

DRAFT FOUNDATION INVESTIGATION AND DESIGN REPORTS

PROPOSED CULVERT REPLACEMENT

CULVERT NO: CV-0006-0115-0028

HIGHWAY 35/115
NORTH OF KIRBY, ONTARIO
DURHAM REGION

GEOCRES NO.
G.W.P. 2051-14-00

WSP Project No.: 141-54753-00 (SPL No.10000161)-1
May 5, 2016

© 2016 WSP Canada Inc.



**DRAFT REPORT ON
FOUNDATION INVESTIGATION
PROPOSED CULVERT REPLACEMENT
CULVERT NO: CV-0006-0115-0028**

HIGHWAY 35/115
NORTH OF KIRBY, ONTARIO
DURHAM REGION

GEOCRES NO.
G.W.P. 2051-14-00

Prepared For:
D.M.Wills Associates Ltd
150 Jameson Drive, Peterborough ON K9J 0B9

WSP Project No: 141-54753-00 (SPL No. 10000161)-1
Date: May 5, 2016

WSP Canada Inc.
51 Constellation Court
Toronto, ON M9W 1K4 Canada

Phone: +1 416-798-0065
Fax: +1 416-798-0518
www.wspgroup.com



TABLE OF CONTENTS

1	INTRODUCTION.....	1
2	GEOLOGICAL SETTING AND SITE DESCRIPTION	1
2.1	GEOLOGICAL SETTING	1
2.2	PREVIOUS GROUND INVESTIGATIONS.....	1
2.3	SITE DESCRIPTION	2
3	FIELD AND LABORATORY WORK	3
3.1	FIELD INVESTIGATION	3
3.2	GEOTECHNICAL LABORATORY TESTING	4
4	SUBSURFACE CONDITIONS.....	5
4.1	GENERAL	5
4.2	OVERVIEW.....	5
4.3	SUBSOIL CONDITIONS	5
4.3.3.1	PAVEMENT GRANULAR FILL	6
4.3.3.2	EMBANKMENT FILL – SAND.....	6
4.3.4	SAND.....	7
4.3.5	SANDY SILT	8
4.3.6	SAND AND GRAVEL	8
4.4	GROUNDWATER OBSERVATIONS.....	8
DRAWING 1		
APPENDIX A: RECORD OF BOREHOLE SHEETS		
APPENDIX B: LABORATORY TEST RESULTS		
APPENDIX C: SITE PHOTOGRAPHS		

LIST OF TABLES

TABLE 2-1 DETAILS OF CULVERT CV-0006-0115-0028 ON HWY 35/115 (BASED ON GA DRAWING PREPARED BY D.M.WILLS, DATED MARCH 23 , 2016).....	2
TABLE 3-1 BOREHOLE DETAILS	3
TABLE 3.2 STANDPIPE PIEZOMETER INSTALLATION DETAILS	4
TABLE 4-1 GRAIN SIZE DISTRIBUTION SUMMARY - EMBANKMENT FILL	6
TABLE 4-2 GRAIN SIZE DISTRIBUTION SUMMARY - SAND TO SILTY SAND.....	7
TABLE 4-3 GRAIN SIZE DISTRIBUTION – SAND AND GRAVEL	8
TABLE 4.4: SUMMARY OF GROUNDWATER OBSERVATIONS.....	9

**DRAFT
FOUNDATION INVESTIGATION REPORT
PROPOSED CULVERT REPLACEMENT
Culvert No: CV-0006-0115-0028
HIGHWAY 35/115
North of Kirby, Ontario (Durham Region)
G.W.P. 2051-14-00**

1 INTRODUCTION

WSP Canada Inc. (WSP), formerly SPL Consultants Ltd., was retained by D. M. Wills Associates Ltd. (Wills) to carry out a foundation investigation to provide necessary geotechnical information and recommendations to replace the existing culvert under the NBL and SBL of Highway 35/115 approximately 610 m south of Highway 35 Interchange, about 5 km north of Kirby, Ontario. This structure (Culvert no: CV-0006-0115-0028) is located within the Regional Municipality of Durham, and is under the jurisdiction of the Central Region of the Ministry of Transportation (MTO). This forms a part of four (4) non-structural culvert investigations that have been investigated by WSP under the present commission.

This report initially presents factual information concerning the subsurface conditions based on all the subsurface information at hand and is followed by an engineering discussion and recommendations for the replacement of the culvert. WSP was informed by Wills that the replacement culvert will be a 910 mm HDPE, as shown on Drawing 1 (as per the General Arrangement (GA) Drawing prepared by Wills, dated March 23, 2016).

2 GEOLOGICAL SETTING AND SITE DESCRIPTION

2.1 GEOLOGICAL SETTING

According to surficial geology of the Scugog Area map (MNDM-M3330; Scale:1:50 000), the project site lies within the Moraine deposits, which has been characterized mainly as a fine sand to gravel. According to Bedrock geology of Ontario-Southern sheet (MNDM Map 2544; 1:1 000 000), the bedrock underlying the site comprises the Simcoe group formation (Limestone, dolostone, shale, arkose and sandstone) from the Middle Ordovician age.

2.2 PREVIOUS GROUND INVESTIGATIONS

We have not been able to locate any prior Foundation Investigation and Design Report at the subject site in the MTO Geocres library listings. However, Geocres 31D-288 at Hwy 35/115 interchange, located about 0.6km north of this site, indicated that the interchange site is generally underlain by compact to very dense silty sand with traces of gravel and clay, extending to depths of about 5 to

11m, which is further underlain by dense to very dense silty sand till. No groundwater was encountered in the boreholes.

2.3 SITE DESCRIPTION

The key plan of site location is shown on Drawing 1. The culvert site lies on a curved (super-elevated) section of the highway visually on a low area between cut sections of the road to the north and south of the culvert site. The surrounding landscape is observed in Photographs 1 to 8 (all photographs in **Appendix C**) which give a general impression of the landscape including the conditions at the culvert ends and at the borehole locations.

Hwy 35/115 is a 4-lane divided highway with fully paved inside shoulders and partially paved outside shoulders.

At this culvert site, the road embankment is approximately 3 m high on the east side and 5.5 m high on the west side of the road, with Elevation 332.9 m on the road centerline along the proposed tunnel alignment (based on the GA drawing, dated March 23, 2016). The side slopes of the road embankment at the culvert's inlet and outlet are approximately 3H:1V and 2.7H:1V (based on the GA drawing), respectively.

The geometry details of the existing and proposed culverts are given in **Table 2-1**.

Table 2-1 Details of Culvert CV-0006-0115-0028 on Hwy 35/115 (Based on GA drawing prepared by D.M.Wills, dated March 23 , 2016)

	Existing CSP Culvert	Proposed Pipe Culvert
Size	920 mm x 920 mm	910 mm dia. Inside 1200 mm liner
Length (m)	50.2	49.0
Culvert Type	Non-rigid frame open (NRFO) concrete culvert with CSP extension at east end	High Density Polyethylene (HDPE) pipe inside steel liner
Skew (degrees)	zero	zero, but offset 5.0 m centre to centre to the south of existing
Cover on Road Centreline (m)	~4	3.5
Inlet: Invert Elevation (m)	328.48	328.50
Outlet: Invert Elevation (m)	327.7	327.74

3 FIELD AND LABORATORY WORK

3.1 FIELD INVESTIGATION

The fieldwork undertaken by WSP consisted of drilling four (4) boreholes and was undertaken on 16th and 30th March 2016. **Table 3-1** presents the borehole details of the WSP field investigation program and the findings were used to develop the ground model. The borehole locations are shown on **Drawing 1**, following the text of the report.

Table 3-1 Borehole Details*

BH No	Co-ordinates (m)	Ground Elevation (m)	Drilled Depth (m)	Remarks
BH-16-1-1	E 375028 N 4879882	332.4	9.8	NBS; Solid stem auger; sampling: auger sample/split spoon; terminated in the sand
BH-16-1-2	E 375002 N 4879881	333.6	9.1	SBS; Solid stem auger; sampling: auger sample/split spoon; terminated in the sandy silt
BH-16-1-3	E 375037 N 4879880	330.2	6.7	Inlet side; Solid stem auger; sampling: split spoon; terminated in the sand
BH-16-1-4	E 374981 N 4879870	328.1	6.7	Outlet side; Solid stem auger; sampling: split spoon; terminated in the sand and gravel

Notes*:

1. Name of Drilling Company: Drilltech Drilling, Newmarket, Ontario
2. Drilling Supervision by: Atiqur Rahman, M.Eng., EIT; WSP staff
3. Borehole Survey : by the above WSP staff using a Differential GPS Survey Equipment made by Sokia
4. NBS - north bound shoulder; SBS – south bound shoulder
5. Co-ordinates: based on MTM NAD 83 Zone 10 coordinates

The WSP borehole drilling was carried out under full-time supervision of WSP engineering staff who directed the drilling and sampling operation, logged borehole data in accordance with MTO Soils Classification System and took custody of soil samples retrieved for subsequent laboratory testing and identification. Solid stem augers were used to advance the boreholes. The recovered soil samples were placed in labelled moisture-proof bags, and returned to WSP's Vaughan laboratory for further assessment. The boreholes were drilled with a rubber track mounted rig (MT-5 rig), which is owned and operated by Drilltech Drilling of Newmarket, Ontario. The soil stratigraphy was recorded by observing the quality and changes of augered materials which were withdrawn from the boreholes, and by sampling the soils at regular intervals of depth using a 50mm O.D. split spoon sampler, 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 or consistency of the sampled soil material. The SPT 'N' values are indicated on the Record of Borehole Sheets (Refer to **Appendix A**). A Dynamic Cone Penetration Test (DCPT) was conducted from the bottom of one of the boreholes (in BH 16-1-2) and the results are also presented on the Record of Borehole Sheet. Soil samples were visually classified in the field and later re-evaluated by a senior engineer in our laboratory.

Groundwater conditions in the boreholes were observed during and on completion of drilling in the open boreholes. A standpipe piezometer was installed in Borehole BH 16-1-4 upon its completion to enable long term groundwater monitoring, as presented in **Table 3-2**. The rest of the boreholes were grouted using a cement/bentonite mixture as per MTO procedures. As part of the construction, the piezometer needs to be decommissioned in accordance with Ontario Regulation 903 (amended by Ontario Regulation 372/07).

Table 3.2 Standpipe Piezometer Installation Details

BH ID	Ground Surface Elevation (m)	Borehole Bottom		Well Screen Depth Interval, m		Well Screen Elevation Interval, m	
		Depth (m)	Elevation (m)	From	To	From	To
BH 16-1-4	328.1	6.1	322.0	4.6	6.1	323.5	322.0

3.2 GEOTECHNICAL LABORATORY TESTING

Visual examination and classification were undertaken on the soil samples returned to the laboratory. A geotechnical laboratory testing program consisting of natural water content tests and grain size analyses, including hydrometer testing, was performed on selected representative samples. The results of the laboratory tests are presented on the appropriate Record of Borehole Sheets in

Appendix A, and also in Appendix B.

4 SUBSURFACE CONDITIONS

4.1 GENERAL

The subsurface conditions encountered at the culvert location are described in the following sections. For purposes of soil description, the MTO soil classification manual was generally followed.

Drawing 1 at the end of the text shows a borehole location plan with a subsurface profile. It should be noted that the subsurface conditions may vary in between and beyond the borehole locations. **Drawing 1** that presents an inferred stratigraphic profile at the culvert location is based on the borehole data. The strata boundaries shown should not be interpreted as exact planes of geological change but rather as inferred transitions from one soil type to another.

The soil descriptions are based on visual and tactile observations, and complemented by the results of field and laboratory soil test results. It should be noted that the subsurface conditions and the topsoil thicknesses encountered may vary in between and beyond the borehole locations.

An overview of subsurface conditions is described below. All depths quoted are below existing ground surface. It is to be noted that based on the borehole data, the elevations (El.) reported for strata boundaries are from the shallowest occurrence to the deepest occurrence.

4.2 OVERVIEW

As an overview, the encountered subsurface conditions at the culvert location consisted of a pavement structure overlying a cohesionless embankment fill underlain by cohesionless deposits. At the borehole locations, the embankment material consists mainly of sand with trace to some silt and gravel and trace of clay while the underlying soils vary from sand to silty sand deposits, underlain by sandy silt and sand and gravel layers. All the boreholes were terminated in these cohesionless deposits. No groundwater was encountered in the boreholes at the time of the investigation. These findings are in general agreement with those reported by others at a nearby locality (See Section 2.2) and generally indicative of the broader surficial geology for the region (See Section 2.1).

The factual data presented on the Record of Borehole Sheets would govern any interpretation of the site conditions.

The following paragraphs are intended to give more detailed descriptions of the data documented on the Record of Borehole Sheets (**Appendix A**).

4.3 SUBSOIL CONDITIONS

4.3.1 TOPSOIL

Topsoil (0.15 and 0.3 m thick) was contacted at ground surface in BH 16-1-4 and 16-1-3, which were in the vicinity of the outlet and inlet locations, respectively. This topsoil thickness should not be relied

upon for any quantity estimation.

Based on our experience, the thickness of topsoil could frequently vary in between and beyond borehole locations, especially in depressed areas and near watercourses.

4.3.2 ASPHALT

BH 16-1-1 was drilled on the partially paved shoulder on the NBL of the Highway and this encountered 180 mm of asphalt.

4.3.3 FILL

4.3.3.1 PAVEMENT GRANULAR FILL

BH 16-1-1 and 16-1-2, which were drilled from the partially paved shoulders of Hwy 35/115, encountered granular base and subbase (sand and gravel) materials with a thickness of about 0.5 to 0.6 m.

