



FOUNDATION INVESTIGATION AND DESIGN REPORT

for

**EVALUATION OF ALTERNATIVES FOR PROTECTION OF SEWER
AND WATERMAIN UTILITIES**

**HIGHWAY 401 WBL (FROM 200 M EAST OF CREDIT RIVER TO
CREDITVIEW ROAD) WIDENING AND**

CREDITVIEW ROAD REALIGNMENT

HIGHWAY 401 WEST EXPANSION

REGIONS OF PEEL AND HALTON, ONTARIO

ASSIGNMENT NO. 2016-E-0004

WORK ORDER #12B

LATITUDE AND LONGITUDE: 43.612238, -79.731439

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PML Ref.: 18TF033
Index No.: 008FIR and 009FDR
GEOCRES No.: 30M12-420
April 23, 2019



PART A - FOUNDATION INVESTIGATION REPORT

for

**EVALUATION OF ALTERNATIVES FOR PROTECTION OF SEWER
AND WATERMAIN UTILITIES
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Part A – Foundation Investigation Report

Evaluation of Alternatives for Protection of Sewer and Watermain Utilities

Highway 401 WBL Widening and Creditview Road Realignment

Assignment No. 2016-E-0004, Work Order 12B, Halton Region and Peel Region, Ontario, Index No.: 008FIR

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For

Evaluation of Alternatives for Protection of Sewer and Watermain Utilities
Highway 401 WBL (from 200 m East of Credit River to Creditview Road) Widening
and Creditview Road Realignment
Assignment No. 2016-E-0004, Work Order #12B
Halton Region and Peel Region, Ontario

1. INTRODUCTION

The Ministry of Transportation Ontario (MTO) has retained AECOM Canada Ltd. (AECOM) as the Prime Consultant, to provide Owner's Engineer services for the Highway 401 west Expansion Project. AECOM retained Peto MacCallum Ltd. (PML) on behalf of MTO to provide geotechnical engineering services for the assignment.

The work reported herein is part of Assignment No. 2016-E-0004, Work Item No. 12B. Work Item No. 12B of the Owner's Engineer Assignment No. 2016-E-0004 involves the Utility Works Support for widening of the Highway 401 mainline from the Credit River in the City of Mississauga.

The Terms of Reference and Scope of Work for the Foundation Engineering services are outlined in the MTO WO No. 12B under Assignment No. 2016-E-0004, received on November 14, 2018 and the PML revised proposal, dated November 20, 2018.

This report summarizes the results of the foundation investigation carried to service work Item #12B, including investigation of slope stability, retaining walls, and sheet piling to assess if the existing 1500 mm diameter sanitary across the Credit River can stay in place and be serviced in the future by Peel Region without undermining Highway 401 or Creditview Road. PML has also been requested to analyse the slope stability along Creditview Road to assess if the existing 400 mm diameter PVC watermain and 1500 mm diameter sanitary can stay in place and be serviced in the future by Peel Region without undermining the proposed realigned Creditview Road.

2. SITE DESCRIPTION

Within the project limits, the Highway 401 alignment extends westerly from the eastern edge of the broad, flat floodplain of the Credit River valley and crosses credit River as well as municipal and regional roads. The terrain in study area is generally flat except where cut by the Credit River. The land use is rural with grass, shrubs and trees and farm fields.

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Based on the cross sections provided by AECOM, the grade of the existing Highway 401 from Station 14+900 to Station 15+220 declines from approximate elevation 169 m to elevation 165 m. A 1500 mm diameter sanitary sewer running along the north side of Highway 401 Westbound Lanes (WBL) is located approximately 30 m to 35 m from existing Highway 401 WBL embankment crest. The obvert of the sanitary sewer ranges approximately from elevation 165 m to elevation 158 m, declining from Station 14+900 to Station 15+220.

Based on the cross sections provided by AECOM, the grade of the existing Creditview road from Station 9+960 to Station 9+900 declines from approximate elevation 176 m to elevation 173 m. The 1500 mm diameter sanitary continues along the east side of Creditview Road and is located about 40 m to 20 m from the existing Creditview Road embankment crest between Station 9+960 and Station 9+900. The depth of the sanitary sewer is approximately between elevation 156 m to elevation 159 m. Furthermore, a 400 mm diameter watermain is also running along the east side of Creditview Road from Station 9+960 to Station 9+900 and is about 32 m to 26 m from the existing Creditview Road northbound lane embankment crest. The depth of the watermain is between approximate elevation 167 m to 170 m.

3. FIELD INVESTIGATION PROCEDURES

The previous boreholes investigated by PML and Golder Associates in the vicinity of the site area are located 18 m to 30m south of the existing 1500 mm diameter sanitary alignment along Highway 401.

An additional 6 boreholes were advanced for this assignment. Refer to Appendix A-2 for a plan showing borehole location and to Appendix A-3 for Records of Boreholes.

The respective utility companies cleared the underground services at the borehole locations. Public stakeholders and private utility authorities were informed and all of the utility clearance documents were obtained before the commencement of drilling work.

PML staff used a portable GPS device to establish the borehole locations in the field. Subsequently, PML surveyed the borehole locations using a Sokkia SHC5000 Differential GPS system, equipped with a GCX3 (Network RTK rover) GNSS Receiver. The vertical and horizontal accuracy of this equipment are within 0.1 m and 0.5 m, respectively. All elevations reported in this

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report are referred to in MTM NAD 83 Northing and Easting (MTM Zone – ON10) Geodetic datum and expressed in meters.

PML commenced utility clearances through Ontario-1-Call and MTO electrical locate department prior to commencing drilling. The boreholes were located to cover the limits of the foundation areas and to roughly avoid conflicts with underground and overhead utilities while allowing for safe operation of a drill rig. However, due to the conflict with existing underground utilities, three (3) boreholes had to be relocated and one (1) of the proposed boreholes was cancelled for safe drilling operation.

The boreholes were advanced using continuous flight hollow stem augers powered by a B57 track mounted drill rig, equipped for rotary core (HQ size) drilling owned and operated by Landshark Drilling Inc. (Landshark), of Brantford, Ontario. The drilling equipment was supplied and operated by a specialist drilling contractor. The drilling crews worked under the full-time supervision of a member of the PML engineering staff. Boreholes BH-1 to BH-6 were drilled between February 15 and 21, 2019.

Representative soil samples were recovered from the boreholes at 0.75 m intervals using a conventional 51 mm OD split spoon sampler in accordance with the Standard Penetration Test (SPT) procedure. Standard penetration tests were conducted simultaneously with the sampling operation to assess the strength characteristics of the substrata. Two (2) boreholes were extended 3.6 m and 3.7 m into the bedrock using rock coring equipment

The groundwater conditions at the borehole locations were observed during the drilling by visual examination of the soil samples as the samples were retrieved. In addition, water level measurements were taken in the open boreholes upon completion of drilling. A monitoring well, consisting of 50 mm outside diameter rigid PVC pipe, was installed in boreholes BH-1 and BH-4. Refer to Record of Borehole Sheets in Appendix A-3 for details of monitoring well installations. Water levels were measured using a Solinst flat tape water level reader.

Upon completion of drilling, the boreholes were backfilled with bentonite/cement grout in accordance with the MTO guidelines and O.Reg. 903 for borehole abandonment procedures. The annular space between the borehole wall and the pipe installed for monitoring well was backfilled above the filter pack to ground surface using bentonite pellets.

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The soil and rock core samples were identified in the field in accordance with the MTO Soil Classification procedures and transported to the Toronto PML laboratory for further visual classification and testing. Index property testing (water content determination, grain size distribution and Atterberg limits) were carried out on selected samples.

4. LABORATORY TEST PROCEDURES

Laboratory tests on representative SPT samples recovered during the fieldwork were conducted by the laboratory owned by PML, located in Toronto. The laboratory testing program included the following:

- Natural moisture content determinations (63)
- Grain size distribution analysis (21)
- Atterberg limit tests (10)

All laboratory tests to determine the index properties were performed in accordance with the MTO test procedures, which follow the American Society for Testing Materials (ASTM) standards, with the exception of hydrometer tests (LS-702). The results of the grain size distribution analyses are presented on Figures GS-1, GS-2, and GS-3. The results of the Atterberg Limit tests are presented on Figures PC-1, PC-2, and PC-3. All of the test results are summarized on the attached Record of Borehole Sheets provided in Appendix A-3.

5. SITE GEOLOGY

The site is located on the South Slope physiographic region. The South Slope region consists of calcareous clay till with lacustrine clay and silt reworked by glaciers, with numerous scattered drumlins and deep valley cuts caused by streams flowing towards Lake Ontario (Chapman, L.J. and Putnam, D.F. *The Physiography of Southern Ontario*, Ontario Geological Survey Special Volume 2, Third Edition, 1984. Accompanied by Map P.2715, Scale 1:600,00).

The Quaternary Geology map published by the Ontario Ministry of Northern Development and Mines (MNDM) indicates that the surface conditions in the area consist of Halton Till and Glaciolacustrine deposits; predominantly silt to silty clay matrix. Based on the Bedrock Geology map (MRD126-REV1, 2011) published by the MNDM, the culvert site lies within the Georgian Bay

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rock formations. The project area consists mainly of Upper Ordovician shale, limestone, dolostone and siltstone.

6. SUBSURFACE CONDITIONS

The subsurface conditions encountered during the course of the investigation, together with the field and laboratory test results are shown on the attached Record of Borehole Sheets (Appendix A-3).

The borehole locations and stratigraphic profile sections are shown in Appendix A-2. The boundaries between soil strata have been established at the borehole locations only. The boundaries of soil strata between and beyond the boreholes are assumed and may vary from location to location.

The soils encountered at this site can be divided into four (4) strata:

- a) General Fill
- b) Clayey Silt (Till)
- c) Silty Sand to Sandy Silt (Till)
- d) Shale Bedrock

6.1. General Fill

Fill was encountered at the existing ground surface in all boreholes.

Silty Sand/Sandy Silt (Fill)

A compact to very dense silty sand/sandy silt fill layer was encountered at the ground surface in all boreholes, excluding boreholes BH-3 and BH-4. This layer generally extends to 0.8 m below the ground surface. In borehole BH-6, this layer extends to a depth of 1.4 m below the ground surface. The SPT 'N' values ranged from 17 blows to 45 blows per 0.3 m penetration. The moisture content of the samples ranged from 9.0% to 25.8%.

Clayey Silt (Fill)

A soft to stiff clayey silt fill was encountered at the ground surface in boreholes BH-3 and BH-4, and extends to a depth of 1.4 m below the ground surface. This layer was encountered below the

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silty sand/sandy silt fill in boreholes BH-1 and BH-5, and extends to a depth of 5.2 m and 4.5 m below the ground surface, respectively. The SPT 'N' values ranged from 2 blows to 21 blows per 0.3 m penetration. The moisture content of the samples ranged from 9.9% to 32.9%. Refer to Appendix A-4 for grain size distribution figures and to Appendix A-5 for Atterberg limit figures. The grain size distribution results of clayey silt fill samples are provided in Figure GS-1 and the related Atterberg limits are provided in Figure PC-1.

Sand (Fill)

A very loose to compact sand fill was encountered below the clayey silt fill in boreholes BH-3 and BH-4, and extends to a depth of 2.2 m below the ground surface. The SPT 'N' values were 10 blows and 15 blows per 0.3 m penetration, and the moisture content of the samples were 9.2% and 23.2%.

6.2. Clayey Silt (Till)

A stiff to hard clayey silt till layer was encountered below the general fill layers in all boreholes, with exception of borehole BH-3. The till layer extends to 3.8 m to 7.5 m below the ground surface in boreholes BH-4, BH-5, and BH-6, and extends to probable bedrock/bedrock, 12.8 m and 5.8 m below the ground surface in boreholes BH-1 and BH-2, respectively. A 1.6 m thick dense silty sand till layer was encountered between the fill layer and clayey silt till in borehole BH-6. The SPT 'N' values of the clayey silt till ranged from 8 blows per 0.3 m penetration to 120 blows for 0.2 m penetration. The moisture content of the samples ranged from 6.4% to 32.1%. Refer to Appendix A-4 for grain size distribution figures and to Appendix A-5 for Atterberg limit figures. The grain size distribution results of selected clayey silt till samples are provided in Figure GS-2, and the related Atterberg limits are provided in Figure PC-2.

6.3. Silty Sand (Till)

A compact to very dense silty sand till layer was encountered below the general fill layers in boreholes BH-3 and BH-6, and below the clayey silt till layer in boreholes BH-4 and BH-5. The till layer extends to bedrock, 9.3 m and 6.0 m below the ground surface in boreholes BH-3 and BH-4, respectively. In boreholes BH-5 and BH-6, the till layer extends to the termination depth of 12.4 m and 9.7 m below the ground surface, respectively. The SPT 'N' values ranged from 21 blows per 0.3 m penetration to 100 blows for 0.11 m penetration. The moisture content of the samples

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ranged from 4.8% to 16.8%. Refer to Appendix A-4 for grain size distribution figures and to Appendix A-5 for Atterberg limit figures. The grain size distribution results of selected silty sand till samples are provided in Figure GS-3 and the related Atterberg limits are provided in Figure PC-3.

6.4. Shale Bedrock

Weathered shale bedrock of Georgian Bay Formation was encountered at approximately 5.3 to 12.8 m below the ground surface. Shale bedrock was penetrated for 3.6 m and 6.8 m by augering and split spoon sampling, with SPT 'N' values ranging from 50 blows to over 100 blows per less than 0.3 m penetration.

Rock core samples of 3.6 m lengths were obtained from boreholes BH-1 and BH-4 below the till layer. The core depths extend to 16.4 m and 12.9 m (El. 155.0 and El. 148.8) below the ground surface in boreholes BH-1 and BH-4, respectively. The measured core recovery of the rock cores is 100%. The RQD measured from the retrieved rock cores ranged from 10% and 91%. Based on the RQD values, the bedrock may be described as very poor to excellent quality.

Refer to Appendix A-6 for the rock core descriptions of the bedrock, photographs of the rock core samples retrieved.

6.5. Groundwater

Groundwater was measured in the boreholes following completion of augering. The measured groundwater depth ranged from 0.9 m to 3.7 m (El. 158.0 to El. 170.2) below ground surface. Please refer to Table 5.2.3 for Groundwater Levels from surface upon completion of drilling.

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**Table 6.5 Groundwater Level Readings**

BOREHOLE NO.	GROUND SURFACE ELEVATION (m)	GROUNDWATER LEVELS FROM SURFACE UPON COMPLETION OF DRILLING		DATE OF READING
		DEPTH (m)	ELEVATION (m)	
BH-1	171.4	1.2	170.2	Feb. 14, 2019
BH-2	163.6	1.2	162.4	Feb. 19, 2019
BH-3	161.5	0.9	160.6	Feb. 21, 2019
BH-4	161.7	3.7	158.0	Feb. 20, 2019
BH-5	164.3	3.6	160.7	Feb. 22, 2019
BH-6	163.3	1.2	162.1	Feb. 21, 2019

Groundwater levels may fluctuate due to the influence of precipitation and seasonal change. The groundwater measurements were observed and measured prior to backfilling the boreholes.

A total of two (2) monitoring wells consisting of a 50 mm diameter PVC pipe were installed in boreholes BH-1 and BH-4. Additional water level measurement readings from the monitoring well installed in BH-1 and BH-4 are shown on the Record of Borehole sheets provided in Appendix A-2.

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7. CLOSURE

Mr. M. Mohamed and Mr. A. Hossain, carried out the field investigations under the supervision of Mr. N. Rahman, P.Eng., Project Engineer. Landshark Drilling Ltd. of Brantford, Ontario supplied the drilling equipment for the subsurface exploration. The laboratory testing of the selected samples was carried out in the PML laboratory in Toronto.

This report was prepared by Ms. N. Leong-Sem, B.Eng., EIT, and Mr. N. Rahman, P.Eng., Geotechnical Services, and reviewed by Mr. D. Dundas, P.Eng., Senior Engineer, Geotechnical Services. Mr. R. Ng, MBA, PhD, P.Eng., MTO Designated Principal Contact, conducted an independent review of the report.

Yours very truly,

Peto MacCallum Ltd.



