FOUNDATION INVESTIGATION AND DESIGN REPORT

Proposed Non-Structural Culvert Replacement, Highway 48, 240 m South of Stouffville Road/Main Street, Town of Whitchurch-Stouffville, Ontario

MINISTRY OF TRANSPORTATION (MTO)

Site Location (Long. -79.280902˚, Lat. 43.961670˚)

GWP: 2075-18-00

GEOCRES NO. 30M14-521

WSP PROJECT NO.: 18M-01021-13
DATE: JUNE 26, 2020

WSP CANDA INC.
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1 INTRODUCTION

This work was carried out under Assignment No: 2017-E-0018 and forms part of Work Order No. 013 under MTO Central Region Large Value Retainer. WSP Canada Incorporated (WSP) was retained by MTO to provide foundation information and recommendations to enable detailed design of the following:

A) Foundation Elements for the Replacement of Little Rouge Creek Structural Culvert (Site No. 37-1221/C). The FIDR for this structural culvert will be addressed under separate cover.

B) Replacement of Non-Structural Culvert (CV-0249-0048-0002). This is the subject addressed in this report and the broader scope is given as follows:

1) The existing 1270 mm x 750 mm CSPA non-structural culvert of elliptical cross section with approximately 2.0 m cover located on Highway 48, approximately 240 m south of the Stouffville Road/Main Street intersection to be replaced by open-cut excavation with a same size CSPA culvert in the same location,

2) Foundation engineering services are required for recommendations and design of possible temporary protection system/shoring for traffic staging work and possible temporary dewatering/unwatering system requirements during construction.

This report is in two parts, i.e. Part A addresses the foundation investigation (factual) and Part B addresses foundation design with recommendations.

The purpose of this geotechnical/foundation investigation was to determine the sub-surface conditions and groundwater observations at the site by means of boreholes, field and laboratory tests. Based on the information obtained, the engineering characteristics of the subsurface soils were assessed, and site conditions described to develop geotechnical recommendations to address the foundation scope.

This part of the report, Part A, i.e. the Foundation Investigation Report (FIR), presents the factual information concerning the subsurface conditions based on all of the subsurface information at hand and is followed by the Foundation Design Report (FDR) wherein engineering discussion and foundation recommendations are made for the design and construction of the proposed replacement of the non-structural culvert and associated works as listed in (B) above.

This report is based on the Culvert Arrangement Drawing supplied by the WSP's Highways Group on November 15, 2019.

2 BACKGROUND INFORMATION

2.1 GEOLOGICAL SETTING

Site geology as per OGS Geology Map No: 3062 on the Surficial Geology of the Greater Toronto and Oak Ridges Moraine Area, Southern Ontario (1:200,000 scale) indicates the surficial geology to be glacial till deposits generally consisting of clayey silt to silt with interbedded fine sand. As indicated in the Physiography of Southern Ontario, the project area is mapped within the physiographic region known as the Peel Plains Region. The Peel Plain region generally consists of glacial till with both shale and limestone fragments within the soil matrix. A veneer of layered or varved clay overlies the glacial till. Glacial lake deposits of silt and clay are also mapped to the east and west of the project area.

Bedrock geology mapping (OGS, Bedrock Geology of Ontario, Southern Sheet, Map No. 2544) indicates shale, dolostone and siltstone of the Georgian Bay Formation, underlies the project area. Bedrock topography mapping of the project area indicates that the bedrock elevation is near elevation 160 m as shown on Mines and Minerals Division Ontario Geology Survey Open File Map 196, Bedrock Topography of the Markham Area, 1992. This translates for the top of bedrock to be approximately 96 m below the existing road surface at the site.

2.2 PREVIOUS GEOTECHNICAL INFORMATION

No Foundation report for the existing CSPA Culvert was available. The following foundation report pertains to approximately 2 km from the area of the proposed culvert location.

— Foundation Investigation and Design Report, Proposed Stouffville 5 -Bay Garage Site, Markham Township, Ontario, GEOCRES NO. 30M14-042, dated May 20, 1959.

According to the report, the soil stratigraphy comprised of a shallow surface deposit of heavy clay overlying dense sandy to silty glacial till.

Further, Ministry of Environment (MOE) Well records (ID 6904046) within approximately 300 m radius from the subject site reveal the presence of a water bearing coarse sand deposit about 15 m deep.

2.3 SITE AND STRUCTURE DESCRIPTION

The key plan of the site is shown on **Drawing No. 1**. For the purpose of this report the geographic north is used as reference. Highway 48 at the existing culvert location is a four-lane undivided roadway with gravel shoulders and roadside ditches. The culvert runs approximately in an east-west direction under Highway 48. The WSP hydrology/hydraulics report (Highway 48 Stouffville – Little Rouge Creek Culvert Replacement, November 18, 2018) describes the existing pipe as a Corrugated Steel Pipe Arch (CSPA) which is 1.270 x 0.750 metres (m) in elliptical cross-section and 29.2 m long. Due to partial inundation close to the obvert levels at the culvert ends, the complete arch nature was not visible during the field visit. The existing CSPA was observed to show signs of rust at the inlet and outlet ends.

Note for reporting purposes, the reconnaissance site visit and field investigation photographs are designated as C1 and C2 respectively in **Appendix C**. A visible transverse crack, which is non-structural in nature, was observed along the culvert axis (see Photo C1-1). Flowing water was also observed both at the culvert inlet and outlet locations during the reconnaissance site visit (See Photos C1-2 to C1-4). There was water accumulation at the culvert outlet. The surface water levels measured at the time of the visit was at depth of 0.3 m and 0.1 m from the existing culvert obvert levels at inlet and outlet locations respectively. At the culvert location (STA. 24+114), the existing embankment slope is relatively higher at the inlet end and well vegetated. There were no observable signs of erosion. The measured side slopes are approximately 2H:1V.

The surrounding area of the culvert site consists of open farmland on the west side and low-lying marshland on the east. A few single-family homes are scattered in the vicinity of the site as well as a hydro station to the south of the culvert location along Highway 48.

3 SUBSURFACE EXPLORATION PROGRAM

3.1 GENERAL

The subsurface exploration program consisted of a field site reconnaissance visit, a field investigation where a series of boreholes were drilled and sampled, and a standpipe piezometer was installed for subsequent groundwater observations. A laboratory testing program on select samples obtained during the field investigation was also carried out as part of the subsurface exploration program.

3.2 FIELD INVESTIGATION

The reconnaissance observations about the nature of terrain and access constraints for conventional drilling equipment were carefully considered in planning the field investigation program. The field investigation consisted of drilling and sampling four boreholes. The exploratory borehole locations are shown on Drawing 1 following the text of this report. RFP Clause 2.6.3.2 has specified the number of boreholes to be advanced and for what purposes so that it identifies the approximate borehole locations with respect to the culvert axis.

Based on the site reconnaissance, locational access to the boreholes permitted the use of a conventional drilling approach, i.e. the use of a truck mounted CME 45 (for drilling on the road surface) and a rubber track mounted CME 75 (for drilling in the ditches) drilling equipment. The boreholes were advanced by means of hollow-stem continuous flight augers.

The fieldwork commenced on June 12, 2019 with notification to MTO and ended on June 14, 2019. The borehole locations (BH 19-1 to BH 19-4) are shown in Photos C2-1 to C2-4 (See Appendix C). The traffic set-up included a single lane closure adopting the TL-23 lane closure in accordance with MTO Book 7 (See Appendix C, Photo C2-5).

The field investigation was carried out under full-time supervision of WSP technical staff who directed the exploration and sampling operation, logged borehole data in accordance with MTO Soils Classification System and took custody of soil samples retrieved for subsequent laboratory identification and testing. Soil samples were visually classified in the field and later re-evaluated by an engineer. The recovered soil samples were placed in labelled moisture-proof bags and returned to WSP's Galaxy laboratory for further assessment.

Table 3-1 presents the exploratory borehole details of the WSP foundation investigation program.

Table 3-1 Summary of Exploratory Borehole Details*

Borehole No.	Borehole Location	Co-ordinates: Easting/Northing (m)	Co-ordinates: Latitude/Longitude	Ground Surface Elevation (m)	Exploration Depth (m)	Drilling Methodology / Remarks
BH 19-1	East end of existing culvert	E 322401.0 N 4869097.3	Lat. 43.961639° Long. -79.280674°	254.2	9.8	Hollow stem / terminated in native soils
BH 19-2	West end of existing culvert	E 322362.2 N 4869096.4	Lat. 43.961637° Long. -79.281160°	254.0	9.8	Hollow stem / terminated in native soils

Borehole No.	Borehole Location	Co-ordinates: Easting/Northing (m)	Co-ordinates: Latitude/Longitude	Ground Surface Elevation (m)	Exploration Depth (m)	Drilling Methodology / Remarks
BH 19-3	North of culvert axis on the northbound (inner lane)	E 322390.8 N 4869085.9	Lat. 43.961541° Long. -79.280801°	254.9	12.8	Hollow stem / terminated in native soils
BH 19-4	South of culvert axis on the northbound (outer lane)	E 322384.9 N 4869102.2	Lat. 43.961687° Long. -79.280885°	255.0	12.8	Hollow stem / terminated in native soils

*Notes:

1) Locates done by CLI with participating companies such as Hydro One, Enbridge Gas & CCS for Bell Canada
2) The spacing and quantity of boreholes generally conform to Work Order Item Specific Terms of Reference (TOR) requirements;
3) Type of drilling rig used: Rubber track mounted - CME 75 rig and Truck mounted – CME 45;
4) Co-ordinates: based on MTM NAD 83 Zone 10 coordinates; Terminology of directions, e.g., Reference to North is geographic;
5) Name of Drilling Company: Pontil Drilling Services Inc., Mount Albert, Ontario;
6) Drilling Supervision: by WSP staff from Toronto office;
7) Traffic control to Book 7 by Geotech Support Services Inc., Markham, Ontario;
8) Borehole Survey by J.D. Barnes Limited, Markham, Ontario.

Samples were retrieved at regular intervals with a 50 mm Outer Diameter (O.D.), split-barrel sampler driven with a hammer weighing 624 N and dropping 760 mm in accordance with the Standard Penetration Test (ASTM D 1586) method. This sampling method recovers samples from the soil strata, and the number of blows required to drive the sampler 300 mm depth into the undisturbed soil (SPT 'N'-values) gives an indication of the compactness condition (cohesionless soil) or consistency (cohesive soil) of the sampled soil material. The SPT 'N' values are indicated on the Record of Borehole Sheets (Refer to **Appendix A**).

3.3 LABORATORY INVESTIGATION

Visual examination and classification were undertaken on the soil samples returned to WSP laboratory. A routine laboratory testing program consisting of natural water content tests, grain size analysis, and hydrometer testing was carried out on selected representative soil samples.

The results of the laboratory tests are summarized on the appropriate Record of Borehole Sheets in Appendix A and compiled test results are included in **Appendix B**.

3.4 GROUNDWATER INVESTIGATION

Groundwater conditions in the boreholes were observed during and on completion of drilling in the open boreholes. A monitoring well (50 mm diameter) was installed in BH 19-1 upon completion of drilling to enable long-term groundwater level monitoring. The installed piezometer will need to be decommissioned as part of the construction, in accordance with

Ontario Regulation 903 (amended to Ontario Regulation 372/07). The other boreholes were grouted (decommissioned) using a cement/bentonite mixture as per MTO procedures.

Table 3-2 provides information about the piezometer installed for this investigation.

Table 3-2 Piezometer Installation Details

Borehole No.	Ground Surface Elevation (m)	Borehole Bottom		Well Screen Interval Depth (m)		Well Screen Interval Elevation (m)	
		Depth (m)	Elevation (m)	Top	Bottom	Top	Bottom
BH 19-1	254.2	9.8	244.4	3.1	4.6	251.1	249.6

4 SUBSURFACE CONDITIONS

4.1 GENERAL

The subsurface conditions encountered at the existing culvert location are described in the following sections.

Drawing 1 shows a borehole location plan along with an embankment cross-section along the pipe culvert axis. The inferred stratigraphic cross-section at the culvert location is based on the borehole data. The soil descriptions are based on visual and tactile observations and complemented by the results of field and laboratory soil test results.

For purposes of soil description, the MTO Soil Classification Manual was generally followed and the secondary components were classified as per CFEM 2006. The strata boundaries shown on the subsurface profile must not be interpreted as exact planes of geological change but rather as inferred transitions from one soil type to another since they are based on non-continuous sampling information at discrete borehole locations. It should be noted that the subsurface conditions and the topsoil thicknesses encountered might vary in between and beyond the borehole locations and the topsoil thicknesses could vary especially in depressed areas. All topsoil and pavement fill thicknesses reported should not be relied upon for quantity estimation as they may vary beyond the borehole locations. Unless otherwise stated, all SPT 'N' values quoted are for 300 mm of penetration.

All groundwater levels observed in the exploratory holes are subject to seasonal fluctuations and variations due to precipitation events.

An overview of subsurface conditions is described below. All depths quoted are below the existing ground surface.

4.2 SOIL CONDITIONS

4.2.1 TOPSOIL

Topsoil was encountered in boreholes BH 19-1 and BH 19-2 at the existing ground surface. The thickness of the topsoil was 230 mm and 200 mm in boreholes BH 19-1 and BH 19-2, respectively.

The measured water contents of two selected samples of the topsoil were 21% and 37%.

