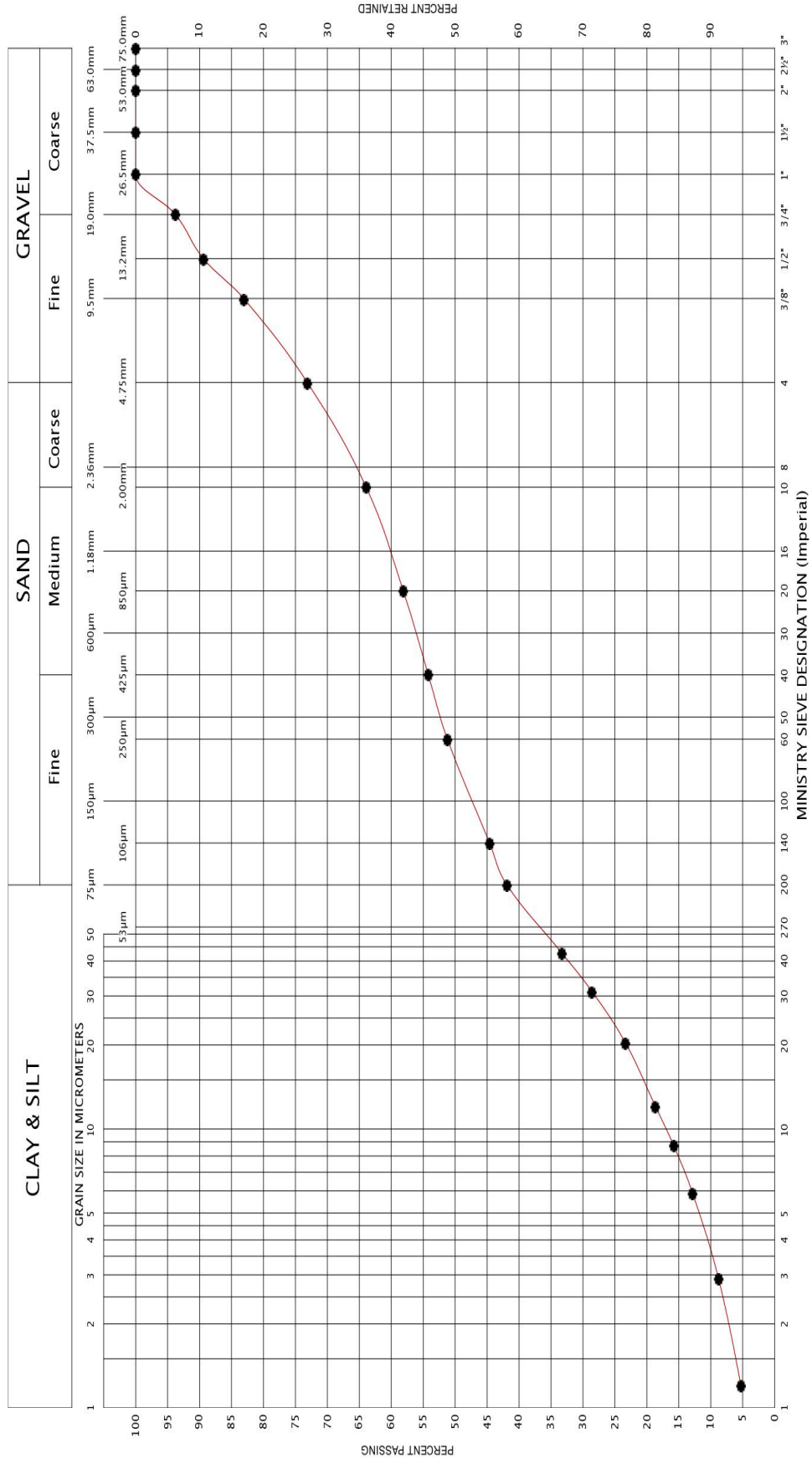
**C-2   Geotechnical Laboratory Test Results**



## **SITE U – MULLET CREEK CULVERT REPLACEMENT**



# UNIFIED SOIL CLASSIFICATION SYSTEM



<b>LEGEND</b>	<b>BH</b>	MC-3
	<b>SAMPLE</b>	12
	<b>SYMBOL</b>	●



Ontario

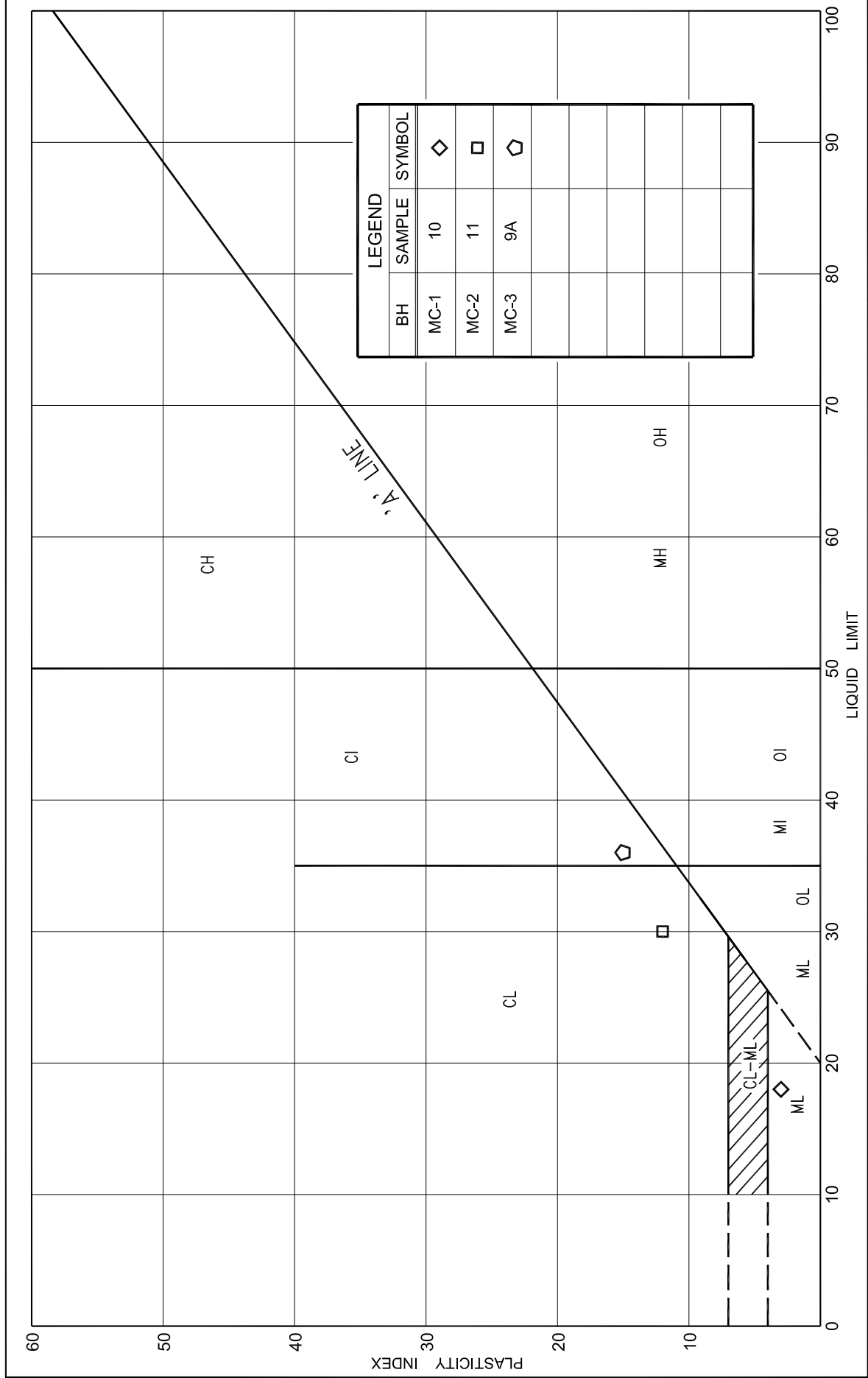
## GRAIN SIZE DISTRIBUTION




### SILTY SAND (TILL)

FIG No.: GS-U-3

HWY : 401

GWP	2016-E-0004
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LEGEND		
BH	SAMPLE	SYMBOL
MC-1	10	
MC-2	11	
MC-3	9A	