Measured moisture contents of the pavement granular fill were reported between 3% and 5% by weight, indicative of a generally dry to moist condition.

As auger samples were retrieved from the pavement fill, no SPT 'N' results are available to characterise compactness.

Note that the pavement fill thickness may vary beyond the borehole locations. Further, this information will not be sufficient for quantity estimation.

4.3.3.2 EMBANKMENT FILL – SAND

Below the pavement granular fill in BH 16-1-1 and BH 16-1-2 and topsoil in BH 16-1-3, embankment fill consisting of brown sand with traces to some silt, was encountered. The fill also contained trace to some gravel and a trace of clay. The thickness of this layer under the road was 5.2 m and 5.1 m and the corresponding elevations of the base of the unit were El. 327.8 m (BH 16-1-2) and El. 326.8 m (BH 16-1-1) respectively. Within this unit, a trace of cobbles was contacted at approximate El. 329.8 m in BH 16-1-2, and trace organics at approximate El. 329 in both boreholes.

The grain size distributions of four (4) samples from the embankment fill was determined in the laboratory and gave the grain size distribution shown in **Table 4-1**.

Table 4-1 Grain Size Distribution Summary - Embankment Fill

Samples Tested	Size Fraction	% Passing by weight	Remarks
BH 16-1-1/SS6	Gravel	0 - 23%	Shown as Figure B-1, Appendix B ;
BH 16-1-2/SS3	Sand	64 - 81%	

BH 16-1-2/SS7 BH 16-1-2/SS8T	Silt	9 - 17%	Summarized on the relevant Record of Borehole Sheet
	Clay	3 - 6%	

The grading results shown above indicate the embankment fill can be classified as cohesionless (**SM**).

The moisture content of samples recovered from the embankment fill generally ranged from 4% to 12% indicative of a moist condition, with one sample with 18% indicating the presence of a clayey silt seam.

SPT testing carried out in the boreholes, gave SPT 'N' values ranging between 4 blows/300 mm and 35 blows/300 mm which indicate a loose to dense, but generally compact relative density.

4.3.4 SAND

Underlying the fill and topsoil, all the boreholes encountered a predominant deposit of brown sand to silty sand. The deposit contained traces of clay and trace to some gravel. The thickness of this deposit varied between 1.8 m (BH 16-1-2) and at least 4.2 m (BH 16-1-1 and BH 16-1-2) where the boreholes were terminated in the sand deposit. The elevations of the base of the unit varied between El. 326.0 m (BH 16-1-2) and below El. 322.7 m (BH 16-1-1).

The grain size distributions of five (5) samples from the sand to silty sand deposit were determined in the laboratory and gave the grain size distribution shown in **Table 4-2**.

Table 4-2 Grain Size Distribution Summary - Sand to Silty Sand

Samples Tested	Size Fraction	% Passing by weight	Remarks
BH 16-1-1/SS8B	Gravel	0% to 1%	Shown as Figure B-2, Appendix B ; Summarized on the relevant Record of Borehole Sheets
BH 16-1-1/SS9	Sand	65% to 83%	
9BH 16-1-2/SS9	Silt	11% to 28%	
BH 16-1-3/SS3B	Clay	4% to 7%	
BH 16-1-4/SS2			

The grading results shown above indicate the deposit to be generally cohesionless (**SM**).

The moisture content based on fifteen (15) samples recovered from this layer ranged from 2% to 11% indicative of dry to moist condition.

SPT testing carried out in the boreholes, gave SPT 'N' values ranging from 4 blows/300 mm to 68 blows/300 mm which indicate a loose to very dense, but generally compact to dense relative density.

4.3.5 SANDY SILT

Below the silty sand, BH 16-1-2 encountered a sandy silt layer at a depth of 7.6 m (El. 326.0 m) and this extended to the remaining depth of the borehole.

The moisture content of one (1) sample recovered from this layer was 18% indicating moist condition.

SPT and DCPT testing carried out in this borehole, gave SPT 'N' and inferred DCPT values of at least 50 blows/300 mm which indicates a dense to very dense relative density.

4.3.6 SAND AND GRAVEL

Below the sand deposit, BH 16-1-4 contacted a coarse sand and gravel layer at a depth of 3.1 m (El. 325.1 m) and this extended to the remaining depth of the borehole. The deposit contained trace to some fines.

The grain size distribution of one (1) sample from the sand and gravel deposit was determined in the laboratory and gave the grain size distribution shown in **Table 4-3**.

Table 4-3 Grain Size Distribution – Sand and Gravel

Samples Tested	Size Fraction	% Passing by weight	Remarks
BH 16-1-4/SS5	Gravel	36%	Shown as Figure B-3, Appendix B; Summarized on the relevant Record of Borehole Sheet
	Sand	53%	
	Silt and Clay	11%	

The grading results shown above indicate the deposit to be generally cohesionless (SM).

The moisture content of three (3) samples recovered from this layer ranged from 1% to 6% indicating dry to moist condition.

SPT testing carried out in this borehole, gave SPT 'N' values of 33 to 38 blows/300 mm, indicating a dense relative density.

4.4 GROUNDWATER OBSERVATIONS

Groundwater conditions were observed in the boreholes (BH 16-1-1, BH 16-1-2, BH 16-1-3 and BH 16-1-4) and were noted upon completion of drilling. A standpipe piezometer was installed in borehole BH 16-1-4 only. The screen was located entirely within the sand and gravel. All the water level observations are shown on the individual Record of Borehole Sheets in **Appendix A** and the observations are summarized in **Table 4.4** below.

Groundwater levels measured on completion are not considered to have stabilized and may not

necessarily represent the groundwater level at the site. The table below summarizes the ground water observations.

Table 4.4: Summary of Groundwater Observations

BH No	Ground Surface Elevation (m)	Water Level Measurements		Remarks
		Depth of water (m)	Elevation (m)	
BH-16-1-1	332.4	Dry	-	
BH-16-1-2	333.6	Dry	-	
BH-16-1-3	330.2	Dry	-	
BH-16-1-4	328.1	Dry	-	Standpipe/piezometer installed; no water observed, 1 week and 3 weeks after completion of drilling

Based on the observations above, groundwater is below Elev. 322 m. Inlet and out ends of the culvert were dry at the time of the investigation.

It should be pointed out that the groundwater levels would be subject to seasonal fluctuations in response to major weather events.

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.

WSP Canada Inc.

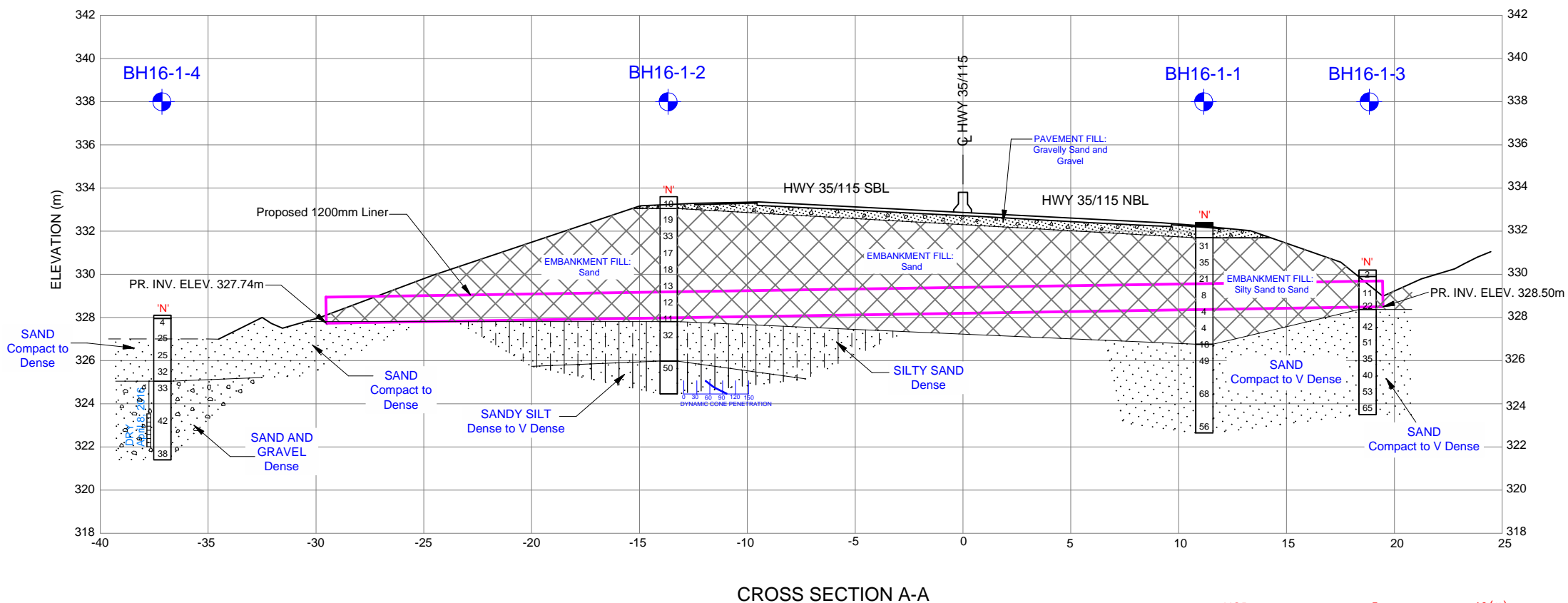
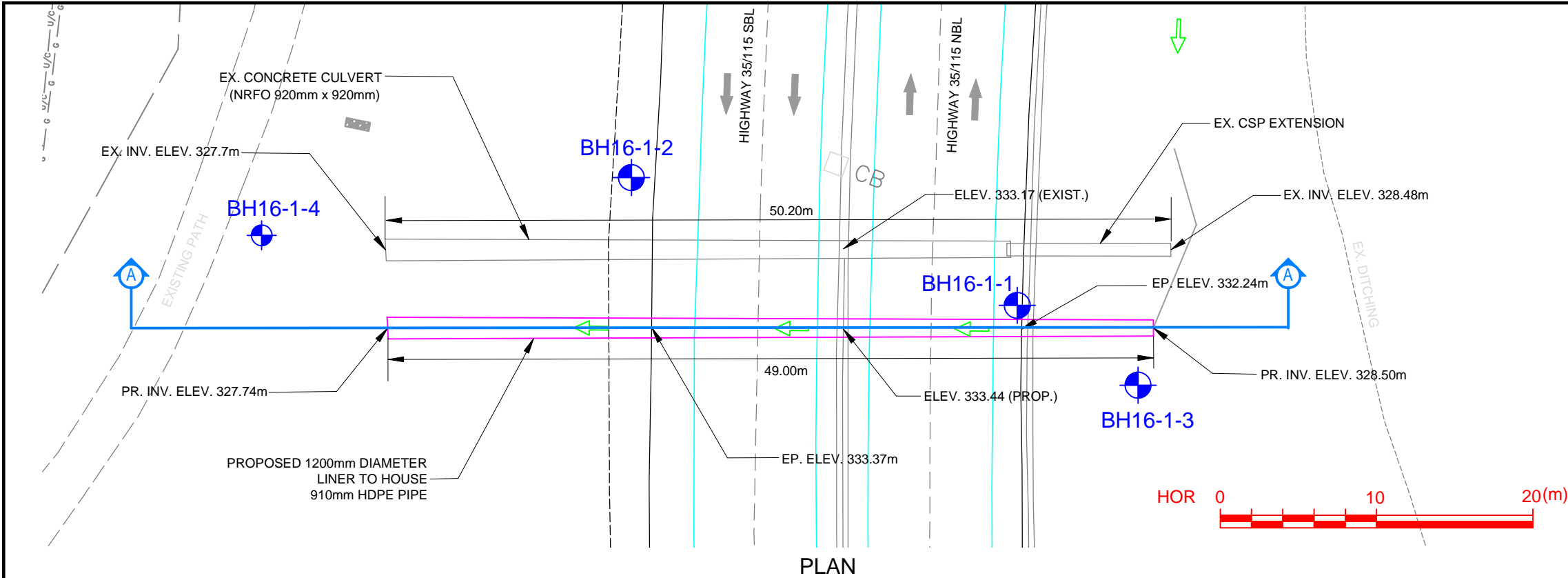


Ramon Miranda., P. Eng.
Senior Geotechnical Engineer



Vasantha Wijeyakulasuriya, M. Eng., P. Eng.
Senior Technical Director, Geotechnical
MTO Designated Contact

Drawing 1



SOIL STRATA SYMBOLS

- Pavement Fill
- Fill
- Sand
- Silty Sand
- Sandy Silt
- Sand and Gravel

CONT No: 2016-2019
WP : 2051-14-00

CV-0006-0115-0028
CULVERT
BOREHOLE LOCATIONS & SOIL STRATA

WSP 51 Constellation Court
Toronto, Ontario
M9W 1K4



KEY PLAN
NOT TO SCALE

LEGEND

- Borehole drilled by WSP
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- WL upon completion
- Monitoring Well

BH No.	APPROX. ELEV. (m)	MTM NAD83 ZONE 10 CO-ORDINATES	
		NORTH (m)	EAST (m)
BH16-1-1	332.4	4879882	375028
BH16-1-2	333.6	4879881	375002
BH16-1-3	330.2	4879880	375037
BH16-1-4	328.1	4879870	374981

NOTES

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore holes the boundaries are assumed from geological evidence.