4.2.2 PAVEMENT STRUCTURE

A pavement structure of flexible construction (asphalt over granular fill) was encountered in boreholes BH 19-3 and BH 19-4. The pavement structure encountered in both boreholes, consists of asphalt supported by cohesionless pavement fill. The asphalt thickness was approximately 380 mm and 230 mm in boreholes BH 19-3 and BH 19-4, respectively. Supporting the asphalt surface was a cohesionless fill layer generally consisting of gravelly sand that extended to a depth of 1.8 m and 0.8 m below the existing pavement surface in boreholes BH 19-3 and BH 19-4, respectively.

The grain size distribution of one selected sample of cohesionless material is presented in Appendix B. A summary of this grain size distribution is also presented in the table below.

Table 4-1 Results of Grain Size Analyses for Cohesionless Fill

Borehole No.	Sample No.	Grain Size Distribution				Remarks
		% Gravel	% Sand	% Silt	% Clay	Shown in **Figure B-1, Appendix B** Summarized on the record of Borehole Sheet
BH 19-3	SS-2	21	69	4	6	

Based on the above grain size distribution, the material does not conform to OPSS 1010 Granular A or B Types grain size distribution requirements due to excess fines.

The measured water content of three selected samples of the cohesionless base ranged from 6 percent to 12 percent.

The SPT 'N' values within the cohesionless fill ranged from 14 blows to 29 blows per 300 mm of penetration, indicating a compact relative density.

4.2.3 SILTY CLAY

A layer of native silty clay was encountered underlying the surficial topsoil in boreholes BH 19-1 and BH 19-2 and underlying the pavement structure in boreholes BH 19-3 and BH 19-4. Sand and gravel seams were also noted within the silty clay. Also noted are trace rootlets and trace to some organics, but the organics were mainly intercepted in the ditch boreholes. The silty clay extended to depths ranging from 1.8 m to 2.6 m below the existing ground surface or to elevations varying from elevation 252.7 m to elevation 252.2 m.

The results of Atterberg limit testing carried out on one selected sample of the silty clay gave a plasticity index value of 26 percent and a liquid limit value of 45 percent, indicating an intermediate plasticity cohesive soil. **Figure B-2** in Appendix B shows the plasticity chart of this silty clay.

The measured water content of the samples of the silty clay ranged from 9 percent to 31 percent. Probably, the high moisture values within the upper horizon can be attributed to the organics identified, however, BH 19-4 within the road platform did not intercept any organics but still had a moisture content of 30% recorded for this deposit.

The SPT 'N' values within the silty clay ranged from 4 blows to 19 blows per 300 mm of penetration, indicating a firm to very stiff consistency.

4.2.4 SILTY CLAY TO CLAYEY SILT (TILL)

A deposit of cohesive silty clay to clayey silt "glacial till" was encountered underlying the silty clay in all four boreholes. The glacial till generally consists of a heterogeneous mixture of the gravel, cobbles, and boulders in a matrix of clayey silt to silty clay with varying amounts of sand. The glacial till extended to the depths of exploration, which ranged from 9.8 m to 12.8 m below existing ground surface.

The grain size curves of selected samples (8 samples) of the glacial till are presented in Appendix B. A summary of these grain size distributions is also presented in **Table 4-2** below. It should be noted that grain size distribution testing was carried out on a sample obtained through SPT testing, which does not recover coarse gravel, cobble and boulder sized particles. Because of this the grain size distribution obtained through drilling may be finer overall than some portions of the material in the field.

The results of Atterberg limit testing carried out on seven selected samples of the clayey silt/silty clay till gave plasticity index values ranging from 3 percent to 17 percent and liquid limit values ranging from 15 percent to 32 percent, indicating a low plasticity soil. **Figure B-4** in Appendix B shows the plasticity chart of this clayey silt/silty clay till. See table below for a summary of the results.

The measured water content of selected samples of the glacial till ranged from 7 percent to 20 percent.

The SPT "N" values within the glacial till ranged from 18 blows to 149 blows per 300 mm of penetration indicating a very stiff to hard consistency, although in some cases higher SPT 'N' values likely reflect the presence of gravel or rock fragments, rather than the relative density of the soil deposit.

Neither auger refusal nor sampler refusal was encountered during the subsurface exploration. Auger grinding was observed during drilling. Therefore cobbles/boulders should be anticipated during excavation.

Table 4-2 Results of Grain Size Analyses and Atterberg Limits Test Results- Silty Clay to Clayey Silt "Glacial Till"

Borehole No.	Sample No.	Grain Size Distribution				Atterberg Limits			Remarks
		% Gravel	% Sand	% Silt	% Clay	Liquid Limit %	Plastic Limit %	Plasticity Index	
BH 19-1	SS-5	3	32	46	19	20	12	8	Grain size distribution results are shown in **Figure B-3** and the Atterberg Limits' results are shown in **Figure B-4, Appendix B;** summarized on the relevant Record of Borehole Sheets.
	SS-9	6	25	51	18	19	14	5	
BH 19-2	SS-4					32	15	17	
	SS-6	2	29	37	32				
	SS-10	4	26	31	39				
BH 19-3	SS-5	6	40	41	13	15	12	3	
	SS-11	1	15	65	19	19	13	6	
BH 19-4	SS-5	3	29	35	33	19	12	7	
	SS-10	0	5	42	53	24	15	9	

4.3 GROUNDWATER CONDITIONS

Groundwater was observed at 9.3 m, 7.0 m and 9.5 m below the existing ground surface in boreholes BH 19-1, BH 19-3 and BH 19-4, respectively at the completion of the drilling of each borehole. Groundwater was not observed in borehole BH19-2. These groundwater levels may not accurately represent the stabilized groundwater level since insufficient time was available to measure the stabilized level. A standpipe piezometer was installed in borehole BH 19-1 to allow for subsequent groundwater level observations. The groundwater level within this standpipe piezometer was observed 14-days after its installation and groundwater was measured at 2.0 m below the existing ground surface or elevation 252.2 m. More recent groundwater level readings are also tabulated.

It should be noted that the groundwater levels can vary and are subject to seasonal fluctuations as well as fluctuations in response to major weather events. Findings are summarized in **Table 4-3**.

Table 4-3 Summary of Groundwater Level Observations

Borehole No.	Existing Ground Elevation (m)	Date of Measurement	Groundwater Level-Depth (m)	Groundwater Level Elevation (m)	Notes/observations
BH 19-1	254.2	June 14, 2019 (upon completion)	9.3	244.9	Hollow Stem Auger used Wet spoon observed at 5.3 m depth No cave-in
		June 28, 2019	2.0	252.5	
		September 5, 2019	0.7	253.5	

Borehole No.	Existing Ground Elevation (m)	Date of Measurement	Groundwater Level-Depth (m)	Groundwater Level Elevation (m)	Notes/observations
		March 7, 2020	3.0	251.2	
BH 19-2	254.0	June 14, 2019 (upon completion)	Dry	Dry	Hollow Stem Auger used No cave-in
BH 19-3	254.9	June 12, 2019 (upon completion)	7.0	247.9	Hollow Stem Auger used Wet Spoon observed at 1.5 m depth Cave-in at 11.6 m upon completion
BH 19-4	255.0	June 12, 2019 (upon completion)	9.5	245.5	Hollow Stem Auger used Wet spoon observed at 3.1 m depth Cave-in at 9.8 m upon completion

4.4 SUMMARY OF SUBSURFACE CONDITIONS

A summary of the soil and groundwater conditions encountered at the culvert location is presented in the table below.

Table 4-4 Simplified Stratigraphy and Groundwater Level Elevations

Borehole No. (Elev. m) Drilling Date	Simplified Stratigraphy (Depth in metres)					Most Current Observed Groundwater Depth (m) / Elevation (m) Date Measured	Notes
	Topsoil	Asphaltic Concrete	Cohesionless Fill	Silty Clay	Glacial Till (Clayey Silt/Silty Clay)		
BH 19-1 (254.2) June 14, 2019	0 – 0.23	N/A (In the ditch)	N/A (In the ditch)	0.23 – 1.8	1.8 – 9.8	3.0/251.2 March 7, 2020	Borehole terminated at 9.8 m depth. Standpipe piezometer installed.
BH 19-2 (254.0) June 14, 2019	0 – 0.20	N/A (In the ditch)	N/A (In the ditch)	0.20 – 1.8	1.8 – 9.8	--	Borehole terminated at 9.8 m depth.
BH 19-3 (254.9) June 12, 2019	--	0 – 0.38	0.38 – 1.8	1.8 – 2.6	2.6 – 12.8	7.0/247.9 June 12, 2019	Borehole terminated at 12.8 m depth. Groundwater level observation taken at the completion of the drilling and is most likely not stabilized.

Borehole No. (Elev. m) Drilling Date	Simplified Stratigraphy (Depth in metres)					Most Current Observed Groundwater Depth (m) / Elevation (m) Date Measured	Notes
	Topsoil	Asphaltic Concrete	Cohesionless Fill	Silty Clay	Glacial Till (Clayey Silt/Silty Clay)		
BH 19-4 (255.0) June 12, 2019	--	0 – 0.23	0.23 – 0.8	0.8 – 2.3	2.3 – 12.8	9.5/245.5 June 12, 2019	Borehole terminated at 12.8 m depth. Groundwater level observation taken at the completion of the drilling and is most likely not stabilized.

SIGNATURES

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MTO Designate (Foundations).

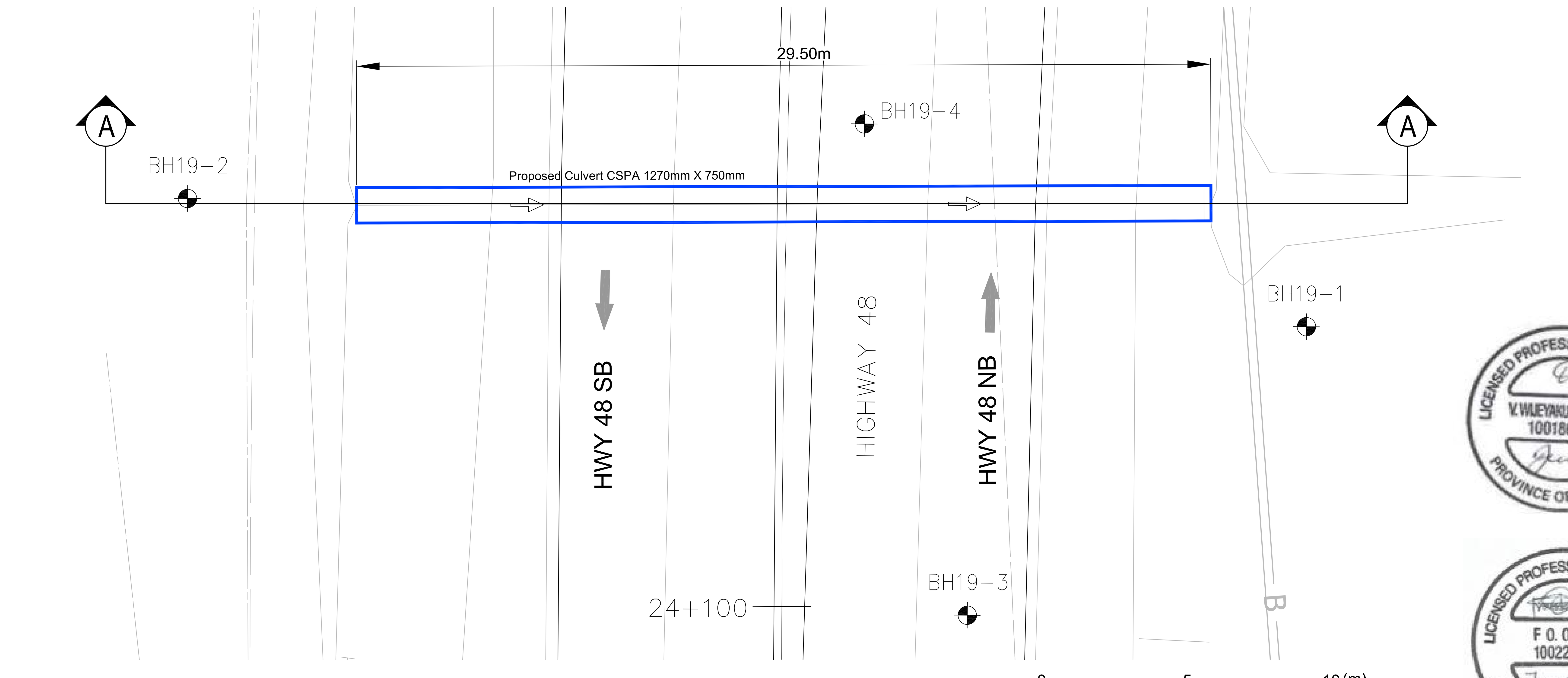
DRAWINGS

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

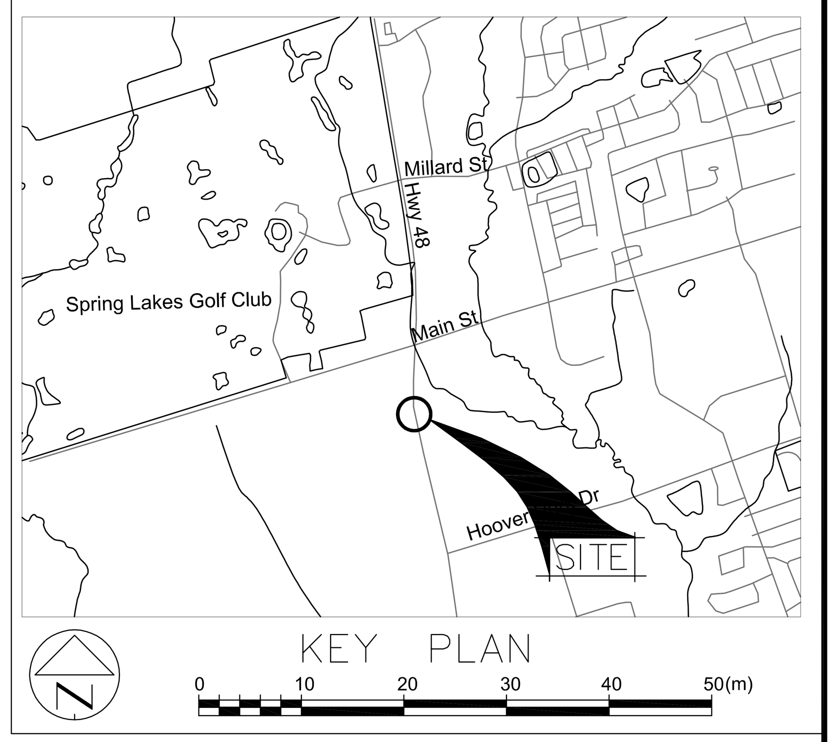
GWP No: 2075-18-00

HWY 48 Stouffville South
Non-Structural Culvert Replacement
CV-0249-0048-0002
BOREHOLE LOCATIONS & SOIL STRATA