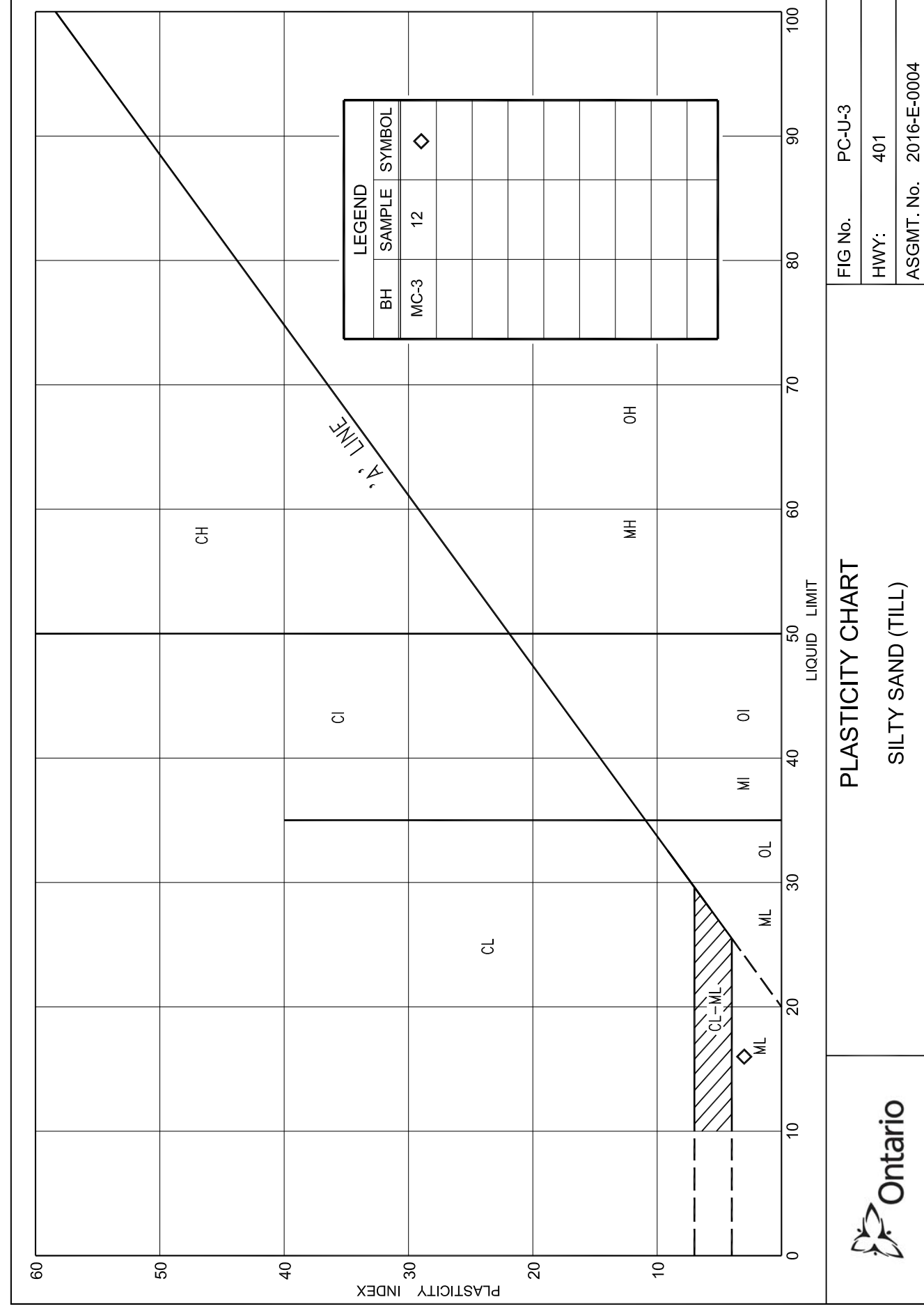
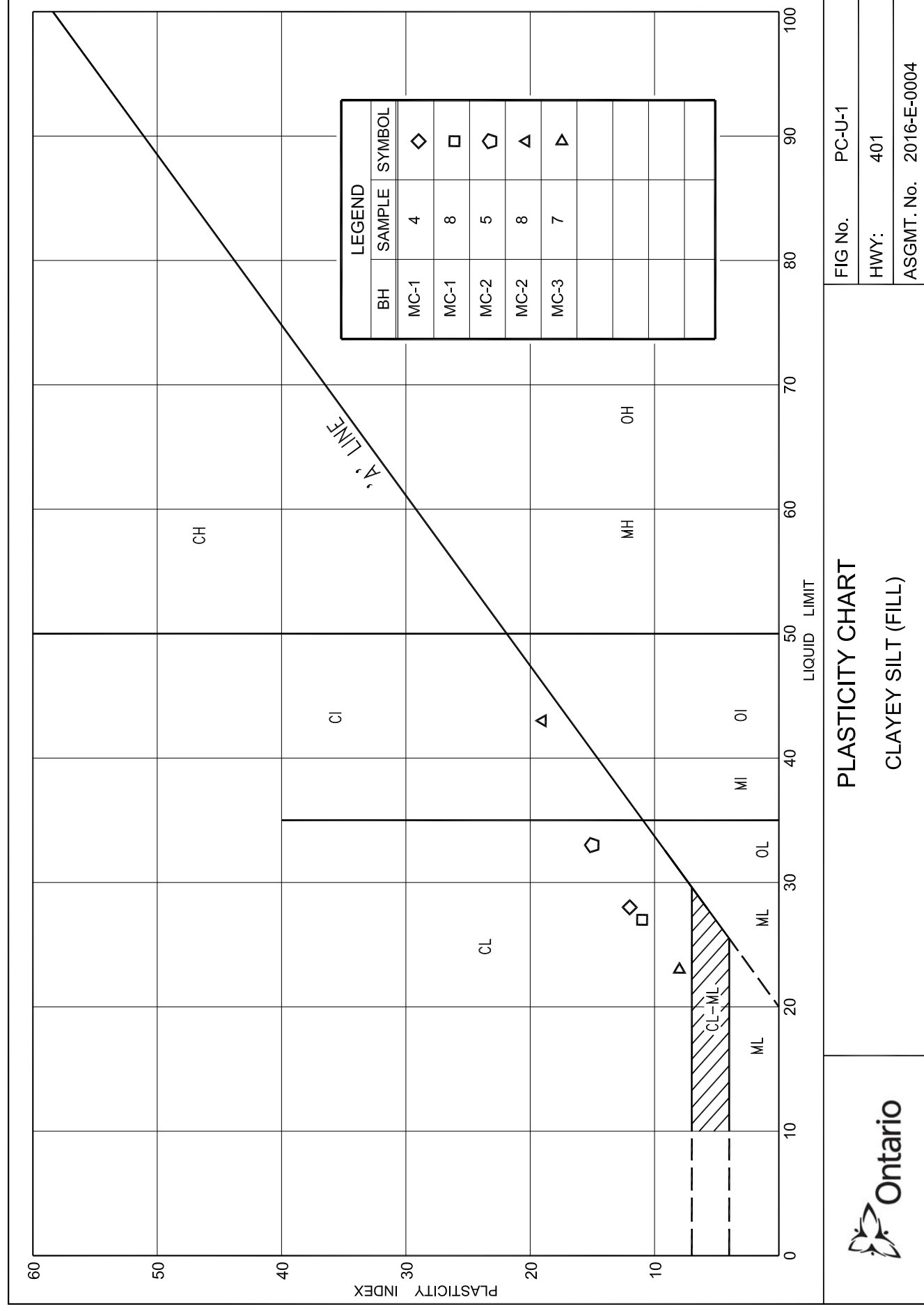
Ontario