Borehole Location plan and profile are based on drawing "01-Contract 4" received on March 23, 2016.

REVISIONS					
Apr 15/16		ZMO		Submission for MTO review	
DATE		BY		DESCRIPTION	
GEOCRES No : -					
HWY No 35/115				DIST -	
SUBM'D		CHECKED MP	DATE April 15, 2016		
DRAWN ZMO		CHECKED MP	APPROVED RM	DWG	1

Appendix A: Record of Borehole Sheets

RECORD OF BOREHOLE No BH16-1-1

METRIC 2 OF 2

W.P. 2051-14-00 LOCATION CV-0006-0115-0028, E 375028, N 4879882 ORIGINATED BY AR
 DIST HWY 35/115 BOREHOLE TYPE Solid Stem Auger COMPILED BY MW
 DATUM Geodetic DATE Mar/16/2016 CHECKED BY RM

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	POCKET PEN. (C _u) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
	SAND: some silt, trace clay, brown, moist, compact to very dense. (continued)																	
322.7 9.8	END OF BOREHOLE Notes: 1) Borehole was open and dry upon completion of drilling.		11	SS	56													

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

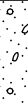

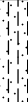

+ 3, X 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

141-54753-00

RECORD OF BOREHOLE No BH16-1-2

METRIC 1 OF 2

W.P. 2051-14-00 LOCATION CV-0006-0115-0028, E 375002, N 4879881 ORIGINATED BY AR
 DIST HWY 35/115 BOREHOLE TYPE Solid Stem Auger COMPILED BY MW
 DATUM Geodetic DATE Mar/16/2016 CHECKED BY RM

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	POCKET PEN. (C _u) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)			GR	SA	SI	CL
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE						W _P	W	W _L				
333.6 0.0	GRANULAR BASE/SUBBASE: 550mm, sand and gravel, brown, moist, loose to compact.		1	SS	10																		
333.1 0.6	FILL: sand, trace to some gravel, trace to some silt, trace clay, brown, moist, compact to dense.						333																
1																							
			2	SS	19																		
2			3	SS	33		332										23	64	10 3				
	trace silt seams																						
			4	SS	17		331																
3																							
			5	SS	18		330																
4																							
	trace cobbles		6	SS	13																		
	trace organics		7	SS	12		329										5	81	9 5				
5.8 327.8	SILTY SAND: trace gravel, trace clay, brown, moist, dense.		8	SS	11		328										12	69	14 5				
6																							
			9	SS	32		327										1	65	28 6				
7																							
7.6 326.0	SANDY SILT: trace clay, brown, moist, dense to very dense.						326																
			10	SS	50																		

Continued Next Page

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to Sensitivity ○ 6=3% Strain at Failure

141-54753-00

ON-MTO-2015 100001614-LOG-16-1.GPJ ON MOT GDT 5/5/16

RECORD OF BOREHOLE No BH16-1-2

METRIC 2 OF 2

W.P. 2051-14-00 LOCATION CV-0006-0115-0028, E 375002, N 4879881 ORIGINATED BY AR
 DIST HWY 35/115 BOREHOLE TYPE Solid Stem Auger COMPILED BY MW
 DATUM Geodetic DATE Mar/16/2016 CHECKED BY RM

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	POCKET PEN. (C _u) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES									
324.5	SANDY SILT: trace clay, brown, moist, dense to very dense. (continued)						325							
9.1	END OF BOREHOLE Notes: 1) Borehole caved in at 7.62m and dry upon completion of drilling.													

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to Sensitivity ○ 3=3% Strain at Failure

141-54753-00

RECORD OF BOREHOLE No BH16-1-3

METRIC 1 OF 1

W.P. 2051-14-00 LOCATION CV-0006-0115-0028, E 375037, N 4879880 ORIGINATED BY AR
 DIST HWY 35/115 BOREHOLE TYPE Solid Stem Auger COMPILED BY MW
 DATUM Geodetic DATE Mar/30/2016 CHECKED BY RM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
330.2 0.0	TOPSOIL: 300mm		1	SS	2		330	20	40	60	80	100	Wp	W	Wl
329.9 0.3	FILL: silty sand, trace gravel, trace organics, trace clay, brown, moist, loose to compact.														
1			2	SS	11		329								
	contains clayey silt seams		3 T	SS	22										
328.4 1.8	SAND: trace to some silt, trace clay, brown, moist, compact to very dense.		3 B	SS			328								
			4	SS	42										
3															
			5	SS	51		327								
4			6	SS	35		326								
			7	SS	40		325								
6			8	SS	53										
			9	SS	65		324								
323.5 6.7	END OF BOREHOLE Notes: 1) Borehole was open and dry upon completion of drilling.														

GROUNDWATER ELEVATIONS

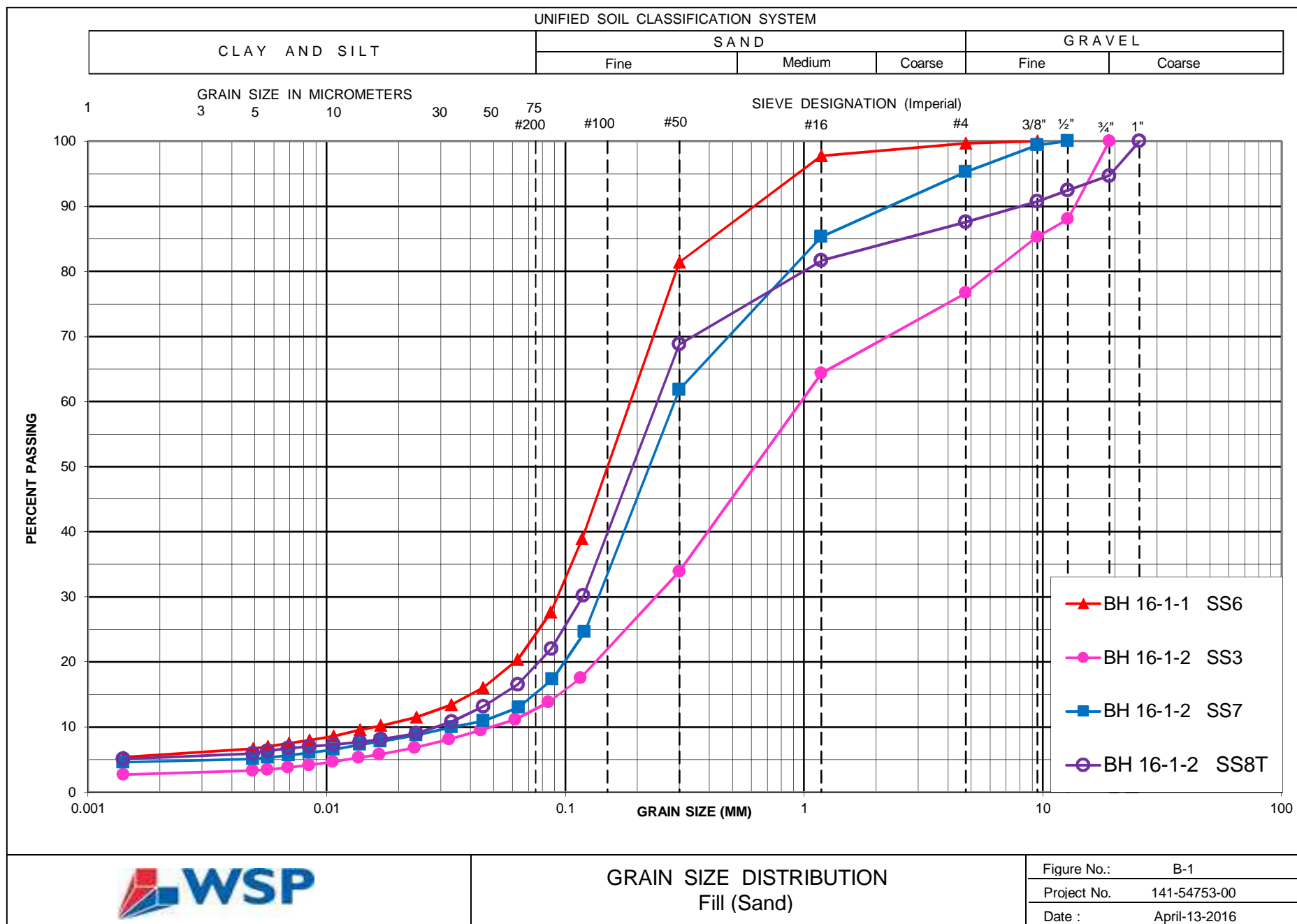
Measurement 1st 2nd 3rd 4th

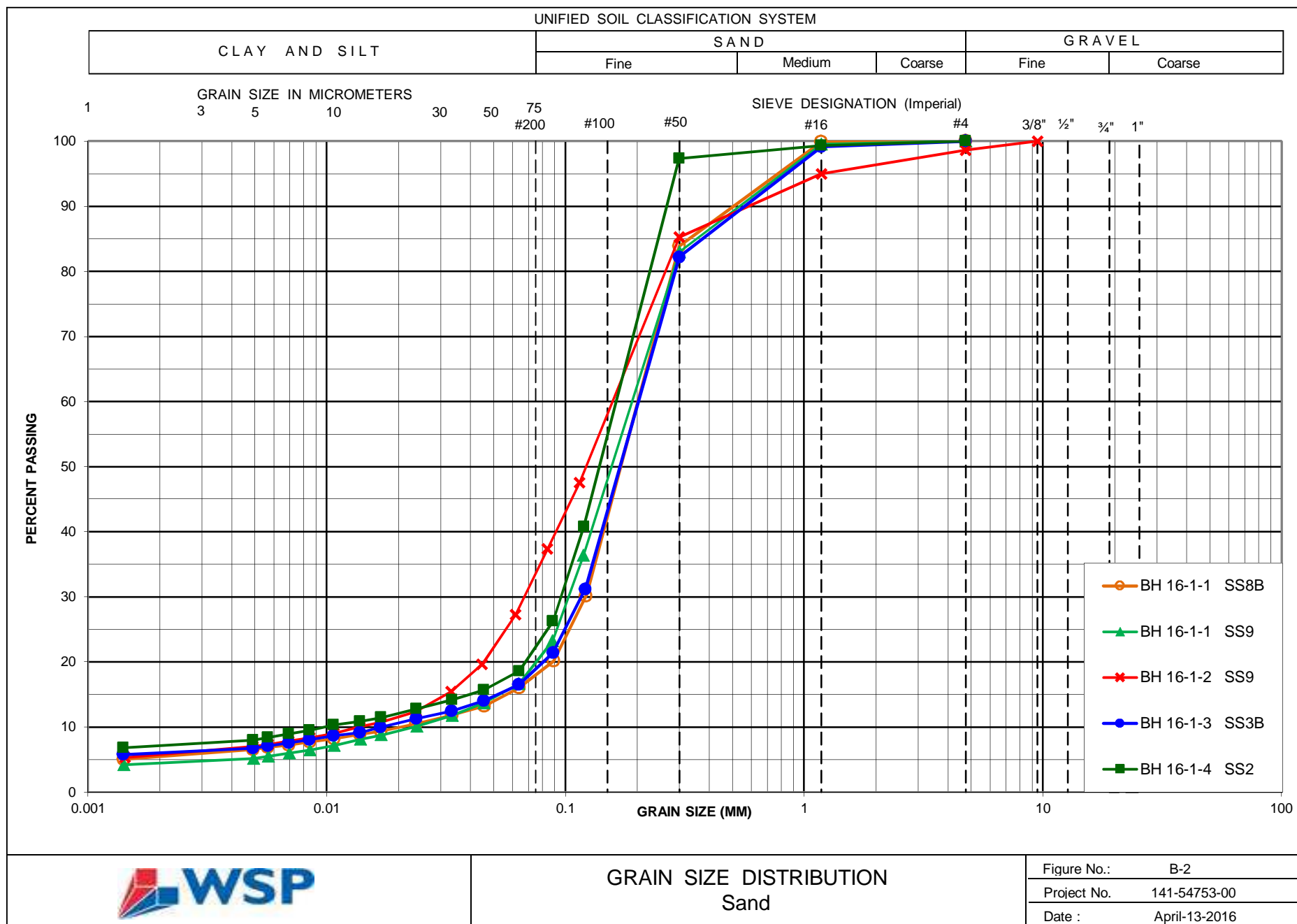
+ 3, X 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