Nazibur Rahman, P.Eng.
Project Manager, Geotechnical Services



Robert Ng, PhD, MBA, P.Eng.
MTO Designated Principal Contact

NLS/NR/DD/RN:nl-nk

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APPENDIX A-1

Explanation of Terms Used in Report

EXPLANATION OF TERMS USED IN REPORT

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

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 (R Q D), FOR MODIFIED RECOVERY, IS:

R Q D (%)	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	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

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

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m ³	DENSITY OF SOLID PARTICLES	n	1, %	POROSITY	e_{max}	1, %	VOID RATIO IN LOOSEST STATE
γ_s	kN/m ³	UNIT WEIGHT OF SOLID PARTICLES	w	1, %	WATER CONTENT	e_{min}	1, %	VOID RATIO IN DENSEST STATE
ρ_w	kg/m ³	DENSITY OF WATER	S_r	%	DEGREE OF SATURATION	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
γ_w	kN/m ³	UNIT WEIGHT OF WATER	w_L	%	LIQUID LIMIT	D	mm	GRAIN DIAMETER
ρ	kg/m ³	DENSITY OF SOIL	w_p	%	PLASTIC LIMIT	D_n	mm	n PERCENT - DIAMETER
γ	kN/m ³	UNIT WEIGHT OF SOIL	w_s	%	SHRINKAGE LIMIT	C_u	1	UNIFORMITY COEFFICIENT
ρ_d	kg/m ³	DENSITY OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	h	m	HYDRAULIC HEAD OR POTENTIAL
γ_d	kN/m ³	UNIT WEIGHT OF DRY SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	q	m ³ /s	RATE OF DISCHARGE
ρ_{sat}	kg/m ³	DENSITY OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	v	m/s	DISCHARGE VELOCITY
γ_{sat}	kN/m ³	UNIT WEIGHT OF SATURATED SOIL	DTPL		DRIER THAN PLASTIC LIMIT	i	1	HYDRAULIC GRADIENT
ρ'	kg/m ³	DENSITY OF SUBMERGED SOIL	APL		ABOUT PLASTIC LIMIT	k	m/s	HYDRAULIC CONDUCTIVITY
γ'	kN/m ³	UNIT WEIGHT OF SUBMERGED SOIL	WTP		WETTER THAN PLASTIC LIMIT	j	kN/m ³	SEEPAGE FORCE
e	1, %	VOID RATIO						

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Assignment No. 2016-E-0004, Work Order 12B, Halton Region and Peel Region, Ontario, Index No.: 008FIR

PML Ref.: 18TF033, April 23, 2019



APPENDIX A-2

Borehole Locations Plan and Soil Strata Drawing SS-1

GWP No 2016-E-0004
WO No 12

HIGHWAY 401 WEST EXPANSION
BOREHOLE LOCATION PLAN
AND SOIL STRATIGRAPHY



PML Peto MacCallum Ltd.
CONSULTING ENGINEERS



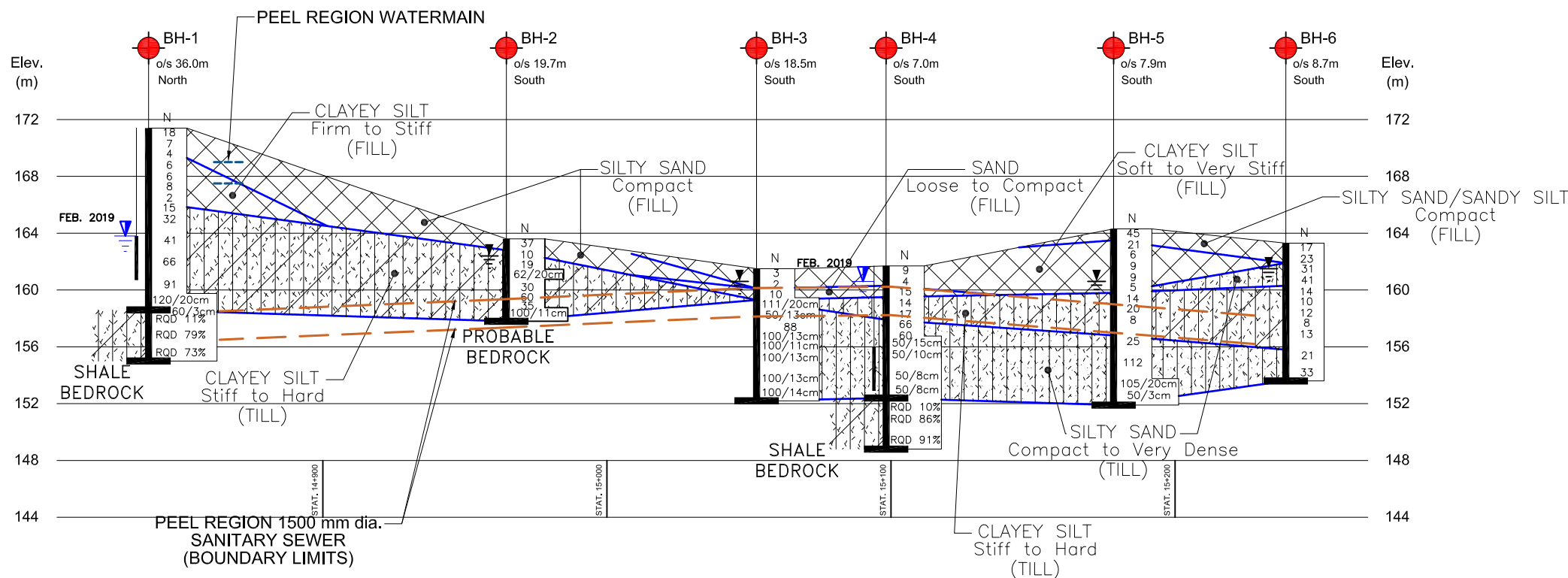
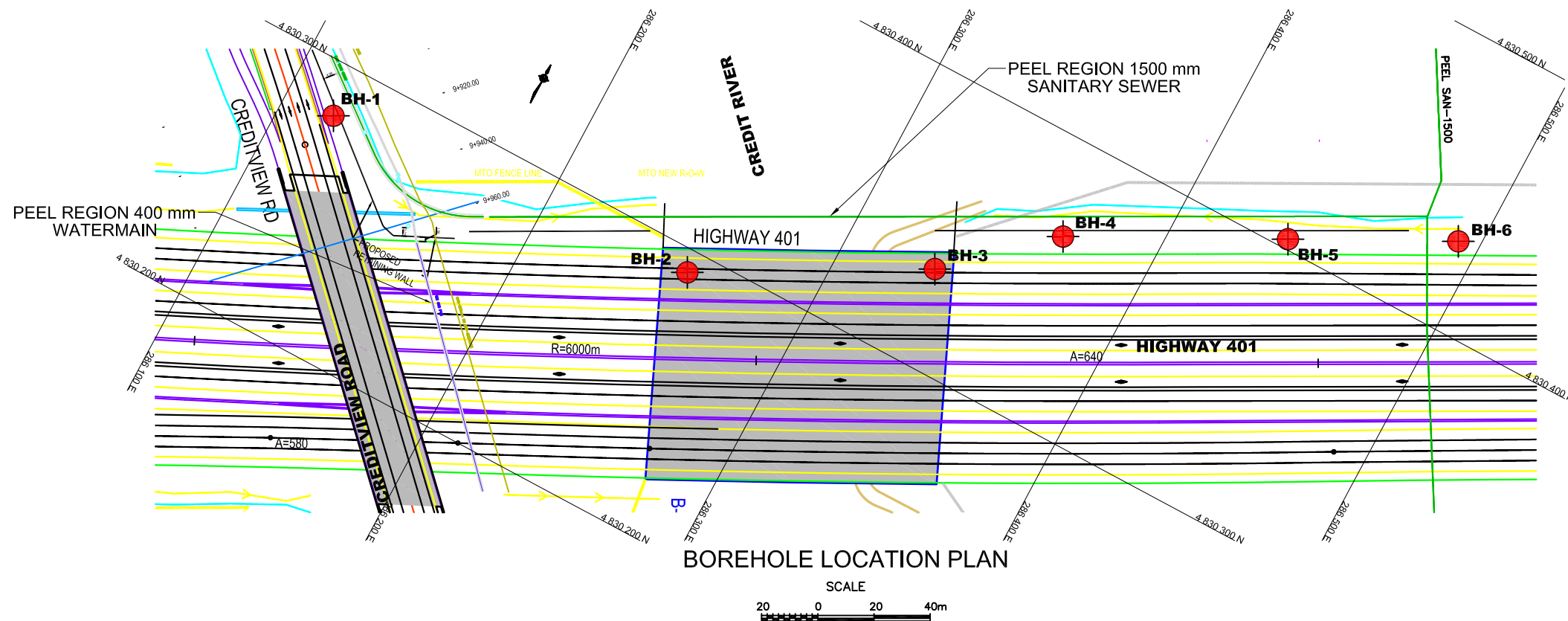
LEGEND			
	BOREHOLE LOCATION		
	BLOWS / 0.3 m (STANDARD PENETRATION TEST, 475 J/BLOW)		
	WATER LEVEL MEASURED UPON COMPLETION OF DRILLING		
	WATER LEVEL MEASURED IN PIEZOMETER		
	PIEZOMETER		

BH No	Elevation (m)	Northings	Eastings
BH-1	171.4	4 830 281.7	286 118.5
BH-2	163.6	4 830 292.1	286 255.8
BH-3	161.5	4 830 334.8	286 332.9
BH-4	161.7	4 830 366.5	286 367.6
BH-5	164.3	4 830 403.5	286 438.6
BH-6	163.3	4 830 431.5	286 492.4

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

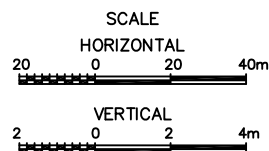
Geocres No. 30M12-420			
HWY No 401	CHECKED DD	DATE APR. 23, 2019	DIST Central
SUBM'D NL	CHECKED NR	APPROVED RN	SITE
DRAWN NL	CHECKED NR	APPROVED RN	DWG. SS-1



PROFILE ALONG C/L OF EXISTING 1500 DIA. SANITARY SEWER

NOTES:

- THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
- THE BOUNDARY LIMITS OF THE PEEL REGION 1500 mm DIA. SANITARY SEWER SHOWN IN THE PROFILE IS BASED ON ELEVATIONS PROVIDED BY AECOM VIA EMAIL, DATED APRIL 12, 2019.
- 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.



REF Drawing: Creditview Retaining Wall Sections_April12.dwg, dated March 2019.

Part A – Foundation Investigation Report

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APPENDIX A-3

Record of Borehole Sheets

RECORD OF BOREHOLE No BH-1

1 OF 2

METRIC

G.W.P. 2016-E-0004 LOCATION Coords: 4 830 281.7 N; 286 118.5 E ORIGINATED BY A.H.
 DIST Central HWY 401 BOREHOLE TYPE Hollow Stem Auger & NQ Rock Coring COMPILED BY N.L.
 DATUM Geodetic DATE 2019.02.15 LATITUDE 43.61223842 LONGITUDE -79.731439 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _p	W	W _L			WATER CONTENT (%)		
171.4	GROUND SURFACE							20	40	60	80	100					
0.0	SILTY SAND, with gravel		1	SS	18												
	Compact, Brown, Moist																
	CLAYEY SILT, trace/some sand, trace gravel		2	SS	7												
	Firm to stiff, Brown, Moist																
	(FILL)		3	SS	4												
			4	SS	6												
			5	SS	6												
			6	SS	8												
			7	SS	2												
166.2	CLAYEY SILT, with sand, some/with gravel																
5.2	Very stiff to hard, Grey, Moist		8	SS	15												
	(TILL)																
			9	SS	32												
			10	SS	41												
			11	SS	66												
			12	SS	91												
			13	SS	120/20cm												
158.6	SHALE BEDROCK																
12.8	unweathered		14	SS	60/3cm												
			15	RC HQ	REC 100%												
			16	RC HQ	REC 100%												
156.4																	

Continued Next Page

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

RECORD OF BOREHOLE No BH-1

2 OF 2

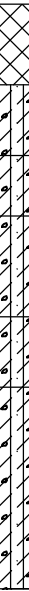
METRIC

G.W.P. 2016-E-0004 LOCATION Coords: 4 830 281.7 N; 286 118.5 E ORIGINATED BY A.H.
DIST Central HWY 401 BOREHOLE TYPE Hollow Stem Auger & NQ Rock Coring COMPILED BY N.L.
DATUM Geodetic DATE 2019.02.15 LATITUDE 43.61223842 LONGITUDE -79.731439 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W _p	W	W _L		
156.4 15.0	SHALE BEDROCK unweathered					156											
			17	RC HQ	REC 100%												
155.0 16.4	End of borehole					155											
	Water level measured in monitoring well NOTES: 1. Groundwater level not encountered during or upon completion of drilling. 2. No cave-in was noted in the borehole upon extraction of hollow stem augers. Monitoring Well Readings: Date Feb.21/19 Depth (m) 8.2 Elev. 163.2 Monitoring Well Legend: PVC Pipe Stick-up Bentonite Seal Filter Sand Screen																

ONTARIO MTO 18TF033.GPJ ONTARIO MTO.GDT 3/13/19

METRIC

SOIL PROFILE						SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	20	40	60			80	100	w _p	w	w _L				
163.6 0.0	GROUND SURFACE SILTY SAND, with gravel		1	SS	37											13 38 36 13			
	Grey, Moist (FILL)																		
162.8 0.8	CLAYEY SILT, with sand, some gravel Stiff to hard, Brown to grey, Moist		2	SS	10												16 37 34 13		
	SILTY SAND, with gravel Wet		3	SS	19														
			4	SS	62/20cm														
	SILTY SAND, trace gravel		5	SS	30														
			6	SS	60														
	(TILL)		7	SS	35														
		8	SS	100/11cm															
157.8 5.8	End of borehole Auger refusal on probable bedrock																		
	Groundwater measured upon completion of drilling																		
	NOTE: Upon extraction of hollow stem augers, the borehole caved in at a depth of 2.4 m below the ground surface.																		

ONTARIO MTO 18TF033.GPJ ONTARIO MTO.GDT 3/13/19

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

RECORD OF BOREHOLE No BH-3

1 OF 1

METRIC

G.W.P. 2016-E-0004 LOCATION Coords: 4 830 334.8 N; 286 332.9 E ORIGINATED BY A.H.
DIST Central HWY 401 BOREHOLE TYPE Hollow Stem Auger COMPILED BY N.L.
DATUM Geodetic DATE 2019.02.21 LATITUDE 43.61272132 LONGITUDE -79.72878539 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 γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)	
								20	40	60	80						100	20
161.5	GROUND SURFACE																	
0.0	CLAYEY SILT, trace sand, trace gravel		1	SS	3													
	Soft, Brown, Moist																	
			2	SS	2													
	SAND, with gravel, trace silt																	
	Loose, Brown, Wet (FILL)		3	SS	10													
159.3	SILTY SAND, with gravel																	
2.2	Very dense, Grey, Wet to moist (TILL)		4	SS	111/20cm											28 36 29 7		
			5	SS	50/13cm													
			6	SS	88													
			7	SS	100/13cm											28 31 28 13		
			8	SS	100/11cm													
			9	SS	100/13cm											24 26 35 15		
			10	SS	100/13cm													

RECORD OF BOREHOLE No BH-4

1 OF 2

METRIC

G.W.P. 2016-E-0004 LOCATION Coords: 4 830 366.5 N; 286 367.6 E ORIGINATED BY M.M.
 DIST Central HWY 401 BOREHOLE TYPE Hollow Stem Auger & NQ Rock Coring COMPILED BY N.L.
 DATUM Geodetic DATE 2019.02.20 LATITUDE 43.61300784 LONGITUDE -79.72835626 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 γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)	
161.7 0.0	GROUND SURFACE CLAYEY SILT, trace sand Stiff to firm, Brown, Moist		1	SS	9		161							GR SA SI CL		
			2	SS	4		160								182	
	SAND, with gravel, trace silt Compact, Brown, Wet (FILL)		3	SS	15		159									
159.5 2.2	CLAYEY SILT, with sand, trace gravel Stiff to very stiff, Brown to grey, Moist (TILL)		4	SS	14		158								8 25 39 28	
			5	SS	17		157									
157.9 3.8	SILTY SAND, with gravel Very dense, Grey, Moist (TILL)		6	SS	66		156									
		7	SS	60	155											18 36 36 10
		8	SS	50/15cm	154											
		9	SS	50/10cm	153											
							152									23 32 32 13
							151									
							150									
152.4 9.3	SHALE BEDROCK unweathered		10	SS	50/8cm		149									
			11	SS	50/8cm											
			12	RC HQ	REC 100%											
			13	RC HQ	REC 100%									RQD 10%		
			14	RC HQ	REC 100%									RQD 86%		
148.8 12.9	End of borehole													RQD 91%		
	Groundwater measured upon completion of drilling Groundwater level measured in monitoring well NOTE: No cave-in noted in the borehole upon extraction of hollow stem augers.															

Continued Next Page

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

RECORD OF BOREHOLE No BH-4

2 OF 2

METRIC

G.W.P. 2016-E-0004 LOCATION Coords: 4 830 366.5 N; 286 367.6 E ORIGINATED BY M.M.
 DIST Central HWY 401 BOREHOLE TYPE Hollow Stem Auger & NQ Rock Coring COMPILED BY N.L.
 DATUM Geodetic DATE 2019.02.20 LATITUDE 43.61300784 LONGITUDE -79.72835626 CHECKED BY M.V.



SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W _p	W	W _L							
146.7	<p><u>Monitoring Well Readings:</u></p> <table border="1"> <thead> <tr> <th>Date</th> <th>Depth (m)</th> <th>Elev.</th> </tr> </thead> <tbody> <tr> <td>Feb.21/19</td> <td>1.1</td> <td>160.6</td> </tr> </tbody> </table> <p><u>Monitoring Well Legend:</u></p> <div style="display: flex; align-items: center;"> <div style="border: 1px solid black; width: 20px; height: 10px; margin-right: 5px;"></div> <div>PVC Pipe Stick-up</div> </div> <div style="display: flex; align-items: center;"> <div style="background-color: black; width: 20px; height: 10px; margin-right: 5px;"></div> <div>Bentonite Seal</div> </div> <div style="display: flex; align-items: center;"> <div style="border: 1px solid black; width: 20px; height: 10px; background: repeating-linear-gradient(45deg, transparent, transparent 2px, black 2px, black 4px); margin-right: 5px;"></div> <div>Filter Sand</div> </div> <div style="display: flex; align-items: center;"> <div style="border: 1px solid black; width: 20px; height: 10px; background: repeating-linear-gradient(-45deg, transparent, transparent 2px, black 2px, black 4px); margin-right: 5px;"></div> <div>Screen</div> </div>	Date	Depth (m)	Elev.	Feb.21/19	1.1	160.6															
Date	Depth (m)	Elev.																				
Feb.21/19	1.1	160.6																				

RECORD OF BOREHOLE No BH-5

1 OF 1

METRIC

G.W.P. 2016-E-0004 LOCATION Coords: 4 830 403.5 N; 286 438.6 E ORIGINATED BY A.H.
 DIST Central HWY 401 BOREHOLE TYPE Hollow Stem Auger COMPILED BY N.L.
 DATUM Geodetic DATE 2019.02.22 LATITUDE 43.61334267 LONGITUDE -79.72747778 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
164.3 0.0	GROUND SURFACE SANDY SILT, trace gravel, asphalt debris Very dense, Brown/grey, Moist CLAYEY SILT, some sand, trace gravel Very stiff to firm, Grey, Moist (FILL)		1	SS	45		164							
			2	SS	21		163							
			3	SS	6		162							
			4	SS	9		161							
			5	SS	9		160							
			6	SS	5		159							
159.8 4.5	CLAYEY SILT, trace sand, trace gravel Very stiff to stiff, Grey, Moist (TILL)		7	SS	14		158							
			8	SS	20		157							
			9	SS	8		156							
156.8 7.5	SILTY SAND, with gravel Compact to very dense, Grey, Moist (TILL)		10	SS	25		155							
			11	SS	112		154							
			12	SS	105/20cm		153							
152.1 12.2	Highly Weathered Shale		13	SS	50/3cm		152							
151.9 12.4	End of borehole													
	 Groundwater level measured upon completion of drilling NOTE: Upon extraction of hollow stem augers, the borehole caved in at a depth of 7.9 m below the ground surface.													

ONTARIO MTO 18TF033.GPJ ONTARIO MTO.GDT 3/13/19

RECORD OF BOREHOLE No BH-6

1 OF 1

METRIC

G.W.P. 2016-E-0004 LOCATION Coords: 4 830 431.5 N; 286 492.4 E ORIGINATED BY A.H.
DIST Central HWY 401 BOREHOLE TYPE Hollow Stem Auger COMPILED BY N.L.
DATUM Geodetic DATE 2019.02.21 LATITUDE 43.61359553 LONGITUDE -79.72681226 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 γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
163.3 0.0	GROUND SURFACE SANDY SILT/SILTY SAND, trace gravel Compact, Brown, Moist (FILL)		1	SS	17		163										11 31 41 17
			2	SS	23		162										
161.9 1.4	SILTY SAND, trace/with gravel Dense, Brown, Wet (TILL)		3	SS	31		161										
			4	SS	41												
160.3 3.0	CLAYEY SILT, some/with sand, trace gravel Stiff, Grey, Moist (TILL)		5	SS	14		160										
			6	SS	10		159										
			7	SS	12												
		8	SS	8	158												
		9	SS	13	157												
155.8 7.5	SILTY SAND, with gravel Compact to dense, Grey, Moist (TILL)		10	SS	21		156										
							155										
153.6 9.7	End of borehole		11	SS	33	154											
	Groundwater level measured upon completion of drilling NOTE: Upon extraction of hollow stem augers, the borehole caved in at a depth of 7.6 m below the ground surface.																

ONTARIO MTO 18TF033.GPJ ONTARIO MTO.GDT 3/13/19

Part A – Foundation Investigation Report

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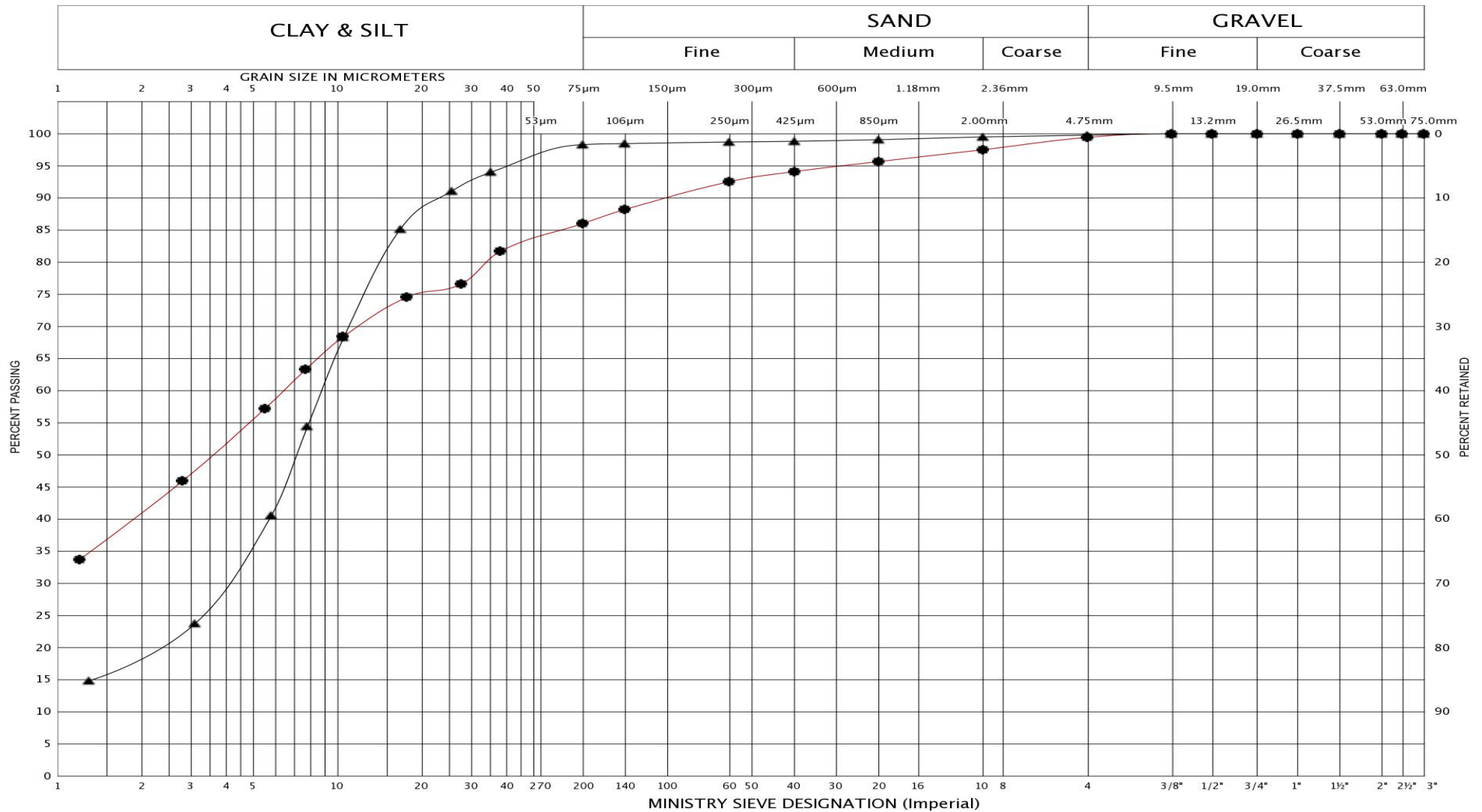
PML Ref.: 18TF033, April 23, 2019



APPENDIX A-4

Grain Size Distribution Analyses – Figures GS-1, GS-2, and GS-3

UNIFIED SOIL CLASSIFICATION SYSTEM



LEGEND	BH	1	1
	SAMPLE	2	5
	SYMBOL	▲	●



GRAIN SIZE DISTRIBUTION

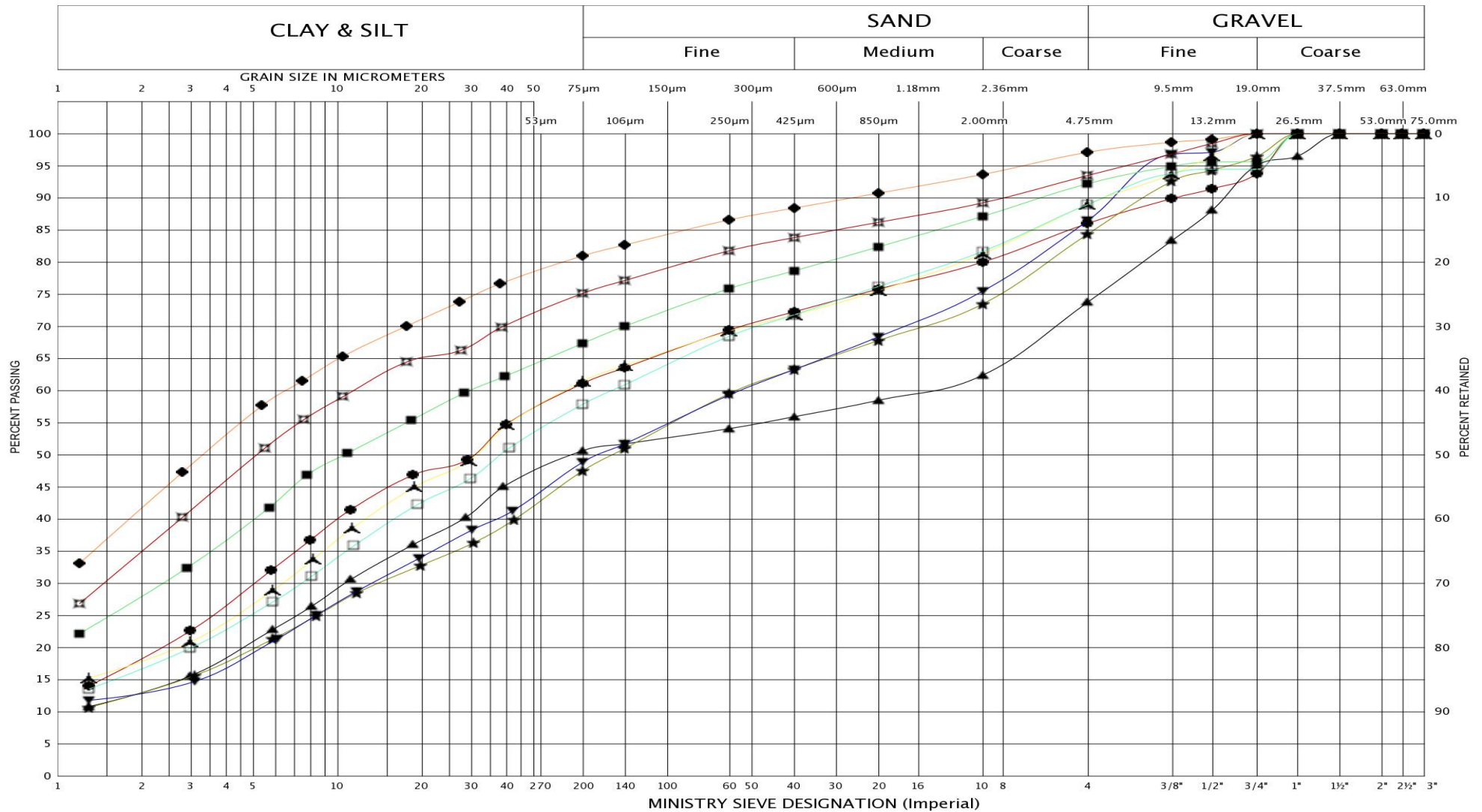
CLAYEY SILT (FILL)

FIG No.: GS-1

HWY : 401

GWP 2016-E-0004

UNIFIED SOIL CLASSIFICATION SYSTEM



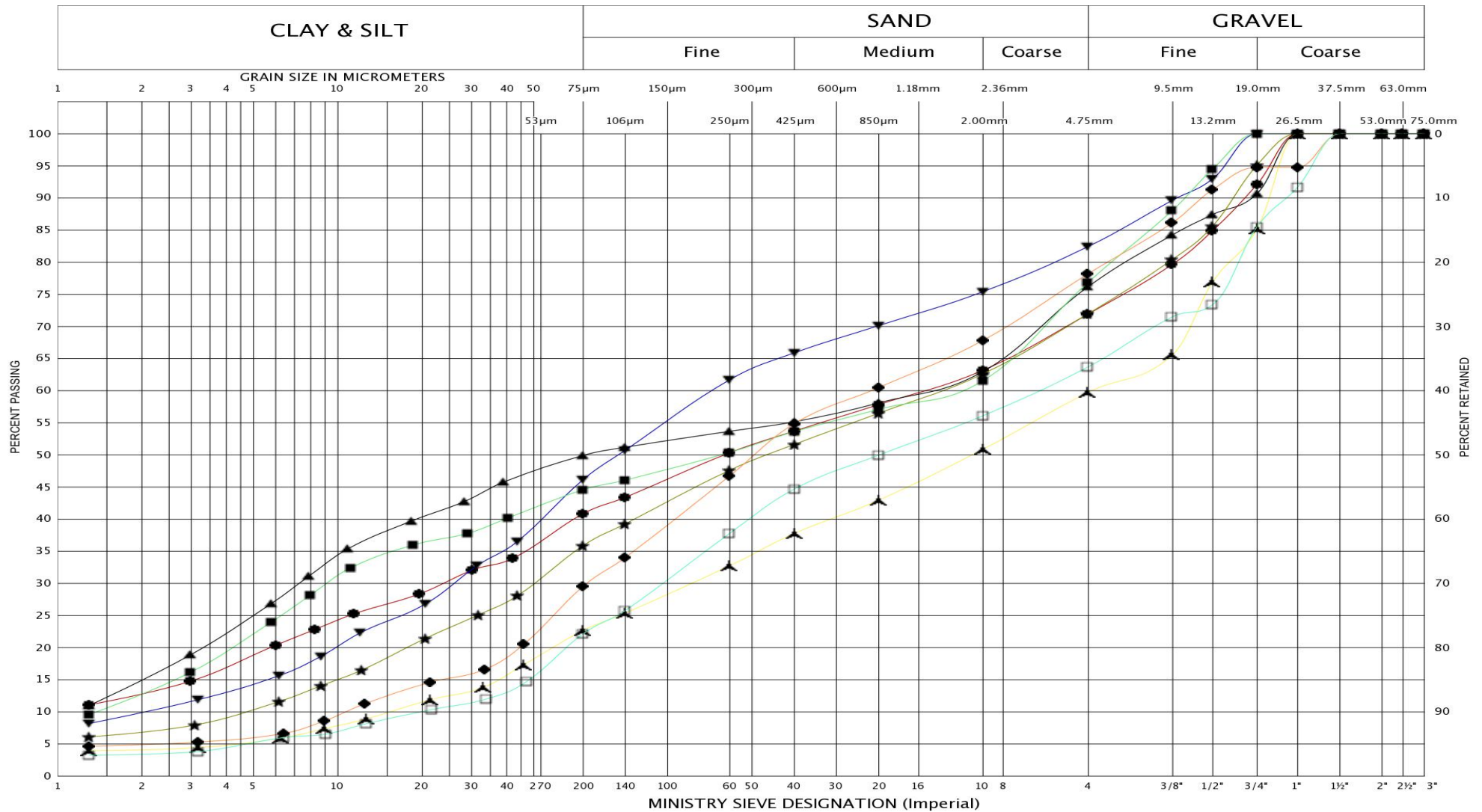
LEGEND	BH	1	1	2	2	4	5	5	6	6
	SAMPLE	8	12	4	6	5	7	9	6	8
	SYMBOL	◆	▲	▼	★	■	△	◇	□	⊠