# PLASTICITY CHART

FIG No. PC-U-2

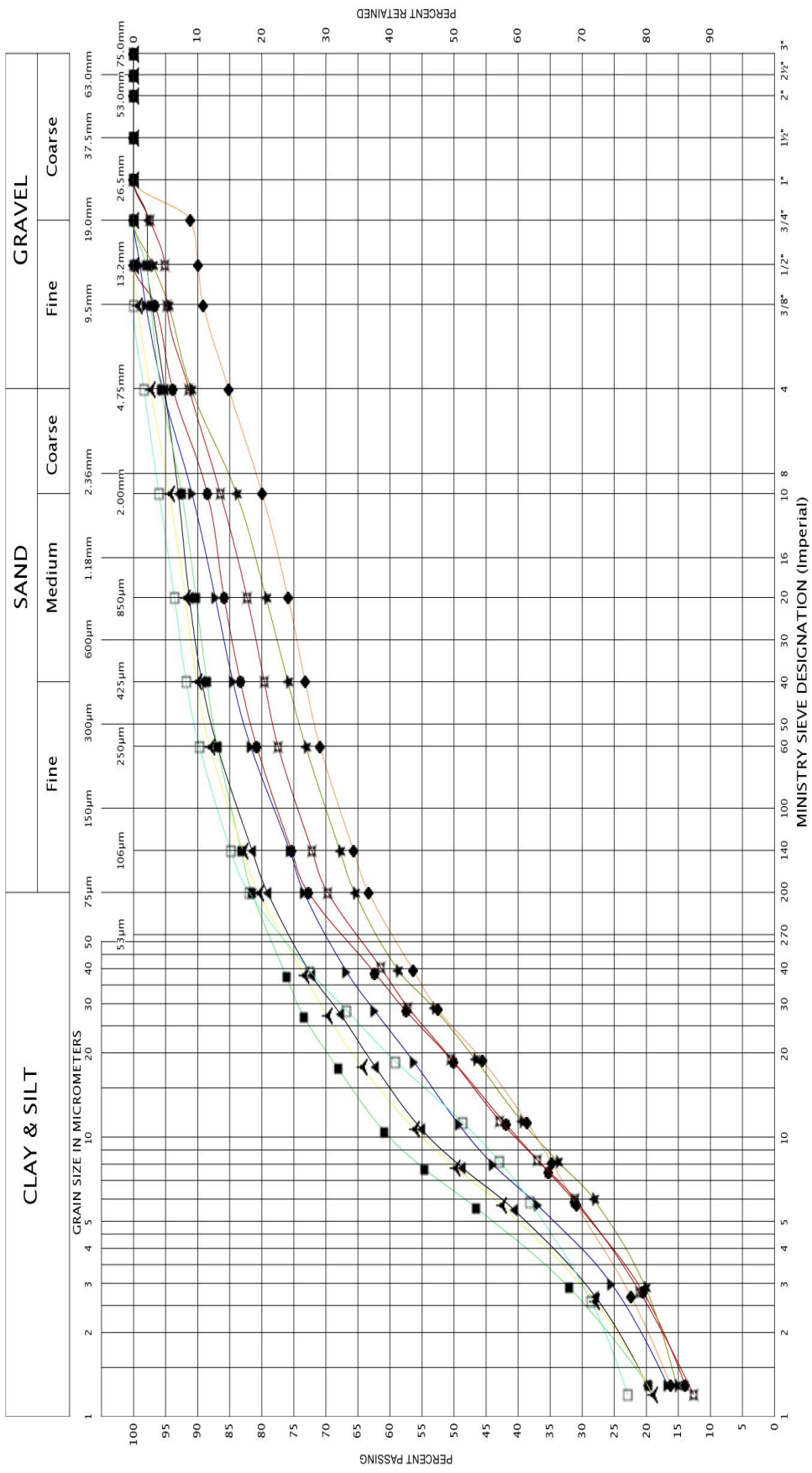
HWY: 401

ASGMT. No. 2016-E-0004



## **SITE V – RETAINING WALL AT NORTH END OF SIXTEEN MILE CREEK (W-C17)**

# UNIFIED SOIL CLASSIFICATION SYSTEM



BH		SME-1	SME-1	SME-3	SME-3	SME-5	SME-5	SME-5	SME-5
LEGEND	SAMPLE	4	9	7	9	10	4	7	8
	SYMBOL	●	▲	★	▼	■	□	◆	✖



Ontario

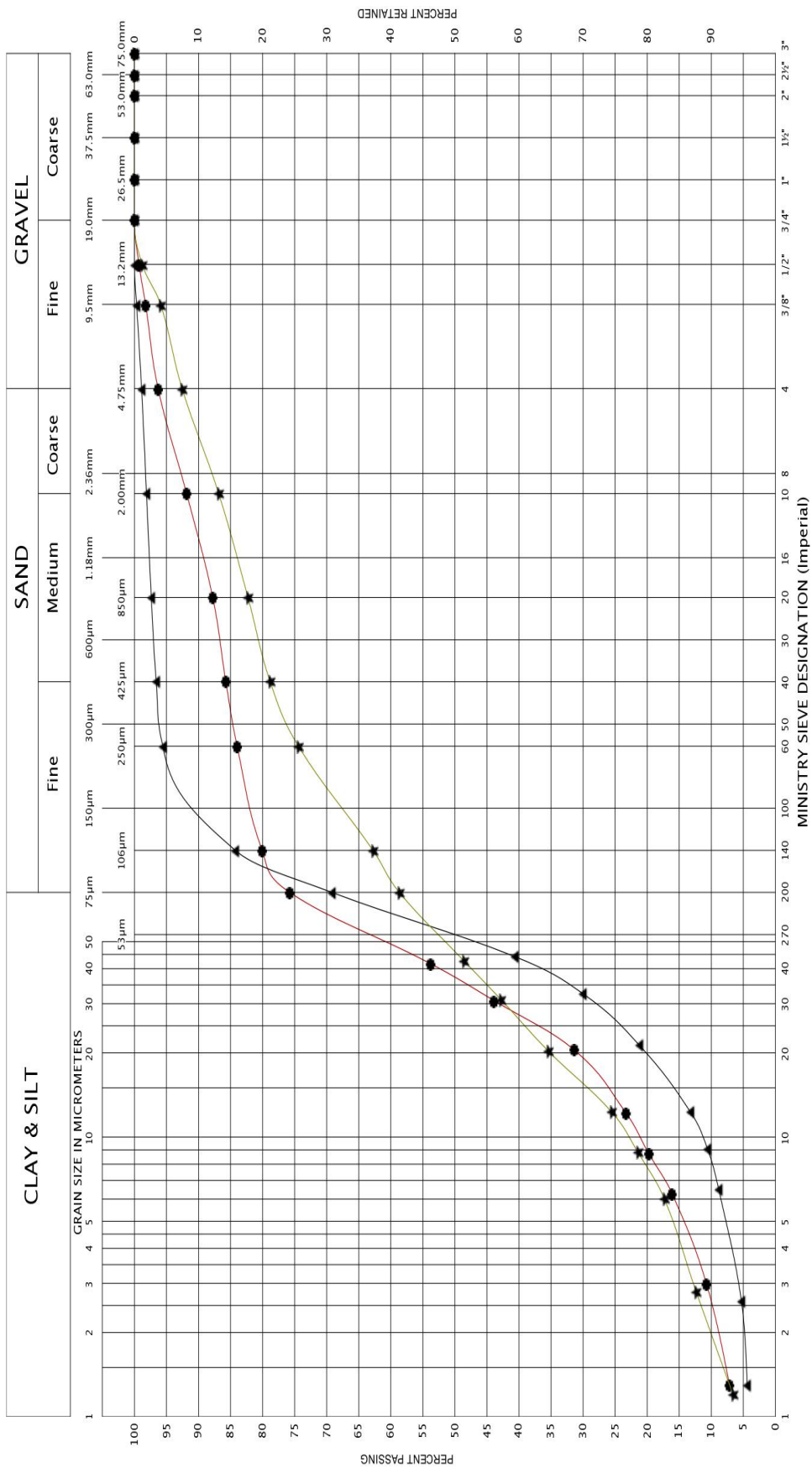
**GRAIN SIZE DISTRIBUTION**  
CLAYEY SILT (TILL)

FIG No.: GS-V-1

HWY : 401

GWP	2016-E-0004
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# UNIFIED SOIL CLASSIFICATION SYSTEM



<b>LEGEND</b>	<b>BH</b>	SME-1	SME-1	SME-5
	<b>SAMPLE</b>	12	14	15
	<b>SYMBOL</b>	▲	●	✱



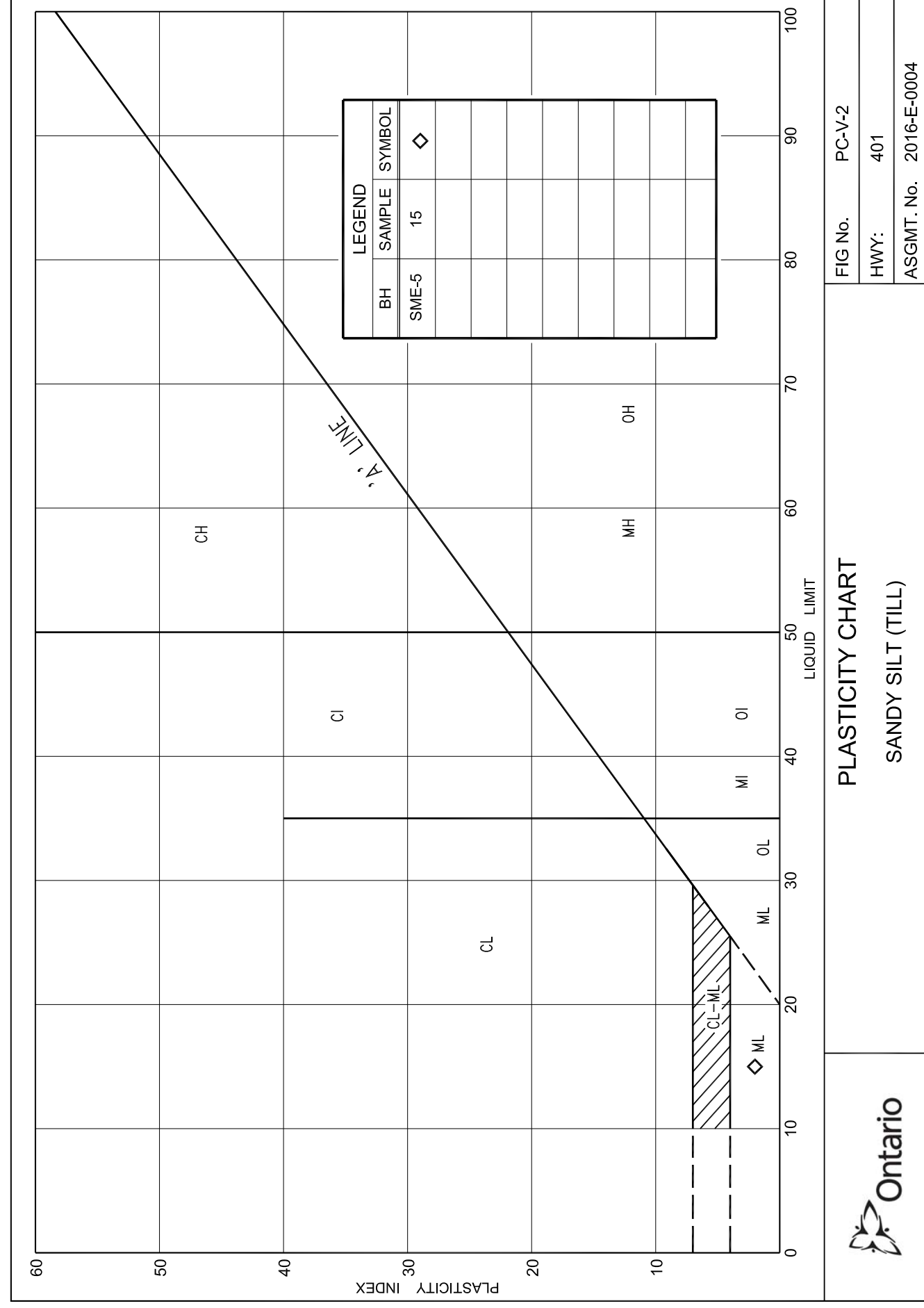
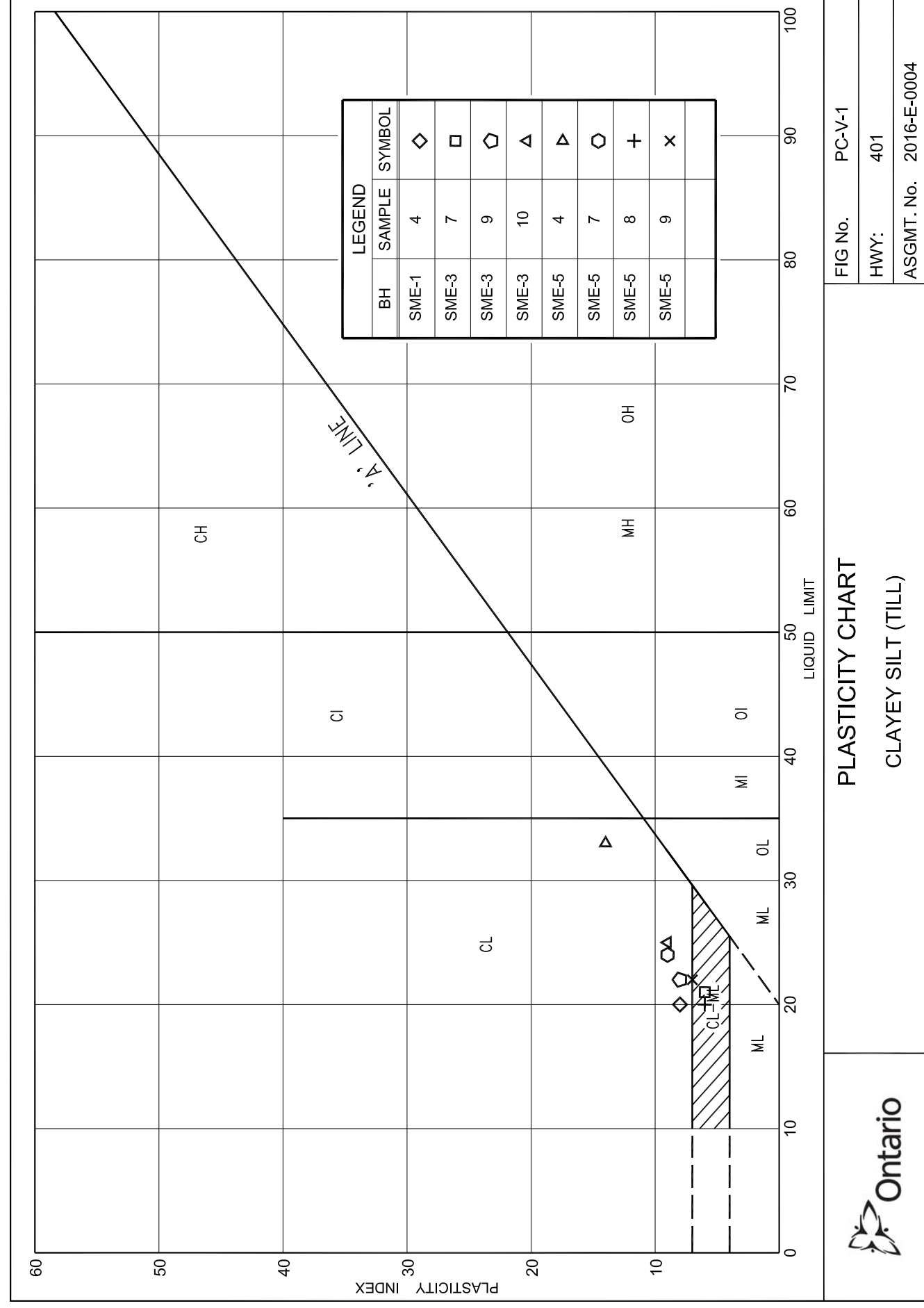
**GRAIN SIZE DISTRIBUTION**  
SILTY SAND TO SANDY SILT (TILL)