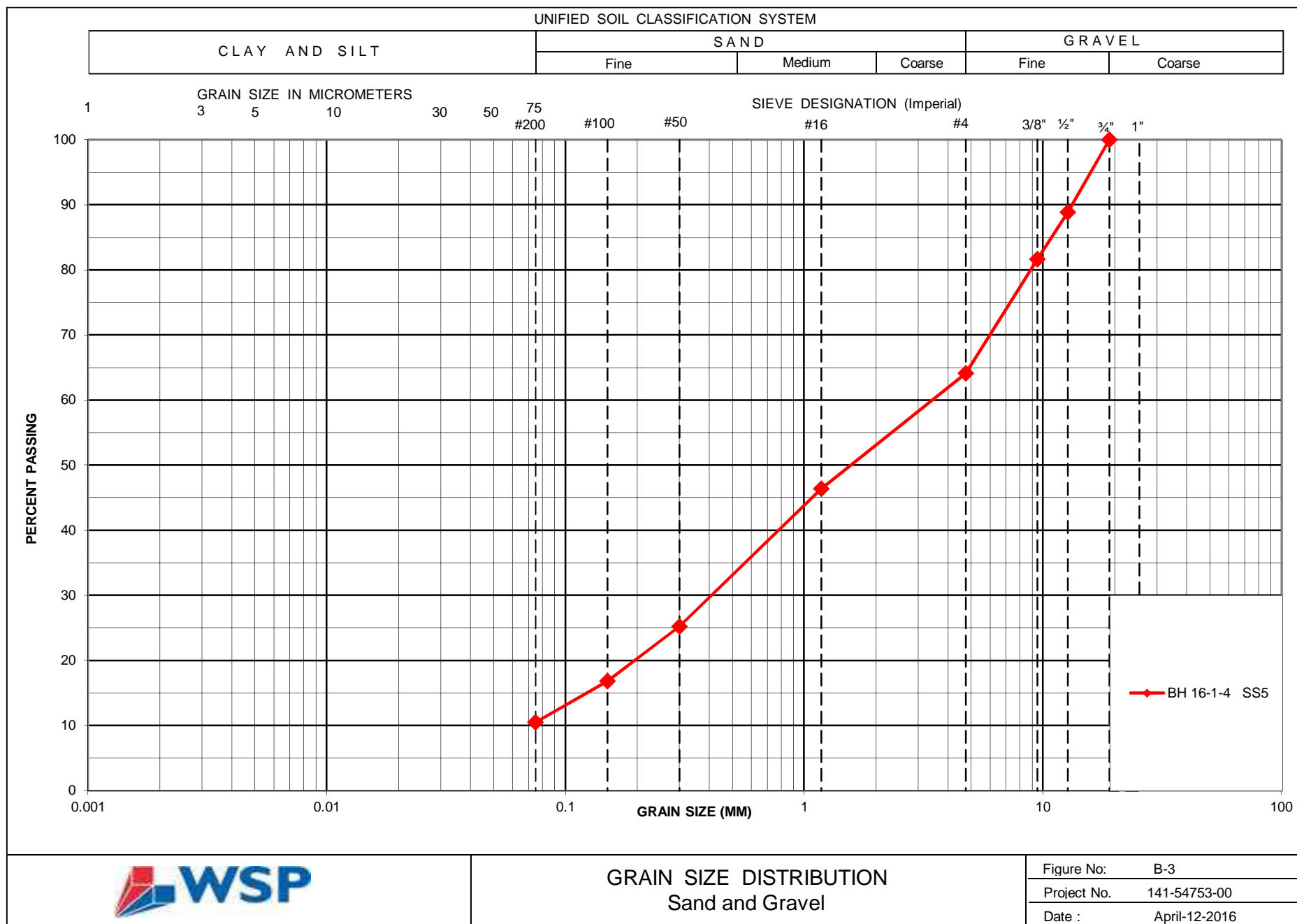
141-54753-00

ON-MTO-2015 10000161-LOG-16-1 GPJ ON MOT GDT 5/5/16

Appendix B: Laboratory Test Results







Appendix C: Site Photographs



Photo 1: North Bound Lanes – Facing South , Highway 35/115 near culvert



Photo 2: South Bound Lanes – Facing South , Highway 35/115 near culvert

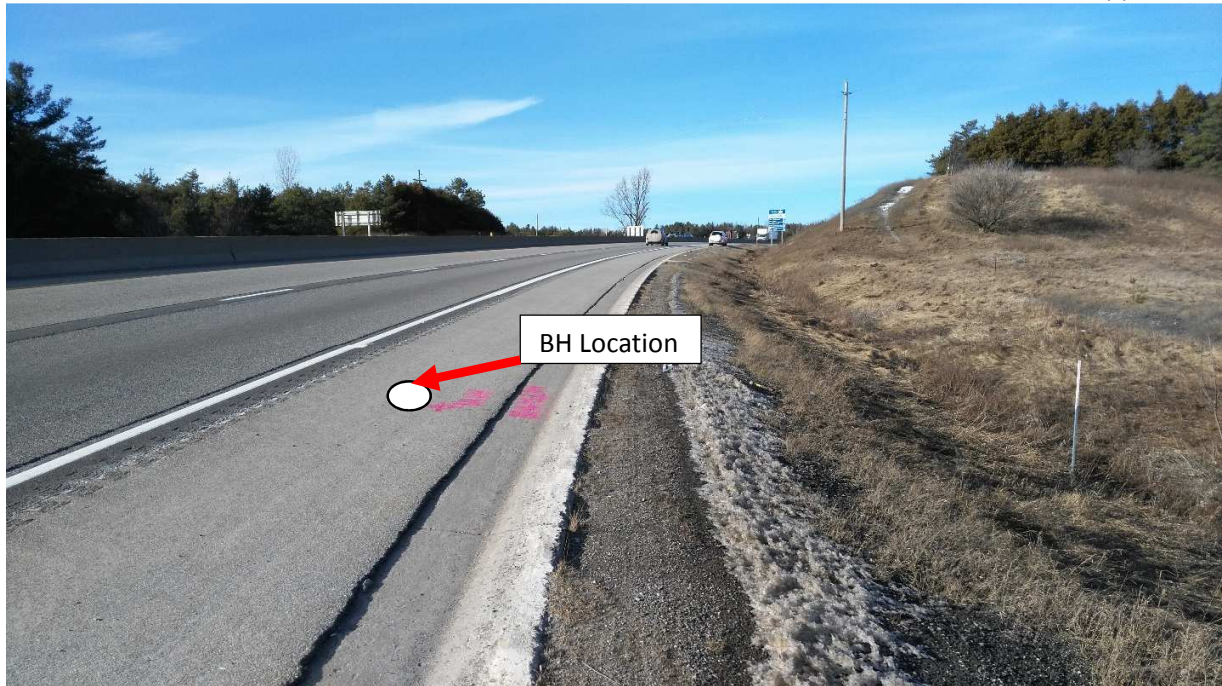


Photo 3: Facing North, North Bound Shoulder (BH16-1-1 location)

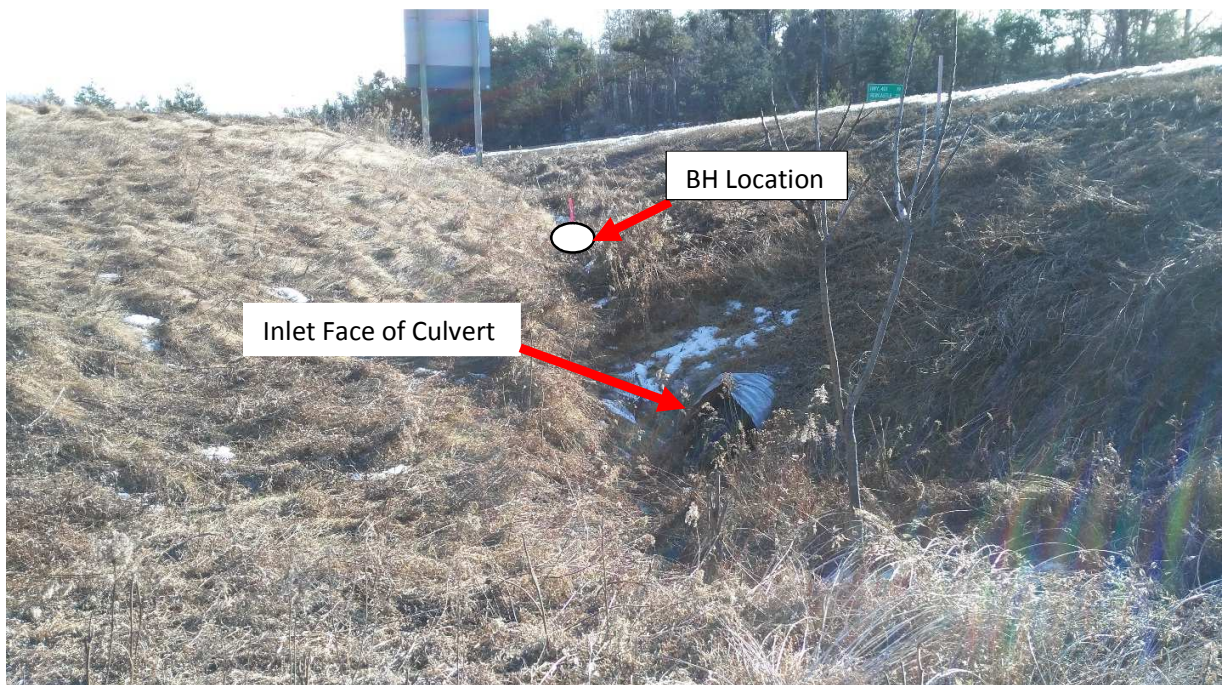


Photo 4: Facing southwest, Eastside of culvert (BH16-1-3 Location)



Photo 5: Facing South, South Bound Shoulder (BH16-1-2 location)



Photo 6: Facing Northeast, West side of culvert (BH16-1-4 location)



Photo 7: Facing Southeast, West side of culvert (BH16-1-4 location)



Photo 8: Facing Southwest, West side of culvert (BH16-1-4 location)

**DRAFT REPORT ON
FOUNDATION DESIGN
PROPOSED CULVERT REPLACEMENT
CULVERT NO: CV-0006-0115-0028
HIGHWAY 35/115
NORTH OF KIRBY, ONTARIO
DURHAM REGION**

**GEOCRES NO.
G.W.P. 2051-14-00**

Prepared For:
D.M.Wills Associates Ltd
150 Jameson Drive, Peterborough ON K9J 0B9

WSP Project No: 141-WSP No. 141-54753-00 (SPL No. 10000161)-1
Date: May 5, 2016

WSP Canada Inc.
51 Constellation Court
Toronto, ON M9W 1K4 Canada

Phone: +1 416-798-0065
Fax: +1 416-798-0518
www.wspgroup.com

TABLE OF CONTENTS

5	DISCUSSION AND RECOMMENDATIONS	10
5.1	GENERAL	10
5.2	GEOTECHNICAL CHARACTERISATION.....	10
5.2.1	OVERVIEW OF SUBSURFACE CONDITIONS	10
5.3	ALTERNATIVE TUNNELING OPTIONS	11
5.4	SELECTION OF TUNNELLING OPTION	16
5.5	CONSTRUCTION CONSIDERATIONS FOR TUNNELING	17
5.5.1	DEWATERING AND DRAINAGE ISSUES.....	17
5.5.2	RISK MANAGEMENT OF GROUND MOVEMENTS.....	17
5.5.2.1	NATURE OF GROUND MOVEMENTS	17
5.5.2.2	INSTRUMENTATION MONITORING	17
5.5.2.3	INTERVENTION BENCHMARKS FOR RISK MITIGATION	18
5.5.3	ENTRY AND EXIT PIT EXCAVATIONS.....	19
5.5.3.1	OPEN CUT EXCAVATIONS.....	19
5.5.3.2	SHORED EXCAVATIONS	20
5.5.4	SOIL DISPOSAL ISSUES	21
5.5.5	BACKFILLING OF PITS	21
5.6	INLET AND OUTLET	21
5.6.1	HEAD WALL/WING WALL DESIGN CONSIDERATIONS	21
5.6.2	EROSION PROTECTION.....	22

DRAWING 2: RECOMMENDED LAYOUT OF GROUND MONITORING ARRAYS

DRAWING 3: INSTALLATION DETAILS AND MONITORING FREQUENCIES OF GROUND MONITORING ARRAYS

APPENDIX D: GROUND CONDITIONS ALONG THE PROPOSED LINER ALIGNMENT

APPENDIX E: TUNNELMAN'S GROUND CLASSIFICATION

APPENDIX F: PIPE INSTALLATION BY TRENCHLESS METHOD

APPENDIX G: LIST OF OPSS, OPSD AND NSSP

APPENDIX H: LIMITATIONS OF REPORT

LIST OF TABLES

TABLE 5-1: COMMON TRENCHLESS METHODS - COMPARISON IN RELATION TO SOME SITE SPECIFIC TECHNICAL ISSUES

TABLE 5. 2: RECOMMENDED GROUND MOVEMENT 'REVIEW' AND 'ALERT' LEVELS

TABLE 5. 3 INTERPRETED OHSA REQUIREMENTS FOR OPEN CUT EXCAVATIONS

TABLE 5. 4: GEOTECHNICAL DESIGN PARAMETERS (UNFACTORED) – FOR TEMPORARY SHORING

TABLE 5. 5 COEFFICIENT OF LATERAL EARTH PRESSURE:

**DRAFT
FOUNDATION DESIGN REPORT
PROPOSED CULVERT REPLACEMENT
Culvert No: CV-0006-0115-0028
HIGHWAY 35/115, North of Kirby, Ontario, G.W.P. 2051-14-00**

5 DISCUSSION AND RECOMMENDATIONS

5.1 GENERAL

WSP Canada Inc. (WSP), formerly SPL Consultants Ltd., was retained by D. M. Wills Associates Ltd. (Wills) to carry out a foundation investigation to provide necessary geotechnical information and recommendations to replace the existing culvert on Highway 35/115, approximately 610 m south of Hwy 35 Interchange, about 5 km north of Kirby, Ontario. This structure (Culvert No: CV-0006-0115-0028) is located within the Regional Municipality of Durham, and is under the jurisdiction of the Central Region of the Ministry of Transportation (MTO). This forms a part of four (4) non-structural culvert investigations being investigated by WSP under the present commission.

The main thrust of the discussion and recommendations of this report will be on analysis of alternative trenchless installation methods to suit project geology and groundwater conditions and to assess associated construction impacts on the highway. Based on this assessment, a recommendation will be made on an installation method from a geotechnical perspective taking into account the viability in terms of costs as well, to facilitate the culvert replacement.

It is our understanding that no widening of the embankment or road pavement grade raise will be involved.