GRAIN SIZE DISTRIBUTION
CLAYEY SILT TILL

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

UNIFIED SOIL CLASSIFICATION SYSTEM



LEGEND	BH	3	3	3	4	4	5	5	6
	SAMPLE	4	7	9	7	10	11	12	11
	SYMBOL	★	●	▲	▼	■	◆	▲	□



GRAIN SIZE DISTRIBUTION
SILTY SAND TILL

FIG No.: GS-3
HWY : 401
GWP 2016-E-0004

Part A – Foundation Investigation Report

Evaluation of Alternatives for Protection of Sewer and Watermain Utilities

Highway 401 WBL Widening and Creditview Road Realignment

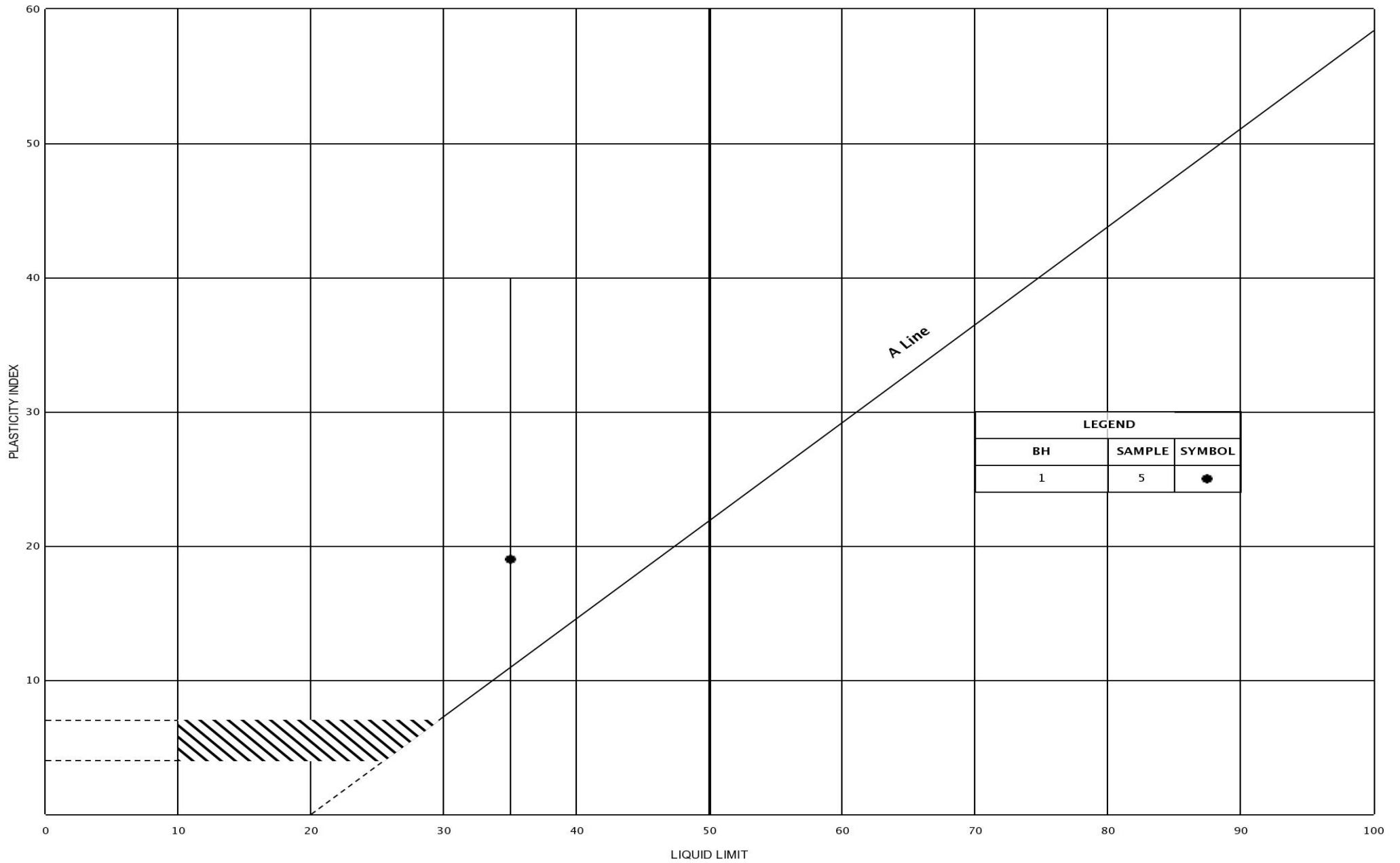
Assignment No. 2016-E-0004, Work Order 12B, Halton Region and Peel Region, Ontario, Index No.: 008FIR

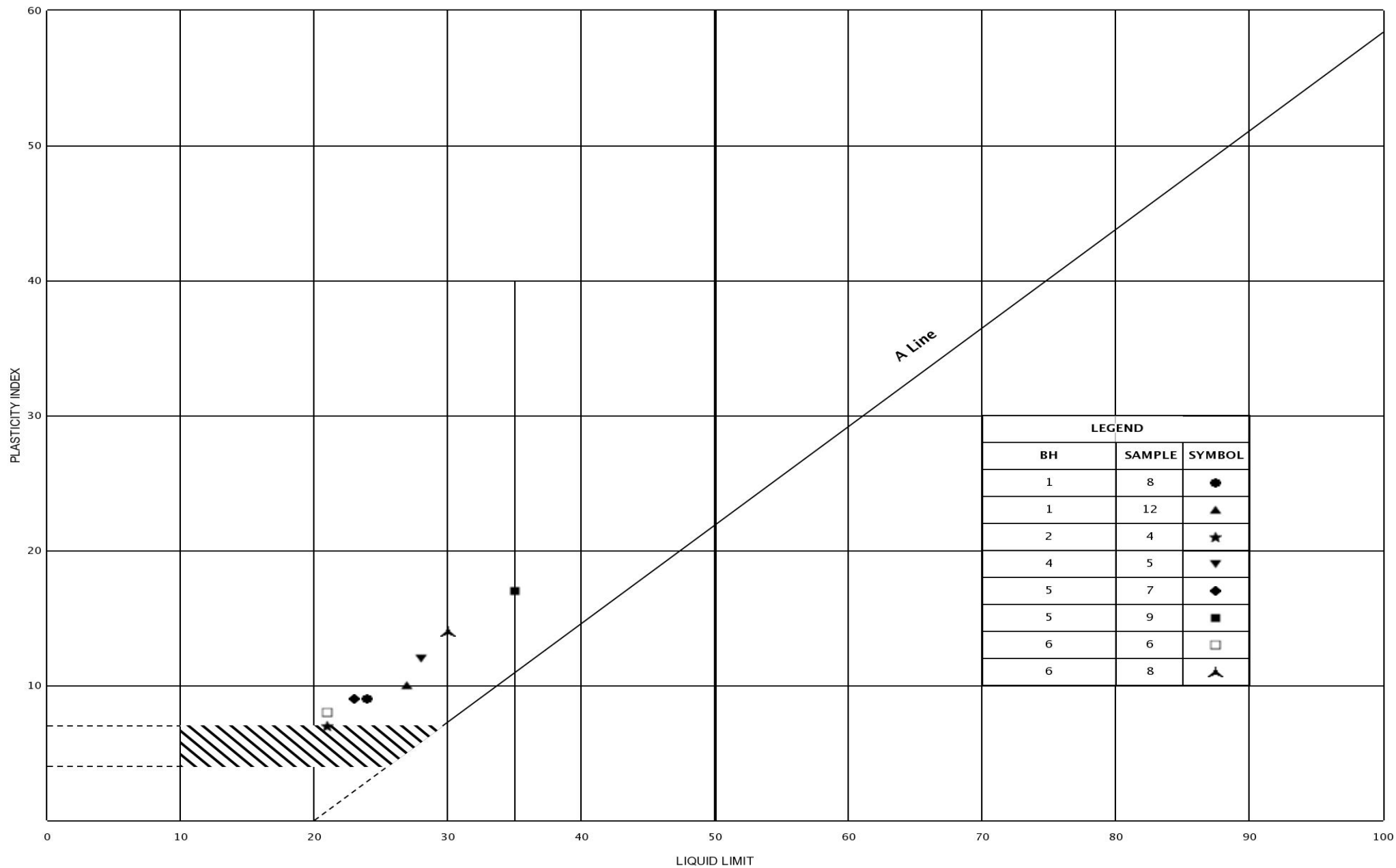
PML Ref.: 18TF033, April 23, 2019

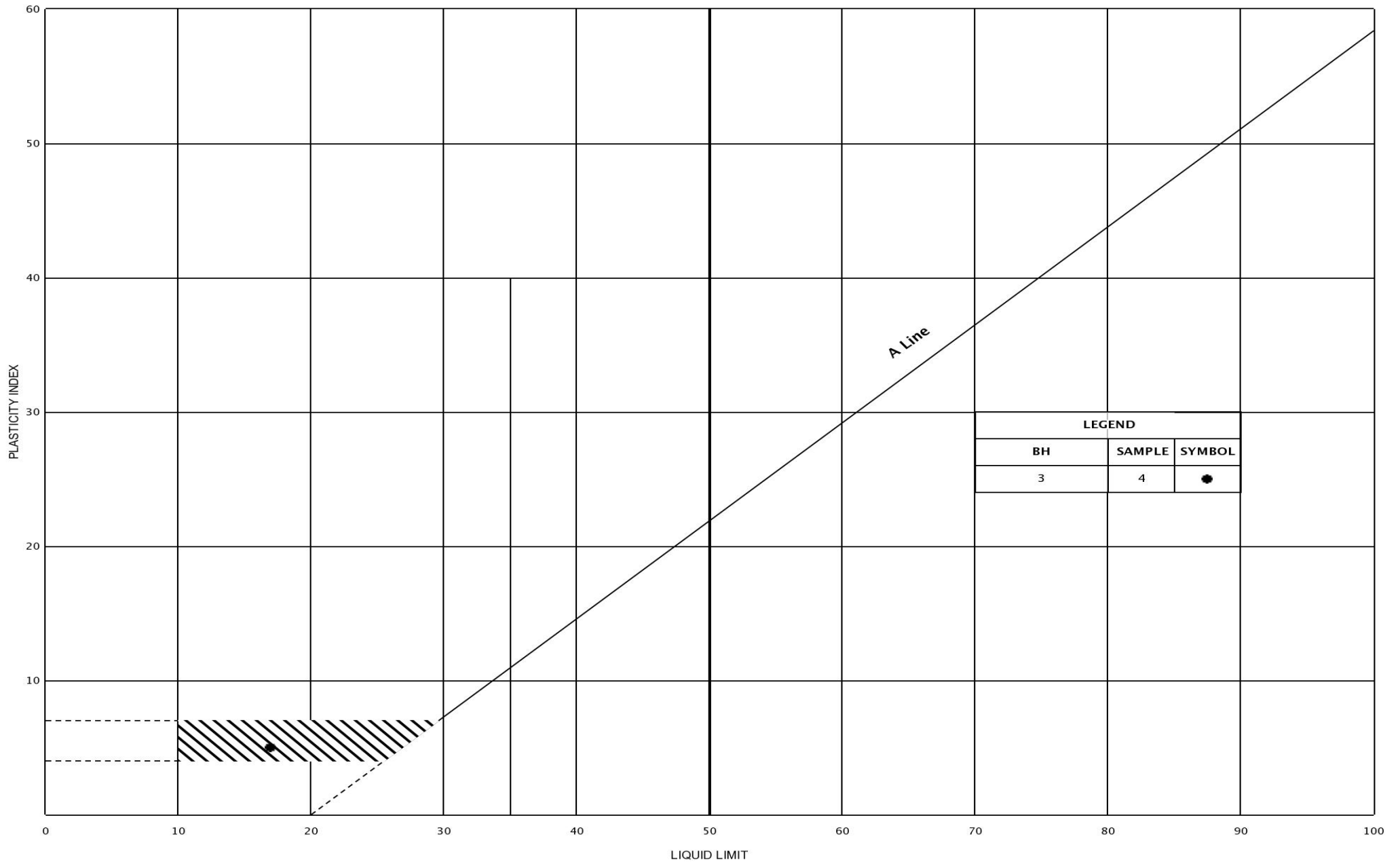


APPENDIX A-5

Atterberg Limit Tests – Figures PC-1, PC-2, and PC-3







Part A – Foundation Investigation Report

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PML Ref.: 18TF033, April 23, 2019



APPENDIX A-6

Bedrock Core Descriptions and Photographs

Part A – Foundation Investigation Report

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PML Ref.: 18TF033, April 18, 2019



ROCK CORE DESCRIPTION

Location: Creditview Road, Mississauga, Ontario **Project Name:** Peel Region Utilities - Highway 401 (WO 12B)

Project Number: 18TF033

BH No.	CORE RECOVERY					CORE DESCRIPTION
	RC No.	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
BH 1	1	12.83	+100.0 (1.12 m)	11.0 (0.12 m)	13.92	<p style="text-align: center;">GEORGIAN BAY FORMATION</p> <p>Unweathered, very fine grained to fissile, thinly laminated, dark grey, soft, slightly calcareous, SHALE with unweathered, fine to medium grained, thinly bedded, dark grey, moderately hard, calcareous, crystalline CARBONATE interbeds (<6.0 cm thick) with thin bituminous seams (<1.0 mm thick). Occasional features: Fossiliferous/white calcite nodules (<5.0 mm wide) found within carbonate interbeds; broken rock at 12.89-12.91 m and 13.93-13.95 m.</p>
BH 1	2	13.92	100.0 (1.52 m)	78.9 (1.20 m)	15.44	<p style="text-align: center;">GEORGIAN BAY FORMATION</p> <p>Unweathered, very fine grained to fissile, thinly laminated, dark grey, soft, slightly calcareous, SHALE with unweathered, fine to medium grained, thinly bedded, dark grey, moderately hard, calcareous, crystalline CARBONATE interbeds (<7.0 cm thick) with thin bituminous seams (<1.0 mm thick). Occasional features: Increase in fossiliferous/white calcite nodules (<10.0 mm wide) found within carbonate interbeds; large carbonate interbeds at 14.48-14.65 m, 14.70-14.82 m and 14.86-14.97 m; clay at 15.39-15.44 m. Sample taken at 14.48-14.62 m (carbonate interbed).</p>

Part A – Foundation Investigation Report

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Assignment No. 2016-E-0004, Work Order 12B, Halton Region and Peel Region, Ontario, Index No.: 008FIR

PML Ref.: 18TF033, April 18, 2019



BH No.	CORE RECOVERY					CORE DESCRIPTION
	RC No.	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
BH 1	3	15.44	+100.0 (0.98 m)	72.8 (0.67 m)	16.36	<p>GEORGIAN BAY FORMATION</p> <p>Unweathered, very fine grained to fissile, thinly laminated, dark grey, soft, slightly calcareous, SHALE with unweathered, fine to medium grained, thinly bedded, dark grey, moderately hard, calcareous, crystalline CARBONATE interbeds (<7.0 cm thick) with thin bituminous seams (<1.0 mm thick).</p> <p>Occasional features: Fossiliferous/white calcite nodules (<10.0 mm wide) found within carbonate interbeds; large carbonate interbeds at 16.02-16.29 m; clay at 16.29-16.36 m; broken rock at 15.49-15.52 m; calcite seam at 15.52-15.53 m.</p> <p>Sample taken at 16.02-16.29 m (carbonate interbed).</p>

CR* - Core Recovery

Logged by: Heather Racher, M.Sc.

RQD* - Rock Quality Designation**Note:** Depths are approximated where core recovery is less than 100%. RQDs are calculated according to core recovery (less than designated 1.52 m runs).

Part A – Foundation Investigation Report

Evaluation of Alternatives for Protection of Sewer and Watermain Utilities

Highway 401 WBL Widening and Creditview Road Realignment

Assignment No. 2016-E-0004, Work Order 12B, Halton Region and Peel Region, Ontario, Index No.: 008FIR

PML Ref.: 18TF033, April 18, 2019

**ROCK CORE DESCRIPTION****Location:** Creditview Road, Mississauga, Ontario **Project Name:** Peel Region Utilities - Highway 401 (WO 12B)**Project Number:** 18TF033

BH No.	CORE RECOVERY					CORE DESCRIPTION
	RC No.	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
BH 4	1	9.22	+100.0 (0.66 m)	9.8 (0.06 m)	9.83	GEORGIAN BAY FORMATION Unweathered, very fine grained to fissile, thinly laminated, dark grey, soft, slightly calcareous, SHALE with unweathered, fine to medium grained, thinly bedded, dark grey, moderately hard, calcareous, crystalline CARBONATE interbeds (<7.0 cm thick) with thin bituminous seams (<1.0 mm thick). Occasional features: Broken rock at 9.22-9.29 m.
BH 4	2	9.83	+100.0 (1.59 m)	85.5 (1.30 m)	11.35	GEORGIAN BAY FORMATION Unweathered, very fine grained to fissile, thinly laminated, dark grey, soft, slightly calcareous, SHALE with unweathered, fine to medium grained, thinly bedded, dark grey, moderately hard, calcareous, crystalline CARBONATE interbeds (<3.0 cm thick) with thin bituminous seams (<1.0 mm thick). Occasional features: Slightly fossiliferous/white calcite nodules (<5.0 mm wide) found within carbonate interbeds; large carbonate interbeds at 11.16-11.42 m; broken rock at 9.83-9.84 m. Sample taken at 10.93-11.09 m.
BH 4	3	11.35	100.0 (1.52 m)	91.4 (1.39 m)	12.87	GEORGIAN BAY FORMATION Unweathered, very fine grained to fissile, thinly laminated, dark grey, soft, slightly calcareous, SHALE with unweathered, fine to medium grained, thinly bedded, dark grey, moderately hard, calcareous, crystalline CARBONATE interbeds (<10.0 cm thick) with thin bituminous seams (<1.0 mm thick). Sample taken at 12.63-12.76 m.

CR* - Core Recovery**RQD*** - Rock Quality Designation**Note:** Depths are approximated where core recovery is less than 100%. RQDs are calculated according to core recovery (less than designated 1.52 m runs).

Logged by: Heather Racher, M.Sc.

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Photograph 1: Cores retrieved from borehole BH-1. Runs 1 and 2 from 12.8 to 15.4 m depth. RQD values ranged from 11 to 79%, indicating very poor to good rock quality.



Photograph 2: Core retrieved from borehole BH-1. Run 3 from 15.4 to 16.4 m depth. RQD value was 73%, indicating fair quality.



Photograph 3: Core retrieved from borehole BH-4. Run 1 from 9.2 to 9.8 m depth. RQD value was 10%, indicating very poor quality.

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Photograph 4: Cores retrieved from borehole BH-4. Runs 2 and 3 from 9.8 to 12.9 m depth. RQD values ranged from 86 to 91%, indicating good to excellent rock quality.



PART B - FOUNDATION DESIGN REPORT

for

**EVALUATION OF ALTERNATIVES FOR PROTECTION OF SEWER
AND WATERMAIN UTILITIES
HIGHWAY 401 WBL (FROM 200 M EAST OF CREDIT RIVER TO
CREDITVIEW ROAD) WIDENING AND
CREDITVIEW ROAD REALIGNMENT
HIGHWAY 401 WEST EXPANSION
REGIONS OF PEEL AND HALTON, ONTARIO
ASSIGNMENT NO. 2016-E-0004
WORK ORDER #12B**

LATITUDE AND LONGITUDE: 43.612238, -79.731439

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April 23, 2019

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Evaluation of Alternatives for Protection of Sewer and Watermain Utilities

Highway 401 WBL Widening and Creditview Road Realignment

Assignment No. 2016-E-0004, Work Order 12B, Halton Region and Peel Region, Ontario, Index No.:009FDR

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PART B – FOUNDATION DESIGN REPORT

For

Evaluation of Alternatives for Protection of Sewer and Watermain Utilities
Highway 401 WBL (from 200 m East of Credit River to Creditview Road) Widening
and Creditview Road Realignment
Assignment No. 2016-E-0004, Work Order #12B
Halton Region and Peel Region, Ontario

8. PROJECT OVERVIEW

The specific site is within the Highway 401 West Expansion project.