FIG No.: GS-V-2

HWY : 401

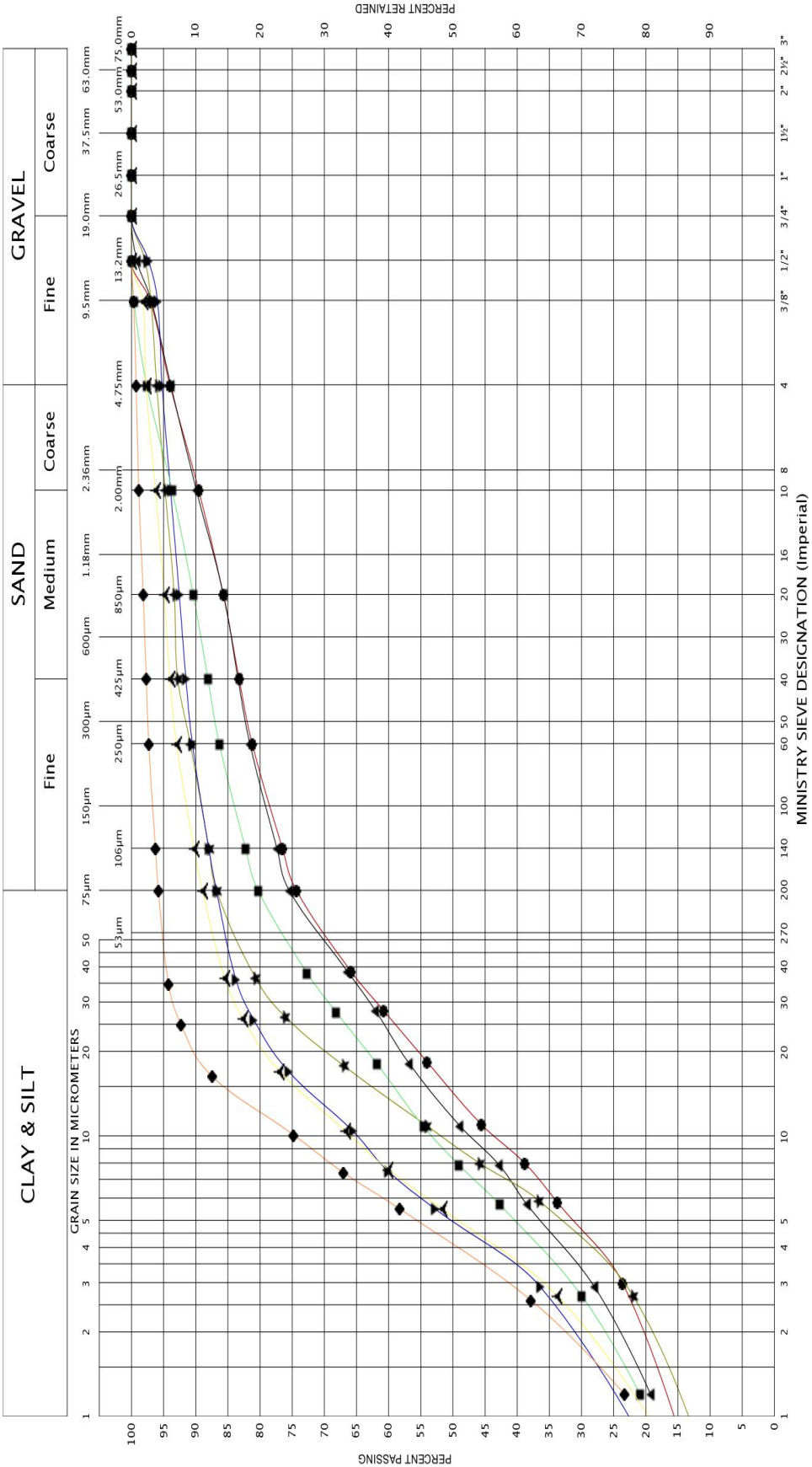
GWP	2016-E-0004
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## **SITE W – NON-STRUCTURAL CULVERT (W-C18)**

UNIFIED SOIL CLASSIFICATION SYSTEM



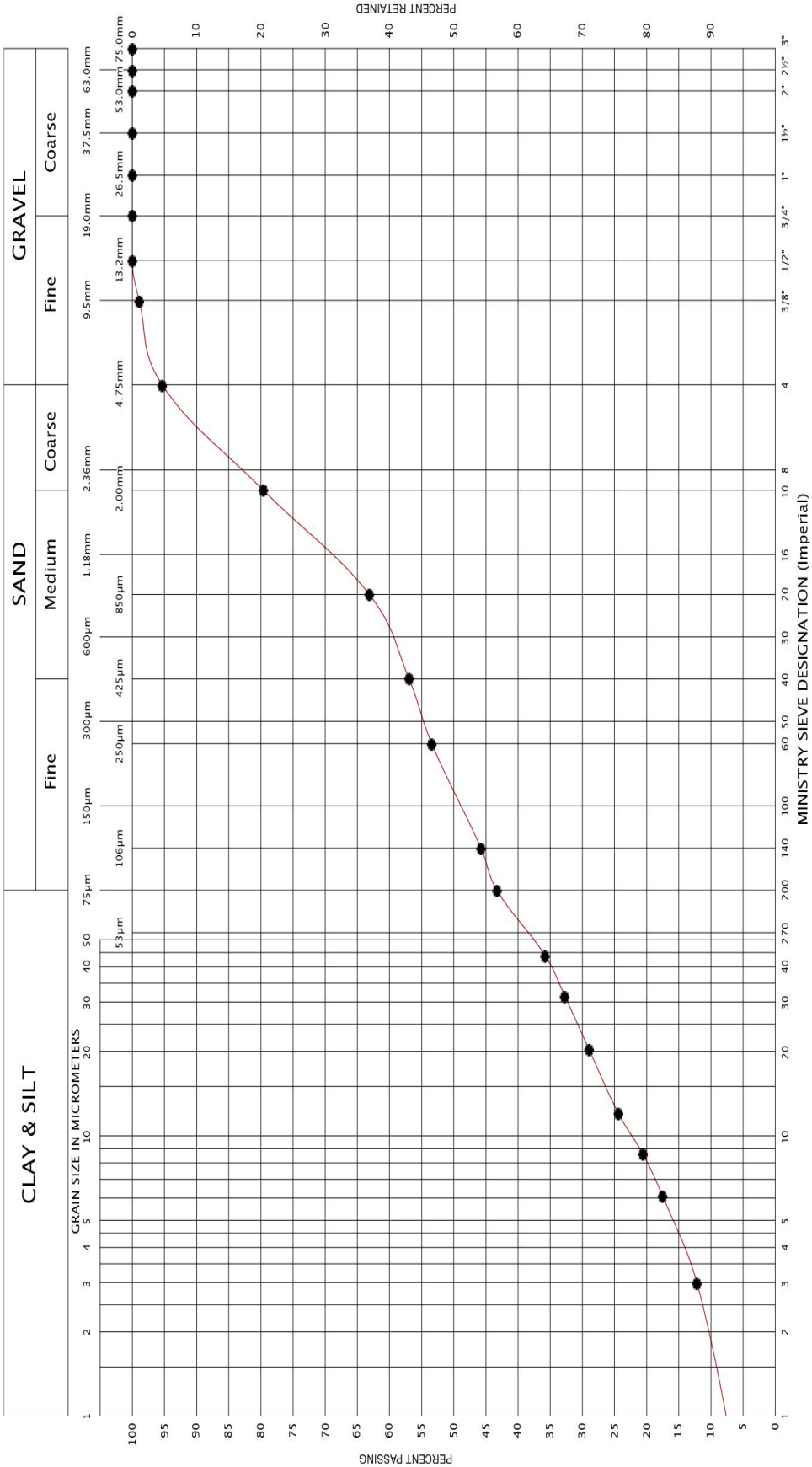
LEGEND	BH	C18-1	C18-1	C18-1	C18-1	C18-2	C18-2	C18-2	C18-2
	SAMPLE	4	8	11	15	5	11	13	
SYMBOL		▲	●	▼	★	■	▲	◆	