WSP
2 International Blvd, Suite 201
Toronto, Ontario
M9W 1A2



PLAN

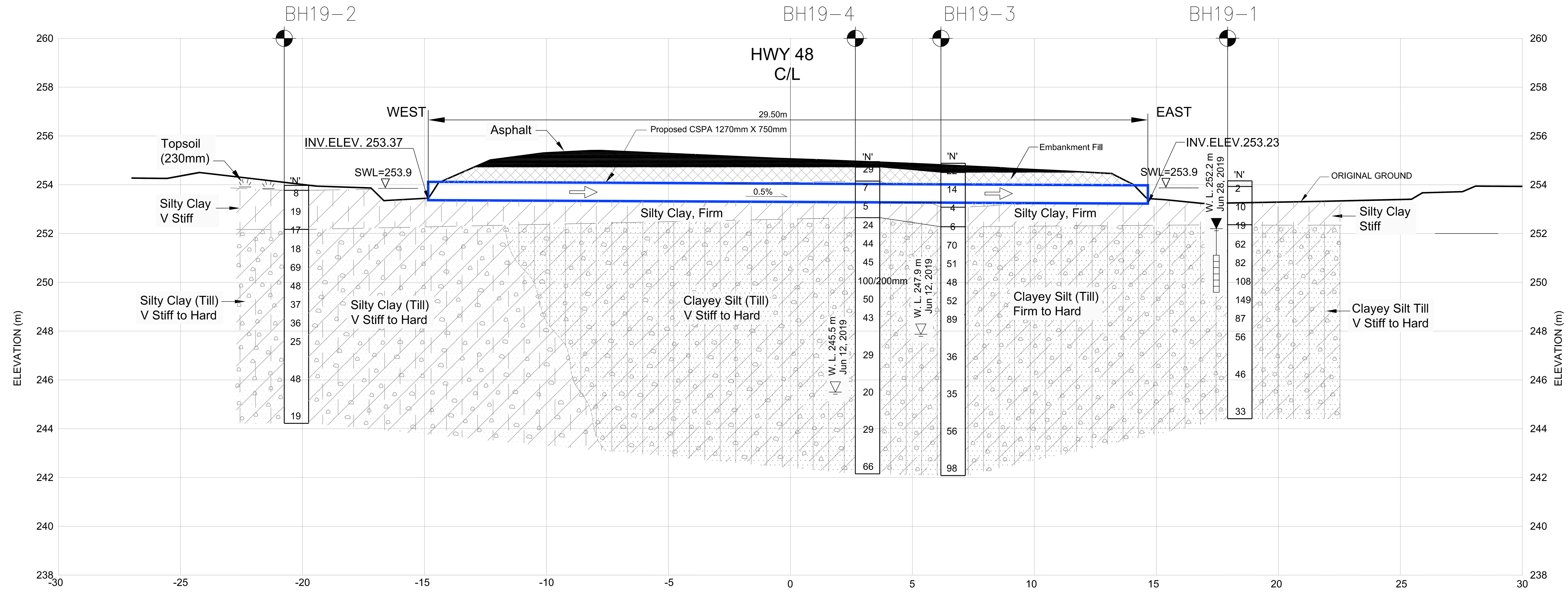


KEY PLAN

0 10 20 30 40 50(m)

SOIL STRATA SYMBOLS

Topsoil
Asphalt
Embankment Fill
Silty Clay
Silty Clay Till
Clayey Silt Till



24+113.88

CROSS SECTION A-A

HOR 0 5 10 (m)

VERT 0 5 10 (m)

LEGEND

- Borehole drilled by WSP
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- WL upon completion of drilling
- WL in piezometer
- Piezometer
- SWL Surface Water Level

BH No.	APPROX. ELEV. (m)	MTM NAD83 ZONE 10 CO-ORDINATES NORTHING (m)	EASTING (m)
BH19-1	254.2	4869097.3	322401.0
BH19-2	254.0	4869096.4	322362.2
BH19-3	254.9	4869085.9	322390.8
BH19-4	255.0	4869102.2	322384.9

CULVERT AT STA. 24+114 LAT: 43.961670°
LONG: -79.280902°

— NOTES —

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

Base plan and profile drawing provided in digital format, drawing file number; "Profile_Culvert #106 Sta. 24+114" received November 12, 2019

REVISIONS DATE	BY	DESCRIPTION
April 22/20	ZMO	Submission for MTO review

WSP No : 18M-01021-13 GEOCRES No : 30M14-521

HWY No 48			DIST CENTRAL
SUBM'D	CHECKED FO	DATE April 22/ 2020	SITE
DRAWN ZMO	CHECKED FO	APPROVED VW	DWG 1

APPENDIX

A

RECORD OF BOREHOLE SHEETS

RECORD OF BOREHOLE No BH 19-1

METRIC

W.P. 2075-18-00	LOCATION MTM NAD 83 (Zone 10), E 322401, N 4869097.3 Lat: 43.961639° Long: -79.280674°		ORIGINATED BY TO
DIST	HWY 48	BOREHOLE TYPE Hollow Stem Auger (150 mm)	COMPILED BY TO
DATUM Geodetic		DATE Jun/14/2019 to Jun/14/2019	CHECKED BY FO

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
254.2	Ground Surface
253.9 / 0.2	**TOPSOIL** (230 mm)
	SILTY CLAY: trace gravel, trace sand, trace rootlets, some organics, dark brown to black, moist, soft to stiff.
252.4 / 1.8	**CLAYEY SILT (TILL):** trace gravel, sandy to trace sand, brown to grey, moist, very stiff to hard.
	----------------------- gravelly -----------------------
244.4 / 9.8	**End of Borehole**

SAMPLES

NUMBER	TYPE	"N" VALUES	POCKET PEN. (Cu) (kPa)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	2		
2	SS	10	50	
3	SS	19	125	
4	SS	62		auger grinding
5	SS	82		3 32 46 19
6	SS	108		
7	SS	149		
8	SS	87		wet spoon
9	SS	56		6 25 51 18
10	SS	46		
11	SS	33		

GROUND WATER CONDITIONS / ELEVATION SCALE (253, 252, 250, 249, 248, 247, 246, 245):

- Rising up casing at 3' above ground
- W. L. 253.5 m Sep 05, 2019
- Hole plug seal
- W. L. 251.2 m Mar 07, 2020
- 8" sand pack below screen
- W. L. 244.9 m Jun 14, 2019

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE: 20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L

WATER CONTENT (%): 10 20 30

NATURAL UNIT WT (kN/m³) γ

Note:
1) No Cave-in upon completion
2)Water level was at 9.3 m depth below GL upon completion
3) Water level in monitoring well measured as follows:

Water level readings:

Date	Depth (m)	Elevation (m)
June 28-19	2.0	252.2
Sept 5-19	0.7	253.5
March 7-20	3.0	251.2

18M-01021-13

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

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

○ ε=3% Strain at Failure

Ministry of Transportation Ontario

wsp

RECORD OF BOREHOLE No BH 19-2

METRIC

W.P. 2075-18-00	LOCATION MTM NAD 83 (Zone 10), E 322362.2, N 4869096.4 Lat: 43.961637° Long: -79.281160°		ORIGINATED BY TO
DIST	HWY 48	BOREHOLE TYPE Hollow Stem Auger (150 mm)	COMPILED BY TO
DATUM Geodetic		DATE Jun/14/2019 to Jun/14/2019	CHECKED BY FO

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
254.0	Ground Surface
253.8 / 0.2	**TOPSOIL** (200 mm)
253.8 / 0.2	**SILTY CLAY:** trace sand, trace organics, brown, moist, very stiff.
252.2 / 1.8	**SILTY CLAY (TILL):** trace gravel, sandy to trace sand, brown to grey, moist, very stiff to hard.
	sand seam
	silty sand seam
244.2 / 9.8	**End of Borehole**

Note:
1) No Cave-in
2) No water upon completion

SAMPLES

NUMBER	TYPE	"N" VALUES	POCKET PEN. (Cu) (kPa)	GR	SA	SI	CL
1	SS	8					
2	SS	19	175				
3	SS	17	225				
4	SS	18	200				
5	SS	69					
6	SS	48		2	29	37	32
7	SS	37	175				
8	SS	36	175				
9	SS	25	225				
10	SS	48		4	26	31	39
11	SS	19	75				

Column headings: GROUND WATER CONDITIONS; ELEVATION SCALE (253, 252, 251, 250, 249, 248, 247, 246, 245); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); POCKET PEN. (Cu) (kPa) γ; NATURAL UNIT WT (kN/m³); REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9

Water content plot label: 45

WSP-SOIL-ROCK-MAY-29-2017.GLB
ON-MTO-2016-WITH WSP 18M-01021-13 HWY 48 LITTLE ROUGE CK SEPT 10 2019.GPJ 4/20/20

18M-01021-13

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

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

○ ε=3% Strain at Failure

Ministry of Transportation Ontario

wsp

RECORD OF BOREHOLE No BH 19-3

METRIC

W.P. 2075-18-00	LOCATION MTM NAD 83 (Zone 10), E 322390.8, N 4869085.9 Lat: 43.961541° Long: -79.280801°	ORIGINATED BY TO
DIST	HWY 48	BOREHOLE TYPE Hollow Stem Auger (150 mm)	COMPILED BY TO
DATUM Geodetic	DATE Jun/12/2019 to Jun/12/2019	CHECKED BY FO

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
254.9	Ground Surface
0.0	**ASPHALT** (380 mm)
254.5 / 0.4	**FILL:** gravelly sand, trace silt, trace clay, brown, moist to wet, compact. ---- wet
253.1 / 1.8	**SILTY CLAY:** trace gravel, brown, moist, soft to firm. ---- sand
252.3 / 2.6	**CLAYEY SILT (TILL):** trace gravel, some sand, brown to grey, moist, firm to hard. ---- sand seams ---- ---- some gravel, some sand, wet
242.1 / 12.8	**End of Borehole**

Note:
1) Borehole caved-in at 11.6 m upon completion.
2) Water level was at a depth of 7.0 m upon completion.

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	22	
2	SS	14	21 69 4 6
3	SS	4	wet spoon
4	SS	6	
5	SS	70	6 40 41 13
6	SS	51	
7	SS	48	
8	SS	52	
9	SS	89	
10	SS	36	
11	SS	35	1 15 65 19
12	SS	56	
13	SS	98	

GROUND WATER CONDITIONS: W. L. 247.9 m Jun 12, 2019

ELEVATION SCALE: 254, 253, 252, 251, 250, 249, 248, 247, 246, 245, 244, 243

DEPTH SCALE: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

POCKET PEN. (Cu) (kPa) — NATURAL UNIT WT (kN/m³) γ

+3, ×3: Numbers refer to Sensitivity O ε=3% Strain at Failure

18M-01021-13

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

Ministry of Transportation Ontario

wsp

RECORD OF BOREHOLE No BH 19-4

METRIC

W.P. 2075-18-00	LOCATION MTM NAD 83 (Zone 10), E 322384.9, N 4869102.2 Lat: 43.961687° Long: -79.280885°	ORIGINATED BY TO
DIST ______ HWY 48	BOREHOLE TYPE Hollow Stem Auger (150 mm)	COMPILED BY TO
DATUM Geodetic	DATE Jun/12/2019 to Jun/12/2019	CHECKED BY FO

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	POCKET PEN. (Cu) (kPa)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
255.0	Ground Surface							
254.7 / 0.2	**ASPHALT** (230 mm)							
254.2 / 0.8	**FILL:** gravelly sand, brown, moist, compact.	1	SS	29				
	SILTY CLAY: trace organic, trace gravel, trace sand, blackish brown, moist, firm.	2	SS	7		254		
		3	SS	5		253		
252.7 / 2.3	**CLAYEY SILT (TILL):** trace gravel, sandy to trace, brown to grey, moist, very stiff to hard.	4	SS	24		252		
		5	SS	44				wet spoon 3 29 35 33
		6	SS	45		251		
		7	SS	100/ 200mm		250		
		8	SS	50		249		
		9	SS	43		248	>225	
		10	SS	29		247	>225	0 5 42 53
		11	SS	20	∇ W. L. 245.5 m Jun 12, 2019	246 / 245		
		12	SS	29		244 / 243	225	
	---------- some gravel, some sand	13	SS	66				
242.2 / 12.8	**End of Borehole** Note: 1) Borehole caved-in at 9.8 m upon completion. 2) Water level was at a depth of 9.5 m upon completion.							