The Highway 401 West Expansion project involves widening of the Highway 401 mainline from the Credit River in the City of Mississauga, westerly for approximately 18 km, to Regional Road 25 in the Town of Milton, Ontario.

This assignment requirement was to evaluate if the proposed widening to the north side of Highway 401 WBL and the proposed realignment of the Creditview Road to the east would preclude Peel Region's future access and services to the following sanitary sewers/watermains:

1. The existing 1500 mm diameter sanitary sewer adjacent to the north side of Highway 401 that extends from the east side of Creditview Road to approximately 100m west of the Credit River.
2. The existing 400 mm diameter PVC watermain and the existing 1500 mm diameter sanitary adjacent to the east side of Creditview Road that extend approximately 60m north from Highway 401 north side. Subsequently, the evaluation of the sanitary sewer along the east side of Creditview Road was withdrawn from the scope. It is understood that this decision was due to its significant depth. In any case, the performance of the watermain along the east side of Creditview Road would be more critical since it is a pressure pipe.

The evaluations were based on slope stability analyses to determine the feasibility of a conventional shoring alternative to compare with a permanent retaining wall alternative. Input assumptions were derived from the following information:

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- A previous report (GEOCRE No. 30M12-344) prepared by Golder Associates, dated September 2012.
- Six additional boreholes advanced by PML for this assignment (refer to FIR portion of this report)
- Plan and cross-sections along Highway 401 from approximately Station 14+900 to Station 15+220. Refer to Appendix B-1 for details.
- Plan and cross-sections along the Creditview Road from approximately Sta. 9+900 to Sta. 9+960. Refer to Appendix B-2 for details.

The evaluations presented in this report are for engineering feasibility and planning purposes only. Further clarification and confirmation of actual geometries and direction on selection of alternative in conjunction with input from expert structural and shoring design services would be required for detail design of roadway protection/shoring and retaining walls.

9. SEWER AND WATERMAIN GEOMETRICS

An existing 1500 mm diameter sanitary sewer is in close proximity to the proposed Highway 401 WBL widening near the Credit River. An existing 1500 mm diameter sanitary sewer and an existing 400 mm diameter watermain are in close proximity to the proposed Creditview Road realignment.

The critical geometric details would be the vertical and horizontal distances from the crest of the roads to the invert of each sanitary sewer and watermain. These dimensions define the slope from the base of an excavation to expose the sanitary sewer/watermain to the crest of the embankment at road level. Tables 9a and 9b present these critical dimensions for both the existing road geometry and for the proposed road geometry. Refer to Appendices B-1 and B-2 for details of the Highway 401 and Creditview Road utility locations, respectively.

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**Table 9a :Summary of Sanitary Sewer Geometrics Adjacent to Highway 401**

Station	Approximate offset of sewer from existing Hwy shoulder (m)	Approximate offset of sewer from proposed Hwy shoulder (m)	Approximate existing ground elevation above sewer (m)	Approximate proposed ground elevation above sewer w/o retaining wall (m)	Approximate sewer invert elevation (m)
14+900	30	6	170	166	163.5
14+920	28	7	168	166	163
14+940	28	7	168	166	162
14+960	28	6	164	166	161.2
15+068	28	6	162	163	158.5
15+080	28	7	162	162	158.5
15+100	30	8	162	162	158.5
15+120	30	8	162	162	158.5
15+140	30	8	162	162	158
15+160	30	8	162	162	158
15+180	28	8	162	162	157.5
15+200	28	8	163	163	157
15+220	30	8	163	163	157

Table 9b: Summary of Sanitary Sewer/Watermain Geometrics Adjacent to Creditview Road

Station	Approximate offset from existing Hwy shoulder (m)		Approximate offset from proposed hwy shoulder (m)		Approximate existing ground elevation above watermain/sewer (m)	Approximate proposed ground elevation above watermain/seer (m)	Approximate watermain invert elevation (m)	Approximate sewer invert elevation (m)
	watermain	sewer	Watermain	sewer				
9+900	24	18	12	8	172	172	167.5-169.5	156.5-159
9+920	24	20	14	10	171	172	167.5-169.5	156.5-159
9+940	26	24	16	12	171	172	167.5-169.5	156.5-159
9+960	56	40	44	28	171	171	167.5-169.5	156.5-159

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**10. SLOPE STABILITY ANALYSIS**

Slope stability analyses were carried with the Slide program (Version 6.0) developed by Rocscience Inc, utilizing the Morgenstern-Price method of slices for limit equilibrium analysis with a target acceptable factor of safety of 1.3 for total stress analysis.

The analyses were based on the critical slope stability assumptions presented in Table 10.

Table 10: Critical Slope Stability Assumptions

Location	Horizontal Extent (m) pipe	Horizontal Offset (m) pipe to edge of existing travelled lanes	Horizontal Offset (m) pipe to edge of proposed widened travelled lanes	Elevation (m) roadway	Elevation (m) original ground at pipe	Approximate embankment height (m)	Elevation (m) pipe invert
Highway 401 Sanitary Sewer	320	26	8	165	162	3	157
Creditview Rd Sanitary Sewer	90	20	8	177	171	6	168
Creditview Rd Watermain	90	26	14	177	171	6	158

The input geotechnical parameters and soil models used in the stability analyses and the results of the slope stability analyses for the Highway 401 sanitary sewer and for the Creditview Rd sanitary sewer and watermain are illustrated in Appendix B-1 and B-2 respectively.

The slope geometries refer to critical sections to validate assumptions made in the evaluation of alternatives for excavation of the sanitary sewer and watermain and are not intended to show detail design level calculations. The critical section approach was selected to assess the practical feasibility of conventional shoring for comparison with the permanent retaining wall alternative. That is, if the conventional shoring alternative is assessed as feasible for the critical section, it follows that it would be feasible for less critical geometries.

Based on the analyses, proposed embankment heights indicated in Table 10:

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- For both Highway 401 and Creditview Road, the Factor of Safety against slope instability is acceptable for permanent 2H:1V slopes.
- For the Highway 401 sanitary sewer, the Factor of Safety against slope instability is marginal for 1H:1V slopes required to expose the invert of the sanitary sewer extending from the base of excavation to the intercept of the widened Highway 401 2H:1V embankment. The implication is that localized shoring would be required to expose the invert of the sanitary sewer adjacent to Highway 401.
- For the Creditview Road watermain, the location of the watermain is outside the footprint of the proposed realigned Creditview Road 2H:1V embankment. The implication is that the requirements for localized shoring to expose the invert of the watermain would be similar to requirements existing before the realignment Creditview Road. The Factor of Safety against slope instability within the confines of excavation to expose the invert of the watermain is acceptable, but should be confirmed during detail design for such excavation.

11. EVALUATION OF ALTERNATIVES

The following Table 11 compares the advantages, disadvantages, risks / consequences and relative costs of selected alternatives.

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**Table 11: Comparison of Alternatives**

ALTERNATIVE		ADVANTAGES	DISADVANTAGES	RISKS/CONSEQUENCES	RELATIVE COSTS
NO.	DESCRIPTION				
1	Conventional shoring	<ul style="list-style-type: none">- can be limited to when and where required- conventional construction	<ul style="list-style-type: none">- time required to design and install shoring- geometric conditions for shoring are more challenging after road widenings/realignments	<ul style="list-style-type: none">- breach of watermain could saturate and erode embankments causing instability if not managed promptly- roadway protection system may require some temporary infringement on road shoulders	<ul style="list-style-type: none">- cost of shoring moderate and only if and where required
2	Permanent retaining structure	<ul style="list-style-type: none">- temporary roadway protection not required to access sewer / watermain invert	<ul style="list-style-type: none">- RSS retaining walls above existing would incorporate sheet piles below existing ground to limit excavation- permanent retaining walls would be constructed prior to widening and influence construction of road widening- OHSA requirements would still apply to excavations to expose sanitary sewers/watermains below existing ground	<ul style="list-style-type: none">- retaining walls would limit space for future road widening	<ul style="list-style-type: none">- high estimated to be in excess of \$400/m² of wall face

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12. DISCUSSION OF ALTERNATIVES

The following 2 options using the configurations and sections provided were considered and are presented in priority of preference from a geotechnical engineering perspective:

- 1) Follow OHSA requirements and utilize localized temporary roadway protection/shoring as necessary to permit excavations to expose the pipes when required - a typical approach for sewer maintenance. The shoring method and design should be the responsibility of the contractor. Shoring methods could include soldier pile and lagging or sheet piling. Ground anchors or braces may be required to supplement horizontal resistance. The height of the shoring would depend upon the location and should extend to intersect a 2H:1V slope extending from the crest of the road embankment. Advantages would include deferring costs until if and when necessary.

Refer to the sections in Appendices B-1 and B-2 for illustration of the proximity of the widened highway embankments to the sanitary sewers/watermains. As illustrated, for most of the sanitary sewer/watermain alignments are either beyond the toe of the proposed 2H:1V road embankment slopes or only marginally covered by the toe of those slopes. Consequently, the conditions for excavation to expose the sanitary sewers/watermains is similar to existing conditions except for the closer proximity of the adjacent road embankment slope.

- 2) Prior to embankment widening, construct permanent retaining walls adjacent to the pipes to protect widened Highway 401 and Creditview Road embankments and maintain a slope geometry that provides the current level of access to existing ground level above the pipes and to permit excavations to expose the pipes without further protection of proposed widened configuration of Highway 401 and Creditview Road. The height of the retaining walls would depend upon the location and should extend to intersect a 2H:1V slope extending from the crest of the embankment. If option 2) is selected, the decision would be based on a possible but uncertain requirement that exposure of the sanitary sewers/watermain would be required. If this option is selected, permanent retaining walls should be completed prior to construction of road widenings and realignments to minimize

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the amount of temporary roadway protection/shoring required for their construction. The walls would have to meet requirements for permanent walls. The type of retaining wall would depend on the space available.

- a) Along Highway 401, hybrid walls with sheet piling below existing ground level and design high water level and with RSS walls above existing ground level and design high water level could be considered.
- b) Along Creditview Rd, space is more limited so that a permanent shoring type wall supplemented with ground anchors might be required for the full height of the wall.

Relocation of the sewer and watermain could also be considered but is beyond the scope of this report. If considered, the accessibility of the appropriate manholes and access points should be maintained and not buried by road widening/realignment.

13. PRELIMINARY DESIGN RECOMMENDATIONS

13.1. Extent of Walls

Retaining walls and temporary roadway protection/shoring respectively, should extend

- vertically, to the base of any excavation
- horizontally, as illustrated in Appendices B-1 and B-2.

13.2 Dewatering

The groundwater level should be maintained a minimum of 0.5 m below the base of all excavations.

The contractor should be responsible for the selection, performance and detailed design of the dewatering system. The dewatering system should be designed to conform to the requirement of OPSS.PROV 517 (Construction Specification for Dewatering).

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13.3 Excavation

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. For excavations through multiple soil types, the side slope geometry is governed by the soil with the highest number designation. For OHSA classification purposes, the ground should be classified as Type 3 soils.

Excavated material should not be stockpiled near the crest of excavations.

Shoring/roadway protection systems should conform to the requirements of OPSS.PROV 539, Construction Specification for Temporary Protection Systems assuming level 2 displacement requirements, and OPSS.PROV 401, Construction Specification for trenching, backfilling and compacting.

13.4 Lateral Earth Pressure

Earth pressure should be computed as per the Clause 6.12 of Canadian Highway Bridge Design Code (CHBDC, 2014) taking into consideration requirements for sloping backfill. In general, the lateral earth and water pressure, p (kPa), may be computed by the following equation assuming a triangular pressure distribution for a cantilever wall or a trapezoidal pressure distribution for a ground anchor wall. The appropriate pressure distribution should be determined by the specialist designer of the wall. The active condition may be assumed provided that the displacement of the top of the wall will exceed $0.001 \times$ height of wall.

$$P = K (\gamma h_1 + \gamma' h_2 + q) + \gamma_w h_2 + C_p + C_s$$

Where, P = lateral earth pressure (kPa)

K = lateral earth pressure coefficient

γ = unit wgt of backfill material above assumed water level (kN/m³)

γ' = unit wgt of submerged backfill ($\gamma - \gamma_w$) material below assumed water level (kN/m³)

γ_w = unit weight of water (9.8 kN/m³)

h_1 = depth below final grade (m), above assumed water level

h_2 = depth below design water level (m)

q = surcharge load (kPa)

C_p = compaction pressure (refer to clause 6.12.3 of CHBDC 2014)

C_s = earth pressure induced by seismic events, kPa (refer to clause 4.6.5 of CHBDC 2014)

Where \emptyset = angle of internal friction of retained soil (35° for Granular A or 30° for Granular B Type II)

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δ = angle of friction between soil and wall (24° for Granular A or B Type II)

Refer to the following table for geotechnical parameters for earth pressure design.

Granular 'A' or 'B' should be utilized as backfill material for retaining walls. For shoring walls, where existing ground is in direct contact with shoring/walls, geotechnical parameters for existing ground should be considered. The following preliminary design geotechnical parameters for earth pressure design.

GEOTECHNICAL PARAMETER	GRANULAR A	GRANULAR B TYPE II	EXISTING GROUND
Angle of Internal Friction, degrees	35°	30°	28°
Unit Weight, kN/m ³	22.5	21.5	21.5

13.5 Bearing Resistance for RSS Walls

For RSS walls, the minimum soil cover above the underside of the levelling pad should be a minimum of 800 mm, or 40% of the actual frost depth for the area, whichever is greater. The minimum soil cover to the top of the levelling pad should be at least 500 mm.

The bases of RSS walls should be founded a minimum 1.0 m below the existing ground surface should be designed for a Factored Geotechnical Resistance of 375 kPa and Geotechnical Resistance at SLS of 250 kPa.

The recommended geotechnical resistances are for vertical concentric loading. The effects of load inclination and eccentricity need to be considered in accordance with CHBDC.

The RSS mass should be designed against sliding and overturning. Sliding resistance along the base native clayey silt till and engineered fill may be estimated using an ultimate friction coefficient of 0.35 and 0.55, respectively.

The internal stability or structural integrity of the RSS walls should be analyzed by the supplier/designer of the proprietary product selected for this site.

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13.6 Foundation Frost Depth

In accordance with OPSD 3090.100, a minimum of 1.2 m earth cover is required to protect against the frost penetration in the area where the site is located.

The frost penetration depth, f , is measured from the top of the grade to the bottom of the footing.

13.7 Seismic Design Considerations

Site Class C may be assumed to evaluate the seismic site response, as per Table 4.1, Clause 4.4.3.2 of the CHBDC 2014.

The peak ground acceleration, PGA, for a 2% in 50-year probability of exceedance at this site is 0.11 g as per the National Building Code of Canada 2015 (NBCC 2015).

In accordance with Clause 4.6.5 of the CHBDC 2014, retaining structures should be designed using active (KAE) and passive (KPE) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in the Table 10.7 may be used:

Table 13.7 Earth Pressure Coefficients for Earthquake Loading

Loading Condition	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	OPSS Granular B Type I or Type III $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$
Active (KAE)*	0.31	0.35
Passive (KPE)	3.5	3.1
At-rest (KOE)**	0.57	0.62

*After Mononobe and Okabe, passive case assumes a horizontal surface in front of the wall.

**After Woods

Given the low seismic ground motions and the scope of the proposed installation, the importance of seismic considerations is low at this site.

13.8 Contract Specifications

A list of standard specifications and draft NSSP's relevant to this report are compiled in Appendix B-3.

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14. CLOSURE

This report was prepared by Mr. N. Rahman, P.Eng. Geotechnical Services, and reviewed by Mr. D. Dundas, P.Eng., Senior Engineer, Geotechnical Services. Mr. R. Ng, MBA, PhD, P.Eng., MTO Designated Principal Contact, conducted an independent review of the report.

Yours very truly,

Peto MacCallum Ltd.