GRAIN SIZE DISTRIBUTION  
CLAYEY SILT (TILL)

FIG No.: GS-W-1  
HWY : 401  
GWP 2016-E-0004

UNIFIED SOIL CLASSIFICATION SYSTEM



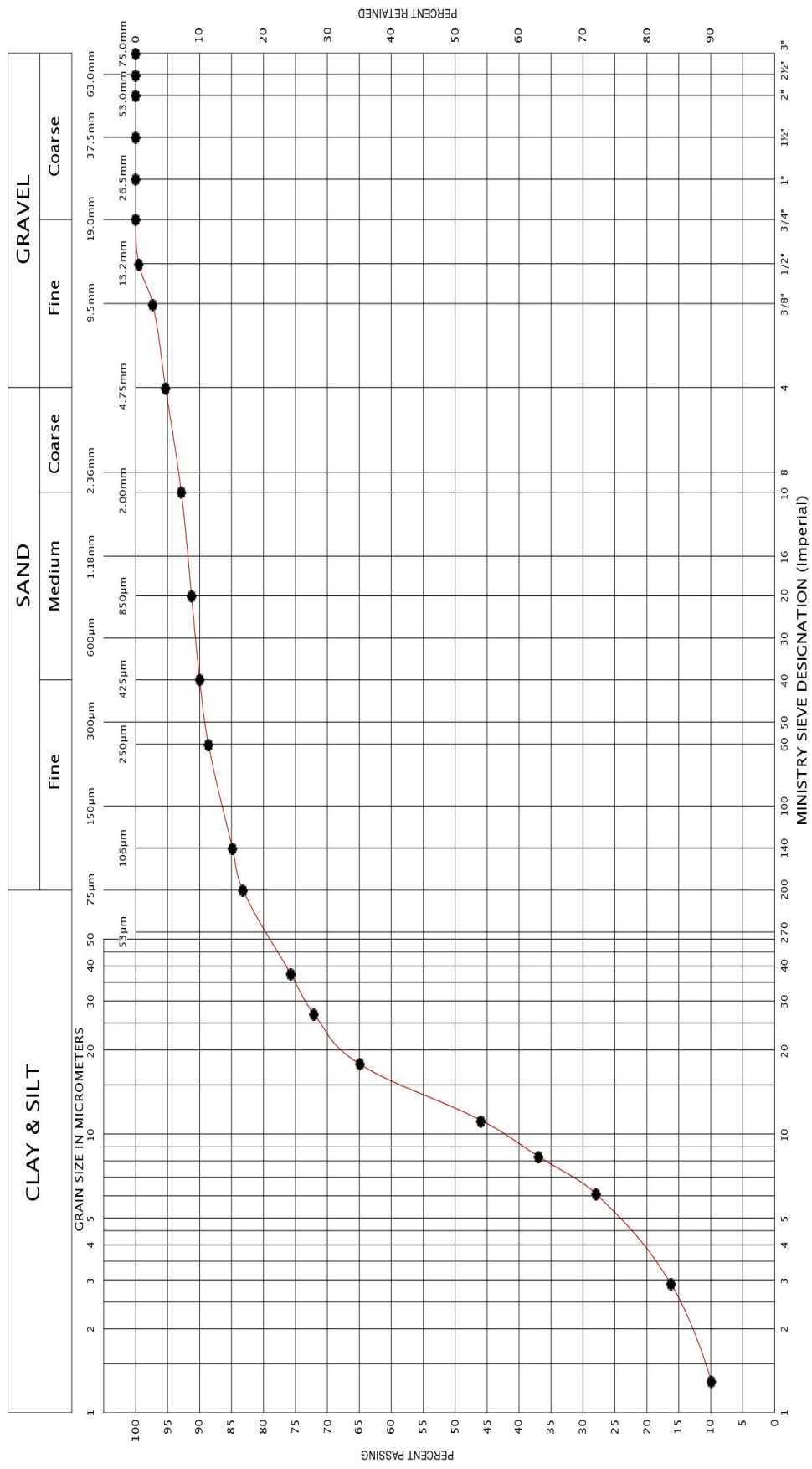
LEGEND	BH	C18-2
	SAMPLE	8
SYMBOL		●



GRAIN SIZE DISTRIBUTION  
CLAYEY SAND (TILL)

FIG No.: GS-W-2  
HWY : 401  
GWP 2016-E-0004

# UNIFIED SOIL CLASSIFICATION SYSTEM



<b>LEGEND</b>	<b>BH</b>	C18-2
	<b>SAMPLE</b>	16B
	<b>SYMBOL</b>	●



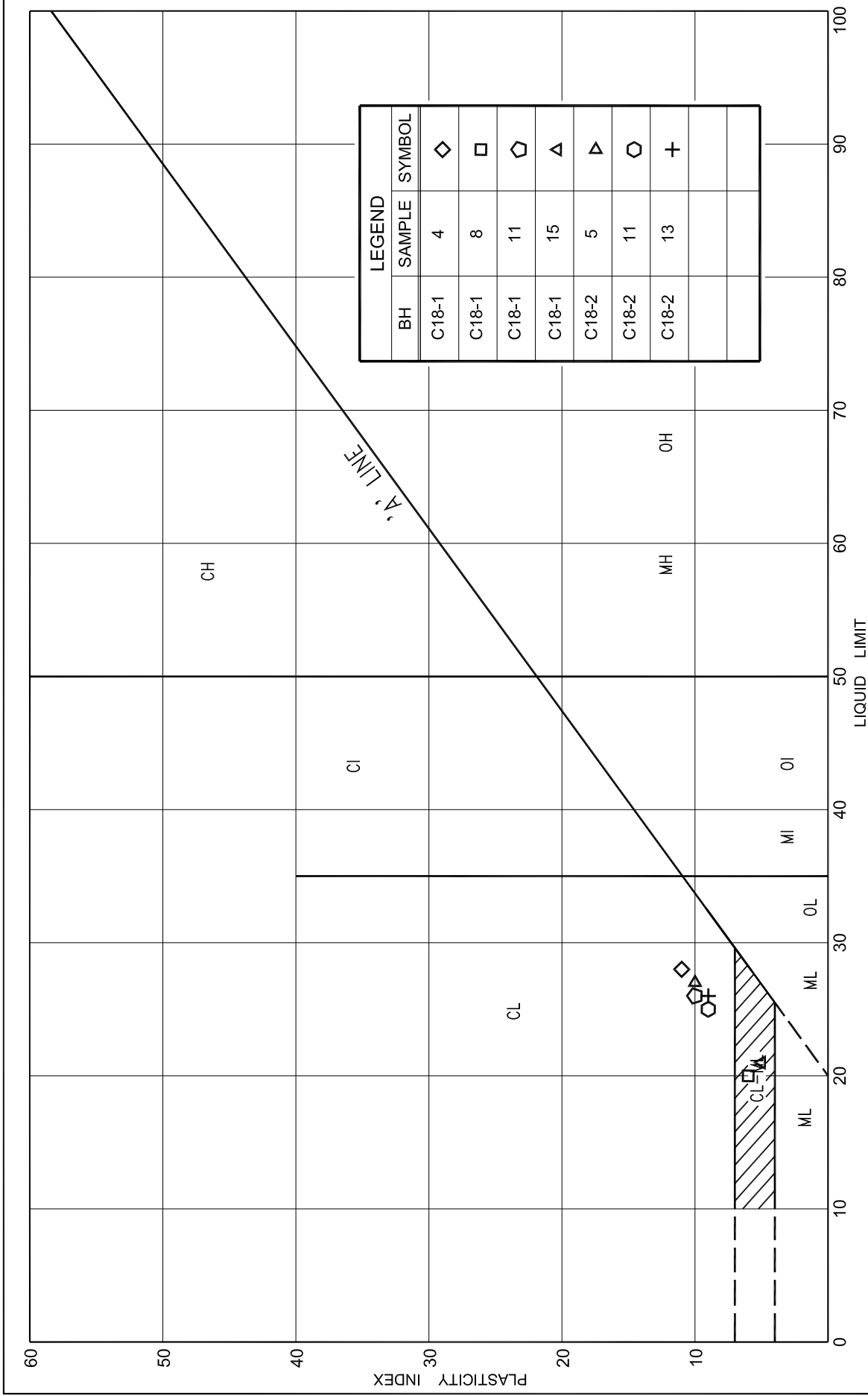
Ontario

### GRAIN SIZE DISTRIBUTION

FIG No.: GS-W-3

HWY : 401

GWP	2016-E-0004
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LEGEND		
BH	SAMPLE	SYMBOL
C18-1	4	◇
C18-1	8	□
C18-1	11	◇
C18-1	15	△
C18-2	5	▷
C18-2	11	◇
C18-2	13	+