WSP was informed by Wills that the replacement culvert will be a 910 mm diameter HDPE within a 1200 mm diameter steel liner, as shown on Drawing 1 (as per the General Arrangement (GA) Drawing prepared by Wills, dated March 23, 2016). The proposed liner is 49 m long with invert elevation at the inlet at El. 328.50 m and at the outlet, the invert elevation will be El. 327.74 m.

5.2 GEOTECHNICAL CHARACTERISATION

5.2.1 OVERVIEW OF SUBSURFACE CONDITIONS

At this culvert site, the road embankment is approximately 3 m high on the east side and 5.5 m high on the west side of the road, with Elevation 333.4 m on the road centerline along the proposed alignment (based on the GA drawing). The side slopes of the road embankment at the culvert's inlet and outlet are approximately 3H:1V and 2.7H:1V (based on the GA drawing), respectively.

As an overview, the encountered subsurface conditions at the culvert location consisted of a

pavement structure overlying a cohesionless embankment fill underlain by cohesionless deposits. At the borehole locations, the embankment material consists mainly of sand with trace to some silt and gravel and trace of clay while the underlying soils vary from sand to silty sand, underlain by sandy silt and sand and gravel layers. All the boreholes were terminated in these cohesionless deposits. Along the liner bore path, at the inlet end (BH-16-1-1) very loose to loose cohesionless soils were encountered. The ground conditions towards the outlet end (BH-16-1-2) were marginally better with loose /compact conditions. No groundwater was encountered in the boreholes at the time of the investigation and stand piezometer installed in BH-16-1-4 was found to be dry even 3 weeks after completion of the borehole

The embankment fill comprises sand with the fine fraction between 13% and 23% including about 5% of the clay size fraction. The moisture content of samples recovered from this material generally ranged from 4% to 12% indicative of a moist condition. SPT testing carried out in the boreholes, gave SPT 'N' values ranging between 4 blows/300 mm and 35 blows/300 mm which indicate a loose to dense, but generally compact relative density.

Earthquake Considerations

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 D' for seismic site response according to Table 4.1.8.4.A of OBC 2012.

Frost Depth/Susceptibility

The frost depth for the project site is 1.4 m. The soils at the proposed culvert site have low frost susceptibility based on the MTO Frost Susceptibility Classification.

5.3 ALTERNATIVE TUNNELING OPTIONS

The most common and cost effective construction method is an open-cut excavation but it will cause traffic disruption on the highway. Installation of pipe using trenchless construction is a good alternative for this project and a suitable tunneling method will need to be implemented with due consideration of the site subsurface, groundwater conditions and operational constraints.

Trenchless technology methods in general have the following advantages in situations with deep excavations and high traffic flows compared to open-cut excavations:

- Environmental effects: Less soil disruptions around the project site
- Social impacts: less impact with road operations
- Project Delivery: can be faster to complete than open-cut methods
- Safety: Exposure to traffic, steep slopes and labour inside trench boxes are significantly reduced

- Less Engineering: documentation, cut/fill calculations and onsite related activities such as site surveying

Pipe installation by tunneling should be carried out in accordance with the attached *NSSP: pipe installation by trenchless method* (see **Appendix E**).

Figure 1 in Appendix D shows penetration resistance (SPT 'N') and moisture content profiles for BH 16-1-1 and BH 16-1-2, the two boreholes sunk from the top of the embankment which are also closest to the proposed pipe axis.

Trenchless installation methods can be divided into two groups based on the ability to steer line and grade, namely, non-steering methods (e.g. Jack and bore and pipe ramming) and steering methods (e.g. Horizontal directional drilling (HDD) and micro-tunneling). In view of the poor control of line and grade, non-steering methods generally use an oversize casing for the product pipe to be inserted in situations where line and grade requirements are important such as in culvert installations, other than for reasons of avoiding possible casing damage due to a particular installation technique. As the pipe to be installed is 910 mm in diameter, an oversize casing of 1200 mm diameter is considered the minimum for the present trenchless installation as shown on the GA drawing. Considerations of ground penetrability within the postulated tunnel zone of 1200 mm (casing), based on **Figure 1** in **Appendix D**, are as follows:

- The zone of tunneling or the bore path for the casing is within the investigated depths at boreholes BH 16-1-1 and BH 16-1-2 locations. Within the bore path, under the embankment, at the inlet end, a moist sand with high fine sand content was encountered. Given the similarity of grain size distribution within the embankment fill and the underlying native sand, it is quite probable that the borrow for embankment fill would have been sourced from native sand borrow pits/cuttings (native sand has more fine sand content, See Fig. B2). Therefore, it is reasonable to assume the embankment fill to consist of similar material (at least in terms of the high fine sand content) that has been established for BH-16-1-1 and BH-16-1-2. Accordingly, it is thus reasonable to assume that the embankment fill in general to consist of moist sand with high fine sand content, See Figs. B1 and B2.
- The bore path appears to straddle a local weaker ground zone, in terms of the penetration resistance, i.e. lower SPT 'N' values of 4 and 8 blows/300mm at BH 16-1-1 location. The soil characteristics within the tunneling zone would classify as "Slow Ravelling" according to the Tunnelman's Ground Classification (attached in Appendix E).
- The soil cover over the new liner is at least 2.8 m or about 2.5 pipe diameters.

The following trenchless installation methods are discussed:

- Jack and Bore (Auger Boring):
 - This technique involves mechanical removal of soil via cutting head (attached to the front of a flight of augers) and augers inside the casings
 - simultaneously jacks the steel casing as soil spoil is removed using screw augers
 - machine torque and thrust are major factors and should be closely monitored; needs a thrust block to take the reaction of jacking
 - non-steerable

- major problem is the susceptibility for subsidence or settlement of the ground above the borehole
- proven method of pipe installation with well-defined standards
- Most widely used trenchless method for culvert installation under road and railway embankments

→ Pipe Ramming:

- An open-ended steel pipe is rammed with a pneumatic or hydraulic hammer through the soil
- soil is displaced
- reduction of friction typically achieved with lubrication
- spoil removal by auger, compressed air or pressurized water (water not suitable for the present ground conditions)
- initial alignment of ram and pipe critical to the operation
- non-steerable

→ Horizontal Directional Drilling:

- The method consists of pilot boring, back reaming and pipe pullback. Drilling begins with a small diameter pilot hole along a designated alignment, using flexible drill rods with a remote controlled steering system. After the pilot boring, a back reamer is installed and drilled back through the pilot hole to achieve the required diameter for the pipe to be installed
- Soils with gravels and cobbles are not particularly favourable for HDD methods; cobbles may jam pipe in bore during pullback and boulders can result in failed bore
- In Southern Ontario, HDD diameters less than 750 mm are fairly commonplace but larger bores add risk, complexity and considerable cost
- For an 910 mm dia. product pipe, with the required overcut, the diameter will be in excess of 1.2 m and may not be attractive given the risks cited above
- Steerable
- Requires large space at entry point for the equipment and to achieve flatter/horizontal grade
- In view of the above, it could be both a risk in terms of time and cost for the project and hence is not discussed further.

→ Micro-Tunneling:

- This technique is an improvement of the pipe jacking technique with a TBM. It is a remotely controlled, guided pipe-jacking process that provides continuous support to the excavation face. It is technically superior and steerable. However, given the nature of the project and the cost prohibitiveness of the method for a project of the subject scale, it is not discussed further.

The following table is a brief summary of possible options and should be read with particular to reference to **Fig.1** in **Appendix D**.

Table 5-1: Common Trenchless Methods - Comparison in relation to Some Site Specific Technical Issues

Criterion	Jack and Bore (also known as auger boring/ horizontal earth boring)	Pipe Ramming
Length of drive and diameter	<p>Typical drive lengths 40 to 60 m</p> <p>Common diameters 250 to 1500 mm</p> <p><i>Site Specific: suits project pipe parameters</i></p>	<p>Typical drive lengths 30 to 60 m</p> <p>Common diameters 100 to 1500 mm</p> <p><i>Site specific: suits project pipe parameters but for more than 600 mm diameter, it can be expensive; project pipe diameter is 910 mm and the casing will be oversize</i></p>
Control of line and grade	Non-steerable; has limited control on line and grade	Non-steerable; has minimal control on line and grade
Control of ground surface displacement	<p>With good construction techniques, surface subsidence can be controlled</p> <p>Works better in firm to stiff cohesive soils</p> <p><i>Site Specific: loose sand in the embankment fill along the bore path may cause ground surface subsidence; consideration may be given to jacking the pipe as far as practicable (i.e. not to auger too far ahead of casing) prior to augering</i></p>	<p>Provides continuous casing support during the drive with no over-excavation;</p> <p><i>Site Specific: Potential for ground surface subsidence impacts due to loose sand in the embankment fill along the bore path (BH-16-1-1 at inlet side). However, this is limited because a soil plug can be maintained inside the pipe;</i></p> <p><i>In the absence of groundwater, the risk of soil plug breach can be controlled</i></p>

Criterion	Jack and Bore (also known as auger boring/ horizontal earth boring)	Pipe Ramming
Ability to deal with slow travelling/unstable face conditions	<p>This is akin to open face tunneling basically relying on zero support pressure.</p> <p><i>Site Specific: With potential for apparent cohesion (capillary suction) to develop in the embankment fill for reasons discussed earlier, this can be mitigated</i></p>	<p>The soil plug can be used to provide limited support pressure</p>
Workspace requirements	<p>Requires carefully designed and constructed launching pit; larger entrance pit than pipe ramming</p> <p><i>Site Specific: West side of road is the preferred launching pit location</i></p>	<p>The required working space at the drive shaft is less for pipe ramming compared to jack and bore; no thrust blocks are required; the required width and depth of pits are smaller</p> <p>Ramming can be launched without an insertion pit, if the ram is designed to start at the side of a slope</p>
Environmental impacts		<p>Vibration induced noise can be an issue; blockages can cause significant ground disturbance</p> <p>Vibration induced settlements especially in the presence of loose sand</p> <p><i>Noise levels unlikely to be an issue to the travelling public in the open rural site conditions at project site; blockages should be avoided through good construction control</i></p> <p><i>Minimum Soil cover above the tunnel zone is about three (2.5) diameters.</i></p> <p><i>The upper level of the embankment fill is compact to dense material which should help to mask any lower level</i></p>

Criterion	Jack and Bore (also known as auger boring/ horizontal earth boring)	Pipe Ramming
		<p><i>local subsidence effect through arching. With no groundwater issues, no risks of liquefaction.</i></p> <p><i>A settlement monitoring programme would help to manage this risk.</i></p>

5.4 SELECTION OF TUNNELLING OPTION

The selection of a preferred option will depend, among other factors, the construction cost, practicability of construction, risk of ground subsidence, scheduling, etc.

Whilst both jack and bore and pipe ramming would be comparable, either method can be adopted from a geotechnical perspective for the project site conditions.

Analysis was undertaken to estimate the apparent cohesion required to advance beyond the liner face up to a distance of 0.5 m and 1.0 m (header cutting lengths), Vermeer et al (2002). The required apparent cohesion values are 3 kPa and 5 kPa respectively. According to Powrie (2014), a face support pressure of 15 kPa is required, in the absence of any apparent cohesion. Both estimates are based on a FoS of 1.2 and a friction angle of 30 degrees and a unit weight of 20 kN/m³ for the embankment fill.

The soil plug that develops during pipe ramming would mitigate surface disruptions in comparison to jack and bore method. However, considering the presence of more compact sand zones in the fill (e.g. BH 16-1-2) above the crown of the liner, the risk of heave by pipe ramming, is possible.

The embankment fill has about 13 to 23% fines content including about 5% clay size fraction and moisture contents less than 10% within the upper 3 m of fill (see **Fig. 1** in **Appendix D**). Given the above, although with the presence of a 'slow ravelling' condition along the proposed tunnel alignment, jack and bore is considered the more favourable option with the potential for apparent cohesion.

Based on the above, it is considered that the jack and bore method of trenchless construction to be the preferred option from a geotechnical point of view as well as it is generally considered to be the cheaper of the two options. Further, it is recommended to undertake jack and bore from the outlet end to the inlet end to allow any moisture egress to flow out without compromising the tunnel heading. Any egress of water drained out will enhance the apparent cohesion (capillary suction) of the embankment fill. Further, at no stage must the auger cutters be in advance of more than 0.5 m ahead of the tunnel liner pipe in order not to rely on high apparent cohesion for face stability. An NSSP addressing Pipe Installation by Trenchless Method issued by MTO under the contract is attached in **Appendix F**.

5.5 CONSTRUCTION CONSIDERATIONS FOR TUNNELING

5.5.1 DEWATERING AND DRAINAGE ISSUES

In view of the “dry” condition at the borehole locations, no dewatering is required for the trenchless construction. PTTW will not be required.

5.5.2 RISK MANAGEMENT OF GROUND MOVEMENTS

5.5.2.1 NATURE OF GROUND MOVEMENTS

Tunneling induced ground movement can consist of an “immediate” component due to ground loss followed by a “delayed” component due to consolidation.

Ground loss is due to over-excavation of material more than the volume of the tunnel and results in a settlement trough at the surface as an immediate response. When a tunnel is excavated, the hoop stress which acts in the circumferential direction exceeds the radial stress (radial stress is reduced at the boundary of the tunnel, if soil loosening at the header face takes place) and this gives rise to shear induced pore pressures leading to consolidation settlements in cohesive media. These movements are influenced by the strength and stiffness of the soils, the method of tunneling and the quality of tunnel operations (including the method of handling localized conditions such as removing boulders).