Nazibur Rahman, P.Eng.
Project Manager, Geotechnical Services



Robert Ng, PhD, MBA, P.Eng.
MTO Designated Principal Contact

NR/DD/RN:nl-nk

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APPENDIX B-1


Plan and Cross-Sections along Highway 401


And Associated Slope Stability Analyses

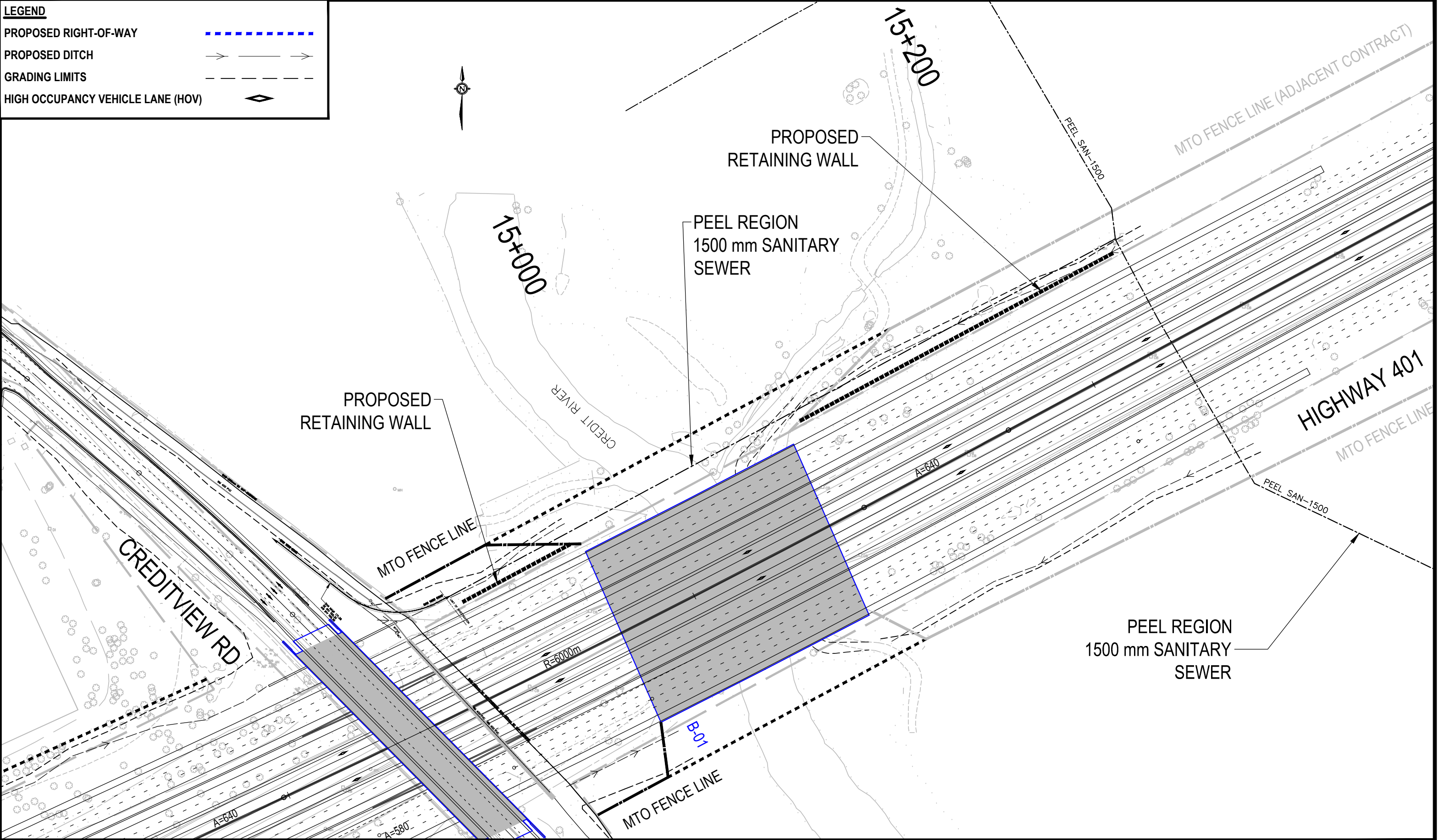
LEGEND

PROPOSED RIGHT-OF-WAY 

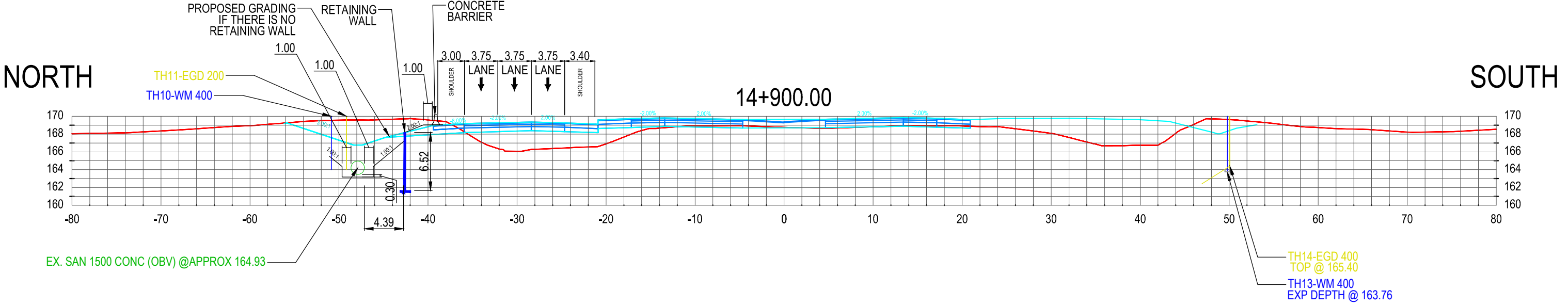
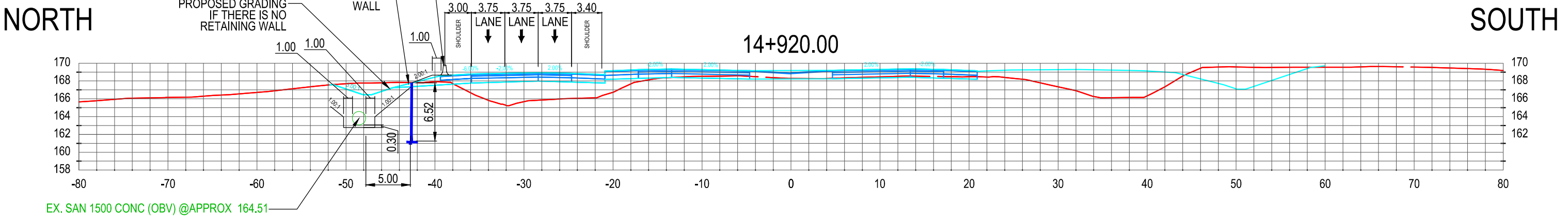
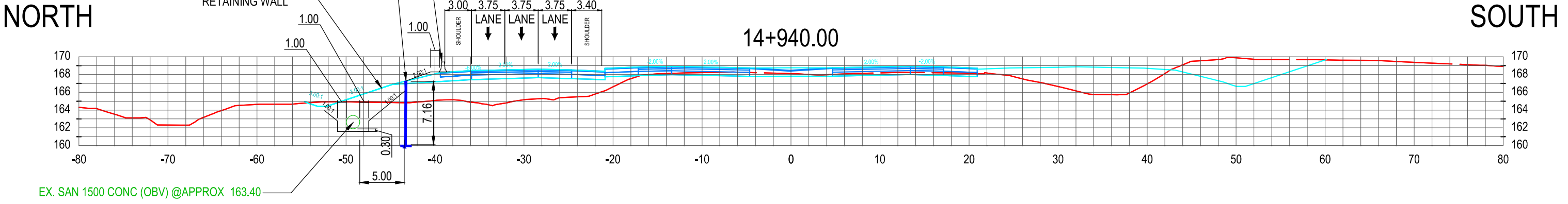
PROPOSED DITCH 

GRADING LIMITS 

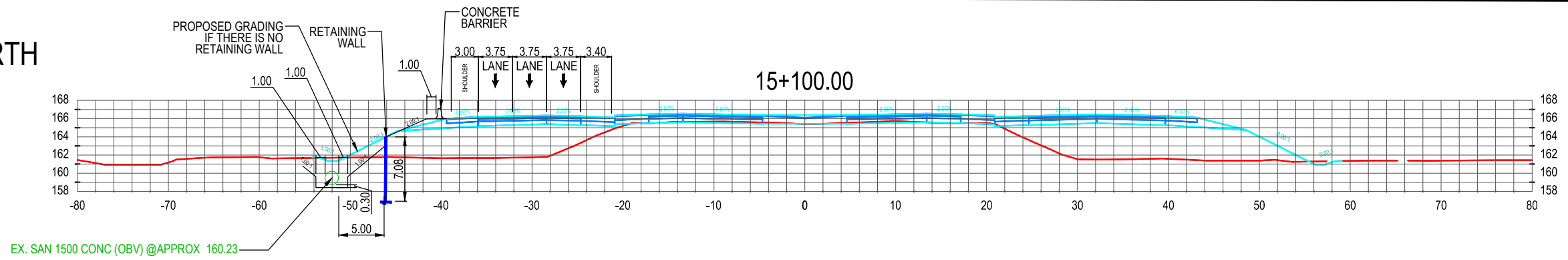
HIGH OCCUPANCY VEHICLE LANE (HOV) 



		HIGHWAY 401 EXPANSION CREDIT RIVER TO REGIONAL ROAD 25 G.W.P. XX-XXXXX	HIGHWAY 401 WINSTON CHURCHILL BLVD. INTERCHANGE PEEL REGION UTILITY CROSSING #1	N.T.S. DATE: MARCH 2019	DWG X
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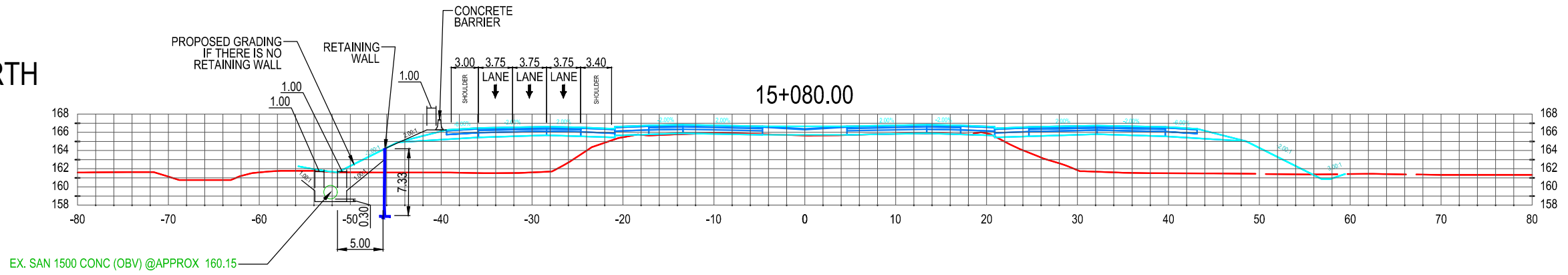


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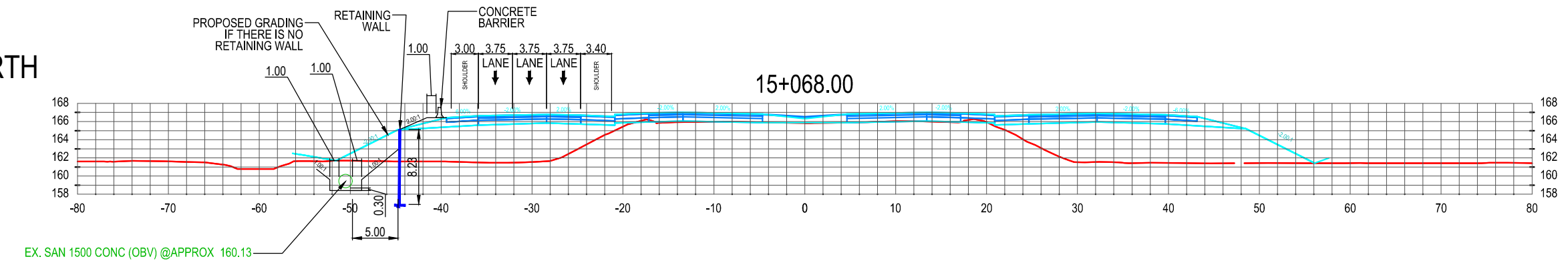
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NORTH



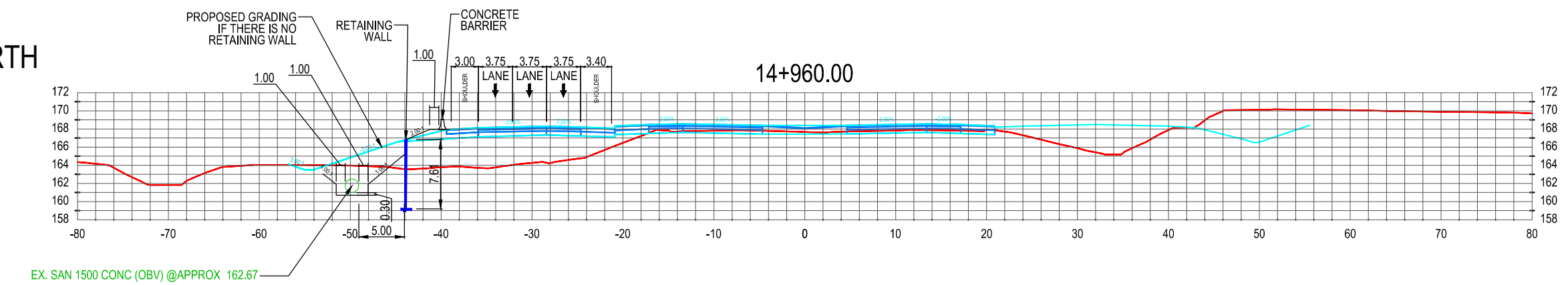
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NORTH

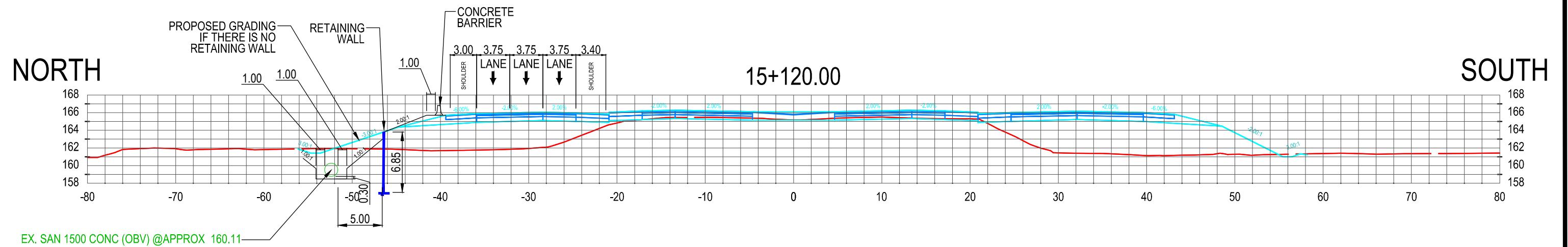
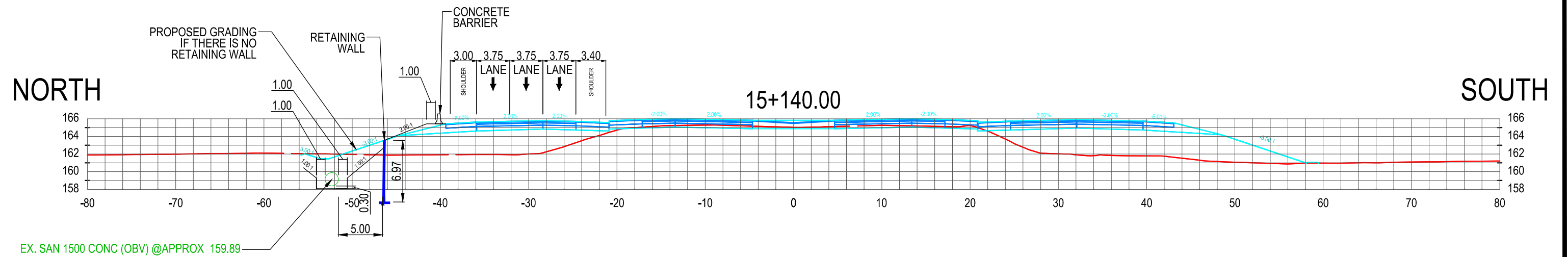
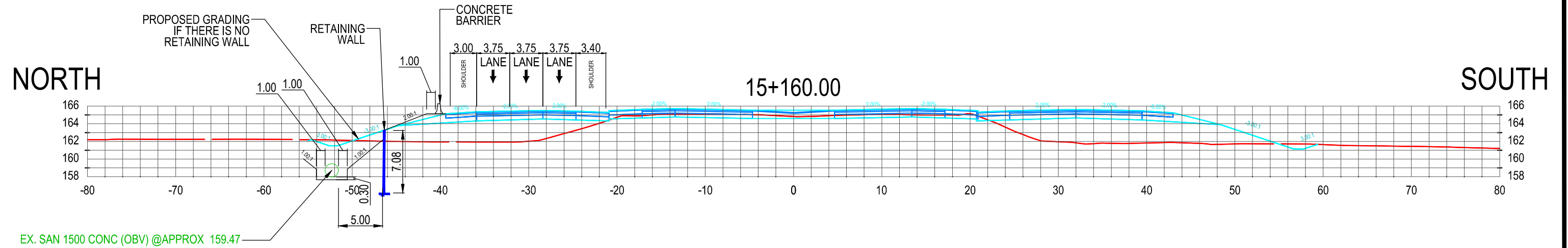