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

NATURAL UNIT WT (kN/m³) γ

18M-01021-13

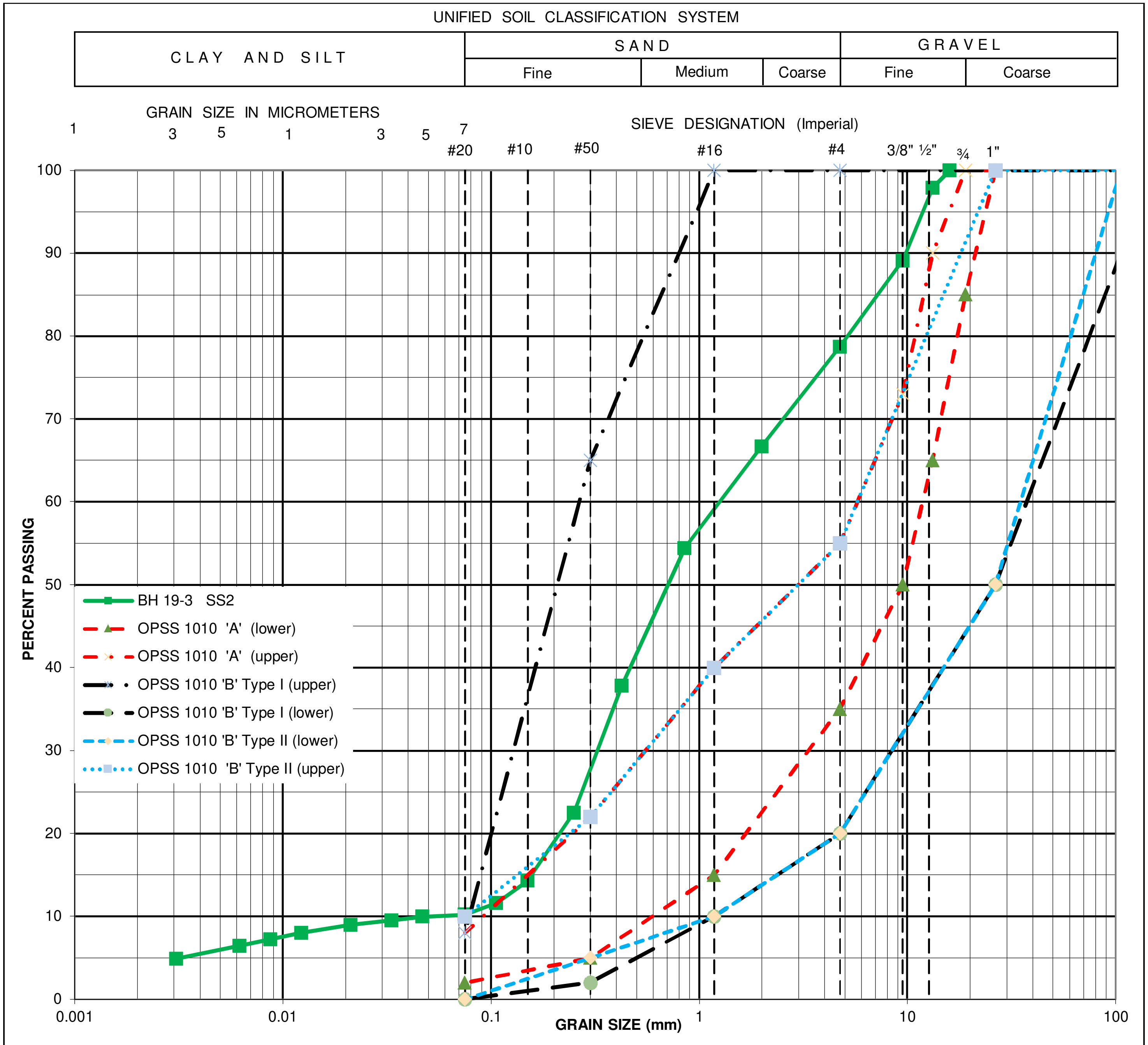
$+^3, \times^3$: Numbers refer to Sensitivity   ○ ε=3% Strain at Failure