Ontario

### PLASTICITY CHART

FIG No. PC-W-1

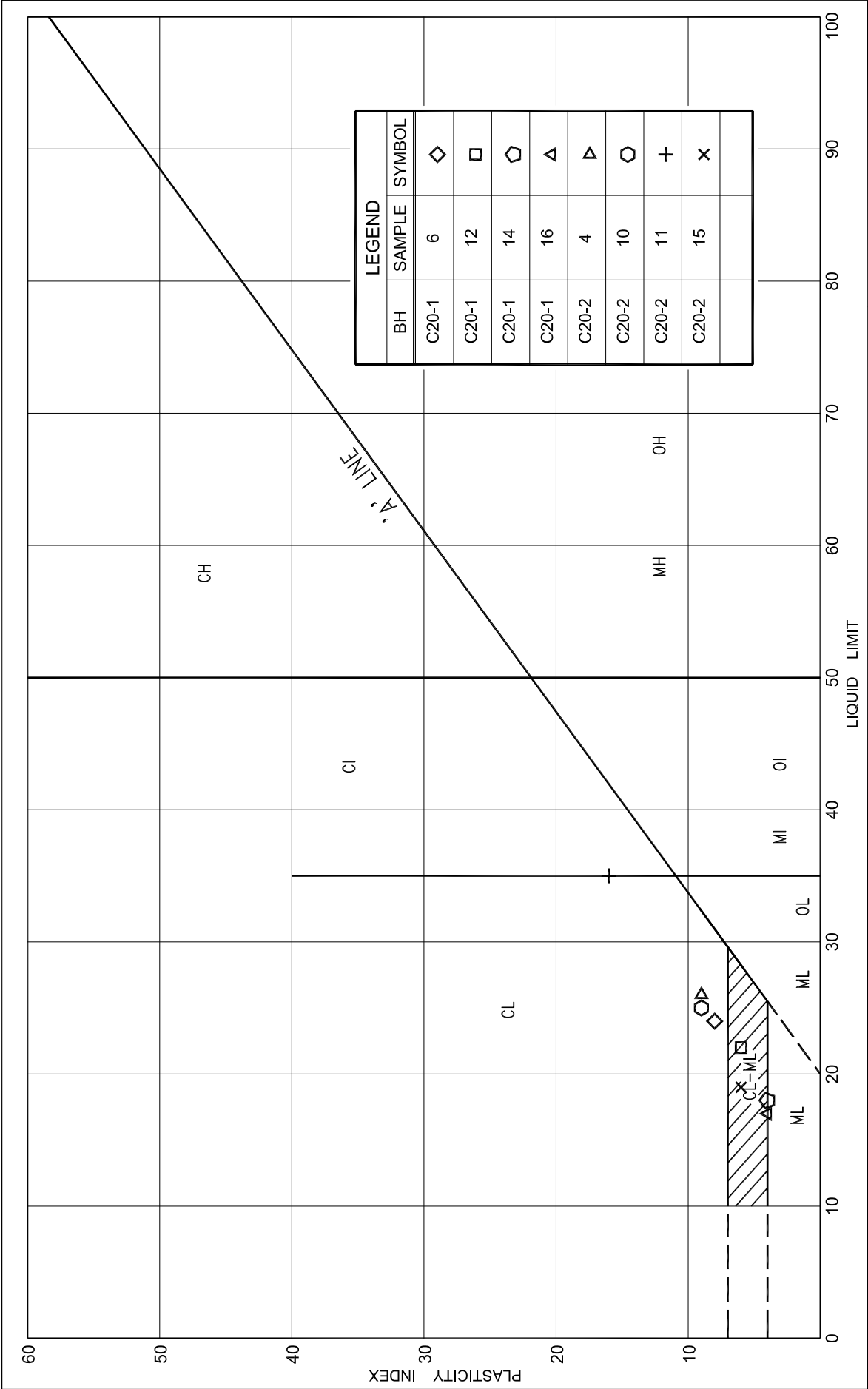
HWY: 401


ASGMT. No. 2016-E-0004



## **SITE X – NON-STRUCTURAL CULVERT (W-C19)**





Ontario

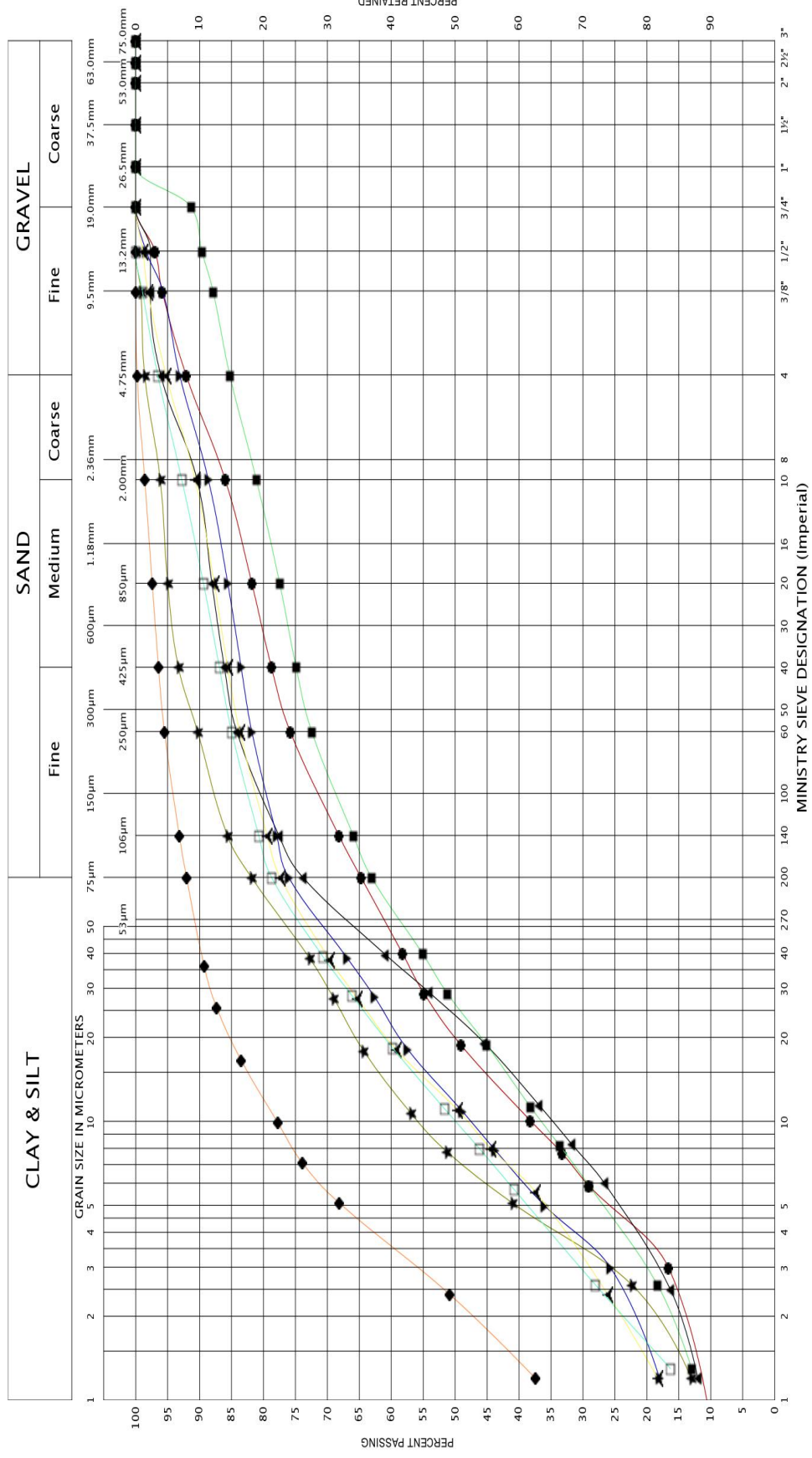
PLASTICITY CHART  
CLAYEY SILT (TILL)