SOUTH

NORTH



SOUTH



Part B – Foundation Design Report

Evaluation of Alternatives for Protection of Sewer and Watermain Utilities

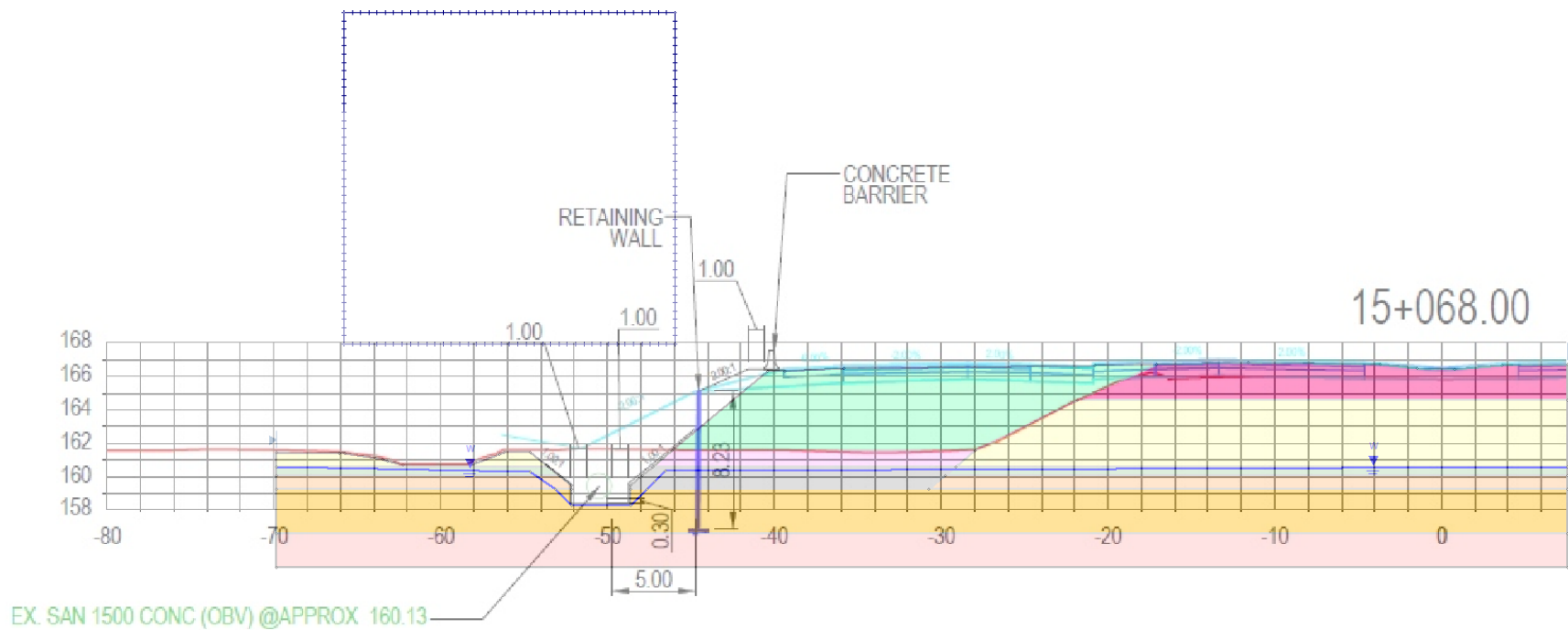
Highway 401 WBL Widening and Creditview Road Realignment

Assignment No. 2016-E-0004, Work Order 12B, Halton Region and Peel Region, Ontario, Index No.: 009FDR

PML Ref.: 18TF033, April 23, 2019



Figure 1.1 – Highway 401 Westbound Lane Station 15+068 – Excavation without Temporary Shoring or Retaining Wall
1H:1V Side Slopes



Part B – Foundation Design Report

Evaluation of Alternatives for Protection of Sewer and Watermain Utilities

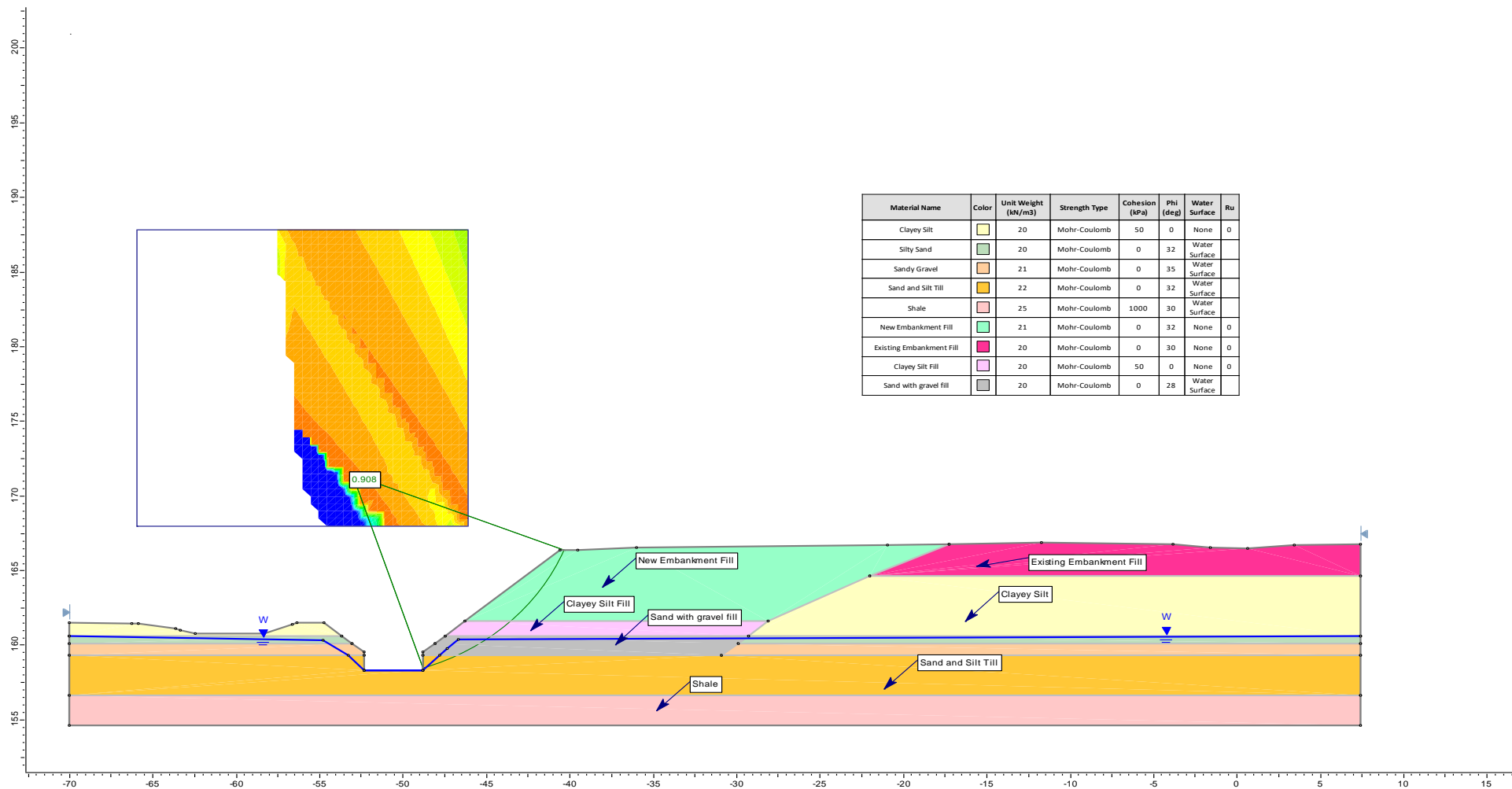
Highway 401 WBL Widening and Creditview Road Realignment

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Figure 1.1 – Highway 401 Westbound Lane Station 15+068 – Excavation without Temporary Shoring or Retaining Wall
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Part B – Foundation Design Report

Evaluation of Alternatives for Protection of Sewer and Watermain Utilities

Highway 401 WBL Widening and Creditview Road Realignment

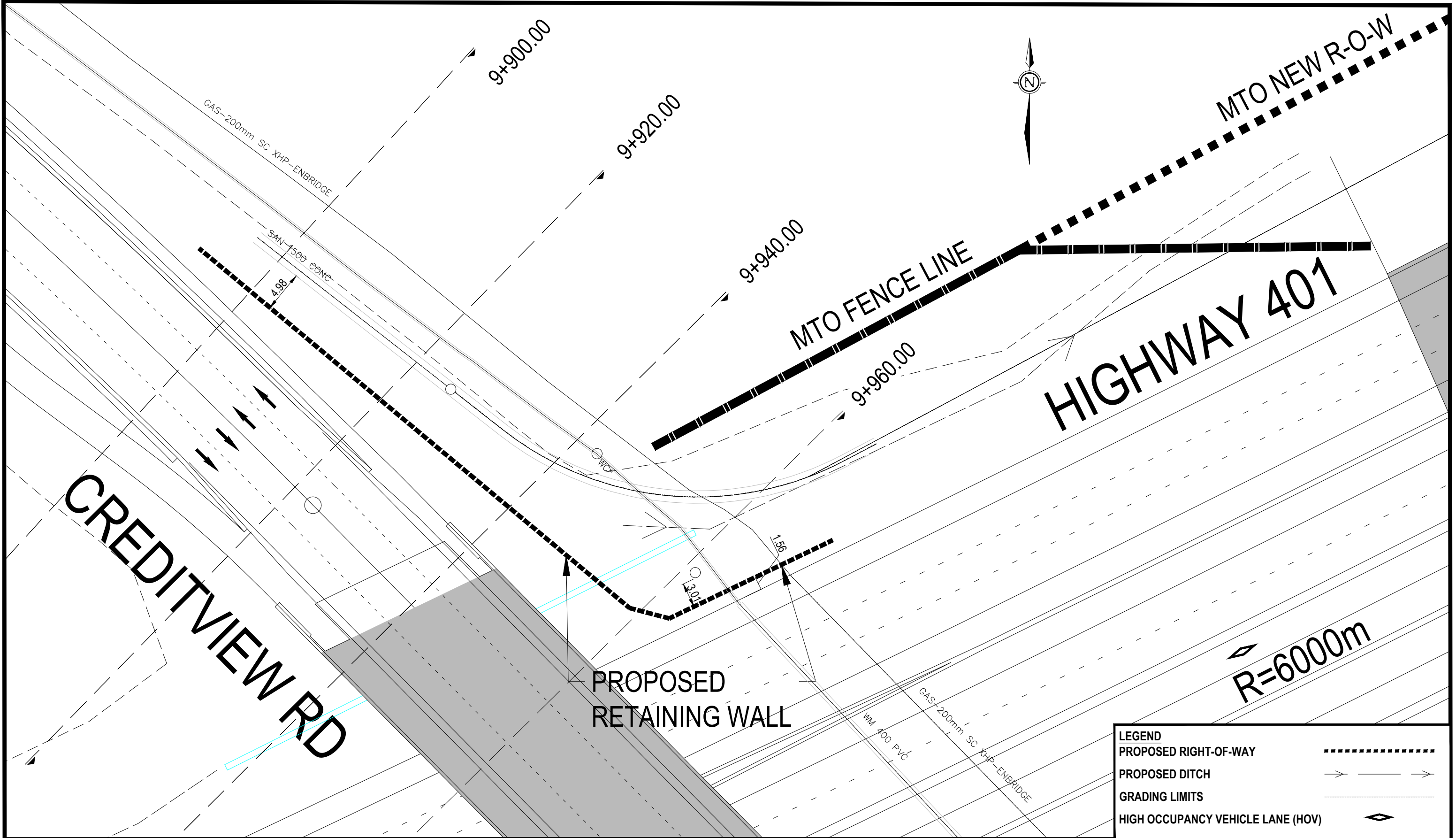
Assignment No. 2016-E-0004, Work Order 12B, Halton Region and Peel Region, Ontario, Index No.:009FDR

PML Ref.: 18TF033, April 23, 2019

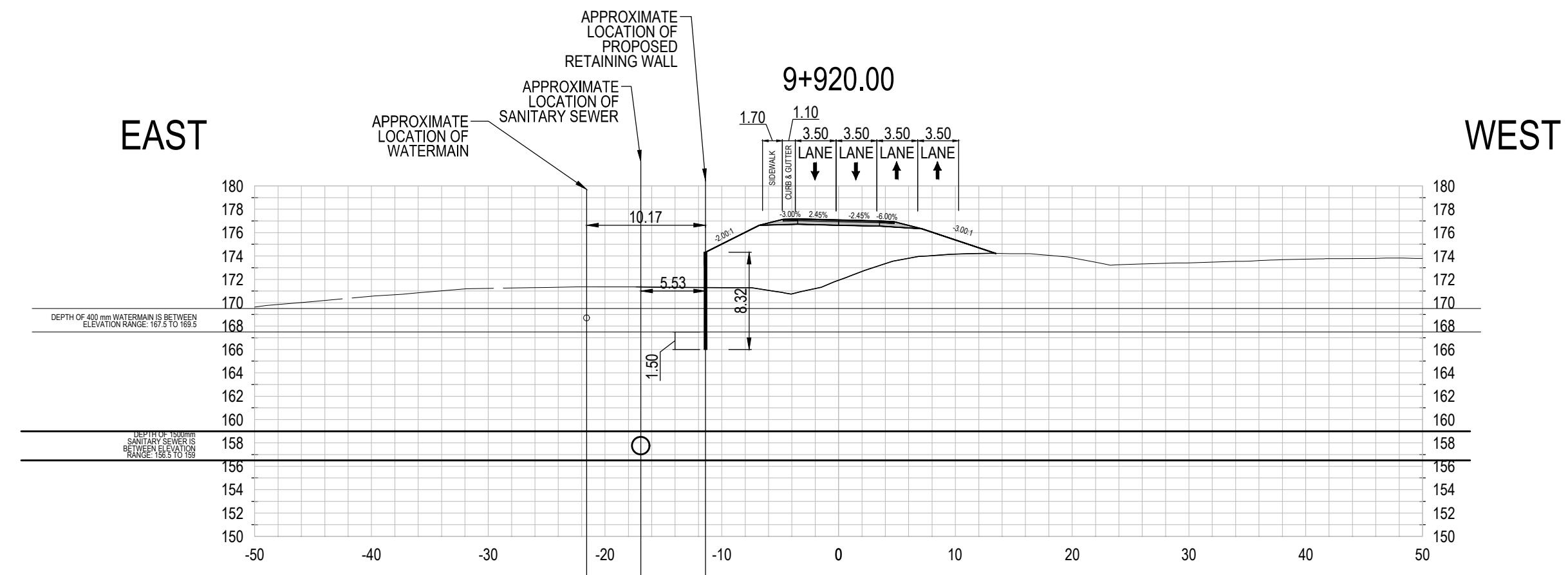
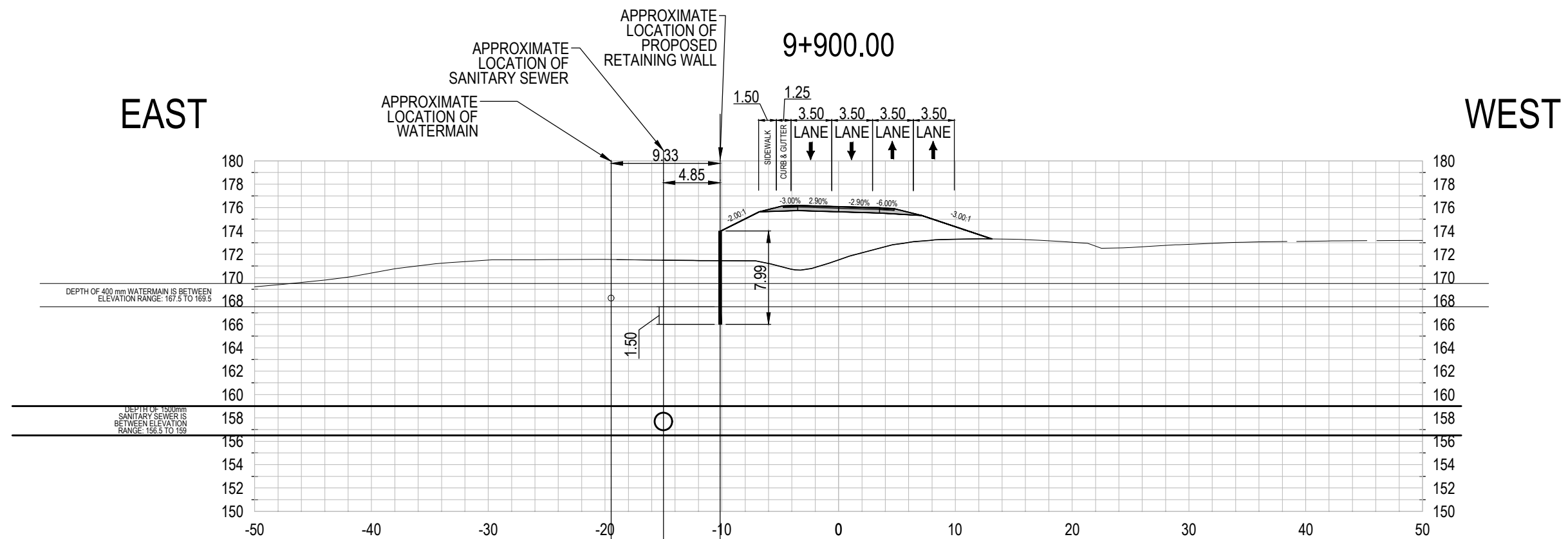