In summary, settlement (or heave) of the road surface due to tunnel construction is difficult to estimate but generally with good workmanship, settlements over the tunnel centerline should not exceed the allowable 10 mm. Beyond the centerline, the settlements would gradually decrease to zero (Gaussian distribution shape), typically at a distance of about three diameters.

The term ‘ground loss’ as discussed above does not include unexpected, uncontrolled loss of ground resulting from face instability. Much greater settlements than the estimates given above will occur where there is instability at the face. Our understanding based on locates and GA drawing is that no buried utilities, e.g. watermain etc. under the highway embankment are reported to be present that are likely to impact the bore path.

5.5.2.2 INSTRUMENTATION MONITORING

To ensure that ground settlements are limited to acceptable values, it is recommended that ground movements along the tunnel in critical areas be monitored during and following the tunneling operation. We also recommend that during tunneling operations the installation be inspected fulltime by a geotechnical engineer appointed by the QVE.

Surface monitoring points should be installed to cover the whole tunnel length within the MTO ROW. Consistent with MTO requirements, surface monitoring points should be installed at not greater than 5 m intervals above the centerline of the tunnel. Settlement monitoring could consist of paint marked points on the pavement along the centerline of the tunnel and beyond the tunnel. Surface settlement points should also be installed beyond the paved portion (i.e. in the shoulder) below frost depth. In

addition, we recommend that consideration be given to deep settlement points (e.g. placed about 0.8 m above the tunnel's crown) in the shoulders. This is because deep settlement points will react to any ground loss settlement during tunneling much faster than surface settlement points, since time-dependent arching effect is less pronounced immediately above the crown. The settlements will need to be monitored with reference to reliable, stable, frost free benchmark(s).

We recommend that a minimum of two sets of repeatable baseline readings be taken on all of the settlement points well in advance of the start of tunneling to provide a baseline against which all subsequent readings can be compared to assess settlements of the ground and the embankment. Settlement monitoring should be conducted at least three times daily, including weekends, during the installation of the tunnel under the road embankment. The frequency of readings can then be further reduced to once daily for ten days, weekly for a period of one month and then once monthly for four months following grouting of the tunnel annular space.

In addition to settlement monitoring, during tunneling, the quantity of the excavated soils should also be monitored and compared with the theoretical volume of excavation in order to assess the risk of over-excavation.

Pre and post condition survey for the pavement is also required.

5.5.2.3 INTERVENTION BENCHMARKS FOR RISK MITIGATION

Should settlement monitoring indicate excessive ground movement prior to the tunnel reaching the travelled lanes, immediate changes to the tunneling and ground support procedures must be adopted. A contingency plan should be provided to the CA prior to tunneling. **Table 5.2** details the recommended monitoring 'Review' and 'Alert' Levels.

Table 5. 2: Recommended Ground Movement 'Review' and 'Alert' Levels

Ground Movement	Notes
<10 mm	Proceed. No action required.
10-15 mm (beyond Review level)	Immediately notify the MTO and the geotechnical engineer for further assessment. Proceed with caution.
>15 mm (Alert level)	Halt construction activities immediately and stabilize the tunnel face until further assessment is carried out by MTO and the geotechnical engineer; Carry out immediate remedial work to the settlement zone as approved by MTO and geotechnical engineer.

Note: If lesser ground movements than 12 mm as indicated by monitoring instruments and/or direct observations cause or threaten to cause damage to the highway pavement, then this should be

treated as having attained the “Alert” level.

No construction shall take place until all of the following conditions are satisfied:

- The cause of the settlement is identified
- The contractor submits a corrective/preventative plan
- Any corrective/preventative measure deemed necessary by MTO is implemented
- The MTO and the geotechnical monitoring consultant deem it safe to proceed

Drawing 2 shows the Recommended Layout for Ground Monitoring Arrays subject to site constraints, whilst **Drawing 3** shows the Installation Details and Recommended Monitoring Frequencies of Ground Monitoring Arrays at the end of the text.

5.5.3 ENTRY AND EXIT PIT EXCAVATIONS

5.5.3.1 OPEN CUT EXCAVATIONS

The launching and receiving pits for the tunneling operation are expected to contact sand to silty sand within the likely excavation depths for entry / exit pits.

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 classification would be applicable for open cut.

Table 5. 3 Interpreted OHSA Requirements for Open Cut Excavations

Material/Deposit	Groundwater	OHSA Classification	Remarks
Granular pavement fill	Above groundwater	Type 3	
	Below groundwater	Not Applicable	
Embankment Fill	Above groundwater	Type 3 or 2H:1V	(compact/dense)/loose
	Below groundwater	Not Applicable	
Sand to Silty Sand	Above groundwater	Type 3	

	Below groundwater	Not Applicable	
--	-------------------	----------------	--

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.

Excavations should be possible in the above soil types using heavy equipment such as a hydraulic excavator.

5.5.3.2 SHORED EXCAVATIONS

It is anticipated that the launching pit will be located on the west side of the road, where an upward tunneling will be carried out. Table 5.4 gives recommended unfactored design parameters for design of temporary shoring. 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 trace cobbles intercepted within the embankment fill should be noted. Shoring for this jack and bore trenchless installation would be required for a carefully designed and constructed launching pit for the thrust reaction, including, for example, on the side slopes of the road embankment for the entry and exit pits. The shoring design should be carried out by a Professional Engineer, experienced in this type of work.

Table 5. 4: Geotechnical Design Parameters (Unfactored) – For Temporary Shoring

Layer Number	Material	D _r ** (Typical)	Unit weight γ' (kN/m ³)	Strength Parameters*					
				Effective Stress					Total Stress (Undrained)
				c' (kPa)	Φ' (deg)	K _a	K _p	K _o	S _u , (kPa)
1	Embankment Fill – sand fill	Compact	20	0	30	0.33	3.0	0.5	Cohesionless
2	Sand to Silty Sand	Dense	21.5	0	34	0.28	3.54	0.44	Cohesionless
3	Sand and Gravel	Dense	22.5	0	36	0.26	3.85	0.41	Cohesionless

* c' – Effective cohesion; Φ' – Effective friction angle; K_a – Active Earth Pressure Coefficient; K_p – Passive Earth Pressure Coefficient; K_o – At Rest Earth Pressure Coefficient; S_u – Undrained Shear Strength

D_{r**} – Relative Density / Consistency

Notes:

- 1 A factor of safety of 2 shall be applied for computing passive resistance to lateral loads
- 2 Adequate allowance should be made for surcharge loads such as traffic with a minimum of 12 kPa surcharge
- 3 Earth pressure coefficients given in the table are for horizontal backfill and level surface in front (toe area). Any departures from this should be taken into account (for example, entry and exit pits abutting the embankment slopes will have sloping backfills). Passive earth pressures within the frost depth in soil should be disregarded.
- 4 Design ground water table can be considered as at El. 322.0 m.

5.5.4 SOIL DISPOSAL ISSUES

The excavated materials from the construction should be stockpiled and checked for contamination prior to removal/disposal off-site, in order to determine which disposal option is best for the excavated materials (OPSS 180).

5.5.5 BACKFILLING OF PITS

Entry and exit pits need to be backfilled and returned to pre-construction grades. Any organic, excessively wet, compressible or otherwise deleterious materials should be discarded from being used for backfilling. Any material shortfall should be met with approved materials and backfilling must conform to OPSS 401 and site restoration to OPSS 492.

5.6 INLET AND OUTLET

5.6.1 HEAD WALL/WING WALL DESIGN CONSIDERATIONS

Computation of earth pressures acting against rigid culvert walls and wing walls, if required, should be in accordance with the Canadian Highway Bridge Design Code, S6-06: (CHBDC) 2006. For design purposes, the following properties can be assumed for backfill.

Compacted Granular 'A' or Granular 'B' Type II with less than 5% passing the 200 sieve.

Angle of Internal Friction $\phi = 35^\circ$ (unfactored), Unit weight = 22 kN/m³

Table 5. 5 Coefficient of Lateral Earth Pressure:

Level Backfill	Backfill Sloping at 3H:1V	Backfill Sloping at 2H:1V
$K_a = 0.27$	$K_a = 0.34$	$K_a = 0.40$
$K_o = 0.43$	$K_o = 0.56$	$K_o = 0.62$

Note: K_a is the coefficient of active earth pressure

K_o is the coefficient of earth pressure at-rest

These values are based on the assumption that the backfill behind the retaining structure is free-draining granular material and adequate drainage is provided.

The earth pressure coefficient adopted will depend on whether the retaining structure is restrained or some movement can occur such that the active state of earth pressure can develop. Allowance should be made for compaction induced stresses in the selection of the appropriate earth pressure coefficients, and reference should be made to Clause 6.9.3 of CHBDC (S6-06). The use of vibratory compaction equipment behind the retaining walls should be restricted in size as per current MTO practice.

5.6.2 EROSION PROTECTION

Typically a wing wall on the inlet end can prevent any water flow through the embankment (typically granular material) around the culvert and it also protects/retains the embankment. Rip-rap protection should be provided at the culvert's inlet and outlet ends and should generally follow OPSD 810.010 and any specific recommendations in the hydrology report. Rip-rap placed at 1H: 1V without an underlying geotextile will be stable. Consideration can be also given to a low permeability clay seal/GCL (OPSS 1205/OPSD 802.095) at the inlet.

These 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). Although no groundwater was observed during this foundation investigation, the surficial native sand with predominance of the fine sand fraction can be very erodible depending on velocity of surface run-off through the pipe conduit and should be noted.

CLOSURE

The "Limitations of Report" as presented in **Appendix H** 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.

WSP Canada Inc.



Ramon Miranda, P. Eng
Senior Geotechnical Engineer



Vasantha Wijeyakulasuriya, M.Eng., P.Eng
Senior Technical Director, Geotechnical
MTO Designated Contact

REFERENCES

Canadian Highway Bridge Design Code (CHBDC) and Commentary on CAN/CSA S6-06. 2006. CSA Special Publication, S6.1 06. Canadian Standard Association.

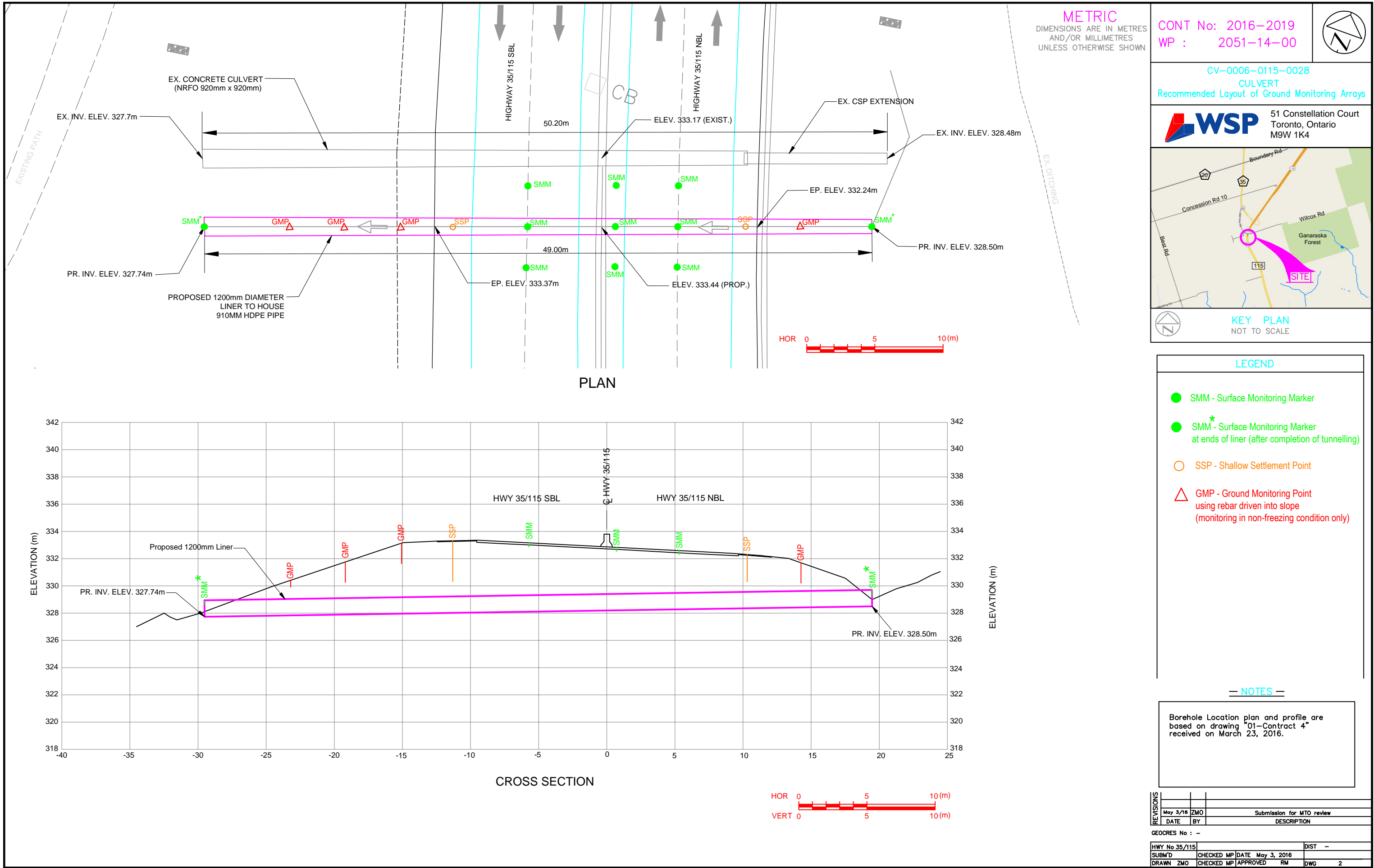
Canadian Geotechnical Society, 2006. Canadian Foundation Engineering Manual, 4th Edition. The Canadian Geotechnical Society c/o BiTech Publisher Ltd, British Columbia.