FIG No. PC-Y-1  
HWY: 401  
ASGMT.No. 2016-E-0004



## **SITE Y – NON-STRUCTURAL CULVERT (W-C20)**

# UNIFIED SOIL CLASSIFICATION SYSTEM



LEGEND	BH	C20-1	C20-1	C20-1	C20-1	C20-2	C20-2	C20-2	C20-2	C20-2
	SAMPLE	6	12	14	16	4	10	11	15	
	SYMBOL	▼	✱	▲	●	人	□	◆	■	



Ontario

### GRAIN SIZE DISTRIBUTION

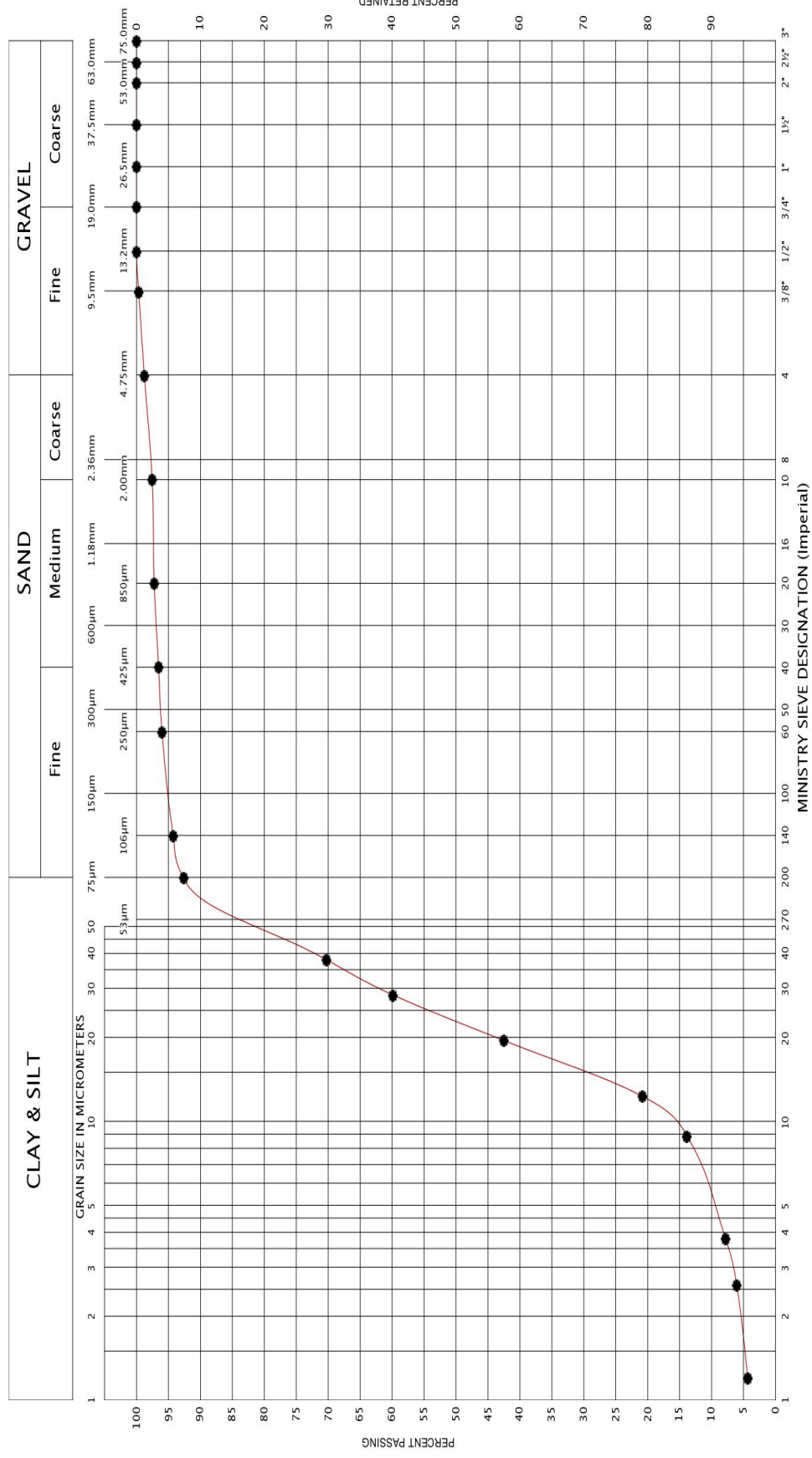
#### CLAYEY SILT (TILL)

FIG No.: GS-Y-1

HWY : 401

GWP	2016-E-0004
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# UNIFIED SOIL CLASSIFICATION SYSTEM



<b>LEGEND</b>	<b>BH</b>	C20-1
	<b>SAMPLE</b>	19
	<b>SYMBOL</b>	●

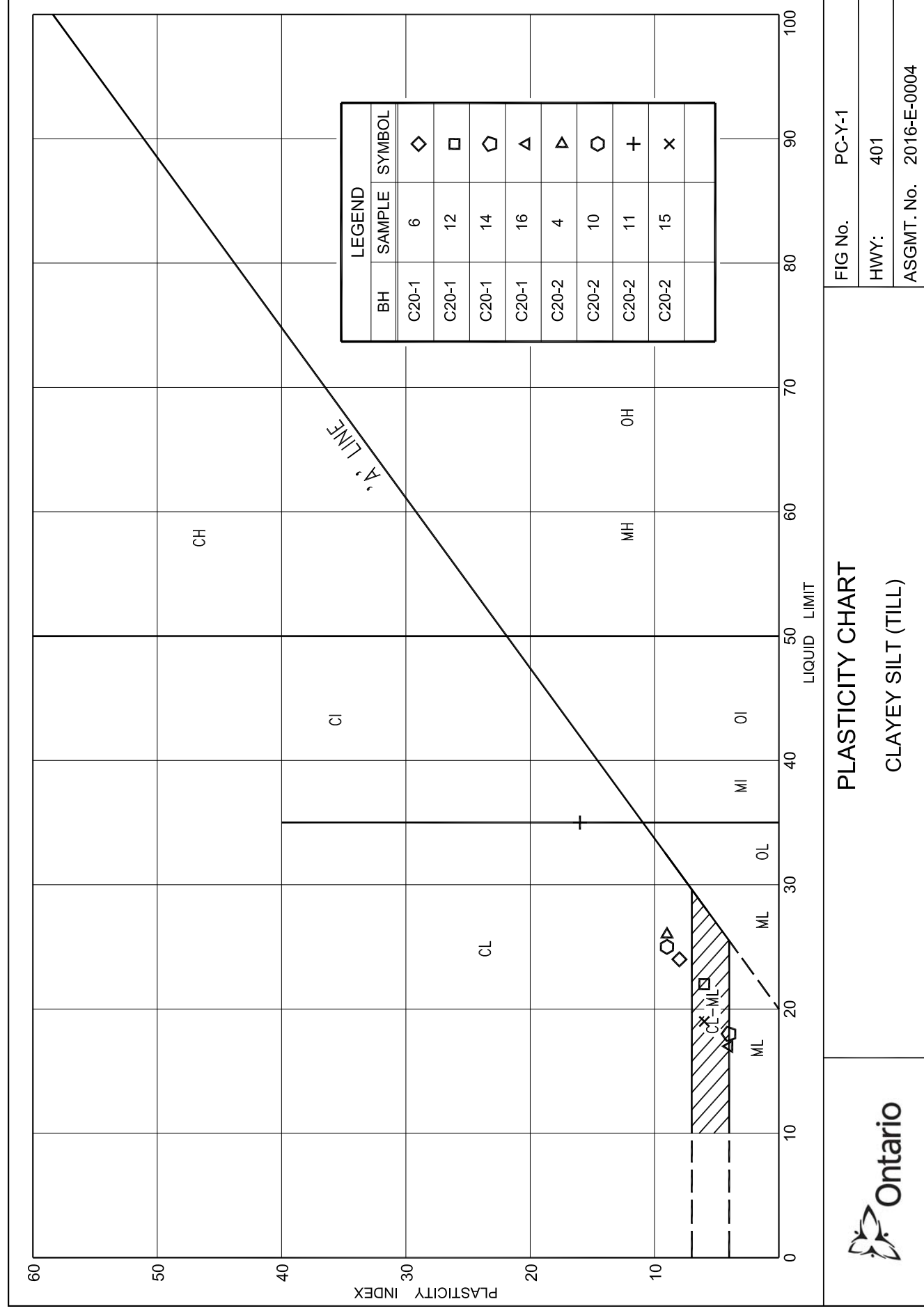


### GRAIN SIZE DISTRIBUTION

FIG No.: GS-Y-2

HWY : 401

GWP	2016-E-0004
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**C-4 Chemical Test Results**





FINAL REPORT

CA14595-NOV18 R1

17TF008A, Hwy 401 West Expansion

Prepared for

Peto MacCallum Ltd

First Page

CLIENT DETAILS		LABORATORY DETAILS	
Client	Peto MacCallum Ltd	Project Specialist	Rob Irwin B.Sc., C.Chem
Address	165 Cartwright Ave	Laboratory	SGS Canada Inc.
	Toronto, ON	Address	185 Concession St., Lakefield ON, K0L 2H0
	M6A 1V5, Canada		
Contact	Nazibur Rahman	Telephone	2361
Telephone	416-785-5110	Facsimile	705-652-6365
Facsimile	416-785-5120	Email	
Email	nrahman@petomaccallum.com	SGS Reference	CA14595-NOV18
Project	17TF008A, Hwy 401 West Expansion	Received	11/27/2018
Order Number		Approved	11/30/2018
Samples	Soil (10)	Report Number	CA14595-NOV18 R1
		Date Reported	11/30/2018

COMMENTS

Temperature of Sample upon Receipt: 9 degrees C  
Cooling Agent Present: yes  
Custody Seal Present: no

Chain of Custody Number: 002497

Corrosivity Index is based on the American Water Works Corrosivity Scale according to AWWA C-105. An index greater than 10 indicates the soil matrix may be corrosive to cast iron alloys.