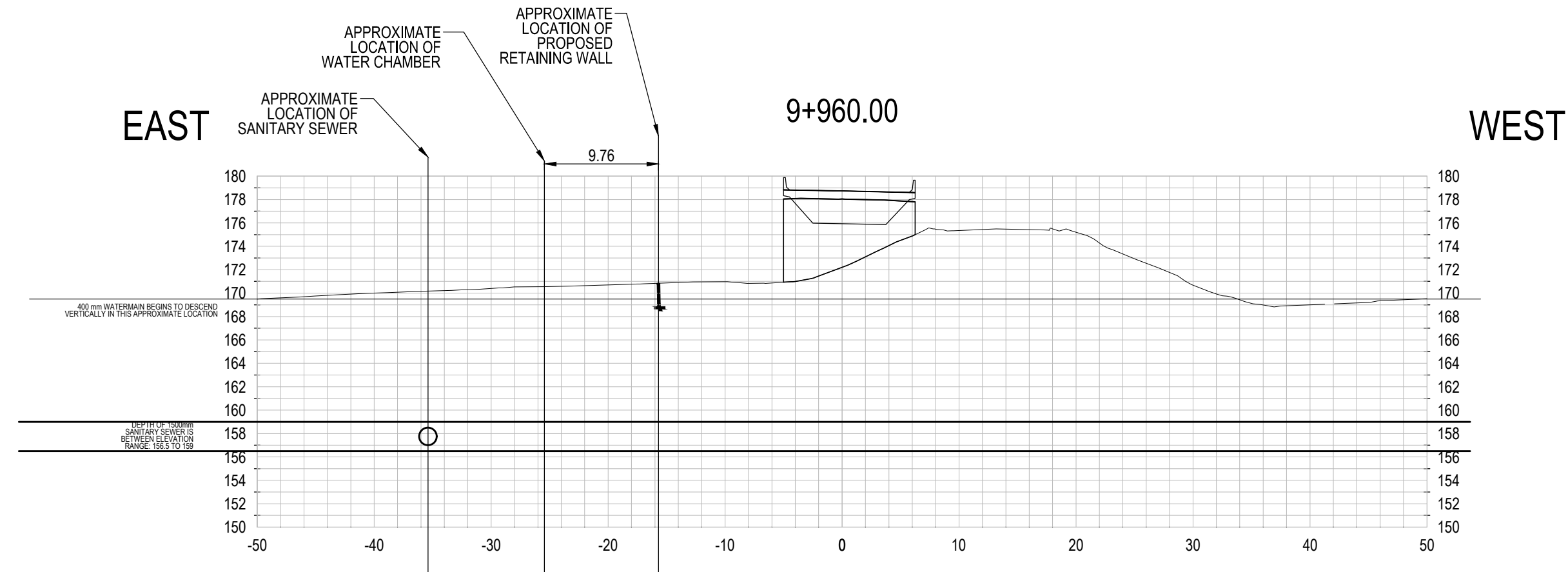
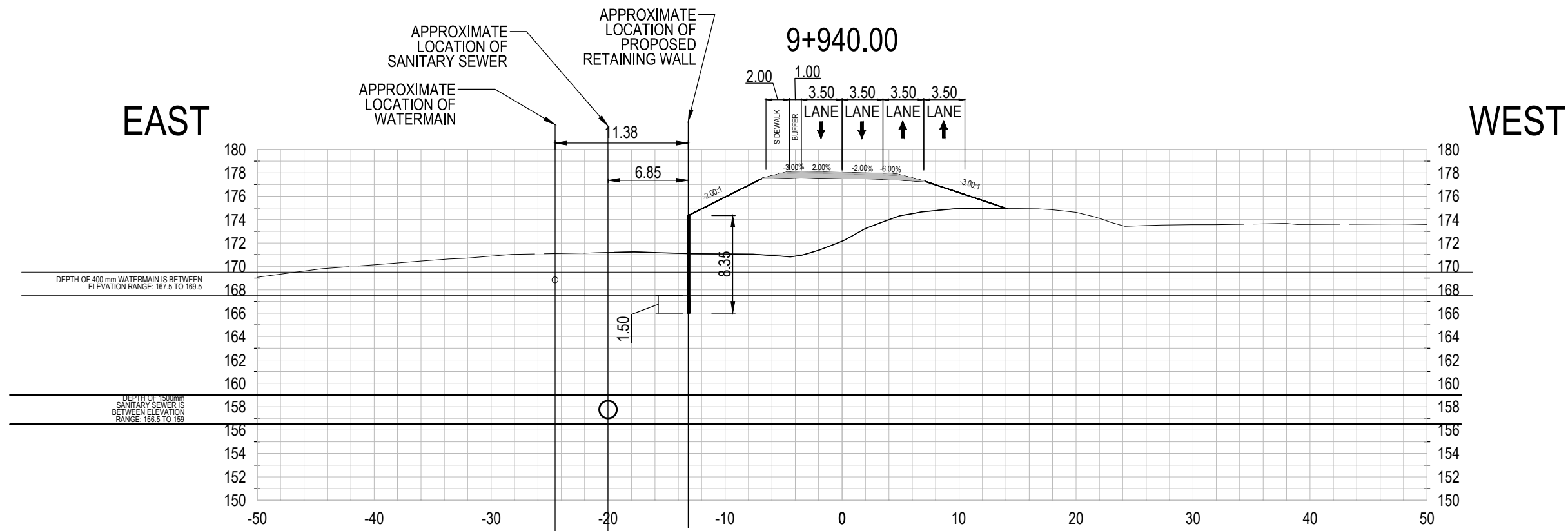
APPENDIX B-2

Plan and Cross-Sections along Creditview Road
And Associated Slope Stability Analyses



LEGEND	
PROPOSED RIGHT-OF-WAY	-----
PROPOSED DITCH	-> - - - ->
GRADING LIMITS	-----
HIGH OCCUPANCY VEHICLE LANE (HOV)	◇





Part B – Foundation Design Report

Evaluation of Alternatives for Protection of Sewer and Watermain Utilities

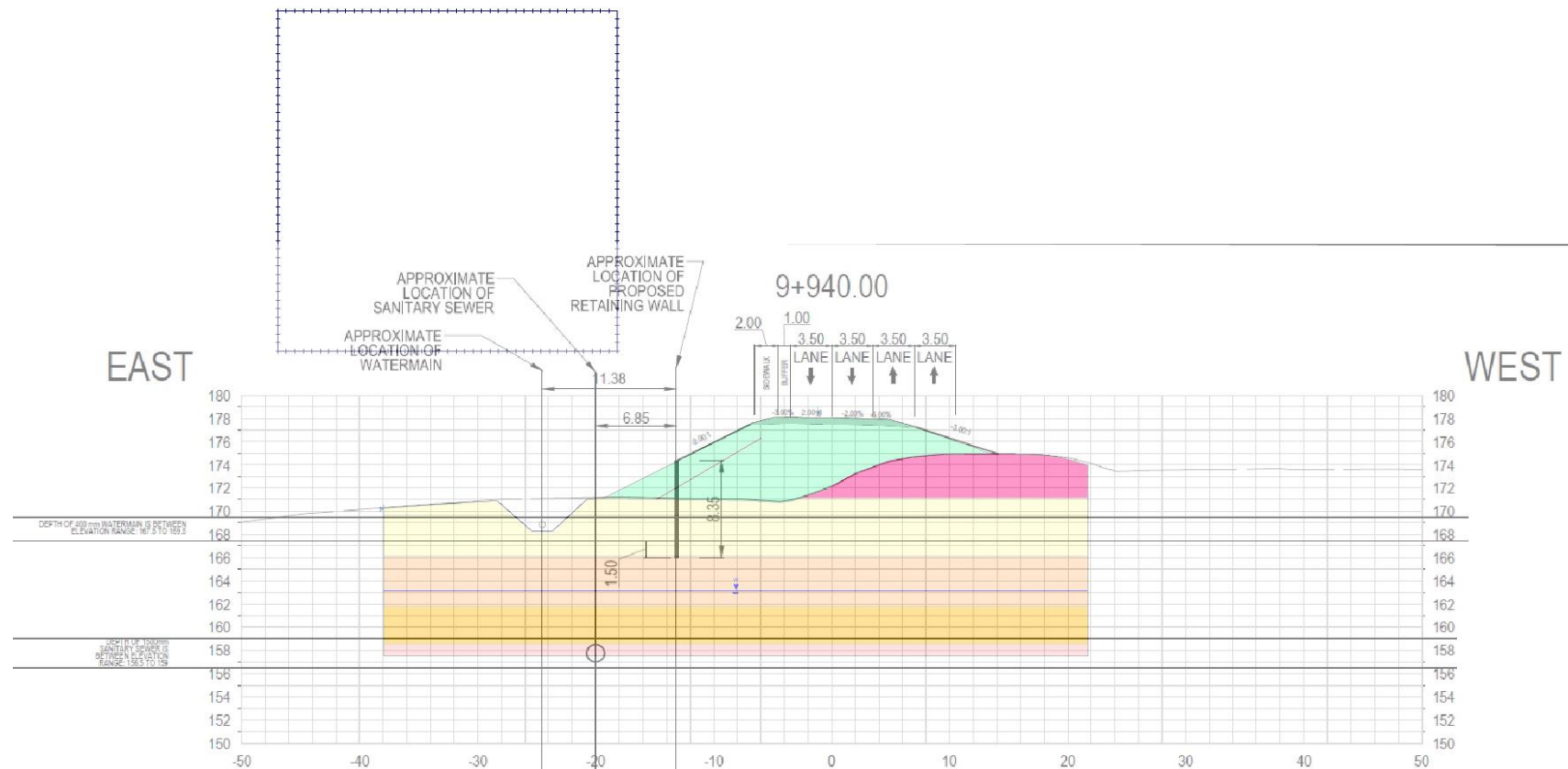
Highway 401 WBL Widening and Creditview Road Realignment

Assignment No. 2016-E-0004, Work Order 12B, Halton Region and Peel Region, Ontario, Index No.: 009FDR

PML Ref.: 18TF033, April 23, 2019



Figure 2 – Creditview Northbound Lane Station 9+940 – New Embankment Fill
1H:1V Side Slopes (Watermain)



Part B – Foundation Design Report

Evaluation of Alternatives for Protection of Sewer and Watermain Utilities

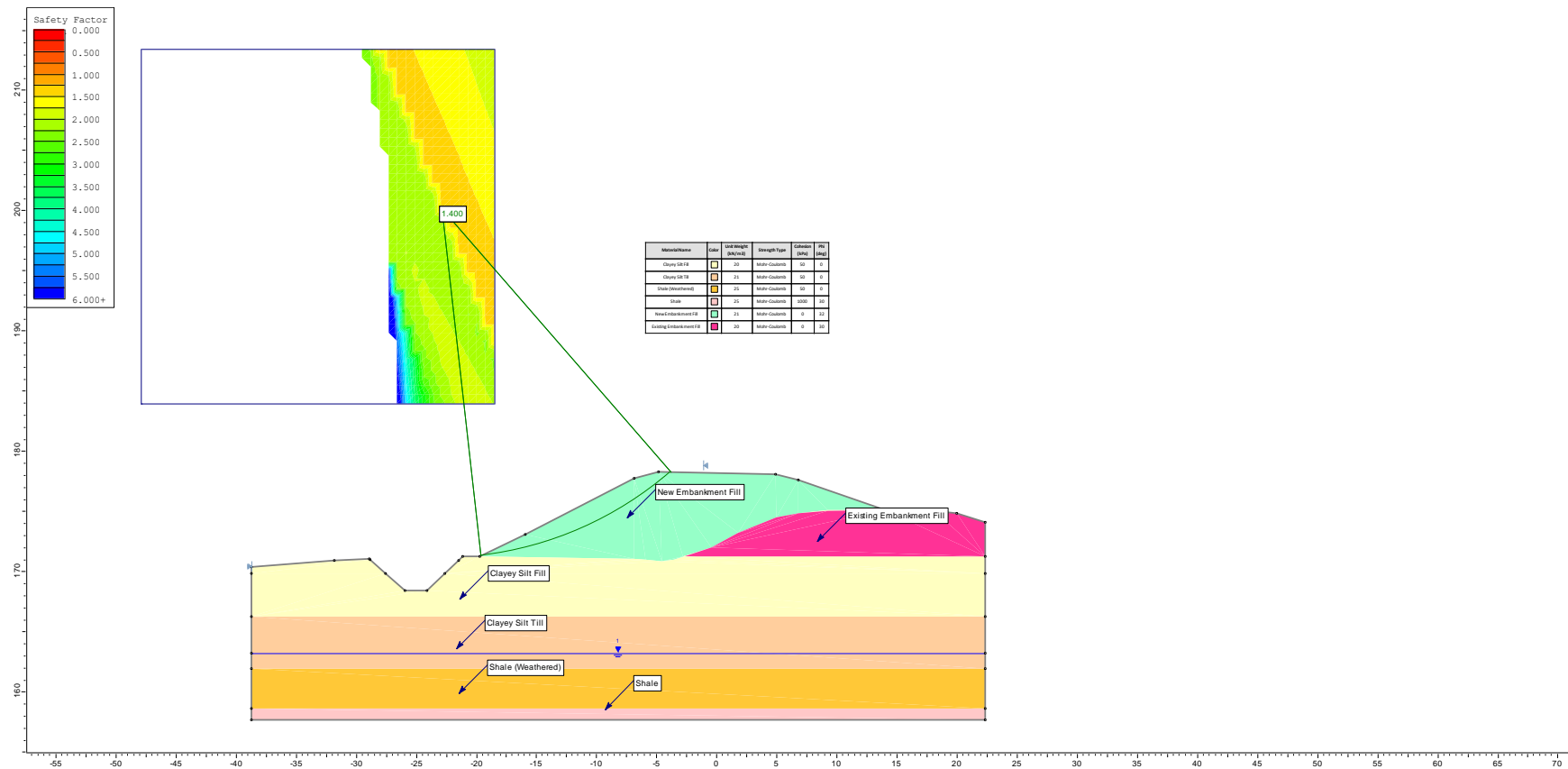
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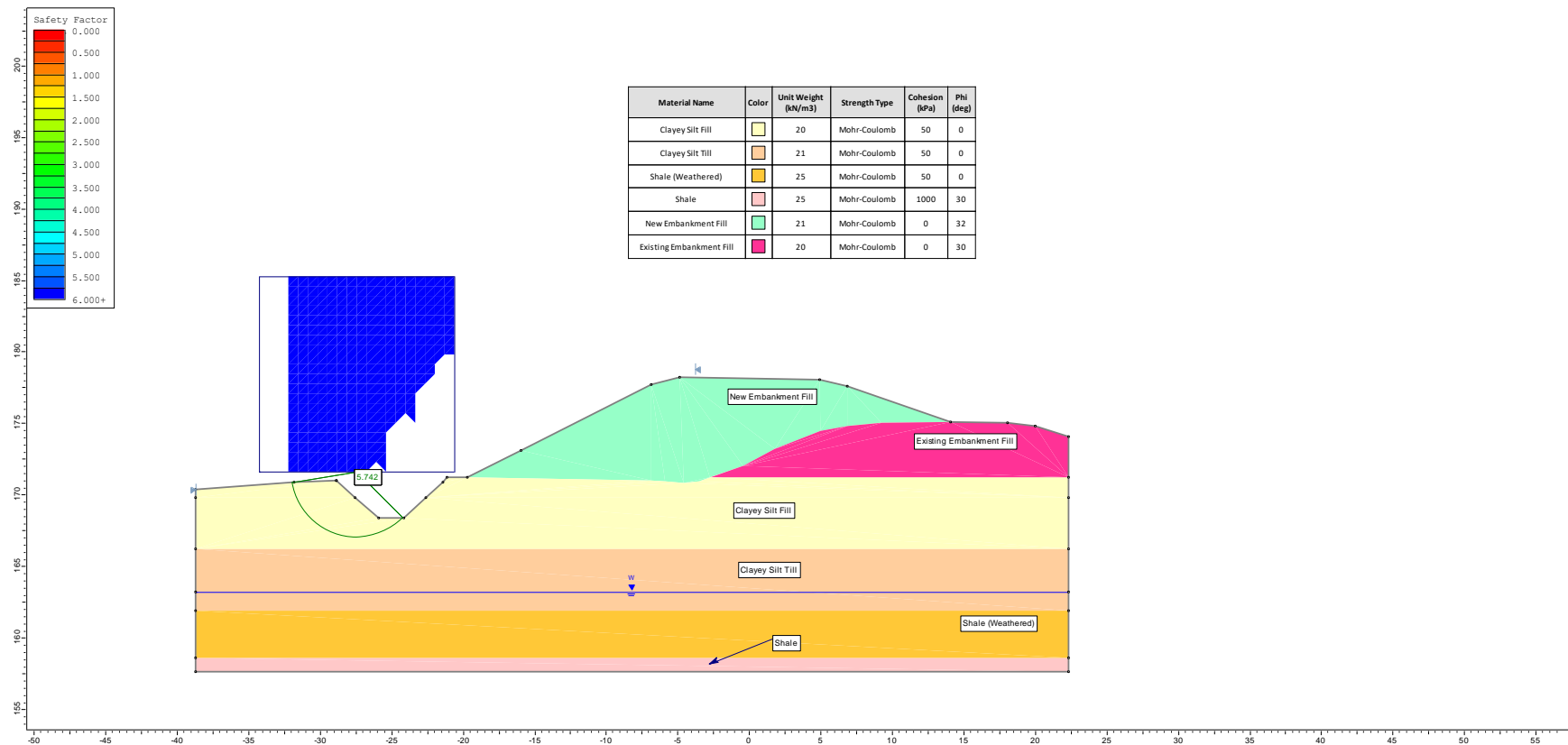
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APPENDIX B-3

List of Standard Specifications Relevant to Report

Part B – Foundation Design Report

Evaluation of Alternatives for Protection of Sewer and Watermain Utilities

Highway 401 WBL Widening and Creditview Road Realignment

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LIST OF STANDARD SPECIFICATIONS RELEVANT TO REPORT

DOCUMENT	TITLE
OPSS.PROV 401	Construction Specification for Trenching, Backfilling and Compacting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 539	Temporary Protection Systems
SP 105S09	Amendment to OPSS.PROV 539
OPSD 3090.100	Foundation, Frost Penetration depths for Southern Ontario
OPSD 3101.150	Walls, Abutment, Backfill, Minimum Granular Requirement