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

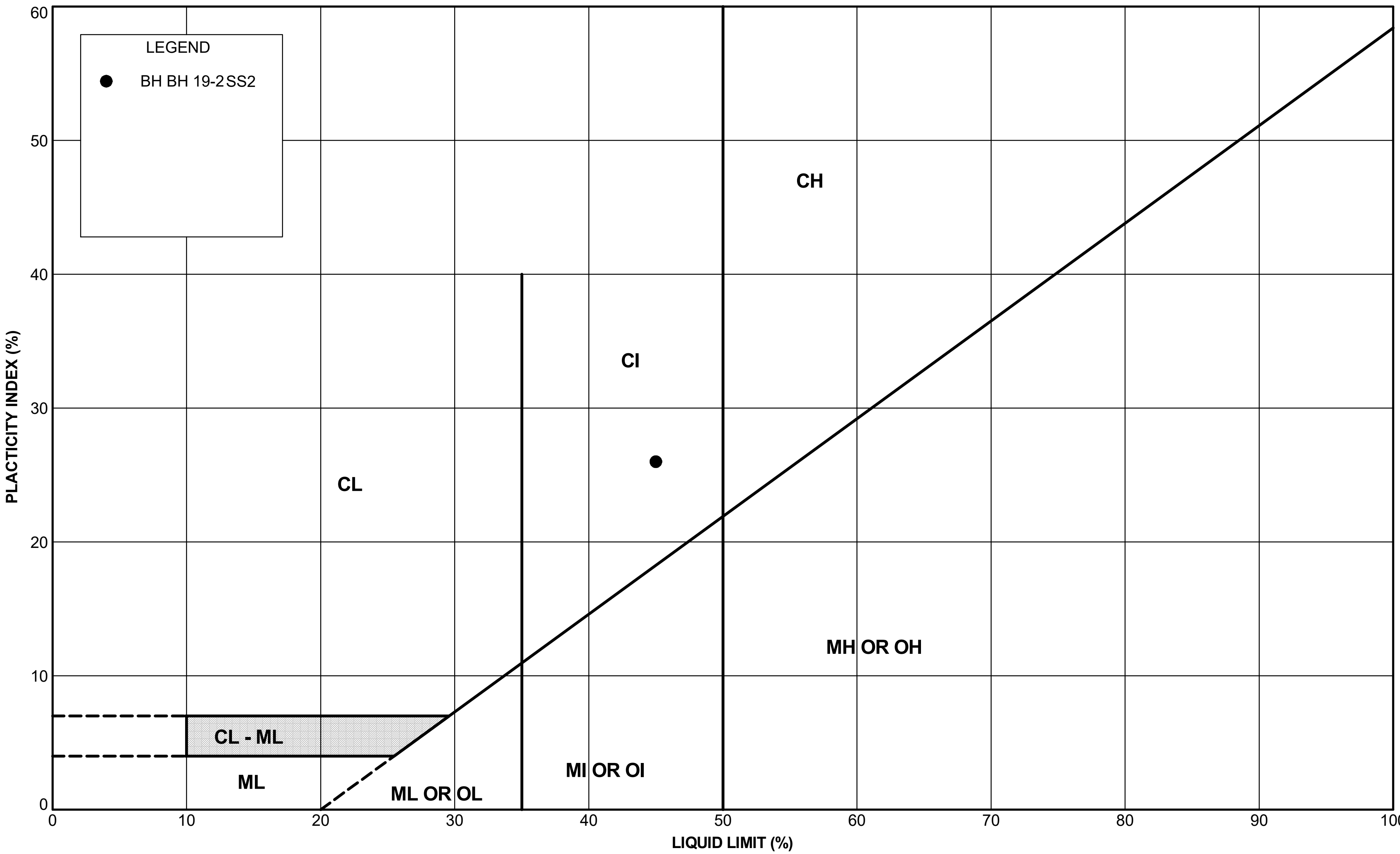
APPENDIX

B LABORATORY TEST RESULTS

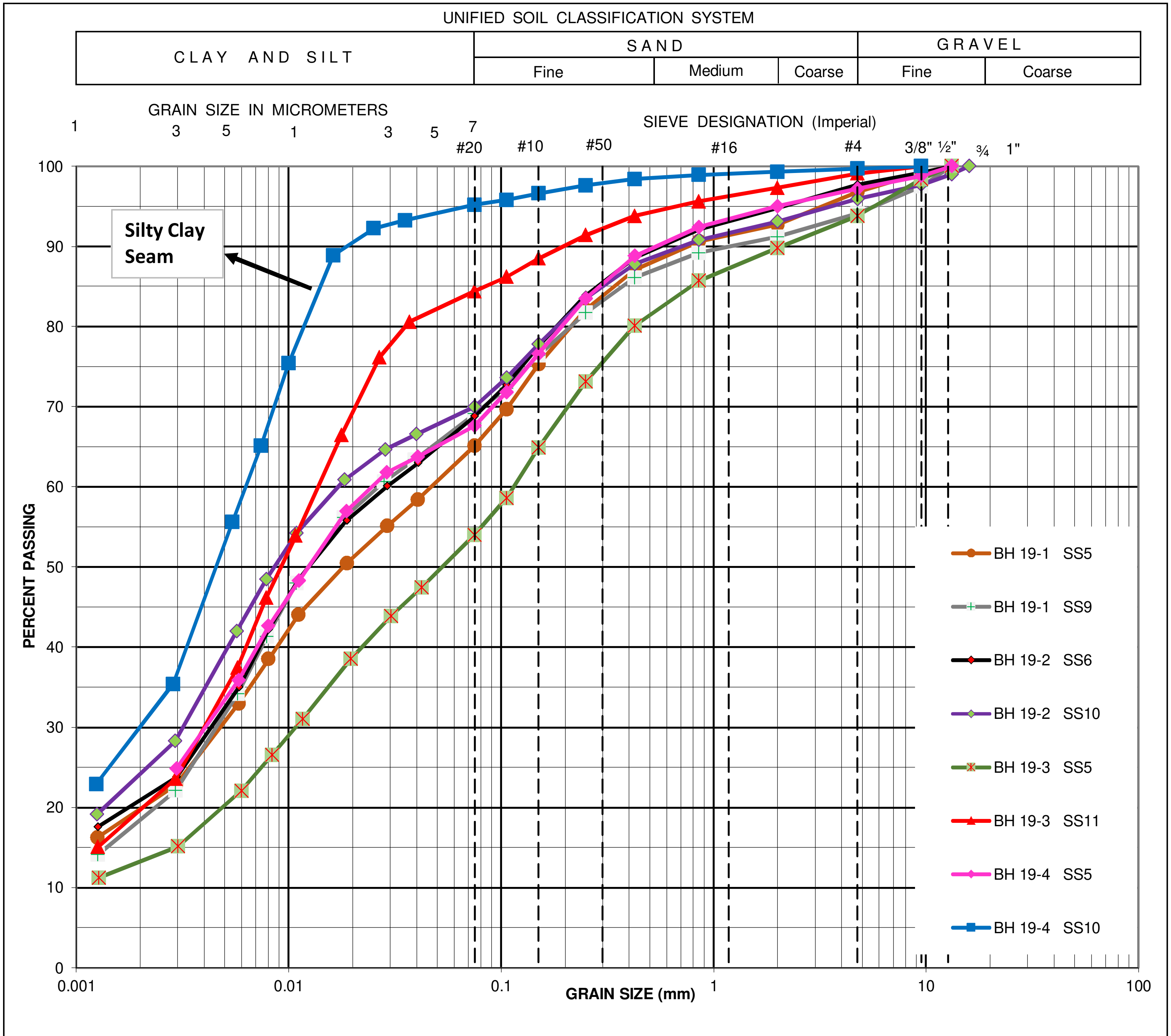


GRAIN SIZE DISTRIBUTION
Cohessionless Fill

Figure No:	B -1
Project No. 18M-01021-13	
Date :	April-07-2020



MINISTRY OF TRANSPORTATION	PLASTICITY CHART **Silty Clay**	FIGURE NO.	B-2
		W.P.	2075-18-00
		DATE	February 5, 2020



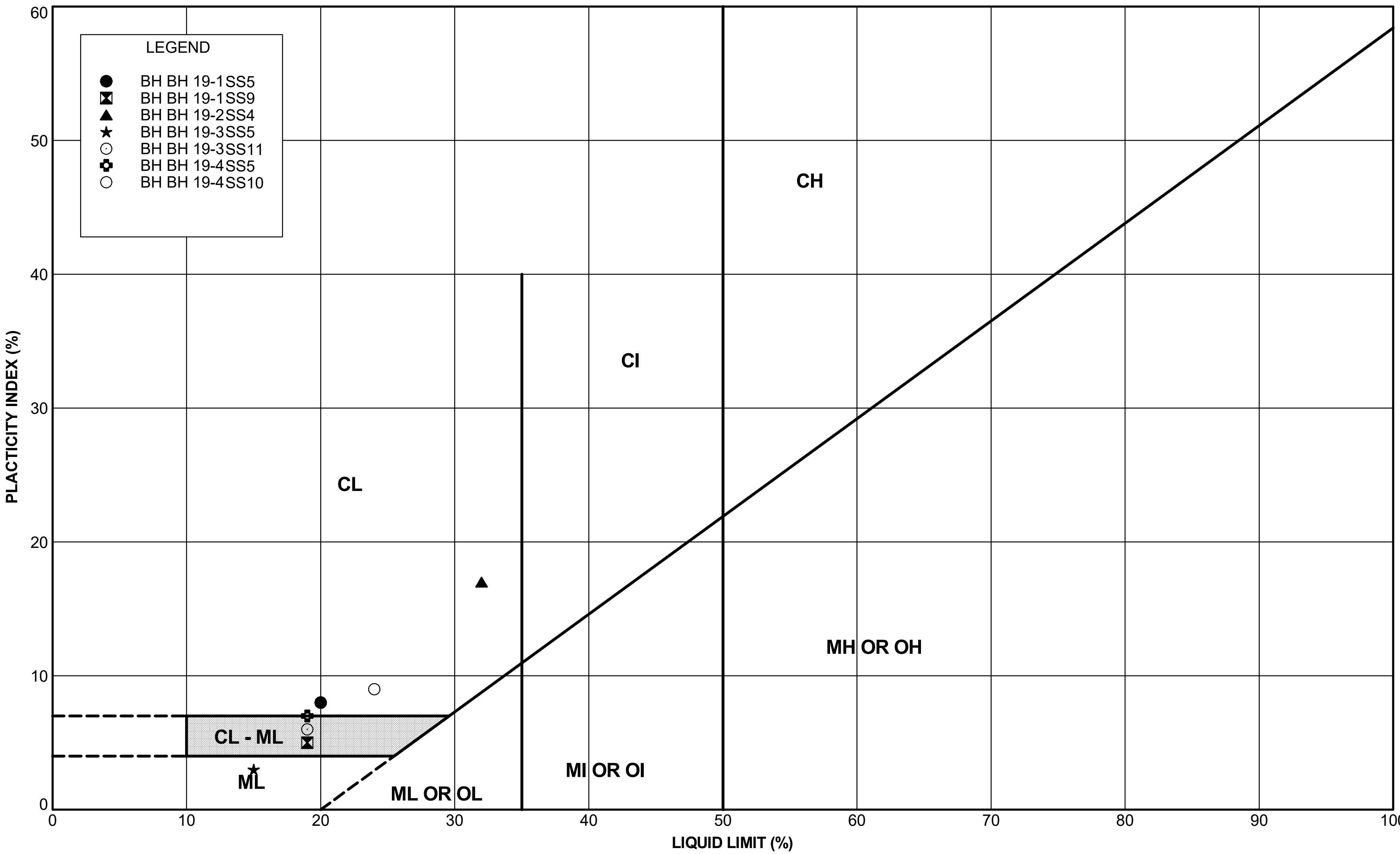
GRAIN SIZE DISTRIBUTION

Silty Clay to Clayey Silt "Glacial Till"

Figure No: B-3

Project No. 18M-01021-13

Date : April-07-2020



MINISTRY OF TRANSPORTATION	PLASTICITY CHART **Clayey Silt "Glacial Till"**	FIGURE NO.	B-4
		W.P.	2075-18-00
		DATE	February 5, 2020

APPENDIX

C

SITE PHOTOGRAPHS

Appendix C

Project: Hwy 48 Stouffville

No. 2017-E-0018/GWP 2075-18-00

SITE VISIT PHOTOGRAPHS – CULVERT AT 24 + 114

C1: Reconnaissance Site Photographs

C2: Field Work Photographs

Photo C1-1: Looking towards West across Highway 48 at Culvet Sta. 24+114 (May 2019)

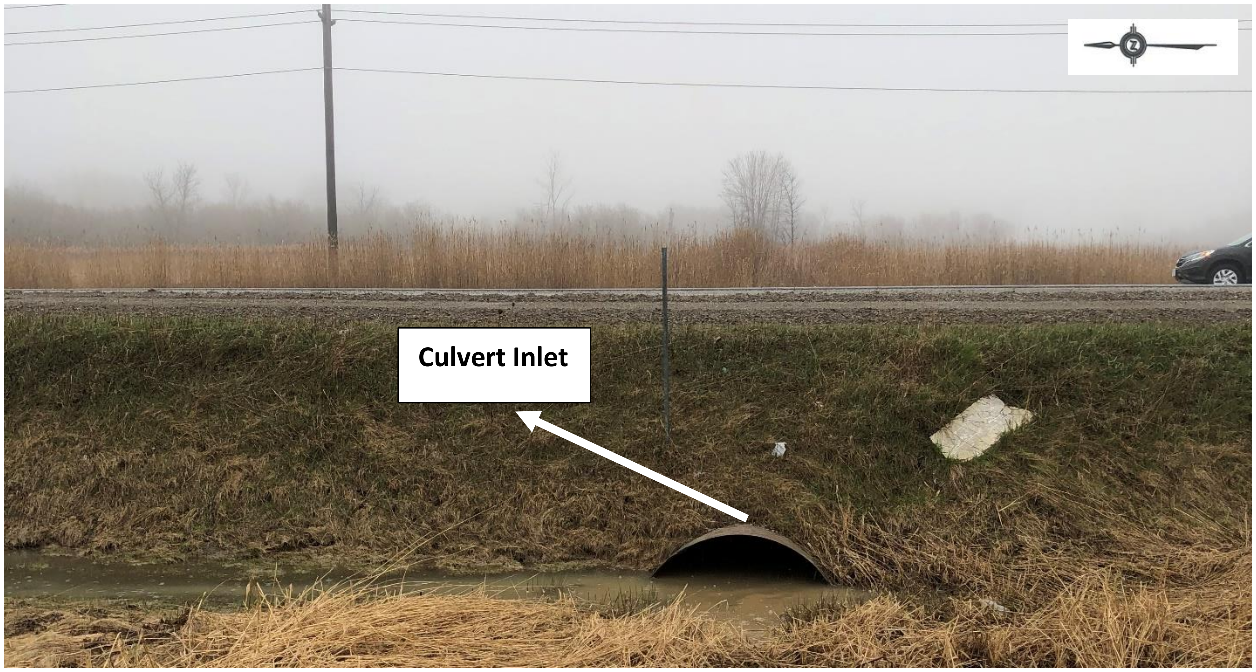


Photo C1-2: Looking towards East at culvert Inlet Sta. 24+114 (May 2019)

Photo C1-3: Looking towards North at culvert Inlet Sta. 24+114 (May 2019)

Photo C1-4: Looking towards West at culvert outlet Sta. 24+114 (May 2019)

Appendix C

Photo C2-1: Looking towards West at culvert outlet location Sta. 24+114 (June 2019)

Photo C2-2: Looking towards West at culvert outlet location Sta. 24+114 (June 2019)

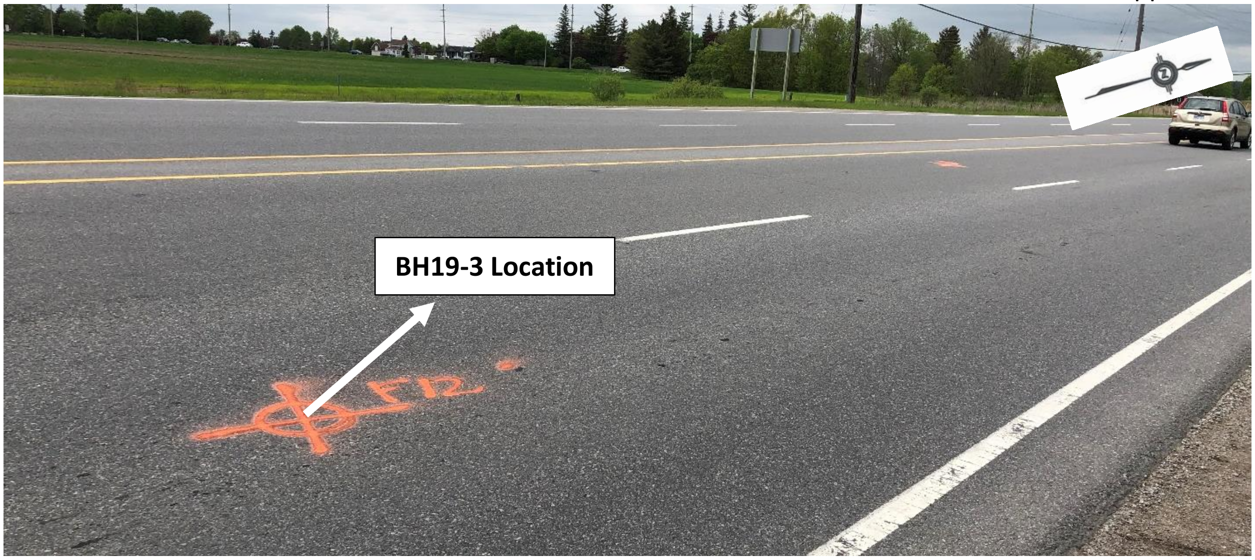


Photo C2-3: Looking towards North near culvert Sta. 24+114 (June 2019)

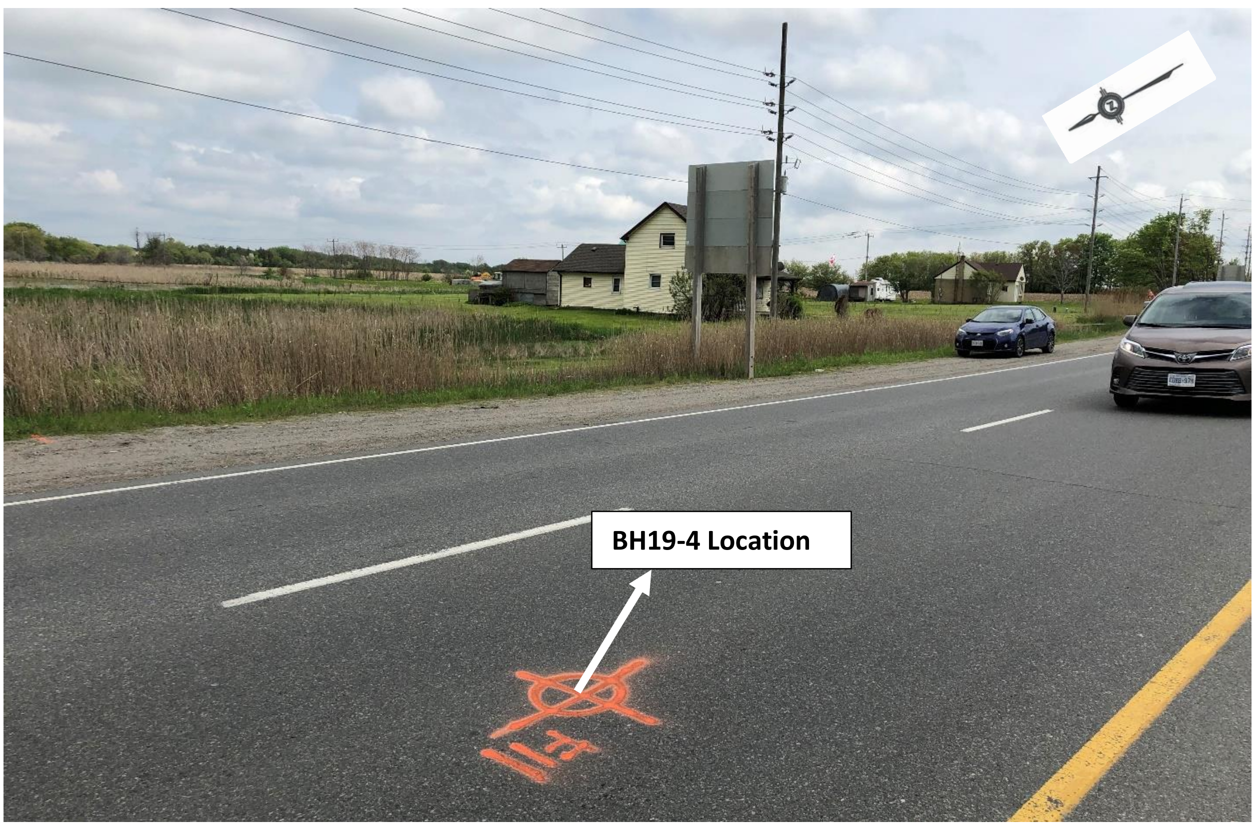


Photo C2-4: Looking towards South near culvert Sta. 24+114 (June 2019)

Photo C2-5: Looking towards North on Highway 48 at BH19-4 location (June 2019)

FOUNDATION DESIGN REPORT

Proposed Non-Structural Culvert Replacement, Highway 48, 240 m South of Stouffville Road/Main Street, Town of Whitchurch-Stouffville, Ontario

MINISTRY OF TRANSPORTATION (MTO)

Site Location (Long. -79.280902°, Lat. 43.961670°)

GWP: 2075-18-00

GEOCRES NO. 30M14-521

WSP PROJECT NO.: 18M-01021-13
DATE: JUNE 26, 2020

WSP CANADA INC.
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TORONTO, ON, CANADA M9W 1A2

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www.wsp.com

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5 DISCUSSION AND RECOMMENDATIONS

5.1 GENERAL

This section of the report (FDR) addresses pertinent geotechnical design issues for the replacement of the existing 1270 mm x 750 mm CSPA culvert of elliptical cross section (non-structural culvert CV-0249-0048-002) at Station 24+114 on Hwy 48 approximately 240 m south of Stouffville Road/Main Street intersection. This work was carried out under Assignment No: 2017-E-0018 and forms part of work order #13, as part of the MTO Central Region Large Value Retainer.