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

Powrie, W. (2014) Soil Mechanics, 3 edition, CRC Publishers

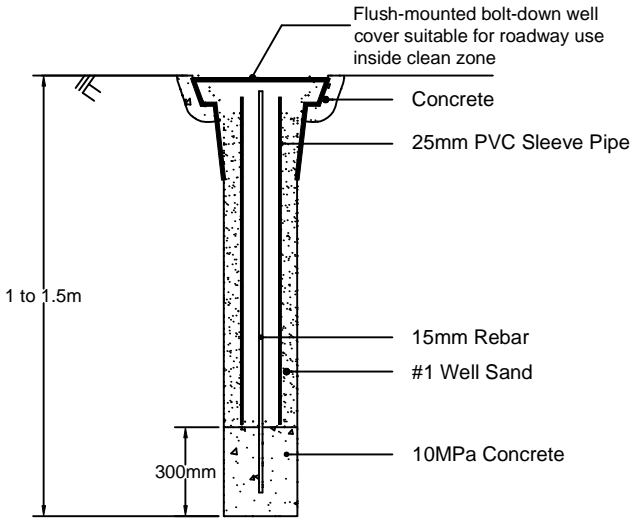
Vermeer, P. A., Ruse, N. and Marcher, T. (2002) Tunnel Heading Stability in Drained Ground, FELSBAU, 20 No 6

DRAWING 2: RECOMMENDED LAYOUT OF GROUND MONITORING ARRAYS

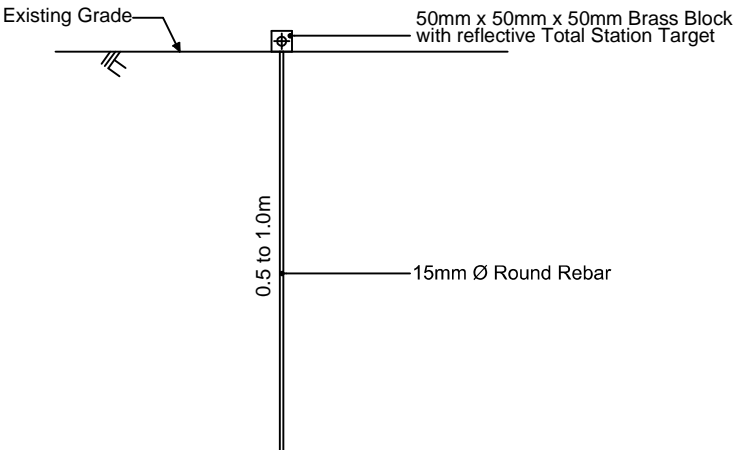


DRAWING 3: INSTALLATION DETAILS AND MONITORING FREQUENCIES OF GROUND MONITORING ARRAYS

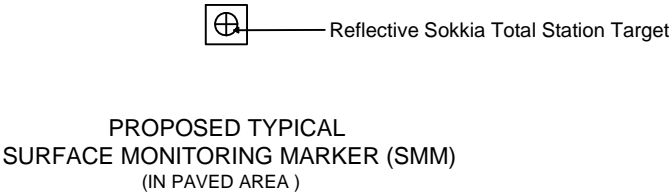
TYPICAL INSTALLATION DETAILS



PROPOSED TYPICAL
SHALLOW SETTLEMENT POINT (SSP)
(IN UNPAVED AREA)



PROPOSED TYPICAL
GROUND MONITORING POINT (GMP)
(DRIVEN INTO GROUND)



PROPOSED TYPICAL
SURFACE MONITORING MARKER (SMM)
(IN PAVED AREA)

NOTES: *USE OF ABOVE-GRADE PROTECTIVE CASING IS PERMISSIBLE ONLY OUTSIDE OF THE HIGHWAY/RAMP 'CLEAR ZONE'; ELSEWHERE USE FLUSH-MOUNTED COVERS.

TABLE 1
FREQUENCY AND ACCURACY OF MONITORING

Installation Schedule	Baseline Reading	Monitoring Schedule	Monitoring Duration
At least one week prior to start of tunnelling	Minimum of two (2) sets of readings prior to tunnelling. Accuracy of readings should be 0.5mm or better.	Three (3) times per day including during work stoppages (eg. weekends).	On completion of tunnelling, monitoring is to be maintained at least once daily for a minimum of ten days; then weekly for a period of one month; then once monthly for the following four months. Monitoring can be stopped, with consultation with the monitoring Geotechnical Engineer, two weeks after completion of the tunnel provided further settlement has stopped.
Note: - During each monitoring visit, all monitoring points are to be recorded. - The above outline is recommended for all installed monitoring devices including the Shallow Settlement Points, Surface Monitoring Marker and Ground Monitoring Point.			

NOTES:

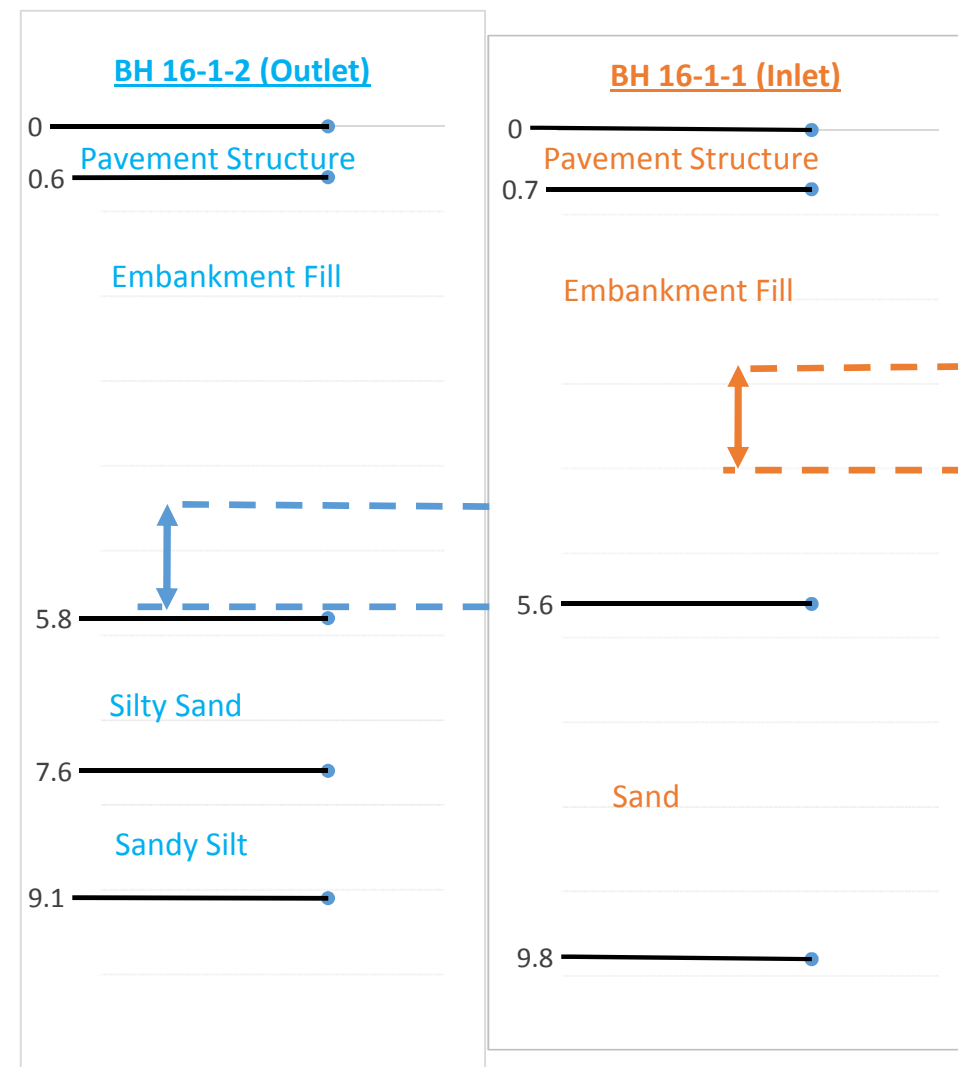
- 1) Shallow Settlement Points are to be founded into the embankment fill; but no closer than 1m above the crown of the tunnel.
- 2) Accurate ground surface elevations and depths to the proposed tunnel obvert are required prior to the installation of any Shallow Settlement Points .
- 3) Shallow Seated Benchmarks are to be installed to a minimum depth of 6m and located at least 20m away from the tunnel alignment.
- 4) Ground Monitoring Points are to be flush with or recessed below the surrounding paved shoulder to protect settlement points and passing traffic from potential damage.
- 5) Ground Monitoring Points with Rebar are to be used only along slope and non-freezing condition.

SETTLEMENT CRITERIA:

Definition	Movement
Review Level	≥ 10mm for SSP & GMP ≥ 5mm for SMM
-Immediately notify MTO & the geotechnical engineer for further assessment; Proceed with caution.	
Alert Level	≥ 15mm for SSP & GMP ≥ 10mm for SMM
- Halt tunnelling until further assessment is carried out by the MTO & geotechnical engineer; Carry out immediate remedial work to the settlement zone as approved by the MTO.	

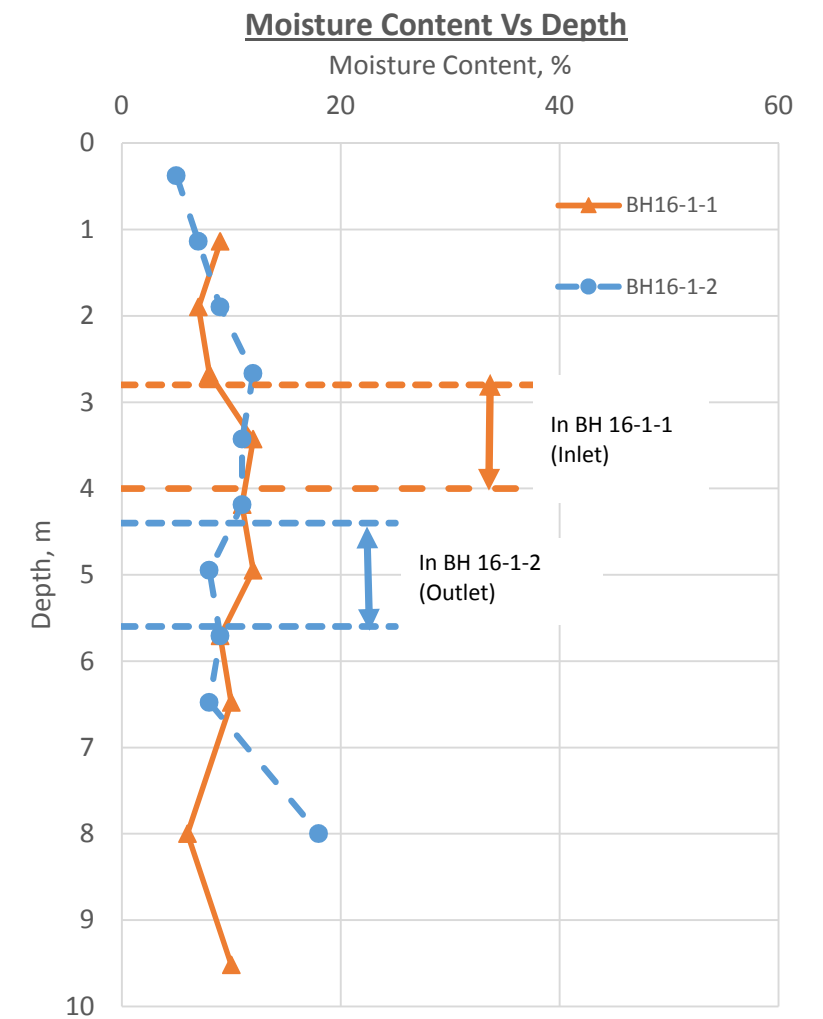
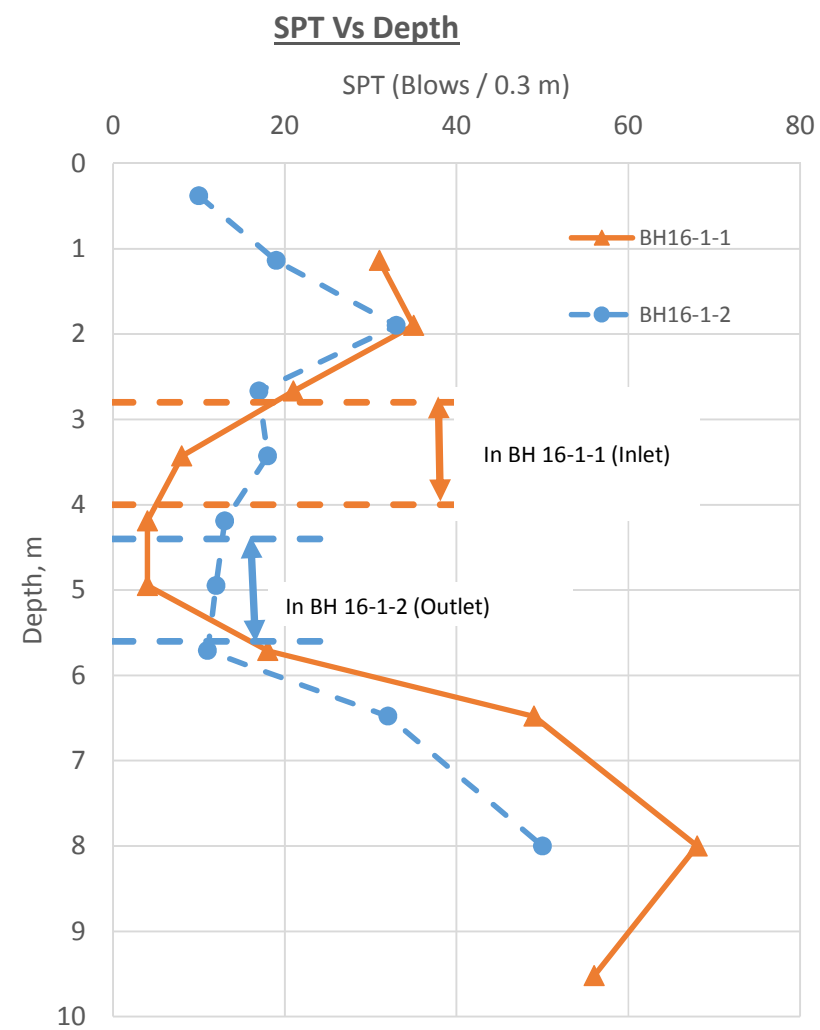
REVISIONS				
	May 3/16	ZMO	Submission for MTO review	
	DATE	BY	DESCRIPTION	
GEOCREs No : -				
HWY No 35/115				DIST -
SUBM'D		CHECKED MP	DATE May 3, 2016	
DRAWN ZMO		CHECKED MP	APPROVED RM	DWG 3