SIGNATORIES

Rob Irwin B.Sc., C.Chem





FINAL REPORT

CA14595-NOV18 R1

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FINAL REPORT

CA14595-NOV18 R1

Client: Peio MacCallum Ltd  
Project: 17TF008A, Hwy 401 West Expansion  
Project Manager: Nazibur Rahman  
Samplers: K Amaty

PACKAGE: - Corrosivity Index (SOIL)

Parameter		Units	RL	Sample Number											
Corrosivity Index				Sample Name											
Corrosivity Index		none	1	C18-1, SS#5											
Soil Redox Potential		mV	-	C18-2, SS#4											
Sulphide		%	0.02	(10'-12')											
pH		pH Units	0.05	Soil											
Resistivity (calculated)		ohms.cm	-9999	27/11/2018											
				Result		Result		Result		Result		Result		Result	
				4.0	6.0	9.5	9.5	157	174	198	252	2750	2310	2040	4830
				345	219	157	174	198	252	2750	2310	2040	4830	2160	2470
				< 0.02	< 0.02	0.19	0.23	0.21	0.21	0.21	0.21	8.14	8.50	8.29	8.67
				8.60	8.47	8.25	8.50	8.14	8.29	8.67	8.48	8.67	8.50	8.29	8.67
				3760	1810	2040	2310	2750	2310	2160	2470	4830	2160	2470	2470

PACKAGE: - Corrosivity Index (SOIL)

Parameter		Units	RL	Sample Number											
Corrosivity Index				Sample Name											
Corrosivity Index		none	1	MC-3, SS#10											
Soil Redox Potential		mV	-	MC-3, SS#11											
Sulphide		%	0.02	(25'-27')											
pH		pH Units	0.05	Soil											
Resistivity (calculated)		ohms.cm	-9999	27/11/2018											
				Result		Result		Result		Result		Result		Result	
				6.0	9.5	232	204	< 0.02	0.09	8.31	8.74	1880	2130		



FINAL REPORT

CA14595-NOV18 R1

Client: Peto MacCallum Ltd  
Project: 17TF008A, Hwy 401 West Expansion  
Project Manager: Nazibur Rahman  
Samplers: K Amatya

PACKAGE: - General Chemistry (SOIL)

Sample Number	5	6	7	8	9	10	11	12
Sample Name	C18-1, SS#5 (10'-12')	C18-2, SS#4 (7.5'-9.5')	C19-1, SS#6 (12.5'-14.5')	C19-2, SS#7 (15'-17')	C20-1, SS#7 (15'-17')	C20-2, SS#9 (20'-22')	SME-5, SS#6 (12.5'-14.5')	SME-5, SS#10 (30'-32')
Sample Matrix	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Sample Date	27/11/2018	27/11/2018	27/11/2018	27/11/2018	27/11/2018	27/11/2018	27/11/2018	27/11/2018

Parameter	Units	RL	Result	Result	Result	Result	Result	Result	Result	
General Chemistry										
Conductivity	uS/cm	2	266	551	489	432	363	464	207	405

PACKAGE: - General Chemistry (SOIL)

Sample Number	13	14
Sample Name	MC-3, SS#10 (25'-27')	MC-3, SS#11 (30'-32')
Sample Matrix	Soil	Soil
Sample Date	27/11/2018	27/11/2018

Parameter	Units	RL	Result	Result
General Chemistry				
Conductivity	uS/cm	2	533	470

PACKAGE: - Metals and Inorganics (SOIL)

Sample Number	5	6	7	8	9	10	11	12
Sample Name	C18-1, SS#5 (10'-12')	C18-2, SS#4 (7.5'-9.5')	C19-1, SS#6 (12.5'-14.5')	C19-2, SS#7 (15'-17')	C20-1, SS#7 (15'-17')	C20-2, SS#9 (20'-22')	SME-5, SS#6 (12.5'-14.5')	SME-5, SS#10 (30'-32')
Sample Matrix	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Sample Date	27/11/2018	27/11/2018	27/11/2018	27/11/2018	27/11/2018	27/11/2018	27/11/2018	27/11/2018

Parameter	Units	RL	Result	Result	Result	Result	Result	Result	Result	Result
Metals and Inorganics										
Moisture Content	%	0.1	10.2	11.1	14.9	11.3	12.9	12.9	15.3	14.1
Sulphate	µg/g	0.4	42	56	330	270	450	310	48	340

PACKAGE: - Metals and Inorganics (SOIL)

Sample Number	13	14
Sample Name	MC-3, SS#10 (25'-27')	MC-3, SS#11 (30'-32')



FINAL REPORT

CA14595-NOV18 R1

Client: Peto MacCallum Ltd  
Project: 17TF008A, Hwy 401 West Expansion  
Project Manager: Nazibur Rahman  
Samplers: K Amatya

PACKAGE: - Metals and Inorganics (SOIL)

Sample Number	13	14
Sample Name	MC-3, SS#10 (25'-27')	MC-3, SS#11 (30'-32')
Sample Matrix	Soil	Soil
Sample Date	27/11/2018	27/11/2018

Parameter	Units	RL	Result	Result
Metals and Inorganics				
Moisture Content	%	0.1	11.7	7.9
Sulphate	µg/g	0.4	49	160

PACKAGE: - Other (ORP) (SOIL)

Sample Number	5	6	7	8	9	10	11	12
Sample Name	C18-1, SS#5 (10'-12')	C18-2, SS#4 (7.5'-9.5')	C19-1, SS#6 (12.5'-14.5')	C19-2, SS#7 (15'-17')	C20-1, SS#7 (15'-17')	C20-2, SS#9 (20'-22')	SME-5, SS#6 (12.5'-14.5')	SME-5, SS#10 (30'-32')
Sample Matrix	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Sample Date	27/11/2018	27/11/2018	27/11/2018	27/11/2018	27/11/2018	27/11/2018	27/11/2018	27/11/2018

Parameter	Units	RL	Result	Result	Result	Result	Result	Result	Result
Other (ORP)									
Chloride	µg/g	0.4	120	210	26	11	12	11	8.9

PACKAGE: - Other (ORP) (SOIL)

Sample Number	13	14
Sample Name	MC-3, SS#10 (25'-27')	MC-3, SS#11 (30'-32')
Sample Matrix	Soil	Soil
Sample Date	27/11/2018	27/11/2018

Parameter	Units	RL	Result	Result
Other (ORP)				
Chloride	µg/g	0.4	260	62



FINAL REPORT

CA14595-NOV18 R1

QC SUMMARY

Anions by IC  
Method: EPA300/MA300-Ions1.3 | Internal ref.: ME-CA-IENVIIC-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High	Low	High	
Chloride	DIO0499-NOV18	µg/g	0.4	<0.4	9	20	94	80	120	94	75	125
Sulphate	DIO0499-NOV18	µg/g	0.4	<0.4	9	20	96	80	120	92	75	125

Carbon/Sulphur  
Method: ASTM E1915-07A | Internal ref.: ME-CA-IENVIARD-LAK-AN-020

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Sulphide	ECS0046-NOV18	%	0.02	<0.02	NV	20	111	80	120			

Conductivity  
Method: SM 2510 | Internal ref.: ME-CA-IENVIEWL-LAK-AN-006

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank				Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)		
								Low	High		Low	High	
Conductivity	EWL0495-NOV18	uS/cm	2	< 2	1	10	98	90	110	NA			

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FINAL REPORT

CA14595-NOV18 R1

QC SUMMARY

pH  
Method: SM 4500 | Internal ref.: ME-CA-IENVIEWL-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.			
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)		
								Low	High		Low	High	
pH	EWL0495-NOV18	pH Units	0.05	NA	1		100				NA		

Method Blank: a blank matrix that is carried through the entire analytical procedure. Used to assess laboratory contamination.  
Duplicate: Paired analysis of a separate portion of the same sample that is carried through the entire analytical procedure. Used to evaluate measurement precision.  
LCS/Spike Blank: Laboratory control sample or spike blank refer to a blank matrix to which a known amount of analyte has been added. Used to evaluate analyte recovery and laboratory accuracy without sample matrix effects.  
Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate laboratory accuracy with sample matrix effects.  
Reference Material: a material or substance matrix matched to the samples that contains a known amount of the analyte of interest. A reference material may be used in place of a matrix spike.  
RL: Reporting limit  
RPD: Relative percent difference  
AC: Acceptance criteria

**Multielement Scan Qualifier:** as the number of analytes in a scan increases, so does the chance of a limit exceedance by random chance as opposed to a real method problem. Thus, in multielement scans, for the LCS and matrix spike, up to 10% of the analytes may exceed the quoted limits by up to 10% absolute and the spike is considered acceptable.  
**Duplicate Qualifier:** for duplicates as the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.  
**Matrix Spike Qualifier:** for matrix spikes, as the concentration of the native analyte increases, the uncertainty of the matrix spike recovery increases. Thus, the matrix spike acceptance limits apply only when the concentration of the matrix spike is greater than or equal to the concentration of the native analyte.

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LEGEND

FOOTNOTES

- NSS** Insufficient sample for analysis.
- RL** Reporting Limit.
- ↑ Reporting limit raised.
- ↓ Reporting limit lowered.
- NA** The sample was not analysed for this analyte
- ND** Non Detect

Samples analysed as received. Solid samples expressed on a dry weight basis. "Temperature Upon Receipt" is representative of the whole shipment and may not reflect the temperature of individual samples.

Analysis conducted on samples submitted pursuant to or as part of Reg. 153/04, are in accordance to the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act" published by the Ministry and dated March 9, 2004 as amended.

SGS provides criteria information (such as regulatory or guideline limits and summary of limit exceedances) as a service. Every attempt is made to ensure the criteria information in this report is accurate and current, however, it is not guaranteed. Comparison to the most current criteria is the responsibility of the client and SGS assumes no responsibility for the accuracy of the criteria levels indicated. This document is issued, on the Client's behalf, by the Company under its General Conditions of Service available on request and accessible at [http://www.sgs.com/terms\\_and\\_conditions.htm](http://www.sgs.com/terms_and_conditions.htm). The Client's attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein. Any other holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents.

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-- End of Analytical Report --