It is our understanding based on the RFP that the proposed culvert replacement will be with a similar size and type of conduit and will be at the same location. The highest thickness of the overlying embankment above the existing CSPA invert level is approximately 2.0 m and found to be at the west embankment edge of pavement (EP). The existing side slopes at the proposed culvert location based on the cross-section supplied are 2H:1V. The proposed CSPA is 29.5 m in length. Based on the Culvert Arrangement Drawing, the culvert is a 1270 mm by 750 mm CSPA of elliptical cross section (i.e. flexible culvert). The proposed invert levels at the inlet and outlet are El. 253.37 m and El. 253.23 m respectively. The road grade from the inlet side to the outlet side was found to be slightly sloping down.

As the main thrust of the discussion and recommendations of this report, focus will be made on the geotechnical aspects associated with the design and construction of the replacement culvert structure and will address staging and road protection issues. It is our understanding that no widening of the embankment or road pavement grade raise will be involved.

Visual observations on the condition/performance of the existing embankment and existing culvert have been described in Section 2.3 of Part A: FIR. According to the observations, no adverse features have been observed that needs addressing in the FDR.

This FDR has assessed and included recommendations with respect to: a) Culvert replacement by open-cut excavation method; b) Temporary protection system/shoring for traffic staging work and; c) Temporary dewatering/unwatering system requirements during construction, from a foundation engineering perspective.

5.2 GEOTECHNICAL CHARACTERISATION

5.2.1 OVERVIEW OF SUBSURFACE CONDITIONS

As an overview, the encountered subsurface conditions at the culvert location between the culvert ends consisted of a pavement structure with a cohesionless pavement fill underlain by a cohesive native deposit of silty clay. This native deposit was intercepted in all boreholes including those at the culvert inlet and outlet locations. This deposit has thickness ranging from 0.8 m to 1.6 m. Further underlying this deposit is a cohesive glacial till with explored thickness varying from 8.0 m to 11.0 m (See **Dwg. No. 1** of the Foundation Investigation Report, FIR).

The pavement fill composition was gravelly sand with SPT 'N' values indicating a compact relative density. The underlying intermediate plasticity, sillty clay deposit was of firm to stiff consistency. Geocress report cited in the FIR from the surrounding area has reported the presence of a shallow heavy clay and the silty clay layer intercepted at the subject site could be probably reflective of this deposit reported in Geocres Report No. 30M14-042. The subject silty clay contained seams of sand and gravel and thus reflective of the low moisture contents recorded in some of the spoons e.g BH19-4, SS4. As a result of these permeable seams, undrained stability of this deposit which in turn requires the maintaining of matric suctions, cannot be relied upon. The implications of this will be discussed later.

Under the existing culvert, it is not known if the silty clay has been partially subexcavated during the original construction and replaced with granular fill since BH19-3 on the road platform closer to the culvert axis could still be outside the subexcvation limits and hence did not intercept any evidence of a subexcavation replacement with granular material. Hence discussion is based on the conservative assumption that this subject deposit still exists under the existing pipe.

The underlying cohesive glacial till layer comprised a heterogeneous mixture of sand and gravel in a matrix of clayey silt or silty clay, as intercepted in the different boreholes. Based on the SPT 'N' values, it was of very stiff to hard consistency.

Long-term groundwater level monitored in a monitoring well installed within the clayey silt till in the borehole at the outlet end (BH 19-1), revealed a stabilized ground water elevation of El. 251.2 m (about nine months after borehole completion). The unstabilized groundwater levels (upon completion) ranged from El. 244.9 m to El. 247.9 m. This gradual but significant rise of groundwater in BH 19-1 would reflect the presence of water conducting seams within the till, something not unexpected in most till deposits.

5.2.2 GEOTECHNICAL MODEL

GEOTECHNICAL STRENGTH MODEL

A geotechnical model was developed based on the stratigraphic model discussed in Section 4 (FIR) and on engineering judgement as shown in **Table 5-1**. The purpose of the geotechnical model is to enable the addressing of foundation bearing issues and open-cut/temporary shoring global stability issues associated with the culvert replacement as discussed in Section 5.4.

Table 5-1 Geotechnical Strength Model

Depth Range (m)	Thickness Range (m)	Material/Deposit	SPT 'N'			PI			Unit Weight, γ (kN/m^3)	C' (kPa)	Phi' (deg)	Undrained Shear Strength, su (kPa)
			Avg.	Range	No. of spoons	Avg.	Range	No. of Tests				
0 - 1.8	0.8 - 1.8	Pavement Fill (Cohessionless)	16	14 - 29	3	N/A*			22	0	32	N/A
0.2 - 2.6	0.8 – 1.6	Silty Clay	8	2 - 19	8	26	-	1	18	0	29	30
1.8 – 12.8	8.0 – 10.5	Clayey silt/Silty Clay (Till)	51	6 - 149	38	8	3 – 17	7	21	2	32	125

*N/A : Not Applicable

SEISMIC SITE CLASSIFICATION

Based on the borehole information and our review of the general subsurface conditions in the area, the subject site for the proposed structures can be classified as 'Class C' for seismic site response according to Table 4.1 of **CSA S6-14**.

FROST DEPTH

The frost depth for the project site is 1.2 m based on the MTO Foundation Frost Depths for Southern Ontario, **OPSD 3090.101**.

5.3 GEOTECHNICAL CONSIDERATIONS FOR REPLACEMENT CULVERT

5.3.1 GENERAL

The Culvert type and size are generally dictated by hydraulics, ecology (e.g. fish habitats) and economics. Geotechnical appraisal will include the suitability of in-situ conditions to support the chosen culvert type, any requirements for ground improvement and construction issues specific to chosen culvert types and in-situ ground conditions.

According to the Culvert Arrangement Drawing, the replacement culvert is a 1270 mm by 750 mm CSPA (i.e. flexible culvert). Hence, geotechnical considerations will be included to address the flexible culvert issues. Flexible culverts are sympathetic to foundation movement and in view of the silty clay deposit (see section 5.2.1) immediately underlying the culvert invert levels, the replacement with a flexible culvert type is recommended from a foundation perspective. However, flexible pipes require greater attention to construction details as they heavily rely on the surrounding soil support to carry the overburden loads. Stiffness and configuration of the soil around the pipe can affect pipe performance limits. In the case of flexible pipes, relative soil stiffness affects material failure (yielding/cracking/crushing), deflection and buckling.

5.3.2 IMPORTANCE OF SOIL-PIPE INTERACTION – FLEXIBLE CULVERTS

A flexible culvert, e.g. CSPA, derives its soil-load carrying capacity by virtue of its haunch support. When the pipe is subject to loads by overburden soils and imposed loads on the road above, the pipe and the soil work as a system in resisting the load. The pipe tends to deflect and in turn mobilizes passive soil support/resistance at the sides of the pipe. The ring deflection also induces arching action in the surrounding soil over the pipe and thereby reduces the vertical load acting on the pipe. Hence, soil is a major component of the soil-pipe interaction system and plays an integral role to support the vertical loads. Soil density (higher the soil density a given material is compacted to, renders a higher soil stiffness) is the most important soil property to ensure that the soil is capable of providing the structural support for the pipe. CSPA culverts though tolerant to movement, carry significant loads but in return require careful attention to detail during construction. In this context, Section 5.4 discusses the importance of sound compaction of both cover materials and backfill. The pipe designers should address corrosion issues in relation to site soil/groundwater chemistry.

5.3.3 PROPOSED FOUNDING LEVELS

As per Drawing 1, the invert elevations at the inlet and outlet of the proposed culvert are El. 253.37 m and El. 253.23 m, respectively. Assuming a bedding thickness of 300 mm, the underside of the bedding elevations will likely be in the silty clay deposit. Based on the wet spoon observations during drilling, they were mostly observed within the till layer further below the proposed founding levels. However, perched water sitting above the silty clay cannot be ruled out. Therefore, the silty clay deposit is likely to be saturated. It is therefore important to establish dry working conditions. Section 5.4.2 further discusses dewatering and construction issues.

5.3.4 FOUNDATION BEARING ISSUES

At the proposed culvert replacement location, there is no change in culvert type and size for the replacement and no grade raise/embankment widening involved, and since the existing culvert has been place for a long time, this applied stress on the existing culvert foundations has become fully effective after possible consolidation. Therefore, subject to good construction control, there should not be an issue with either bearing or settlements, as the net increase in load that will be experienced by the CSPA foundation due to replacement is effectively negligible.

Sliding is unlikely to pose a problem as the major horizontal earth pressure thrust on the culvert is along the road axis, which subject to proper backfill placement with regard to differential height control as discussed in Section 5.3.5, should not pose an issue. An unfactored friction angle of 30 degrees can be considered for interface sliding resistance at the bedding interface with the culvert base. Construction considerations to ensure the integrity of the subgrade are discussed in Section 5.4.5 and bedding and cover issues are discussed in Section 5.3.5.

5.3.5 BEDDING AND COVER

The bedding thickness should be at least 300 mm given the low strength of the native subgrade. Any requirement for thicker bedding due to prevailing subgrade conditions should be managed at the time of construction through bearing subgrade protection (Section 5.4.5) and maintaining dry working conditions (Section 5.4.2 for dewatering and drainage issues).

Uniform bedding conditions should be provided below the pipe to prevent localized concentrated foundation support which can lead to possible distress at invert and haunches.

The bedding and cover material should consist of a well-graded granular material and use of OPSS 1010, Granular 'A" is recommended. The cover should extend to at least one pipe diameter above the obvert of the pipe to promote arching action in the case of flexible culverts. The bedding material should be placed as soon as practicable after pouring the mud mat (see Section 5.4.5). The placement and compaction should follow **OPSS 401**, **OPSD 802.010** and and frost treatment shall follow **OPSD 803.031**. The level difference in backfill between opposite sides of the culvert, at any time during compaction of embedment material, must conform to OPSS 401 Clause 401.07.10.03 constraints.

5.3.6 BACKFILL

Backfill, outside the bedding, haunch and cover material, should match the existing embankment fill, i.e. gravelly sand, and therefore should be OPSS 1010 Granular B Type I or better. Backfilling operations must conform to OPSS 401.

5.3.7 EMBANKMENT RECONSTRUCTION/MATERIAL RE-USE

Embankment must be reconstructed to restore side batters to adjacent existing side slopes as stated in Section 5.1. Excavated non-cohesive embankment fill free of cobbles and boulders can be used for borrow and compaction shall conform to **OPSS 501** and engineered to meet pavement requirements. Any material shortfall should be met with approved materials and backfilling must conform to OPSS 401.

5.3.8 EROSION PROTECTION

Riprap protection should be provided at the culvert's inlet and outlet ends and should be generally followed by **OPSD 810.010** and any specific recommendations in the hydrology report. Riprap placed up to 1.5H: 1V without an underlying geotextile will be stable. Based on MTO Erosion and Sediment Control Guide, 2015, the surficial silty clay has a Soil Erodibility Rating of Medium.

Required erosion/scour protection systems should be designed by a specialist River Engineer/Scientist (as erosion and scour largely depend on the hydraulic energy, i.e. velocity of water in the watercourse and its regime and the erodible nature of stream bed material).

5.3.9 SLOPE PROTECTION/EROSION

The embankment side slopes should be provided with adequate erosion protecton against surface water runoff; proper erosion control measures should be implemented both during construction and permanently. This can be achieved by silt fencing (OPSD 219.131) during construction, and prompt seed and cover (OPSS 804) or sodding (OPSS 803) at the end of construction.

5.4 CONSTRUCTION CONSIDERATIONS

5.4.1 CONSTRUCTION STAGING

Construction staging plans are attached in **Appendix D**. Shown are the temporary lane closures for culvert replacement in two stages, i.e. the culvert segment under the southbound to be replaced first, followed by construction switching to replace the culvert segment under the northbound. Given the nature of the staging, it may be possible for the contractor to undertake culvert replacement entirely by an open-cut, unshored excavation. In this context, global stability analysis of a plausible excavation geometry has been undertaken (see **Appendix E, Fig. 5.1 & Fig. 5.2**) with the drained case giving the critical safety factor. Based on the analysis, the cut face parallel to the operational traffic lanes should not be made steeper than 1.5H:1V for FoS to exceed 1.3. The stability analysis undertaken provides for an excavation of 600 mm below the culvert invert level to accommodate bedding and possible sub-excavation with an overall excavation depth of 2.6 m.

5.4.2 DEWATERING AND DRAINAGE ISSUES

High groundwater levels (El. 253.5 m) were recorded in BH 19-1 (outlet borehole) in a monitoing well with the filter screen installed within the glacial till. The proposed culvert replacement will not require excavations into the cohesive glacial till and as such the need for unwatering the glacial till to depress the watertable is not considered necessary.

On completion (unstabilized) groundwater levels were very deep. In BH19-2 there was no detectable groundwater on completion. Lateral groundwater flows in seams are likely to have produced the water levels as measured in BH 19-1 in the cohesive till. Although, groundwater levels as high as El. 253.5 were recorded, and this elevation likely be locally higher than the basal elevation of the silty clay deposit, the likelihood of the silty clay deposit being subjected to hydraulic heave (uplift/blow-out) locally is considered to be of low probability, given the stiff to hard consistency of the cohesive till. Strategically placed sumps can be used to manage any perched water by gravity drainage due to the silty clay cap over the till. However, preparedness for positive dewatering cannot be ruled out altogether.

According to WSP hydraulic advice, inflows to the inlet of the culvert should be able to be managed by temporary damming, say, with adjustable weirs, e.g. sandbags, inflatable rubber bags, woodlogs/timber, and the impounded water to be discharged through low-volume pumping. Any surface water runoff should be diverted from the excavations during construction, to ensure dry working conditions within the construction footprint.