APPENDIX D: GROUND CONDITIONS ALONG THE PROPOSED LINER ALIGNMENT



Notes: 1) All depth dimensions are in metre
2) Not to Scale

Casing Pipe level	BH 16-1-2 (side of outlet)	BH 16-1-1 (side of inlet)
	Ground elevation - 333.6 m	Ground elevation - 332.4 m
At Obvert	Depth 4.4 m / El.329.2 m	Depth 2.8 m / El. 329.6 m
At Invert	Depth 5.6 m / El. 328.0 m	Depth 4.0 m / El. 328.4 m



Legend:

BH16-1-2

BH16-1-1

Bore sizes are shown for a 1200 mm dia pipe.

Anticipated Ground Condition Along the Proposed Alignment (Under the Embankment)

Figure 1

APPENDIX E: TUNNELMAN'S GROUND CLASSIFICATION

Tunnelman's Ground Classification and Probable Working Conditions

Soil Classification	Representative Soil Types	Tunnel Working Conditions
Hard	Very hard calcareous clay; cemented sand and gravel	Tunnel heading may be advanced without roof support
Firm	Loess above GWT; Various calcareous clay with low plasticity	Tunnel heading may be advanced without roof support and the permanent support can be constructed before the ground will start to move
Slow Ravelling and Fast Ravelling	<i>Fast Ravelling</i> occurs in residual soils or in sand with clay binder below the GWT. Above the GWT, the same soils may be <i>Slowly Ravelling</i> or even Firm	Chunks or flakes of material begin to drop out of roof or the sides sometime after the ground has been exposed. In <i>Fast Ravelling</i> ground, the process starts within a few minutes; otherwise it is classed as Slow Ravelling
Squeezing	Soft or medium-soft clay	Ground slowly advances into tunnel without fracturing and without perceptible increase of water content in ground surrounding the tunnel (may not be noticed in tunnel but cause surface subsidence)
Swelling	Heavily pre-compressed clays with a plasticity index in excess of about 30; Sedimentary formations containing layers of anhydrite.	Like squeezing ground, moves slowly into tunnel, but the movements is associated with a very considerable volume increase in the ground surrounding the tunnel.
Cohesive Running and Running	<i>Cohesive running</i> occurs in clean, fine moist sand <i>Running</i> occurs in clean, coarse or medium sand above the GWT	The removal of the lateral support of any surface rising at an angle of more than about 34° to the horizontal is followed by a 'run,' whereby the material flows like granulated sugar until the slope angle becomes equal to about 34°. If the 'run' is preceded by a brief period of raveling, the ground is called <i>Cohesive Running</i>
Very Soft Squeezing	Clays and silts with high plasticity index	Ground advances rapidly into the tunnel in a plastic flow
Flowing	Any ground below the GWT that has an effective grain size in excess of about 0.005 mm	Flowing ground moves like a viscous liquid. It can invade the tunnel not only through the roof and the sides but also through the bottom. If the flow is not stopped, it continues until the tunnel is completely filled.
Bouldery	Boulder glacial till; rip-rap fill; some land slide deposits, some residual soils. The matrix between boulders may be gravel, sand, silt, clay or combinations of thereof.	Problems occurred in advancing shield or in forepoling; blasting or handmining ahead of machine may become necessary.

APPENDIX F: PIPE INSTALLATION BY TRENCHLESS METHOD

PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.

Special Provision

1. SCOPE

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

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

2. REFERENCES

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

Ontario Provincial Standard Specifications, General

OPSS 180	Management and Disposal of Excess Materials
----------	---

Ontario Provincial Standard Specifications, Construction

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

Ontario Provincial Standard Specifications, Material

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

American Society for Testing and Materials (ASTM) International Standards

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

Canadian Standards Association Standards:

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

3. DEFINITIONS

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

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

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

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

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

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

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

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

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

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

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

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

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

Grouting: injection of grout into voids.

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

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

HDPE: high density polyethylene.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Tunnelling: An underground method of constructing a passage using a tunnel boring machine (TBM), a microtunnel boring machine (MTBM) or hand mining using a shield to support the opening.

4. DESIGN AND SUBMISSION REQUIREMENTS

4.01 General

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

4.02 Working Drawings

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

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

a) Plans, Elevations and Details:

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

b) Design Criteria:

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

c) Materials:

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

d) Upstream/Downstream Portal Installation Procedure:

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

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

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

f) Excavation and Dewatering:

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

g) Monitoring Method:

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

4.03 Site Survey

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

4.04 Certificate of Conformance

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

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

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

Installation of the Product Grouting Operations

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

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

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

5. MATERIALS

5.01 Product

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

5.02 Concrete

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

5.03 Concrete Reinforcement

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

5.04 Timber

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

5.05 Grout

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

5.06 Auger Jack & Bore Materials

5.06.01 Pipe Materials

Steel pipe shall conform with ASTM A252-93 welded joints suitable for jacking operations. The Contractor shall select pipe class for pipe jacking.

Concrete pipe as per OPSS.PROV 1820.

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

5.07 Pipe Ramming Materials

5.07.01 Pipe Materials

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

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

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

Pipe wall thickness shall be determined by the Contractor based on static and dynamic loads from traffic loading and anticipated ramming forces for selected pipe and driven pipe lengths. The wall thickness shall be increased as required to ensure the casing is not damaged during handling and installation. The pipe minimum wall thickness shall be as per Table 1 of OPSS 1802.

Pipe segments shall be determined by the Contractor.

Steel pipe joints shall be pressure fit type or welded.

All steel casing pipe shall be square cut.

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

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

5.07.02 Mill Certificates

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

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

5.08 Directional Drilling Materials

5.08.01 Drilling Fluids

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

5.08.02 Pipe Materials

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

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

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

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

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

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

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

5.09 Tunnelling Materials

5.09.01 Primary Liner

Tunnelling methods will require installation of a primary liner. The primary liner shall be designed by the Contractor and the design/drawings shall be stamped/signed by the Design Engineer. The design shall be submitted to the Contract Administrator as specified herein.

5.09.02 Secondary Liner

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

5.09.02.01 Concrete Pipe

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

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

5.09.02.02 High Density Polyethylene (HDPE)

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

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

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

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

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

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

6. EQUIPMENT

6.01 Auger Jack & Bore Equipment

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

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

6.02 Pipe Ramming Equipment

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

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

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

6.03 Directional Drilling Equipment

6.03.01 General

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

6.03.02 Drilling Rig

The directional drilling rig shall:

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

6.03.03 Drill Head

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

6.03.04 Guidance System

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

6.03.05 Drilling Fluid Mixing System

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

6.03.06 Drilling Fluid Delivery System

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

6.04 Tunnelling Equipment

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

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

7. CONSTRUCTION

7.01 General

The Contractor shall notify the Contract Administrator at least 48 hours in advance of starting work. The proposed method of pipe installation to be used by the Contractor shall be submitted to the Contract

Administrator for information purposes prior to commencing the work and shall be subject to the limitations presented in the following subsections.

7.01.01 Layout, Alignment and Depth Control

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

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

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

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

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

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

7.01.02 Construction Shafts

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

Shafts shall be maintained in a drained condition.

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

7.01.03 Protection Systems

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

7.01.04 Settlement or Heave

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

7.01.05 Stability of Excavation

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

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

7.01.06 Preservation and Protection of Existing Facilities

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

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

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

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer's handling and storage recommendations shall be followed.

7.01.08 Trenching, Backfilling and Compacting

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

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

If any open excavation will encroach into the highway embankment the protection system shall satisfy the requirements for Performance Level 2 as specified in OPSS.PROV 539.

7.01.10 Dewatering

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

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

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

Should water enter the excavation in amounts that could adversely affect the performance of the work or could

cause loss of ground, the Contractor shall take immediate steps to control the inflow.

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

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Boulders

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

7.01.12 Record Keeping

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

7.01.13 Testing

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

7.01.14 Management and Disposal of Excess Material

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

7.01.15 Site Restoration

Site restoration shall be according to OPSS 492.

7.01.16 Supervision

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

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

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

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

- Selection of the excavation method and jacking equipment shall take into consideration the conditions at each pipe crossing.

7.02.02 Pipe Installation

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

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

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

7.03 Pipe Ramming Installation

For pipe ramming installation the following requirements apply:

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

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

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

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

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

7.04 Directional Drilling Installation

7.04.01 General

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

7.04.02 Site Preparation

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

7.04.03 Pilot Bore

The pilot bore shall be drilled along the bore path in accordance with the grade, alignment, and tolerances as indicated on the Contractor's submitted drilling plan to ensure that the product is installed to the line and grade

shown on the Contract Drawings. The Contractor's methods shall take into consideration the conditions at each crossing within the pipe alignment and shall be suitable to advance through such obstructions such as cobbles and boulders and address the potential for deflection off these obstruction and/or soil conditions.

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

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

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

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

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

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

7.04.04 Drilling Fluid Fracture (Frac-Out)

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

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

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

7.04.05 Reaming

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

7.04.06 Product Installation

7.04.06.0 General

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

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

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

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

7.04.06.02 Pullback and Grouting

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

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

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

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

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

7.05 Tunnelling Installation

7.05.01 General

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

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

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

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

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

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

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

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

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

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

7.05.01 Tunnelling Method

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

7.05.02 Primary Liner (Support System)

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

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

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

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

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

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

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

7.05.03 Secondary Liner

7.05.03.01 Placing of Grout

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

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

7.06 Instrumentation Monitoring

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

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

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

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

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

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

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

- Three consecutive readings at least one week prior to commencement of the work (Baseline Reading);
- Once per shift during tunnelling operations period; and
- Weekly after completion of the work for one month, or until such time at which all parties agree that further movement has stopped.

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

7.07 Criteria for Assessment of Roadway Subsidence/Heave

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

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

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

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

9. MEASUREMENT FOR PAYMENT

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

10. BASIS OF PAYMENT

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

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

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

protection system and performing any necessary restoration work.

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

- (a) Where such drains and service connections are shown on the contract drawings the cost of connections shall be included in the contract price for pipe installation.
- (b) Where such drains and service connections are not shown on the contract drawings, the cost of connections will be considered an allowable extra to the contract.

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

APPENDIX G: LIST OF OPSS, OPSD AND NSSP

Appendix F: List of SPs, OPSSs, OPSDs and NSSP referenced in the Report

Document	No.	Title
OPSS	180	GENERAL SPECIFICATION FOR THE MANAGEMENT OF EXCESS MATERIALS
OPSS	416	CONSTRUCTION SPECIFICATION FOR PIPELINE AND UTILITY INSTALLATION BY JACKING AND BORING
OPSS	450	CONSTRUCTION SPECIFICATION FOR PIPELINE AND UTILITY INSTALLATION IN SOIL BY HORIZONTAL DIRECTIONAL DRILLING
OPSS	492	CONSTRUCTION SPECIFICATION FOR SITE RESTORATION FOLLOWING INSTALLATION OF PIPELINES, UTILITIES, AND ASSOCIATED STRUCTURES
OPSS	404	CONSTRUCTION SPECIFICATION FOR SUPPORT SYSTEMS
OPSS	517	CONSTRUCTION SPECIFICATION FOR DEWATERING OF PIPELINE, UTILITY, AND ASSOCIATED STRUCTURE EXCAVATION
OPSS.PROV	539	CONSTRUCTION SPECIFICATION FOR TEMPORARY PROTECTION SYSTEMS
OPSD	810.01	GENERAL RIP-RAP LAYOUT FOR SEWER AND CULVERT OUTLETS
OPSS.PROV	1205	MATERIAL SPECIFICATION FOR CLAY SEAL
OPSD	802.09 5	CLAY SEAL FOR PIPE TRENCHES
NSSP		PIPE INSTALLATION BY TRENCHLESS METHOD, dated December 2014

APPENDIX H: 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.