A Permit To Take Water (PTTW) is not considered a requirement. Any dewatering shall conform to **OPSS 517**.

5.4.3 SHORT-TERM OPEN CUT EXCAVATIONS

All excavations should be carried out in accordance with the Province's Occupational Health and Safety Act (OHSA), O. Reg. 213/91, as well as OPSS.PROV 539 Construction Specification for Temporary Protection Systems.

In accordance with the Province's Safety Regulation, the following soil classifications would be applicable for open cut as shown in **Table 5-2**. However, based on site specific ground conditions and engineering judgement, OHSA classifications have been qualified and adopted to err on the side of safety. These open-cut recommendations in Table 5-2 do not allow for any surcharge loading effects, i.e. highway traffic loading adjacent to a cut face and are limited to excavation depths not exceeding 3.0 m. Prior to worker entry into an unshored excavation, the excavation stability must be assessed by a geotechnical engineer.

Table 5-2 Interpreted OHSA Requirements for Short-Term Open-Cut Excavations

Material/Deposit	OHSA Classification	Remarks
Granular pavement fill	1.25H:1V	Wet fill at the bottom
Silty Clay	Not steeper than 1.5H:1V	Wet sand seams
Clayey Silt/Silty Clay (Till)	1.25H:1V	Water bearing seams; Subject to confirmation by Geotechnical Engineer; excavations unlikely to extend into the till deposit

These temporary slopes for the above soil types as per OHSA are only as guidelines for temporary excavation slopes to be used for a short duration. We also recommend that these slopes be visually monitored for any movement especially if workers are present at the toe of the slopes.

All excavations should be undertaken with care to minimize disturbance especially to the saturated foundation subgrade. No material stockpiling should be undertaken beside the excavation within a horizontal distance equal to the depth of the excavation.

Excavations should be possible in the above soil types using equipment such as a a hydraulic excavator but obstructions, cobbles and boulders within the excavation depths cannot be ruled out.

5.4.4 SHORED EXCAVATIONS

Table 5-3 gives recommended unfactored design parameters for design of temporary shoring for the proposed half and half construction staging (Appendix D), if required. The shoring system should be designed so that the lateral movement of the portion of the 'roadway protection system' will not exceed the established criterion for the structure performance level. In this case, the required Performance Level is considered to be 2 (OPSS.Prov 539). The presence of potential cobbles within the embankment fill and cobbles and boulders in the basal till layer should be taken into consideration in deciding means and methods for shoring support. An **NSSP** should be included in the contract to 'red flag' the precautions to be undertaken to mitigate obstructions to excavatability and installation of shoring. A Professional Engineer experienced in this type of work should carry out the shoring design.

Table 5-3 Geotechnical Design Parameters (Unfactored) – For Temporary Shoring*

Layer Number	Material	Relative Density/ Consistency (Typical)	Unit Weight, γ (kN/m^3)	Effective Stress Strength Parameters		Earth Pressure Parameters		
				c' (kPa)	Φ' (deg)	K_a	K_p	K_o
1	Pavement Structure	Compact	22	0	32	0.31	3.26	0.47
2	Silty Clay	Firm	18	0	29	0.35	2.88	0.52
3	Cohesive Till	Stiff to Hard	21	2	32	0.31	3.26	0.47

*Notes:

C' = Effective Cohesion; Φ' = Effective Friction Angle; S_u = Undrained Shear Strength

K_a = Active Earth Pressure Coefficient; K_p = Passive Earth Pressure Coefficient; K_o= At-Rest Earth Pressure Coefficient

1) A factor of safety of 2 shall be applied for computing passive resistance to lateral loads. Disregard any passive resistance within the frost depth.
2) Adequate allowance should be made for surcharge loads such as traffic with a minimum of 16 kPa surcharge
3) Earth pressure coefficients given in the table are for horizontal backfill and level surface in front. Any departures from this should be taken into account.
4) El. 252.4 m can be assumed as the design groundwater level
5) The temporary road protection system shall conform to the requirements of the OPSS.PROV 539 Construction Specification for Temporary Protection Systems

5.4.5 BEARING SUBGRADE

Prior to culvert replacement, the existing culvert has to be exhumed. This operation should be undertaken carefully to minimize disturbance to the foundation subgrade. Given the presence of the saturated, silty clay deposit of intermediate plasticity which is prone to construction disturbance, in order to enhance the bearing subgrade and to facilitate trafficability, a minimum 75 mm thick mud mat should be poured as soon as possible on the foundation bearing surface after excavation and approval of the subgrade. Any sub-excavations should be backfilled with engineered OPSS 1010 Granular A. An **NSSP** should be included in the contract to address the requirement for the mud mat. The suggested wordings are included for reference in **Appendix F**.

The transportation and placement of the culvert elements will need to proceed with caution to ensure the newly constructed bedding and/or the underlying subgrade are not disturbed or subjected to rutting failure.

A geotechnical engineer who is familiar with the findings of this investigation should evaluate all bearing surfaces prior to placement of mud mat to confirm that the founding conditions are consistent with the recommendations given in the report. All organic, loose/soft/disturbed or otherwise unsuitable soils should be removed prior to pouring the concrete.

5.4.6 SOIL DISPOSAL/SITE RESTORATION ISSUES

The unsuitable excavated materials should be checked for contamination prior to removal/disposal off-site, in order to determine which disposal option is best for the excavated materials (**OPSS 180**). Site restoration should conform to **OPSS 492.**

REFERENCES

Canadian Highway Bridge Design Code (CHBDC) and Commentary on CAN/CSA S6-14. 2014. CSA Special Publication, S6.1 14. Canadian Standard Association.

Canadian Geotechnical Society, 2006. Canadian Foundation Engineering Manual, 4th Edition. The Canadian Geotechnical Society c/o BiTech Publisher Ltd, British Columbia.

Chapman, L.J. and D.F. Putnam. *The Physiography of Southern Ontario,* Ontario Geological Survey Special Volume 2, Third Edition, 1984

Highway 48 Stouffville – Little Rouge Creek Culvert Replacement Hydrology and Hydraulics Report, November 19, 2018

M.T.O Soil Classification Manual, Ministry of Transportation, Ontario.

CLOSURE

The "Limitations of Report' as presented in **Appendix G** are an integral part of this report.

SIGNATURES

We trust that the information contained in this foundation investigation report is satisfactory. Should you have any questions, please do not hesitate to contact this office.

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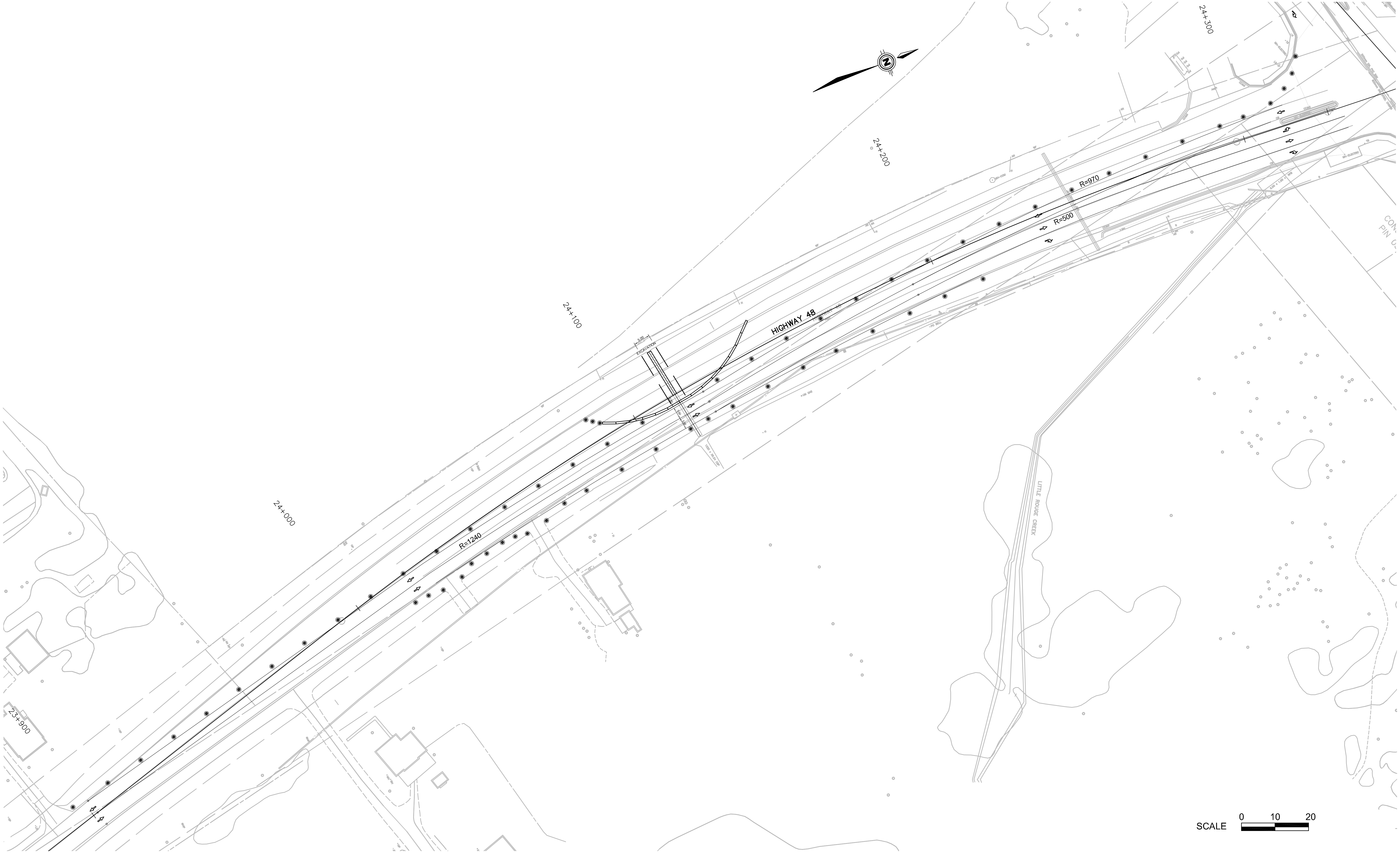
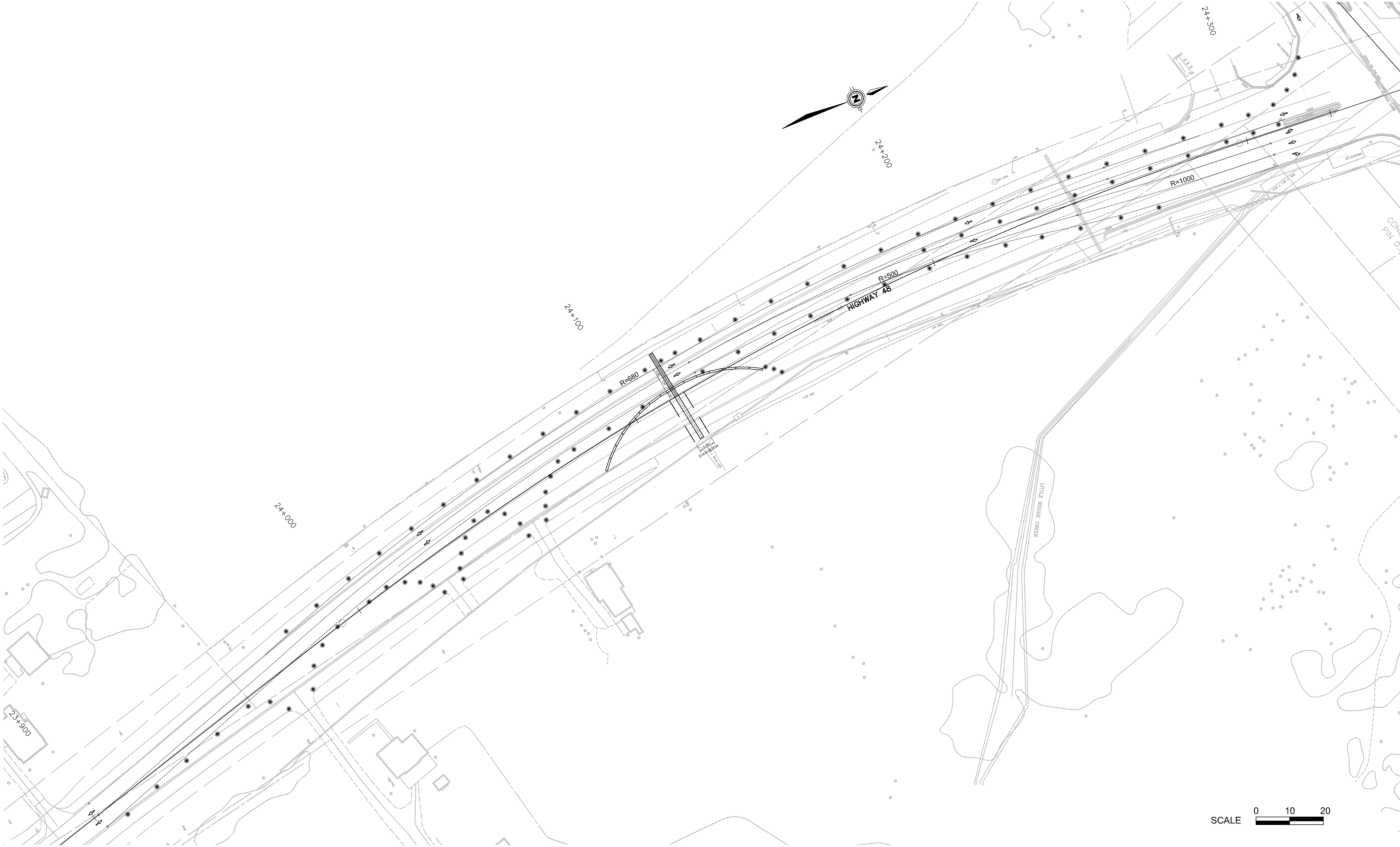
APPENDIX

D

STAGING PLANS



CSP CULVERT AT STATION: 24+114
STAGE 1 PLAN



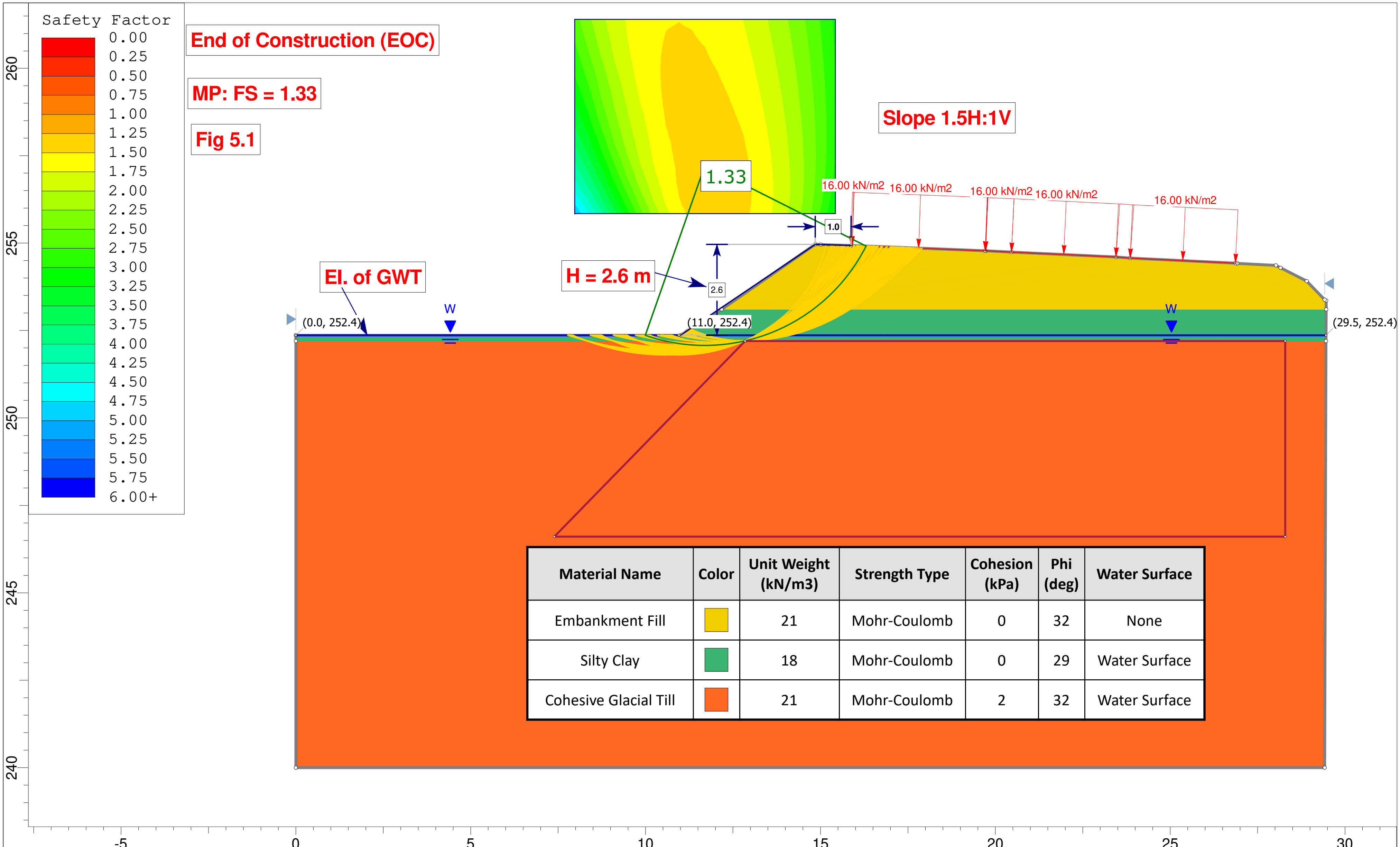
CSP CULVERT AT STATION: 24+114

STAGE 2 PLAN

APPENDIX

E

SLOPE STABILITY ANALYSES

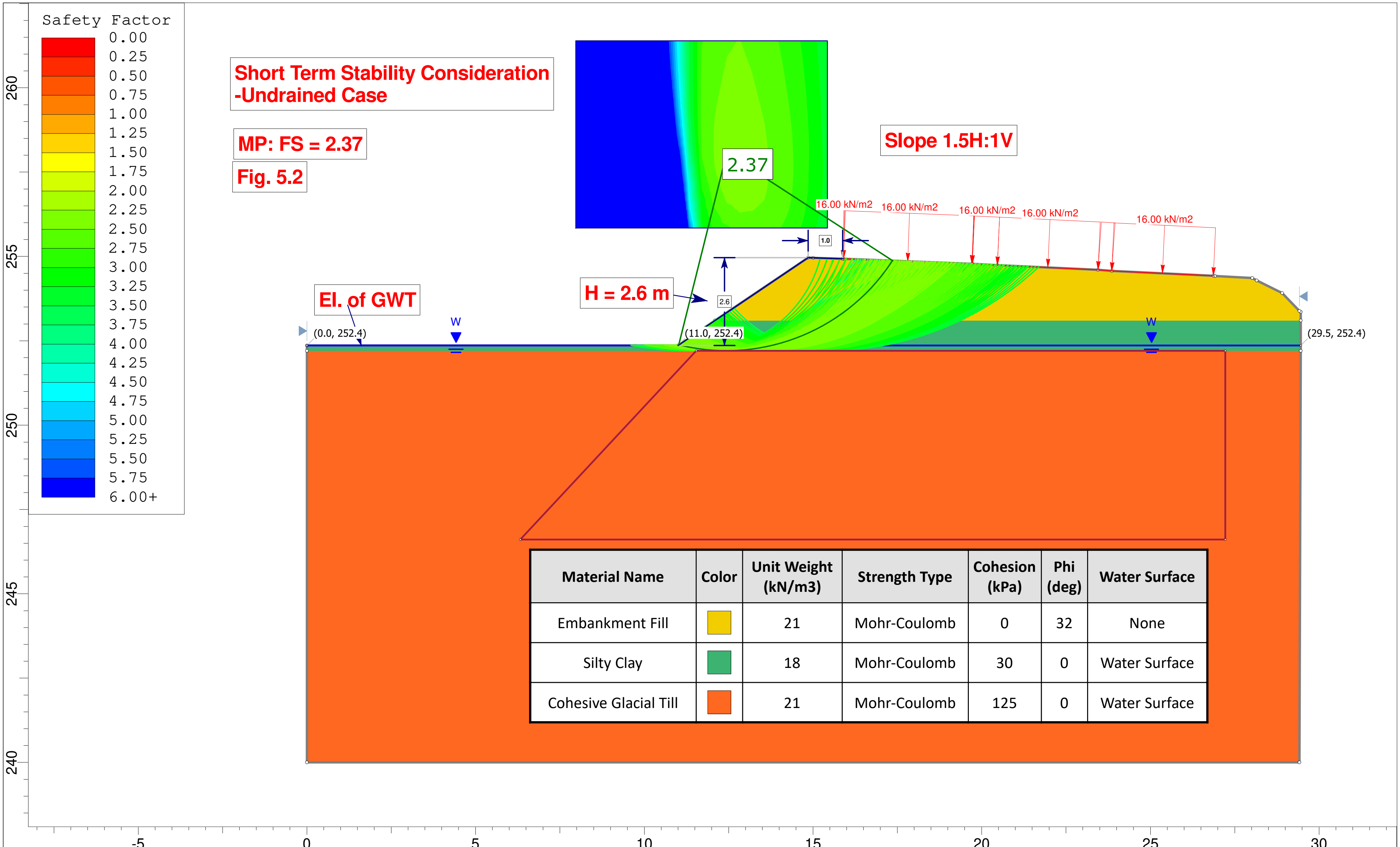


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface
Embankment Fill		21	Mohr-Coulomb	0	32	None
Silty Clay		18	Mohr-Coulomb	0	29	Water Surface
Cohesive Glacial Till		21	Mohr-Coulomb	2	32	Water Surface

wsp

SLIDEINTERPRET 8.028

Project	Little Rouge Creek Hwy 48 South Non-Structural Culvert Replacement		
Analysis Description	Stability for Temporary Shoring - End of Construction (Drained Case)		
Drawn By F.O.	*Scale* 1:149	*Company*	WSP Canada Inc.
Date April 24, 2020		*File Name*	Hwy 48 Stouffville South CV_East End_EOC_Drained_Slope_1.5_1_H_2.6_HWL-Levelled.slmd



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface
Embankment Fill		21	Mohr-Coulomb	0	32	None
Silty Clay		18	Mohr-Coulomb	30	0	Water Surface
Cohesive Glacial Till		21	Mohr-Coulomb	125	0	Water Surface

wsp

SLIDEINTERPRET 8.028

Project	Little Rouge Creek Hwy 48 South Non-Structural Culvert Replacement
Analysis Description	Stability for Temporary Shoring - Short Term Consideration
Drawn By	F.O.
Scale	1:155
Company	WSP Canada Inc.
Date	April 24, 2020
File Name	Hwy 48 Stouffville South CV_East End_ST_Undrained_Slope_1.5_1_H_2.6_HWL -Levelled.slmd

APPENDIX

F

LIST OF OPSS, OPSD AND NSSP

List of OPSSs, OPSDs and NSSPs Referenced in the Report

OPSS	180	GENERAL SPECIFICATION FOR THE MANAGEMENT OF EXCESS MATERIALS
OPSS	401	CONSTRUCTION SPECIFICATION FOR TRENCHING, BACKFILLING, AND COMPACTING
OPSS	421	CONSTRUCTION SPECIFICATION FOR PIPE CULVERT INSTALLATION IN OPEN CUT
OPSS	492	CONSTRUCTION SPECIFICATION FOR SITE RESTORATION FOLLOWING INSTALLATION OF PIPELINES, UTILITIES, AND ASSOCIATED STRUCTURES
OPSS	501	CONSTRUCTION SPECIFICATION FOR COMPACTING
OPSS	517	CONSTRUCTION SPECIFICATION FOR DEWATERING OF PIPELINE, UTILITY, AND ASSOCIATED STRUCTURE EXCAVATION
OPSS	803	CONSTRUCTION SPECIFICATION FOR SODDING
OPSS	804	CONSTRUCTION SPECIFICATION FOR SEED AND COVER
OPSS	1801	MATERIAL SPECIFICATION FOR CORRUGATED STEEL PIPE (CSP) PRODUCTS
OPSS.PROV	539	CONSTRUCTION SPECIFICATION FOR TEMPORARY PROTECTION SYSTEMS
OPSS.PROV	1010	MATERIAL SPECIFICATION FOR PAVING AND BACKFILL
OPSS.PROV	1205	MATERIAL SPECIFICATION FOR CLAY SEAL
OPSD	219.131	HEAVY-DUTY WIRE-BACKED SILT FENCE BARRIER
OPSD	802.010	FLEXIBLE PIPE EMBEDMENT AND BACKFILL EARTH EXCAVATION
OPSD	802.014	FLEXIBLE PIPE EMBEDMENT AND BACKFILL EARTH/ROCK EXCAVATION
OPSD	810.01	GENERAL RIP-RAP LAYOUT FOR SEWER AND CULVERT OUTLETS
OPSD	3090.101	FROST PENETRATION DEPTHS - SOUTHERN ONTARIO
NSSP		MUD MAT
NSSP		OBSTRUCTIONS TO EXCAVATABILITY

LEAN CONCRETE (MUD MAT) Culverts

Non-Standard Special Provision

Scope of Work:

The scope of work for the above noted tender item includes supply and installation of the lean concrete (i.e. mud mat) to prevent erosion and/or disturbance to the foundation soils. Subject to inspection and approval of the founding subgrade, a working mat of lean concrete should be placed in the excavation to protect the integrity of the bearing stratum.

Construction

Lean concrete shall have a compressive strength of at least 5 MPa, shall be placed in general accordance with OPSS 904, and the working mat shall have a minimum thickness of 100 mm. The elevation of the underside of the mud mat and plan dimensions shall be as per the tender documents.

Basis of Payment

Payment at the contract price for the above noted tender item includes full compensation for all labour, equipment and materials to do the required work.

OBSTRUCTIONS TO EXCAVATABILITY

Non-Standard Special Provision

The interception of debris, cobbles, boulders and hard layers has been recorded in some Record of Borehole Sheets. Consideration of the presence of these obstructions must be made in the selection of appropriate equipment and procedures for sub-excavation for the proposed culvert works and associated construction of temporary roadway protection systems.

Basis of Payment

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.

APPENDIX

G

LIMITATIONS OF REPORT

LIMITATIONS OF REPORT

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

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

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

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

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

We accept no responsibility for any decisions made or actions taken as a result of this report unless we are specifically advised of and participate in such action, in which case our responsibility will be as agreed to at that time.